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FOREWORD

Continuing the journey through the transformative power of green sciences, issue 6.2 of the **SGEM Vienna Green Conference Proceedings deepens our exploration into the intersection of advanced technologies, sustainable solutions, and innovative design principles**. This volume highlights the groundbreaking efforts that are reshaping the way we live, build, and interact with our environment, offering pathways to a more sustainable and resilient future.

The section on *Micro and Nano Technologies for Sustainable Development* showcases the immense potential of nanotechnology and micro-scale innovations in addressing global sustainability challenges. From eco-friendly synthesis methods and novel chemosensors to exploring public perceptions of nanotechnology risks and benefits, these contributions reveal the critical role that **advanced materials and precision technologies play in driving environmental and social progress**.

In *Biotechnology for Sustainable Solutions and Bioengineering*, the focus shifts to leveraging biological systems for sustainable practices. Studies on nutraceuticals, biopolymer packaging, and biofertilizers underline **how bioengineering can enhance food security, reduce waste, and promote healthier ecosystems**. Research on sustainable farming, innovative fermented products, and freezing techniques for food preservation further demonstrates the alignment of biotechnology with circular economy principles.

The section on *Green Building Materials and Eco-Technologies* highlights the importance of rethinking construction practices to minimize environmental impact. From using recyclable waste in construction materials to integrating artificial intelligence in project management, these studies present innovative approaches to reducing emissions, conserving resources, and creating energy-efficient infrastructures. **Contributions on vernacular traditions and clay-based materials underscore the value of blending traditional knowledge with modern innovation to achieve sustainability in construction**.

Green Design, Sustainable Cities, and Architecture celebrates the role of urban planning and design in fostering sustainable living environments. From **green city initiatives and blue-green infrastructure to integrating urban agriculture and**

renewable energy systems, the research presented here **offers actionable strategies for creating cities that are not only resilient but also vibrant hubs of biodiversity and innovation**.

As the global community works toward achieving *the Sustainable Development Goals (SDGs)*, the contributions in this volume serve as a testament to the power of collaboration and interdisciplinary thinking. By combining expertise from engineering, biology, architecture, and social sciences, these studies demonstrate **how collective efforts can address complex environmental challenges and contribute to a thriving, sustainable planet.**

This edition concludes the SGEM Vienna Green Conference Proceedings, encapsulating the spirit of innovation and determination that drives the global green sciences community. We extend our deepest gratitude to the authors, reviewers, and organizers who have contributed their knowledge and dedication to this publication.

May this final issue for 2024, inspire readers to continue exploring, innovating, and collaborating in the pursuit of a greener future. **Together, we can build a world that harmonizes human progress with environmental stewardship, ensuring a sustainable legacy for generations to come.**

Sincerely yours,

Prof. Dr. hab. oec. Baiba Rivza
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SECTION

MICRO AND NANO TECHNOLOGIES FOR SUSTAINABLE DEVELOPMENT

BENZIMIDAZOLE – PYRIDINE: A NEW TYPE OF HGHLY SENSITIVE CHEMOSENSOR FOR ZN^{2+}

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ABSTRACT
Discovery of new chemosensors for M^{2+} cations represent a continuously and challenging issue for researcher because of their potential applications in nano and micro technologies. Among the other metals, zinc is the second most abundant transition metal ion in human body and plays a crucial role in many biological and environmental processes. In this work we present the design, synthesis and characterization of a Zn^{2+} chemosensors and its coordination complexes based on podants with benzimidazole - pyridine skeleton. The new chemosensor have in the same molecule a π–reach heterocycles (benzimidazole) and a π–deficient heterocycles (pyridine) connected via a methylene linker. The complexation ability of our podant with Zn^{2+} was investigated. The chemosensor proved to be highly sensitive for Zn^{2+} in the nanomolar range.

Keywords: chemosenzor, Zn^{2+}, pyridine, benzimidazole.

INTRODUCTION

It is well known that M2+ metal ions such as Co2+, Cu2+, Ni2+, and Zn2+ play a crucial role in many biological and environmental processes, particularly in keeping human nutrition and health [1-5]. Among these metals, zinc ion is one of the most frequent metal ions existing in living organism, being present bound in different enzyme or free in different cells (e.g. hippocampus) and playing important physiological roles. The deficits of zinc in human organism could lead to serious neurodegenerative illness such us Alzheimer's or Parkinson's disease, ischiemic stroke, epilepsy, etc.[1,2,9,10]. Most of the existing Zn chemosensors are organic compounds belong to azaheterocycles, especially five and six member ring one [1,2]. In this respect, pyridine, quinoline and imidazole heterocycles are among the most used building blocks in chemosensors chemistry, mostly because of their electronic and electrotechnical proprieties [6-14] but also because of their huge biological potential, these azaheterocycles being the key pharmacophoric motif of many drugs or potential drugs [15-19]. According with the literature data [1-14] there are numerous advanced in zinc ions detection, but there is still an urgent need for new chemosensors for selective detection and quantification of zinc.
Having in view the above mentioned considerations and taking into considerations our previously experience in the field of azaheterocycles chemosensors and metal complexation, we decide to study the ability zinc detection and complexation of some

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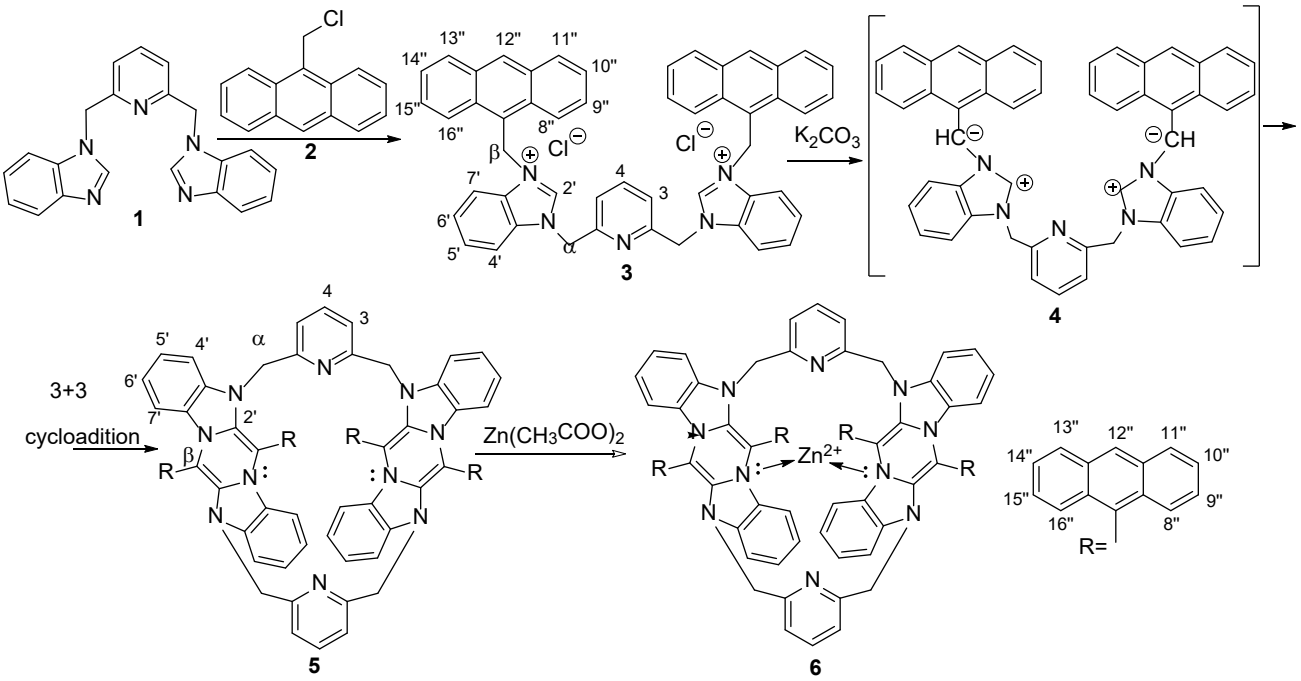
new ligands based on pyridine ligands anchored with anthracene-benzimidazole skeleton.

MATERIALS AND METHODS

All the reagents and solvents were purchased from TCI and Sigma Aldrich. Melting points were determined using an electrothermal Mel-Temp apparatus and were uncorrected (Barnstead International, IA, USA). The nuclear magnetic experiments (1H-NMR, 13C-NMR, 2D-COSY, 2D-HMQC, 2DHMBC) were recorded using Bruker Avance III 500/Bruker Avance DRX 400 spectrometers (Bruker, Vienna, Austria) operating at 500/400 and 125/100 MHz for 1-H and, respectively, 13-C nuclei. All chemical shifts are reported in δ units (p.p.m.) relative to the residual peak of solvent (ref: DMSO, 1H: 2.50 p.p.m.; 13C: 39.52 p.p.m.). Coupling constants (J) are given in Hz. The micro-analyses were in satisfactory agreement with the calculated values: C, ± 0.15; H, ± 0.10; N, ± 0.30.

RESULTS

In order to obtain our pyridine- benzimidazole chemosensor **5** we used an efficient and straightforward reaction pathway, adapting the existing literature data [19,20], in two steps: in the first step an alkylation reaction of pyridine- benzimidazole **1** with chloro-anthracene **2** is leading to salt **3**, then, in the second step, a complexation process of dimer chemosensor **5** with zinc took place, Scheme 1. The dimer **5** was obtained by a 3+3 dipolar cycloaddition of the corresponding ylide **4**.



Scheme 1. Reaction pathway to obtain dimer chemosensor **5** and complexation with zinc.

Synthesis of salt **3**

Pyridine benzimidazole **1** (1 mmol, 0.34 g) was dissolved in 40 ml acetone, than chloro-anthracene **2** (2.8 mmol, 0.63 g), dissolved in 15 ml acetone, was added dropwise. The reaction mixture was refluxed, stirred, for 12 h, than left at room temperature for another 24 h to give the corresponding salt **3**. The obtained salt was filtered off, washed two times with acetone (10 ml) and dried in vacuo. No other purification required.

Synthesis of dimer chemosensor **5**

To 400 μL (2.5 x 10^{-3} M) solution of salt **3** was added 25 μL (2 x 10^{-3} M) solution of K_2CO_3 in D_2O and 5 μL (2.5 x 10^{-1} M) solution of K_2CO_3 in H_2O. After the preparation of the dimer solution, 1H-NMR spectra was registered.

Synthesis of dimer complex with zinc ***6***

To 400 μL (2.5 x 10^{-3} M) solution of salt **3** was added 25 μL (2 x 10^{-3} M) solution of K_2CO_3 in D_2O and 5 μL (2.5 x 10^{-1} M) solution of K_2CO_3 in H_2O. Than 100 μL (1.25 x 10^{-2} M) solution of $Zn(CH_3COO)$ in D_2O was added. After the preparation of the solution, 1H-NMR spectra was registered.

DISCUSSION

The structure and NMR characterization of the pyridine- benzimidazole chemosensor and its ability of coordination with zinc was investigated. The main H-NMR spectral data of salt **3**, dimer chemosensor **5** and dimer complex with zinc **6** are listed in Table 1.

Table 1. The main H-NMR spectral data (δ, ppm) of compounds **3**, **5** and **6**.

Cmpd./H	$H_{2'}$	$H_{12''}$	$H_{8''}$, $H_{16''}$	$H_{11''}$, $H_{13''}$	H_α	H_β
3	9.82	8.77	8.46	8.16	5.34	6.46
5	-	8.60	8.25	8.05	6.32	-
6	-	8.32	8.06	7.88	6.14	-

As we could notice in Table 1, the proton $H_{2'}$(α-endocyclic proton between the 2 nitrogen protons from benzimidazole unit) appear in salt **3** at a high chemical shift (9.82 ppm) because of the powerfully unshielded effect of the positive nitrogen and the second nitrogen atom. This signal disappear in both dimer chemosensor **5** and dimer complex with zinc **6**, which is in accordance with the proposed structure. The H_β protons in salt **3** (from methylene group in α-position to positive benzimidazole nitrogen) appear at a high chemical shift (6.46 ppm) because of the powerfully unshielded effect of the positive nitrogen from the closely proximity. This signal disappear in both dimer chemosensor **5** and dimer complex with zinc **6**, which is also in accordance with the proposed structure. The H_α protons in salt **3** (from the 2 methylene groups in α-position to pyridine ring) appear also at a high chemical shift (5.34 ppm) because of the strong unshielded effect of the nitrogen atom from the closely proximity of benzimidazole unit and because of the unshielded effect of pyridine unit. This signal appear in dimer chemosensor **5** at 6.32 ppm while in dimer complex with zinc **6**,appear at a lower field, 6.14 ppm. The most unshielded proton from the anthracene unit in salt **3** is $H_{12''}$, being unshielded by the two neighbour phenyl units from anthracene. This proton appear in dimer chemosensor **5** at 8.60 ppm (shielded with about 0.2 ppm

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comparative with salt **3**) while in the dimer complex with zinc **6** appear at 8.32 ppm (shielded with about 0.5 ppm comparative with salt **3** and with about 0.3 ppm comparative with dimer chemosensor **5**). A similar situation is happening with anthracene protons $H_{8''}$ and $H_{16''}$ (which appear in salt **3** at 8.46 ppm, in dimer chemosensor **5** at 8.25 ppm, and in dimer complex with zinc **6** at 8.06 ppm) respectively anthracene protons $H_{11''}$ and $H_{13''}$ (which appear in salt **3** at 8.16 ppm, in dimer chemosensor **5** at 8.05 ppm, and in dimer complex with zinc **6** at 7.88 ppm).We may notice that dimer complexation with Zn^{2+} induce a strong shielded effect on the chemical shifts of the protons from the vicinity (H_{α}, $H_{12'}$, $H_{8''}$ and $H_{16''}$, $H_{11''}$ and $H_{13''}$) with about 0.5 to 0.3 ppm, which is a solid prove of the complexation process. All the remaining signals from H-NMR spectra appear in accordance with the proposed structures.

CONCLUSION

In conclusion we present herein the design, synthesis and NMR characterization of a pyridine- benzimidazole chemosensor and its ability of coordination with zinc. The new chemosensor was obtained using an efficient and straightforward method, using an alkylation reaction of pyridine- benzimidazole with chloro-anthracene, followed by the complexation process of dimer chemosensor with zinc. The new chemosensor have in the same molecule a π–reach heterocycles (benzimidazole) and a π–deficient heterocycles (pyridine) connected via a methylene linker. The structure of compounds was proven by elemental and spectral analysis and are in accordance with the proposed structures. The complexation ability of our pyridine- benzimidazole chemosensor with Zn^{2+} was investigated by using NMR spectroscopy. The dimer chemosensor proved to be highly sensitive for Zn^{2+} in the nanomolar range. The complexation with Zn^{2+} of the pyridine- benzimidazole chemosensor induce a powerful shielded effect on the chemical shifts of the aliphatic and aromatic protons from the vicinity (H_{α}, $H_{12'}$, $H_{8''}$, $H_{16''}$, $H_{11''}$, $H_{13''}$) with about 0.5 to 0.3 ppm, which is a solid evidence of the complexation process.

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CLOSING THE KNOWLEDGE GAP: EXPLORING GENERATION Z CZECH UNIVERSITY STUDENTS' AWARENESS AND PERCEPTIONS OF NANOTECHNOLOGY

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ABSTRACT

Nanotechnology is increasingly becoming a part of everyday life. Despite this growing integration, public awareness of nanotechnology's functionality, benefits, and potential risks remains limited. This is particularly true for Generation Z, the first digitally native generation, which is expected to play a pivotal role in shaping the future of technology and its applications. Given their position as future leaders and consumers, it is important to understand how Generation Z, specifically university students, perceives and understands nanotechnology. The primary aim of this study was to assess the current level of knowledge about nanotechnology among the Czech public, with a specific focus on Generation Z university students. This focus on Generation Z is particularly important as their views on new technologies, including nanotechnology, will likely shape public discourse and innovation trends in the coming decades. A cross-sectional online survey was conducted using the Nano-Knowledge Instrument and a Sociodemographic questionnaire. The research sample consisted of 107 Generation Z university students aged 19-26, from diverse fields of study. The findings revealed knowledge gaps regarding the benefits and applications of nanomaterials. These results highlight the necessity for targeted educational initiatives to address these gaps, particularly within Generation Z, to ensure informed public engagement. Enhancing awareness among younger generations is essential for fostering responsible innovation and creating a supportive environment for the development of NT policies.

Keywords: nanotechnology, public perception, Generation Z

INTRODUCTION

Nanotechnology has become a significant catalyst for change in modern society, with nanomaterials being utilized across a multitude of fields such as healthcare, electronics, environmental management, and energy production. These materials, designed at the molecular and atomic levels, not only offer groundbreaking innovations but also introduce distinct challenges and risks that require public comprehension and involvement. Although nanotechnology is increasingly found in everyday items, the general public's awareness of its functions, benefits, and potential risks remains insufficient. This lack of understanding is especially evident among Generation Z, the first cohort to have grown up entirely in a digital age, making them crucial players in influencing future technological developments.

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A key factor in understanding public perception is the concept of *attitudes*. Attitudes are generally defined as an individual's favourable or unfavourable evaluations or feelings towards an object, person, or issue [1, 2]. Attitudes are complex, multidimensional constructs composed of three primary components: cognitive, affective, and behavioural. The *cognitive* component refers to the beliefs, knowledge, and thoughts one holds about a particular subject, which play a critical role in shaping how an individual evaluates it. The *affective* component involves the emotional reactions or feelings one associates with the subject, while the *behavioural* component reflects the intentions or actual actions taken in response to the subject [1, 2].

In the context of nanotechnology, the cognitive component of attitudes is particularly significant. This component includes what individuals know about nanotechnology—such as its applications, potential risks, and societal benefits—and can strongly influence how they react to it. For example, if someone perceives nanotechnologies primarily as beneficial for medical advancements, their overall attitude towards it is likely to be positive, and they may be more inclined to support its development. Conversely, if someone holds strong beliefs about the risks of nanomaterials to human health or the environment, their attitude may be more negative, leading to opposition or caution in its adoption [1, 2].

The cognitive dimension of attitudes plays a crucial role in shaping behaviour. According to Ajzen's "Theory of Planned Behaviour" [3], an individual's intention to act is influenced by their attitudes towards a behaviour, along with perceived behavioural control and societal norms. Consequently, knowledge and beliefs about nanotechnology can directly influence behaviours such as endorsing nanotechnology-related policies, purchasing nanotechnology-based products, or engaging in discussions about its regulation. For Generation Z, who are constantly exposed to vast amounts of digital and scientific information, their attitudes toward nanotechnology may be particularly susceptible to external influences, including formal education and media exposure.

Additionally, an individual's general disposition toward science and technology significantly shapes their attitudes toward nanotechnology. Those who have a more positive outlook on science and technology, in general, tend to also hold favourable views on nanotechnology [4, 5, 6]. This effect is driven by the rational evaluation of risks and benefits associated with nanotechnology applications. Greater interest in and engagement with scientific advancements often lead to a perception of increased benefits from nanotechnology, further reinforcing positive attitudes toward its development and use.

This study aims to assess the current level of knowledge about nanotechnology among the Czech public, with a specific focus on Generation Z university students. The findings of this study will help inform targeted educational strategies to address knowledge gaps, ensuring that Generation Z is well-prepared to engage with and shape the future of nanotechnology in a responsible and informed manner.

Based on the study's objectives, the following research question was formulated:

RQ: What is the current level of knowledge about nanotechnology among Generation Z university students in the Czech Republic?

MATERIALS AND METHODS

Participants and data collection

The sample consisted of 107 respondents aged 19–26 out of which 76.5% were female and 23.5% male) from various academic disciplines, including natural sciences, engineering, humanities, and medicine. Data collection was conducted electronically via Google Forms, which adhered to methodological and research standards for online data collection, including secure data handling, encrypted transfer, archiving, and access control through a generated password. The survey link was distributed by email to university students from Generation Z across the Czech Republic. The introductory section of the questionnaire provided participants with information about the study, assurances of anonymity and confidentiality, and an option to consent to participate voluntarily. Only individuals who confirmed their willingness to participate were granted access to the questionnaire. Data collection occurred over a one-month period, from September to October 2024.

Measures

Data collection was performed through the following methods:

a) Socio-demographic questionnaire collecting information such as age, gender, field of study.

b) The self-perceived knowledge of nanomaterials was assessed through the item, “What level of knowledge do you have about nanomaterials?” using a Likert scale ranging from 1 (no knowledge) to 5 (extensive knowledge).

c) Six items, inspired by the NanoKI instrument, were presented sequentially on the screen, each requiring participants to "Indicate whether each of the following statements is true or false, or indicate if you do not know," following the order presented in the Appendix. Scoring was based on assigning a value of 1 to each correct response (i.e., selecting “True” for a true statement and “False” for a false statement) and a value of 0 to each incorrect response (i.e., selecting “True” for a false statement or “False” for a true statement). Responses marked as “Don't know” were also assigned a value of 0. The sum of correct responses determined an individual's total score, with possible scores ranging from 0 to 6 [7]. The Cronbach’s alpha coefficient for the 6 items was $\alpha = 0.86$ demonstrating a high reliability of the scale.

Data processing and evaluation

The study employed a quantitative survey design, with data collected electronically via Google Forms. This platform met the methodological requirements for online research, offering high data security, archiving, data encoding during transfer, and restricted access through password protection. In the second phase, data underwent formal and logical validation, revealing no missing values. Data integrity was maintained by configuring the collection process to prevent incomplete responses. Subsequent analyses were conducted using STATISTICA, version 13.

Statistical analyses

An analysis of the distribution of results confirmed normality in the data, justifying the use of parametric statistical methods. Descriptive statistics, including means, standard deviations, and frequencies, were computed for demographic variables. To examine the

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relationship between age, self-perceived knowledge of nanomaterials, and factual knowledge of nanomaterials, Pearson correlation coefficients were calculated. All statistical tests were conducted at a 5% level of significance.

Ethical considerations

This study adhered to ethical guidelines for research involving human subjects, ensuring that all participants were treated with respect and dignity throughout the research process. Prior to participation, informed consent was obtained from all respondents. Participants were provided with detailed information about the study's purpose, procedures, potential risks, and benefits, allowing them to make an informed decision regarding their involvement. The survey was designed to maintain confidentiality and anonymity; no personally identifiable information was collected. Participants were assured that their responses would be aggregated and reported in a manner that would not reveal individual identities.

RESULTS

Demographic overview and knowledge levels

A total of 107 university students aged 19–26 (mean age = 20.97, SD = 2.21) participated in the study, with a gender distribution of 81.31% female and 18.69% male. Participants represented a range of academic disciplines, with the highest representation from technical, medical, and natural sciences (57.01%), while 42.99% were from humanities-related fields. Socio-demographic status varied across income levels, with the majority identifying as low-income individuals (62.62%) or students without income (28.97%).

Table 1. Self-perceived knowledge of nanomaterials

	N	%
None	28	42.99%
Minimal	46	27.10%
General level	29	26.17%
Fairly good	2	1.87%
Excellent	2	1.87%

The results in Table 1 reveal that most participants self-reported having minimal to no knowledge about nanomaterials. Specifically, 42.99% indicated having "None" of the knowledge, while 27.10% reported "Minimal" knowledge. A smaller portion, 26.17%, perceived their understanding as being at a "General level." Only 3.74% rated their knowledge as "Fairly good" or "Excellent." These findings suggest that while the public may recognize the concept of nanomaterials, their detailed understanding is limited.

Table 2. Factual knowledge levels of nanotechnology

	Mean	SD	Correct n	Correct %
1 nanometre (nm) is a million times smaller than a metre.	0.420561	0.495972	45	42.06%
Nanotechnology includes objects ranging in size from 1 nm to 100 nm.	0.551402	0.499691	59	55.14%
At the nanoscale, materials have different properties than at conventional dimensions.	0.803738	0.399038	86	80.37%
Objects at the nanoscale are visible to the naked eye.	0.728972	0.446582	78	72.90%
Nanoscale objects have no volume.	0.841121	0.367283	90	84.11%
Nanoscale objects can be used to treat diseases such as cancer.	0.747664	0.436397	80	74.77%
Factual knowledge- total score	4.093458	1.247887		

The results in table 2. indicate varying levels of knowledge about nanotechnology concepts among participants. Knowledge about the fact that "1 nanometer (nm) is a million times smaller than a meter" was relatively low, with only 42.06% answering correctly (M = 0.42, SD = 0.50). Understanding that "nanotechnologies involve objects sized from 1 nm to 100 nm" was slightly higher, with 55.14% correct responses (M = 0.55, SD = 0.50). Participants demonstrated a stronger understanding of the unique properties of materials at the nanoscale, with 80.37% identifying correctly that "materials have different properties at the nanoscale compared to regular scales" (M = 0.80, SD = 0.40). Additionally, misconceptions about visibility and volume of nanoscale objects were relatively low, as 72.90% correctly indicated that such objects are not visible to the naked eye (M = 0.73, SD = 0.45) and 84.11% disagreed with the incorrect statement that nanoscale objects have no volume (M = 0.84, SD = 0.37). Furthermore, 74.77% recognized the potential application of nanoscale objects in treating diseases like cancer (M = 0.75, SD = 0.44). The total knowledge score (M = 4.09, SD = 1.25) reflects a moderate to high understanding of nanotechnology among participants.

Table 3. Pearson correlations between age, self- perceived knowledge and factual knowledge of nanotechnology

	Age	Self-perceived knowledge	Factual knowledge-total score
Age	1		
Self-perceived knowledge	0.39 *	1	
Factual knowledge-total score	0.17	0.29 **	1

Note: * $p < 0.01$, $p < 0.05$

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The correlation analysis presented in table 3. reveals several notable relationships among the variables concerning nanotechnology knowledge and perception. Age is positively correlated with self-perceived knowledge ($r = 0.39$, $p < 0.001$), suggesting that older participants report higher levels of familiarity with nanotechnology. Self-perceived knowledge also correlates positively with factual knowledge scores ($r = 0.29$, $p = 0.002$), which suggests that participants with higher perception of their knowledge tend to have higher factual knowledge. Lastly, the factual total score knowledge does not significantly correlate with age ($r = 0.17$, $p = 0.070$) suggesting that factual knowledge levels are relatively stable across age groups.

DISCUSSION

The results indicate a moderate level of public understanding of nanotechnology, with relatively high awareness of practical applications but notable gaps in foundational knowledge; only 42.06% of participants correctly understood that a nanometer is one million times smaller than a meter. This aligns with other studies showing that while the public often grasps application-based aspects of nanotechnology, core concepts, like scale and measurement, are less understood, the high recognition of unique nanoscale properties (80.37%) and medical applications (74.77%) suggests that applied uses of nanotechnology are more accessible to the public, possibly due to their prominence in popular media and discussions about medical innovations [8]. When discussing attitudes, particularly focusing on the cognitive component which involves knowledge, participants' familiarity with nanotechnology applications—such as medical uses—may reinforce a positive cognitive bias, supporting a favourable view of nanotechnology's potential. This cognitive component of attitudes, which includes knowledge and beliefs about the technology, appears more developed for application-based knowledge than for foundational understanding. This disparity in knowledge may influence attitudes: while practical applications are readily accepted, uncertainty surrounding core concepts could impact overall perceptions of nanotechnology's risks and benefits [9, 10].

Future studies could examine the influence of foundational knowledge gaps on public attitudes and how enhancing cognitive components of understanding might affect attitudes toward nanotechnology. Additionally, research could investigate how different educational interventions could improve public comprehension of foundational concepts, potentially leading to more nuanced and informed attitudes toward emerging nanotechnologies.

CONCLUSION

In conclusion, this study reveals a moderate to high level of knowledge about nanotechnology among participants, with strong understanding in areas like the unique properties of nanoscale materials and applications in medicine. However, specific knowledge gaps exist, particularly regarding the precise scale of nanometers, indicating that foundational concepts may need emphasis in educational efforts. The observed positive correlation between age and self-perceived knowledge suggests that familiarity with nanotechnology may increase over time or with exposure, while the correlation between self-perceived and factual knowledge points to a reasonable alignment between confidence and understanding among participants.

A key limitation of this study is its reliance on self-reported measures, which could introduce bias in both perceived and actual knowledge assessments. Additionally, the

sample may not represent the broader population, as it was focused on Generation Z university students, potentially limiting generalizability to other age groups or educational backgrounds.

Future research could address these limitations by including a more diverse sample across different demographics to determine if similar knowledge trends and correlations are consistent. Furthermore, longitudinal studies or intervention-based research could examine how specific educational strategies impact nanotechnology knowledge over time, helping to identify the most effective methods to fill knowledge gaps and prepare individuals to engage thoughtfully with emerging nanotechnologies. Enhancing education on fundamental principles, especially nanoscale measurement, could support a more comprehensive understanding. Given the promising association between self-perceived and actual knowledge, targeted educational efforts could leverage this awareness to build on existing public interest and comprehension.

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INVESTIGATION OF HEAT TREATMENT EFFECT ON MICROSTRUCTURE AND PROPERTIES OF IRON-CARBON ALLOYS OBTAINED USING Fe-Mn-B-SHS COMPLEX LIGATURE

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ABSTRACT

In the current paper the effectiveness of complex Fe-Mn-B SHS alloys and carbide-forming additives into iron-carbon alloys and for obtaining 30MnB5, 22MnB5 steels and bainite cast iron has been established. The influence of alloying components on the structure and properties of the obtained alloys has been investigated. On the basis of the analysis of the obtained experimental data the influence of heat treatment on the microstructure and properties of the obtained alloys has been established. The conducted researches have confirmed the practical value of the work, which consists in the use of cheap complex Fe-Mn-B Self-propagating High-temperature Synthesis (SHS) ligature and carbide-forming additives, obtained from production waste and cheap oxides, for alloying of iron-carbon alloys. The effectiveness of influence of complex Fe-Mn-B SHS ligature on heat treatment and structure for obtaining the required properties of 30MnB5, 22MnB5 steels and bainite cast iron has been studied.

Keywords: Alloying, Production wastes, Steel, Cast Iron, Self-propagating High-temperature Synthesis, Heat Treatment

INTRODUCTION

Existing studies on the production of various ligatures by Self-propagating High-temperature Synthesis (SHS) are clearly presented in a number of works [1-3]. SHS ligatures were obtained from production waste, which predetermined their relatively low cost. In addition, the low cost of SHS ligatures is due to the fact, that other components of the chasm are oxides, which are much cheaper than their metallic and non-metallic analogues [4,5]. Using the SHS method in the Fe-Mn-B system, in our laboratory have also been obtained a complex alloy, which was taken as the basis for alloying iron-carbon alloys.

The aim of the present work is to introduce complex Fe-Mn-B SHS alloys and carbide-forming additives into iron-carbon alloys and to establish their effectiveness for obtaining 30MnB5, 22MnB5 steels and bainite cast iron; Determination of the effect of

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heat treatment on the microstructure and properties of the obtained alloys and analysis of the obtained data.

The selection of these alloys was determined by the demand from industry, where they have a wide range of applications, which are described below.

Steel 30MnB5 - designed for the manufacture of parts and products, which after heat treatment (quenching with tempering) because of the reduced carbon content in the steel are characterized by good wear resistance and strength, toughness and resistance to mechanical stress. Boron-alloyed, quenched and tempered steels are widely used for hot stamping in the automotive industry [6-8]. 22MnB5 steel is intended for hot forging, it is designed to meet the requirements of the automotive industry guaranteeing higher passive safety and weight reduction [9]. The addition of molybdenum to steel promotes the formation of a fine-grained structure and increases the load-bearing capacity at high temperatures and impact loads. Molybdenum is added to steel in small quantities. Molybdenum additions should be rational, as small doses may be ineffective and too large doses may lead to brittleness[10]. For the alloying Molybdenum is introduced in the amount of 0.2-5 %. It increases the strength and hardness of steel, improves its plastic properties up to 0.6%, significantly increases the hardenability of steel, and also has the property of eliminating temper embrittlement [11].

In contrast to conventional cast irons, austenitic-bainitic cast irons have higher strength, wear resistance, hardness and corrosion resistance [12-14]. In world practice austenitic-bainitic cast irons (ABI) are widely used in automotive and other industries. They are used to produce: gear parts, highly loaded gears, springs for trucks, railroad couplings, connecting frames, brake, cranks and other parts for critical applications, successfully replacing carbon and low-alloy steels.

Molybdenum additive in cast iron retards the graphitization of carbon and promotes carbide formation. As the molybdenum content increases, hardness increases without affecting machinability and wear resistance increases. Molybdenum promotes grinding of pearlite and graphite inclusions, increases tensile strength, slows down the process of carbon graphitization.

MATERIALS AND METHODS

Experimental melting of iron-carbon alloys was carried out in small-size induction furnaces of MM-2000 and MM-5000 models. To obtain steels with the calculated composition, low-carbon steel, composition: C- 0,218; Si- 0,213; Mn- 0,608; P- 0,0098; S- 0,0038; B- 0,000062; Fe- the rest portion, was used as a feedstock.

Gray cast iron, composition: C- 3.3-3.4; Si- 2.0-2.1; Mn- 0.25-0.28; P- 0.02; S- 0.003-0.005; Mg- 0.035-0.048; Fe- rest portion, was used as feedstock for austenite-bainite cast iron.

At the initial stage, in order to obtain steels of the specified grades, preliminary melting was carried out and alloys close to the calculated compositions were established (Table 1, Exp.1M-7M), afterwards, one basic composition of steel and cast iron was selected. Subsequently, alloying and additives were gradually increased till the compositions of the required grades were obtained (Table 1, exp.1-21).

Table 1. Chemical composition of the obtained alloys.

Experiments	C	Si	Mn	P	S	B	Gr	Other metals
№ 1M steel	0,18	0,226	2,335	0,01	0,018	0,0046	0,085	
№ 2 M steel	0.207	0,285	2,346	0,0097	0,01	0,016	0.083	
№ 3 M cast iron	3,188	1,265	1,31	0,033	0,0087	0,007	0,005	
№ 4 M steel	0,217	0,233	1,874	0,0086	0,017	0,021	0,083	
№ 5 M steel	0,314	0,223	1,331	0,0097	0,076	0,036	0,087	
№ 6 M steel	0,333	0,204	1,383	0,01	0,024	0,0057	0,084	
№ 7 M cast iron	3,568	1,37	0,801	0,027	0,0056	0,0033	0,051	
№ 1 steel	0,311	0,239	2,341	0,016	0,040	0,0079	0,1	
№ 2 steel	0,253	0,223	1,343	0,014	0,049	0,0084	0,104	
№ 3steel	0,276	0,212	1,108	0,013	0,038	0,0049	0,101	
№ 4 steel	0,212	0,212	1,183	0,011	0,025	0,0036	0,097	
№ 5 steel	0,129	0,218	1,339	0,012	0,029	0,004	0,102	
№ 6steel	0,265	0,217	1,514	0,012	0,056	0,0094	0,107	
№ 7 steel	0,139	0,209	0,951	0,012	0,03	0,0058	0,1	
№ 8 steel	0,176	0,284	1,34	0,0096	0,021	0,0069	0,096	
№ 9 steel	0,144	0,222	1,73	0,0093	0,02	0,0031	0,1	
№ 10 steel	0,213	0,275	2,330	0,012	0,021	0,08	0,101	
№ 11steel	0,185	0,228	1,377	0,012	0,022	0,01	0,105	Mo- 0,175
№ 12 steel	0,152	0,262	2,094	0,01	0,015	0,021	0,103	Mo-0,725
№ 13 steel	0,184	0,22	1,575	0,012	0,018	0,006	0,104	V- 0,378
№ 14 steel	1,91	0,21	1,306	0,012	0,02	0,0064	0,104	W-0,309
№ 17 cast iron	3,548	1,287	0,792	0,051	0,011	0,0032	0,005	
№ 18 cast iron	3,585	1,28	1,182	0,052	0,0048	0,0059	0,005	
№ 19 cast iron	3,751	1,333	0,894	0,045	0,0071	0,01	0,0058	Mo- 0,243
№ 20 cast iron	3,621	1,321	1,101	0,052	0,0051	0,012	0,0072	V- 0,336
№ 21 cast iron	3,557	1,283	0,813	0,051	0,056	0,0064	0,0056	W-0,303

Remark*: the rest, as a portion, is the Iron.

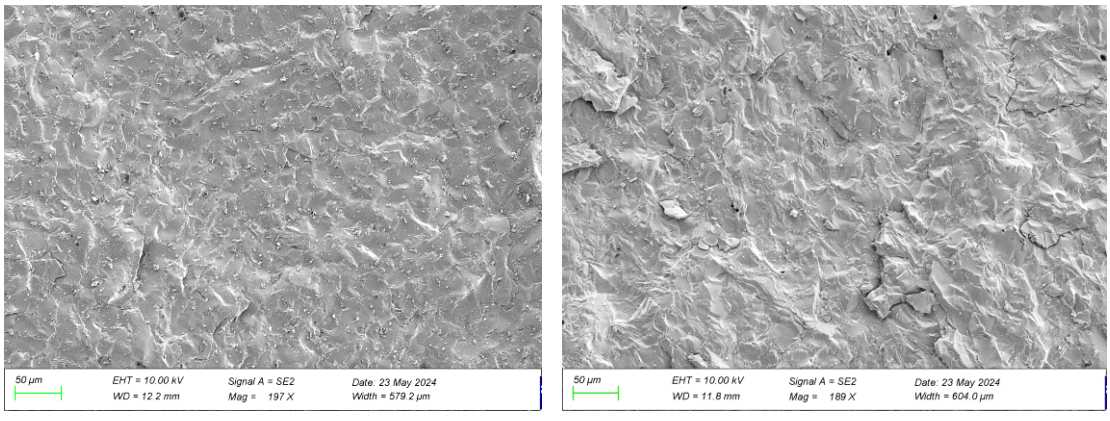
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It should be noted that to carry out a full-scale study of the properties of all the obtained alloys is an interesting and very wide research work, but it is not the purpose of this study. Therefore, we limited ourselves to the study of alloys under the numbers: #3; #9; #11; #18 and #19 from the table 1.

RESULTS AND DISCUSSIONS

To obtain steel alloy grade 30MnB5 SHS ligature composition: Mn-69,8; Si-17,1; B-0,27; the rest - Fe, was introduced in an amount of 0.7 per cent (composition No. 3, Table 1, Fig. 1a). To obtain steel 22MnB5 SHS ligature of composition: Mn-69,5; Si-17,0; B-0,46; the rest - Fe, was introduced in an amount of 1,5% (composition №9, Table 1, Fig.1b). To obtain alloys close to industrial alloys, the SHS ligatures used are characterized by a homogeneous structure. There are no impurities in the ligatures, which are displaced from the synthesis zone (self-cleaning) in the SHS process. Both ligatures are free of pores and cracks. The fracture is ductile with a characteristic dimpled structure, depressions are visible, between which more or less narrow lintels are observed on Figures 1a and 1b. Besides, SHS-ligature of composition: Mn-64,2; Fe -16,1; Mo- 18,2; B-1,5 in amount of 2% was introduced into low-carbon steel of initial composition (composition No. 11, Table 1). It should be noted that due to the absence of carbon in the steel together with SHS ligature, graphite in the amount of 0.1 % was additionally introduced.

To obtain austenitic-bainitic cast iron, SHS ligature of the following composition was introduced into grey cast iron: Mn-69.8; Si-17.1; B-0.27; ost-Fe in the amount of 1.5% (composition No. 18, Table 1). In addition, in grey cast iron was introduced SHS-ligature of the composition Mn-64,2; Fe -16,1; Mo- 18,2; B-1,5 in the amount of 2% (composition № 19, Table 1). To obtain austenitic-bainitic cast iron, SHS ligature of the following composition was introduced into grey cast iron: Mn-69.8; Si-17.1; B-0.27; ost-Fe in the amount of 1.5% (composition No. 18, Table 1). In addition, in grey cast iron was introduced SHS-ligature of the composition Mn-64,2; Fe -16,1; Mo- 18,2; B-1,5 in the amount of 2% (composition № 19, Table 1).



a b

Figure.1 Microstructures of SHS ligature:

a - steel 30MnB5 SHS ligature of composition: Mn-69,8; Si-17,1; B-0,27; the rest - Fe

b - steel 22MnB5 SHS- ligature of composition: Mn-69,5; Si-17,0; B-0,46; the rest - Fe.

The process of melting iron-carbon alloys was carried out according to a single scheme, which included. The initial low-carbon steel or cast iron, in the amount of 200g, was placed in a special refractory ceramic bowl of conical shape, which in turn was located in the refractory crucible of the induction furnace, and subjected to melting. The required amount of SHS ligature as well as the necessary additives were immersed in the superheated liquid melt and kept for 1 min for their complete dissolution.

After fusion, the crucible with the ceramic cup was removed from the crucible of the induction furnace and cooled down. Then the obtained parts were subjected to mechanical processing to make samples for thermal and isothermal treatment, according to the scheme presented on Fig. 2.

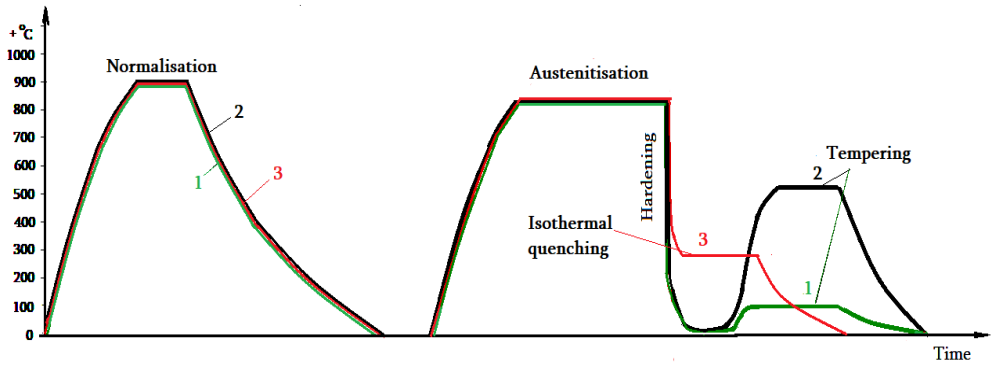


Fig. 2. Scheme of thermal and isothermal treatment of the obtained iron-carbon alloys. 1 and 2 curves of thermal treatment of samples of obtained steels;
3 - curve of isothermal treatment of obtained cast irons.

Due to the fact that the conditions of cooling mode of cast samples for technological reasons was different, so all of them, before thermal and isothermal treatment, were subjected to high-temperature annealing (above the GSE line) with subsequent cooling in air. From all the obtained samples, samples were selected for further metallographic studies, which, in terms of chemical composition, satisfied the comparable compositions of industrial iron-carbon alloys. Steel specimens (curve 1) were heated and kept for 10-15 min in a furnace at 870-890^{0}C, quenching was carried out in water, subsequent tempering was carried out for 1h (cooling in the furnace) at 100^{0}C. Steel samples (curve 2) were heated and kept for 10-15 min in an oven at 870-890^{0}C, quenching was carried out in water, subsequent tempering at 550^{0}C was carried out for 0.5h (oven cooling) at 150^{0}C. Cast iron samples (curve 3) were heated and held for 40 min in an oven at 950-990^{0}C, isothermal quenching was carried out for 1h in liquid lead at 290^{0}C, cooling in an oven at 100^{0}C. Table 1 shows the chemical composition of the obtained samples depending on the amount of complex SHS ligature and additives.

Table 2 shows the comparison of compositions of industrial and investigated alloys by chemical composition.

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Table 2. Chemical composition of industrial and investigated iron-carbon alloys

	C	Si	Mn	P	S	B	Gr	Fe	Other elements
30Mn5B	0,27-0,33	<0,4	1,15-1,45	0,025	0,035	0,0008-0,005		96,81	
22Mn5B	0.19-0,25	<0,4	1,1-1,4	0,025	0,015	0,0008-0,005	<0,4	96,73	
Grey cast iron	3,3	2,1	0,25	0,033	0,0087	---	---	94,04	
№ 3 steel	0,276	0,212	1,108	0,013	0,038	0,0049	0,101		
№ 9 steel	0,144	0,222	1,73	0,0093	0,02	0,0031	0,1		
№ 11 steel	0,185	0,228	1,377	0,012	0,022	0,01	0,105		Mo- 0,175
№ 18 cast iron	3,585	1,28	1,182	0,052	0,0048	0,0059	0,005		
№ 19 cast iron	3,751	1,333	0,894	0,045	0,0071	0,01	0,0058		Mo- 0,243

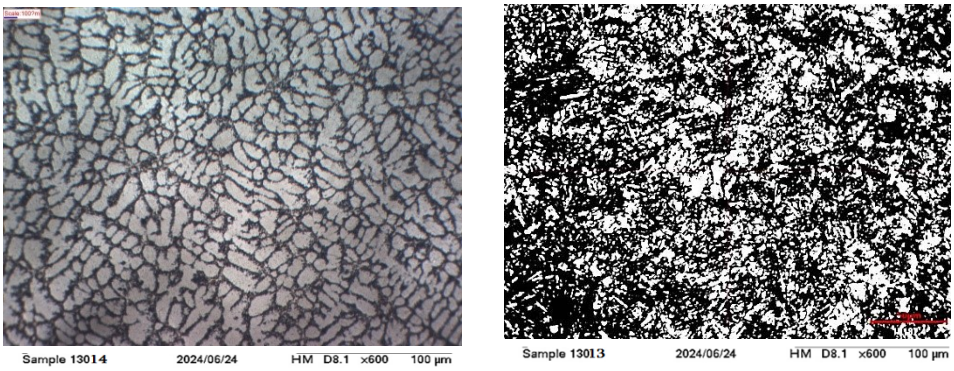
Table 3 shows comparison of hardness of industrial and investigated alloys depending on heat treatment modes.

Table 3: Hardness of industrial and investigated iron-carbon alloys

№, sample	**Hardness after heat treatment**		
	Normalization. Heating to 900°C, holding for 10-15 minutes and cooling in the furnace	Heating and holding for 10-15 min in an oven at 870-890°C, quenching in water, tempering for 1 h at 100°C.	Heating and holding for 10-15 min in an oven at 870-890°C, quenching in water, tempering at 550°C for 0.5 h, cooling in an oven at 150°C.
	Regime1	Regime2	Regime3
30Mn5B	---	47 HRC	26 HRC
22Mn5B	114(HB)	---	---
3 (SHS-30Mn5B)	83 (HRB)	46,7 HRC	27,3 HRC
9(SHS-22Mn5B)	113,6(HB)	43,9 HRC	24,3 HRC
11 (steel+ SHS Fe-Mn-B-Mo)	97,5 (HRB)	40,3 HRC	32,7 HRC
	Normalization. Heating to 900^0C, holding for 10-15 minutes	Heating and holding for 40 min at 950-990^0C, isothermal quenching for 1 h in liquid lead at 290^0C,	

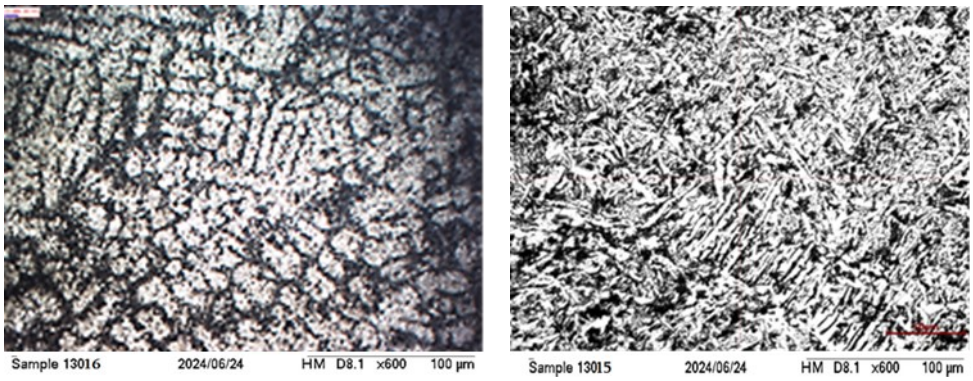
	and cooling in the furnace	oven cooling at 100^0C.	
Grey iron	14-25,5 HRC		
18 (SHS- Grey iron)	15 HRC	24,3 HRC	----
19 (Grey iron + SHS Fe-Mn-B-Mo	48 HRC	45 HRC	----

After establishing the chemical composition, carrying out the necessary heat treatment regime and determining the hardness, the samples were examined by methods of metallographic analysis on and electron microscopes.



#3-1 #3-2

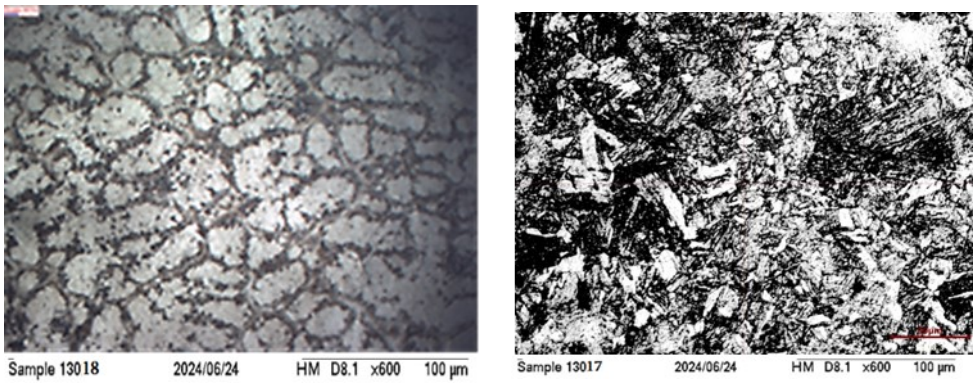
Figure 3: Sample No. 3. 3-1 microstructure of 30Mn5B grade steel (obtained by SHS ligature) after heat treatment according to mode 1 (Table 3); 3-2 microstructure of 30Mn5B grade steel (obtained by SHS ligature) after heat treatment according to mode 3 (Table 3).



#9-1 #9-2

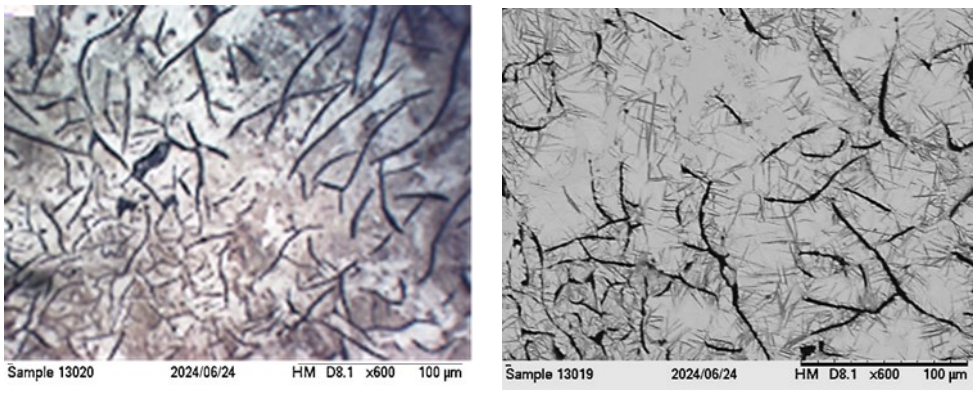
Figure 4. Sample No 9. 9-1 microstructure of 22Mn5B grade steel (obtained by SHS ligature) after heat treatment according to mode 1 (Table 3); 9-2 microstructure of 22Mn5B grade steel (obtained by SHS ligature) after heat treatment according to mode 3 (Table 3).

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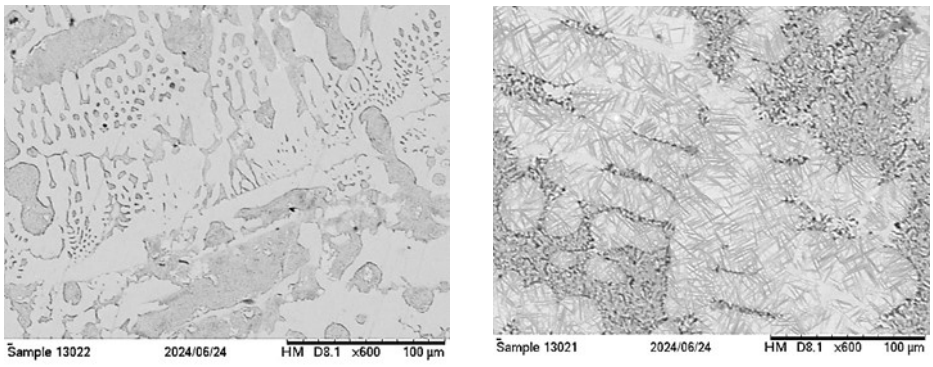
#11-1 #11-2

Figure 5: Sample No. 11. 11-1 microstructure of SHS Fe-Mn-B-Mo alloyed low-carbon steel after heat treatment by mode 1 (Table 3); 11-2 microstructure of SHS Fe-Mn-B-Mo alloyed low-carbon steel after heat treatment by mode 3 (Table 3).



#18-1 #18-2

Figure 6: Sample No. 18. 18-1 microstructure of grey cast iron (obtained by SHS ligature) after heat treatment under mode 1 (Table 3); 18-2 microstructure of grey cast iron (obtained by SHS ligature) after heat treatment under mode 2 (Table 3).



19-1 19-2

Figure 7: Sample No. 19. 19-1 microstructure of grey cast iron alloyed with SHS Fe-Mn-B-Mo ligature after heat treatment according to mode 1 (Table 3); 19-2 microstructure of grey cast iron alloyed with SHS Fe-Mn-B-Mo ligature after heat treatment according to mode 2 (Table 3).

The microstructure of the obtained samples 3-1; 9-1 and 11-1 (Fig.3-5) corresponds to the structure of pre-eutectoid steel (obtained after normalisation and furnace cooling). In this case, the matrix consists of pearlite (dark areas), in which ferrite grains are present (light areas). The formation of such a structure is possible as a result of the decomposition of austenite. The microstructure of the obtained samples after quenching and tempering 3-2; 9-2 (Fig. 3,4) corresponds to the martensitic structure. More finely dispersed structure is observed in sample 3-2, which is favoured by higher carbon content. Thus, sample 9-2 has a higher residual austenite content due to its low carbon content. This circumstance affected the hardness of these materials. At the same time, they correspond to the hardness of industrial analogues with similar heat treatment of materials. Sample 11-2 (Fig. 5) is characterised by a higher content of residual austenite, which is due to the fact that molybdenum, being a strong stabiliser of γ-phase, reduces the temperature of martensitic transformation onset. At the same time its volume fraction in steel decreases. Accordingly, the hardness of the material decreases (Table 3). The main elements contained in SHS ligature significantly influence the kinetics of residual austenite decomposition, and also allow to control structural transformations during tempering of steel and to estimate the carbon content at different stages of heat treatment.

The conducted theoretical and experimental investigations lead to make the preliminary assessment and conclusions. The figures 6 and 7 show microstructures of the obtained austenitic-bainitic cast irons for the production of which the complex SHS ligature Fe-Mn-B was also used. Fig. 6 #18-1 shows grey cast iron before heat treatment, and Fig.6 18-2 shows cast iron after isothermal quenching (see Table 3). In the initial state, the microstructure of the metal matrix of grey cast iron is a mixture of pearlite and 12-14 % ferrite.

Isothermal quenching of this cast iron resulted in the formation of lower bainite crystals, which are located in the volume of residual austenite (#18-2). In the cutting plane 40-45% of residual austenite is observed, the amount of which can be reduced by increasing the isothermal holding time.

Thereby the hardness of cast iron increased (see Table 3). At the same time, alloying of cast iron with SHS Fe-Mn-B complex ligature with molybdenum additive, before and after isothermal quenching, Fig. 7 (19-1 and 19-2) allowed to increase the hardness of cast iron at least twice. This was due to an increase in the dispersity of structural components and an increase in the volume fraction of the bainite phase. Thus, the effectiveness of SHS ligatures for obtaining austenitic-bainitic cast irons was also confirmed.

CONCLUSIONS

1. The microstructure of the resulting steels after normalization and cooling in a furnace corresponds to the structure of hypoeutectoid steel, and after quenching and tempering they correspond to the martensitic structure.
2. A higher content of retained austenite, due to the low carbon content, affected the hardness of the resulting steels and corresponds to the hardness of industrial analogues, with similar heat treatment of materials.

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3. The carbide-forming additive in the SHS master alloy in the form of molybdenum lowered the temperature at which the martensitic transformation began, thereby reducing the hardness of the steel as its volume fraction decreased.
4. The presence of manganese and boron micro additives makes it possible to obtain a finely dispersed structure with evenly distributed needle-shaped crystals in the steel matrix. The same structure is inherent in industrial alloys. Thus, we can say that SHS alloys make it possible to obtain steel with the required properties and are analogues of industrial alloys.
5. When alloying SHS cast iron Fe-Mn-B with a complex alloy with a molybdenum additive after isothermal hardening, the hardness of the cast iron increased at least twice, due to an increase in the dispersity of the structural components and an increase in the volume fraction of the bainite phase.
6. The conducted investigations have confirmed the practical value of the work, consisting in the use of cheap complex Fe-Mn-B SHS alloys and carbide-forming additives obtained from production wastes, as well as from cheap oxides for alloying iron-carbon alloys . Moreover, the effectiveness of influence of complex Fe-Mn-B SHS ligature on heat treatment and structure in obtaining the required properties of steel analogs 30MnB5, 22MnB5 steels and bainite cast iron has been established.

ACKNOWLEDGEMENTS

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MICROWAVE AND ULTRASOUND ASSISTED SYNTHESIS AS ECOLOGICALLY FRIENDLY METHODS IN NITROGEN HETEROCYCLIC CHEMISTRY

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ABSTRACT

On the last few years, microwave and ultrasound irradiation has become a successful tool in modern medicinal and organic chemistry especially (but not only) because in many cases synthesis became ecologically friendly. As part of our ongoing efforts in the field of nitrogen heterocyclic derivatives, we present herein some core results obtained by our group in the field of *N*-alkylation and 3+2 cycloadditions reactions applied in the nitrogen heterocycles series, by using microwave and ultrasound irradiation. Comparative with conventional thermal heating, undeniable advantages of using microwave and ultrasound irradiation was observed in terms of higher yields, better selectivity, milder reaction conditions, decreasing of the amount of used solvent comparative with thermal heating, a dramatically decrease of the reaction time from days to minutes, decreasing of the consumed energy, etc. As a result, these reactions under microwave and ultrasound irradiation could be considered environmentally friendly.

Keywords: environmentally friendly methods, microwave, ultrasound, phthalazine

INTRODUCTION

During the last decades, microwave (MW) and ultrasound (US) technology has become a successful tool applied in modern medicinal and organic chemistry [1-11]. Thus, comparative with conventional thermal heating (TH), both MW and US irradiation have several important advantages: shorter reaction times, increased selectivity, spectacular accelerations of chemical reactions, higher yields and higher product purities. Also, the MW and US assisted reactions become in many cases ecologically friendly, being energy saving methods, having milder reaction conditions, using small amounts, or no organic solvents, suppressing side reactions, having lower costs and simplicity in handling and processing [4,5,9-11]. On the other hand, nitrogen heterocyclic derivatives are reported as invaluable scaffolds in modern medicine and pharmacy (drugs, as antimicrobial, antiviral, anti-inflammatory, antihypertensive, diuretics, anticancer, anticoagulants, antidepressant, etc. [4,12-14]), organic materials for opto-electronics (electroluminescent and fluorescent materials, semiconductor devices, sensors,

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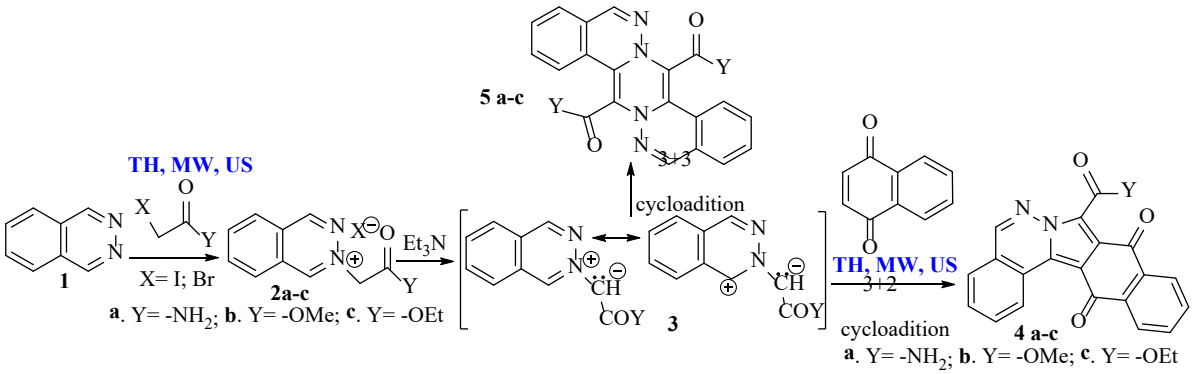
etc.[15,16]) and agriculture (grow up factors and herbicides [17,18]), etc. Having in view the above considerations and our previously experience in the field of MW and US irradiation applied in the field of nitrogen heterocycles, we decide to study the influence of MW and US irradiation in *N*-alkylation and 3+2 cycloadditions reactions applied in the phthalazine heterocycle series.

MATERIALS AND METHODS

All the reagents and solvents were purchased from TCI and Sigma Aldrich. Melting points were determined using an electrothermal Mel-Temp apparatus and were uncorrected (Barnstead International, IA, USA). The nuclear magnetic experiments (1H-NMR, 13C-NMR, 2D-COSY, 2D-HMQC, 2DHMBC) were recorded using Bruker Avance III 500/Bruker Avance DRX 400 spectrometers (Bruker, Vienna, Austria) operating at 500/400 and 125/100 MHz for 1-H and, respectively, 13-C nuclei. All chemical shifts are reported in δ units (p.p.m.) relative to the residual peak of solvent (ref: DMSO, 1H: 2.50 p.p.m.; 13C: 39.52 p.p.m.). Coupling constants (J) are given in Hz. The micro-analyses were in satisfactory agreement with the calculated values: C, ± 0.15; H, ± 0.10; N, ± 0.30. Infrared (IR) data were recorded as films on potassium bromide (KBr) pellets on a FT-IR Shimadzu Prestige 8400s spectrophotometer. Ultrasound assisted reactions were carried out using a Bandelin (Sonopuls GM 3200) reactor with a nominal power of 200 W and a frequency of 20 kHz. The booster horn SH 213 G of reactor was fixed tightly to the ultrasonic converter. The titanium flat probe tip TT13 (diameter: 12.7 mm; length: 7 mm) was fixed tightly to the booster horn. The titanium probe tips were immersed in the used solvent. with an integrated magnetic stirrer (0 to 1200 rpm) and cooling with compressed air. The best results under US irradiation were obtained applying a pulse irradiation (5s pulse/ 5s pause), for *N*-alkylation using 50% from the full power of the generator. while for 3+2 cycloadditions reactions were used 100% from the full power of the generator. For the microwave irradiation we used a 800 W STAR SYSTEM-2 monomode reactor (CEM Corporation, USA). The best results were obtained when we used 20% of the full power of the magnetron (800 W) for *N*-alkylation, respectively 50% of the full power of the magnetron for 3+2 cycloadditions reactions.

RESULTS

In order to achieve our goal, we performed a thoroughly comparative study concerning the influence of conventional TH, MW and US irradiation in the *N*-alkylation and 3+2 cycloadditions reactions applied in the phthalazine heterocycle series. In this respect, by using an adaptation of literature data [5,19,20], phthalazine **1** was *N*-alkylated with alkylbromoacetate or iodoacetamide, leading to salts **2a-c**, Scheme 1. In the second step, the cycloimmonium ylides **3** (generated in situ from the salts **2a-c**, in alkaline medium of Et_3N) react with 1,4-naphthoquinone, leading (*via* a 3+2 dipolar cycloaddition reaction) to the cycloadducts **4a-c**. As a secondary reaction, an undesirable 3+3 dipolar cycloaddition reaction of one to each other molecule of ylide took place, leading to dimeric structure **5a-c**, Scheme 1.



Scheme 1. MW, US and TH synthesis of salts **2a-c** and cycloadducts **4a-c**.

Synthesis under MW, US and TH of salt **2a-c**

In a round bottom flask, phthalazine derivatives (10 mmol) was dissolved in 10 mL methanol, then a solution of alkylbromoacetate or iodoacetamide (12 mmol, in 30 mL methanol) was added dropwise, under stirring. Under MW and US irradiation, the same amount of reagents (in 10 mL methanol) was placed in the reaction tubes (Pyrex glass or quartz) for MW synthesis respectively Pyrex tube for US synthesis. The reaction mixture was then refluxed (under conventional TH) or irradiated (under MW and US) for the appropriate period of time (Table 1). The obtained salts were filtered off then washed twice with the solvent used (10 mL). No purification required.

*Synthesis under MW, US and TH of cycloadducts **4a-c***

Phthalazium salts **2a-c** (2 mmol), 1,4-naphthoquinone (2.2 mmol) and triethylamine (3 mmol) in chloroform, was placed in a round bottom flask (for TH, in 25 mL solvent) or reaction vessel tube (Pyrex glass, in 10 mL solvent) for MW and US irradiation. The reaction mixture was then refluxed (under conventional TH) or irradiated (under MW and US) for the appropriate period of time (Table 1). The crude product were filtered off, then was crystallized from an appropriate solvent or purified by column chromatography on silica gel

DISCUSSION

In first instance, the structure of compounds was proved by elemental and spectral analysis [IR, 1H NMR, 13C NMR, NOE, DEPT, 2D-COSY, 2D-HETCOR (HMQC), long range 2D-HETCOR (HMBC)], and are in accordance with the proposed structure.

Under conventional TH the *N*-alkylation and 3+2 cycloadditions reactions have some disadvantages, in terms of long reaction time, medium yields (mostly because of the secondary reaction of 3+3 dipolar cycloaddition), high energy consumption, high amount of used solvents, etc. This is why we decide to study these reactions under MW and US irradiations, as nonconventional green methods of synthesis. The obtained results are listed in Table 1.

As it could be seen for Table 1, in the case of *N*-alkylation reactions (which are leading to the salts **2a-c**) under MW and US irradiations a significantly decrease of the reaction time (from days to 5 minutes under MW respectively 10 min under US) took place and consequently a decreasing of the consumed energy took place, and the yields are higher (slightly under US and substantially higher under MW). We also notice a remarkably

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decrease of the amount of the used solvent under MW and US irradiation, with about 4 to 5 folds.

Table 1. Synthesis of compounds **2a-c** (*via N*-alkylation reactions) and **4a-c** (*via* 3+2 cycloadditions reactions) under conventional TH and MW and US irradiation.

Cmpd.	Conventional TH		Microwave		Ultrasounds	
	Reaction time (min)	Yield	Reaction time	Yield	Reaction time	Yield
2a	1920	69	5	91	10	73
2b	1440	74	5	89	10	74
2c	1440	83	5	92	10	83
4a	1860	50	5	57	6	71
4b	2040	20	5	26	5	49
4c	3660	44	5	54	5	68

In the case of 3+2 cycloadditions reactions (which are leading to the cycloadducts **4a-c**), a comparative analysis of the data from Table 1 (conventional TH *versus* MW and US irradiation), reveal very interesting data: under MW and US irradiations a remarkable rate of acceleration was found, the reaction time decrease dramatically, from days to 5 minutes under MW respectively 5-6 min under US; consequently a decreasing of the consumed energy also took place; the yields are higher both under MW and US, but significantly higher under US (in the case of compound **4b** is more than double); we also notice a strong decrease of the amount of the used solvent under MW and US irradiation, with about 3 folds. As we mentioned before, in the case of 3+2 cycloaddition reactions of ylides **3** to 1,4-naphthoquinone, a secondary reaction of 3+3 dipolar cycloaddition took place, with the formation of dimeric structures **5a-c**. The significantly increase of reaction yield in the case of 3+2 cycloaddition under MW and US irradiations cold be explained by the fact that the cycloaddition reactions became selective in this case, the concurrent reaction of 3+3 cycloaddition being unfavoured.

CONCLUSION

In conclusion we present herein a thoroughly comparative study, conventional thermal heating *versus* microwave and ultrasound irradiation, in *N*-alkylation and 3+2 cycloadditions reactions applied in the nitrogen heterocycles series. Comparative with conventional TH, these reactions possess some certain advantages under MW and US irradiations, the most relevant being a remarkable rate of acceleration, a dramatically decrease of the reaction time (from days under TH to 5-10 minutes under MW and US) and consequently a decreasing of the consumed energy, a significantly increase for the reactions yields (yields are higher under both MW and US, but significantly higher under US), better selectivity (for 3+2 cycloaddition), a strong decrease of the amount of the used solvent with about 3 to 5 folds. As a result, *N*-alkylation and 3+2

cycloadditions reactions applied in the nitrogen heterocycles series under microwave and ultrasound irradiation could be considered environmentally friendly.

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SHAPING THE FUTURE: UNIVERSITY STUDENT´S PERCEPTIONS OF NANOTECHNOLOGY RISKS AND BENEFIT

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ABSTRACT

Nanotechnology plays a crucial role in the development of innovative products, yet public apprehension regarding its potential risks remains a significant barrier to its acceptance. This study investigates the knowledge, attitudes, and fears associated with nanomaterials among university students in the Czech Republic, aiming to inform policy formulation that aligns with public interests. Focusing on this demographic is essential, as university students are poised to influence future public discourse and innovation trends. Utilizing a cross-sectional online survey, we assessed perceptions of risks and benefits related to nanotechnology while considering sociodemographic factors such as gender and field of study. The sample comprised 107 university students aged 19-26 from diverse academic backgrounds. Our findings reveal a moderate overall familiarity with nanomaterials, while attitudes toward nanotechnology were generally positive. These insights highlight the necessity for targeted communication and educational strategies to address diverse viewpoints within society. As future decision-makers, understanding university students' perspectives is crucial for developing public policies that promote the responsible advancement and regulation of nanotechnology. Further research is needed to explore the underlying factors influencing these perceptions and to enhance public understanding of nanotechnology's benefits and risks.

Keyowords: Nanotechnology; Public perception; Risk-benefit analysis; University students; Sociodemographic factors

INTRODUCTION

Nanotechnology represents a transformative force in various sectors, including medicine, environmental science, and consumer products. As an interdisciplinary field, it encompasses the manipulation of matter at the nanoscale to create materials and devices with novel properties and functionalities. Given its potential to revolutionize industries and improve quality of life, understanding public perception, particularly among university students, is crucial. This demographic not only embodies the current generation of learners but also represents future innovators and decision-makers who will shape the discourse surrounding emerging technologies [1].

The importance of studying university students' perceptions of nanotechnology lies in their role as future leaders and influencers in both public policy and scientific research. Their understanding and attitudes towards nanotechnology can significantly impact societal acceptance and the direction of technological advancements. Furthermore, as

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these students engage with complex scientific concepts, their insights can help bridge the gap between scientific knowledge and public understanding, fostering informed decision-making processes regarding technology adoption and regulation [2].

Common public concerns regarding nanotechnology in the Czech Republic reflect a blend of general apprehensions observed globally, as well as specific local sentiments. These concerns can be categorized into several key areas:

1. **Health risks:** Many individuals express fears about the potential health impacts of nanomaterials. There is a worry that nanoparticles could pose unknown long-term health risks, particularly due to their ability to penetrate biological barriers and accumulate in the body [3].
2. **Environmental impact:** Concerns about the environmental consequences of nanotechnology are prevalent. Public apprehension centers on the potential for nanomaterials to cause harm to ecosystems, especially if they enter water supplies or soil, leading to unforeseen ecological disruptions [4].
3. **Ethical and social implications:** Ethical considerations surrounding the use of nanotechnology are significant. Issues such as privacy violations through surveillance technologies and the potential for misuse in military applications raise alarms among the public. There is also concern about equity in access to nanotechnology benefits, fearing that it may exacerbate existing social inequalities [5].
4. **Lack of understanding and misinformation:** A general lack of understanding about what nanotechnology entails contributes to public fear. Misinformation and sensationalized media portrayals can amplify these fears, leading to resistance against adopting nanotechnology applications [6].
5. **Regulatory concerns:** There is skepticism regarding the adequacy of existing regulations governing nanotechnology. Many people feel that current policies do not sufficiently protect public health and safety or address ethical issues related to its use [7].

This study seeks to contribute to a nuanced understanding of university students' perceptions of nanotechnology's risks and benefits. By addressing these perceptions through targeted educational strategies and communication efforts, stakeholders can better align technological advancements with public interests, ensuring responsible development that prioritizes safety and ethical considerations.

MATERIALS AND METHODS

Participants and data collection

The sample consisted of 107 respondents aged 19–26 out of which 76.5% were female and 23.5% male) from various academic disciplines, including natural sciences, engineering, humanities, and medicine. Data was collected electronically using Google forms, which met the methodological and research criteria of online research relevance (i.e., high degree of security, archiving and encoding during data transfer, access via generated password). The link to the survey, was distributed via email to university students of the Czech Republic, belonging to Generation Z. In the first part of the questionnaire, participants were informed about the study and were given guarantees of anonymity and confidentiality, after which they were given the option to participate or

not. Only participants who declared their intention to participate voluntarily could access the questionnaire. Data collection took place between September 2024 and October 2024.

Measures

Data collection was performed through the following methods:

a) socio demographic information such as age, gender, field of study.

b) the self-reported knowledge of nanomaterials was assessed through the item, “What level of knowledge do you have about nanomaterials?” using a Likert scale ranging from 1 (no knowledge) to 5 (extensive knowledge).

c) attitudes toward nanotechnology were assessed using the following questions: "What is your perception of the term nanotechnology?", "Do you feel concerned when you think about nanotechnology?", "Do you feel hopeful when you think about nanotechnology?", and "Do you feel anger when you think about nanotechnology?". Respondents could answer each question with "yes," "no," or "unsure."

d) trust in risk-benefit information was assessed with the following question: "How much do you trust the information about risks and benefits of products provided by experts on their packaging?" Participants responded on a scale from 1 (do not trust at all) to 7 (trust very much).

Data processing and evaluation

The study was designed as a quantitative survey, with data collected electronically via Google Forms. This platform satisfied the necessary methodological and research criteria for online data collection, ensuring high levels of security, data archiving, and encryption during transfer, as well as access control via a generated password. In the subsequent phase, the data underwent formal and logical checks, revealing no missing values. The integrity of the data was preserved throughout the collection process, which was designed to prevent incomplete responses. Further analysis was conducted using STATISTICA version 13.

Statistical analyses

An analysis of results distribution confirmed normal data distribution; for this reason, a parametric statistical approach was selected, involving descriptive statistics including means, standard deviations, and frequencies, were computed for demographic variables and key measures such as knowledge levels, attitudes, and fears. Pearson correlation coefficients were calculated to examine the relationship between knowledge about nanomaterials and attitudes toward nanotechnology. The tests were conducted at a 5% level of significance.

Ethical considerations

This study adhered to ethical guidelines for research involving human subjects, ensuring that all participants were treated with respect and dignity throughout the research process. Prior to participation, informed consent was obtained from all respondents. Participants were provided with detailed information about the study's purpose, procedures, potential risks, and benefits, allowing them to make an informed decision regarding their involvement. The survey was designed to maintain confidentiality and anonymity; no personally identifiable information was collected. Participants were assured that their

responses would be aggregated and reported in a manner that would not reveal individual identities.

RESULTS

Demographic overview and knowledge levels

A total of 107 university students aged 19–26 (mean age = 20.97, SD = 2.21) participated in the study, with a gender distribution of 81.31% female and 18.69% male. Participants represented a range of academic disciplines, with the highest representation from technical, medical, and natural sciences (57.01%), while 42.99% were from humanities-related fields. Socio-demographic status varied across income levels, with the majority identifying as low-income individuals (62.62%) or students without income (28.97%).

Knowledge and attitudes toward nanomaterials

The results in Table 1 reveal that most participants self-reported having minimal to no knowledge about nanomaterials. Specifically, 42.99% indicated having "None" of the knowledge, while 27.10% reported "Minimal" knowledge. A smaller portion, 26.17%, perceived their understanding as being at a "General level." Only 3.74% rated their knowledge as "Fairly good" or "Excellent." These findings suggest that while the public may recognize the concept of nanomaterials, their detailed understanding is limited.

Table 1. Self-perceived knowledge of nanomaterials

	N	%
None	28	42.99%
Minimal	46	27.10%
General level	29	26.17%
Fairly good	2	1.87%
Excellent	2	1.87%

The results indicate that most participants do not feel concerned when thinking about nanotechnology, with 81.31% responding "No" and only a small percentage (8.41%) feeling worried. Similarly, negative emotions like anger are uncommon, as 87.85% of respondents reported not feeling angry about nanotechnology, with just 1.87% expressing such feelings. In contrast, a sense of optimism is more prevalent, as 55.14% of participants indicated they feel hopeful about nanotechnology, suggesting that, overall, attitudes toward nanotechnology are more positive or neutral than negative.

Table 2. Attitudes toward nanotechnology

	No		Yes		I do not know	
	n	%	n	%	n	%
Do you feel uneasy at the thought of nanotechnology?	87	81.31%	9	8.41%	11	10.28%
Do you feel hopeful at the thought of nanotechnology?	19	17.76%	59	55.14%	29	27.10%
Do you feel anger at the thought of nanotechnology?	94	87.85%	2	1.87%	11	10.28%

Correlation between knowledge, perception of nanotechnology and perception of risk and benefits

The results show several significant correlations among participants' age, self-reported knowledge, perceptions of the term "nanotechnology as well as risk and benefits perception. Age is positively correlated with self-reported knowledge indicating that older participants tend to rate their understanding of nanotechnology higher. However, perceptions of nanotechnology are negatively correlated with both age and self-reported knowledge implying that older participants and those with higher self-reported knowledge may view the term "nanotechnology" less favorably. These findings highlight that while knowledge increases with age, attitudes toward nanotechnology might become less positive. The correlation analysis of risk-benefit perceptions shows weak correlations between the variables. However, none of these correlations are statistically significant. These results suggest that the relationships between the risk and benefit factors may not be robust enough to draw meaningful conclusions, and any observed associations are likely due to random variation. Therefore, further research with larger sample sizes or different methodologies may be required to explore potentially significant relationships.

Table 2. Pearson correlations between chosen variables

	Correlation			
Variable	Age	Knowledge	Perception	Risk-Benefit
Age	1			
Knowledge	0.39*	1		
Perception	0.29**	0.34*	1	
Risk-benefit	0.04	0.05	0.10	1

Note: * $p < 0.01$, $p < 0.05$

DISCUSSION

The results of this study provide significant insights into the knowledge, attitudes, and fears associated with nanomaterials among university students. The demographic overview reveals most female participants and a diverse representation across academic disciplines, particularly in medical and natural sciences. This distribution is crucial as it underscores the potential for varying levels of engagement with nanotechnology based on educational background.

The original research question sought to investigate how knowledge of nanomaterials influences attitudes and comfort levels regarding their application. The findings substantiate this hypothesis, demonstrating a positive correlation between knowledge and comfort with nanotechnology applications. This aligns with recent studies indicating that increased familiarity with emerging technologies correlates with more favorable attitudes [8; 9]. The results are consistent with existing literature that emphasizes the importance of knowledge in shaping public perception of nanotechnology. For instance, Joubert et al. (2020) found that public understanding significantly influences attitudes toward nanotechnology applications in various sectors [4]. Furthermore, students from engineering and natural sciences reported significantly higher knowledge scores

compared to those in the humanities, corroborating findings from previous research that highlight disciplinary differences in technological familiarity [9].

The implications of these findings are profound for educational strategies aimed at enhancing knowledge about nanotechnology. Targeted interventions should focus on increasing awareness in disciplines where familiarity is low, such as the humanities. Furthermore, addressing specific fears—especially those related to health and environmental risks—could facilitate greater public acceptance of nanotechnology. Previous studies have indicated that providing clear information and fostering trust in scientific institutions can mitigate fears associated with emerging technologies [10, 11].

In conclusion, this study underscores the necessity for ongoing educational initiatives that not only enhance knowledge but also address demographic disparities in perceptions of nanotechnology. By fostering informed attitudes through tailored educational strategies, stakeholders can promote a more nuanced understanding of the benefits and risks associated with nanomaterials.

CONCLUSION

The findings of this research underscore the critical role that knowledge plays in shaping attitudes toward nanotechnology among university students. The positive correlation between familiarity and comfort levels suggests that enhancing educational efforts in nanotechnology could lead to greater acceptance and application of these technologies in various fields. However, the significant fears regarding health and environmental risks highlight the need for targeted communication strategies to address public concerns effectively. Further research is necessary to explore the underlying reasons for the gender disparities observed in fear levels and to investigate how socio-economic factors influence perceptions of risk associated with nanomaterials. Longitudinal studies could provide insights into how attitudes evolve as students gain more exposure to nanotechnology through their academic programs. Additionally, qualitative research could delve deeper into the specific concerns that students have about nanomaterials, allowing for a more nuanced understanding of public sentiment.
In summary, while this study provides valuable insights into the current state of knowledge and attitudes toward nanotechnology among university students, it also raises important questions about how to effectively communicate the benefits and risks associated with these emerging technologies. Addressing these questions through further research will be essential for fostering informed public discourse and acceptance of nanotechnology in society.

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WILLINGNESS TO PAY FOR NANOTECHNOLOGY PRODUCTS: THE CZECH REPUBLIC EXPERIENCE

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ABSTRACT

The current development of nanotechnology responds to climate change, sustainability issues, the energy crisis, and the need to improve the quality of life. The question, however, is what are the societal impacts and public acceptance of nanotechnology? To explore this, a pilot cross-sectional study was conducted in the Czech Republic.

The main objective of this study is to discuss consumers' willingness to pay for products containing nanotechnology. A sub-objective is to present the results of a pilot cross-sectional study on willingness to pay for nanotechnology products in the Czech Republic. The methods of literature review, questionnaire survey and subsequent statistical evaluation are used. The number of respondents in the pilot cross-sectional study is 216. Respondents commented on 2 groups of products: 1) products containing nanotechnology, identical to conventional products, and 2) products containing nanotechnology with improved properties and/or design.

The findings reveal that people's willingness to pay for nanotechnology products varies, largely depending on their knowledge of nanomaterials, education, and income. Importantly, respondents showed a higher willingness to pay for products with nanotech- enhanced performance or design. Educating the public and raising awareness about the benefits of nanotechnology could be crucial steps in increasing its societal acceptance and promoting its role in addressing global challenges.

Keywords: Nanotechnology; Willingness to Pay; Sustainability; Consumers; Czech Republic

INTRODUCTION

The current development of nanotechnology responds to climate change, sustainability issues, the energy crisis and the need to improve the quality of life. Moreover, new materials based on nanotechnology greatly contribute to the realization of the circular economy concept and the reduction of material intensity. The question, however, is what are the societal impacts and public acceptance of nanotechnology? To explore this,

a pilot cross-sectional study was conducted in the Czech Republic, using demographic data and a willingness-to-pay questionnaire.

Based on the literature review, research on willingness to pay (WTP) for nanotechnologies is currently conducted mainly at the national level, in the form of case studies, and deals with different types of products. Thus, the level of WTP may also vary depending on whether the product is a packaging product, a product for external use or a product for internal use (food, medicine).

For example, the study by Schnettler et al. [1] focuses on the analysis of the level of a consumer food neophobia to the acceptance of innovative technologies applied to food production, taking nanotechnology as an example of the innovative technologies. This study is based on a questionnaire survey conducted in Chile. The authors examined WTP for foods with nanotechnological applications and WTP for food packaging with nanotechnological applications.

Another study examining WTP using a questionnaire survey was conducted by O'Callaghan and Kerry [2]. The authors focused on WTP for products containing nanotechnologies. Based on their research, willingness increased after participants received information about the value of using such technologies. Based on the results of their research, education and knowledge of nanotechnology play a key role in WTP.

Concerning the food industry in the USA, Zhou et al. [3] observe consumer attitude and preference for specific products (food and food-related products) that are produced using nanotechnology. The authors examined WTP for nano-attributes using online survey, a choice experiment focusing on canola oil. The results showed that respondents would only be willing to buy oil produced from nanoscale-modified seeds or packed with nanotechnology-enhanced technique if it cost less than comparable conventional products.

Another study also deals with food and uses an experiment as a method. Bieberstein et al. [4] focused on consumers in France and Germany and WTP for food nanotechnology, such as nano-fortification with vitamins and nano-packaging. The findings show that a considerable proportion of consumers in both countries exhibit a reluctance to accept the incorporation of nanotechnology in food products. On the contrary, the results of the research by Erdem [5] show that consumers generally do not show any strong preference or aversion to nanotechnology.

The study by Liu et al. [6] in China observes pesticide users and food consumers and their WTP for nano pesticides. The authors used a questionnaire survey as their method. The results showed that consumers are willing to pay more for nano pesticides, compared to conventional products.

The literature search shows that the authors of published scientific studies use various methods, especially questionnaire surveys or experimental methods, to figure out WTP. It is also clear that the results for WTP vary across countries and product types. In the Czech Republic, no research has yet been conducted on WTP for products containing nanotechnology. There are studies investigating consumer behaviour in different areas [7], [8], [9], but not focusing on nanotechnology and nanocomponent products and their perception from the consumers' point of view. Therefore, the authors of this paper try to fill this gap and conduct research focusing on consumers in the Czech Republic.

MATERIALS AND METHODS

The main objective of this study is to discuss consumers' WTP for products containing nanotechnology. A sub-objective is to present the results of a pilot cross-sectional study on WTP for nanotechnology products in the Czech Republic.

Regarding the research goals, the following research questions are set:

RQ1: Are consumers in the Czech Republic willing to pay more for products containing nanotechnology/nanocomponents?

RQ2: Does WTP vary among consumers in the Czech Republic based on their socio-economic characteristics?

The methods of literature review, questionnaire survey and subsequent statistical evaluation are used. The questionnaire survey deals with the level of awareness, attitudes and behaviour regarding nanotechnology. The key part of the survey focused on consumer behaviour and WTP. The willingness to pay questions are based on the study of Liu et al. [6], the same research design on the questions and the price increase was chosen, i.e., 10% - 130%. Respondents commented on 2 groups of products: 1) products containing nanotechnology, identical to conventional products, and 2) products containing nanotechnology with improved properties and/or design.

The pilot research was conducted in the Czech Republic between September 1, 2024, and November 4, 2024. The questionnaire was sent to various institutions in the Czech Republic and shared on the social network LinkedIn. The sample of respondents is therefore random.

The number of respondents in the pilot cross-sectional study is 216. More details about the sample are described in Table 1.

Table 1. Description of the sample

Average age	**Standard deviation (age)**
30.27	12.97
Size of city/municipality	**Number of respondents**
1 – 1,999 inhabitants	51
2,000 – 9,999 inhabitants	32
10,000 – 49,999 inhabitants	45
more than 50,000 inhabitants	88

Source: authors

RESULTS

Given the limited length of this paper, this chapter will present the results of a pilot WTP survey for nanotechnology/nanoparticle-containing products among consumers in the Czech Republic, focusing on respondents' education and income. Respondents commented on 2 groups of products: 1) products containing nanotechnology, identical

to conventional products, and 2) products containing nanotechnology with improved properties and/or design.

Education

Respondents were divided into groups according to their level of education. Specifically, the following groups were selected: primary education (PE), secondary education (SE), secondary education with high school diploma (SED), higher education – bachelor (HEBC), higher education – master (HEMA), and postgraduate education (PGE).

The following Table 2 shows the WTP results for products containing nanotechnology that are identical to conventional products for respondents overall and by education group.

Table 2: EDU - Product containing nanotechnology, identical to a conventional product.

Education	Lower price	Same price	+10%	+25%	+40%	+50%	+75%	+100%	+130%
PE	100%	0%	0%	0%	0%	0%	0%	0%	0%
SE	100%	75%	75%	25%	0%	0%	0%	0%	0%
SED	61%	54%	29%	23%	10%	12%	7%	5%	6%
HEBC	67%	71%	42%	24%	7%	5%	2%	4%	2%
HEMA	84%	84%	74%	42%	19%	16%	9%	9%	7%
PGE	77%	80%	57%	47%	30%	17%	17%	17%	17%
ALL	**70%**	**68%**	**46%**	**30%**	**13%**	**12%**	**7%**	**7%**	**6%**

Source: authors

The following Table 3 shows the WTP results for products containing nanotechnology with improved properties and/or design for respondents overall and by education group.

Table 3: EDU - Product containing nanotechnology, improved properties and/or design.

Education	Lower price	Same price	+10%	+25%	+40%	+50%	+75%	+100%	+130%
PE	100%	100%	100%	0%	0%	0%	0%	0%	0%
SE	100%	100%	50%	25%	0%	0%	0%	0%	0%
SED	60%	52%	39%	31%	22%	14%	13%	10%	11%
HEBC	85%	84%	69%	47%	27%	15%	9%	7%	5%
HEMA	86%	88%	84%	70%	40%	33%	21%	16%	12%
PGE	87%	93%	83%	67%	53%	50%	27%	27%	27%
ALL	**76%**	**74%**	**62%**	**48%**	**31%**	**23%**	**15%**	**13%**	**12%**

Source: authors

We first look at all respondents and their WTP in both product groups - identical to conventional products and a product with improved features or design. While for identical products a majority of respondents are only willing to pay either a lower or the same price, for products with improved design or features more than 50% of respondents are willing to pay a higher price. The tables also show that respondents with higher education are willing to pay a higher price. For example, one third of the

respondents in the HEMA category are willing to pay a price higher by 50% to buy a product containing nanotechnology with improved design or features.

Income

Respondents were divided into groups according to their level of income. Specifically, the following groups were selected: no income (NI), low income (LI), average income (AI), higher income (HI), and highly above average income (HAI).

The following Table 4 shows the WTP results for products containing nanotechnology that are identical to conventional products for respondents overall and by income group.

Table 4: INC - Product containing nanotechnology, identical to a conventional product.

Income	Lower price	Same price	+10%	+25%	+40%	+50%	+75%	+100%	+130%
NI	61%	52%	36%	24%	15%	12%	3%	0%	0%
LI	71%	63%	37%	24%	6%	9%	5%	5%	3%
AI	68%	74%	54%	31%	13%	11%	10%	10%	10%
HI	82%	82%	54%	50%	32%	18%	14%	14%	11%
HAI	100%	100%	100%	50%	25%	25%	0%	0%	0%
ALL	**70%**	**68%**	**46%**	**30%**	**13%**	**12%**	**7%**	**7%**	**6%**

Source: authors

The following Table 5 shows the WTP results for products containing nanotechnology with improved properties and/or design for respondents overall and by education group.

Table 5: INC - Product containing nanotechnology, improved properties and/or design.

Income	Lower price	Same price	+10%	+25%	+40%	+50%	+75%	+100%	+130%
NI	67%	52%	52%	36%	21%	21%	18%	9%	12%
LI	72%	71%	53%	38%	25%	15%	10%	5%	6%
AI	82%	82%	69%	54%	31%	22%	15%	15%	15%
HI	82%	86%	75%	68%	54%	43%	25%	29%	18%
HAI	100%	100%	100%	75%	50%	50%	25%	25%	0%
ALL	**76%**	**74%**	**62%**	**48%**	**31%**	**23%**	**15%**	**13%**	**12%**

Source: authors

The results for all respondents are the same as in the above-described Tables 2 and 3. Concerning the income-specific results, it is interesting to observe the WTP for consumers in each income group and for both product groups. For the product identical to the conventional product, WTP is highest for the average and higher income groups. Conversely, the highest income group is more likely to be willing to pay more for products with improved properties and/or design.

If we generalise the results, higher income groups are willing to pay more for products containing nanotechnology. Higher-income groups are also willing to pay extra for products with improved properties and/or design.

DISCUSSION

Firstly, we focus on answering our research questions.

Concerning RQ1 (Are consumers in the Czech Republic willing to pay more for products containing nanotechnology/nanocomponents?), we can say that consumers in the Czech Republic (respondents from the pilot research) are willing to pay more, but mostly for products with improved characteristics or design (nanotech-enhanced products). If it is a product with identical characteristics to a conventional product, more than 50% of consumers will only buy it at a lower or the same price as its substitute. If we take a closer look at the structure of the respondents, the answers vary.

Within RQ2 (Does WTP vary among consumers in the Czech Republic based on their socio-economic characteristics?), we can comment on the education and income categories. Here we can generalise that WTP increases with higher education and with higher income. Thus, we can answer this research question yes, socio-economic characteristics have an influence on consumer behaviour and decision-making for products containing nanotechnology.

However, it is necessary to mention the limitations of our study. As this is a pilot study, we only have a limited sample of respondents (216). Increasing the number of respondents will contribute to increasing the significance of the research. Due to the limited space, only simple statistics were also presented. The use of advanced statistical methods will contribute to a more sophisticated analysis of possible relationships and connections between variables.

On the other hand, even the pilot results can be compared with scientific studies.

The results of the study Schnettler et al. [1] show, that 48.7% of consumers in Chile would be willing to buy foods with nanotechnological applications and 69.1% would be willing to buy packaging for foods with nanotechnological applications. Our pilot research shows that 70% of consumers would be willing to buy products containing nanotechnologies and 76% of consumers would be willing to buy products containing nanotechnologies with improved properties and/or design. If we consider that our results refer to general consumer products (without distinguishing whether they are materials, food, medicines, cosmetics, or others), we can compare our result for general product with the result for packaging material in Chile. Thus, the two results are similar, WTP fluctuates around 70%.

Liu at al. [6] found that 97.4% of pesticide users were willing to pay for nano pesticides, with a main price from 25% to 40% higher than for conventional pesticides. Comparing this with our results for general product, 30% of consumers would be willing to buy product containing nanotechnologies with a main price 25% higher than for conventional product. 48% of consumers would be willing to buy enhanced product with a main price 25% higher than for conventional product.

At this point, it is important to stress that nanotechnology can be part of the production process at any stage, so it is good to consider global value chain issues. The global value chain does not only involve production processes, but preproduction (such as design) and postproduction processes (such as marketing and distribution) [10].

Further research should be aimed at expanding the pilot study in terms of increasing the number of respondents as well as focusing on identifying WTP for several types of

products such as materials, clothing, medicines, cosmetics, food, electronics, and others. In addition to expanding the questionnaire survey, experimental approaches and focus groups would also be useful.

CONCLUSION

The main objective of this paper was to discuss consumers' WTP for products containing nanotechnology. A sub-objective was to present the results of a pilot cross-sectional study on WTP for nanotechnology products in the Czech Republic. The methods of literature review, questionnaire survey and subsequent statistical evaluation were used.

The number of respondents in the pilot cross-sectional study is 216. The findings reveal that people's WTP for nanotechnology products varies, largely depending on their knowledge of nanomaterials, education, and income. Importantly, respondents showed a higher WTP for products with nanotech-enhanced performance or design.

In conclusion, nanotechnology has the potential to significantly enhance sustainability and improve product performance, but public acceptance plays a key role in its broader adoption. The study highlights that while people are generally willing to pay more for superior nanotech-enhanced products, their willingness is closely tied to their socioeconomic characteristics, such as education and income. Educating the public and raising awareness about the benefits of nanotechnology could be crucial steps in increasing its societal acceptance and promoting its role in addressing global challenges like climate change and resource efficiency.

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SECTION

BIOTECHNOLOGY FOR SUSTAINABLE SOLUTIONS.

BIOENGINEERING

DONKEY MILK ACROSS DIFFERENT STAGES OF LACTATION: A NUTRITIONAL ASSET FOR SUSTAINABLE FARMING AND SOCIAL IMPACT

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ABSTRACT

The social significance of donkey milk for human health stems from its potential advantages for vulnerable populations, including children and those with special dietary needs. The variation in its composition throughout lactation indicates that it can be adapted to fulfil the specific nutritional demands of these groups. The focus of this paper is to investigate the chemical profile of donkey milk and the changes that occur during lactation. The study was performed on samples taken at various stages of lactation, from colostrum to milk. The results revealed fluctuations in protein, fat, lactose and dry matter, reflecting the milk's adaptation to the changing needs of the foals. The results indicate a significant increase in lactose content from 6.24% in the second month of lactation to 6.42% in the sixth month. Regarding the protein level, it decreased from 1.88% in early lactation to 1.41% during late lactation. This study has important implications for the use of donkey milk in human nutrition, providing insight into its potential use in product development for targeted sensitive groups such as infants and people with special nutritional needs.

Keywords: donkey milk quality, chemical profile, human health, lactation stages, colostrum

INTRODUCTION

Donkey milk is recognized for its excellent nutritional potential due to its characteristic low-fat content and high content of essential fatty acids, short- and medium-chain fatty acids, and proteins [1], [2]. However, the variation of its composition during the lactation period results in modifications of its nutritional and energetic value. As the consumption of donkey milk and its derivatives has been growing worldwide, it is important to transmit information about this variation to consumers in order to assess its nutritional benefits more accurately, promoting beneficial effects in particular during the most critical periods [3]. However, few studies are available on the variability of donkey milk at the key stage of the first 150 days of lactation concerning both social implications and nutritional benefits overall.

Lactation in female mammals typically occurs in three distinct stages: early, mid, and late lactation. During early lactation, particularly in the colostrum phase, donkey milk is rich in proteins and immune factors, providing vital antibodies to newborn foals [4]. As lactation progresses to mid and late stages, the composition changes, impacting the levels of fat, protein, and minerals [5]. Understanding these variations is essential not only for optimizing the nutritional benefits for consumers but also for improving management practices in donkey farming. In conclusion, our research aims to contribute to the knowledge of donkey milk composition in order to promote the consumption of this valuable food product.

MATERIALS AND METHODS

The research evaluated the nutritional composition of donkey milk across different stages of lactation, specifically focusing on the colostrum phase and subsequent lactation months. The objective was to analyse the average milk compositional changes during the first four days of colostrum and throughout the first six months of lactation.

The study was conducted between March and May 2024 and the samples were collected from different jennies in various stages of lactations. A total of 3 farms and 48 females were included in the data collection. The sampling occurred in a systematic manner to ensure comprehensive data collection. Milk was collected daily, from 7 jennies, for the first four days postpartum. A total of 20 milk samples were collected from the first farm. These samples included colostrum collected in the initial four days postpartum and also samples from donkeys between two and six months of lactation. From the second farm, 15 milk samples were collected, which also included samples from the colostrum phase as well as monthly samples. In the third farm, 13 milk samples were collected, following the same collection protocol as the previous farms.

In total, we collected colostrum samples from 7 jennies the selected farms, along with 11 samples of milk from jennies in the second month of lactation, 8 samples in the third month, 7 samples in the fourth month, 9 samples in the fifth month, and 13 samples in the sixth month of lactation. The milking was performed manually, adhering to strict hygiene conditions during the milking process.

All female donkeys selected across the three farms were confirmed to be healthy, with no known health issues that could affect their milk production or composition. Prior to participation, veterinary assessments ensured that each animal exhibited good health and normal physiological functions during lactation.

The selected jennies were maintained in a natural, free-ranging environment across all three farms. The donkeys had access to extensive pastureland, allowing them to graze freely and exhibit natural behaviours. The forage consisted primarily of fresh grass available on the pasture.

The samples were analysed immediately after milking to ensure the integrity and accuracy of the nutritional data. Analysing the samples promptly allowed for the evaluation of their fresh composition, minimizing the risk of any changes in the physicochemical properties that could occur over time. The milk samples were conducted via infrared spectrometry, using a Lactoscope to determine the milk's nutritional profile, enabling rapid and non-destructive assessment of the components. Multiple compositional parameters were determined, including protein, lactose, fat, and dry matter.

RESULTS

3.1. Nutritional parameters in colostrum

The nutritional parameters of colostrum are presented in figure 3.1. The analysis of fat content in colostrum during the initial days postpartum reveals a high concentration on the first day. The average fat content was recorded at 0.72%, which is substantially higher than typical mature milk. Subsequent measurements indicated a gradual decline in fat content, decreasing to 0.53% on the second day, 0.39% on the third day, and reaching 0.24% by the fourth day.

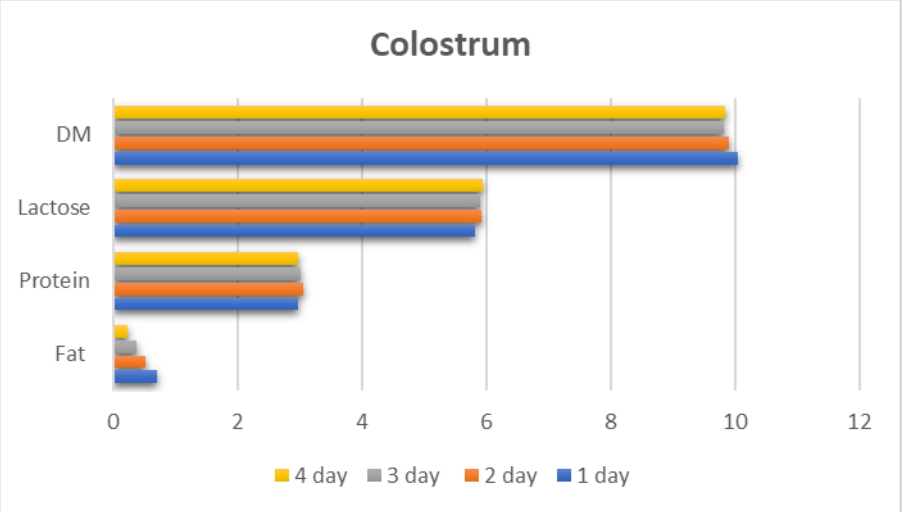


Figure 3.1. Chemical composition of colostrum

Similar trends are observed in protein content. On the first day postpartum, the average concentration was recorded at 2.97%. In the following days, protein levels exhibited a slight increase. On the second day, protein content reached 3.06%, and on the third day the value was 3.02%. These fluctuations may reflect the specific physiological variations between individuals, which can influence the overall nutrient profile of the milk. By the fourth day, the protein content further declined to 2.98%. This gradual decline in protein concentration correlates with the foal's growing dietary independence.

In contrast to fat and protein, lactose content exhibited a different pattern. The lactose concentration at this stage was relatively low with an average value of 5.82%, as the primary focus of colostrum is nutrient provision over carbohydrate content. There was a steady increase in lactose levels throughout this period, reaching 5.93% on the second day, 5.90% on the third day, and peaking at 5.94% by the fourth day. This increase serves to provide a growing energy source as the foal transitions from reliance on colostrum to incorporating more carbohydrates in its diet.

Regarding the dry matter content, on the first day it was high at an average value of 10.04%. This level indicates that colostrum is nutrient-dense and suitable for meeting the foal's initial energy and nutritional needs. Over the initial days, the DM content began to decrease steadily, recording 9.91% on day two, 9.82% on day 3, and reaching 9.84% by day 4. This decline highlights the transition as the foal's diet starts to shift, impacting the overall concentration of nutrients present in the milk.

https://doi.org/10.5593/sgem2024v/6.2/s24.07

3.2. Nutritional parameters in milk

The chemical analysis of the milk samples revealed variations in nutritional composition based on lactation stages. The components analyzed included fat content, protein content, lactose levels and total solids. The results are shown in fig. 3.2.

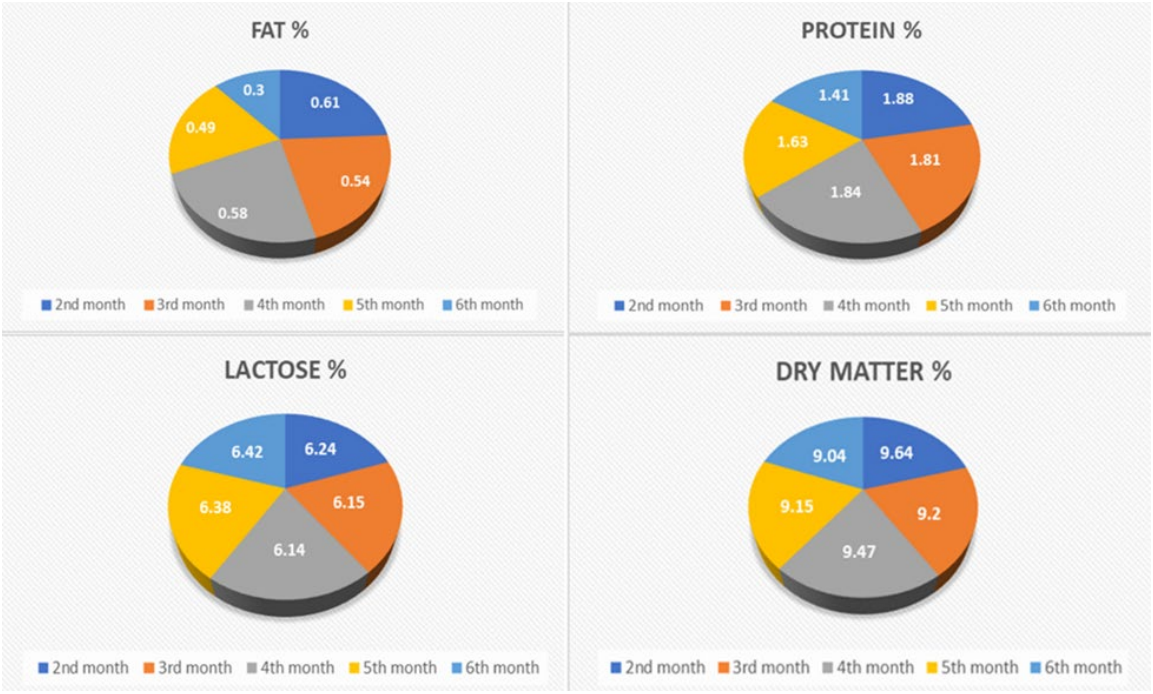


Figure 3.2. Chemical composition of milk

The fat content was between 0.37% and 1.02% during the second month of lactation, with an average of 0.61%. This decrease, compared to colostrum, indicates the transition from colostrum to mature milk. In the fallowing months, a progressive decline was recorded, with values decreasing to 0.54% in the third month, 0.58% in the fourth month, 0.49% in the fifth month and 0.30% in the last month. By the sixth month, fat values ranged between 0.10% and 0.50%, reflecting the adaptation of the milk composition as the lactation period progresses.

Similarly, the protein content started at an average of 3% in colostrum and decreased to 1.88% in the second month, with values ranging from 1.09% to 2%. Continuing the same pattern, it decreases gradually to an average of 1.81% in the third month, down to 1.84% in the fourth month, 1.63% in the fifth month and 1.41% in the sixth month with a range between 1.20% and 1.55%. The overall trend indicates a reduction in protein levels mirroring the decline observed in fat content.

On the opposite spectrum, the lactose content began at an average of 5.82% on day one of colostrum, and rose steadily to 6,24% in the second month, with values spanning from 5.75% to 6.80%. This rise in lactose is associated with the transition from colostrum to mature milk, as the nutritional composition begins to adapt to the growth requirements of the foal. In the following two months, lactose levels experienced a slight decrease, measuring an average of 6.15% in the third month and 6.14% in the fourth month. This decline may reflect a shift in the milk composition as the female adjusts to the changing nutritional demands and metabolic adaptations of the lactating period. Further on, the lactose experienced a noticeable increase, reaching an average of

6.38% in the fifth month and 6.42% in the sixth month with values falling between 6% and 6.75%.

The dry matter content provided an overview of the overall density of nutrients in donkey milk, displaying a similar downward trend as fat and protein levels. The values were noted at an average of 10.4% in colostrum, providing a baseline for nutrient composition. The dry matter continued to decrease, recording 9.64% within the second month, with values measured between 9.15% and 10%. In the third month the decrease was significant, the average being 9.2%. Subsequently, the pattern changes slightly and increased to 9.47 during the fourth month but then showed a gradual decrease to 9.15% in the fifth month and 9.04% in the sixth month. This ongoing reduction indicates that as the lactation progresses, the nutritional density of the milk diminishes, aligning with the foal's increasing consumption of solid food.

The analysis of nutritional components in donkey milk revealed significant variability among individuals, underscoring the unique physiological and nutritional profiles that each jenny may present. By representing the values as monthly averages, we gain enhanced clarity regarding the nutritional changes occurring in the milk throughout the lactation period.

DISCUSSION

The composition of donkey colostrum is critical for the health and development of the newborn foal. This study examined the nutritional parameters of colostrum collected during the first four days postpartum, focusing on the fluctuations in fat, protein, lactose, and dry matter (DM) content. The results demonstrated that while fat and protein levels generally decreased, lactose content exhibited an upward trend during this period. These findings align with previous studies indicating that colostrum is richer in immunoglobulins and nutrients immediately after birth, making it vital for the foal’s initial growth [6], [7].

In this study, the fat content in donkey milk showed a declining trend throughout the lactation period, with an average of 0.61% observed during the second month and decreasing to 0.3% by the sixth month. This decrease aligns with previous findings in the literature, where it has been noted that fat levels in donkey milk tend to decrease as lactation progresses [8]. The initial high fat content serves to provide essential energy and support satiety for the foal, especially during the early stages of lactation when the foal is primarily reliant on milk for nutrition [9].

Protein content in donkey milk also exhibited trends similar to those observed in fat levels. The average protein content at the beginning of lactation was recorded at 1.88%, which subsequently fluctuated, reaching a peak of 1.41% by the sixth month. This finding corroborates research conducted by Davis et al. in 2021, which emphasized the importance of protein in supporting both the immune function and growth of the foal during early development [10]. Another study, publish by Martini et al. in 2014, supports these discoveries, demonstrating similar findings in their research. They observed that the protein content in donkey milk decreases from a value of 1.77% at 30 days postpartum to 1.5% at 270 days postpartum [11].

The dry matter content in donkey milk reflected a more complex dynamic, demonstrating variations in response to the lactation phase. Total solids decreased from 9.64% in early lactation to 9.04% by the sixth month. This decline in dry matter is

indicative of the ongoing adjustments in milk composition as the foal transitions in its feeding habits and nutrient intake [5].

The ability of donkey milk to provide consistent nutrition despite these fluctuations underscores its value not only for the health of the foal but also presents opportunities for human consumption, especially in the context of lactose intolerance or dairy allergies, as donkey milk is often touted for its favourable composition [12].

In contrast to fat and protein, lactose levels increased throughout the lactation stages. The increase in lactose aligns with findings from Malacarne et al. (2019), indicating that as the foal matures and starts to consume solid feed, the energy demands increase [13]. Lactose serves as a primary carbohydrate source in donkey milk, and its gradual rise is crucial to support the energetic needs of the growing foal [8].

The significance of jenny milk production extends beyond its nutritional value. Donkey farming is recognized as a sustainable agricultural practice that requires fewer resources compared to traditional dairy farming. Donkeys are well-adapted to arid environments and can thrive on marginal lands, promoting biodiversity and reducing the environmental footprint of dairy farming.

CONCLUSION

Overall, the findings from this study highlight the dynamic nature of donkey milk's nutritional profile and its adaptability to meet the foal's changing needs. The fluctuations in fat, protein, lactose, and dry matter emphasize the necessity of understanding jenny milk's unique properties, which not only support the health of foals but also offer opportunities for human consumption, particularly for those with lactose intolerance. Additionally, the promotion of donkey farming as a sustainable practice can positively impact rural economies and enhance food security. Further research is essential to explore the long-term impacts of these nutritional variations and the broader implications of donkey dairy production.

In conclusion, this study underlines the significant nutritional advantages of donkey milk, particularly for targeted sensitive groups such as infants and people with special nutritional needs. By understanding the composition and adaptability of donkey milk, across the different periods of lactations people and stakeholders in the dairy industry can better address the nutritional changes that are continuously evolving for both animals and humans, while also supporting sustainable agricultural practices.

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EDIBLE BIOPOLYMER PACKAGING, ZERO-WASTE ALTERNATIVES FOR PRESERVATION AND CONSUMING POWDERED BEVERAGES

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ABSTRACT

Refinement of consumer preferences made the food industry to develop new products, with improved characteristics, with openness to monocomponent products. Unfortunately, the preference for this type of products leads to high costs, especially due to the packaging used. International policies, and especially European ones, are looking for solutions to eliminate the hazardous waste for the environment. The present study discusses the development of a biopolymeric material intended for the packaging of powdered drinks, solubilized and consumed together with them. Based on a patent-pending composition of sodium alginate, agar, glycerol and water, the newly developed material has very good physical, mechanical and solubility properties, comparable to those of conventional packaging, often multilayered, difficult to sort and almost impossible to recycle. According to laboratory tests, the material dissolves completely in water at a temperature of 80 degrees. For the sensory analysis, 80 students from the food industry program constituted a group of panelists who tested soluble coffee with and without solubilized edible packaging. According to the results obtained after the application of two questionnaires, the panelists are open to consuming such materials and scored the attributes of the new product with good to very good scores. The results indicated the possibility of using biopolymer-based material for soluble coffee packaging. For the safety of the consumer and the increase of the product's shelf life, it is recommended that it be delivered in a secondary packaging, based on cardboard, in order to continue the initiative to respect the environment.

Keywords: food; environment; alginate; agar; innovation

INTRODUCTION

Current research regarding the use of biopolymers as films and coatings in the food industry has been ongoing for a long time, and the results have been a game changer for the industry. Although initially used as substances with the role of texturing, preservation, stabilization, etc., biopolymers, due to their properties, have become more and more used for other purposes. For example, the development of smart packaging or coatings, antimicrobial or antioxidant, with additions of substances that can improve or potentiate various characteristics (flavours, colours, biological properties). All these, among other very good properties, have made them great candidates for food packaging, with comparable characteristics and sometimes superior to conventional synthetic ones [1]. Biopolymers are extensively used due to their characteristics such as regenerability, sustainability, compostability, edibility, lack of allergens, toxicity, but also properties

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such as: *i)* mechanical - high tensile strength and elongation at break; *ii*) physical - different thicknesses, from nanometres to meters, colours, pleasant textures, which can be improved due to the ability of the matrix to retain various compounds, different aromas, good optical properties (transmittance, opacity, UV barrier), optimized retraction ratio; *iii*) chemical - due to the structure of the matrix, they allow the development of new chemical bonds with other molecules and the modification of the initial structure; *iv*) biological - by adding active substances they can receive new characteristics, such as antioxidant, antimicrobial, regenerator or accelerator, intelligent sensors etc; *v*) thermal stability; *vi*) barrier – can control the exchange of gases, aroma, moisture, or water vapor with other environments [2].

Food packaging is one of the most important steps in ensuring the safety and the acceptance of the final product. In addition to the ability to ensure preservation and maintain the characteristics of the product, a material used for packaging must be economical in terms of manufacturing costs, comply with the regulations and those related to waste disposal [3]. Many times, due to these factors, the final price of the products is higher, an unfavourable aspect for the industry. The studies carried out on consumers and their preferences have highlighted the fact that, often, they choose the product depending on the packaging [4]. Therefore, packaging has become not only a way to provide a safer product for consumption, but a real marketing strategy.

Polysaccharides and proteins are among the most used biopolymers for the development of packaging for the food industry. Using a packaging based on biopolymers, accepted for consumption in *quantum statis* doses, a series of problems are eliminated, such as those related to product safety, the costs of raw materials and processing, those related to the elimination of waste because they are completely biodegradable, compostable and edible, generating zero waste.

The aim of the current study was to develop a material based on biopolymers, used for packaging soluble drinks, coffee and cappuccino, and consumed together with them. Unfortunately, the disposable packages used for coffee or other types of soluble drinks are difficult to sort and almost impossible to recycle, due to the multilayer component (usually they contain 2 or 3 layers of different materials, of which at least one is metallic or polyethylene base, glued and coloured with synthetic substances) [5]. Thus, our packaging, entirely obtained from biopolymers, completely solubilized together with the contained product, aligns with the EU directives on reduce, reuse and recycle packaging and eliminates the problems generated by the waste resulting from the use of conventional packaging, so harmful to the environment [6].

MATERIALS AND METHODS

For this study, polysaccharides such as alginate and agar were used to obtain a completely soluble packaging in water at temperatures above 70°C. Once obtained, the material was tested in order to establish the physical-chemical and mechanical characteristics. Thus, the microstructure, thickness, retraction ratio, color, transmittance, opacity, water activity index, microbiological and solubility tests were performed. For consumers' testing, it was used for packaging single servings of instant coffee and cappuccino. In order to evaluate the acceptability and preferences of the consumers, they were distributed and tested by 80 students from Stefan cel Mare Suceava University (age 20-24 years old, 42% - 21 years old).

After testing, they filled in two questionnaires regarding their habits about the consumption of coffee and other soluble drinks, as well as the openness to a bio-edible packaging. The second questionnaire, filled in after consumption presented the scores obtained by the tested and control samples, following characteristics such as appearance, smell, colour, taste, aroma, smoothness and palatability. For the second questionnaire, the scores were assigned as follows: 1 – very bad, 2 – bad, 3 – no changes, regardless, 4 – good and 5 – very good.

Biopolymeric packaging development - The was obtained through casting method. Thus, for a 30 x 60 cm material, 2 g of sodium alginate, 1 g of agar, 1 g glycerol, and 150 ml water were used. This composition has been tested in our previous research studies [7] and it is included in a patent proposal registered at the State Office for Inventions and Trademarks. The film-forming solution was stirred at 450 rpm and 90°C ± 1.5°C for 20 minutes. After that, the solution was poured in a silicone plate and maintained until complete dry (approx. 40 hours at 25°C ± 2°C).

Physico-chemical evaluation - After development, the film was tested in order to evaluate the physico-chemical properties. For microstructure and roughness, the MAHRSURF CWM 100 confocal microscope was used. The images were processed and analysed using Mountain Map 7.4 software. The thickness (t) was measured with 0.001 accuracy digital Yato micrometer (Shanghai, China) and expressed as average after at least 10 readings in different areas of material. The retraction ratio (RR), an important parameter for industrial production, was calculated as average between solution thickness and film thickness. The colour was evaluated using the Chroma Meter CR400 (Konika Minolta) colorimeter and CIE Lab method, taking into account parameters such as a^*, b^* and luminosity (L^*). The result represents the average of min 10 reads in different areas of material. Transmittance (T) and opacity (O) were read spectrophotometrically (Epoch, BIOTEK Instruments, Winooski, VT, USA). 1 cm x 3 cm samples were used and an empty cuvette was used as standard. The transmittance was read at 600 nm. The opacity of the material was calculated as absorbance/thickness, after the absorbance at 660 nm was read. Water activity index (w_a) was expressed by average at least 10 readings of the material (23°C ± 1.5°C). Thus, an AquaLab 4TE equipment (Meter Group, München, Germany) was used. The determination it is important in order to establish the type of products that can be packaged in this material, but for microbial safety as well. A water activity index below 0.6 prevents the development of microorganisms. Therefore, in industry, reducing the water activity index is a method of preserving food products and avoiding microbiological contamination. Sometimes, when the water activity index values are reduced, microbiological tests are no longer carried out, being considered unnecessary.

Mechanical tests - The tensile strength (TS) and elongation (E) were determined using ESM Mark 10 texturometer with 5 KN cell and grips for thin films and foils attached. As reference, the Standard Test Method for Tensile Properties of Thin Plastic Sheeting ASTM D882 was used. Samples of 1 cm x 10 cm were used. The travel speed was set at 10 mm/min and the working temperature was 24°C ± 2°C.

Microbiological evaluation - Plates with specific culture medium (Nissui Pharmaceutical, Tokyo, Japan) were used to evaluate the incidence of the *Staphylococcus aures (X-SA)*, *Escherichia coli (EC)*, *Listeria monocytogenes (LM)*, yeasts and molds (YM) or total count (TC). 1 g of biopolymeric material was solubilized

in 9 ml of saline solution after homogenization at 500 rpm. 1 ml from this solution was poured onto the plate with medium and maintained at 37 °C ± 2 °C for 48-72 hours, according to the suppliers' recommendations. The results were expressed as CFU/ml.

Solubility tests - Because the material is intended to be consume with the soluble coffee, this test is very important for the future features of the product. Thus, moisture content (*MC*) and water solubility (*WS*) were performed. For *MC* evaluation, 3 cm x 3 cm sample was weighed, dried in a hot oven (110° C) for 24 hours and weighted again. For *WS* evaluation, 3cm x 3 cm sample was weighed, immersed in a container with 50 mL water and maintained for 8 hours. After that, the water excess was eliminated with filter paper and the film was let to dry at 110°C for 24 hours. After this time, the sample was weighed.

For consumers perception, soluble coffee was packed in edible material and prepared according to the manufacturer: one coffee bag was solubilized in 80°C water and stirred for 30 seconds. After that, the panellists received the control sample (No.1) and tested sample (No.2). After testing, they filled in questionnaires regarding their habits about the consumption of coffee and other soluble drinks, as well as the openness to a bio-edible packaging.

Statistical analysis was performed with Minitab statistical software trial version.

RESULTS AND DISCUSSION

Material testing results regarding physico-chemical and mechanical properties are presented in Table 1.

Table 1. The main properties of biopolymeric material

Physical and mechanical evaluation				
T, µm	**RR, %**	**Roughness, µm**	**TS, MPa**	**E, %**
58.12 ± 0.84	42.45 ± 0.71	14.57 ± 0.54	26.82 ± 0.66	71.49 ± 0.24
Optical evaluation				
Color			**T, %**	**O, A/mm^2**
L*	**a***	**b***		
89.17 ± 0.33	-5.21 ± 0.33	18.46 ± 0.33	81.74 ± 0.25	3.82 ± 0.01
Solubility evaluation				
MC, %		**WS, %**		**a_w**
11.24 ± 0.03		62.67 ± 0.71		0.381 ± 0.15

The thickness is an important feature for the material, mainly due to the fact that it will be dissolved and consumed once with product. In this case, it is recommended that thickness to present lower values to not interfere too much with the food. Even if the thickness of the material is very low, we must state that mechanical properties are very good and problems related to the disintegration of the packaging are unlikely to occur. The amount of sodium alginate is strongly correlated with thickness, tensile strength and elongation. Li et al. demonstrated that films with 2% sodium alginate into composition presented higher thickness (97.8 µm) and better mechanical properties: elongation 7.67% and strength 67.21MPa, compared with those with 0.5% sodium alginate (thickness 53.7, elongation 6.15 and resistance 46.48 MPa) [8]. Furthermore, the addition of water and glycerol as plasticizers increased the free volume from the matrix and decreased the intermolecular forces. According to other research, glycerol is

suitable for polysaccharides – based materials development because possess the same solubility properties and lead to stronger and more elastic materials when it was used as plasticizer in sodium-alginate based films, compared with sorbitol, which was stiffer [9]. The roughness of material is a good one, taking into account that, according to the microstructure from Figure 1, the film does not present pores or fissures into structure. The same results were observed by Arzate-Vasquez et al. when compared the alginate - based films with alginate-chitosan-based films. According to their research, sodium alginate is a good biopolymer to develop smooth and uniform material [10].

The colour of the material is highly influenced by the mass of biopolymers into composition. The temperature represents another factor that may influence the final colour of the material. Thus, Soazo et al. demonstrated that a higher temperature for sodium-alginate film drying favoured the development of a yellow ochre colour and more brittle material [11]. In our case, the colour does not represent a problem due to the fact that is very similar with coffee powder colour and it is much lighter than that of instant coffee. The higher transmittance of the packaging is important because the consumer can observe the contain, but may be a negative point regarding the UV light transmission. In this case, it is recommended that biopolymeric coffee bags to be sold in a secondary packaging, made of cardboard, similar to teas. Studies regarding consumer perception demonstrated that a product with transparent packaging material will be choose over another one, with full covered content [12].

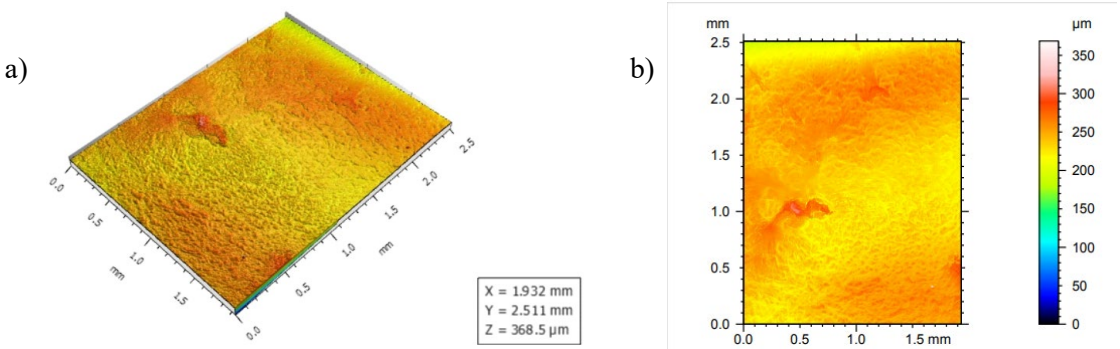


Fig. 1. Microstructure (a) and microtopography (b) of biopolymeric material

According to microbiological assessment, the product is safe to consume. No pathogens were identified on the material surface and waster activity index is very low and prevents the development and proliferation of microorganisms. In several cases, the w_a is the main responsible factor for food stability [13]. In our case, the water activity index is 0.381, a much lower value than 0.6, the reference standard for microbial development and proliferation. The min w_a necessary for the growth of the most known bacteria is 0.87 (0.75 for halophile ones). Even the *Staphylococcus aureus*, adapted to environment with low values of w_a cannot survive at values lower than 0.85 [14].

Consumer perception results

One of the main inclusion criteria of panellists was to be coffee drinkers. More than 60% of them drink 1-2 coffees per day, more than 15% used to drink 3-4 coffee per day, and 5% - more than 4. The rest of the people involved in our study drink one coffee less than 1-2 times/day. Most of the panellists that used to drink one coffee per day are women (40%); men preferred to drink more than 3-4 coffees/day. Almost 60% from students drink coffee for pleasure, 12% as a habit, and 28% for both

reasons. Most of the them started to drink coffee at 17-19 years old (48 %); 12% at 14 years old, 34% at 15 or 16 years old, and 18% at 20 or 21.

In the present study, the most of the panellists liked the beverage with edible material solubilized and will choose this type of product over the conventional one. The young male panellists are more open to consuming edible materials together with the food product. According to results, the most of the panellists preferred edible and biodegradable packaging material (43.8%), followed by those that preferred glass (33.8%) or cardboard (15%); 6.2% preferred plastic packaging material. According to Babaremu et al., the consumers are not aware by the plastic harmful effect. In their study, eight in ten people are convinced that plastic packaging remains the best option for long-term materials and considered that bioplastic is not so convenient and practical [15]. A better acceptance of edible packaging material was reported by Taylo et al. For example, in their study that evaluated the consumer attitude, acceptability and purchase intent, the panellists positively reacted and considered that edible packaging material for powdered lemonade is a great alternative to synthetic ones. Furthermore, their liking scores were almost 7.48, where 1- extremely dislike and 9 – extremely like [16].

The complete solubilization of biopolymeric packaging into food product is more accepted by consumers than the edible layer separately. Studies demonstrated that consumers prefer an edible packaging material that is integrated into principal food product and are more likely to consume the product for its features than the environmental benefits [17]. In the present study, the students are aware by the benefits of replacing plastic-based materials with those based on completely natural composition and the most response that eating a biopolymeric material does not endanger their health. Another aspect is that young generation is more open to consuming such products, unlike older people who are usually more conservative and hardly respond to innovations in the food industry.

The panellists involved in this study preferred to consume coffee with sweeteners. Thus, sugar is overwhelmingly the most preferred sweetener, with 45 out of 62 respondents (72.58%) indicating it as their choice. Honey is the second most preferred, chosen by 4 respondents (6.45%). Brown sugar is chosen by 6 respondents (3.23% + 6.45%). Several other sweeteners like agave syrup (1.61% for each variation), milk (1.61%), sugar/sweetener (1.61%), and other sweeteners (3.23%) have been chosen by a small number of respondents. Most preferred additives in coffee beverages are natural sweeteners: 8 respondents (13.33%), chocolate: 7 respondents (11.67% when combined), flavours: 8 respondents (10.00% for "flavours", and additional responses for related terms), vanilla: 5 respondents (8.33%), and sweeteners: 6 respondents (10.00%). As recommendations, they mentioned the focus on popular additives, respectively to emphasize natural sweeteners, chocolate, and various flavours in product development and marketing and to highlight the inclusion of vanilla and sweeteners as secondary options. Furthermore, they considered that the market should consider diverse preferences and to offer a variety of product lines that include fewer common additives to cater to niche markets.

The results obtained after product testing are mentioned in Table 2. Both tested products have similar high ratings for appearance, with Product 1 slightly higher. The variation in ratings is also similar. Product 2 is slightly preferred over Product 1 in terms of smell. The variation in ratings is similar for both products. Product 1 is rated higher for colour.

The ratings' variability is similar for both products. Product 1 is slightly preferred for taste, though both products have similar ratings with some variability. Product 1 is slightly preferred in terms of flavour. There is a bit more variability in Product 2's ratings. Product 2 is slightly preferred in terms of unctuosity, though the difference is minimal and both products have similar variability. Both products have nearly identical ratings for palatability, indicating no clear preference.

Table 2. The average of the scores obtained after the test

Attribute	Product 1 – soluble coffee	Product 2 – coffee with edible packaging	P-Value
Appearance	4.225 ± 0.927	4.162 ± 0.980	0.684
Smell	3.988 ± 0.907	4.108 ± 0.869	0.401
Colors	4.275 ± 0.841	4.000 ± 0.827	0.043
Taste	3.713 ± 0.970	3.568 ± 1.111	0.392
Flavour	3.800 ± 0.920	3.662 ± 1.101	0.403
Uonctuozity	3.675 ± 0.938	3.743 ± 0.922	0.650
Palatability	3.588 ± 0.964	3.581 ± 0.951	0.967

The results are expressed as mean and standard deviation

The small differences in means suggest that both products are quite similar in most attributes. The attribute that most differentiates the two products from the consumer's perspective is the colour.

For appearance, since the p-value (0.684) is much greater than the common significance level of 0.05, we fail to reject the null hypothesis. This means there is no statistically significant evidence to suggest a difference in the mean ratings between Product 1 and Product 2 for the attribute tested. The observed difference in mean ratings between the two products is likely due to random variation rather than a true difference in preference or perception.

CONCLUSION

The current study aimed to develop a new packaging material for soluble coffee products, packaged in disposable packaging, often obtained from conventional, synthetic, petroleum-based materials. Developed from sodium alginate, agar, glycerol and water, based on a composition already submitted for patenting, the material possesses good physical, mechanical and, above all, solubility properties. Tested on a group of 80 panellists, the drink that contained both powdered coffee and the solubilized packaging received good and very good reviews, comparable to those of the classic drink, without the possibility of discovering the product during testing.

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EVALUATING FREEZING TECHNIQUES AND QUALITY INDICATORS FOR FROZEN CAKES: EFFECTS ON SHELF LIFE, TEXTURE, AND SENSORY PROPERTIES

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ABSTRACT
In recent years, the domestic frozen bakery and pastry market has shifted towards ready-to-bake frozen products, driven by the global trend for convenience and on-the-go consumption. This study aims to analyze the quality indicators of cakes subjected to freezing to determine their shelf life and optimize freezing conditions. Four sample categories were evaluated: fresh cake (P1), cake subjected to thermal shock (P2), cake frozen for 3 months (P3), and cake frozen for 6 months (P4). Quality assessments included sensory characteristics (appearance, shape, color, core properties), physico-chemical attributes (acidity, humidity, insoluble ash, fat content), and texture properties. Results showed that rapid freezing lowered the internal temperature of the cake to -5°C to -18°C within 4 hours. This process effectively preserved freshness for up to 12 months. The findings confirm that freezing is a viable method for maintaining the taste and nutritional quality of cakes, while also offering environmental benefits.The study highlights the importance of understanding and controlling the physico-chemical changes during freezing to enhance product quality and extend shelf life.

Keywords: frozen dough, quality characteristic, safety, consumer preference

INTRODUCTION

Adapting food to the physiological needs of the human body, to the wishes and preferences of the consumer for quality products can be achieved through various technical innovations (new raw and auxiliary materials, as well as, new processing technologies, new conditioning and packaging methods) and commercial innovations. Frozen bread dough is widely used in the bakery industry, mainly due to its convenience. Freezing dough can reduce processing time and labor intensity, increase product shelf life, improve productivity, and facilitate distribution to remote locations[1]. However, the freezing process used to prepare frozen dough can induce numerous negative effects on the quality of baked goods compared to those baked from non-frozen dough. Incidentally, a number of studies have focused on how to preserve gluten networks and the viability of yeast from freeze-dried lesions by supporting yeast gases and retention capacity gas in gluten networks[1,2]. Many researchers have suggested that the formation of ice crystals in frozen dough could have two negative effects. Researchers have studied the main factors affecting the quality of frozen dough and suggest effective methods to minimize the loss of quality of frozen dough. The use of additives is a method of increasing the freezing tolerance of yeast and improving the

rheological and thermophysical properties of dough, which is, so that close finished products can be made as the quality of fresh bread.[3,4,5]. Breeding yeast has a higher content of trehalose and proline, so the freezing tolerance and fermentation capacity of yeast could be improved. Optimizing freezing speed and avoiding temperature fluctuations could keep yeast active and prevent the moisture from being recrystallized in frozen dough [6.7]. There are some flour materials that can also be used as additives to improve the rheological properties of the dough [8]. In addition, new freezing technologies can speed up the freezing process and improve heat transfer and mass transfer, and ultrasound-assisted freezing has been shown to have positive effects on dough properties and cell viability, however, there are few studies available and future research should focus on this area[9]. Although frozen dough has been widely studied, few studies focus on the micro frozen dough perspective, on the other hand, there is little research on the physical and chemical reactions of certain components in frozen dough, and little information is available about the interaction between additives and components in the dough, all of this requires additional research attention[10]. In addition, the safety of the genetic engineering technique and the mechanism of action of certain genes are still unclear, which also requires further studies. There are four frozen dough products that have been developed and produced over time: unfermented frozen dough (U-FD), where the dough is prepared, shaped and frozen, however, baking is done after fermentation. However, no study has yet been attempted to verify the efficacy and viability of the concept and therefore further investigation is needed[11,12,15].

MATERIALS AND METHODS

The quality of a product is a set of characteristics that can be determined based on methods of analysis. The quality characteristics of the products are set by international ISO standards as well as national ones. Four samples were taken: fresh, subjected to thermal shock, after three months of freezing, and after six months of freezing. For the characterization of qualitative indices were determined: sensory characteristics (outer and section appearance, product shape, colour, properties of the core) were analyzed with the help of a team of tasters; physico-chemical, characteristics, acidity, humidity, insoluble ash, reported fat; porosity, elasticity; texture properties. The recipe for obtaining the product is found in table no.1.

Table. nr.1. Recipe cake

	Ingredients	**Quantity**		**Ingredients**	**Quantity**
Dough	Flour	0.8 Kg	**Mixture**	Cottage cheese	0.8Kg
	Barm			eggs	0.04 Kg
	Milk	0.3 l		sugar	0.08 Kg
	Salt	0.001Kg		salt	0.003 Kg
	Eggs	0.2 Kg		The essence of rum	0.010 l
	Butter	0.05 Kg		Lemon peel	0.01kg
	Orange peel	0.01Kg			

For the specific technological operations of obtaining frozen products, the following technological parameters were used. They are described in Tables 2 and 3

Table nr.2.Technological parameters

Nr.crt.	Technological operation	Technical parameters	Sample
1.	Precoating	190÷200ºC	P_1, P_2, P_3, P_4
2.	Cooling	8 min at temperature de 190-200 ºC	P_1, P_2, P_3, P_4
3.	Freezing	Slow freezing at temperature de –18÷-20ºC, time de 210÷220 min;	P_1, P_2, P_3, P_4
4.	Storage	Stored at temperature de -15÷-20ºC, over variable durations	P_1-10 days; P_2-20 days; P_3-30 days ;P_4-45 days
5.	Defrost	slow defrosting: time 100÷110 min; -temperature of defrosting 28÷30ºC.	P_1, P_2, P_3, P_4
6.	Baking	in rotary type oven, 8 min, at temperature of 220-230ºC	P_1, P_2, P_3, P_4

Table nr.3. Analyzed samples(frozen or baked)

Sample	Frozen cake	Baked cake
P1 fresh cake		
P2 cake subjected to thermal shock		
P3 frozen cake analyzed after 3 months of freezing		
P4 frozen cake analyzed after 6 months of freezing		

Methods for determining the quality indicators of the resulting doughs and pastries obtained from experiments. In order to determine the quality indicators, the methods of analysis in Table 4 and Table 5 were used in the works.

Table 4. Methods used in experiments raw materials, semi-finished

Quality indicator	U.M.	Analytical reference method
Rheological characteristics of doughs: Pharyngeal method:ability to hydrate flour, dough development, stability dough, elasticity dough, dough soaking, flour power Alveographic method:resistance to deformation P the extensibility of the dough L, ratio P/L, W	 %,min. min. UB mm. cm	SR ISO: 27971:2008 SR ISO 5530 –1:1999 SR ISO 5530 – 4

Tabel 5. Methods used in experiments finished product

Nr. Crt.	Analytical method	Principle of method
1.	Product mass - (SR 2213-3:2009)	It is determined by weighing a technical balance and the result is expressed in grams without decimal places.
2.	Determination of porosity - - (SR 2213-3:2009)	Determine the total volume of pores in a total volume of the core, knowing its density and mass.
3.	Determination of core elasticity (STAS 91/1983)	Pressing a piece of core of a determined shape and height, a given time and measuring the height to which it returns, after removing the pressing force.
4.	Determination of humidity - SR ISO 712:2010	The method is based on the measurement of the mass loss that the analysis core suffers when it is put to dry under certain conditions.
5.	Determinarea aciditãţii-Metoda titrimetrică (SR 2213-22:2009)	Metoda se bazează pe neutralizarea aciditãţii din produs cu soluţie de NaOH n/10
6.	Ash content insoluble in hydrochloric acid. 10%- SR ISO 2171:2010	Calcinate the sample for analysis at 750±25°C, separate insoluble mineral substances into hydrochloric acid and weigh.
7.	Sugar on dry matter %	SR ISO 2213-12:2009
8.	Fats reported on dry matter % SR ISO 2213-11:2007	Extract the fat from the sample with petroleum ether or ethyl ether, into the Soxhlet apparatus, evaporate the solvent, dry to constant mass and weigh.
9.	Protein (Kjeldahl)	*SR ISO 2213-13:2007*
10.	Sensory analysis - SR ISO 91:2007	Sensory evaluation was conducted using a 10-member panel and a 5-point hedonic rating scale, with 0 = inconsumable, 1 = unacceptable, 2 = acceptable, 3= satisfactory, and 4 = excellent
11.	Texture- SR ISO 11036:2022	For the texture profile was used a Perten TVT-6700 texturometer. Firmness, adhesiveness, pringiness and cohesiveness were analyzed.

RESULTS

The results obtained from the research demonstrate that a proper technological regime without additional fermentation and long leavening can lead to obtaining high quality pastry products without diminishing their volume.

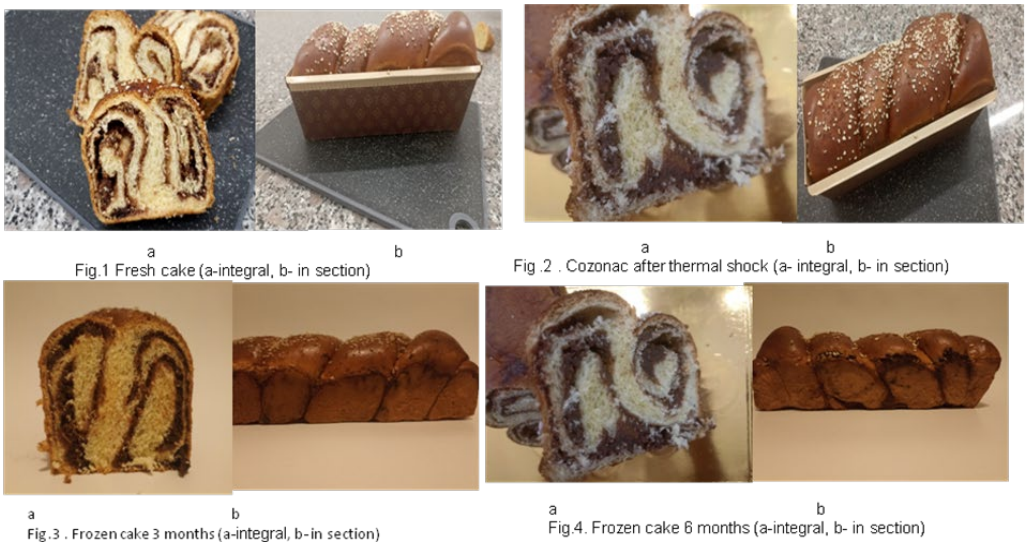


Fig.1. Finished products

Tabelul .6. Rheological characteristics of the dough

Sample	Alveogram characteristics			
	P[mm]	L[mm]	W[10 $^{-4}$J]	P/L
P1	92	75	236	1,24
P2	93	69	241	1,37
P3	112	59	264	1,89
P4	110	58	248	1.65

Table nr.7 . Texture profile analysis

Sample	Firmness	Adhesiveness	Cohesiveness	springiness
P1	3475	0.025	0.5011	1741
P2	2618	0.023	0.4506	1179
P3	5470	0.022	0.3896	2131
P4	5320	0.020	0.3546	2121.

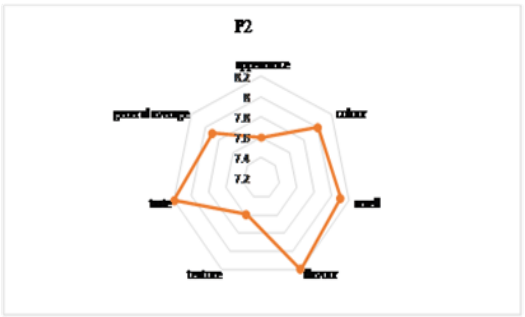
Table nr.8. **P**hysico-chemical, characteristics

Sample	Elasticity%	Porosity (cylinder mass in core) %	Sugar content	Protein content
P1	48	40.38	47.76	8.17
P2	49	43.20	47.89	8.15
P3	52	57.54	47.91	7.89
P4	54	67.69	47.98	7.58

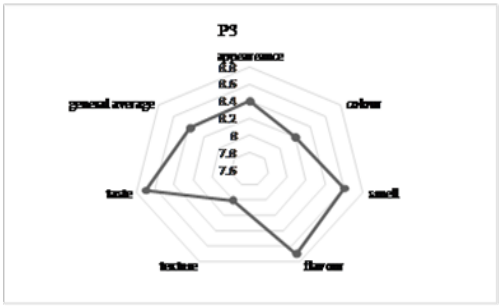
The hedonic test was the basis of the sensory analysis of the cake. The purpose of the test was to monitor the influence of the freezing process on the organoleptic characteristics of the product. In order to keep under control the physico-chemical phenomena that occur from the moment of freezing of the cake, the rheological and textural characteristics must be analyzed, the phenomena that occur from the moment of freezing and the parameters on which it is possible to maintain, and especially to improve, the quality of the finished products. During the quick freezing process, the temperature inside the product drops to +5°C - 18°C, over the course of 4 hours. The biggest advantage of rapid freezing is maintaining freshness over a long shelf life (6 and 12 months respectively). (Fig.2)



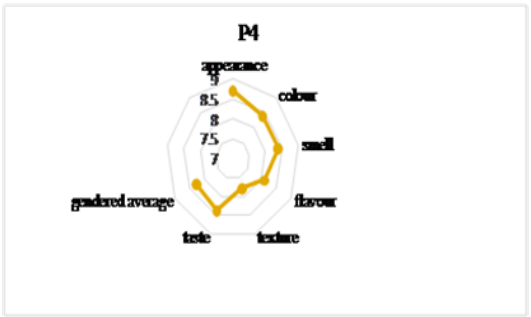
Sample 1 (fresh cake)



Sample 2 (frozen cake thermal shock)



Sample 3 (frozen cake after 3 months)



Sample 4 (frozen cake after 6 months)

Figure 2. Sensory analysis

In the figures below are graphically represented the results of the determinations for the respective humidity acidity.

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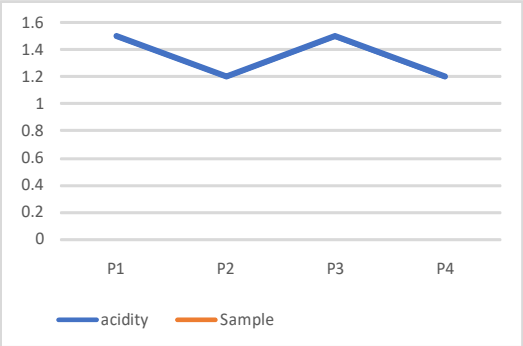


Fig. 3. Graphical representation of acidity

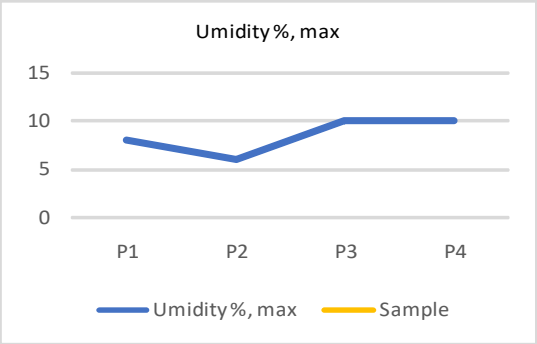


Fig.4. Graphical representation of humidity

A lower acidity value is observed for sample 2 when it was subjected to heat shock for sample 4, at the time of storage for 6 months. The optimum value of the aw water activity for yeast is 0.88. Between water activity, temperature and nutrition factors there is a correlation, in the sense that if aw is low, regardless of temperature, the growth capacity of cells is reduced, while the presence of nutrients in the environment widens the scope of the,, in which yeasts can survive.

The results for the determinations made respectively content in ashes, fat content are found in figures 5,6.

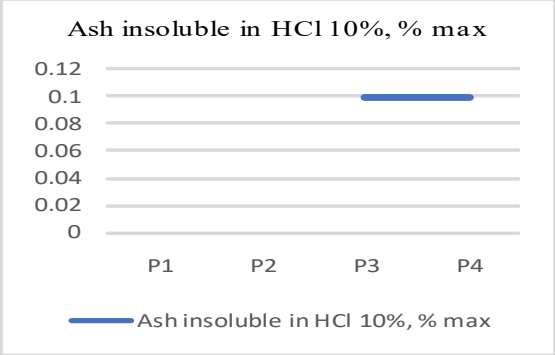


Fig.5 Graphical representation of ash

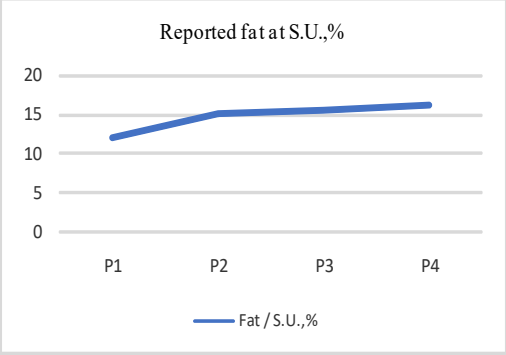


Fig.6. Graphical representation of fat reported to U. S.,%

From the above graphs it is clear that the total mineral substances in the products under consideration remain unchanged regardless of their storage period. The fat content related to the dry substance is higher for sample 2, subjected to thermal shock compared to the others.

DISCUSSION

The quality of the frozen dough depends on the CO_2 production capacity of the yeast and the CO_2 holding capacity of the bread after fermentation. Decreased yeast viability and destruction of dough network structure are considered two major factors that lead to deterioration of dough quality, while both are caused by ice crystals [7,11]. The effects of ice crystals could be multiple: the mechanical action of ice crystals can affect the structure and properties of the dough, and the larger the ice crystals, the greater the possible damage to the dough structure; the formation of intracellular ice crystals would pierce the cell membrane leading to the death of yeast, and finally the formation of

extracellular ice crystals would increase the intracellular osmotic pressure, leading to dehydration of yeast cells and decrease their viability. Therefore, in order to obtain a quality pastry product, it is necessary to control the formation of ice crystals. There are two ways to control ice crystals, one is to add protective agents to inhibit the formation and growth of ice crystals and another is to control the freezing rate to produce fine ice crystals with a more uniform distribution [12,13]. The dough should be frozen as soon as possible, in the range from -8°C to -15°C in 10 to 30 minutes and freezing and storage at -18°C to -22°C. [4,14] Treatment of freezing and storage of freezes has a negative impact on the structure and composition of the dough. For example, disrupting the integrity of the gluten network, decreasing the volume and increasing the textured hardness of bread are common effects seen in frozen dough products. Optimizing freezing speed and avoiding temperature fluctuations could keep yeast active and prevent the moisture from being recrystallized in frozen dough.

CONCLUSION

The low-temperature freezing of the cake allows the rational organization of the manufacture and the feeding of the baking and/or selling points in the major shopping centers. In order to keep under control the physico-chemical phenomena that occur from the moment of freezing of the cake, the rheological and textural characteristics must be analyzed, the phenomena that occur from the moment of freezing and the parameters on which it is possible to maintain, and especially to improve, the quality of the finished products. According to European Union standards, during the rapid freezing process, the temperature inside the product drops to +5°C - 18°C, over 4 hours. The biggest advantage of rapid freezing is maintaining freshness over a long shelf life (6 and 12 months respectively). Frozen cakes have a small market share, but are expected to have the fastest growth rate of 9.2% in the coming period. This study aimed at making consumers aware of the benefits of canning by freezing, such as making easier use of exotic flavours or developing new cooking techniques. Classic pastry products usually face problems with the final volume due to the loss of yeast's fermentative activity and lower gas retention of the dough. The products no longer require additional fermentation before baking, the degree of fermentation before freezing being 80%. This allows the complete formation of a ripe product without crust, followed by freezing and frozen storage, and finally, a second and final baking that is done at the baking point to create a crust. The final baking gives the pre-baked product its flavor, taste and crispy crust, as expected by the consumer.

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EXPLORING THE NUTRITIONAL BENEFITS AND SENSORY PROPERTIES OF MANGO JAMS WITH DIFFERENT SWEETENERS

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ABSTRACT

This study investigates the nutritional composition and sensory characteristics of mango-based jams prepared with different sweeteners, evaluating their potential as a nutritious and appealing food product. Mango, a tropical fruit rich in vitamins A, C, and dietary fiber, is an ideal base for jams, contributing both health benefits and natural sweetness. The study analysed the effects of various sweeteners, including refined sugar, honey, agave syrup, and stevia, on mango jams' nutritional profile and sensory properties.

Nutritional analysis revealed that mango jams are high in antioxidants, particularly vitamin C and polyphenols, supporting immune function and skin health. The choice of sweetener had a marked impact on the caloric content and sugar levels of the jams. Jams prepared with natural, low-calorie sweeteners like stevia exhibited significantly lower sugar content than those made with traditional sugar or honey, offering a healthier alternative for diabetic or calorie-conscious consumers.

Sensory evaluation showed that the type of sweetener influenced not only sweetness but also texture/consistency, appearance/color, taste and flavor profile. Consumer preferences leaned towards jams that balanced sweetness with the mango's vibrant, fruity taste, with honey and agave syrup receiving the highest ratings for taste and overall acceptance.

The findings indicate that mango jams, when sweetened with natural alternatives, can provide both nutritional advantages and high sensory satisfaction, catering to a wide range of dietary preferences. Future research should explore the long-term stability and shelf life of these jams when prepared with alternative sweeteners.

Keywords: mango jam, stevia sweetener, honey, agave syrup, nutritional composition, sensory analysis

INTRODUCTION

This study explores an innovative approach to producing mango jam by incorporating different sweeteners like stevia, honey and agave syrup as a natural, low-glycemic sweetener. Mango, a tropical fruit rich in antioxidants and bioactive compounds, with numerous health benefits, such as anti-inflammatory and blood sugar regulation properties [2]. Agave syrup, which also contains antimicrobial properties, is proposed to extend the jam's shelf life without the need for synthetic preservatives [3] Stevia is a

natural sweetener with nutritional, therapeutic and industrial importance, and is used all over the world. Stevia has anti-hyperglycemic, anti-oxidative, hypotensive, nephroprotective, hepato-protective, antibacterial and antifungal properties [1]. Honey is considered a nectar because of its nutritional value, including minerals, vitamins, carbohydrates, fats, proteins, etc. 100 g of honey contains the following nutrients: carbohydrates (82.4 g), sugars (82.12 g), fructose (38.2%), glucose (31.3%), maltose (7.1%), sucrose (1.3%), higher sugars (1.5%), dietary fiber (0.2g), fat (0g), protein (0.3g), amino acids (0.05—0.1 %), water (17.10 g) [6]. The pH of honey is generally between 3.2 and 4.5, this relatively acidic pH prevents growth of many bacteria [7.].
This study aimed to obtain four types of mango jams: Mango Jam with Refined sugar (MJRS); Mango Jam with Honey (MJH); Mango Jam with Stevia (MJS) and Mango Jam with Agave Syrup (MJAS) and evaluate their nutritional value, by determining the polyphenols content and ascorbic acid, the moisture content, acidity and the total solids. Studied samples prepared from pome waste fruits were sensorial evaluated for appearance/color, aroma/flavor, taste, texture/consistency and overall acceptability, using 9 point hedonic scale.

MATERIALS AND METHODS

2.1. Material and manufacturing of mango jams.

Mango fruits, refined sugar, honey, stevia and agave syrup, were bought from a local market (Timisoara, Romania) and stored until processing. The ripe fruits (5 pieces) were peeled and the seeds (core) were removed. The mango jams with different sweeteners were prepared in the *Preservation Laboratory* of *Faculty of Food Engineering* of ULS Timisoara, Romania. Mango was chopped into chunks and then blended into a smooth purée. In a large saucepan, mango purée was combined with the studied sweetener (see Table 1). The mixture was brought to boiling, then the heat was reduced to a simmer, stirring frequently to prevent sticking. 2 tablespoons (30 g) of lemon juice were added to balance the sweetness and help the jam set. After 20-30 minutes of cooking, the mixture was thickening. The jam was removed from heat and poured into sterilized jars, leaving a small gap at the top. The jars were sealed, allowed to cool and stored at 12^0C.

Table 1. Recipe of the studied mango jams

Ingredients	Mango Jam with Refined sugar (MJRS)	Mango Jam with Honey (MJH)	Mango Jam with Agave Syrup (MJAS)	Mango Jam with Stevia (MJS)
Mango Purée	600 g	600 g	600 g	600 g
Sweetener	400 g refined sugar	200 g honey	150 g agave syrup	3 g stevia
Lemon Juice	30 g	30 g	30 g	30 g

2.2. Physical-chemical characteristics of mango jams

Analyses were conducted in the chemical laboratories of the *Faculty of Food Engineering,* by analysing the physical-chemical composition using the official AOAC methods (AOAC 2005): Ash (923.03) and moisture content (925.09) [16] The total soluble solids (TSS) were determined by using DR201-95 refractometer at room temperature.

2.3. Titrable Acidity (%)

Titrable acidity in jams was measured by dissolving 5 g of sample in 10 ml distilled water and titrated with 0.1 N sodium hydroxide (NaOH) solution, using phenolphthalein as an indicator. This method quantifies the total acidity, primarily from organic acids like citric or malic acid, which contributes to the jam's flavor and preservation. Results were expressed as grams of citric acid per 100 g of jam [17].

2.4. Determination of total phenolic content (TPC) from mango jams

The total phenolic content (TPC) of studied mango jams was analyzed using a modified Folin-Ciocâlteu method. In brief, 0.5 mL of each diluted jam solution was mixed with 1.25 mL of 1:10 diluted Folin-Ciocâlteu reagent (Sigma-Aldrich Chemie GmbH, Munich, Germany), followed by a 5-minute incubation at room temperature. Then, 1 mL of Na_2CO_3 (60 g/L) was added, and the mixture was incubated for 30 minutes at 50°C. Absorbance was measured at 750 nm with a Specord 205 spectrophotometer (Analytik Jena AG, Jena, Germany). A blank with distilled water and a calibration curve with gallic acid (5-250 µg/mL) were used, and results were reported as µg/mL extract. [4].

2.5. Titrimetric determination of ascorbic acid with 2,6-dichlorophenol indophenol

The titrimetric determination of ascorbic acid (vitamin C) using 2,6-dichlorophenol indophenol (DCPIP) is a method is based on the redox reaction between ascorbic acid and DCPIP, where the color of the indicator changes from blue to colorless upon reduction by ascorbic acid [18]. The samples were prepared with a solution of 70% acetic acid and 30% metaphosphoric acid, and ascorbic acid concentration was calculated using the following formula:

Ascorbic acid (%) = Dye volume × 100/100

2.6. Sensorial properties

Four mango jam samples (MJRS; MJH; MJS and MJAS) were evaluated by a sensory panel of 21 assessors (8 males and 13 females), non-smokers aged 20 to 42 years, all without known food allergies. The samples were presented in glass cups and served in randomized order at room temperature under standardized lighting conditions. Each sample cup was coded with double-digit identifiers to ensure anonymity. The assessors were instructed to evaluate the sensory attributes of the mango jams, specifically appearance (color), aroma (flavor), taste, texture (consistency), and overall acceptability. Ratings were assigned based on individual preference using a nine-point hedonic scale, with 1 indicating extreme dislike and 9 indicating extreme liking. This method allowed for precise quantification of sensory appeal across the four formulations [5].

2.7. Statistical Analysis

All measurements were taken in triplicate, and the findings are given as mean values with standard deviation (SD). Statistical processing data was performed using Microsoft Excel 365. Data were analysed by one-way analysis of variance (t-test). Statistical differences between the recorded values for the samples analyzed were considered significant when $p < 0.05$.

RESULTS

3.1. Physical-chemical composition of studied jam samples

The results, presented in Table 2, refer to the physical-chemical characteristics of different types of mango jams: MJRS; MJH; MJS and MJAS, analyzed through four main parameters: moisture, ash content, total soluble solids (TSS), and titratable acidity. Statistical analysis was performed using the t-test method to determine significant differences between the samples, with a significance level of $p < 0.05$.

Table 2. Physical-chemical characteristics of 4 types of mango jams with different sweeteners.

Samples	Nutritional Characteristics			
	Moisture	Ash Content	Total Soluble solids (TSS)	Titrable acidity
	(%)	(%)	(°Brix)	% (expressed as citric acid)
Mango Jams				
MJRS	39.25±0.92 [a]	0.25±0.03 [a]	70.45±0.75 [c]	0.77±0.02 [b]
MJH	43.88±0.57 [c]	0.46±0.04 [c]	63.53±1.26 [b]	0.76±0.02 [b]
MJS	48.28±0.09 [d]	0.27±0.01 [a]	48.50±1.56 [a]	0.69±0.01 [a]
MJAS	41.95±0.67 [b]	0.36±0.02 [b]	64.53±0.51 [b]	0.78±0.02 [b]

**The results of the parameters listed in the table represent the mean value of the three determinations performed individually for each sample ± standard deviation (SD). Statistically significant differences between samples were compared using the t-test, and different superscript letters (a-c) in the same column indicate statistically significant differences between samples ($p < 0,05$).*

3.2. Total polyphenols content of studied jam samples

Polyphenols are significant bioactive compounds recognized for their health benefits, primarily due to their antioxidant and anti-inflammatory effects, and are crucial in scavenging free radicals [14]. Figure 1 shows the polyphenol content in four types of mango jams expressed in mg of gallic acid equivalents (GAE) per 100 grams. The notations (a, b, c) denote statistically significant differences between the samples.

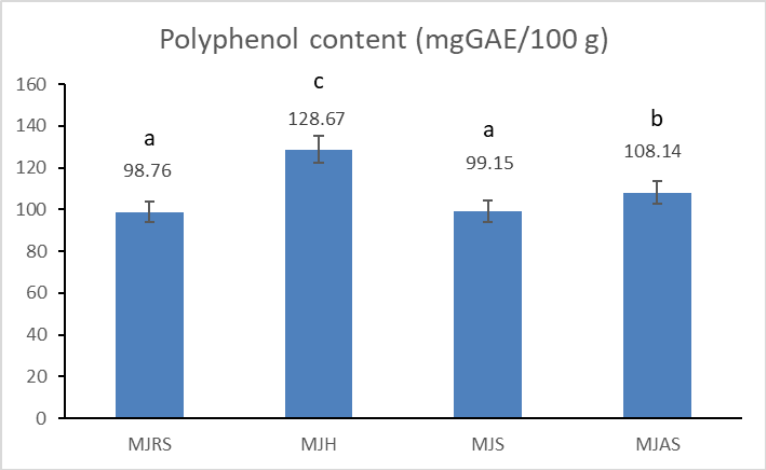


Figure 1. Total polyphenol content (mgGAE/100g) in studied of mango jams. Results are expressed as the mean of three determinations ± standard deviation (SD). Different letters (a-c) indicate statistically significant differences between samples ($p < 0.05$) according to the t-test.

3.3. Ascorbic acid content (mg/100 g) of studied jam samples

Figure 2 presents the ascorbic acid content (mg/100 g) in mango jams prepared with different sweeteners: refined sugar (MJRS), honey (MJH), stevia (MJS), and agave syrup (MJAS). The data indicates that mango jam with agave syrup (MJAS) has the highest ascorbic acid content at 29.5 mg/100 g, significantly higher than jams made with refined sugar (MJRS, 21.1 mg/100 g), honey (MJH, 22.5 mg/100 g), and stevia (MJS, 23.4 mg/100 g).

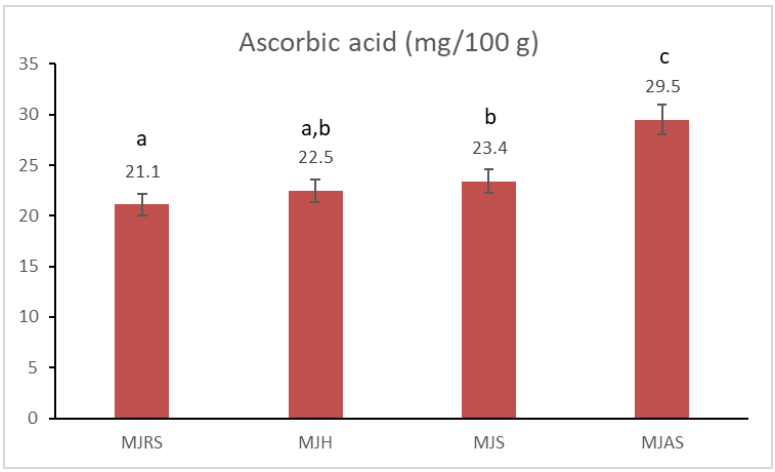


Figure 2. Ascorbic acid (mg/100g) content in mango jam samples. Results are expressed as the mean of three determinations ± standard deviation (SD). Different letters (a-c) indicate statistically significant differences between samples ($p < 0.05$) according to the t-test

3.4. Sensory evaluation of studied mango jams

Consumer's acceptability of the mango samples was carried out using sensory evaluation by a panel of 21 assessors using nine-point hedonic scale. Figures 3 indicate the mean scores for the sensory attributes (appearance/color, flavour/aroma, taste, texture/consistency and overall acceptability).

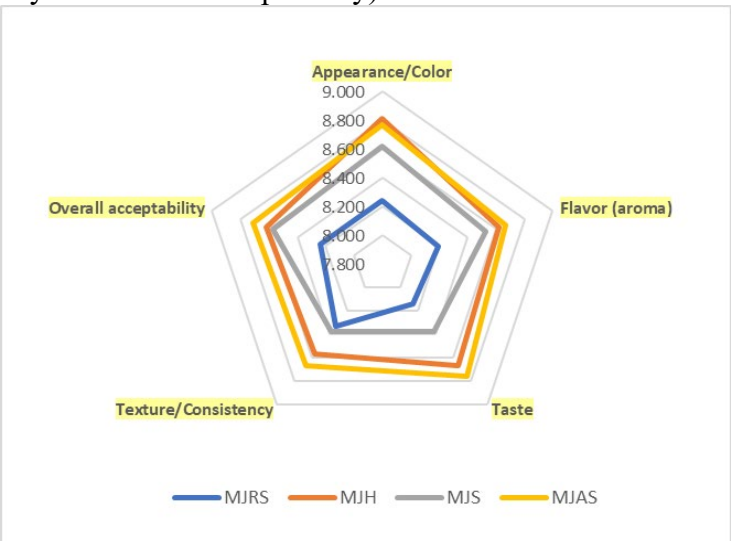


Figure 3. Mean scores (n=21) of sensory attributes (appearance/color, flavor (aroma), taste, texture/consitency and overall acceptability) for mango jams (MJRS, MJH, MJS, MJAS).

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DISCUSSION

4.1. Physical-chemical characteristics

The results presented in Table 2 show significant differences in moisture content between the analyzed samples. The MJS sample (48.28%) exhibits the highest value, followed by MJH (43.88%), MJAS (41.95%), and MJRS (39.25%). These variations could be correlated with processing technology or ingredient composition. Higher moisture content, as observed in MJS, may impact the texture and stability of the jam. Ash content, which reflects the mineral composition of the product, varies among the samples, with MJH showing the highest value (0.46%), followed by MJAS (0.36%), while MJRS (0.25%) and MJS (0.27%) have similar and significantly lower values. The significant differences between these samples suggest variable mineral composition, which may be influenced by the source of the fruits or their processing. Results are in agreement with other studies carried out by Mozakkin, Md et al., 2023 [9], who highlighted moisture levels ranging from 19.0% to 51.2%, in different jam assortments, the moisture being influenced by fruit pulp content and the presence of preservatives and additives such as sugar and pectin. These results on ash content agreed with other studies that showed an interval of the content of mineral substances between 0.12 - 0.52 % [12].

Humidity plays a crucial role in determining the shelf life of jams and preserves because it affects water activity, a critical factor for the microbiological and chemical stability of the product. Generally, higher moisture content leads to increased water activity, which can promote the growth of microorganisms and chemical reactions, such as fermentation or mould formation, thereby shortening the shelf life [15].

Total soluble solids (TSS), measured in °Brix, indicate the concentration of sugars and other soluble components. MJS had the lowest value (48.50 °Brix), while MJRS had the highest (70.45 °Brix). This significant difference reflects considerable variation in sugar content between the jams, which could influence the taste of the final product. Other studies pointed out TSS values between 63% and 68% for mango and pineapple jams, with higher TSS indicating a sweeter product (table 2). Our findings are consistent with these values, particularly in the higher TSS range for certain samples [10].

Titratable acidity, expressed as citric acid, did not show major significant differences between the samples, with values ranging from 0.69% to 0.78%. MJS had the lowest acidity (0.69%), while MJAS exhibited the highest value (0.78%) (table 2). These minor variations may slightly affect the taste and stability of the jam, but the differences between samples do not seem substantial. Similar findings were highlighted by Suzy R.G, in 2019 [15], across different jam samples with values ranging from 0.33% to 1.02%.

*4.2. Total polyphenols content (*mg GAE/100 g)

MJH sample, registered the highest polyphenol content at 128.67 mg GAE/100 g, indicated by the letter "c" (figure 1). This means MJH sample has significantly more polyphenols compared to the other jams, likely due to honey's natural antioxidant properties, which could enhance the polyphenol content when used as a sweetener. MJAS sample had the second highest polyphenol content at 108.14 mg GAE/100 g**,** suggesting that agave syrup, being a natural sweetener with lower processing, could also contribute to a higher polyphenol concentration compared to refined sugar or stevia.

4.3. Ascorbic acid content

Jams with honey and stevia registered slightly higher ascorbic acid levels (figure 2), than those with refined sugar, potentially due to honey's antioxidant properties, which can mitigate the oxidative loss of vitamin C [2]. Similar observations were found by Salar, FJ., et al., 2022 [13] who reported 21.39 mg/100 g ascorbic acid in mango jam with stevia.

The elevated ascorbic acid levels in the agave-sweetened jam could be attributed to lower thermal degradation of vitamin C during processing, possibly due to agave syrup's lower glycemic properties, which may contribute to a more stable acid balance and lower pH, factors known to preserve vitamin C in processed foods [11;14]. This is consistent with findings from similar studies where low-glycemic or natural sweeteners, like agave or maple syrup, have shown better retention of ascorbic acid compared to refined sugar or honey in fruit-based products [5;8].

4.4. Sensory attributes

In terms of all sensory attributes, the assessors ranked the mango jam samples in the following order: MJAS>MJH>MJS>MJRS. The most highly appreciated was the sample with agave syrup (MJAS), which obtained mean scores of 8.752 for taste, 8.667 for flavour and texture/consistency, 8.762 for appearance/color and 8.714 for Overall acceptability (figure 3). Among all studied samples, MJRS was less appreciated compared with other samples, for appearance, taste, texture, and overall acceptability (figure 3).

CONCLUSION

This study successfully demonstrated that incorporating alternative sweeteners—such as honey, stevia, and agave syrup—into mango jam not only enhances its nutritional profile but also maintains the fruit's beneficial properties. The jams prepared with honey (MJH) and agave syrup (MJAS) exhibited superior polyphenol and ascorbic acid content, suggesting significant health benefits due to their antioxidant properties. Sensory evaluations revealed that the mango jam with agave syrup was the most favored among participants, indicating a strong preference for its taste and overall acceptability compared to traditional refined sugar. These findings underscore the potential for using natural sweeteners in fruit preservation, promoting healthier dietary choices without compromising flavor or quality. Future research should explore the long-term storage stability and consumer acceptability of these innovative jams, paving the way for healthier fruit-based products in the market.

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LABORATORY ANALYSIS OF BACTOFERT-L BODEN'S EFFECT ON CUCUMBER SEEDLINGS UNDER SALINE STRESS

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ABSTRACT

The increasing interest in biostimulants as sustainable solutions for agriculture has been widely documented in high-impact scientific literature. Biostimulants are recognized for their ability to promote plant growth, enhance nutrient uptake, and increase resilience to environmental stress.

This study researches the effects of the newly developed Georgian biostimulant BactoFert–L Boden on the growth and development of cucumber seedlings (Cucumis sativus) under various saline stress conditions. Soil salinization is a critical issue affecting global agricultural productivity, particularly in arid and semi-arid regions. The experiment was conducted in a laboratory setting, where cucumber seedlings were exposed to saline solutions of sodium chloride (NaCl) and sodium sulfate (Na_2SO_4) at concentrations of 0.2; 0.4; 0.6; 0.8; 1.0; 1.2, and 1.4%. Following the GOST-54221-2010 methodology, the research evaluated the biostimulant's impact on seedling growth, focusing on parameters such as stem length, leaf surface area, and biomass accumulation. The results demonstrated that BactoFert–L Boden significantly enhanced seedling growth in solutions with moderate salinity (0.2%–0.8%), leading to increased stem length, root development, and overall biomass. However, at higher salinity levels (1.0%–1.4%), the saline conditions proved toxic, inhibiting plant growth despite the application of the biostimulant. The study highlights the potential of BactoFert–L Boden as an effective solution for improving plant resilience to salinity stress in environments with low to moderate salinity. While BactoFert–L Boden shows promise in mitigating the adverse effects of salinity, its effectiveness is limited in environments with high salinity concentrations. Further research is recommended to assess its applicability across various plant species and environmental conditions.

Keywords: Salinity stress[1], Biostimulant[2], BactoFert–L Boden[3], Chloride[4], Sulfate[5].

INTRODUCTION

Land degradation, particularly soil salinization, is a growing global issue, with the annual rate of degraded land increasing by approximately 10% due to various natural and anthropogenic factors. Soil salinization, defined as the accumulation of soluble salts in the soil, is one of the primary causes of reduced soil fertility and decreased agricultural productivity. This process leads to abiotic stress in plants, severely impacting crop growth and yields. Salinization can result from natural processes

(primary salinization) or human activities such as irrigation mismanagement and deforestation (secondary salinization) [15].

According to recent estimates, around 20% of cultivated agricultural land and 33% of irrigated land globally are affected by salinization, representing a critical threat to food security in many regions [12],15]. The Food and Agriculture Organization reports that over 900 million hectares of land are affected, with approximately 77 million hectares impacted by human activities [9]. The increasing pressure on agricultural systems, especially in arid and semi-arid regions where evaporation exceeds precipitation, makes salinization a significant concern for future agricultural productivity [10].

While soil salinization is most prevalent in arid and semi-arid regions, poor drainage, rising sea levels, and saline water intrusion into groundwater systems exacerbate the problem in coastal areas [4]. In Georgia, soil salinization is recognized in regions such as Kvemo Kartli and Kakheti, where soils naturally contain soluble salts [10]. Additionally, improper irrigation practices, flooding, and saline water intrusion from the Black Sea contribute to soil degradation in western regions of the country.

Recent advancements in plant biotechnology have highlighted the potential of biostimulants to enhance plant resilience to abiotic stresses, including salinity. Biostimulants, derived from natural or synthetic substances, help improve plant growth, nutrient uptake, and stress tolerance, reducing the adverse effects of salinization on crop yields [14]. Various biostimulants have been studied for their efficacy in different agricultural systems, showing promising results in mitigating the negative effects of salinity [2;6]. In this context, the use of biostimulants such as BactoFert-L Boden offers a potential solution for addressing soil salinization, particularly in regions where traditional farming methods are unsustainable.

MATERIALS AND METHODS

This study aimed to evaluate the effects of the Georgian biostimulant BactoFert–L Boden (BF Boden) on cucumber seedlings (*Cucumis sativus*) grown under laboratory conditions with varying concentrations of salt solutions. The specific objectives of the research are: To assess the toxic effects of different concentrations of saline solutions on the growth and development of cucumber seedlings; To evaluate the effectiveness of BF Boden in enhancing the growth of cucumber seedlings in saline conditions; To analyze the biological activity of cucumber seedlings under combined conditions of salinization and biostimulant application. The study was conducted using the GOST-54221-2010 methodology, where cucumber seedlings were exposed to controlled saline conditions (varied concentrations) in a laboratory setting, with and without the application of BF Boden.

This study was conducted in 2023, utilizing an experimental design that assessed the impact of salinity on cucumber seedling growth. The experimental setup involved using sodium chloride (NaCl) and sodium sulfate (Na_2SO4) solutions, prepared at concentrations of 0.2%, 0.4%, 0.6%, 0.8%, 1.0%, 1.2%, and 1.4%. These solutions were composed of various chloride and sulfate ratios to simulate different saline environments: 100% Cl^- (pure sodium chloride solution), 75% Cl^- and 25% SO_4^{2-}, 50% Cl^- and 50% SO_4^{2-}, 25% Cl^- and 75% SO_4^{2-}, 100% SO_4^{2-} (pure sodium sulfate solution). Control cucumber seedlings were germinated in distilled water to establish a baseline for comparison.

The methodology employed to assess the biological activity of BF Boden on cucumber seedlings involved quantifying changes in mass, stem length, and root length in response to various saline treatments. The experiment used sodium chloride (NaCl) and sodium sulfate (Na_2SO_4) solutions at concentrations ranging from 0.2% to 1.4%, representing a gradient of saline stress. Control seedlings were grown in distilled water for baseline comparison.

Ba based on mass - $Ba\ (M) = \frac{(M-M1)\times 100}{M1}$. Where M represents the mass of seedlings treated with the biostimulant, and M1 is the mass of the control seedlings. This calculation measures the relative growth in biomass due to biostimulant treatment under saline stress.

Ba based on stem length - $Ba\ (Sl) = \frac{(l-l1)\times 100}{l1}$. Here, l and l_1 represent the stem lengths of the treated and control seedlings, respectively. This formula quantifies the effect of the biostimulant on stem elongation under different saline conditions.

Ba based on root length - $Ba\ (Rl) = \frac{(l2-l3)\times 100}{l3}$, Where l_2 and l_3 are the root lengths of the treated and control seedlings, respectively. This calculation is used to evaluate the impact of biostimulants on root development, which is crucial for plant stability and nutrient uptake under saline stress.

Ba the leap surface area calculation was performed using the formula: $Ba\ (lsa) = l4\ X\ l5X\ 2X4x3.14)$, where l4 is the leaf length, and l5 is the leaf width, 2 is the number of leaves if they are completely identical in size. If there is a difference in size between them, or there is a third additional leaf, it is measured separately and added to the previous indicator.

RESULTS

The experimental investigation conducted in April-May 2022 provided quantitative insights into the biological activity of 10-day-old cucumber seedlings under various saline conditions. Sodium chloride (NaCl) and sodium sulphate (Na_2SO_4) were used in solutions of varying concentrations (0.2; 0.4; 0.6; 0.8; 1.0; 1.2 and 1.4%) to explore their toxic effects on seedling growth, compared to a control group grown in distilled water.

The study revealed a progressive increase in toxicity with higher concentrations of the salt solutions. The toxic effects were particularly evident when analysing the biomass of the roots. Specifically, Diagram 1 illustrates that seedlings exposed to 0.4% solutions of 100% Cl^- and 75% Cl^- + 25% SO_4^{2-} exhibited an 80% and 60% stimulation in root biomass, respectively, compared to the control. However, the biological activity was notably lower (20%) in solutions composed entirely of sulphates (100% SO_4^{2-}). Root growth was stimulated by 0.2% solutions of 100% SO_4^{2-}, 75% Cl^- + 25% SO_4^{2-}, and 25% Cl^- + 75% SO_4^{2-}.

Adding the BF Boden to the salt solutions further influenced seedling root biomass, particularly at 0.4% and 0.2% concentrations. The highest biological activity was observed in the BF Boden + 100% SO_4^{2-} solution, reaching a peak index of 100. A similar high biological activity was also noted in the 0.8% solution of 75% Cl^- + 25% SO_4^{2-} compared to the control. For salt solutions at concentrations of 1.0, 1.2, and 1.4%,

there was a significant restriction in seedling development, indicating severe toxicity under high-salinity conditions (Diagram 1, Image 1). The results were consistent when BF Boden was added to these salt solutions. It appears that the cations present in the biostimulant, in conjunction with the salt cations, were highly toxic for plant development.

The increase in root biomass was particularly pronounced in lateral roots and basal bush roots (Image 1). Similar findings have been supported by literature, specifically, bacteria of the genera *Pseudomonas spp.* and *Bacillus spp*. are known to stimulate plant growth under stressful conditions [11].

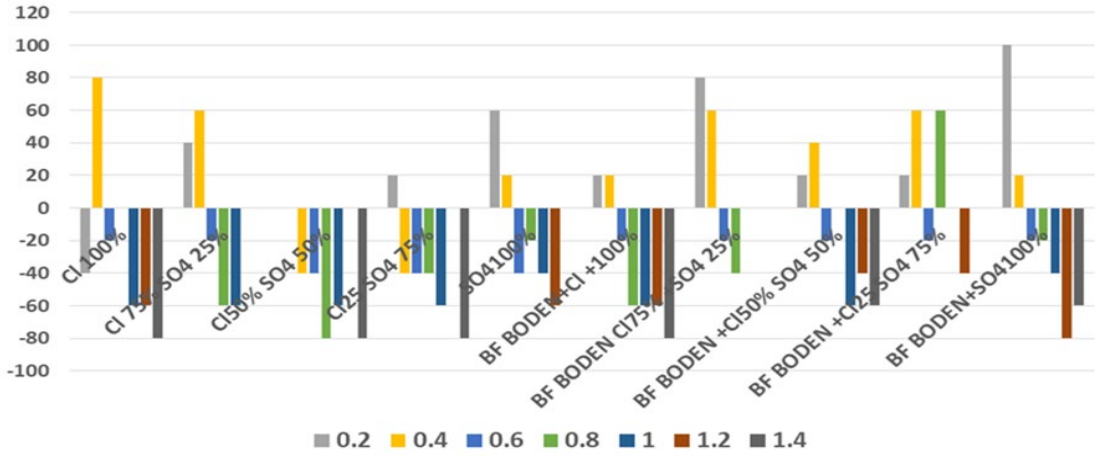


Figure 1: Variation in Root Biomass in Different Concentrations of Salt Solutions

Changes in root development allow the plant to absorb water and nutrients more efficiently due to a larger and more developed root system [13]. Consequently, this should positively influence the biomass and the development of the stems and leaves. However, the results obtained for stem length in the seedlings are somewhat unusual. In saline solutions, stem growth was inhibited compared to the control. Only a slight stimulation was observed in the lower concentrations of the salt solutions (0.2%). The results were more favorable when BF Boden was added to the salt solutions, with biological activity (Ba) increasing in the 35-150% range under the influence of 0.2% and 0.4% solutions. Minor stimulation was also noted at 0.6 and 0.8% concentrations, while higher concentrations of salts (1.0; 1.2; 1.4%) inhibited stem growth, similar to the effects on root biomass. However, an increase in stem thickness and diameter was observed, which ultimately influenced changes in the plant's overall biomass (Figure 3).

Figure 3 shows that the seedling biomass is stimulated in various salt solutions as well as in the presence of the BF Boden when added to these solutions at 0.2, 0.4, 0.6, and 0.8% concentrations. In these cases, the biological activity (Ba) of the salt solutions ranges from 32.7 to 202. When BF Boden is added to the salt solutions, the Ba increases, ranging from 66 to 517, which is 2 to 2.6 times higher than the biological activity of the salt solutions alone. The highest effect of Ba (517) is observed with the combination of BF Boden and 75% Cl^- + 25% SO_4^{2-} at 0.4% concentration. It is noteworthy that while a positive effect on biomass is observed in salt solutions of 1.0, 1.2, and 1.4% concentrations, these higher concentrations clearly exhibit stress effects on both the salts and the biostimulant-treated solutions. In addition to this, the leaf surface area of cucumber seedlings was also examined, and the biological activity of the solutions was determined based on this characteristic (Figure 4).

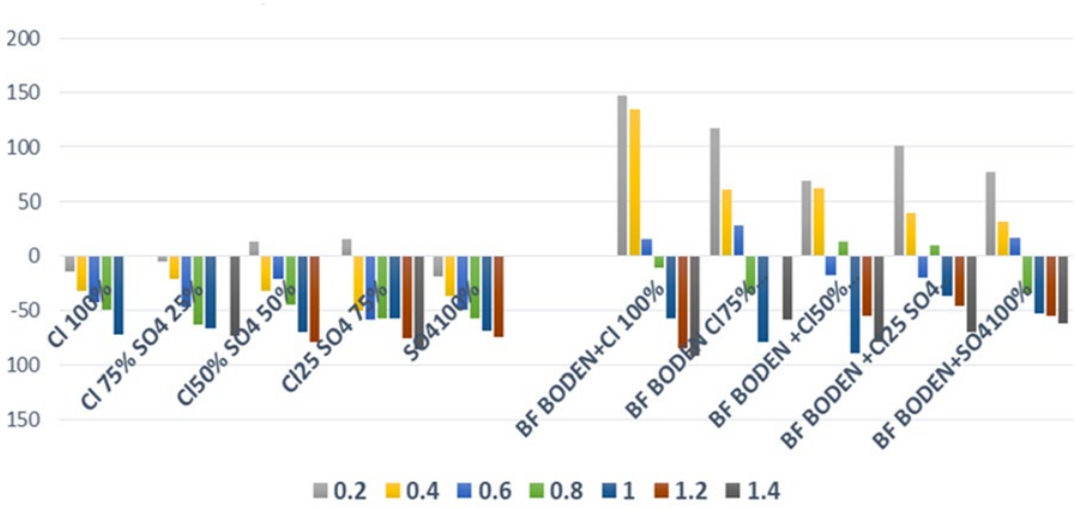


Figure 2. Ba of Seedling Stem Length in Various Salt Solutions

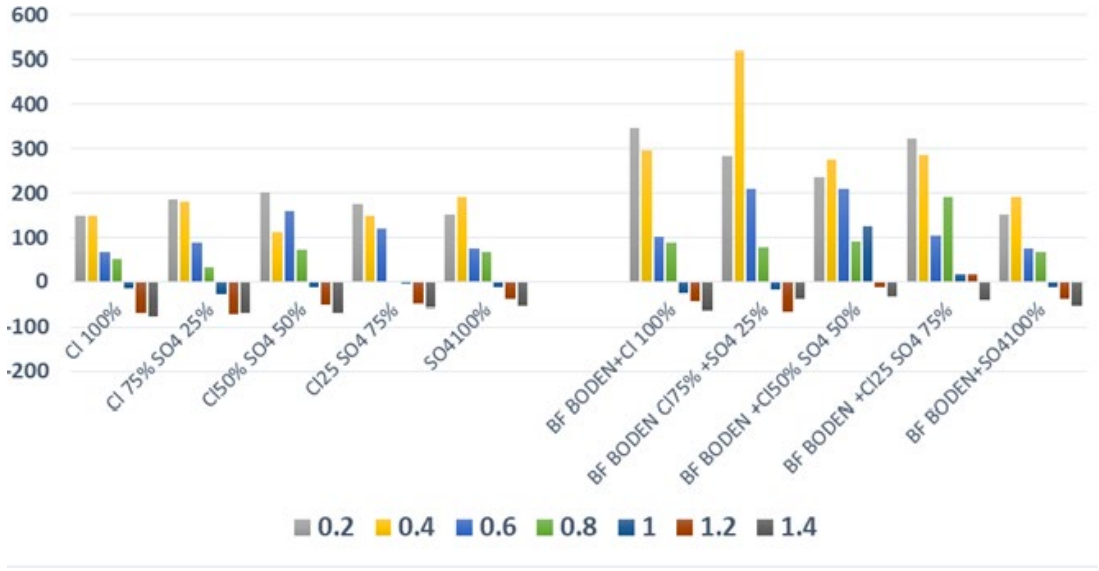


Figure 3: Biological Activity of Various Salt Solutions Based on Seedling Biomass

The visual data demonstrate an increase in Ba when BF Boden is added to the salt solutions. However, the effect remains significant primarily in combination with 0.2, 0.4, 0.6, and 0.8% salt solutions. Higher concentrations continue to inhibit the development of plant leaves, with only minimal results observed. When comparing the toxic effects of chloride and sulfate salinization, it becomes evident that the increase in sulfate ion concentration significantly hinders plant growth (Image 1,2).

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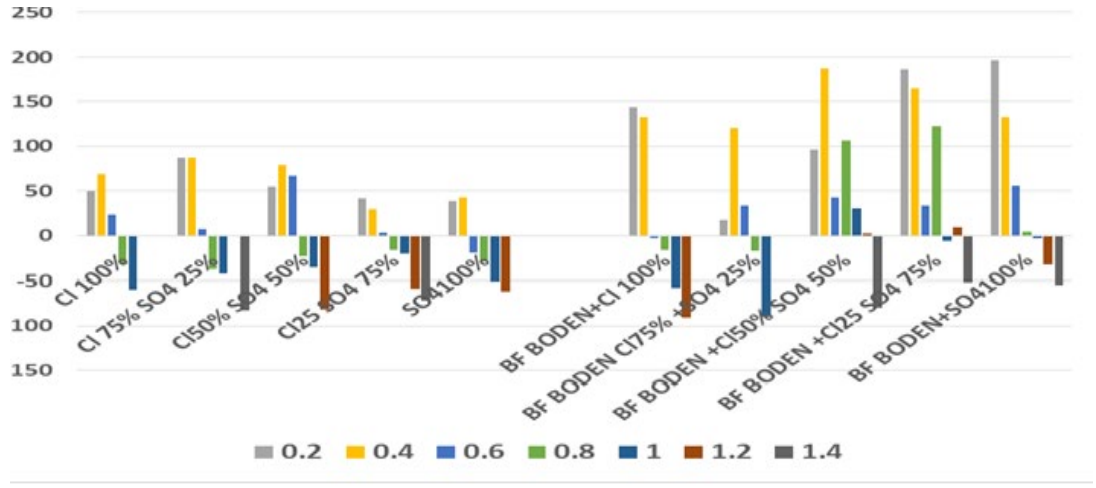


Figure 4. Ba of the Investigated Solutions Based on Seedling Leaf Surface Area



Images 1,2. Inhibition of Seedling Development in Response to Increasing Salt Concentration.

DISCUSSION

Due to the accumulation of salts in the root system, an osmotic phase occurs, which leads to a water deficit in the roots [12]. This results in a reduction in plant growth rate and the closure of stomata to minimize water loss by the plant [15]. This is followed by the ionic toxicity phase, caused by the excessive accumulation of ions [12]. As the concentration of salts increases, the build-up of these ions leads to structural and functional changes in the cell [12]. Osmotic stress and ionic toxicity, in turn, lead to a photosynthetic imbalance, causing oxidative stress [7]. These metabolic changes affect cellular components, potentially leading to programmed cell death.

Thus, the growth of vegetative organs in experimental plants was disrupted by the stressful effects of salinity [15]. With the addition of the biostimulant, plants were able to mitigate the stress caused by salinity through the regulation of stress-related genes, improving nutrient uptake and pigment production or reducing oxidative stress [3;8].

CONCLUSION

In chloride, chloride-sulfate, sulfate-chloride, and sulfate-dominant environments, low concentrations of the salt solutions (0.2%, 0.4%, 0.6%) weakly, but still positively, support the development of seedlings compared to the control group. The addition of BF Boden to these salt solutions reveals a slight increase in biological activity based on root biomass, and a pronounced stimulation in stem length, plant biomass, and leaf surface area. Moreover, the biological activity increased not only at low concentrations (0.2%, 0.4%) but also at relatively higher concentrations of 0.6% and 0.8%.

In contrast, higher concentrations of salts (1.0, 1.2, 1.4%) proved to be highly toxic to cucumber seedling development. The addition of BF Boden in these solutions showed stimulation in some cases compared to the control.

Recommendations: We recommend the use of BactoFert Boden as an effective biostimulant for plant growth and development in soils with low to moderate salinity. It is crucial to further test the biostimulant's effects on different plant species, soil types, and under various environmental stress conditions.

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PHYSICOCHEMICAL CHARACTERIZATION AND SENSORY EVALUATION OF WHOLEMEAL FLOUR AND CARROT-ENRICHED BISCUITS: NUTRITIONAL AND CONSUMER IMPACT

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ABSTRACT

The aim of the project concerns the production, characterization and impact on consumers of biscuits with wholemeal flour and grated carrots.

The innovative character results from the use of wholemeal flour, which, unlike white flour, retains the bran and wheat germ, making it richer in fiber, vitamins and minerals. This contributes to a lower glycemic index and a superior nutritional profile.

Carrots provide moisture and natural sweetness and are also an important source of beta-carotene, fiber and other vitamins and by adding orange essence, the flavor of the biscuits is greatly enhanced, adding a dose of vitamin C, boosting the nutritional value of the biscuits. The carrot, wholemeal flour and orange essence biscuit is a tasty and healthy product that is also a child-friendly product.

In the present work, the obtained biscuits were analyzed from physicochemical and sensory points of view. From the physicochemical point of view the moisture, mineral, fat, protein and finally the carbohydrate content and energy value were evaluated. From a sensory point of view, the external appearance, in cross-section, taste, odor and general acceptability were evaluated.

Keywords: wholemeal flour, grated carrots, biscuits, proximate composition, sensory characteristics

INTRODUCTION

Whole-wheat wholemeal wheat flour is known for its high nutritional values and health benefits compared to refined white flour. Expert studies have shown that this flour contains fibre, vitamins, minerals and antioxidants that contribute to digestive health, prevention of chronic diseases and maintenance of optimal body weight [1]. Wholemeal flour includes the essential parts of the grain - the bran, germ and endosperm - providing fibre, B-complex vitamins and essential minerals. Fibre supports digestive health and antioxidants protect against oxidative stress [1]. The insoluble and soluble fibres in wholemeal flour help intestinal transit and support the gut microbiota, reducing the risk of constipation and colonic disorders [2].

Fiber induces long-lasting satiety and helps maintain a healthy weight, helping to prevent obesity [3].

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Studies suggest that wholegrains reduce the risk of cardiovascular disease by lowering cholesterol and improving lipid profile [4].

The high fibre content of wholegrain flour lowers the glycemic index and reduces the risk of type 2 diabetes by stabilizing blood glucose levels [5].

Carrots, rich in beta-carotene, fiber, vitamins and minerals, are used as an addition in bakery products to enhance the nutritional value, texture and color of bakery products. Thus, bread and biscuits enriched with carrots are higher in fiber and antioxidants and are healthier and more sensory pleasing [6,7]. They contribute to eye health, digestion and immunity, and have antioxidant and benefits in reducing the risk of chronic diseases [8,9].

Carrots add fibre and antioxidants, increasing the intake of beta-carotene and dietary fibre in bread and biscuits, making them healthier [10]. The products have a vibrant colour and softer texture and are well tolerated by consumers. Carrots increase the water holding capacity of the dough, prolonging shelf life [11].

The aim of this project was to develop a new biscuit recipe and to use whole wheat flour as raw material and carrots, butter, eggs, etc. as auxiliary materials. The stages of the technological process were established and the products obtained were characterized from the physico-chemical and sensory points of view.

MATERIALS AND METHODS

Materials

The raw and auxiliary materials used in this study were purchased from a local supermarket in western Romania. Reagents used in the physico-chemical analyses were of analytical grade and purchased from Sigma-Aldrich (St. Louis, MO, USA) and Chimreactiv (Bucharest, Romania).

Obtaining the biscuit samples

The biscuit samples were prepared in the bakery laboratory of the Faculty of Food Engineering, University of Life Sciences "King Mihai I" of Timisoara, Romania. Three different biscuit samples were prepared, namely with 12% fiber and carrot pulp (BFC12), 25% fiber and carrot pulp (BFC25) and a control biscuit sample without any addition (BC), according to the recipe presented in table 1.

Table 1. The recipes used to obtain biscuit samples

Sample	White wheat flour (g)	Whole wheat flour (g)	Sugar (g)	Baking powder (g)	Egg (pieces)	Butter (g)	Orange essence (g)	Grated carrot (g)
BFC12	175	175	200	10	2	100	2	44
BFC25	175	175	200	10	2	100	2	88
BC	175	175	200	10	2	100	2	-

The technological process and technical parameters of biscuit production are realized according to the steps shown in figure 1. The biscuit doughs were prepared using a Maxima spiral mixer, MSM 10, and then baked in an FM pastry oven, which is electric and has 10 trays and a touch screen control panel, according to the technological parameters presented in figure 1 for biscuits.

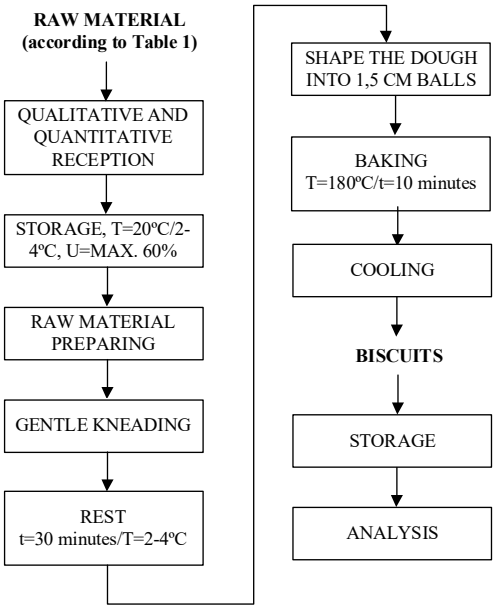


Figure 1. Chart-flow of biscuit samples

Physical characteristics of the biscuit samples studied

The main physical analyses carried out on whole wheat and carrot flour biscuits were: mass of defective biscuits, biscuit dimensions, and biscuit soakability, according to STAS 1227/2/A1-1998.

Proximate composition of the biscuit samples analyzed

Determination of proximate composition of biscuit samples was carried out using the following ISO methods: SR 91/2007 pct. 10 for moisture; SR 91:2007 pct. 14.4 for lipids; SR EN ISO 8968-1:2014 for protein; STAS 90-2007, pct. 20 for sugar; and SR ISO 2171/2010 for ash determination. carbohydrate content (%) was calculated as the difference between 100 and the sum of water, lipid, protein and ash. The energy values of the samples were calculated as the sum of the values determined for the macronutrients multiplied by their caloric coefficients, as follows 1 g lipid = 9 kcal, 1 g carbohydrate = 4 kcal and 1 g protein = 4 kcal.

Carbohydrate = 100-(water content+ash content+protein content+lipid content) (%) (1)

Energy = (fat content×9)+[protein content×4)+(carbohydrate content×4) (2)

Sensory analysis

The biscuit samples were evaluated by a group of 30 trained evaluators (15 men and 15 women, aged between 20 and 30 years) in the sensory analysis laboratory of the Faculty of Food Engineering in Timisoara, Romania. Throughout the sensory analysis, natural lighting (daylight) and a constant room temperature were provided. Biscuit samples were prepared 5 minutes before the evaluation. The characteristics analyzed were appearance, texture, aroma (smell), taste and overall acceptability. Each characteristic was assessed using a nine-point hedonic scale with the following ratings: extremely pleasant (9), very pleasant (8), moderately pleasant (7), mildly pleasant (6), indifferent (5); mildly unpleasant (4); moderately unpleasant (3); very unpleasant (2); extremely unpleasant (1).

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Statistical Data Analysis

The results were presented as the mean of three determinations ± standard deviation (SD). Statistical differences between samples ($p < 0.05$) were analyzed using the t-test in Microsoft Excel 365 (Version 2208, Redmond, WA, USA).

RESULT AND DISCUSSION

Physical characteristics of the biscuit samples studied

The physical properties (biscuit size, soakability and defected mass) are shown in figure 2.

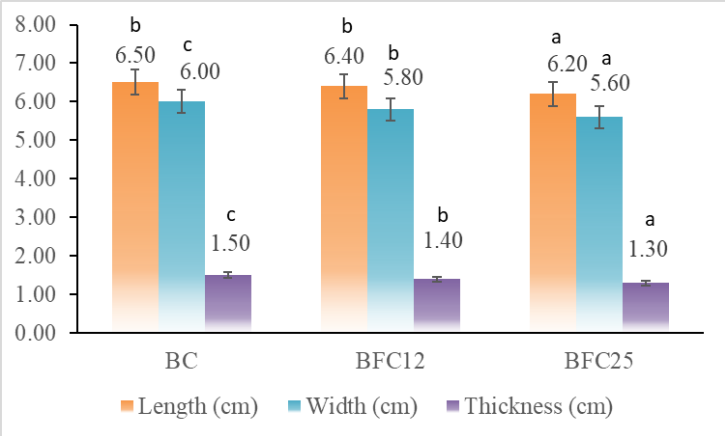


Figure 2. Size variation of the biscuits studied

a-c different letters between samples signify statistical differences acording to t-test

In terms of size values of carrot biscuits, comparing the three types of biscuits analyzed, it can be seen that in the case of length significant differences were recorded between BC (6.5cm), BFC12 (6.40 cm) and BFC25 (6.20 cm). In case of width and thickness significant differences were recorded for all three biscuit samples.

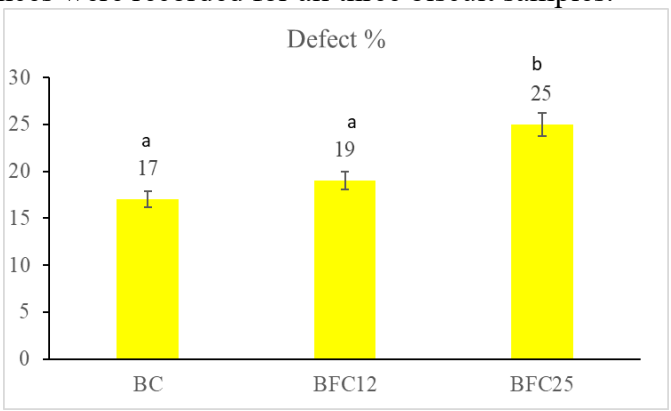


Figure 3. Mass variation of biscuits studied with defects

a-b different letters between samples signify statistical differences acording to t-test

The main appearance defects concern: warping, reduced volume, swelling, flattening, cracking or sticking. The samples with 12% carrots (BCF12) show the best organoleptic characteristics, with a defective biscuit mass of 19% compared to the sample with 25% carrots (BCF25), with a defective biscuit mass of 25%. This could be due to defective homogenization of carrots in the dough (figure 3).

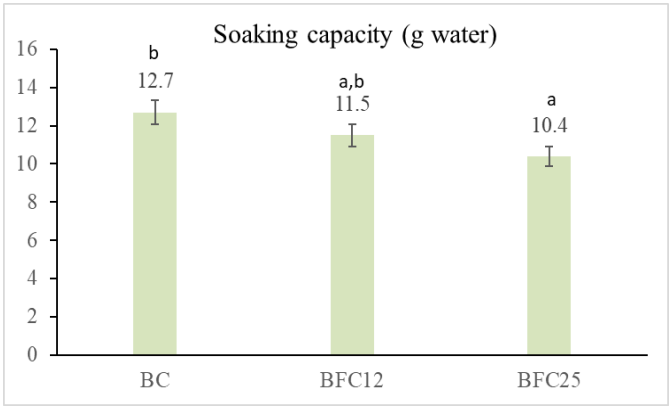


Figure 4. Variation in soak capacity during biscuit storage
a-b different letters between samples signify statistical differences acording to t-test

As shown in Figure 4., the soakability is higher in the control sample 12.7 g water (BC) and decreases with increasing percentage of carrot, 11.5 g water (BFC12), 10.4 g water (BFC25).

According to other studies fruit additions, such as banana pulp and apples, tend to influence the extensibility and diameter of biscuits. This is due to the ability of these ingredients to retain more water, which increases volume and allows expansion during baking. Pumpkin and banana pulp, for example, resulted in an increase in biscuit diameter compared to standard recipes [12,13]. Carrot pulp and other fiber-rich vegetables tend to create a denser texture, but thus reduce the incidence of cracking, as the fibers act as dough stabilizing agents [14]. Additions of fruit and vegetable pulps considerably increase the water absorption capacity of the biscuits, which helps to increase moisture and improves freshness. Studies on biscuits with added pumpkin and sweet potato pulp have shown that vegetable fibers increase water retention, providing a softer texture and longer shelf-life in bakery products [15,16].

Proximate composition of the biscuit samples analyzed

Table 2. Proximate composition of the biscuit samples

Sample			Chemical Parameters				
	Moisture content (g/100 g)	**Ash (g/100 g)**	**Protein (g/100 g)**	**Lipids (g/100 g)**	**Carbohy-drates (g/100 g)**	**Fibre (g/100 g)**	**Energy Value (kcal/100 g)**
BFC12	4.35±0.13 [b]	1.80±0.05 [c]	4.38±0.12 [a]	10.00±0.22 [a]	79.47	8.00±0.27 [b]	425.40
BFC25	4.20±0.12 [a]	1.65±0.04 [b]	4.57±0.13 [b]	8.00±0.31 [b]	81.58	9.00±0.25 [b]	416.60
BC	4.15±0.11 [a]	1.45±0.03 [a]	5.10±0.15 [c]	12.00±0.37 [c]	77.3	6.00±0.17 [a]	437.60

[a-c] different letters between samples signify statistical differences acording to t-test

The ash content in whole wheat wholemeal flour is usually higher than in white flour because it contains more of the mineral components of the outer wheat husk. Typically, whole wheat flour can have an ash content of about 1.5-2.0%. The ash content of BFC12 (1.8%) and BCF25 (1.65%) was higher than that of BC (1.45%) (table 2) considering that carrots have a different mineral content than whole wheat flour and the total ash content of the biscuits is influenced by the presence of minerals.

Whole wheat flour biscuits have a moderate lipid content, mainly from flour and any added oil or butter. BCF12 had a lipid content of 10%, as carrots have a low lipid content, so in this sample the lipids are mainly from flour and butter. BCF25 had a lipid content of 8%, although the higher percentage of carrots may slightly dilute the lipid content (table 2).

BC recorded 77.3% carbohydrate, wholemeal flour in general has a significant carbohydrate content. Whole wheat flour contains both starch and dietary fiber, which contribute to the total carbohydrate. BCF12 had a slightly higher carbohydrate content (79.47%) than plain wholemeal flour biscuits, as carrots also come with a proportion of carbohydrate. BCF25 had a higher carbohydrate content (81.58%) compared to BCF12 (79.47%), due to the increased presence of carrots, which also come with a carbohydrate intake (table 2).

BC generally have a high fiber content due to the presence of wheat bran and wheat germ, recording 6 g/100 g of product. BCF12 had a slightly higher fiber content due to the addition of carrots, which are a good source of dietary fiber, with 8 g/100 g of product. BCF25 had an even higher fiber content due to the higher amount of carrots in the composition, 9 g/100 g of product.

The recorded results are in agreement with literature studies reporting that wholemeal biscuits with added fruits and vegetables show significant variations in proximate composition due to the added ingredients. In terms of moisture content, research indicates that fruits and vegetables slightly increase this parameter due to the natural water in these ingredients [17]. Minerals are also better represented in fruit and vegetable enriched biscuits, contributing to a higher content of essential minerals such as potassium and calcium [18]. In terms of lipids, studies show that, for example, the addition of apple peel powder slightly increases lipid content [19]. At the same time, vegetable powders such as beetroot or carrot add beneficial phytonutrients but have little impact on fat content [20]. Other studies show a higher protein content when protein-rich ingredients such as almonds are included, contributing to a more balanced protein source [17]. Carbohydrates come mainly from wholemeal flour and, in some cases, the addition of dried fruits, which provide natural sugars and increase the energy value of the biscuits [18]. Overall, the addition of fruits and vegetables improves the energy value and nutritional profile of the biscuits, making them a healthier option compared to traditional biscuits.

Evaluation of Sensory Analysis

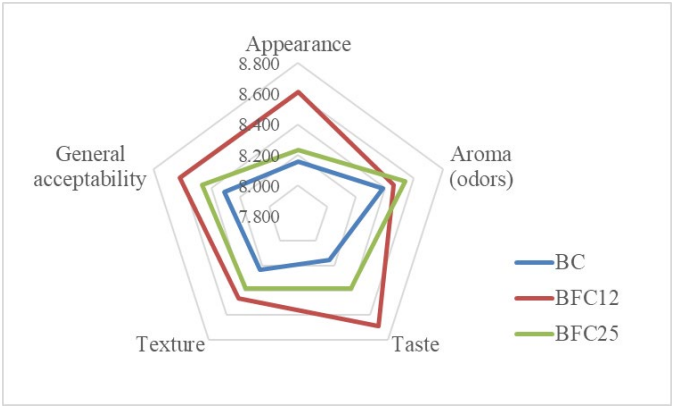


Figure 5. Sensory analysis of the analyzed biscuit samples

Sensory analysis assessed the effect of the addition of carrots in the biscuit composition on the sensory characteristics of the product. Figure 5 shows the results obtained from the sensory evaluations for the three biscuit samples, with total values recorded ranging from 8.154 to 8.692. Within the five analytical characteristics evaluated (appearance, aroma (smell), taste, texture and general acceptability), sample BCF12 scored the highest except for aroma where BCF25 scored the highest. BCF25 and BC followed BCF25 and BC. These results suggest that the addition of carrots in moderate proportions contributes significantly to improve the sensory characteristics of pates, thus indicating their potential in food formulation.

CONCLUSION

This research aimed to investigate the use of carrots as a functional ingredient in biscuit formulation. The evaluation of the physical characteristics of the samples led to the conclusion that the moderate addition of carrots in the biscuit composition leads to improved physical characteristics Proximate analysis showed that the use of carrots improves nutritional characteristics and reduces fat content and energy value. The results of sensory analysis indicated that the addition of carrots in moderate proportions significantly contributes to the improvement of the sensory characteristics of biscuits, thus confirming the potential of carrots as a promising functional ingredient for food products.

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SUSTAINABLE CABBAGE PRODUCTION IN KENYA USING OBLIGA BONACRAFT BIOFERTILIZER

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ABSTRACT

Cabbage (*Brassica oleracea* var. *capitata*) is a vital crop for Kenyan smallholder farmers, contributing to food security and income. However, declining soil fertility and reliance on costly synthetic fertilizers pose significant challenges. This study aimed to evaluate the efficacy of OBLIGA BONACRAFT P20S10, a microbiological phosphorus-sulfur fertilizer, as a sustainable alternative. Field trials were conducted in four agroecological zones: Kiambu, Kirinyaga, Machakos, and Murang'a, using a randomized complete block design (RCBD) with three replications per site.

The experimental plots (12 m²) received BONACRAFT P20S10 at 150, 200, and 250 kg/ha, compared against a standard fertilizer program (RFP) and an untreated control. Growth parameters such as plant height, stem diameter, and head width were measured biweekly. Data analysis focused on determining the optimal application rate and its impact on yield and soil health.

Results showed that BONACRAFT P20S10 significantly enhanced cabbage growth and yield, with the 250 kg/ha rate achieving the highest yield (83.4 tons/ha) in Kirinyaga. This study demonstrates the potential of the biofertilizer as a cost-effective, sustainable solution for improving cabbage production while addressing soil degradation and environmental concerns.

Keywords: Organic fertilizer, BONACRAFT P20S10, Cabbage, Sustainable agriculture, Soil health.

INTRODUCTION

Sustainable agricultural practices are gaining prominence as a response to the negative impacts of intensive farming systems that rely heavily on synthetic fertilizers and pesticides. These inputs, widely adopted during the Green Revolution, have led to increased crop yields but at the cost of long-term soil health, biodiversity, and environmental stability [12]. The use of synthetic fertilizers has been linked to soil degradation, water contamination, and increased greenhouse gas emissions, prompting the urgent need for alternative solutions [11], [15].

Organic fertilizers, derived from natural sources, offer an environmentally friendly approach to maintaining soil fertility while reducing the ecological footprint of agriculture [3]. They improve soil structure, enhance microbial activity, and promote

nutrient cycling, which is essential for sustainable crop production [1], [6]. Additionally, organic inputs mitigate the effects of climate change by enhancing soil resilience and reducing vulnerability to extreme weather events [4], [5].

Research has shown that integrating organic and synthetic fertilizers can optimize nutrient availability and improve crop performance. Studies demonstrate that organic fertilizers release nutrients more slowly and steadily, which sustains plant growth over longer periods [14]. Shi et al. highlighted the role of organic manure in enhancing nitrogen fixation and improving soil fertility, particularly in degraded soils [10]. Similarly, Rayne and Aula emphasized the importance of livestock manure in improving soil health and increasing carbon sequestration [7].

Recent advancements in biofertilizer technology have focused on formulations that incorporate beneficial microorganisms to further enhance soil fertility and crop productivity. Dumbadze et al. demonstrated the efficacy of new Georgian biofertilizers, which improved plant growth and stress tolerance under various environmental conditions [2]. Calvo et al. noted that plant biofertilizers, can enhance nutrient use efficiency and improve plant resistance to abiotic stress [13]. Such innovations are critical for smallholder farmers, particularly in regions like Kenya, where soil fertility is declining, and the cost of synthetic inputs remains prohibitive [9], [8].

The primary aim of this study is to evaluate the efficacy of OBLIGA BONACRAFT P20S10 (BC P20S10), a microbiological phosphorus-sulfur fertilizer, in enhancing the growth, yield, and quality of cabbages (*Brassica oleracea* var. *capitata*) under varying agroecological conditions in Kenya. Specifically, the research seeks to determine the optimal application rates of BC P20S10 to maximize crop performance. To achieve this, the study compares the performance of BC P20S10 against a standard reference product, Evergrow Organic Fertilizer, and an untreated control.

MATERIALS AND METHODS

BC P20S10 is a microbiological phosphorus-sulfur fertilizer specifically designed for alkaline soils. Its granular formulation incorporates essential minerals, including rock phosphate, elemental sulfur, and Leonardite, alongside beneficial microbial strains. These microorganisms enhance nutrient solubilization, converting phosphorus, potassium, calcium, and sulfur into plant-available forms. This dual action addresses immediate nutrient deficiencies while improving soil structure and fertility, supporting sustainable agricultural productivity.

This study was conducted across four agroecological zones in Kenya: Kiambu, Kirinyaga, Machakos, and Murang'a. These regions were strategically selected for their diverse climatic and soil conditions, representing the varied environments in which cabbages (*Brassica oleracea var. capitata*) are cultivated in Kenya. The experimental design followed a randomized complete block design (RCBD) with three replications per site to ensure robust and reliable data. Each plot measured 12 m², with treatments randomly assigned within each block to mitigate potential biases and environmental variability.

Treatments and Application Rates. The experiment assessed the performance of BC P20S10 at three different application rates: 150 kg/ha, 200 kg/ha, and 250 kg/ha. These treatments were compared to a standard organic fertilizer, Evergrow, and an untreated

control (blank). Evergrow Organic Fertilizer, registered in Kenya by Sanergy LTD, was chosen as the reference product due to its comparable nutrient composition and similar mode of action. This comparison allowed for a comprehensive evaluation of BC P20S10's effectiveness relative to existing organic fertilization options.

Data Collection. Key growth parameters were monitored biweekly throughout the cabbage growth cycle. Data collected included plant height, stem diameter, and head width. At harvest, yield data were obtained by measuring the weight of cabbage heads in each plot to assess productivity. Additionally, soil samples were collected both before the experiment commenced and after the final harvest to evaluate changes in soil nutrient content, focusing on parameters such as organic matter, phosphorus, and potassium levels. These soil analyses provided insights into the broader impacts of BC P20S10 on soil health and fertility. Ten sampling plants were selected per plot (net area: 6 m²) for biometric observations. Growth parameters, including root biomass, plant height, and spread, were recorded at 30, 60 DAT, and harvest. Yield parameters (head weight, circumference, and diameter) were assessed on five tagged plants per plot. Buffer zones (0.5 m²) minimized treatment interference.

BC P20S10 and Evergrow fertilizers were applied once at planting, following manufacturer recommendations. Conventional fertilizers were applied per standard protocols. Mature cabbage heads were harvested, and graded, and yields translated to tons/ha. The data were analyzed using analysis of variance (ANOVA) in GenStat software, ensuring a statistical power of 95%. Means were separated using Duncan's Multiple Range Test at a significance level of $P < 0.05$, providing robust comparisons across treatments.

RESULTS

Effect of treatments on the growth and yield parameters in Kirinyaga

Treatments differed significantly ($P \leq 0.05$) on the plant height, stem diameter and head width of cabbages in Kirinyaga (Table 1). The tallest plants were observed on the low, medium and high rates of BC P20S10 organic fertilizer at 150, 200 and 250 kg/ha respectively, which were more comparable to the reference product and the conventional practice. The same trend was observed on the stem diameter and the head width which however the combinations were significantly higher comparable to the reference product. The shortest cabbages were on the untreated control due to lack of essential nutrients important for growth and development.

Table 1: Influence of treatments on the plant height, stem diameter, and average head width of Cabbages at Kirinyaga

Treatment	**Plant height (cm)**	**Stem diameter (cm)**	**Head width (cm)**
P20S10 150kg/ha	23.2 a	3.5 ab	15.6 ab
P20S10 200kg/ha	23.9 a	3.6 ab	15.7 ab
P20S10 250kg/ha	24.9 a	3.6 ab	16.4 a
Reference	21.8 b	3.4 ab	14.8 ab
RFP	22.0 b	3.2 b	14.3 b
Untreated Control	15.9 c	2.0 c	9.5 c
P-Value	**<.001**	**<.001**	**<.001**
LSD	**1.675**	**0.4635**	**1.624**

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Treatments with the same letter along the columns are not significantly different according to DMRT at P≤0.05. RFP-Recommended Fertilizer Program

There were significant differences (P≤0.05) between the treatments on the head height, individual head weight, and the final yield in Kirinyaga (Table 2). The highest yield (83.4 tons/ha) was realized on the highest rate of BC P20S10 (250 kg/ha) which was however significantly comparable to the medium and low rates of the test product. The lowest rate of BC P20S10 had a lower linear yield probably compared to the higher rates probably because of the lower nutrients compared to the crop need throughout the cropping cycle but insignificantly different and superior to the reference product which has a low nutritional status compared to the test product. The untreated control had less than half of the marketable yield compared to the test product treatments indicating a need for the provision of nutrients to cabbage crops.

Table 2: Treatment effect on the head height, average head weight and marketable yield of cabbages at Kirinyaga

Treatment	**Head height (cm)**	**Head weight (kgs)**	**Yield (tons/ha)**
P20S10 150kg/ha	17.1 a	4.3 a	79.1 ab
P20S10 200kg/ha	17.3 a	4.4 a	80.7 ab
P20S10 250kg/ha	17.8 a	4.5 a	83.4 a
Reference	16.8 a	4.0 ab	76.4 b
RFP	15.6 b	3.3 b	66.5 c
Untreated Control	11.0 c	1.8 c	32.5 d
P-Value	**<.001**	**<.001**	**<.001**
LSD	**1.109**	**0.6988**	**6.825**

Effect of treatments on the growth and yield parameters in Machakos

The plant height, stem diameter, and head width of cabbages were significantly influenced by the application of treatments in Machakos (Table 3). The most influences were realized on the low, medium, and high rates (150,200 and 250 kg/ha) which were significantly comparable to the reference product on the head width while superior efficacy was realized on the test products on the plant height and the stem diameter.

Table 3: Influence of treatments on the plant height, stem diameter, and head width of cabbages at Machakos

Treatment	**Plant height (cm)**	**Stem diameter (cm)**	**Head width (cm)**
P20S10 150kg/ha	18.0 ab	2.3 ab	11.0 a
P20S10 200kg/ha	18.1 ab	2.3 ab	11.1 a
P20S10 250kg/ha	19.4 a	2.5 a	11.8 a
Reference	17.5 b	2.0 b	10.4 a
RFP	17.3 b	1.9 b	9.7 a
Untreated Control	11.4 c	0.9 c	5.7 b
P-Value	**<.001**	**<.001**	**0.002**
LSD	**1.927**	**0.4653**	**2.363**

Treatments with the same letter along the columns are not significantly different according to DMRT at P≤0.05. RFP-Recommended Fertilizer Program

The marketable yield of cabbages more than tripled by application of the low, medium, and high rates of BCP20S10 in Machakos compared to the untreated control (Table 4). The same trend was observed in the head weight and the head width which was comparable to the reference product. The untreated control had the least head weight, head height, and marketable yield probably due to the limited availability of nutrients due to the depletion of inherent poor soil fertility as well as continued cropping which mines nutrients.

Table 4: Influence of treatments on the head weight, head width and the marketable yield of Cabbages at Machakos

Treatment	Head height (cm)	Head weight (kgs)	Yield (tons/ha)
P20S10 150kg/ha	13.1 ab	2.9 a	63.6 a
P20S10 200kg/ha	13.6 a	3.0 a	64.2 a
P20S10 250kg/ha	13.7 a	3.1 a	69.3 a
Reference	12.9 ab	2.8 a	60.4 ab
RFP	11.8 b	1.9 b	51.0 c
Untreated Control	7.2 c	0.5 c	16.2 d
P-Value	**<.001**	**<.001**	**<.001**
LSD	**1.462**	**0.7305**	**9.79**

Treatments with the same letter along the columns are not significantly different according to DMRT at P≤0.05. RFP-Recommended Fertilizer Program

Effect of treatments on the growth and yield parameters in Kiambu

Treatments differed significantly (P≤0.05) on the plant height, stem diameter and the head width due to treatment application in Kiambu (Table 5). Application of Bonacraft P20S10 biofertilizer at the three treatment rates (150,200 and 250 kg/ha) led to the tallest plants, widest stems and widest cabbage heads which were only comparable to the reference product on the height but superior on the other two parameters while the lowest effects were recorded on the untreated control. The effect of the organic fertilizer application programs confirmed the importance of all essential nutrients required by cabbages.

Table 5: Treatments effect on the plant height, stem diameter and head width of cabbages at Kiambu

Treatment	Plant height (cm)	Stem diameter (cm)	Head width (cm)
P20S10 150kg/ha	20.5 ab	3.2 ab	15.0 a
P20S10 200kg/ha	20.7 a	3.3 a	15.2 a
P20S10 250kg/ha	21.2 a	3.3 a	15.6 a
Reference	20.6 ab	3.1 ab	14.6 b
RFP	19.4 b	2.8 b	13.7 c
Untreated Control	14.03 c	1.7 c	8.8 d
P-Value	**<.001**	**<.001**	**<.001**
LSD	**1.235**	**0.4601**	**0.37**

Treatments with the same letter along the columns are not significantly different according to DMRT at P≤0.05. RFP-Recommended Fertilizer Program

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There were significant differences (P≤0.05) between the treatments on the head weight, head height and yield of cabbages tested in Kiambu (Table 5). The application of Bonacraft P20S10 at the low, medium and high rates had the highest efficacy on the yield which was comparable to the reference products. The untreated control had lowest influence probably because of the lower essential nutrients available in the soil to support cabbage growth and development. The untreated control had 2.5 times less marketable yield compared to the treated plots due to unavailability and limited essential nutrients.

Table 6: Treatment effect on the head height, individual head width and marketable yield of cabbages at Kiambu

Treatment	**Head height (cm)**	**Head weight (kgs)**	**Yield (tons/ha)**
P20S10 150kg/ha	16.1 a	3.7 a	79.0 a
P20S10 200kg/ha	16.5 a	3.8 a	82.9 a
P20S10 250kg/ha	16.6 a	3.9 a	83.1 a
Reference	15.9 a	3.5 a	79.4 a
RFP	14.2 b	2.6 b	67.4 b
Untreated Control	9.8 c	1.2 c	30.5 c
P-Value	**<.001**	**<.001**	**<.001**
LSD	**1.4**	**0.6845**	**5.808**

Treatments with the same letter along the columns are not significantly different according to DMRT at P≤0.05. RFP-Recommended Fertilizer Program

Effect of treatments on the growth and yield parameters in Muranga

Treatments differed significantly (P≤0.05) in the yield parameters tested at Murang'a due to treatment application (Table 7). The low, high, and medium rates of Bonacraft P20S10 at 150,200 and 250 kg/ha increased the lateral growth and diameter as well as the head width significantly and were comparable to the reference product. The lowest head weight was recorded on the untreated control which ultimately will affect the final marketable yield of cabbages in terms of firmness and hence lower yields because they are precursors for small and less compact heads.

Table 7: Treatments effect on the plant height, stem diameter, and head width of cabbages at Muranga

Treatment	**Plant height (cm)**	**Stem diameter (cm)**	**Head width (cm)**
P20S10 150kg/ha	21.7 a	2.9 ab	17.3 a
P20S10 200kg/ha	22.1 a	3.0 ab	17.4 a
P20S10 250kg/ha	23.2 a	3.2 a	17.8 a
Reference	21.6 a	2.6 ab	16.5 a
RFP	21.7 a	2.5 b	16.3 a
Untreated Control	15.8 b	1.6 c	11.7 b
P-Value	**<.001**	**<.001**	**<.001**
LSD	**2.096**	**0.5322**	**2.14**

Treatments with the same letter along the columns are not significantly different according to DMRT at P≤0.05. RFP-Recommended Fertilizer Program

The application of Bonacraft P20S10 biofertilizer led to the highest marketable yield of cabbages under the low, medium, and high rates of 150,200 and 250 kg/ha in Murang'a (Table 8). The conventional practice alone had lower efficacy on the head weight, head width, and marketable yield probably because of the less availability and uptake of nutrients needed by the crop as compared to where BC P20S10 was applied. The three rates Bonacraft P20S10 of were comparable to the reference product in all the tested yield and quality parameters in Murang'a.

Table 8: Treatment effect on the head height, individual head weight, and yield of cabbages at Murang'a

Treatment	**Head height (cm)**	**Head weight (kgs)**	**Yield (tons/ha)**
P20S10 150kg/ha	18.3 a	4.9 ab	72.3 a
P20S10 200kg/ha	18.9 a	5.0 ab	73.1 a
P20S10 250kg/ha	19.0 a	5.3 a	79.7 a
Reference	18.2 ab	4.7 ab	71.7 a
RFP	16.9 b	4.3 b	60.7 b
Untreated Control	12.6 c	2.6 c	26.5 c
P-Value	**<.001**	**<.001**	**<.001**
LSD	**1.383**	**0.794**	**8.5**

Treatments with the same letter along the columns are not significantly different according to DMRT at P≤0.05. RFP-Recommended Fertilizer Program

DISCUSSION

The study demonstrated that BONACRAFT P20S10 significantly enhances cabbage growth and yield across diverse agroecological zones in Kenya. The highest application rate (250 kg/ha) consistently delivered optimal results, particularly in Kirinyaga, where it outperformed the reference product. This confirms the fertilizer's efficacy in providing essential nutrients like phosphorus and sulfur, crucial for cabbage development.

The results highlight the importance of nutrient supplementation in addressing soil fertility challenges, as seen from the poor performance of untreated controls. Similar findings in previous studies emphasize the role of organic fertilizers in improving crop productivity while enhancing soil health [4], [9].

Moreover, BC P20S10 supports sustainable agriculture by improving soil organic matter and nutrient retention, aligning with global efforts to reduce synthetic fertilizer use and mitigate environmental degradation [10]. This positions it as a cost-effective and eco-friendly alternative for smallholder farmers. Overall, BC P20S10 is a valuable tool for sustainable, high-yield cabbage production, supporting both economic and environmental goals.

CONCLUSION

The study demonstrates the efficacy of OBLIGA BONACRAFT P20S10 as a sustainable biofertilizer for cabbage production in Kenya. Across four agroecological zones, BC P20S10 significantly enhanced cabbage growth and yield, with the highest performance observed at 250 kg/ha in Kirinyaga, where it outperformed the reference

fertilizer, Evergrow. In other regions, its performance was comparable or superior, highlighting its adaptability to diverse conditions.

In addition to boosting yields, BC P20S10 improved key soil health indicators, including pH balance, organic matter content, and nutrient availability, contributing to long-term soil fertility. These results emphasize its dual role in providing immediate nutrient support and enhancing soil sustainability, making it particularly suitable for smallholder farmers facing declining soil quality and high input costs.

The optimal application rate of 150 kg/ha is recommended for commercial use, balancing productivity and environmental sustainability. The adoption of BC P20S10 offers a viable solution for improving food security and promoting eco-friendly farming practices in Kenya.

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RESEARCH ON DEVELOPMENT NOVEL FERMENTED BEVERAGES FROM SWEET WHEY

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ABSTRACT

Whey is a significant environmental contaminant since its waste load is estimated to be 100–175 times more than that of an equivalent volume of household wastewater. It is estimated that around half of the whey produced is used for human or animal use, and the other half is released into the environment as waste water, which adds to pollution. Thus, in accordance with the guidelines established by the EU Green Deal Program, its valorisation through the development of health-promoting products is an important step for the environment and the food sector. Numerous whey-based beverages are mentioned in the specialized literature. Wine-like beverages can be made by fermenting whey with different kinds of yeasts, producing liqueur-style drinks, a drink with an alcohol concentration of 10–14% etc. The purpose of the research was to obtain fermented drinks from deproteinized whey, endogenously impregnated with CO_2. The novelty of these beverages consisted of using local ingredients to improve the nutritional value of the finished product – berry syrup. The technological process of production was similar to that for obtaining bottled sparkling wines. The finished products were analyzed from a physical-chemical and sensory point of view. The study emphasizes that a contemporary beverage should meet the four primary demands of the consumers: sensory quality, thirst-quenching properties, affordability, and a good health profile. By repurposing whey into a value-added product, this research contributes to sustainable food production practices and offers a new solution for whey waste management.

Keywords: fermented drinks, berry syrup, pollution, sparkling wines, valorisation

INTRODUCTION

The dairy industry's growth has led to increased production of by-products, specifically whey, which arises from cheese manufacturing and presents environmental and disposal challenges. Whey disposal, particularly when dumped into water bodies, causes significant pollution. In response, research has sought to transform whey into value-added products, reducing its environmental footprint and creating profitable alternatives [1]. Whey can be repurposed into biofuels (such as bioethanol and biohydrogen), bioplastics, bacterial cellulose, food additives, bioactive peptides, and single-cell

proteins, among other valuable materials. This approach aligns with sustainable industrial practices and opens new commercial avenues for dairy by-products [2,3].

Whey is produced in substantial amounts globally; about 80-90% of milk used in cheese production becomes whey, generating an estimated 180-190 million tonnes yearly. Within this by-product stream, "second cheese whey" emerges when whey is further processed, typically through heat treatment, to make certain types of cheese such as Ricotta. This second cheese whey is often discarded by small and medium dairy enterprises due to the lack of valorisation processes for human consumption, resulting in it being used largely as animal feed. Countries such as Italy, Spain, Portugal, Greece, Turkey, and Romania commonly follow this practice, though some efforts have been made to limit environmental impacts by using it as livestock feed [4].

Second cheese whey retains about half of the whey's original dry content, consisting mostly of lactose, minerals, residual fats, and protein fractions. These nutrients make it a valuable substrate for biotechnological processes, allowing for the extraction of lactose, proteins, and minerals. The composition of second cheese whey, however, varies depending on the initial cheese-making process and the type of milk used. For example, ovine whey has a higher protein content and mineral concentration due to added salt, while its pH remains moderately acidic [5].

Owing to its nutrient-rich profile, second cheese whey holds potential for various applications beyond animal feed. It can be leveraged in food formulations, nutraceuticals, and biofuels. The recovery of lactose, a key component, is of particular interest due to its high value in food processing and infant formula. Techniques such as ultrafiltration and nanofiltration can isolate lactose from second cheese whey, turning it into a powdered form suitable for commercial uses [6,7].

To minimize the environmental impact, European regulations promote using dairy by-products like second cheese whey in alternative production processes. Potential applications include using whey for sweeteners in ice cream and baby food, ethanol fermentation, lactic acid production, and biogas. Additionally, second cheese whey serves as a source material for bioplastics, especially in producing biodegradable polymers like polyhydroxyalkanoates [8].

Research into second cheese whey as a fermentation substrate has shown promise. Studies have explored its potential in producing fermented beverages, particularly those enriched with probiotics and prebiotics (symbiotic drinks), which have significant health benefits. These drinks offer unique nutritional value, catering to a broad consumer base, including children and the elderly. Some studies, like those by Vasilakis et al. (2022), have developed ready-to-drink whey-based beverages and assessed their shelf life and resistance to thermal abuse, indicating positive results with added starter cultures and fruit purees [9]. The production of whey beverages with added fruits or vegetables has also been explored, although research on vegetable juice combinations remains limited. These products highlight the nutritional versatility of whey beverages and their potential to address diverse dietary needs across age groups [9].

This paper purpose to obtain fermented drinks from deproteinized whey endogenously impregnated with CO_2. The novelty of these beverages consisted of using local ingredients to improve the nutritional value of the finished product – berry syrup. The technological process of production was similar to that for obtaining bottled sparkling wines.

MATERIALS AND METHODS

In the experiments, sweet deproteinized whey resulting from the manufacture of whey cheese (urda) from the company Tudia Lactate Suceava was used with the following characteristics: total dry substance - 5.62%, of which, fat - 0.02%, proteins – 0.47%, lactose – 4.50%, acidity – 15.8°T, density – 1.0198 g/L. To obtain the whey drink, syrup from forest fruits was used, produced by Răureni SA Romania with 63% carbohydrate content. A strain of wine yeast from Danstar Ferment AG (Switzerland) was used as the fermentation agent.

Sweet deproteinized whey (ZD) was combined with berry syrup (SZ) in 4 variants, as follows: variant 1(V1): ZF:SZ 90:10 (v/v ratio), variant 2(V2): ZF :SZ 80:20 (v/v ratio), version 3(V3): ZF:SZ 70:30 (v/v ratio), version 4(V4): ZF:SZ 60:40 (v/v ratio). All the mixture variants were brought to pH=5 with citric acid and to the same initial sugar content of 260 g/L and bottled in 500 mL bottles. The bottles with the blend were pasteurized at 65°C for 30 minutes, and then cooled to 20°C. At this temperature, the inoculation with the yeast culture was carried out in a proportion of 1%. From this moment the endogenous alcoholic fermentation began, for 10 days at room temperature for the primary fermentation and 15 days at 4°C for the completion of fermentation and maturation.

The finished product deproteinized whey drink samples were then analyzed from a physical-chemical and sensory point of view. The Anton Paar apparatus (Anton Paar GmbH, Austria) was used to evaluate the main physical-chemical characteristics: density, g/cm^3, apparent extract, % m/m; alcohol concentration, % v/v; final degree of fermentation, %; real extract, % m/m. The total soluble solids (°Brix) in the berry syrup were measured with a digital refractometer (HI 96801; Hanna Instruments, Bedford, UK) and the pH using a digital multi-parameter meter (InoLabR Multi 9310 IDS; WTW,Weilheim, Germany).

Sensory evaluation was performed in the Sensory Analysis Laboratory of the Ștefan cel Mare University, Faculty of Food Engineering (Suceava, Romania) using for this purpose 25 semi-trained evaluators. Deproteinized whey drink samples were presented at 8°C in an amount of 70 mL in glass cups, identified with a three-digit numbers. Between samples the evaluators used water and unsalted crackers to cleanse their mouths. For the sensory evaluation, a nine point structured hedonic scale ranging from “dislike extremely” = 1 to “like extremely” = 9 was used. All samples were analyzed for the fallowing characteristics: general acceptability, mouthfeel, body, carbonation, general taste, aroma, colour and appearance.

All data were performed in triplicate and results were expressed as mean ± standard deviation. Physical-chemical and sensory characteristics of experimental samples were performed by one-way ANOVA and Tukey’s HSD at alpha = 0.05 were computed for significant differences between means data. Using the design of experiment software (DOE) (Design Expert, trial edition, Stat-Ease, Inc., Minneapolis, MN, USA), the data illustrating the fluctuation of deproteinized whey drink parameters according to the varied levels of sweet deproteinized whey and berry syrup were plotted. The mean value of the sensory data was graphically displayed by the assessors using Microsoft Excel (Microsoft, Redmond, WA, USA).

RESULTS

The deproteinized whey drink obtained in the 4 variants was analyzed from a physical-chemical and sensory point of view after the period of fermentation in bottles and maturation. The obtained results are summarized in table 1 and table 2.

Table 1

Physical-chemical properties of deproteinized whey drink

Characteristic	Deproteinized whey drink recipe variant			
	V1	V2	V3	V4
Density, g/cm^3	1.0198±0.002	1.0200±0.004	1,0207±0.002	1.0214±0.002
Apparent extract, % m/m	5.28±0.02	5.66±0,06	5.71±0.02	5.44±0.04
Alcohol content, % v/v	12.14±0.02	12.80±0.04	13.10±0.04	12.32±0.02
Real extract, % m/m	9.70±0.04	9.48±0.05	9.86±0.02	9.90±0.02
Final degree of fermentation, %	79.08±0.75	79.80±0.76	81.20±0.74	79.38±0.82
CO_2, g/L	4.28±0.02	4.56±0.03	4.84±0.02	4.90±0.04
pH	4.96±0.02	5.02±0.01	5.04±0.02	5.00±0.01

Results represents mean values ± standard deviation (SD), n=3

Table 2

Sensory characteristics of deproteinized whey drink

Characteristic	Deproteinized whey drink recipe variant			
	V1	V2	V3	V4
Appearance	7.04±1.18^{c}	7.06±0.33^{b}	8.60±0.13^{e}	6.82±1.03^{b}
Colour	6.12±1.40^{b}	6.71±0.23^{a}	7.96±0.57^{bc}	8.10±0.23^{d}
Aroma	6.67±0.33^{d}	6.83±0.14^{a}	8.32±0.18^{d}	8.21±0.77^{c}
General Taste	6.82±0.21^{d}	6.82±0.15^{a}	8.36±0.22^{e}	8.12±0.30^{c}
Carbonatation	8.02±0.18^{bc}	8.31±0.11^{a}	8.54±0.09^{c}	8.52±0.18^{bc}
Body	7.02±0.25^{c}	7.06±0.95^{a}	8.21±0.24^{d}	7.31±0.34^{b}
Mouthfeel	7.01±0.53^{c}	7.22±0.77^{a}	8.08±0.57^{c}	8.13±0.25^{b}
General acceptability	7.01±0.20^{d}	7.41±0.82^{a}	8.52±0.36^{d}	8.42±0.77^{c}

Data are expressed as mean ± standard deviation. $^{a-d}$- mean values in the same column followed by a different letter are statistically different ($p < 0.05$)

According to the researchers, using deproteinized whey to make various drinks not only gives them a unique flavour but also helps the beverage sector be more sustainable by using a valuable component and cutting down on food waste [10,11].

DISCUSSION

Research has shown that it is possible to obtain high-quality deproteinized whey alcoholic beverages, sparkling, naturally impregnated with CO_2 and with an alcohol content that varied between 12.14% v/v and 13.10% v/v. Whey deproteinization is very important in these drinks. The production of these alcoholic beverages based on deproteinized whey has also been studied in other research carried out to date. After the sugars from the whey, mainly lactose and other monosaccharides, have been converted to ethanol, the alcohol must be concentrated to alcohol content suitable for alcoholic beverages. In the literature, the ethanol yield during whey fermentation is given as 2 to 5% vol. The rest of the alcohol comes from the fermentation of the sugar in the berry syrup or from the sugar added initially up to the amount of 260 g/L. The alcohol content of the analyzed samples varied between 12.14 % alc. v/v and 13.10 % alc. v/v. The alcohol content of the new obtained drink is high, similar to that of wine. Moreover, and due to the high CO_2 content, these new drinks are very similar to sparkling wines

obtained by the fermentation method in bottles (Champenoise method) [12]. According by Njoya et al. (2020) the high alcohol content could be related with the high concentration of fermentable sugars and the performance of yeast [13]. The alcoholic fermentation proceeded normally, a relatively high degree of fermentation was obtained, which varied between 79.08% and 81.20%.

The sensory characteristics of deproteinized whey drink samples are shown in Table 2. Mean general acceptability score ranged between 6.41 and 8.52. According to our data, all drink samples were liked by the panellists from “like slightly” to “like very much”. No significant differences ($p < 0.05$) were obtained for general acceptability between beers V3 and V4. It seems that these types of drinks were also similar from the aroma and carbonatation sensory characteristics. These types of drinks were the most appreciated by the panellists. Our findings are consistent with those of Oliviera et al. (2022), who demonstrated that using large amounts of whey could give whey drinks an astringent flavour that lowers consumer acceptance [11]. As shown by Ayed et al. (2023) in their study fruits can improve the sensory properties of whey-based beverages such as taste, color and flavor [14]. The specialists show that further research is necessary to understand how the species of yeast might positively or negatively impact the flavor compounds in various whey beverages during fermentation [15]. Sample V3 was the most appreciated one, receiving the highest score for sensory characteristics appearance, aroma, general taste, carbonatation, body and general acceptability. The sample V2 was less appreciated receiving the lowest scores for sensory characteristics colour, aroma, carbonatation, body, mouthfeel and general acceptability. All the drink samples were very well appreciated for carbonatation which means value ranged between 8.02 and 8.54. This fact was explainable that there was enough fermentescible sugar to lead to an appreciable amount of carbon dioxide.

CONCLUSION

The obtained products are part of the category of effervescent alcoholic beverages, the composition of which includes only natural ingredients: whey, berry syrup, without the addition of food additives. The uniqueness of the products consists in the use of deproteinized whey, a by-product resulting from the whey cheese industry when obtaining an effervescent alcoholic drink.

With an original recipe, the new assortment of alcoholic drink presents special sensory characteristics, unmistakable freshness, flavor given by the berry syrup from the manufacturing recipe and perlage, conferred by the carbon dioxide of endogenous origin resulting from the alcoholic fermentation.

In conclusion, whey is a by-product, multipurpose product that may benefit the environment and human health if it is produced responsibly. As a result, it's critical to assess how whey is processed into products and derivatives while also creating techniques that reduce the impact on the environment. Expanded markets for sustainable manufacturing may result from the various strategies being developed to profit on whey through food products. To fully comprehend the potential and constraints of these technologies on an industrial scale, more research is frequently required.

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STUDY ON THE INFLUENCE OF WINTERING TEMPERATURE ON CERTAIN SEMEN CHARACTERISTICS IN STERLET (*ACIPENSER RUTHENUS*)

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ABSTRACT

Sterlet (*Acipenser ruthenus*) is a species with seasonal reproduction, temperature being considered one of the most important key factors that ensures the seasonal reproductive cycle. The wintering temperature should be carefully controlled to prevent any adverse effects on reproduction. In many fish species, the wintering at high temperatures have a negative impact on reproduction success. The aim of this study is to evaluate the impact of wintering temperature on sterlet males by evaluating the quantity and quality of the semen collected from them during the breeding season. Two groups of males were overwintered at different temperatures, with minimums of 10 degrees C (G1) and 6 degrees C (G2), respectively. The semen collected from these males was analyzed, determining the volume of collected sperm, the concentration of spermatozoa and the number of spermatozoa, all of which were determined for two collections made at an interval of 2 hours. Gonadal measurements were also taken to determine if there were any differences between the two groups. The results showed that the volume of milt, sperm concentration, as well as gonad mass and the gonadosomatic index, did not differ significantly between the two groups. Thus, it can be concluded that wintering of sterlet males at temperatures no lower of 10 degrees C does not negatively influence the reproductive characteristics analyzed, showing only insignificant differences compared to males wintered at lower temperatures.

Keywords: sterlet, wintering temperature, semen characteristics

INTRODUCTION

Sterlet (*Acipenser ruthenus*) is a sturgeon species valued by consumers not only for the quality of its meat but also for its more affordable caviar compared to that of other sturgeon species. Sterlet farming has proven feasible indoors using recirculating aquaculture systems (RAS), which have become increasingly widespread in recent years [5]. RAS are increasingly used in fish farming across numerous European countries, enabling the controlled and sustainable cultivation of various high-value species [4, 5]. However, RAS does not provide natural conditions for fish, even though it meets their biological needs to achieve very good productive performance. Artificial environments that lack natural spawning stimuli fail to induce adequate endogenous responses in fish, and cultured sturgeon often exhibit reproductive dysfunction during the late gametogenesis stage [12]. It has been demonstrated that fish raised in RAS are exposed

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to multiple factors and mechanisms with direct or indirect negative effects on reproduction. These include high nitrate levels, the accumulation of hormones and other endocrine disruptors [7], chronic stress caused by microbial imbalance [14], unbalanced diets, or elevated temperatures [1]. While elevated temperatures in RAS have been found to accelerate fish growth rates, they alter gametogenesis [1]. Studies by Xiaoli et al. [15] revealed that overwintering crucian carp at elevated temperatures, although accelerating growth rates, led to reduced sperm quality in this species. Similarly, in Siberian sturgeon, it was shown that overwintering at high temperatures shortens the spermatogenesis period and reduces sperm quality [11]. Gilroy & Litvak [6] found that thermal stress, including that experienced during overwintering, can affect sperm quality in shortnose sturgeon. Thus, there is ample evidence suggesting that both the quantity and quality of reproductive products can be negatively impacted by overwintering sturgeon broodstock at high temperatures. However, information on this subject concerning sterlet is sparse.

The aim of this study was to evaluate the impact of wintering temperature on sterlet males by evaluating the quantity and some quality characteristics of the semen collected from them during the breeding season.

MATERIALS AND METHODS

Experimental design. For the experimental setup, two indoor RAS units were used in two different halls. Two groups (G1 and G2) of five-year-old male sterlet breeders, each containing five individuals, were placed in two separate RAS units, with G2 being wintered at lower temperatures in a non-thermally insulated hall. The difference in wintering temperature between the two groups was monitored daily, as shown in Figure 1.

As shown in the graph (Figure 1), the males in G2 were wintered in a recirculating system that allowed the water temperature to drop to approximately 6°C, while the G1 males were wintered in a thermally insulated recirculating system, which prevented the water from cooling below 10°C. Starting from February 19, 2024, the males from both groups were housed in the same recirculating system within the thermally insulated hall to begin preparation for reproduction. The sterlet males from G1 reproduced on March 15, while those from G2 reproduced nearly a month later, on April 12, 2024. The difference in reproduction timing occurred due to the wintering conditions at different temperatures, with the higher wintering temperature accelerating the maturation of the sexual products in the G1 males.

Husbandry conditions. The husbandry conditions in the two RAS units were identical, with the exception of temperature, which differed as previously mentioned. The main physico-chemical parameters of the water were monitored daily, all of which remained within normal limits to meet the biological requirements of the sterlet. During the day, natural light was used, and the maximum light intensity did not exceed 30 lux in either of the two halls. Feeding of fish in both groups was done ad libitum, but only when the temperature was higher than 10°C. Dry pellets (SUPREME-10, 6 mm) manufactured by Alltech-Coppens were used, administered around the clock using semi-automatic FIAP (Germany) belt feeders.

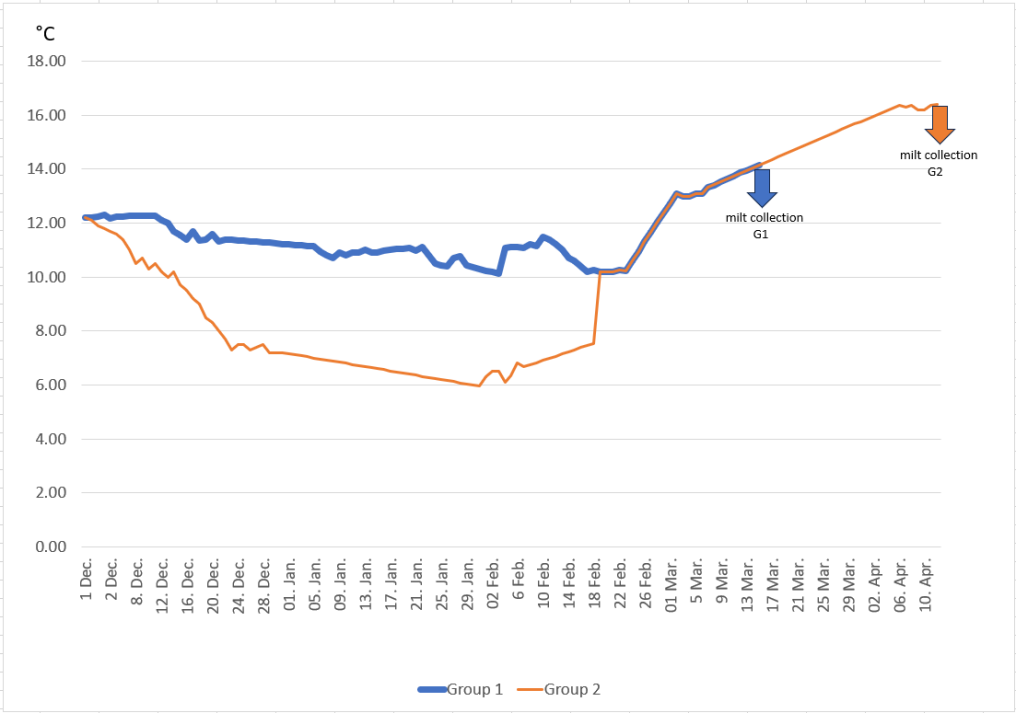


Figure 1. Water temperature dynamics (°C) in recirculating systems used for wintering male sterlets from G1 and G2.

Fish Biometry. Biometric data of the males were obtained from measurements taken prior to hormonal stimulation, using a measuring tape and a scale. The following parameters were recorded: total length (TL), standard length (SL), maximum body depth (MBD), body circumference (C), and body weight (BW). [5]. Based on the obtained data, Fulton's condition factor was calculated:

$$K = (BW\ (g) \times 100) / TL^3\ (cm)$$

where: BW – body weight, TL – total length,

Hormonal stimulation and sperm collection. Spermiation was induced using pituitary extract, with a dose calculated at 2 mg of carp pituitary gland (CPG) per kilogram of body weight. Pituitary extract was administered intramuscularly in two doses, with the first dose representing 10% of the total amount. The second dose representing 90% of the total amount was administered 12 h after the first one. Twenty-four hours after the second pituitary dose, the first milt collection was performed, followed by a second collection two hours later. Milt was collected directly from the sperm duct using disposable 3 ml Pasteur pipettes. The sperm collected from each male was placed in plastic test tubes with a volume of 10 ml, these being stored at approx. 4°C for 2-4 h until laboratory analyses.

Semen analysis. The semen from each male was analyzed in the laboratory to determine volume, sperm concentration, and sperm count. Sperm concentration was measured using the hemocytometric method, following the protocol described in the specialized literature [10]. The total sperm count was determined by multiplying the volume of the collected semen by the sperm concentration, for each individual.

Anatomical and biometric study of the gonads. After the second semen collection, the males were euthanized using the Fiap Mini#1986 stunner (Fiap, Germany), and their

testes were subsequently collected. The testes were individually weighed and measured, with both length and thickness recorded. Thickness was measured at the most developed area. Gonadosomatic index (GSI) was calculated as the ratio between the gonad weight and the body weight of the fish, expressed as a percentage.

$$GSI = (Gonad\ Weight / Body\ Weight) \times 100$$

Statistics. Excel software was used to calculate the mean and dispersion indices. Data in this study are presented as mean ± SEM (standard error of the mean). The Mann-Whitney test was applied to assess the significance of differences.

RESULTS

The male sterlets from both groups used in the experiment showed similar biometric characteristics, with differences between the two batches being insignificant for all analyzed traits (Table 2).

Table 1. Biometric data of male sterlets from the two groups

Group	Total length (cm)	Standard length (cm)	Body circumference (cm)	Maximum body depth (mm)	Body weight (kg)	Fulton's condition factor
G1	67.26±1.14[a]	55.50±1.07[a]	22.96±0.79[a]	8.36±0.36[a]	1.27±0.09[a]	0.42±0.02[a]
G2	66.54±0.41[a]	54.72±0.52[a]	22.52±0.37[a]	8.84±0.15[a]	1.15±0.03[a]	0.39±0.01[a]

Mean values with same uppercase letters indicate insignifficant differences (*P>0.05*) between the groups for the same parameter.

The data in Tables 2 and 3 indicate that two semen collections were achievable from each male in both G1 and G2 following hormonal stimulation with pituitary suspension. For G1, although a larger volume of milt per batch was obtained during the first collection, with an average of 6.10 ± 1.71 ml, the difference was not significant (*P>0.05*) compared to the milt volume from the second collection, which averaged 5.50 ± 1.14 ml. For G2, 5.77 ± 1.97 ml of milt was obtained during the first collection and 5.28 ± 2.17 ml during the second, but this difference was also not significant (*P>0.05*). However, the differences in milt volume between individuals within both groups were substantial for both collections, as indicated by the very high coefficient of variation.

Regarding the sperm concentration in the semen, the differences between collections 1 and 2 within both groups were also insignificant (*P>0.05*) (Tables 2 and 3).

Table 2. Some characteristics of the milt collected from the males from the group G1 (n = 5)

Specification	Volume of collected milt (ml)		Sperm concentration (no. of spermatozoa x 10^9/ml)		Total sperm count (no. x 10^9)	
	Collection 1	Collection 2	Collection 1	Collection 2	Collection 1	Collection 2
$\bar{X}$	6.10	5.50	1.83	2.70	13.43	15.32
s	3.82	2.54	1.91	1.91	17.63	13.37
SEM	1.71	1.14	0.85	0.85	7.88	5.98
CV	62.60	46.19	104.47	70.77	131.25	87.28

$\bar{X}$ - mean; S – standard deviation; SEM - standard error of the mean; CV - coefficient of variation

However, very high variability was observed between individuals. For example, one male from group G1 had a sperm concentration of 0.525 x 10^9 spermatozoa/ml at the first collection and 0.275 x 10^9 spermatozoa/ml at the second collection, while another male from the same group had a sperm concentration of 4.80 x 10^9 spermatozoa/ml at the first collection and 5.25 x 10^9 spermatozoa/ml at the second. Another example from group G2, where, one male had a sperm concentration of 0.2 x 10^9 spermatozoa/ml at the first collection and 0.175 x 10^9 spermatozoa/ml at the second collection, while another male from G2 had a concentration of 6.475 x 10^9 spermatozoa/ml at the first collection and 6.975 x 10^9 spermatozoa/ml at the second.

Table 3. Certain characteristics of the milt collected from the males from the group G2 (n = 5)

Specification	Volume of collected milt (ml)		Sperm concentration (no. of spermatozoa x 10^9 / ml)		Total sperm count (no. x 10^9)	
	Collection 1	Collection 2	Collection 1	Collection 2	Collection 1	Collection 2
$\bar{X}$	5.77	5.28	2.24	2.36	19.95	23.01
s	4.41	4.86	2.58	2.93	28.01	34.85
SEM	1.97	2.17	1.15	1.31	12.53	15.59
CV	76.34	91.98	115.31	124.42	140.41	151.44

$\bar{X}$ - mean; S – standard deviation; SEM - standard error of the mean; CV - coefficient of variation

Regarding the total number of spermatozoa obtained on average from a male in groups G1 and G2, the differences between them were insignificant (*P>0.05*).

Table 4. Comparison of total semen collected from sterlet males in the two groups

Group	Total volume of semen collected per male - two collections (ml)	Average sperm concentration (no. of spermatozoa x 10^9 /ml)
G1	11.60±2.14[a]	2.26 ± 0.59[a]
G2	11.05±4.09[a]	2.30 ± 0.82[a]

Mean values with same uppercase letters indicate insignifficant differences (P>0.05) between the groups

Regarding the average volume of semen that could be collected per male, combining the results from both collections, the data are very similar between the two groups: 11.60 ± 2.14 ml for G1 and 11.05 ± 4.09 ml for G2, respectively (Table 4). The significance test applied indicated that the differences were not significant (*P>0.05*), as was also the case for the mean concentration of spermatozoa per ml.

Therefore, it follows that wintering sterlet males at temperatures above 10°C does not negatively affect either the volume of sperm collected or its concentration of spermatozoa.

Table 5. Gonad dimensions from males in group G1 (n = 5)

Specification	Gonad weight (g)			Gonad length (cm)		Gonad thickness (cm)		Gonado somatic index (%)
	Left testis	Right testis	Total	Left testis	Right testis	Left testis	Right testis	
$\bar{X}$	39.00	38.80	77.80	20.64	20.40	2.96	3.42	6.02
s	12.98	16.42	28.79	2.01	1.85	0.72	0.70	1.31
SEM	5.81	7.34	12.87	0.90	0.83	0.32	0.31	0.58
CV	33.28	42.33	37.00	9.75	9.07	24.43	20.41	21.69

$\bar{X}$ - mean; S – standard deviation; SEM - standard error of the mean; CV - coefficient of variation

The gonads collected from males in groups G1 and G2 following dissection showed the dimensions presented in Tables 5 and 6. A high variability (CV>20%) was observed in all analyzed characteristics, except for gonad length, where the coefficient of variation was low (CV ≤ 10%) in both groups.

The average gonad weight recorded in group G1 was 77.80 ± 12.87 g, with a minimum of 60 g and a maximum of 129 g. The gonadosomatic index, which reflects the proportion of gonad weight to body mass, had an average value of 6.02 ± 0.58% in group G1, with limits ranging from 4.69% to 8.01%.

Table 6. Gonad dimensions from males in group G2 (n = 5)

Specification	Gonad weight (g)			Gonad length (cm)		Gonad thickness (cm)		Gonado somatic index (%)
	Left testis	Right testis	Total	Left testis	Right testis	Left testis	Right testis	
$\bar{X}$	36.80	35.60	72.40	21.44	21.12	2.36	2.84	6.29
s	11.10	7.13	17.99	0.98	1.54	0.52	0.24	1.48
SEM	4.96	3.19	8.05	0.44	0.69	0.23	0.11	0.66
CV	30.16	20.02	24.85	4.59	7.32	22.14	8.48	23.47

$\bar{X}$ - mean; S – standard deviation; SEM - standard error of the mean; CV - coefficient of variation

The average gonad weight recorded in group G2 was 72.40 ± 8.05 g, with a minimum of 46 g and a maximum of 95 g. The gonadosomatic index, had an average value of 6.26 ± 0.66% in group G2, with limits ranging from 4.11% to 7.66%.
Following the application of the significance test, it was found that none of the biometric characteristics measured in the gonads showed significant differences between groups G1 and G2 (*P>0.05*). The gonadosomatic index, showed small differences between the males in the two groups; however, these differences were not significant (*P>0.05*).

DISCUSSIONS

In the present study, the effect of wintering temperature on sterlet males was investigated by analyzing the quantity and some characteristics of semen collected from them during the breeding season. In many fish species, it was observed that wintering at

high temperatures negatively impacts reproductive success. Temperature during spermatogenesis or the spawning period has been found to influence sperm volume, motility, as well as the velocity and morphology of spermatozoa [12].

Data from the specialized literature reveal that, in several fish species, wintering at lower temperatures positively influences semen volume during the breeding season [15]. Wintering Siberian sturgeon males at low temperatures (4–6°C), according to data published by Melchenkov et al. [11], led to an increase in the volume of semen collected during the breeding season and improved reproductive performance. Other researchers [6] concluded that sturgeons wintered at temperatures above 12°C produce a reduced semen volume due to metabolic stress and asynchrony in germ cell development. Furthermore, high winter temperatures can accelerate spermatogenesis, and the reduced time for sperm accumulation leads to a decrease in the total sperm volume [2]. However, our results indicated that there were no significant differences between the two groups of males wintered at different temperatures. This could be attributed to the temperature difference between the two groups, which did not exceed 4°C. The same applies to sperm concentration and the total number of spermatozoa obtained per sterlet male, where the differences between the two groups in our study were also not significant. Some studies have shown that higher sperm concentrations were obtained in Russian sturgeon and Siberian sturgeon when males were kept at lower wintering temperatures (4–6°C) [11].

In the present study, no significant differences were observed in the gonad dimensions of males from the two groups wintered at different temperatures. These results, most likely due to the relatively small differences in wintering temperatures, need to be complemented by future studies involving histological analyses of the gonads. Histological studies on Russian sturgeon gonads wintered at high temperatures have revealed abnormal gonadal structures, such as intersex gonads [8]. However, there are studies indicating strong correlations between wintering temperature and gonad size. For example, while wintering Siberian sturgeon at low temperatures (4–6°C) results in normal gonad development, higher wintering temperatures lead to an increase in adipose tissue at the expense of gamete-producing tissue [13]. Doroshov et al. [3] also reported that in white sturgeon, wintering at high temperatures may accelerate maturation while simultaneously leading to the development of smaller and less functional gonads.

CONCLUSIONS

From all males included in the study, regardless of wintering temperature, two semen collections could be performed after hormonal stimulation with pituitary suspension. A very high variability among individuals in both groups regarding sperm quantity and quality was observed. The differences in semen volume, sperm concentration, and sperm count were insignificant ($P>0.05$) both between collections and between groups. None of the biometric characteristics measured in the gonads showed significant differences between groups G1 and G2 ($P>0.05$). Therefore, it can be concluded that wintering sterlet males at temperatures that do not fall below 10°C does not negatively affect the volume of sperm collected, sperm concentration, or other biometric characteristics of the gonads.

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THE IMPACT OF AVOCADO ADDITION ON NUTRITIONAL COMPOSITION AND ORGANOLEPTIC PROPERTIES OF CHICKEN LIVER PATE

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ABSTRACT

Our study explored the impact of adding avocado to chicken liver pate, focusing on both nutritional composition, oxidative stability and organoleptic (sensory) characteristics. By incorporating avocado, we aimed to create a healthier, more nutritious alternative to traditional pate. Nutritional analysis included determining protein, fat, minerals, water, salt, carbohydrate content, and energy value. The results showed that adding avocado led to a decrease in fat content and an increase in beneficial omega-3 fatty acids and dietary fiber. Peroxide value (PV), TBA value and total oxidation (TOTOX) were determined to assess oxidative stability. These changes significantly improved the pate's nutritional profile, making it a healthier choice. We also evaluated organoleptic properties, assessing the pate's taste, smell, texture, and color. Sensory analysis was conducted with a panel of participants who rated the avocado pate on these attributes. The feedback indicated that the avocado-enhanced pate was well-received, with positive ratings for its appearance, flavor, and smooth consistency. The fresh taste of avocado complemented the richness of the chicken liver, while the bright green color added visual appeal. In conclusion, the addition of avocado to chicken liver pate not only improved its nutritional content but also maintained or enhanced its sensory qualities. This suggests that avocado pate is a flavorful and healthy alternative, appealing to consumers looking for both nutrition and taste.

Keywords: avocado, proximate composition, chicken pate, oxidative stability, bioactive characteristics

INTRODUCTION

Reducing meat consumption and introducing plant protein sources, including avocados, are promising approaches for public health and environmental sustainability. High consumption of red meat is associated with chronic disease risks and its intensive production has a major environmental impact [1]. Plant-based alternatives, such as soy protein, legumes and avocado, offer significant nutritional benefits and low environmental impact [2].

Plant products can partially or completely replace meat while maintaining optimal nutrient intake. Studies show that the partial replacement of meat with plant protein significantly reduces greenhouse gas emissions and water consumption, which are essential in the context of climate change. These substitutes are also low in saturated fat, making them a healthier and more environmentally friendly choice [2].

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There are several ways in which meat consumption can be reduced, and the use of vegetable substitutes is an affordable and effective option. These products are textured to simulate the texture and taste of meat and are increasingly accepted by consumers [3].

Partial substitution of meat in preparations are also strategies to help reduce meat consumption. Consumers can gradually adopt these alternatives without compromising the taste and quality of their meals, thus contributing to a smoother transition to plant-based diets [4].

Avocado, recognized for its unsaturated fat, protein and fiber, is an effective substitute for improving the nutritional value of meat products. For example, avocado added to pâté or sausages protects against lipid oxidation, prolonging freshness and reducing the need for preservatives [5].

Avocado pulp can be combined with meat in processed products, reducing postprandial inflammation and improving cardiovascular health. Thus, avocado not only complements the nutrient profile of meat products, but also adds antioxidant and anti-inflammatory benefits essential for a healthier diet [6].

Due to bioactive compounds and antioxidants, avocado can improve the stability of meat products by inhibiting lipid oxidation and protecting against spoilage. Oxidation is a process that affects the quality of meat products and reduces shelf life. Avocado can be used as a functional ingredient to prolong the freshness of foods and reduce the need for artificial preservatives, making products more natural and healthier for consumers [7].

In the present work we aimed: (i) to replace the meat with avocado pulp in different proportions (5%, 10% and 20%); (ii) to evaluate the proximate composition of the obtained pâté samples; (iii) to evaluate the oxidative stability of the obtained pâté samples and (iv) to analyze the sensory properties of the pâté samples.

MATERIALS AND METHODS

Materials

Fresh raw materials were purchased from a local producer in Timis County, Romania. Spices such as ground black pepper, nutmeg, bay leaf, (Kamis SRL, Romania) and salt (Salrom, Romania) were purchased from a local supermarket. Reagents used in the physico-chemical analyses were of analytical grade and purchased from Sigma-Aldrich (St. Louis, MO, USA) and Chimreactiv (Bucharest, Romania).

Manufacture of Pate Formulas

The pâté samples were prepared in the meat technology laboratory of the Faculty of Food Engineering, University of Life Sciences "Regele Mihai I" in Timisoara, Romania. Five different pâté samples, namely with 5% avocado pulp (PA5), 10% avocado pulp (PA10), 20% avocado pulp (PA20), meat-only control sample pâté (CSP) and one pâté sample with added sodium nitrite (PSN), were prepared according to the recipe shown in Table 1.

Table 1. The recipes used to obtain pate formulas

Sample	Chicken meat (g)	Chicken liver (g)	Chicken fat (g)	Avo cado pulp (g)	Black pepper (g)	Onion flakes (g)	Nutmeg (g)	Sugar (g)	Salt (g)	Sodium nitrite (g)
CPS	583.2	250	100	-	1.4	50	1	2.4	12	-
PSN	583.1	250	100	-	1.4	50	1	2.4	12	0.1
PA5	558.2	250	100	25	1.4	50	1	2.4	12	-
PA10	533.2	250	100	50	1.4	50	1	2.4	12	-
PA20	483.2	250	100	100	1.4	50	1	2.4	12	-

The chicken meat was cut into pieces of approx. 25 g and parboiled for approx. 15 minutes. The liver was washed, cleaned, sliced and kept in cold water for about 2 hours. The fat was used raw and as fresh as possible. All ingredients were chopped using a volf (Maxima Holland MMM 12-229, Mijdrecht, The Netherlands) through a 3 mm sieve. Subsequently, they were processed in a cuter (La felsinea 10M, Piazzola sul Brenta PD, Italy) by adding salt, sugar, ground spices and the juice from the meat rendering (10% of the composition) to the composition, resulting in an aliphatic paste, which is the pateu control sample (PCN). In a similar sample to the cutering, sodium nitrite was added. In three other pate samples meat was substituted with avocado in proportions of 5%, 10% and 20%. The resulting pate mixtures were placed in glass jars that were hermetically sealed. The pate jars were sterilized at 72°C for 40 min and cooled in cold water to 37°C. The cooled product was labeled and stored in the refrigerator at +4°C until they were analyzed.

Proximate Composition of Pate Samples

In order to determine the proximate composition of the pâté samples, the water content (according to SR ISO 1442:2010) [8], mineral substances (according to SR ISO 936:2009) [9], total protein (according to SR ISO 936:2009) [10], total fat (according to SR ISO 1443:2008) [11] and salt (according to SR ISO 91-2007) [12] were determined. The carbohydrate content and energy value were calculated using equations 1 and 2.
Carbohydrate = 100 - (water content + ash content + protein content + lipid content) (%) (1) (1)
Energy = (fat content x 9)+[protein content x 4)+(carbohydrate content×4) (2)

Oxidative Stability Assessment

Determination of Peroxide Value (PV)
The determination of the peroxide value (PV) in pâté formulas was carried out by the iodometric method, expressed in meq O2/kg fat [13].

Determination of Thiobarbituric Acid (TBA)
The TBA assay was performed according to the method described by Cadariu et al [13]. Three determinations were performed from each pate sample, the mean ± standard deviation (SD) was reported and the results were expressed in μM MDA/g sample.

Total Oxidation Value (TOTOX)
Using the PV and TBA value, the TOTOX value was calculated according to equation (3) [14].

$$\text{TOTOX} = 2 \times \text{PV} + TBA \quad (3)$$

Sensory analysis

The pâté samples were evaluated by a group of 40 trained evaluators (20 men and 20 women, aged between 18 and 25 years) in the Sensory Analysis Laboratory of the Faculty of Food Engineering in Timisoara, Romania. During the sensory analysis, natural lighting (daylight) and constant room temperature were ensured. Pate samples were prepared 5 minutes before the evaluation on slices of bread. Characteristics analyzed were: appearance, color, odor, taste, texture and overall acceptability. Each characteristic was evaluated using a nine-point hedonic scale with the following ratings: very pleasant (5); moderately pleasant (4); neutral (3); slightly unpleasant (2); moderately unpleasant (1); extremely unpleasant (0).

Statistical Data Analysis

The results were presented as the mean of three determinations ± standard deviation (SD). Statistical differences between samples ($p < 0.05$) were analyzed using the t-test in Microsoft Excel 365 (Version 2208, Redmond, WA, USA).

RESULT AND DISCUSSION

Proximate Composition of Pate Samples

Proximate food composition is the analysis of the main nutrient components, such as moisture, protein, fat, carbohydrate and ash, providing an overview of the nutritional value and helping to assess the quality and stability of products in the context of processing and storage [15]. Table 2 shows the proximal composition of pâté samples. The water content in pâté samples ranged between 59.14 and 66.10% (Table 2). Analysis of these values shows that as the avocado pulp content increases, the water content in the pate samples also increases.

Table 2. Proximate composition of the pate samples

Sample	Chemical Parameters						
	Moisture content (g/100 g)	Ash (g/100 g)	Protein (g/100 g)	Lipids (g/100 g)	Chloride content (g/100 g)	Carbohy-drates (g/100 g)	Energy Value (kcal/100 g)
CPS	59.14±1.88 [a]	0.71±0.02 [a]	10.46±0.28 [a]	20.24±0.62 [a]	1.52±0.05 [a]	7.93	255.72
PSN	59.55±1.91 [a]	0.72±0.02 [a]	10.87±0.30 [a]	20.18±0.61 [a]	1.51±0.05 [a]	7.17	253.78
PA5	60.08±1.94 [a,b]	0.98±0.03 [b]	11.59±0.31 [b,c]	18.26±0.57 [b]	1.49±0.05 [a]	7.60	241.10
PA10	62.46±1.98 [b,c]	1.08±0.03 [b]	12.07±0.33 [c,d]	16.47±0.46 [c]	1.45±0.04 [a]	6.47	222.39
PA20	66.10±2.05 [c]	1.16±0.03 [c]	12.44±0.35 [d]	14.23±0.41 [d]	1.39±0.04 [a]	4.68	196.55

[a-d] different letters between samples signify statistical differences acording to t-test

Table 2 presents the mineral content of the analyzed pâté samples, showing values between 0.71% and 1.16%. Notably, mineral content increases with the proportion of avocado pulp, which is essential for fluid balance, bone health, and overall metabolic functions, thus preventing various health conditions [16].

The protein content of the pâté samples ranged from 10.46% to 12.44%, with higher levels corresponding to increased proportions of avocado pulp. High-protein foods support muscle development, enhance immune function, and are crucial for a balanced diet [17].

Fat content varied from 14.23% to 20.24%, decreasing as avocado pulp increased, remaining below the 30% limit. Low-fat diets help maintain healthy weight and reduce chronic disease risk [18].

The NaCl content was between 1.39% and 1.52%, compliant with the 2% limit set by Order 210/2006. Carbohydrate content ranged from 4.68% to 7.93%, with an energy value between 196.55 and 255.72 Kcal/100 g, indicating that higher avocado pulp content correlates with lower energy values. The control sample (CPS) had the highest energy value, while the lowest was found in the sample with 20% avocado pulp (PA20).

Chicken pâté typically contains 10% to 15% protein, highlighting its nutritional significance [19]. High-quality chicken protein aids muscle development. Fat content in chicken patties ranges from 10% to 20%, affecting both texture and nutritional profiles [20]. The type of fat is important, with saturated fats posing health risks while unsaturated fats may offer benefits [21].

Carbohydrate content is generally low, ranging from 1% to 5%, primarily from additives for texture [22]. Reducing carbohydrates may benefit those on low-carb diets, but maintaining product texture is essential [23].

Oxidative Stability Assessment

Determination of Peroxide Value (PV), Thiobarbituric Acid (TBA) and TOTOX value

The peroxide value (PV) is a crucial indicator of the initial oxidation stage of fats in food, reflecting oxidative stability and product quality. A PV below 10 mEq O_2/kg indicates that the product is not prone to rancidity, ensuring high quality and extended shelf life [24].

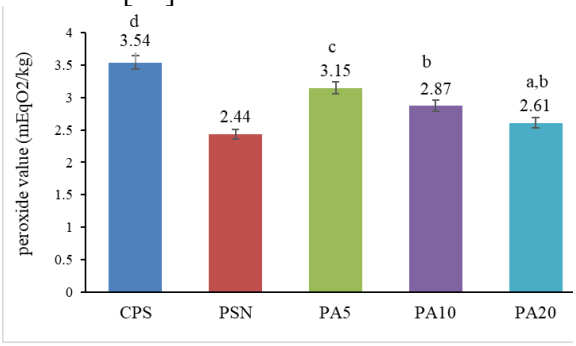


Figure 1. Effect of supplementation of avocado pulp pate formulas on peroxide value (PV)
a-d different letters between samples signify statistical differences acording to t-test

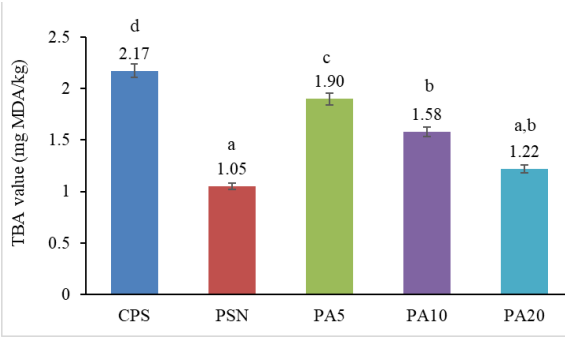


Figure 2. Effect of supplementing avocado pulp pate formulas on TBA value
a-d different letters between samples signify statistical differences acording to t-test

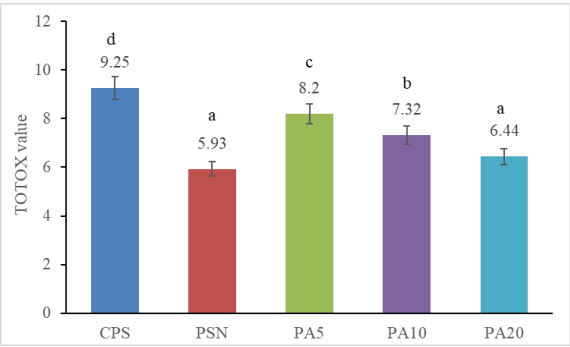


Figure 3. Effect of supplementing avocado pulp pate formulas on TOTOX value
a-d different letters between samples signify statistical differences acording to t-test

Figure 1 illustrates how avocado pulp supplementation affects the peroxide value in the analyzed pâté formulations, comparing them with the control sample (CPS) and the sodium nitrite variant (PCN). This data is vital for assessing the influence of natural additives on oxidative stability, enhancing understanding of the antioxidant potential of natural ingredients versus synthetic preservatives.

The peroxide value (PV) determination (Figure 1) revealed the highest value for the control sample (CPS - 3.54 mEq O_2/kg), compared to the sodium nitrite-added pâté (PSN - 2.44 mEq O_2/kg) and avocado pulp-added samples (PA5 - 3.15 mEq O_2/kg, PA10 - 2.87 mEq O_2/kg, PA20 - 2.61 mEq O_2/kg). The data indicate that increasing avocado pulp proportion reduces PV, with PA20 (2.61 mEq O_2/kg) being comparable to PSN (2.44 mEq O_2/kg), highlighting the antioxidant benefits of avocado.

Figure 2 presents TBA values, where the control sample (CPS - 2.17 mg MDA/kg) showed significantly higher MDA than PSN (1.05 mg MDA/kg) and the avocado pulp-added samples (PA5 - 1.90 mg MDA/kg, PA10 - 1.58 mg MDA/kg, PA20 - 1.22 mg MDA/kg). MDA levels decreased with increased avocado pulp, with PA20 (1.22 mg MDA/kg) comparable to PSN (1.05 mg MDA/kg), indicating 20% avocado pulp effectively replaces the synthetic antioxidant.

Figure 3 illustrates TOTOX values, with the control sample (CPS - 9.25) having higher values than PSN (5.93) and avocado pulp samples (PA5 - 8.20, PA10 - 7.32, PA20 - 6.44). TOTOX values decreased with increasing avocado pulp proportion, with PA20 (6.44) close to PSN (5.93), suggesting 20% avocado pulp can substitute synthetic antioxidants.

Literature supports the use of natural antioxidants in meat products, emphasizing their effectiveness in reducing lipid oxidation and extending shelf life. Shahidi and Ambigaipalan [25] found that natural antioxidants, such as plant extracts, offer protection against oxidative degradation comparable to synthetic preservatives. Hayes et al. [26] demonstrated improved oxidative stability in meat products with antioxidants like sesamol and ellagic acid, while Pokorný [27] highlighted that natural antioxidants are safer and more acceptable to consumers, making them ideal for products like chicken pâté.

Evaluation of Sensory Analysis

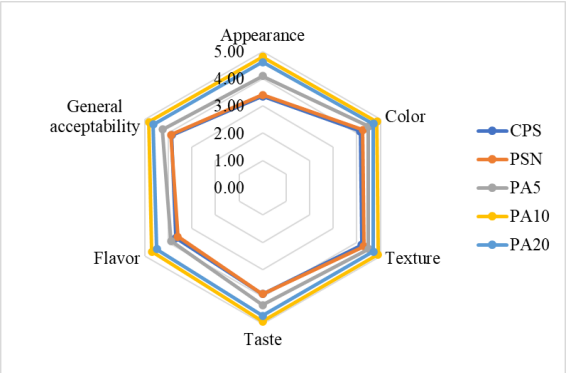


Figure 4. Sensory analysis of the analyzed sausage samples

Sensory analysis assessed the effect of the addition of avocado pulp to chicken pâté on the sensory characteristics of the product. Figure 4 shows the results obtained from the sensory evaluations for the five pâté samples, with total values recorded ranging from 3

to 5. Within the five analytical characteristics evaluated (appearance, color, texture, taste, flavor, aroma and overall acceptability), sample PA10 scored the highest, followed by PA5 and P20, while the lowest scores were associated with samples CPS and PSN. These results suggest that the addition of avocado pulp in moderate proportions contributes significantly to improve the sensory characteristics of pâté, thus indicating their potential in food formulation.

CONCLUSION

This research aimed to investigate the use of avocado pulp as an alternative to sodium nitrite in pate formulations. Proximate analysis showed that the use of avocado pulp improves nutritional characteristics and oxidative stability. The results of sensory analysis indicated a comparable overall acceptability of avocado pulp pâté compared to meat pâté, thus confirming the potential of avocado pulp as a promising ingredient to replace sodium nitrite in pâté formulations.

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THE BACTERIOSTATIC IN VITRO EVALUATION OF EFFICIENCY OF CHICKEN EGGS YOLK POLYCLONAL ANTIBODIES (IgY) AGAINST STAPHYLOCOCCUS AUREUS

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ABSTRACT

This study investigates objectives and aims. A novel method of targeting the bacteriostatic efficacy of chicken egg yolk polyclonal antibodies (IgY) against *Staphylococcus aureus in vitro. Specific IgY targeting Staphylococcus aureus was produced by immunizing hens with formaldehyde-killed Staphylococcus aureus (ATCC 33593) as an antigen. The IgY was extracted from egg yolks and purified to 94% purity. Cultures of S. aureus were treated with IgY at concentrations of 5, 10, and 15 µg/ml, alongside blank controls without IgY. Growth inhibition assays were performed by measuring density (OD 600nm) at 8-hour intervals. The results indicate that anti-Staphylococcus aureus IgY, particularly at 15 µg*/ml, exhibited the highest inhibitory potency, reducing the viability of *Staphylococcus aureus* colonies. The specificity of IgY binding and its ability to inhibit bacterial growth suggest a potential treatment for methicillin-resistant *Staphylococcus aureus* (MRSA). This study highlights the potential of IgY antibodies from chicken egg yolks as a promising A novel method of targeting the bacteriostatic efficacy of *Staphylococcus aureus* infections.

Keywords: Egg yolk immunoglobulin; *S. aureus*; Growth inhibition; Austria, Österreich linz

INTRODUCTION

Staphylococci are among the most robust microbes that infect humans, This and its propensity to develop antibiotic resistance establish this microbe as a major human pathogen infacted [1]

Immunoglobulins "Ig" are glycol-proteins called "antibodies". Serum IgG of the hen is transferred from the mother hens to the offspring egg yolk to acquire immunity. IgY is called this because it is present in the egg yolk and due to the differences in protein nature compared to that of the mammalian Immunoglobulins Ig. [2] Advantages of (IgY) antibodies against highly conserved mammalian proteins [3]

MRSA characterization of methicillin-resistant it I kind of bacteria *S. aureus* [4] methicillin-resistant *S. aureus* is infections widespread in numerous infections hospitals worldwide, but it is still among the most important causes of hospital-associated bacterial infections [5]

https://doi.org/10.5593/sgem2024v/6.2/s24.16

This study project aims to produce specific IgY antibodies against Staphylococcus aureus (anti-*S. aureus* IgY) by immunizing hens, and to evaluate the effectiveness of these antibodies in inhibiting the growth of S. aureus, including MRSA strains. The immunization process and the subsequent methods for obtaining and testing the anti-S. aureus IgY are detailed to provide insights into their potential use as an alternative or complementary approach in combating staphylococcal infections.

METHOD

The anti-S. aureus IgY was produced by the immunization of hens using formaldehyde-killed 0.5% [2] *S. aureus* -ATCC 33593 as an antigen. 22-week-old white leghorn laying hens were immunized through breast muscle by injecting 0.5 ml of antigens incorporated in 0.5 ml (FCA), and re-stimulate immunizations were performed four times at an interval of two weeks [6]. Anti-*S. aureus* IgY, of 94% purity, was obtained from yolks by water dilution and the 60% ammonium sulfate precipitation method. S. aureus (ATCC 33593) was cultured in TSB and adjusted to 0.5 McFarland [7]. Then they were cultured without IgY as a blank control and with anti-*S. aureus*. . IgY at concentrations of 5, 10, and 15 µg was incubated overnight at 37°C with shaking. Then samples were taken every 8 hours for growth inhibition assay through measuring the OD at 600 nm. After reading, each 100µl of samples (1/2 dilution) was inoculated onto nutrient agar with a spread plate to evaluate the viability of the cells (CFU/ml.)[8]

RESULT

The growth inhibition rate varied according to the anti-S. aureus IgY concentration. anti-S. aureus IgY with 15 µg/ml had the highest inhibitory potency. anti-S. aureus IgY reduces the viability of S. aureus (CFU/ml) or plate. Show in "fig 1" the anti-S. aureus IgY concentration 15 µg/ml treatment: Exhibited the most pronounced inhibition (80%) 10 µg/ml treatment: Showed moderate inhibition (54%.) and 5 µg/ml treatment: Demonstrated baseline inhibition (22.%)

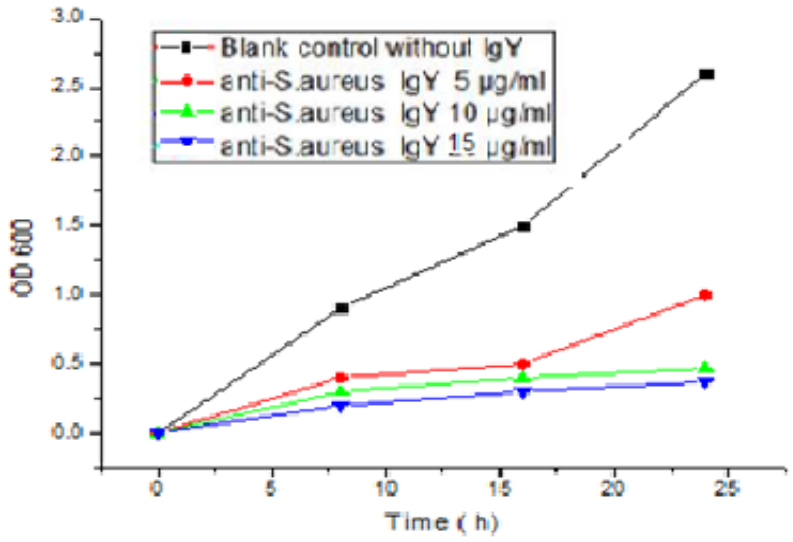


Fig.1. The OD 600 measurements of *S. aureus* liquid cultures with different concentrations (5, 10, and 15 µg/ml)

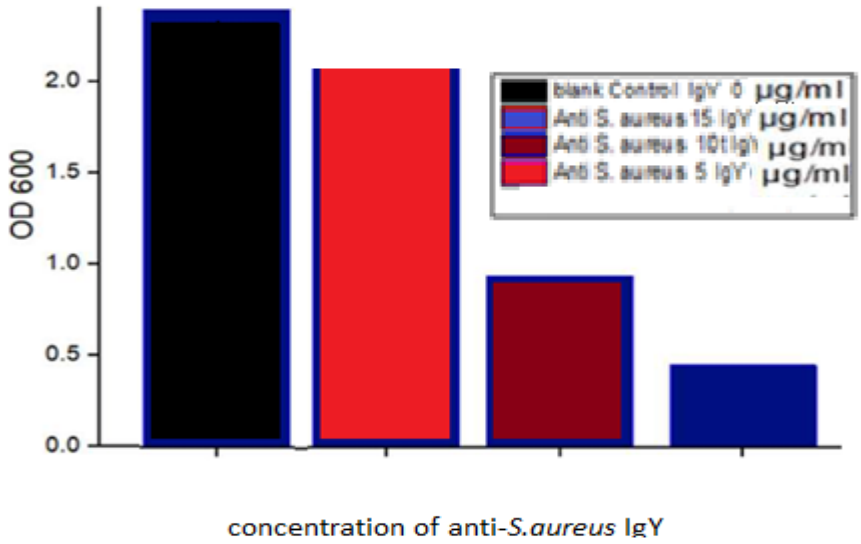


Fig. 2. anti-*S.aureus* IgY concentration (5, 10, and 15 µg/ml)

Fig 2 shows that the growth inhibition rate varied according to the anti-S. aureus IgY concentration. anti-S. aureus IgY with 15 µg/ml had the highest inhibitory potency. anti-S. aureus IgY reduces the viability of S. aureus (CFU/ml) o

Visual Turbidity Assessment

Figure 3 . presents the macroscopic changes in culture turbidity after 24-hour incubation: The growth inhibition rate varied according to anti-S.aureus IgY concentration. anti-S.aureus IgY with 15 µg /ml had the highest inhibitory potency. anti-S.aureus IgY reduces the viability of S.aureus (CFU/ml) / plate.

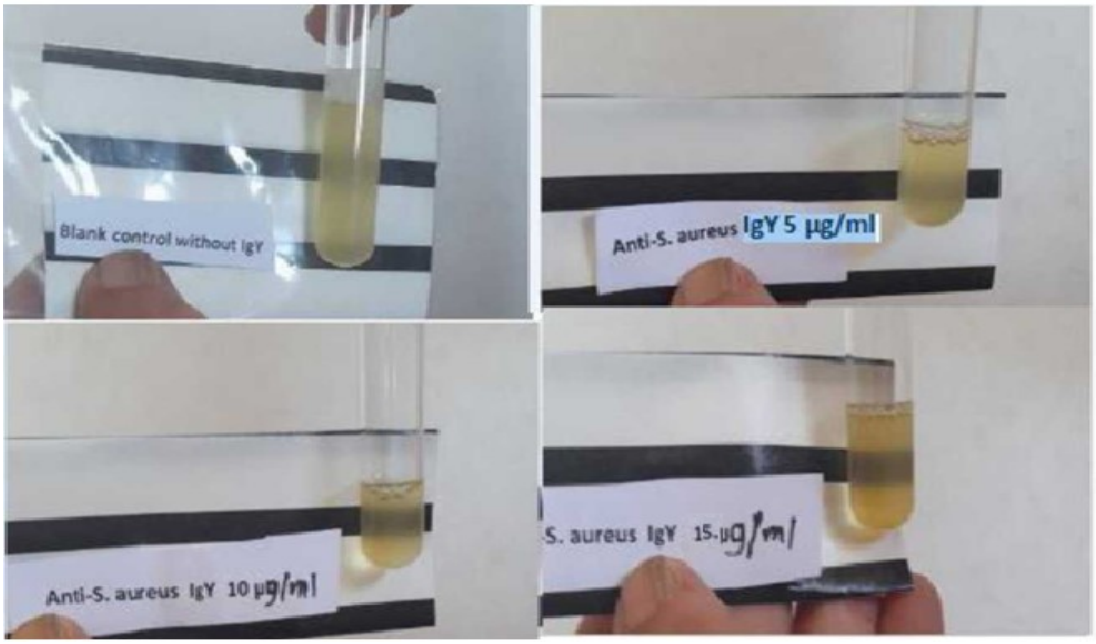


Fig. 3. The visual changes Turbidity in samples after 24h of incubation

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Figures 4. Growth inhibition activity assays of anti-S.aureus IgY on S. aureus, reduction the viability of S.aureus. onto nutrient agar.

The number of colony-forming units (CFU/ml) per plate. pre and post treatment with different concentrations of anti-S.aureus IgY (5, 10, and 15 µg/ml) . On left Fig. 4 - negative Controls showing confluent growth of S. aureus, and on right isolated colonies after treatments Colony Formation Analysis provides compelling evidence of IgY's biological impact through colony counting assays: Control plates exhibited confluent growth, Treated plates showed dose-dependent reduction:5 µg/ml: 1.4×10^8 CFU/ml.10 µg/ml: 6.7×10^7 CFU/ml ,15 µg/ml: 2.3×10^6 CFU/ml

DISCUSSION

The findings show a definite concentration-dependent inhibitory effect, with the highest efficacy observed at 15 µg/ml)." fig 1 and 2" polyclonal antibodies (IgY) as an effective agent against (MRSA) Staphylococcus aureus (ATCC 33593)

The bacteriostatic activity of IgY is likely attributed to its ability to bind specifically to surface antigens of S. aureus, potentially disrupting bacterial adhesion or interfering with essential surface proteins. the observed reduction in both colony (CFU/ml) and optical density (OD 600 nm)" fig 4" in treated cultures compared to untreated controls.

Because the experiments were carried out in vitro, which may not fully Additionally, while the purity of the extracted IgY was high (94%), further refinement of the purification process could be improved with additional purification process improvement. and a low risk of inducing bacterial resistance. These characteristics make IgY a viable candidate for further development, particularly in regions with limited access to advanced healthcare resources,

CONCLUSION

In vitro, specific IgY had high binding specificity and inhibited bacterial growth, possibly by interrupting interactions with surface antigens. Anti-S. Aureus IgY may be a potential treatment for MRSA, and this method is a cheap and rapid method to immunotherapy By use IGY. This research highlights the considerable potential of IgY immunotherapy as an

alternative approach to combat MRSA infections, offering distinct practical advantages over traditional antibody production methods. The methodology utilizes readily available laboratory infrastructure, with production costs substantially lower than conventional mammalian cell-based antibody systems. Rapid Response the avian immune system generates specific IgY antibodies within 14 days of antigen exposure, Our optimized purification process achieves 94% antibody purity in under two days, suggesting potential utility in emergent public health situations. Clinical Applications need more studies for antimicrobial therapy and Translational Considerations: Comprehensive safety pharmacokinetic evaluation The IgY production platform described herein represents a scientifically sound and pragmatically advantageous strategy for addressing the growing challenge of MRSA infections.

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SECTION GREEN BUILDING MATERIALS AND ECO-TECHNOLOGIES

ARTIFICIAL INTELLIGENCE AND BUILDING INFORMATION MODELING AS A TOOL FOR THE MANAGEMENT OF SAFETY AND SUSTAINABILITY OF GREEN CONSTRUCTION PROJECTS

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ABSTRACT

Artificial intelligence (AI) is breaking through more and more into all sectors of the economy. A groundbreaking tool that can change several industries is still at the beginning of the journey and mass implementation, with questionable results. Sustainability and safety in the construction industry have been a priority for the last decades. Pursuing sustainable and safe implementation of construction projects brings several challenges regarding innovations and implementation in practice. This research solves the safety issue by reducing accidents and improving health and sustainability in the management of construction projects. Sustainability and green buildings are close to safety and a healthy environment, which can point to some correlations of the overall sustainable approach in the industry. The research aims to analyze digital tools such as artificial intelligence and information modelling of buildings and the possibilities of use and impacts on the safety and sustainability of construction projects. The research was based on data from a construction industry survey. Data processing uses statistical testing of the research sample and relevant methods. The results point to the possibilities and impacts of using AI and BIM on the safety and sustainability of construction projects.

Keywords: artificial intelligence, safety, sustainability, construction.

INTRODUCTION

Construction is one of the least digitized industries in the world, which makes it difficult to solve the problems it is currently facing [1]. On the contrary, the survey suggests that the construction sector is the sector most affected by AI due to the complexity of large-scale projects in this sector [2].

The issue of artificial intelligence and building information modelling has brought several challenges and opportunities to the field of digitization [3]. BIM tools bring several advantages associated with increased quality, a more detailed model and better planning of construction processes. The advanced use of BIM in several studies also pointed to safety in the construction industry, especially in the case of simulating the degree of risk [4]. This leads to reflection and search for ways to improve these processes. On the one hand, this leads to the improvement of identifying a potential critic, on the other hand, to the search for the possibility of finding ways to eliminate the risk or reduce the rate. It also approaches the need for sustainability.

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Green projects in themselves are a big challenge. Sustainability in the construction industry is perceived in many ways. In an environmental context, it is detrimental to the environment. Within the social framework, these are the impacts on society. The perception of economic sustainability is also critical. In the case of green construction projects, this must be assessed from the point of view of the entire life cycle of the construction project. Better prioritization of risks and sustainability in the planning and construction of green projects can also help other digitisation trends and new digital technologies. Among them is undoubtedly the use of AI [5]. Therefore, it is crucial to understand the current state and the potential of using these technologies for the mentioned purposes, to stay informed and prepared for the future.

ARTIFICIAL INTELLIGENCE FOR THE MANAGEMENT OF SAFETY AND SUSTAINABILITY IN CONSTRUCTION OF GREEN PROJECTS

Knowledge-based AI tools can be useful in multiple industries, primarily to increase profitability, efficiency, safety, and security [1]. Artificial intelligence in construction is essential and has improved the understanding of AI applications [6]. However, these reviews have yet to be critical in examining specific areas of AI applications [7]. The most important advantages are the ease of comparing knowledge with problems, the quick acquisition of data, the increased ability to create new knowledge, the increased competence, and the improved decision-making process in each area. This also applies to the safety and sustainability of construction projects [2]. Another study examined the awareness and application of AI in Nigerian construction based on the potential of artificial intelligence that should improve planning construction costs, time, and safety. Stakeholders noted the need to invest in others. The main benefits of implementing AI in BIM include improving quality, productivity, and the decision-making process [8].

The Health and Safety Analysis (HSA) is important in the safety framework. It can be practised using technologies that use advanced data analysis techniques to predict and prevent workplace accidents [1]. The construction industry records a significantly higher rate of occupational accidents and deaths compared to other industries [9].

Sustainability in the construction industry can be addressed using alternative materials, waste minimization and new management approaches. Sustainable management can also be included in this area, that is, the use of information technology for the purposes of achieving a goal [10]. Artificial intelligence can also bring positive changes to these processes [11]. Streamlining processes is more than desirable. The context of economic sustainability is often associated with the use of artificial intelligence and building information modelling [12].

In the following image, business values are predicted and AI type in dollars. According to this data, AI will probably be one of the most important technologies in this decade. This only confirms the validity of this research and solutions to the given issue.

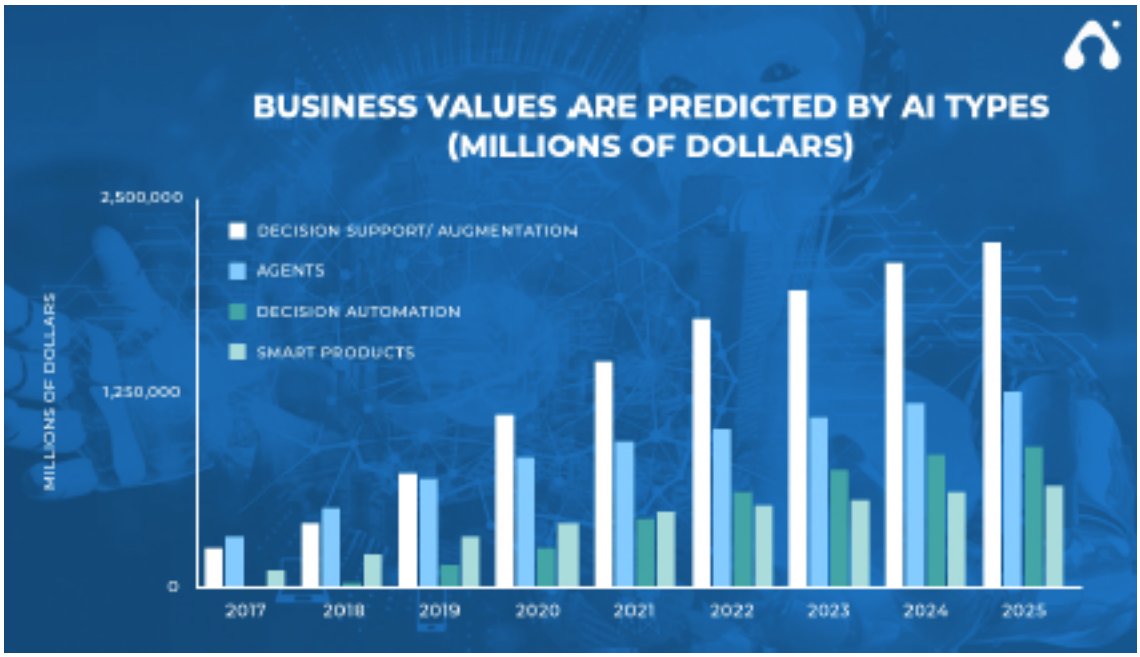


Fig. 1 Business values predicted by AI types [13]

METHODOLOGY

This research addresses the implementation of digital technologies such as BIM and AI for the purpose of safety planning in construction projects and sustainability. Mapping of the perception of the status of the use of digital technologies such as AI and BIM for the given purposes was carried out through a questionnaire survey.

The research was focused on the potential of using AI in BIM for the purpose of impact on safety management in construction and sustainability. Construction companies in Slovakia participated in the research. When identifying the rate of use of digital technologies, it is often associated not only with the digital skills of users, but also with the age structure. This can be seen in fig. below.

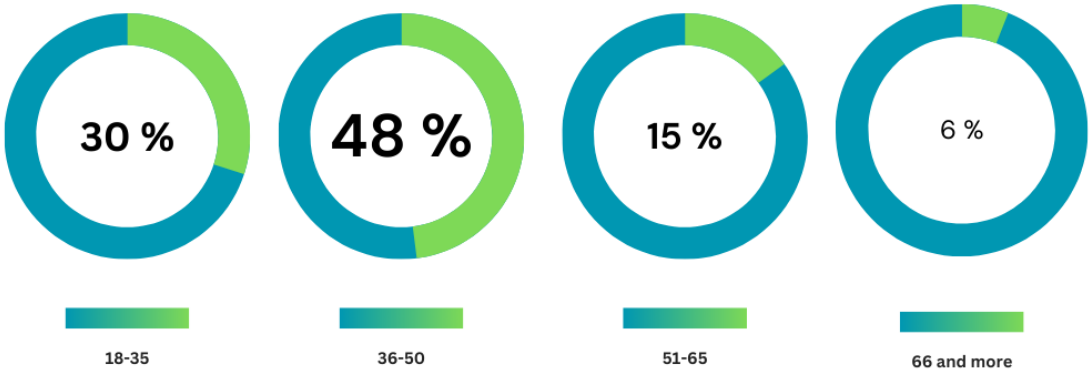


Fig. 2 Research sample by age of users

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A questionnaire survey ensured data collection. Data evaluation was based on essential descriptive statistics tools and statistical testing. Questions and answers were scaled and quantified based on a Likert scale. The rate of use and impact ranged from 1, least used to 5, the most used, respectively the impact rate.

RESULTS AND DISCUSSION

The research results point to a low rate of AI use in the construction industry. The rate of BIM usage is better, but even so, it still does not show the potential of this technology. These results point to the trend and possibilities of use but also to relatively weak use, mainly from the point of view of AI.

The rate of AI adoption is relatively weak. fig. 3 indicates whether the respondents are familiar with any AI tool. More than 61% said they know or have already heard about AI. This represents the potential for the rate of use to grow in the future.

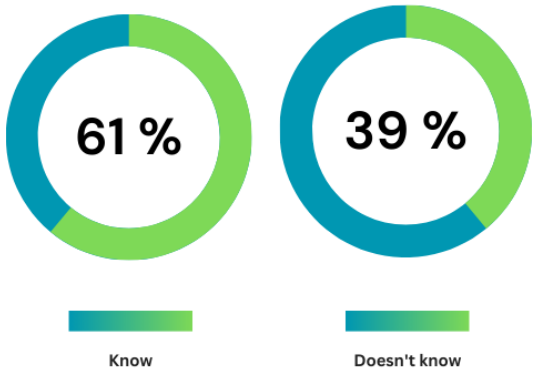


Fig. 3 Knowledge of some of the freely available AI tools

However, the reality is different. As many as 58% of respondents of the research sample said that they have no experience using an AI tool, which explains the current utilization rate (Fig. 4). Only 42% of respondents said they had already tried an AI tool. However, most just tried it. The frequency of use is minimal, and many respondents need to use this tool regularly.

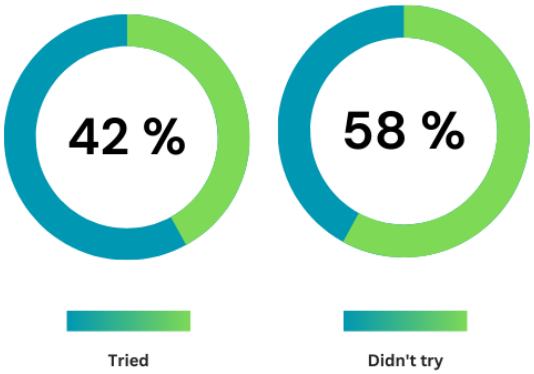


Fig. 4 Experience with artificial intelligence

Regarding using BIM and AI in BIM, scenarios can be simulated for situations and safety evaluation. However, this is more difficult to apply within the framework of implementing the measures, which may also be the reason for weaker expectations.

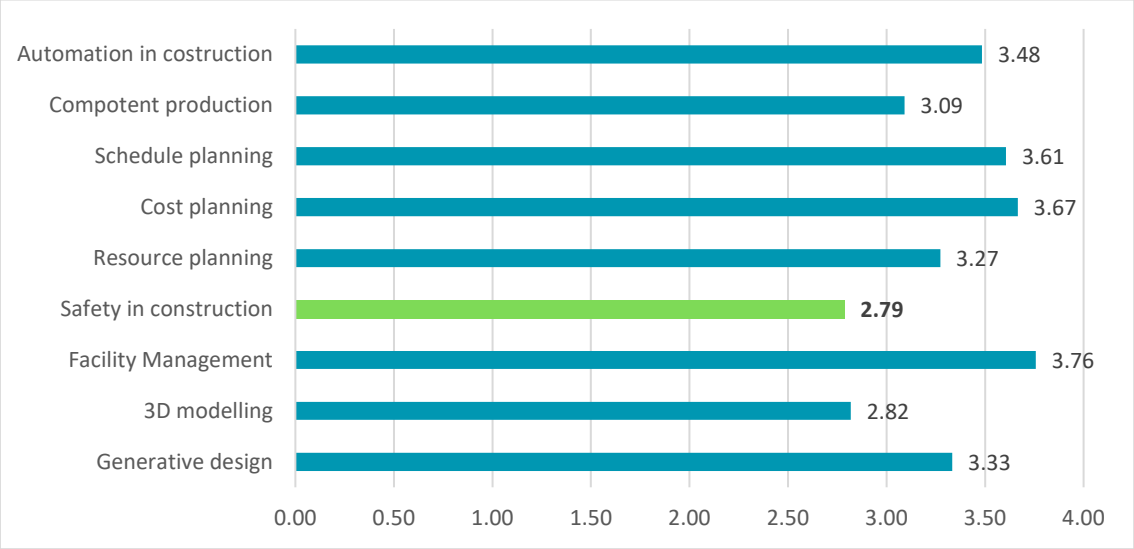


Fig. 5 AI effects on issues in construction

On the other hand, it must be said that the expected value is not extremely low. Paradoxically, it is very close to the form of 3D modelling, which has an effect in the design and planning phase but minimal in the implementation phase.

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CONCLUSION

Research focused on the possibilities of using AI and BIM for safety management on construction sites has yielded interesting results. The basic finding and confirmation of the assumption was the knowledge of AI and the respondents' knowledge of this topic. More than 60% of respondents know AI and tools, but the degree of knowledge is not quantified. Due to the frequently discussed topic, the level of knowledge is possibly lower than the survey itself says, where the respondents' knowledge was not quantified.

On the other hand, this study investigated the frequency of AI use and the perception of rare use of AI. The results are already less satisfactory. Many users have not tried AI, and many respondents who have tried AI do not use it on a regular basis. The means that in many cases, it was only an isolated experience, not frequent use.

An overview of AI's impact on the selection of activities for managing the safety or sustainability of green projects also brought important results. The results for safety were low, with the lowest values respectively. All of this assumes that the planning phase is important, but executive respondents perceive a gap in the use and impact of AI.

On the other hand, it is important to remember that this topic is constantly developing, and these results were not considered low in terms of impact. AI has great potential in the construction industry, and it is assumed that, with appropriate implementation and use of simulations, safety in the industry will also improve.

The development of AI will be on the rise in the coming years, and the next decade will be technologically focused on AI. This supports the need to address this issue in the construction industry and the issue of safety. Future research should also go in this direction and compare these results globally and on a broader scale. The connection of BIM and AI within the framework of solving sustainability and safety, as well as green construction projects, is an area where the results have the potential to be implemented in practice.

ACKNOWLEDGEMENTS

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ASSESSING THE EFFECTIVENESS OF DUNE SAND AS A SUPPLEMENTARY CEMENTITIOUS MATERIAL TO PRODUCE ADHESIVE MORTARS

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ABSTRACT

In order to valorize our natural resources especially dune sand, the physical and mechanical properties of adhesive mortars based on local mineral additions, have been studied in this present work. The experimental study was carried out on various adhesive mortars made with different contents of dune sand by partial substitution of cement. Adhesive mortars were made from Portland cement (PC; at 35%, 30% and 25%wt), Dune Sand (DS; at 60%, 65% and 75%wt), fillers and redispersible polymer powder (RDP; at 0.6%, 1.0% and 1.4%wt.). The physical (Slump test, normal consistency and bulk density) and mechanical and (initial adhesion, adhesion after immersion in water and adhesion after heat treatment) properties of elaborated adhesive mortars were determined and compared to commercial adhesive mortars.

Keywords: Dune sand, Cellulose ether, Slump test, adhesion after immersion in water and adhesion after heat treatment.

INTRODUCTION

Adhesive mortars are widely used to fix ceramic tiles as decorative finishes or for fixing polystyrene sheets on to building walls as part of external insulation systems; this is because their bond strength and flexural properties increase the cladding's life-time. To achieve the required adhesive properties, polymer dispersions are added to the mortar formulation. Adhesion between tiles and mortars are of paramount importance to the overall stability of ceramic tile systems. The interfaces between ceramic tiles and polymer modified cement mortars are derived from several physical and chemical phenomena that take place when they are formed. The interfacial resistance is affected by a number of factors, such as ceramic tile water absorption, cement amount and composition, the amount and type of polymer used as cement modifier, installation procedures, and water to cement ratio, among other factors [1-2]. Many works have carried out on using dune sand (DS) as a substitute for natural sand to produce mortars or concretes [1-5]. For many years, mortar—a mixture of water, sand, and cement—has been a widely used building material in the construction sector. The high demand for mortar has led to significant increases in consumption and, consequently, mortar production. However, this production process requires a substantial amount of energy, resulting in an increased carbon dioxide (CO2) footprint. According to [1], cement production alone, a key ingredient in mortar, contributes to over 4% of the total carbon dioxide emissions into the environment. Given the indispensable nature of cement mortar in the construction industry, it is crucial to ensure its sustainable production [2]. One effective approach to achieve sustainable mortar production is by enhancing the mortar mixture with the use of sustainable materials. Apart from the primary mortar ingredients, various other materials can be added as admixtures to improve mortar characteristics. Polymer-based admixtures have long been utilized to enhance the properties of concrete and mortar [3]. However, many of these admixtures are synthetic

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materials that can have adverse effects on the environment. Synthetic admixtures have been identified as sources of numerous toxic substances in the environment and can also escalate construction costs [4,5].

Recently, there has been growing interest in utilizing fascinating biopolymers and sustainable raw materials as low-cost and eco-friendly substitute admixtures for synthetic alternatives. Various aspects of biomaterial admixtures have been explored [6]. Additionally, the use of herbs as admixtures in ancient buildings has been studied [7]. In 1998, Chandra et al. [8] conducted research demonstrating the benefits of adding gum extracted from cacti to cement mortar. Furthermore, research on the effects of different starches obtained from wheat, potato, corn, and waxy corn has shown that potato and waxy corn starches offer optimal performance [9]. Potato starch, as a biodegradable additive, has been found to improve lime-based mortar characteristics [10]. Methylcellulose extracted from mango seeds has been shown to increase bond tensile strength by approximately 29%, making the resulting mortar suitable for adhesive applications [11]. Liquor extracted from palms has been used as a concrete retarder and to improve workability [12]. Various guar gum derivatives have been studied for their effects on cement mortar properties [13-14]. Blue gum has been found to reduce the rate of concrete shrinkage [15]. Another research investigated the effects of okra extract on cement mortar and concrete characteristics, revealing potential improvements in durability and mechanical properties [2]. More recently, the use of cooking oil waste as a bio-admixture has been explored for its potential to reduce concrete shrinkage [16].

According to this modest bibliographic research, this study focuses on assessing the physical and mechanical properties of adhesive mortars containing local mineral additions, particularly dune sand, to valorize natural resources. Various adhesive mortars were experimentally investigated, with dune sand partially replacing cement. The compositions of the adhesive mortars comprised Portland cement (PC) at 35%, 30%, and 25% by weight, dune sand (DS) at 60%, 65%, and 75% by weight, fillers, and redispersible polymer powder (RDP) at 0.6%, 1.0%, and 1.4% by weight. Physical properties such as slump test, normal consistency, and bulk density, along with mechanical properties including initial adhesion, adhesion after immersion in water, and adhesion after heat treatment, were determined for the developed adhesive mortars. These properties were compared to those of commercial adhesive mortars.

EXPERIMENTAL STUDY

Materials used

For the formulation of the adhesive mortar has been chosen in accordance with standard NF EN 12004-2 and the materials used for this are; Cement, Dune Sand (0-2mm), Fillers Limestone, and a redispersible polymer powder (RDP). In our study, we recommended the formulation of a base mortar for the various compositions. Mixing time and speed are rigorously identical from one test to the next. Adhesive mixes were prepared in accordance with standard NF EN 1348. Preparation of a 2 kg quantity of adhesive in a mixer, using low speeds [1].

Test methods:

The tests used to determine the characteristics of adhesives used for setting ceramic tiles at the bottom are as follows: fresh and hardened tests

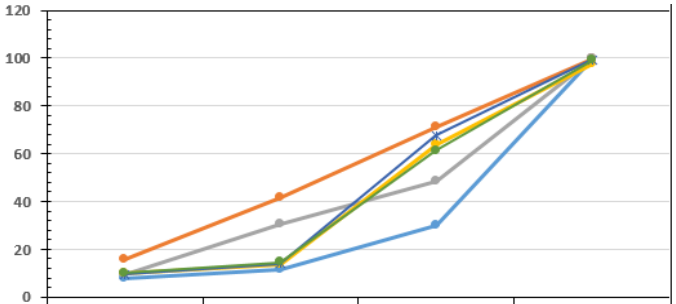
1). Fresh mortar tests:

Fresh mortar consistency: The dry density of a given specimen of hardened mortar is determined by the quotient of its dry oven-dry mass and the volume it occupies when immersed in water in a saturated state, in accordance with standard EN 1015-3.

Flowbility and slump test of fresh mortar: The workability period of a fresh mortar sample, initially brought to a defined spread value, is measured by the time, in minutes, after which it reaches a defined limit of stiffness or workability, during a test of this type defined in accordance with EN 1015-9.

Bulk density of fresh mortar

The apparent density of fresh mortar is determined by the quotient of its mass by the volume it occupies when introduced, or introduced and compacted, in a prescribed manner in a measuring vessel of a given capacity in accordance with EN 1015-6.



	0,630 mm	0,315 mm	0,125 mm	FT
Mortier Colle Privé	7,8	11,5	29,8	99,8
Mortier Colle Importation	15,9	41,6	71,3	99,8
Mortier Colle Local	9,2	30,5	48,5	99,5
mortier colle AH	9,8	13,6	64	97,8
mortier colle AH 2	9,6	14	67,6	99,4
mortier colle AH 3	10	14,4	61,2	99,1

Fig. 1. Particle sizes of all used adhesive mortars

Table 1. Mix design of all adhesive mortars

Mix	PC (%)	DS (%)	F (%)	CE (%)	RDP (%)	Water (mL)	Slump test (mm)	Normal consistency (%)	Bulk Density (g/cm3)
AM1	25	70	5	0,3	0,6	254	150	25,4	1,62
AM2	30	65	5	0,3	0,6	260	155	26,0	1,67
AM3	35	60	5	0,3	0,6	272	160	27,2	1,72
AM4	25	70	5	0,3	1,0	265	160	26,5	1,65
AM5	30	65	5	0,3	1,0	210	150	21,0	1,68
AM6	35	60	5	0,3	1,0	275	170	27,5	1,73
AM7	25	70	5	0,3	1,4	275	175	27,5	1,68
AM8	30	65	5	0,3	1,4	278	160	27,8	1,69
AM9	35	60	5	0,3	1,4	285	170	28,5	1,66
AM10	25	70	5	0,3	0,6	220	110	22,0	1,60

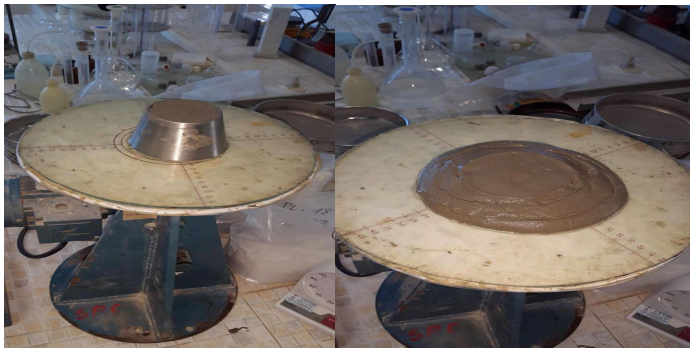


Fig. 2. Flowbility and slump test of fresh mortar

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Preparing test models: Apply a thin layer of adhesive mortar to the concrete slab using a straight-edged trowel. Then apply a thicker layer and comb with the notched trowel at a 60° angle. After five minutes, place the ceramic tiles on the adhesive and load each tile with the weight (20±0.05) N for 30s.

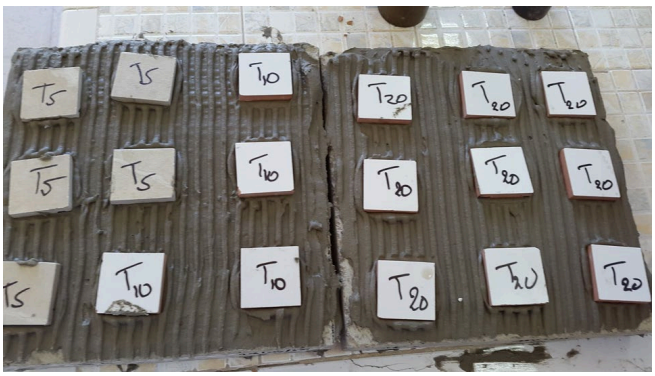


Fig. 3. Preparing test models using our studied adhesive mortar



Fig. 4. Tensile pull-out test

Hardened mortar tests:

Tensile bond strength: This test applies to all adhesive mortars, including those with separate components for laying ceramic tiles on interior or exterior floors, in accordance with standard EN 1348.

Measure of initial adhesive mortar: According to NF EN 12004-1, initial bond is the tensile strength of the adhesive mortar after 5 minutes' rest.



Fig. 5 Test models after tear-out



Fig. 6 Slip test of the studied adhesive mortars

RESULTS AND DISCUSSION:

Normal consistency of adhesive mortar:

The normal consistency of adhesive mortar is the quantity of water required to prepare a standardized cement paste using a shaking table, giving us cakes with a diameter of between 14 and 20 cm. A study of the influence of various additives on the rheological behavior of our paste. Equivalent to a plastic mortar in compliance with standard NF EN 1015-6: 1998, by varying the quantity of mixing water [17]. After noting that the 9 formulas did not meet the requirements of NF EN 12004-1 relating to the slip test. We therefore reduced the amount of water in the tenth formulation to check the influence of normal consistency on the physic-mechanical properties of our adhesive mortar.

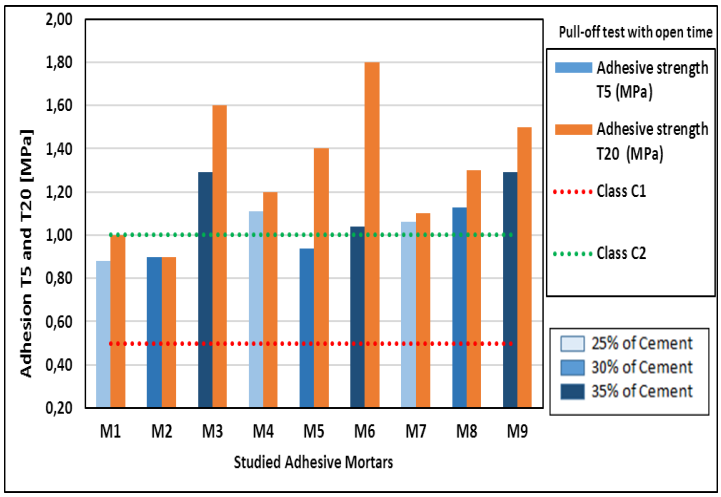


Fig. 7. Results of Pull-out test of the studied adhesive mortar

Open time by tensile adhesion:

The open time test required by standard NF EN 12004-1 consists in observing the time of use of the adhesive mortar, giving it a class of C1 for adhesion ≥ 0.5 MPa and a class of C2 for adhesion ≥ 1 MPa.

From the results in fig. 7 below, we can see that the quantity of cement and additives have a direct influence on the mortar's adhesion, and that the additive increases setting times, without influencing physical-mechanical characteristics. We also note that this histogram describes the open time test after 20 minutes' rest, showing that the longer our mortar is rested, the greater the increase in adhesion. Increasing the quantity of cement and the additive (redispersible powder) also considerably improves pull-out strength. It can be concluding that formulations (1, 2) meet the requirements of a C1, which confirms that each formula had a result of ≥ 0.5 MPa, and formulations (3, 4, 5, 6, 7, 8, 9) have a C2 classification according to NF EN12004-1, ≥ 1 MPa on the pull-out test.

Initial tensile adhesion

Initial tensile adhesion is a test required by standard NF EN 12004-1, for the basic characteristics of a tile adhesive mortar, which determines pull-out values in MPa after five minutes' rest. Our mixes, shown in Fig. 8, show a direct correlation between initial pull-out and cement and redispersible powder dosage. If we also compare formula 01 with formula B in the bibliography [11-12], where the percentage of additives and cement are similar with 25% cement and 0.60% additives, we see that our results are satisfactory, bearing in mind that they used a class 52.5 cement. According to these results and those presented in the bibliography, we can say that formulations (1, 2, 5) meet the requirements of class C1, whose bond strength must be ≥ 0.5 MPa, while formulations (3, 4, 6, 7, 8, 9) meet the requirements of class C2, with an initial pull-out strength ≥ 1 MPa, in accordance with the requirements of standard NF EN 12004-1.

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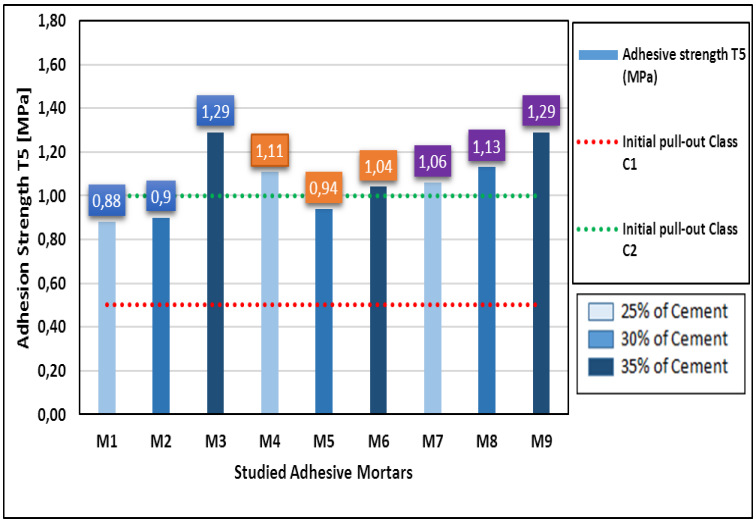


Fig. 8. Results of Open time by tensile adhesion test of the studied adhesive mortar

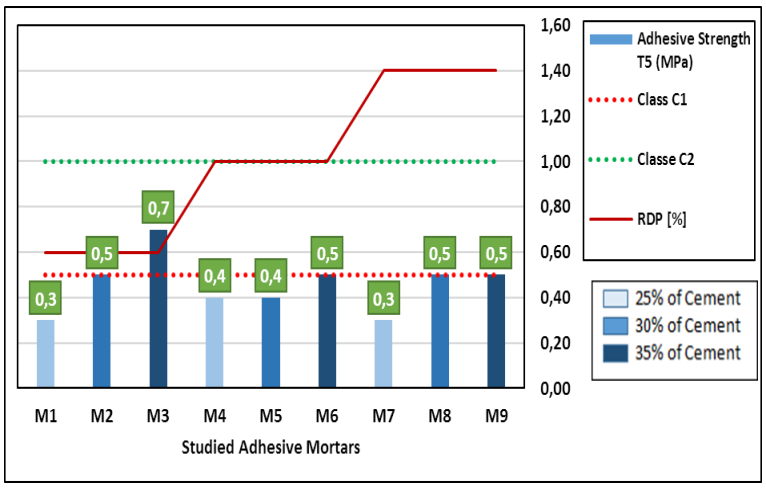


Fig. 9. Results of pull-out after immersion test of the studied adhesive mortar

Tensile adhesion after water immersion

Tensile adhesion after water immersion is a NF EN 12004-2 test which determines the impact of water immersion on the classification of tile adhesive as required by standard 12004-1. Fig. 9 below shows that with 0.6% redispersible powder, pull-out strength after immersion in water increases proportionally with cement dosage. On the other hand, with 1% and 1.4% redispersible powder respectively, bond strength does not follow cement dosage. We also note that the dosage with 0.6% redispersible powder of formula 01 gives identical results to those of formula B in the bibliography [11-12]. We deduce that our formulations (2, 3, 6, 8, 9) meet the requirements of class C1 ≥ 0.5 MPa, for tensile adhesion after immersion in water as per the requirements of NF EN 12004-1.

By optimizing the amount of water in the first formula, adhesion under the action of heat is increased fivefold. It should be noted that heat or heat treatment creates a high degree of porosity in the mortar, as the water evaporates under the effect of heat, resulting in a reduction in its resistance.

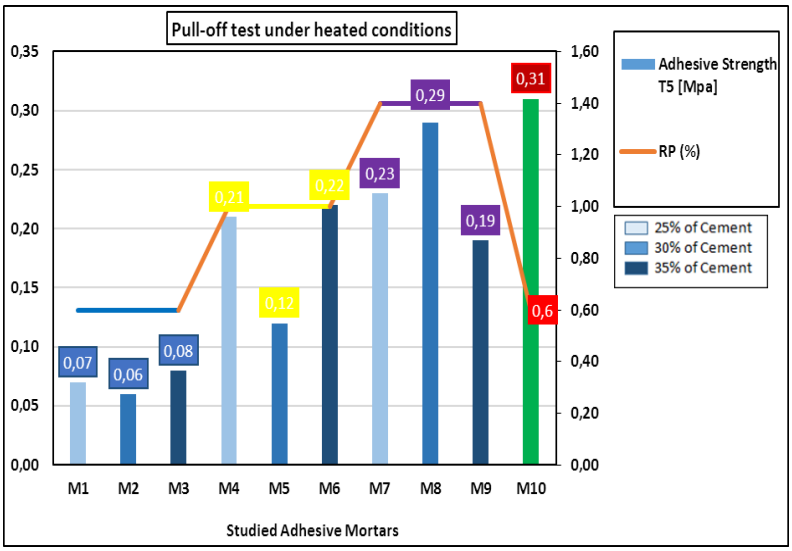


Fig. 9 Results of pull-out after heat action test of the studied adhesive mortar

CONCLUSION:

The aim of this study was to develop and optimize tile adhesive formulations based on local materials, with a view to satisfying national market needs and reducing imports. Indeed, the optimization of a tile adhesive mortar is established with several compositions, in accordance with the requirements of standards NF EN 12004-1 and NF EN 12004-2.
According to the results obtained on the formulations carried out, several types of adhesive mortar with different percentages of cement, sand, fillers and additives have been developed:

- Formulation 2 with the following composition (30% cement, 65% sand, 5% filler, 0.3% cellulose ether and 0.6% redispersible powder), complying with the C1 class requirement of the standard in force. This formulation can be used for interior and exterior floor tiles. For wall tiles, a 3.4% water reduction is required. The cost price of a kilogram (1kg) of adhesive mortar made from this formulation is 10 DA.
- Formulations 3, 6, 8 and 9 comply with the C2 class requirement of the current standard, and are valid for use indoors, outdoors and in water immersion.
- Formulation 10: (representing the optimization of formulation 01) and belonging to class C 1 according to the standard in force, with an additive dosage (redispersible powder) of 1%, can be used in areas exposed to heat (terrace, sauna, hammam ....etc.).

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BIOSYNTHESIS AND CHARACTERIZATION OF SILVER NANOPARTICLES ANTIOXIDANT FILMS FROM ALOE VERA DRIED GEL

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ABSTRACT

Biopolymer-based packaging materials are increasingly favored for their eco-friendly and biodegradable properties. Among the promising biopolymer materials, agar-based biodegradable films stand out since they are made from water and plasticizers like glycerol. However, they often suffer from reduced mechanical strength and higher moisture sensitivity compared to synthetic alternatives. To address these issues, this study explores the incorporation of silver nanoparticles (AgNPs) into agar-based films using Aloe vera gel as a green synthesis agent. The study demonstrates that Aloe vera gel effectively stabilizes AgNPs, resulting in nanoparticles with distinctive reddish-brown coloration. The agar-based films with AgNPs exhibited enhanced antioxidant activity, with inhibition rates up to 85.39%. These films also maintained smooth surfaces and evenly dispersed nanoparticles, ensuring both mechanical stability and bioactivity. The results suggest that Aloe vera gel not only facilitates the synthesis of AgNPs but also preserves their functional properties, offering a promising approach for developing advanced food packaging materials with improved antioxidant and antimicrobial characteristics.

Keywords: Nanoparticles, Antioxidants, Ultrasounds, Aloe vera, Films.

INTRODUCTION

Plastic food packaging materials are prevalent in modern society, but their negative impacts on human health and the environment are increasingly apparent [1]. Harmful chemicals such as phthalates and bisphenol A can leach from plastic packaging into food, causing health issues like developmental disorders, cancer, and endocrine disruption [2]. As a result, researchers are exploring alternative polymeric materials to replace petroleum-based plastics [3].

Biopolymer packaging, including polysaccharides, proteins, and lipids, forms protective films that preserve food quality by controlling moisture, gas, and microbial contamination. Some biopolymers, such as agar-based films, are particularly promising due to their compostability, transparency, and flexibility, making them viable substitutes

for plastic [4]. However, biopolymer materials can lack the mechanical strength and moisture resistance of synthetic packaging, spurring research into nanoparticle reinforcement [5].

Silver nanoparticles (AgNPs), known for their antimicrobial properties, can improve biopolymer functionality without affecting food sensory qualities [6]. Two primary methods for incorporating AgNPs into biopolymers exist: the in-situ method, where the polymer stabilizes nanoparticles during synthesis, and the ex-situ method, where the polymer disperses pre-formed nanoparticles [7]. Traditional nanoparticle synthesis often produces toxic by-products, so green synthesis methods using microorganisms or plant extracts are being developed [8]. These eco-friendly methods utilize plant-derived biomolecules, which act as reducing and stabilizing agents, to create stable, functional nanoparticles such as Ag-Au bimetallic nanoparticles derived from extracts of plants like *Gloriosa superba* and *Azadirachta indica* [9, 10].

Aloe vera, long esteemed for its medicinal properties, has gained contemporary significance in the food industry due to its incorporation into functional foods, health drinks, and beverages for its purported health benefits. With potent antibacterial and anti-inflammatory properties, aloe vera contains over 200 active compounds, including polyphenols and proteins, which naturally function as reducing and capping agents in the formation of metallic nanoparticles [11]. The present study investigates the stability and activity of aloe vera gel's active compounds following drying treatment. It employs green synthesis techniques involving ultrasound to reduce incubation time and explores the addition of agar to generate film samples. These agar-enhanced films are evaluated for their potential use in food packaging due to their strong antioxidant characteristics.

MATERIALS AND METHODS

Plant material and preparation of the extract: For this experiment, dried Aloe vera gel was utilized to prepare the plant extract. The gel was processed by drying in an oven at 50±5°C for 24 hours or alternatively, subjected to lyophilization. To prepare the extract, 0.3 g of the dried gel was weighed and dissolved in 30 ml of distilled water. The mixture was then subjected to sonication for 15 minutes, with intermittent pauses of 5 minutes after every 5 minutes of sonication. Subsequently, the extract was centrifuged at 6000 rpm for 5 minutes.

Preparation of silver nanoparticles: Silver nanoparticles were synthesized by combining 10 ml of aqueous Aloe vera gel extract with 10 ml of 0.02 M $AgNO_3$ solution. Control samples were prepared by substituting either the gel extract or the silver nitrate solution with distilled water. Prior to sonication, the pH of the samples was adjusted to 7. The sonication process was carried out for 30 minutes, with 10-minute intervals following every 10 minutes of ultrasound treatment. After sonication, the reaction mixture was incubated in the dark at 40°C for 7 hours with mechanical stirring. Below is presented the method of naming the samples depending on the biological material, the method of drying the samples and the solvent used (table 1).

Table 1. Composition and nomenclature of samples

Sample	Aloe extract (ml)	Drying method	$AgNO_3$ (ml)	Water(ml)
1	10	Oven	10	-
2	10		-	10
3	10	Freez	10	-
4	10		-	10
5	-	-	10	10

Preparation of agar-silver nanoparticles film: The biopolymer films were prepared by combining 0.3 g of agar with 20 ml of the silver nanoparticle solution. The resulting mixture was subjected to microwave treatment for 20 seconds, with a 10-second pause midway through. Subsequently, the mixture was poured into five Petri dishes and allowed to dry at room temperature for 4 days before analysis.

Physico-chemical evaluation: The thickness (T) of the films was measured using a digital micrometer (Yato, Shanghai, China) with an accuracy of 0.001 mm. The color of the films was assessed using a Chroma Meter CR400 colorimeter (Konica Minolta) employing the CieLAB color space. The evaluation involved recording parameters such as a*, b*, luminosity (L*), and chroma (C*). The water activity index (wa) was determined using an AquaLab 4TE device (Meter Group, Munich, Germany). The reported values represent the average of at least 10 measurements taken from different areas of the material.

Fourier-transform infrared spectroscopy: To identify biomolecules associated with silver nanoparticles, Fourier transform infrared (FTIR) spectra of prepared films were recorded using an FTIR spectrometer equipped with an attenuated total reflection (ATR) accessory. The samples were uniformly applied to the surface of a zinc selenide crystal. Spectra were collected over the wavelength range of 4000 to 400 cm^{-1} with a resolution of 4 cm^{-1}.

Scanning electron microscopy: The morphology of the silver nanoparticle films was analyzed using scanning electron microscopy (SEM) with a Quanta 200 device (ESCM), operating at an accelerating voltage of 20 kV. The SEM images were subsequently evaluated using ImageJ, an open-source software for scientific image analysis.

Antioxidant activity was assessed using the ABTS radical scavenging method. This procedure involves generating the ABTS radical by reacting ABTS reagent (2,2′-Azinobis (3-ethylbenothiazoline-6-sulfonic acid)) with potassium persulfate ($K_2S_2O_8$). Prior to use, the reagent was adjusted to an absorbance of 1.0 by dilution with ethanol. In brief, 10 mg of film samples were incubated in the dark with 2 ml of the ABTS reagent for 3 hours. Following incubation, the absorbance was measured at 734 nm against a blank using a spectrophotometer (Dlab Scientific SP V1000, Beijing, China). The radical scavenging activity (%) was calculated using the formula: ABTS, (%) = $[(A_{control} - A_{sample})]/(A_{control})] \times 100$.

RESULTS

Figure 1 illustrates the solution samples before and after film formation. The samples containing silver nanoparticles reduced by aloe gel (samples 1 and 3) exhibit noticeable opalescence compared to the control samples. Deposits of metallic silver are also

observed in control sample 5, attributed to light-induced degradation rather than reduction by bioactive compounds. Additionally, the pink coloration of the samples is attributable to compounds present in the aloe gel, while the metallic colloids contribute a subtle reddish hue.

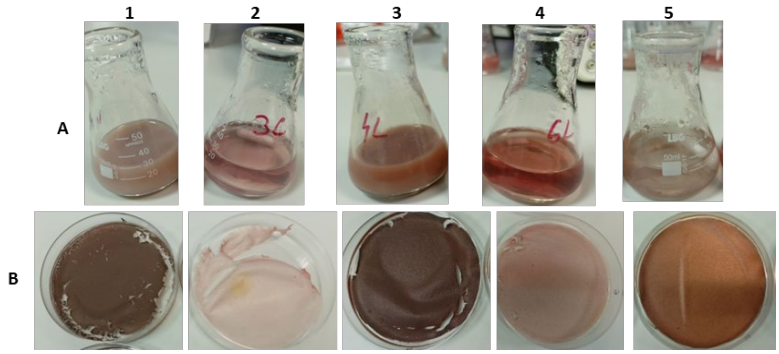


Figure 1. Samples (A) before and (B) after drying

The physical and chemical properties of the samples are shown in Table 2. In this study, the distinct coloration of the films offers an advantage for packaging applications, as it effectively reduces UV light transmission, helping to protect food from degradation. Furthermore, the observed water activity index below 0.6 in the AgNP samples suggests microbiological stability during storage, enhancing the protective features of the packaging.

Table 2. The main properties of agar-based silver nanoparticles material

Sample	*Physical and chemical evaluation*					
	Thickness	Color				Solubility
	T, mm	L*	a*	b*	C*	a_w
1	0.231 ± 0.045	29.42 ± 0.27	4.31 ± 0.31	5.13 ± 0.43	10.40 ± 0.17	0.556 ± 0.028
2	0.082 ± 0.017	62.75 ± 0.42	5.00 ± 0.34	5.75 ± 0.18	8.94 ± 0.23	0.571 ± 0.032
3	0. 107 ± 0.016	27.87 ± 0.14	6.54 ± 0.21	5.02 ± 0.37	12.52 ± 0.14	0.596 ± 0.019
4	0. 082 ± 0.026	55.43 ± 0.72	9.95 ± 0.30	7.98 ± 0.24	15.39 ± 0.29	0.605 ± 0.041
5	0.041 ± 0.003	39.31 ± 0.25	10.74±0.18	10.34 ± 0.36	21.21 ± 0.34	0.614 ± 0.036

The FTIR spectra of agar-based AgNPs are illustrated in Figure 2. The nanocomposite films exhibit absorption bands at approximately 3270 cm^{-1} and 2910 cm^{-1}, corresponding to O-H stretching and C-H stretching vibrations, respectively [12]. The peak observed around 1590 cm^{-1} in spectra of samples without AgNPs (1 and 3) indicates the presence of amino groups (NH_2) characteristic of the polysaccharide structure. An absorption band near 1732 cm^{-1} is associated with the stretching vibration of the –C=O group. Notably, a shift in the peak from 1034 cm^{-1} to 1023 cm^{-1} was detected in the sample prepared with oven-dried aloe gel. Additionally, the FTIR spectra reveal a characteristic peak at 770 cm^{-1}, attributable to aromatic group vibrations. Overall, the FTIR spectra of the agar/AgNPs composite films closely resemble those of the control film, with no formation of new peaks, suggesting that no significant chemical bonding occurs between agar and AgNPs.

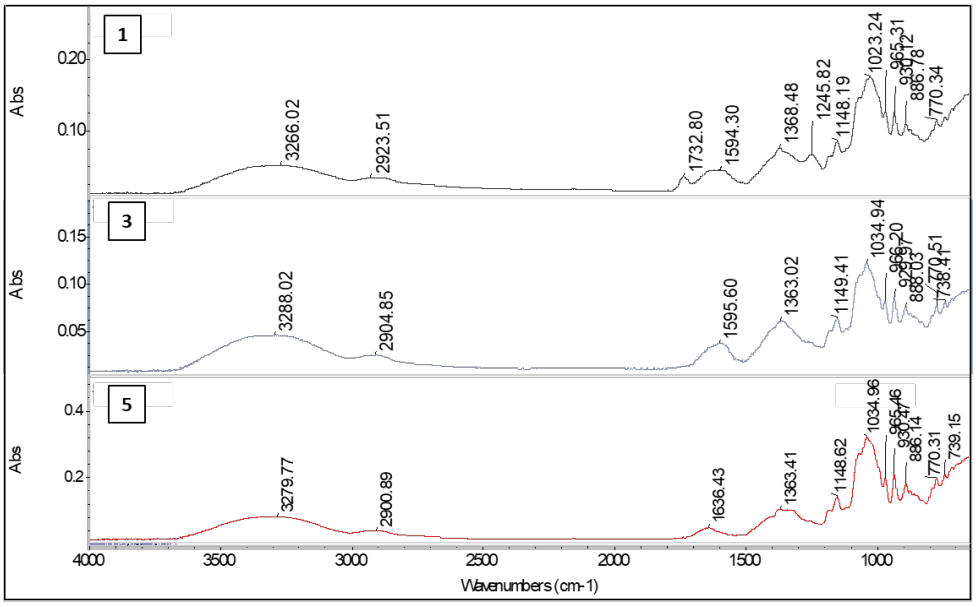


Figure 2. Microstructure FT-IR spectra for agar-based films with silver nanoparticles: (1) formed in the presence of oven dried aloe gel; (3) formed in the presence of freez dried aloe gel; (5) control sample without aloe extract

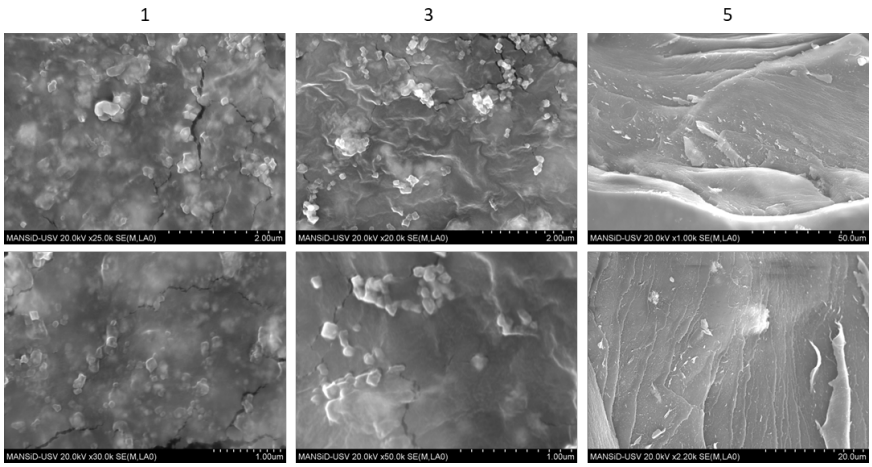


Figure 3. SEM images of nanoparticle films: (1) formed in the presence of oven dried aloe gel; (3) formed in the presence of freez dried aloe gel; (5) control sample without aloe extract

The surface microstructure of films with and without AgNPs was analyzed using scanning electron microscopy (SEM), as depicted in Figure 3. The SEM images reveal a high density of AgNPs and confirm that the agar/AgNPs films possess smooth surfaces with uniformly dispersed silver particles. The incorporation of aloe gel extract has notably stabilized the silver nanoparticles, in contrast to the control films. This morphological change is primarily attributed to the addition of AgNPs, which effectively integrates into the polymer network, filling its mesh. The SEM images also reveal fibrillar formations characteristic of agar polysaccharides. Additionally, the AgNPs observed are predominantly rectangular in shape. Antioxidant activity was assessed using the ABTS radical scavenging method. Analysis of the results, as

illustrated in Table 3, reveals that the highest inhibition percentages were observed in the agar/AgNPs films, with values of 85.34% for the oven-dried gel and 85.39% for the freeze-dried gel, indicating no statistically significant differences between them. In contrast, the control sample without gel extract demonstrated a significantly lower inhibition percentage of 27.77% ($p < 0.01$). Notably, films without silver nanoparticles (samples 2 and 4) also exhibited antioxidant activity, with the freeze-dried gel film showing a substantial inhibition of 74.13%, significantly higher than the 41.06% observed in the oven-dried gel film.

Table 3. Antioxidant capacity of analysed samples (n=3)

Sample	Inhibition percentage %	Standard Deviation
1	85.345	±1.792
2	41.066	±1.792
3	85.394	±2.607
4	74.133	±2.08
5	27.775	±1.169

DISCUSSION

In this study, silver nanoparticles (AgNPs) were synthesized using a green approach with dry *Aloe vera* gel acting as both a reducing and capping agent. Acemannan, a bioactive polysaccharide in *Aloe vera*, likely aids in capping the reduced AgNPs through its hydroxyl and acetyl groups [13]. In alkaline conditions, acemannan forms a hydrogel via cross-linking, and the presence of Ag^+ ions facilitate their reduction, creating a network of AgNPs [14]. The initial color change from colorless to reddish-brown arises from the absorption of visible light (380–450 nm) due to the excitation of surface plasmon resonance in AgNPs [15].

The material thickness is crucial for food packaging, where minimal thickness is preferred to prevent interference with the food. Here, film thickness significantly increased ($p < 0.01$) with AgNPs addition, contrasting findings by Rhim et al., where agar/AgNP films showed negligible thickness changes with nanoparticle inclusion [16]. Similarly, other studies have observed slight thickness increases with solid content in agar/AgNP films prepared via laser ablation [12]. The films displayed a desirable water activity index (wa) below 0.6, suggesting microbial stability and suitability for food preservation, as this low index inhibits microbial growth. In industrial settings, maintaining a low w_a index can often reduce the need for additional microbiological testing, minimizing contamination risks [17].

The FTIR and SEM analyses show a stable, uniform AgNP distribution within the agar matrix, providing the films with beneficial properties for packaging. Notably, SEM images revealed a rectangular morphology of AgNPs, differing from the spherical forms reported in laser-ablation-synthesized agar/AgNP films [24]. This variation in shape may reflect differences in synthesis conditions or the influence of bioactive compounds in the aloe extract. Interestingly, even films without AgNPs exhibited significant antioxidant activity, especially in freeze-dried samples, suggesting that freeze-drying better preserves active compounds than oven drying. This effect, combined with AgNP stabilization, enhances the films' protective capabilities, making them promising for food packaging applications that require microbial stability and UV protection.

Additionally, the consistent antioxidant activity in AgNP films indicates that silver ions may play a role in stabilizing the bioactive properties over time.

CONCLUSION

This study successfully synthesized silver nanoparticles (AgNPs) using *Aloe vera* gel as a natural reducing and capping agent, achieving a distinct reddish-brown color characteristic of surface plasmon resonance. The green synthesis method confirmed that *Aloe vera* gel can facilitate efficient AgNP formation, contributing to enhanced bioactivity in agar-based films. These films exhibited high antioxidant activity, with inhibition percentages reaching 85.39% in freeze-dried aloe gel samples. Structural analysis revealed that AgNPs were evenly distributed within the films, attributed to the stabilizing properties of *Aloe vera*, which maintained a smooth surface morphology and mechanical stability even in films with reduced thickness. Additionally, a water activity index below 0.6 indicated microbiological stability, a key requirement for food preservation. This study suggests that *Aloe vera*-mediated AgNP films are highly suitable for food packaging applications, offering protective qualities through antioxidant and antimicrobial effects. These findings highlight the potential of integrating biopolymers and natural stabilizers in developing sustainable, functional packaging materials.

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CIRCULAR ECONOMY IN CONSTRUCTION AS AN ELEMENT OF THE GREEN BUILDING PHILOSOPHY

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ABSTRACT

Construction is a branch of the economy that occupies a leading place in waste production. The problem is both the demolition of buildings ending their activity and the construction process itself. During the demolition process, waste is segregated, and most often concrete and brick rubble is recycled. In addition, wooden and wood-based elements, metal and glass are most often recycled. However, there is still a large amount of mixed waste, which often contains hazardous waste. It is necessary to store them safely. Another problem is waste generated during construction. The largest percentage of their mass is packaging. In construction practice, they are most often transported to companies that deal with their segregation and partial processing as mixed waste. However, in the idea of a closed-loop economy, in addition to waste processing, it is about reducing the negative impact on the environment associated with, among others, the transport of this waste. The article proposes the possibility of using some packaging waste directly on the construction site. A scheme of processes allowing waste processing on the construction site and using them to produce elements used on site is presented. This approach allows for the implementation of the Green Building philosophy in a more comprehensive form.

Keywords: circular economy, construction waste, Green Building

INTRODUCTION

The development of any branch of the economy is inextricably linked to the generation of waste, and the construction industry is one of the biggest producers of this type of environmental hazard. Large amounts of waste are generated during construction works as well as other stages of a building's life cycle, and this waste needs to be handled. Over 30% of waste generated in the European union, which corresponds to 800 tons of waste annually, originates from the construction sector [1, 2, 3 4]. This is a global issue, which motivates the European Parliament to take measures in order to reduce the emission of waste and to maximise its recycling. Numerous regulations and directives issued by the European Union contain many suggestions and recommendations aimed at improving the situation, e.g. companies are recommended to draw attention to the efficient use of resources, or to support initiatives undertaken to improve the use of the waste they generate [19, 20].

Construction waste management should be based on the hierarchy of activities in compliance with the applicable regulations. First and foremost, a construction process

should be planned and conducted so as to reduce the amounts of waste generated. The waste that is nevertheless generated should be prepared for reuse, and it is best to consider the possibility of waste processing at the site from which it originates. Further recommended actions include recycling, other recovery technologies and, finally, waste disposal [5, 6]. Reusing and recycling construction waste opens up many opportunities for creative building design and construction. Circular architecture, which aims to make designs of buildings in accordance with the principles of circular economy, is an example of such innovative solutions. According to circular architecture, it is recommended to design buildings which involve the use of recycled materials, and which are shaped in a way that will make it possible to recover some component parts of these buildings in the future, at the time of demolition [7, 8]. Figure 1 shows a linear model of a construction approach considered traditional, whereas Fig. 2 illustrates the circular model.

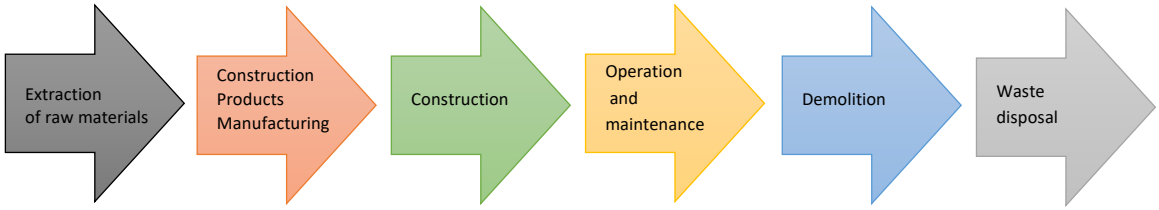


Fig. 1. Linear model of construction

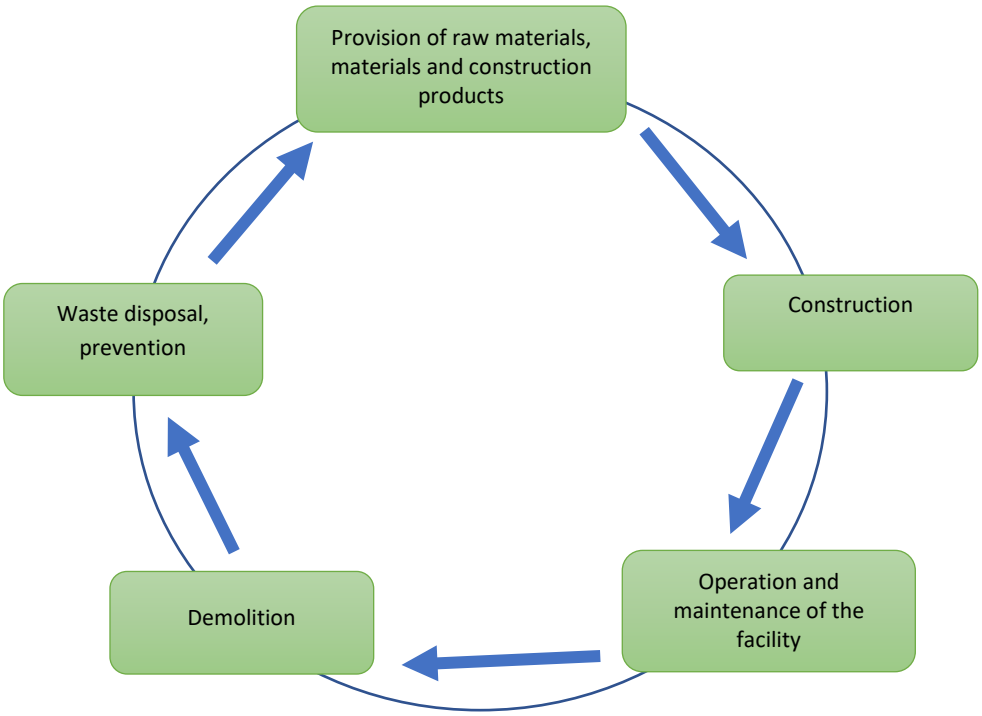


Fig. 2. Circular model of construction

In order to implement the waste management principles, it is necessary to ensure that different types of waste are properly sorted out on site [19, 20]. For this purpose, among other aims, a catalogue of waste has been developed, and construction waste was included in Chapter 17 – waste from construction, renovation and demolition of

buildings and road infrastructure, including excavated soil from contaminated areas. The catalogue is divided into chapters and subchapters, as demonstrated in Table 1.

Table 1. The catalogue of the waste from construction, renovation and demolition of buildings and road infrastructure

Code	Chapters, subchapters
17	Waste from construction, renovation and demolition of buildings and road infrastructure (including excavated soil from contaminated areas)
17 01	Waste from building materials, elements and road infrastructure (e.g. concrete, bricks, tiles, ceramics)
17 02	Wood, glass and plastic waste
17 03	Bituminous mixtures, coal tar and tarred products
17 04	Metallic and metal alloy waste and scrap
17 05	Soil and stones (including soil and stones from contaminated areas and dredging spoil)
17 06	Insulation materials and construction materials containing asbestos
17 08	Gypsum-based construction materials
17 09	Other mixed construction and demolition waste

Source: [19, 20]

Apart from construction waste listed in Chapter 17, any construction project also generates large volumes of packaging waste. These are classified in Chapter 15 subchapter 01, and comprise packaging from paper, cardboard, plastics, wood, metal, glass, textiles, mixed and contaminated. All kinds of waste mentioned above appear at a construction site.

In line with the circular economy, the right approach to waste primarily ensures closing of the loop in accordance with a circular scheme that brings together the launching of building works and the termination of a building's useful life and its demolition [9, 10, 11]. When designing buildings in compliance with the Green Building philosophy, architects and constructors are recommended to take into account elements which will be submitted to reusing when the building is torn down, or recycled; however, they are also advised to design a building in a way that will maximise the amount of construction materials and elements that will be reusable [12, 13, 14]. The waste generated during construction works and the associated processes are mentioned far less frequently. However, a considerable amount of waste must be dealt with at this stage. Construction of a typical single-family house generates about 10 tons of waste. When larger buildings are raised, this amount will increase many-fold. Disposal of construction waste from a building site generates additional economic, social and environmental costs [15, 16, 17]. In a costs-breakdown of a construction project, the contribution of costs incurred by the disposal of waste can be up to 10% of the total costs related to the development. The exact percentage of these costs in total costs depends on the character of construction works and technologies employed, as well as the size of a development. The social and environmental costs are mostly due to the need to transport large amounts of waste, often over long distances. In view of the above considerations, the authors of this article

decided to review a solution which would facilitate the handling of the largest possible mass of waste on a construction site so as to reduce the costs of transport and, above all, the environmental costs thereof [18, 19].

MATERIALS AND METHODS

The research begins with a review of the relevant literature and an analysis of source materials and information (stage 1 in the diagram). The materials and data submitted to the study were collected during site visits and seminars held for contractors of construction works. Data pertaining to quantities and structure of waste as well as distances over which waste had to be transported were summarised. This enabled us to define the research problem.

The subsequent stage aimed to identify benefits achieved from limiting amounts of waste removed from a construction site. Also, problems arising from the fact that waste was managed on a building site were determined. The next step was to suggest a solution that would help to reduce the stream of waste discharged from a construction site. The last step was to summarise the research and suggest conclusions based on the solution proposed. The research process is illustrated in fig. 3.

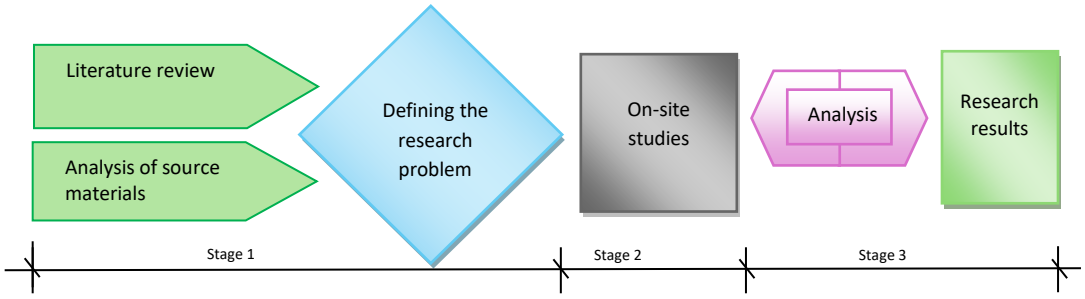


Fig. 3. The research process

RESULTS

In line with the circular economy and its foundations, we speak of a closed circle of construction materials and products, but the whole circle closes when a building is demolished. It seems justified to add to the circle smaller loops that will take into account the use of waste at the construction site where this waste is generated. This may also apply to the stage of preparing and producing construction materials and products, as well as later stages, such as construction itself or the useful life of a building (fig. 4)

Because most of mixed construction waste is generated on a construction site, the objective of this research was how such waste could be utilized on site. This approach calls for certain organisational measures, including such planning of a construction site that provides enough space to store and process the waste (fig. 5).

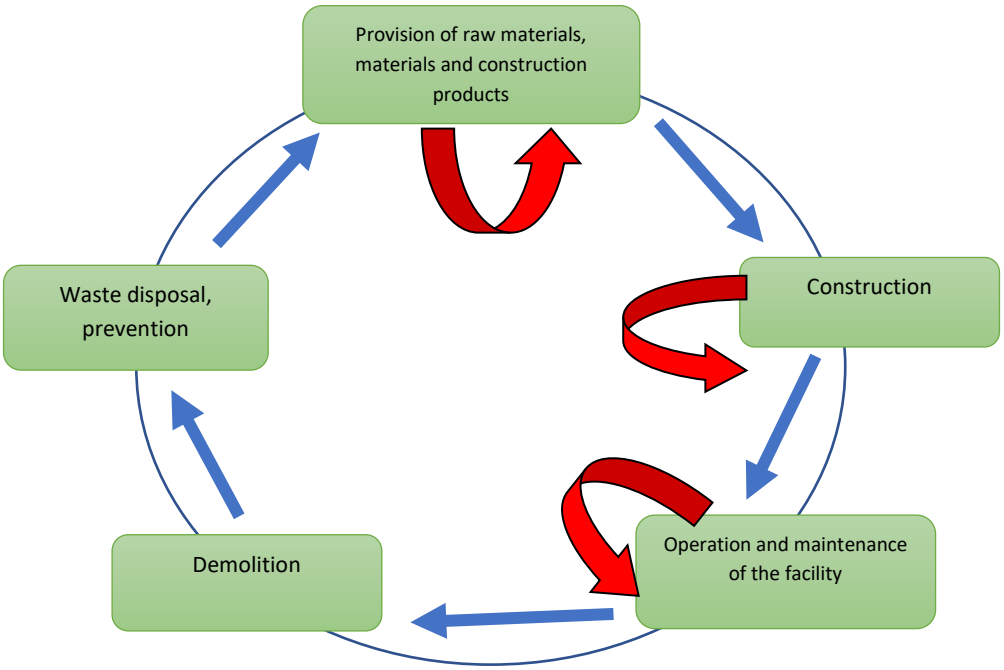


Fig. 4. Modernized circular economy scheme in construction

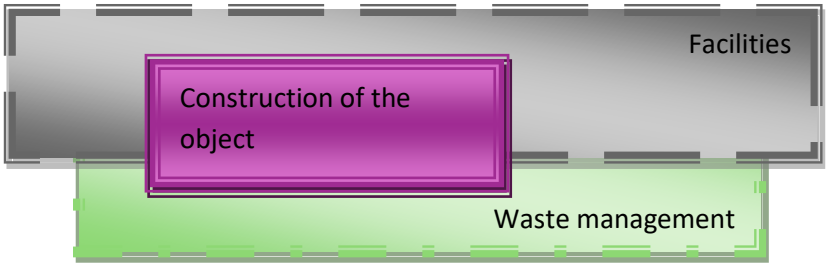


Fig. 5. Organization chart of the planned construction

Following the hierarchy of steps in a procedure recommended by regulations on waste, the possibility of processing waste on a construction site deserves special attention. A variety of methods and technologies can be employed to process waste where it is generated. One option is to crush it. Crushing can be applied to construction debris, styrofoam from insulation works and packaging, and to glass. Crushed material can be then used as insulating backfill, an additive to concrete and mortar (partial aggregate substitute) or as a soil improver in landscaping after the completion of construction works. Another method is the fragmentation of materials that cannot be crushed, for example plastics, paper, textiles, but which can be added to concrete mixture or mortars after shredding. Some of such shredded waste can also be used as different types of loose levelling or insulating layers, and in the landscaping of the surroundings of buildings under construction. Styrofoam can also be dissolved using organic solvents. The resulting liquids can be used for hydroinsulation or as impregnates. In order to be able to carry out such waste processing on a building site, it is necessary to create a waste management area (scheme on fig. 6). It should include a selective waste collection and storage point, a place for waste processing, a place for preparation for the use on the construction site, points for the production of concrete mixtures with the

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addition of shredded waste, and production of construction products from such mixtures. Our research has led us to the following solution, illustrated in fig. 6

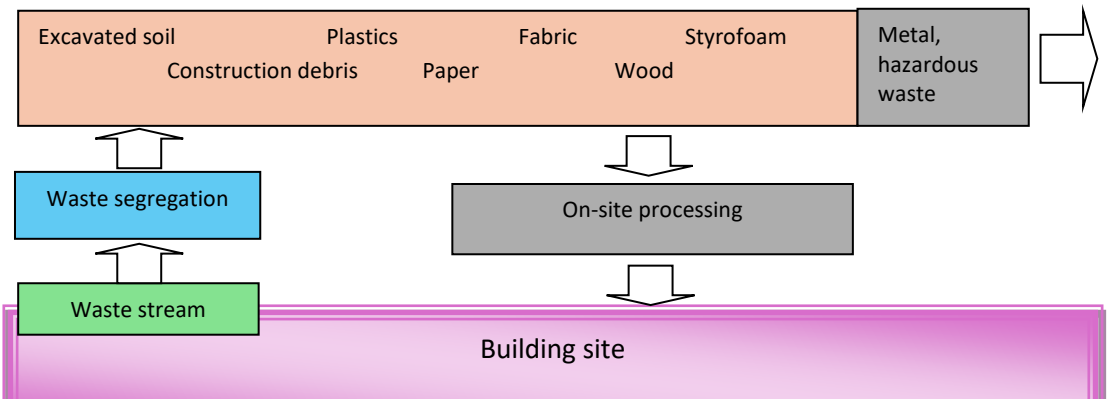


Fig. 6. Proposal for a solution for the new circular economy proposal in construction

It is also necessary to arrange a place for storing the waste that cannot be processed or reused on the construction site. These include hazardous waste, paint and varnish residues, paint and varnish packaging, metal, roofing paper and mastic waste.

DISCUSSION

There are many solutions enabling the processing of waste on a construction site. Their implementation creates opportunities for reducing the stream of waste originating from building works. Considering the fact that approximately 80% of such waste can be recycled, the suggested approach seems noteworthy. The solution proposed in this paper envisages the processing of some construction waste, which gives measurable benefits for contractors and investors. For example, there is less waste that must be transported away from a construction site, which means the associated costs are lower. Furthermore, the use of recycled materials leads to a lower demand for such building materials as aggregate or loose insulation materials. Besides, with good work organisation, it is possible to use shredded construction waste as an additive to concrete and to make small concrete products, for instance paving tiles, plant pots, walls, needed for the landscaping of a site. Such products can be made from mixtures containing shredded waste. The solution also aligns with the Green Building Policy, and helps to diminish the negative impact of a development on the natural and social environment, mainly by decreasing amounts of generated waste, but also by reducing the burden of heavy road transport.

CONCLUSION

To summarise the results of our study, the proposed solution seems to set a good direction in the framework of construction waste management theories. The most important conclusion drawn from this study is that the waste generated during a construction project is best to be managed on the construction site, and consequently this will help to supplement the circular construction cycle scheme. Obviously, both the actual plans to create such waste processing facilities on a construction site, including waste processing technologies implemented, and the use of recycled materials can vary. Having refined the solutions adjusted to the technologies used on a given building site, it is possible to develop a unique solution that will be best suited for a given

development project. Both waste recycling technologies and possibilities of manufacturing new building materials or products with the use of processed construction waste deserve further research, including laboratory tests. The proposed solution allows for some reduction of the waste that must be removed from a construction site, less transport and consumption of fuels, less pollution caused by motor vehicles, reduction of the traffic load on roads, and less noise on roads, which all contribute to the implementation of the Green Building Policy.

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EFFECT OF CLIMATE CHANGE ON INFRASTRUCTURE – CROATIAN PERSPECTIVE

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ABSTRACT

Although the construction sector is aware of climate change, it still does not have sufficient knowledge of its impact on infrastructure and a detailed strategy for possible adaptation and mitigation measures. The strategy for adaptation to climate change in the Republic of Croatia is presented in this paper, with a focus on measures for the construction sector. Croatia is one of the three most vulnerable countries in the European Union, with an estimated highest share of climate change damage in relation to gross national income. Based on the presented climate change projections for Croatia for the period up to 2040 and 2070, an analysis of the impact of various climate parameters on bridges and other infrastructure, including various construction sectors, is presented. In general, the impacts of climate change on infrastructure can be systematized into two groups: extreme weather conditions such as floods, strong winds and storms, which can lead to the collapse of an infrastructure or part of it, and progressive changes such as a gradual increase in air temperature, relative humidity and concentration of greenhouse gases, which will have a long-term impact on shortening the service life of infrastructure. The focus in this paper is on bridges and concrete structures, but the findings presented are also applicable to other infrastructure.

Keywords: climate change, infrastructure, bridges, concrete structures, construction sector

INTRODUCTION

The consequences of climate change can be observed on a daily basis all over the world in the form of floods, droughts, severe storms, hurricanes and tornadoes, fires, rising sea levels and temperatures, etc. The intensity and frequency of extreme weather events has increased significantly in recent years and is expected to accelerate further. Climate change has a significant impact on infrastructure, which will continue to increase in the future, especially on bridges and other strategic structures with longer service lives that are exposed to aggressive environments and climate.

In general, the effects of climate change on infrastructure can be categorised into two groups: extreme weather conditions such as floods, strong winds and storms, which can lead to the collapse of an infrastructure or part of it, and progressive changes such as a gradual increase in air temperature, relative humidity and concentration of greenhouse gases, which will have a long-term impact on shortening the service life of infrastructure.

Croatia is one of the most biodiverse countries in Europe. There are four types of biogeographical regions in Croatia: Mediterranean along the coast, Alpine in the high

mountains of the Lika and Gorski Kotar regions, Pannonian in the valleys of Drava River and Danube River; and continental in the remaining areas. It is therefore not surprising that Croatia has experienced many different consequences of climate change in the last decade (Figure 1), such as major floods in eastern Croatia, fires on the coast, snowstorms in the mountains and strong bora winds on the coast in winter, supercell storm in Zagreb and heatwaves throughout the country in summer. In addition, Croatia is one of the three most vulnerable countries in the European Union, with the estimated highest proportion of climate change damage in relation to gross national income.

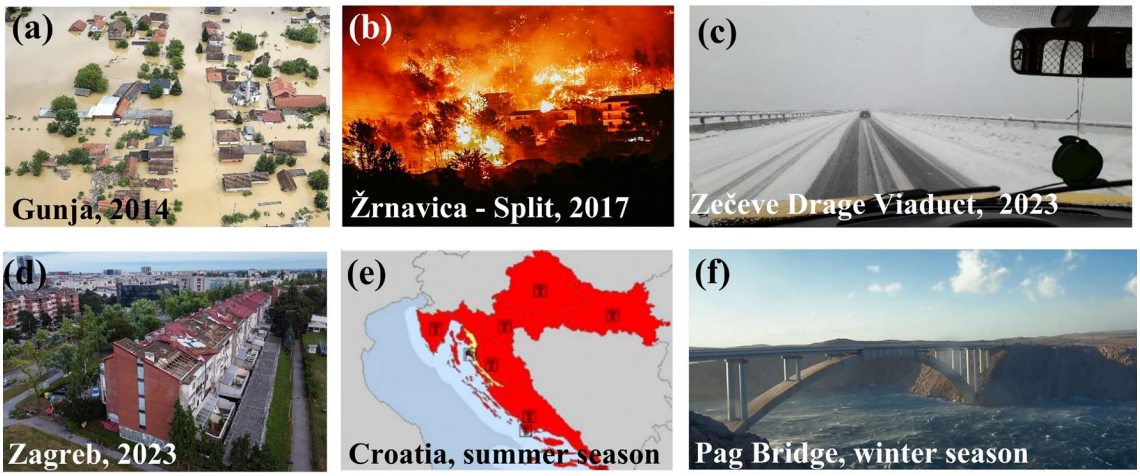


Figure 1. Some consequences of climate change in Croatia: (a) flood, (b) fire, (c) snowstorm, (d) Zagreb after supercell storm, (e) heat waves, (f) strong wind

MATERIALS AND METHODS

This research comprises two parts [1]. The first part analyses the strategy for adaptation to climate change in Croatia for the period up to 2040 with a view to 2070 [2], which was adopted by the Croatian Parliament in 2020, and highlights measures related to infrastructure and the construction sector. The strategy was adopted on the basis of extensive reports from experts in the fields of climate modelling, water and marine resources, hydrology, agriculture, forestry, biodiversity, fisheries, tourism, spatial planning and management of coastal areas, construction, health and risk management.

The second part of the research analyses a climate change projection for Croatia for the periods up to 2040 and 2070 and identifies possible impacts on infrastructure. The climate change projection is developed using the regional climate model RegCM4 as part of a strategy for adaptation to climate change in the Republic of Croatia [2]. The current "historical" climate covers the period 1971–2000 and forms the reference period labelled P0. In developing an adaptation strategy for the Republic of Croatia, two climate scenarios were considered, RCP4.5 and RCP8.5, which represent a future in which mitigation and adaptation measures are envisaged, in which GHG concentrations (greenhouse gases) increase until 2040 and then decrease (RCP4.5); and a future in which no significant mitigation and adaptation measures are envisaged, i.e. a continuous increase in GHG concentrations (RCP8.5) [1,2].

RESULTS

A. Measures of the strategy of the Republic of Croatia for adaptation to climate change relevant to the construction sector

The strategy for adaptation to climate change in Croatia for the period up to 2040 with a view to 2070 envisages 80 measures for 10 sectors and three general measures of very high importance. Table 1 shows the number and importance of measures by sector and their relevance for the construction sector. Of the 83 measures, 19 relate to the construction sector. Construction-related measures are mainly found in two sectors: Water Resources and Spatial Planning and Design, but construction-related measures can also be found in other sectors: energetics, health, tourism, biodiversity and risk management [1,2]. Most of these measures are non-structural measures, e.g. measures focusing on raising awareness and knowledge about climate change, risk monitoring and the need for adaptation. Only a small proportion of the measures consist of structural measures, including the construction of mitigation facilities and other technical measures that are closely linked to the building sector. These measures focus primarily on hydrology, the management of water and marine resources and spatial planning [1].

Table 1 Measures of the strategy of the Republic of Croatia for adaptation to climate change and their relevance to construction sector

Sector	Measures		
	Level	Quantity	Relevant to construction sector
Water resources	Very high importance	3	2
	High importance	3	3
	Middle importance	4	0
Agriculture	Very high importance	5	0
	High importance	3	0
	Middle importance	1	0

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Forestry	Very high importance	4	0
	High importance	2	0
	Middle importance	6	0
Fisheries and aquaculture	Very high importance	7	0
	High importance	2	0
	Middle importance	1	0
Biodiversity	Very high importance	4	0
	High importance	2	0
	Middle importance	3	1
Energetics	Very high importance	3	1
	High importance	2	0
	Middle importance	2	0
Tourism	Very high importance	4	1
	High importance	1	0
Health	Very high importance	3	0
	High importance	3	1
	Middle importance	3	1
Spatial planning and arrangement	Very high importance	4	4
	High importance	1	1
Risk management	Very high importance	3	1
	High importance	2	0
General measures	Very high importance	3	3
Total		**83**	**19**

B. Projection of climate change in Croatia with impact on infrastructure

According to [2], the optimistic scenario of RCP4.5. in the Republic of Croatia predicts a smaller increase in total precipitation in winter and spring and a decrease in autumn and summer with an increase in dry periods. Observations in the period 1961–2010 showed a trend towards rising air temperatures throughout Croatia. An almost uniform increase in the average annual air temperature is expected until 2040, with a further increase until 2070. The increase in the maximum air temperature could reach 2.3°C by 2070. The largest increase in minimum temperature occurs in winter in the coldest region of Gorski Kotar. The increase in hot days is between six and eight days in most parts of Croatia and will increase further to 12 days by 2070, which would mean an almost doubling of hot days for the mountain regions. In the area with the strongest wind in the climate, a decrease in the maximum wind speed in winter was expected. Evapotranspiration will increase and soil moisture will decrease. Humidity will increase throughout the year, especially in summer in the Adriatic region. The decrease in snow cover in the Gorski Kotar region is about 50% of the reference value. The estimates for sea level rise were not determined by the RegCM model, but the results were taken from the IPCC AR5, and the conclusions were drawn on the basis of research by local authors and observations of the current trend of changes in the mean water level of the Adriatic Sea. According to the results of the global models, the expected rise in global mean sea level by the middle of the 21st century is 19–33 cm under RCP4.5 and 22–38 cm under RCP8.5 [1,2].

DISCUSSION

A. Measures of the strategy of the Republic of Croatia for adaptation to climate change relevant to the construction sector

Most of the measures in the adaptation strategy of the Republic of Croatia to climate change that are relevant for the construction sector belong to the so-called "non-structural" measures. The reason for the lower number of structural measures related to the construction sector is that experts from the construction sector were not involved in the development of the Croatian Climate Change Adaptation Strategy. For this reason, the construction sector, both in Croatia and globally, needs to systematically reflect on the impact of climate change on structures and, consequently, on measures to adapt and reduce the effects of climate change.

According to global building practices and scientific evidence, there is a need for structures that are more resilient to climate change conditions. In addition, more durable buildings preclude more frequent demolition and new construction cycles, i.e. they reduce material consumption and lower the carbon footprint. Finally, it is necessary to develop appropriate and accurate systems for monitoring and maintaining the buildings themselves, as climate change has many implications for the safety and durability of buildings.

B. Projection of climate change in Croatia with impact on infrastructure

After analyzing the projections of climate change, it can be concluded that the effects of climate change on infrastructure are felt in all areas of civil engineering, from hydraulic engineering, geotechnics and load-bearing structures to building materials, construction organization and management, as well as on all regions in Croatia. Figure 2 shows the effects of climate change on bridges and the associated causes.

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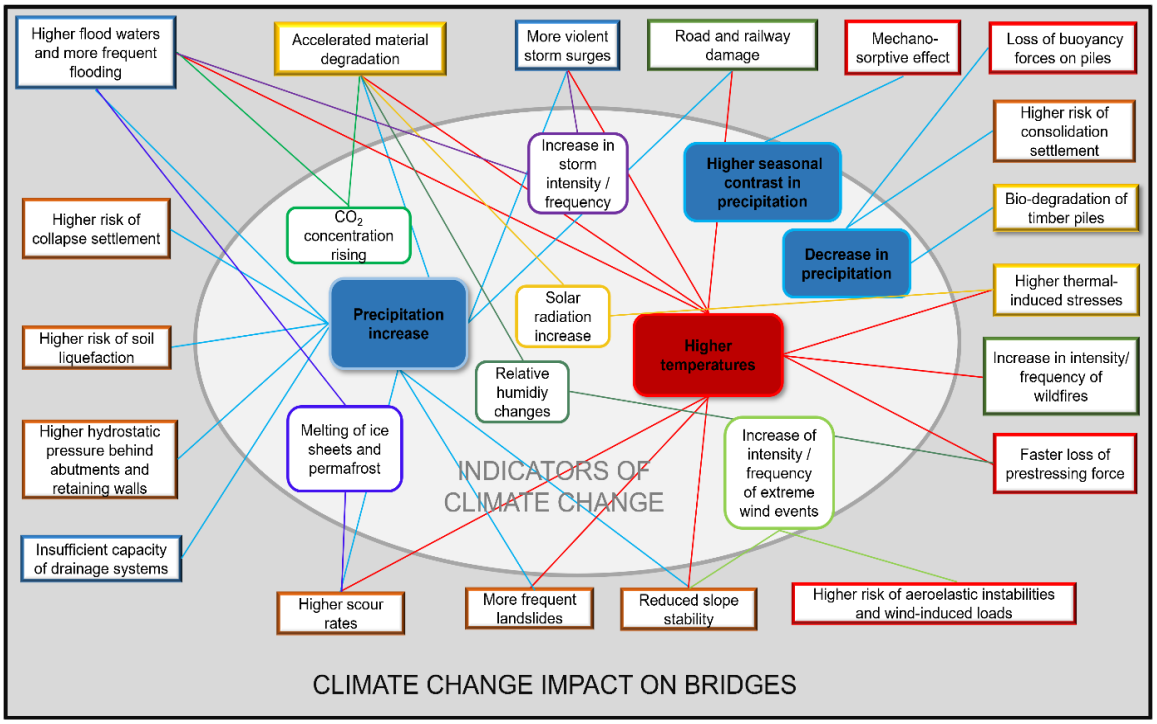


Figure 2. Impact of climate change on bridges [1]

For a detailed analysis, the effects of climate change on infrastructure are categorised into two groups: extreme events and progressive changes. Extreme weather conditions such as flooding and heavy rainfall lead to bridge scour, soil liquefaction and foundation collapse, insufficient capacity of drainage systems, landslides, road and railway damage, accelerated material degradation and reduced slope stability. Strong storms and gusts of wind lead to the failure of structural elements (light roofs, façades) and the collapse of light and/or temporary structures. Heat waves and sudden temperature fluctuations lead to major thermal stresses, deformations, unserviceability of structures and infrastructure due to buckling of rails, as well as problems and delays on the construction site due to poor working conditions.

Droughts and forest fires can lead to traffic disruptions, problems with supplies and the functionality (destruction) of infrastructure. Fires can sometimes destroy entire infrastructures, as in August 2023 in Hawaii, when an entire tourist resort was destroyed.

Progressive changes include rising sea levels, the concentration of greenhouse gases, relative humidity and air temperature. Sea level rise can lead to flooding in coastal areas and other associated problems similar to intense rainfall, e.g. foundation problems, damage to buildings and facilities, etc. In addition, seawater contains salt, which is very aggressive to materials and causes corrosion of steel in metal and reinforced concrete

structures. All progressive changes (rise in sea level, relative humidity, temperature and greenhouse gases concentration) lead to accelerated material degradation.

Most of the infrastructure in Croatia is made of concrete, and the situation is similar worldwide. The main degradation mechanism of concrete structures is the corrosion of the steel reinforcement in the concrete. Corrosion of reinforcement can be triggered by the presence of CO2, which causes carbonation, or by chloride ions from de-icing salts or seawater, and climate change can accelerate this degradation in several ways, as can be seen in Figure 2. The increase in greenhouse gases concentration, sea level and salinity accelerates initiation of reinforcement corrosion, while the increase in relative humidity and temperature causes a higher corrosion rate and faster deterioration of the structure.

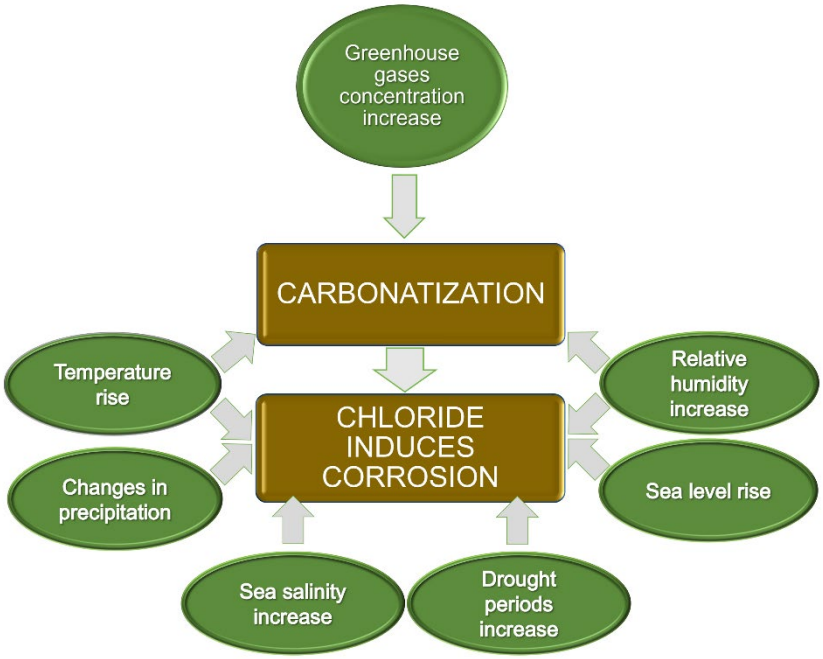


Figure 2. Climate change impact on reinforcement concrete corrosion [1]



Figure 3. Damage of bridge in Sisak-Moslovina County because of long-term deterioration caused by climate and environment and earthquake in December 2020

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Corrosion of steel in concrete is not just an aesthetic problem and a maintenance issue. Advanced corrosion reduces the load-bearing capacity and ductility of the structure and causes a redistribution of stiffness and stresses in the structure. Due to this deterioration process, frequent, expensive and complex repairs are required, and if these are not carried out in time, the structure may collapse, especially in a multi-hazard environment. This was the case with several bridges after the 6.3 magnitude earthquake near the town of Sisak in Croatia (Figure 3). As a result of irregular maintenance of the structure and corrosion of the reinforcement due to carbonation and de-icing salts, the deterioration of the structure accelerated, and a strong earthquake damaged the bridge to such an extent that it could no longer be used.

In addition to the fact that climate change reduces the resistance of the structure due to accelerated deterioration, it also has the effect of increasing the action on the structures. The basic rule in the design of structures is that the actions on the structure should be less than its resistance to these actions. Climate change therefore has a doubly unfavourable effect on buildings. The only positive effect on buildings may be a reduction in the snow load. On the other hand, the increase in wind load, thermal stresses, ground settlement, load on foundation will increase action on the structure.

CONCLUSION

On the basis of the research presented, the following conclusions are drawn.

Infrastructures, such as bridges, have a lifespan of 100 years or more. Existing and new structures are exposed to the current and future effects of climate change. Climate change has multiple impacts on reducing the stability, load-bearing capacity, serviceability and functionality of structures and infrastructure.

Measures to adapt and mitigate climate change are crucial in every sector, including construction. It is therefore important to recognise all possible impacts of climate change on buildings and infrastructure in order to define and implement adaptation and mitigation measures.

Buildings and their materials age and deterioration processes reduce the load-bearing capacity of the structure. Climate change will accelerate the deterioration of structures. By neglecting the influence of the environment and climate change during the service life, the load-bearing capacity (resistance) of the structure can be significantly overestimated – especially in the event of extreme events such as an earthquake.

Codes and requirements for structures must be adapted to new environmental conditions and climate changes in order to make new buildings more resilient to extreme weather conditions and natural disasters.

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ENVIRONMENTAL ASSESSMENT OF VENTILATION DUCTS IN AN EDUCATIONAL BUILDING: A ROMANIAN CASE STUDY

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ABSTRACT

Accounting for 40% of final energy consumption and 34% of emissions in the European Union, buildings have a significant role to play in achieving a carbon neutral Europe before 2050. But to make buildings more sustainable we need to assess and reduce carbon emissions at every stage of their life cycle, from construction materials to ongoing energy use.

As heating, ventilation and air-conditioning (HVAC) systems are the primary energy consumers in buildings, they offer significant potential for energy saving and it is imperative to assess the environmental impact of the materials used in these systems. This study evaluates the environmental footprint of an HVAC system from an educational building in Romania, through the methodology of life cycle assessment using One Click LCA software, focusing on the impact of different types of ventilation ducts, namely rectangular and circular. Our initial analysis revealed that energy use and materials production were the primary contributors to global warming. Within the HVAC system, the air handling unit and the ventilation ducts had the most significant impacts, with emissions gradually decreasing as we transitioned from rectangular to circular ducts shapes.

We also investigated how a country's national energy mix and transportation distances affect the environmental impact of a circular ventilation duct. Due the lack of a comprehensive database of Environmental Product Declarations (EPDs) within the software, this analysis relied also on an EPD produced for Romania, which awaits verification. Our findings revealed that encouraging local sources materials and energy from renewable sources for ventilation ducts reduces the environmental impact of the whole HVAC system.

Keywords: environmental impact, ventilation duct, HVAC, educational building

INTRODUCTION

In the current energy and climate context, where demographic, economic and technological development leads to increased energy demand and greenhouse gas emissions, the building sector plays a key role. As a cornerstone of the global economy, the building sector faces ongoing challenges. Despite its dynamism, it's a major driver of energy consumption and greenhouse gas emissions, accounting for 40% of energy use and 34% of emissions in the European Union [1].

To achieve the objective of climate neutrality by 2050, buildings can be a significant component of our transition to a future with net-zero greenhouse gas emissions [2]. However, the decarbonization of the building sector necessitates the implementation of

mandatory measures, including the promotion of energy efficiency, the establishment of rigorous building standards, the integration of design and energy systems, the renovation of existing structures, the utilization of low-carbon materials, and a transition from conventional fossil fuels towards more efficient and environmentally friendly technologies based on renewable energy sources [3].

Over its lifetime, a building's carbon footprint, known as "whole-life carbon", consists of operational and embodied carbon. Operational carbon refers to the emissions related to energy consumption during the operational phase of the building, whereas embodied carbon encompasses emissions associated with the building materials from the extraction to the final disposal [3-5].

Heating, ventilation and air-conditioning (HVAC) represents the largest end-use of energy in buildings, offering significant opportunities for both energy saving and environmental sustainability, and due to rising thermal comfort and air quality standards, HVAC systems are becoming increasingly crucial in all buildings [6,7]. But, in tandem with the rising need for sustainability and energy efficiency, there is a greater emphasis on selecting materials that are both environmentally friendly and energy efficient, analyzing their impact throughout their entire lifespan [8]. Life cycle assessment (LCA), a comprehensive approach for assessing the environmental impact of a product or service throughout its entire existence, is increasingly being used to make informed decisions about sustainability [9].

While scientific literature abounds with life cycle assessments, the HVAC industry, particularly ductworks, remains understudied [7,10-12]. Also, the assessment of environmental impact of materials in the energy supply systems, such as HVAC, is largely hampered by a lack of data from the producers. In response to the urgent environmental challenges and the increasing focus on sustainability, this study aims to conduct a thorough LCA of HVAC systems in an educational building. The goal is to offer valuable insights that can inform decision-making related to the selection of HVAC ductwork, encourage the local sourcing of raw materials, and facilitate the shift of production facilities to renewable energy sources. Ultimately, this research seeks to minimize the environmental footprint of ventilation ducts and, by extension, the entire HVAC system.

MATERIALS AND METHODS

The present study employs the LCA methodology using One Click LCA software [13], to assess the environmental impact of an HVAC system in an educational building, with a particular emphasis on the influence of different ventilation duct types.

The educational facility, namely the Faculty of Building Services Engineering is situated in Cluj-Napoca, Romania. Following a major refurbishment and modernization, started in 2005, a new Amphitheatre was built, establishing itself as the largest Amphitheatre within the Technical University of Cluj-Napoca. A dedicated rooftop HVAC system serves the Amphitheatre. The system comprises rectangular ventilation ducts made from galvanized steel, mounted in the suspended ceiling, which carry the conditioned air from the air handling unit (AHU) rooftop mounted to the diffusers.

One Click LCA is a user-friendly software tool that streamlines LCA processes. Its intuitive interface and vast database of environmental impact data empower professionals of all levels to conduct sustainable assessments. Following EN 15978 and

EN 15804 guidelines, One Click LCA software provides a comprehensive assessment of HVAC system's environmental impacts [13,14]. It leverages life cycle carbon (LCC) and LCA methodologies, incorporating Environmental Products Declarations (EPDs) data, to analyze both carbon emissions and a broader environmental performance. Twelve indicators are used to assess the potential for: global warming (GWP), ozone depletion (ODP), acidification (AP), eutrophication (EP), photochemical ozone formation (POCP), abiotic depletion for fossil resources (ADPF), abiotic depletion for non-fossil resources (ADPE), use of renewable primary energy resources as raw materials (PERM), use of primary energy without raw materials (PERE), total use of renewable primary energy (PERT), total use of non-renewable primary energy (PENRT) and use of net fresh water (FW) [13].

The LCA modelling of the HVAC system considered solely the ventilation ducts, ceiling diffusers, extraction grills, noise attenuators, the AHU rooftop mounted and the annual energy consumption.

Despite its usefulness, the OneClick LCA software exhibited limitations, particularly in its reliance on incomplete EPDs for HVAC components, especially ventilation ducts and AHU rooftop mounted. To mitigate this, analogous products were selected. This issue highlights the ongoing need for a standardized and comprehensive database in the scientific field.

RESULTS

The Amphitheater's operational usage in 2023 was notable, consuming 9.66 MWh of electricity and 29.74 MWh of natural gas annually. This significant energy usage highlights the need for sustainable practices to reduce environmental impact.

Given the limited EPD database within the software, the selected components for the existing system/baseline scenario (scenario 1) have been integrated based on their alignment with the EPDs presented in Table 1.

Table 1. Data input and assimilated EPDs

HVAC components	Quantity	Assimilated EPD	Service life [years]
Diffuser Ø 250mm	90 kg	Square ceiling diffuser, Ø125-400 (Norway)	30
Extraction grill 0.6x0.6m	7 units	Smoke extraction grill and flap, surface libre=12.5 à 50dm^2 (France)	30
Sound attenuator 800x250mm	104.8 kg	Sound attenuator for air ventilation system, RD-A (Swegon Group AB)	25
Flexible ventilation duct Ø 250mm	3 kg	Flexible ventilation ducting, DN=300mm (France)	15
Galvanized steel vent duct Ø 250mm	130 kg	Circular ventilation ducts from galvanized steel (Belgium)	50
Rectangular ventilation duct 250x600mm, 250x800mm, 600x800mm	755 kg	Rectangular ventilation ducts from galvanized steel (Belgium)	50
AHU rooftop mounted	1 unit	Rooftop mounted, 1546.7 kg/unit, 99.8 kW (France)	22

The simulations conducted in One Click LCA over a 25-year timeframe yielded a life-cycle carbon footprint output of 322 574.83 kg CO_2e and 51.16 kg CO_2e/m^2/year for the

baseline scenario (scenario 1), with the biggest impact from energy consumption (91%) and material production (5.2%). By transitioning from rectangular to circular ventilation ducts (scenario 2), the LCC footprint is lowered to 321816.70 kg CO_2e and 51.04 kg CO_2e/m^2/year.

A categorized analysis of global warming, as illustrated in Figure 1, reveals that natural gas and electricity were the dominant sources of emissions in both scenarios. The fuel used (natural gas) by the AHU rooftop mounted to heat the air was responsible for almost 58% of total emissions, while electricity contributed around 33%. The air handling unit, ductwork and distribution system had significantly smaller impacts, accounting for 7.3% and less than 2%, respectively. Furthermore, the transition from rectangular to circular ducts resulted in a notable decrease in the impact of the ductwork and distribution system, from 1.83% to 1.5%.

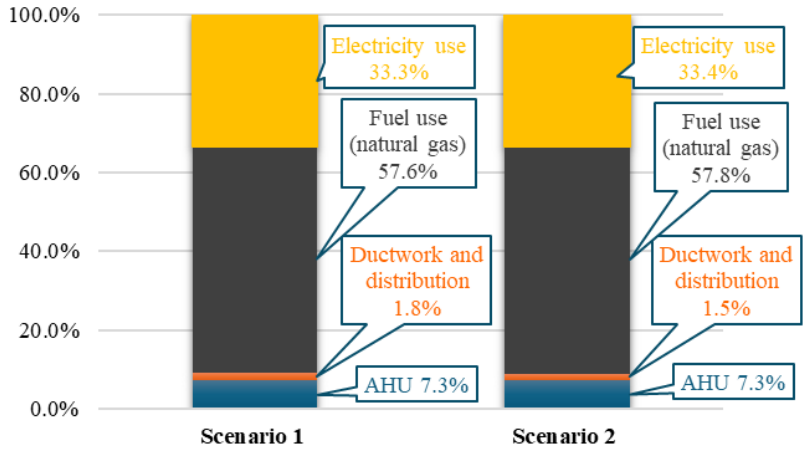


Figure 1. Global warming classification by category for both scenarios

Within cradle to gate impacts, the AHU had the most significant impact, contributing 68.3% to global warming in scenario 1 and 71.3% in scenario 2. In scenario 1, ventilation ducts were the next largest contributor with 16.5% while in scenario 2 circular ventilation ducts followed the AHU with only 12.8%, as depicted in Figure 2.

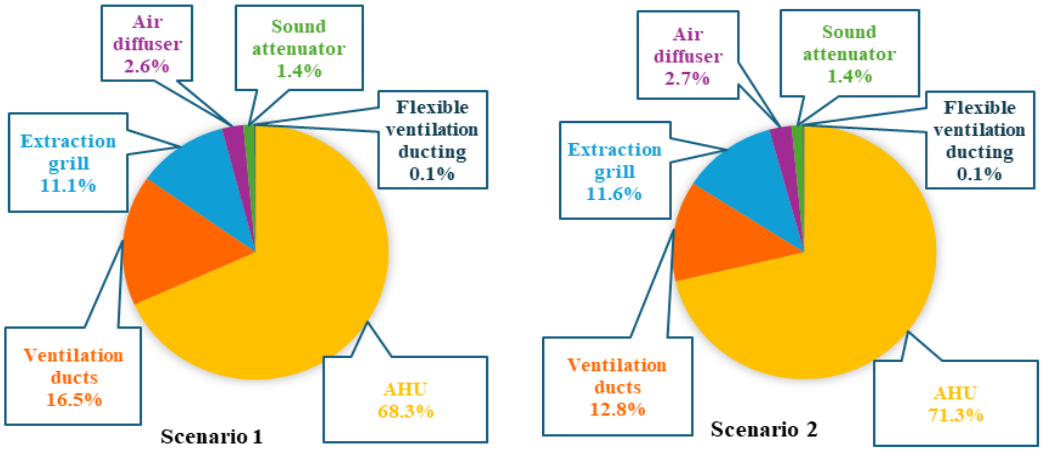


Figure 2. Highest impact HVAC components to global warming

The HVAC system's LCA was assessed across all 12 specific impact indicators. Figures 3 and 4 provide a comprehensive comparative analysis between the two scenarios, with

a meticulous examination of each indicator. Switching from rectangular to circular ducts yielded the most substantial declines for PERM (5.2%) and ADPE (2.8%). A detailed examination of the reductions, disaggregated by stage (Figure 3) for each impact indicator, highlighted the largest decreases for construction/installation processes (A5), followed by transportation to site (A4).

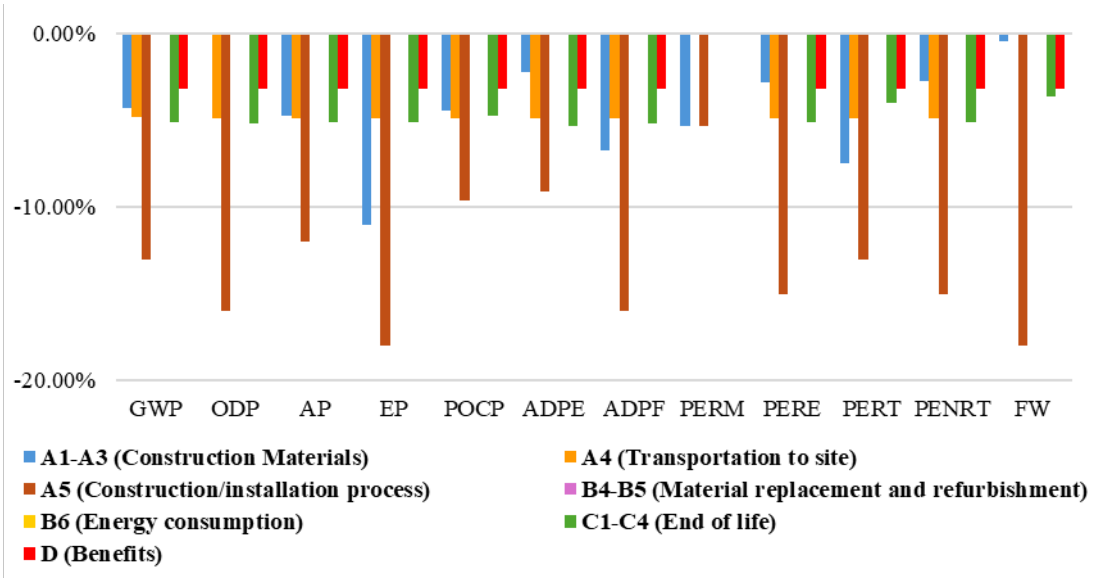


Figure 3. Environmental impacts reduction by life cycle stage for scenario 2 compared to scenario 1

Among all system components (Figure 4), the AHU had the greatest impact on ODP, ADPE and FW indicators, sound attenuators on PERM indicator, while air diffusers and ventilation ducts impacted PERM and ADPE indicators. Natural gas and electricity were the main drivers for 9 of 12 indicators.

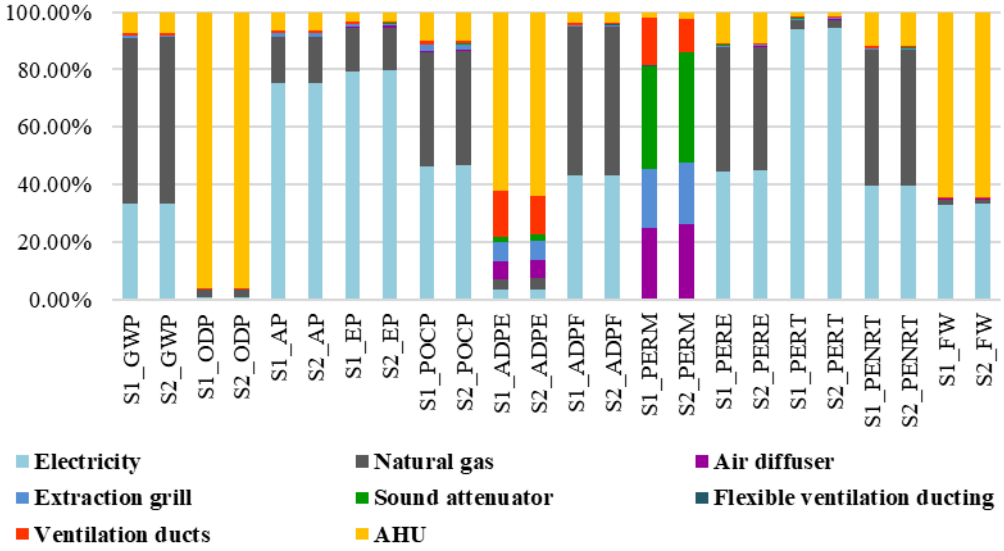


Figure 4. Life cycle impacts by HVAC components for both scenarios

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DISCUSSION

Since circular ventilation ducts have become the European industry standard, offering significantly improved airflow efficiency compared to rectangular ducts and leading to lower energy consumption and reduced operating costs [7], the first objective of the study was to assess the impact of switching from rectangular to circular ducts within the HVAC system. The stage-by-stage assessment revealed that ventilation ducts contribute significantly to global warming: 52% on A5, 29% on C1-C4, 27% on A4 and only 17% on A1-A3. The shift towards circular ones led to a 26% drop in the impact of ventilation ducts on global warming at stage A1-A3, 18% at A4 and C1-C4, and 25% at A5. Following the implementation of circular ventilation ducts, GWP levels of the HVAC system decreased by 4.3% at stage A1-A3, 4.8% at A4, 13% at A5 and 5.1% at C1-C4.

Given that the research is limited to the HVAC system and recorded Amphitheatre energy consumption, natural gas and electricity are dominant factors in most of the 12 environment and resources indicators. Nevertheless, along with the AHU, ventilation ducts have an overwhelming impact on ODP (96%), ADPE (77) and FW (65%).

To gain a deeper insight into the environmental implications of a circular ventilation duct, we investigated how a country's specific environmental policies, energy resources availability, and transportation network efficiency impact their overall environmental footprint. The analysis relied on One Click LCA software and circular ventilation ducts from different countries: Lindab Belgium (scenario 2), Lindab United Kingdom (scenario 3), Hallströms Sweden (scenario 4) and Romania (scenario 5). For Romania was used an EPD developed by the authors for a circular ventilation duct manufactured by Lindab Romania, pending independent verification. Considering the distances differences and modes of transportation, the energy mix, and the impact on carbon intensity [15], the transition from rectangular to different circular ducts led to reductions for the whole HVAC system. The highest global warming decreases have been achieved for Sweden, followed by Belgium, Romania and UK. A stage-by-stage analysis (Figure 5) revealed significant reductions for different circular ventilation ducts compared to rectangular ducts.

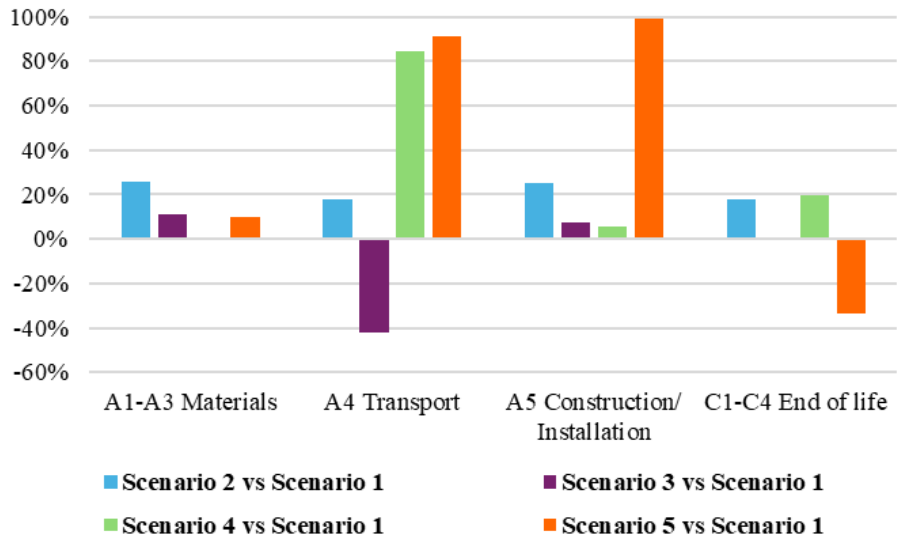


Figure 5. Global warming reductions of ventilation ducts by life stage

Notably, Romania showcased impressive reduction in transportation (91%) and construction/installation (99%) stages, Belgium in materials production (26%) and construction/installation processes (25%), and Sweden in transportation (84%) and end-of-life (20%) stages.

CONCLUSION

Given the substantial energy consumption and environmental impact of HVAC systems and the rising standards for thermal comfort and air quality, especially in educational buildings, this research employs a life cycle assessment approach, through One Click LCA software, to evaluate the environmental performance of an HVAC system, and guide sustainable ductwork selection in an educational building.

The transition from rectangular to circular ventilation ducts has mitigated impacts on all 12 life cycle indicators. The most significant reductions were achieved in the stage of construction and installation (A5), but considerable decreases were also found in transportation to the site (A4), the initial stage of material production (A1-A3) and end of life stage (C1-C4).

For the HVAC system's assessment, the operational use and the material production were identified as the primary contributors to global warming. Among the HVAC components the AHU rooftop mounted, and ventilation ducts had the largest impact from the system (84%). Rectangular ventilation ducts exhibited a 16.5% impact, while changing to circular ducts reduced this impact to 12.8%.

By delving into the environmental performance of circular ventilation ducts, this research revealed a critical link between countries energy mix and transportation network. Leveraging One Click LCA for different national ventilation ducts, including one externally EPD created for Romania, it was unveiled the potential of environmental benefits of adopting circular ventilation ducts on the HVAC system. To further optimize environmental performance, policymakers should encourage the use of local materials and renewable energy sources in the production and transportation of ventilation ducts.

ACKNOWLEDGEMENTS

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TOOLS FOR ENVIRONMENTAL PLANNING IN POLAND - HOW EFFECTIVE THEY ARE AND COULD BECOME

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ABSTRACT

The study attempts to examine the current and potential effectiveness of selected tools used in environmental planning of construction projects in Poland. Environmental planning is a complicated and demanding process, and as such it should be supported by the use of environmental management applications. At the early investment planning stage, it is necessary to verify whether a construction project to be developed, in addition to a building permit, does not require a decision on environmental conditions. This decision precedes the issuance of building permits for projects implemented as undertakings with a significant impact on the environment. It should provide the authorities responsible for the procedures and the public with the information on what environmental effects the construction project may have on a local scale. The environmental impact assessments (EIA) database is an IT system used to collect, process and share information on EIA proceedings on a national scale. One of the key functionalities of this system should be to streamline the work of bodies participating in EIAs and to accelerate investment processes. The study focuses on a multidimensional analysis of the effectiveness of environmental management tools from the point of view of main stakeholders in construction projects, and proposes appropriate improvements.

Keywords: effectivity, environmental management tool, EIA, construction project, Poland

INTRODUCTION

The progressing complexity of construction projects forces an interdisciplinary approach to the process of their preparation. In recent years, environmental planning has been gaining importance in Poland and elsewhere. Stakeholders in construction developments recognise the role of maintaining a balance between urbanisation and environmental protection, and ensuring that the implementation of a building project will do as little harm to the environment as possible. In order to reduce the negative impact of development projects on the environment, a variety of analytical tools are employed across the world [1,2,3,4,5,6,7]. This trend also occurs in Poland [8,9,10,11,12]. Locally, the basic tool in environmental planning is a document called the decision on environmental conditions (DoEC). This decision specifies the conditions for the preparation and implementation of a construction project. At the national level, an analogous role should be played by a database of environmental impact assessments. This is an IT system serving to collect, process and share information on proceedings in the field of environmental impact assessment. The literature perusal substantiates the conclusion that relatively little attention is paid to evaluation of the effectivity of the mentioned tools. The following study fills this gap.

MATERIALS AND METHODS

Our study analyses only the effectivity of selected environmental management tools applied to construction projects, and proposes the methodology for the assessment of their effectivity.

In order to achieve the intended main objective, the following interim goals were set and reached: • identification of environmental planning tools applied to construction projects and a selection of the tools for analysis, • presentation of the essence of the effectivity of these tools, • suggestion how the effectivity of environmental tools can be assessed, • presentation of the ways to improve their effectivity for users. The following research methods were employed in the study: • literature perusal, • expert-based method, • pairwise comparison, • analysis and conclusion.

RESULTS

Maintaining an equilibrium between progressing urbanisation and environmental protection is a difficult and complex process. It is therefore justified to support this process by using appropriate analytical tools. Our study does not propose any new tools, but only assesses the effectiveness of some existing instruments, such as a decision on environmental conditions (DoEC) and database of environmental impact assessments (DoEIA).

The DoEC analyses and assesses the permissibility of a planned development in respect of its broadly understood impact on the environment. A decision on environmental conditions can be issued under the full procedure (with the participation of the public at every stage of the procedure) or under the simplified procedure. Among the organs authorised to issue DoECs for construction projects there are heads of municipalities, mayors of towns and cities or organs specifically dedicated to environmental protection (regional directors of the Environmental Protection Directorate and its general director). The list of development projects that require obtaining a DoEC is specified by law. Development projects with a considerable influence on the environment are divided into two groups: those that will invariably have a strong impact on the environment, which will always require the issuance of a DoEC, and those that can have a strong impact on the environment and which, prior to issuing a DoEC need to have a project's information sheet prepared. In the latter case, the obligation to draw a report can be imposed by the competent authority during the proceedings. The development projects that require DoECs include investments which consist of the extension, reconstruction or assembly of previously completed projects, with some of the parameters of a given project being added together. A decision is received by the applicant (the investor) and all other parties to the proceedings. These are all entities that have a property right to any real estate located in the area exposed to the impact of the planned project in the variant proposed by the investor. Currently, this area is determined according to a fixed distance criterion (100 m) and a criterion determined in each case on the basis of the type of effect produced by the project.

The authority responsible for issuing a DoEC sends a notice of initiation of the proceedings to all parties if their number is 10 at the most; if there are more than 10 parties to a proceedings, the authority may notify the parties by means of an announcement, or in any other customary way (e.g. in the online Public Information Book). An announcement about the initiation of the DoEC issuance procedure should be posted for a period of 14 days on a notice board in the office building or on the website.

After that time, the parties are deemed to have been informed. The legal regulations have reduced the catalogue of entities entitled to raise an objection to the issuing of a decision on environmental conditions (an entity which is not a party to the proceedings cannot appeal against the issued decision). This seems rational in a situation where the complainant has other intentions than those rooted in ecological and substantive considerations. On the other hand, it is far more difficult for an entity that does not have a status of a party to the proceedings to become engaged in it, and the following options are advised:

- to act through an environmental organisation;
- to present an analysis of the environmental documentation (the Project Information Sheet or the Environmental Impact Assessment Report), demonstrating that the project will have an excessive range of impact on the area to which the applicant holds a legal title; this, however, means the need to cover the costs incurred without a guarantee that the authority competent to issue the DoEC will grant this application.

The other environmental planning tool analysed in our study is a database of environmental impact assessments (DoEIA). This is an IT system for which, in accordance with law, the responsibility is borne by the General Director for Environmental Protection. The database serves to collect, process and share information on proceedings in the scope of: environmental impact assessments, assessments of the impact of development projects on Natura 2000 areas, repeat assessments of the impact of development projects on the environment, and strategic assessments of the impact on the environment. Two groups of users can access to the DoEIA: logged users, that is authorised bodies (General Directorate for Environmental Protection, regional directorates for environmental protection, district (poviat) authorities, municipalities and other administration bodies), and unlogged users (natural persons, developers, environmental organisations). The former are entitled to enter and modify data; the latter can view the most important information on environmental impact assessments, but are unable to modify any data. The obligation to enter information into the DoEIA has replaced the earlier requirement to submit annual reports to the General Director for Environmental Protection.

By entering information into the environmental impact assessment database, in the full extent determined for this database, representatives of the authorities are granted:

- the possibility of multiple access to detailed data on proceedings, without having to retrieve original paper documentation,
- a tool to find the information they need by using a search engine;
- an option to share selected information with the public in the form of separate data or summary reports.

Browsing information in the database by natural persons is more difficult because it requires entering several details concerning the administrative proceedings the user is interested in. This constraint may arise from the widespread belief that the public might have a significant influence on the implementation of construction projects. The current law grants great power in this regard, especially to environmental organisations. This could result in a situation where the public, without any repercussions for themselves

but with considerable consequences for the developer, can hinder or even prevent the implementation of construction projects.

DISCUSSION

Although the environmental management tools considered herein are not new solutions, as they were launched in 2005 (DoEC) and in 2012 (a pilot version of the DoEIA), there is still relatively little discussion about what criteria should be applied to assess their effectivity. Both study [13,14] and analyse [15] have proven that such assessment is needed.

According to [13], the environmental data revealed in examined DoECs did not meet the quality requirements expected by their users. They were poorly comparable and highly descriptive, which resulted in little content matter, no verifiability, lack of comprehensiveness and a low level of comprehensibility for users with an average knowledge of environmental issues. The effectivity of DoECs was also questioned in [14]. According to surveys conducted in 23 selected municipalities, it was found that DoEC was needed in the entire environmental management system (none of the surveyed communes questioned this). However, in the opinion of municipal executive authorities, the DoECs did not always ensure full environmental protection. This was especially visible in the group of surveyed urban and urban-rural communes.

In [15], the Polish Supreme Audit Office (NIK) expressed a negative opinion on the functioning of the DoEIA in terms of its very important component, such as the environmental impact assessment data. According to the NIK, the identified incompleteness of the database prevented the achievement of the objectives for which the legislator mandated its maintenance, for example improving quality standards applied to proceedings and the documentation prepared in their course, facilitating the work of the offices involved in the process, and enabling the monitoring of making an environmental impact assessment by collecting, processing and sharing the data on EIA.

The outcome of our study consists of the proposed criteria applicable to measuring the effectivity of DoECs and the DoEIA. An expert method was chosen to evaluate the effectivity of these tools, and the reason was the level of knowledge that evaluators need to have. When selecting the criteria, likewise an expert-based system was employed, which allowed us to gather the relevant information through questionnaires. These results are not presented herein due to editorial limitations.

Criteria applied to evaluate both tools were defined in the same way: C1. Up-to-datedness – compliance with the binding regulations, recommendations and best practices; C2. Usefulness – useful for identification and handling potential environmental threats; C3. Reliability – a measure of the degree of verifiability of presented information; C4. Comprehensiveness – a measure of supplying all data related to an analysed phenomenon in order to fill the existing information gap; C5. Accessibility – a measure of the accessibility of the tool to all interested parties, with special emphasis on the public. All the criteria were evaluated by pairwise comparison by teams composed of two to five experts.

In the pairwise comparison, a 9-point scale was used, in which the value of 1 indicates that the compared criterion is equal to the criterion being compared, 3 – slightly more important, 5 – more important, 7 – much more important, and 9 – definitely more important than the one with which it is compared.

For the respondents, the most important criterion in the evaluation of DoECs was reliability. Fig. 1. shows the sources of the evidence for DoEC's reliability. Comprehensiveness, in turn, was seen as the least important. As regards the DoEIAs, accessibility scored the highest and the up-to-datedness was evaluated as the least significant criterion.

Tables 1-3 show the key elements focusing on the process of evaluating the effectivity of DoECs, while tables 4-6 contain the same information about the DoEIAs.

Tab. 1. The decision hierarchy for the criteria in the DoEC assessment

Criteria	C1	C2	C3	C4	C5
C1	1	0.5000	0.2	3.0000	1.0000
C2	2.0000	1	0.5	3	1.0000
C3	5.0000	2	1	2	3.0000
C4	0.33333	0.3333	0.5000	1	0.3330
C5	1.0000	1	0.3333333	3	1.0000
Summ aij	9.3333	4.8333	2.5333	12.0000	6.3330

Tab. 2. Calculation of the vector of preferences for the DoEC assessment criteria

wij	C1	C2	C3	C4	C5	Summ wij	Vector priority wij/n	Max Eigen value of matrix wij/n x sum aij
C1	0.1071	0.1034	0.0789	0.2500	0.1579	0.6974	0.1395	1.30189
C2	0.2143	0.2069	0.1974	0.2500	0.1579	1.0265	0.2053	0.99224
C3	0.5357	0.4138	0.3947	0.1667	0.4737	1.9846	0.3969	1.00554
C4	0.0357	0.0690	0.1974	0.0833	0.0526	0.4380	0.0876	1.05111
C5	0.1071	0.2069	0.1316	0.2500	0.1579	0.8535	0.1707	1.08107
						5.0000	1.0000	

Tab. 3. Ranking of the DoEC assessment criteria

Criterion	Cn	Ranking
Up-to-datedness	C1	4
Usefulness	C2	2
Reliability	C3	1
Comprehensiveness	C4	5
Accessibility	C5	3

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Tab. 4. The decision hierarchy for the criteria in the DoEIA assessment

Criteria	C1	C2	C3	C4	C5
C1	1	0.3333	0.3333333	0.3330	0.7000
C2	3.0000	1	2	1	0.5000
C3	3.0000	0.5	1	0.5	0.2000
C4	3	1.0000	2.0000	1	0.3330
C5	7.0000	2	5	2	1.0000
Summ aij	17.0000	4.8333	10.3333	4.8330	2.7330

Tab. 5. Calculation of the vector of preferences for the DoEIA assessment criteria

wij	C1	C2	C3	C4	C5	Summ wij	Vector priority wij/n	Max Eigenvalue of matrix wij/n x sum aij
C1	0.0588	0.0690	0.0323	0.0689	0.2561	0.4851	0.0970	1.64926
C2	0.1765	0.2069	0.1935	0.2069	0.1829	0.9668	0.1934	0.93455
C3	0.1765	0.1034	0.0968	0.1035	0.0732	0.5533	0.1107	1.14354
C4	0.1765	0.2069	0.1935	0.2069	0.1218	0.9057	0.1811	0.87542
C5	0.4118	0.4138	0.4839	0.4138	0.3659	2.0891	0.4178	1.14193
						5.0000	1.0000	

Tab. 6. Ranking of the DoEIA assessment criteria

Criterion	Cn	Ranking
Up-to-datedness	C1	5
Usefulness	C2	2
Reliability	C3	4
Comprehensiveness	C4	3
Accessibility	C5	1

CONCLUSION

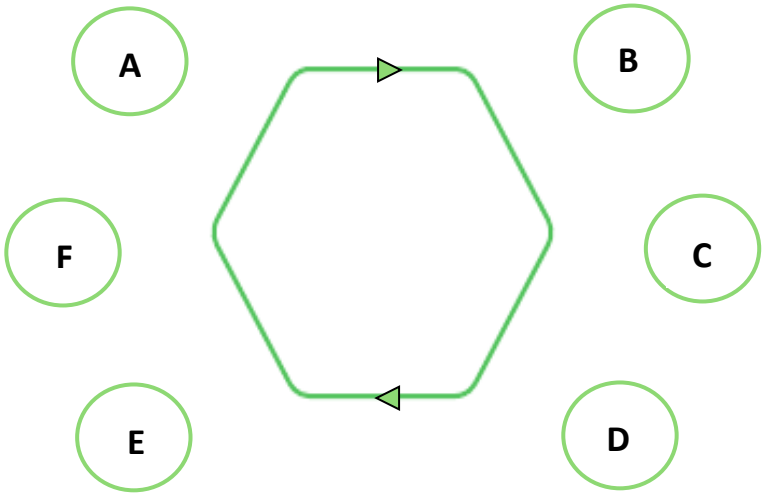
In compliance with current law, environmental issues are among the most crucial ones concerning the construction project planning phase.

Many management tools can be used in order to reduce the environmental nuisance of a construction project. The most popular are a decision on environmental conditions (DoEC) and the database of environmental impact assessments (DoEIA). Both of them have been entered into the Polish legal system as a consequence of the EU regulations but their effectivity has not been evaluated.

The study has demonstrated the need to define assessment criteria applied to DoECs and the DoEIA, of which, respectively, reliability or accessibility proved to be of key importance.

The conducted research has enabled to verify the degree of significance of the attributes which define the effectivity of DoEC and DoEIA in two dimensions: 1) users' assessment of the level of importance of each criterion, 2) a pairwise comparison, which allowed us to determine the hierarchy of criteria in the absence of significant differences in the assessment of absolute significance.

Both DoECs and the DoEIA were created by public administration bodies acting at the appropriate local or central levels. The principal task of administration is to serve the the public interest, which can be exemplified by ensuring a public access to the analysed tools.



Legend:

A - reliable qualification of a construction project

B - detailed description of investors activities (date of submission of an application and its supplements, dates of submitting of Project Information Sheets and/or Reports about impact of the project on the environment together with the dates of their supplementations or corrections)

C - precisely indicated environmental requirements that should be included in documentation required for issuing other decision and notifications

D - adequate to treats conditions for using the environment at the stage of implementation and realization of the project

E - detailed requirements for limiting cross-border environmental impact of the project (if required)

F - detailed requirements in the scope of counteracting the effects of an industrial failures (if required)

Fig. 1. The sources of the evidence for DoEC's reliability.

The study confirmed the need to maintain the same communication channels with respect to DoECs. Improving the accessibility to this information may consist of providing an online access to any DoEC and documents involved in its issuance for a period longer than 14 days, on the websites of the offices responsible for their issuance. This is particularly valid for DoECs with a large number of parties of administrative proceedings. It should be possible to submit an application for DoEC via the portal e-construction (it allows investors to fill out applications related to the construction process online in the same place). This change could make the lives of investors, architects and engineers easier.

The DoEIA also needs improvement. In order to increase the availability of Reports about impact of the project on the environment and Project Information Sheets for

unlogged users, a dedicated portal could be created where such users could view documents without having to provide many detailed data such as, for example, the sign of the case. This portal should be compatible with the portal e-construction.

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INFLUENCE OF FILLERS ON THE HYDRATION OF TERNARY BINDER

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ABSTRACT

While the interaction between the cement-based binders and different types of fillers is described sufficiently, the behaviour of composites, containing gypsum and any type of filler was studied less frequently and studies focused on the interaction between the composite binder and filler are rare. We studied ternary binder composed from gypsum, lime and silica fume in combination with several types of fillers (sand, expanded perlite, expanded clay and waste polyurethane). The strength of the composites was measured in 7 and 28 days. While in the pure gypsum the maximal strength is achieved very quickly (in hours), in the ternary materials it increased between the 7 and 28 days at about 10 to 20%, because the pozzolanic reaction is slower than hydration of pure gypsum and the type of the used filler influences the hydration as well. Composites with sand and expanded clay achieved the compressive strength over 10 MPa (15.9 and 12.7 respectively), the strength of material with expanded perlite was 8.3 MPa and material with waste polyurethane achieved about 3.6 MPa. The images obtained by electron microscopy showed the different structure of hardened materials and different shape of gypsum crystals in materials with different types of filler. The environmental impact of the material with the waste polyurethane was lowest from all tested materials, while its properties allowed it to be used for less demanding purposes.

Keywords: ternary binder, gypsum, filler, structure, hydration

INTRODUCTION

A study of gypsum, as one of the most environmentally favourable binders, has recently gained increased attention. Gypsum can be used not only as a pure binder but also in combination with other materials, such as supplementary cementitious materials (SCM). Gypsum is added to cement clinker as a setting retarder and gypsum-lime plasters are used traditionally. Numerous studies were focused on composite systems based on gypsum or anhydrite [1,2]. Particular attention is given to ternary binders, i.e. binders composed of gypsum, SCM, and an activator of pozzolanic reaction [3,4, 5]. The presence of alkaline activator is necessary, because gypsum itself does not provide the environment enabling pozzolanic reaction. The products of the pozzolanic reaction, hydrated silicates (C-S-H) and hydrated aluminates (C-A-H) can significantly enhance the strength of gypsum and especially its resistance to moisture [6,7].

A less studied area is the behaviour of gypsum itself in combined binders. However, the chemical composition of gypsum, its hydration reactions, and its setting and hardening processes are fundamentally different from other commonly used binders. Likewise, there are still few studies focusing on the influence of fillers in combined binders, while the effect of fillers on pure gypsum binders has already been somewhat explored. Krejsová et al. [8] found that the influence of aggregate particles on the properties of gypsum mortars is similar to the influence of aggregates in cement-based materials. It was

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observed that the interfacial transition zone is formed in gypsum similarly to cement materials, and the strength of gypsum mortar increases with increasing grain surface roughness, while the initial setting time shortens. Doleželová et al. [9] studied the influence of different types of fillers on the properties of gypsum mortar. It was found that the strength of a composite with expanded clay was comparable to the strength of a reference composite with standard sand, even though its bulk density was 40% lower. Material with crushed PUR foam had the lowest strength, but it was the most environmentally friendly and still had properties sufficient for less demanding constructions.

This work focuses on research of composites, made from ternary binder (composed of gypsum, silica fume and lime) with various types of fillers (silica sand, expanded clay, expanded perlite, and waste polyurethane foam). The effect of these fillers on the structure and properties of the ternary composite was studied.

MATERIALS AND METHODS

Four ternary composites with different fillers were designed and tested. Ternary binder was composed from commercial calcined gypsum (producer Rigips, Czech Republic), lime hydrate (producer Lhoist, Czech Rep.) and the silica fume (producer Stachema CZ, Czech Rep., particle size distribution d50 = 0.35 μm). The composition of the binder was 81.5% gypsum, 10% lime hydrate and 8.5% silica fume.

Expanded perlite EP 150 (producer PERLIT Ltd., Czech Rep.), expanded clay aggregate Liapor (producer LIAS Vintířov, Czech Rep.) and crushed waste polyurethane foam (PUR) from white goods (DAXNER Technology, Czech Rep.) were used as lightweight fillers. Standardized sand CEN ČSN EN 196–1 (Filtrační písky Ltd., Czech Rep.) was employed for preparation of the reference composite.

The amount of fillers was calculated so that the volume of filler was the same in all composites. Firstly, the reference composite with standard sand (REF) was designed according to the ČSN EN 13454–2 [10]. The mass ratio between the dry binder and standard sand was 1: 3. The dose of binder was always 450 g/batch. Mass of each lightweight filler m was calculated from its bulk density ρ_V (Tab. 1) and the volume of standard sand V_{REF} in reference composite according the equation (1).

$$m = \rho_V \, . \, V_{REF} \quad (1)$$

Table 1: Bulk density and mass of filler in the one batch

Filler		Standard sand	Expanded clay	Expanded perlite	Crushed PUR foam
Bulk density	kg/m^3	2575	1050	80	180
Mass	g	1350	550.5	41.9	94.4

The amount of water was determined for the flow diameter 165 ± 5 mm. Setting retarder was added to all materials in the amount of 0.02% from dry binder mass. Final composition of all tested composites is in Table 2.

Table 2: Composition of tested materials

	Filler type	Gypsum	Lime hydrate	Silica fume	Setting retarder	Filler	Water
		g/batch					ml/batch
C$_{REF}$	Standard sand	366.75	45	38.25	0.09	1350	270
C$_{EC}$	Expanded clay					550.5	320
C$_{EP}$	Expanded perlite					41.9	260
C$_{PUR}$	Crushed PUR					94.4	400

All composites were prepared in the same way according to EN 196–1[11]. The dry components of binder were homogenized thoroughly by hand. Retardant was added to measured amount of water in the mixing bowl and mixed until dissolved. Dry binder was then added to the water and material was mixed in automatic mixer for 30 s at low speed (140 rpm), then filler was added steadily during next 30 s of mixing and then the material was mixed for 30 s at high speed (285 rpm). After that there was 90 s pause to remove the mortar from the bowl wall and mixing continued for another 60 s at the high speed. The fresh composite was poured into the rectangular moulds (160x40x40 mm) and compacted mechanically by a jolting table. The surfaces of the samples were levelled using a metal knife. The hardened samples were put out of the moulds after three hours and stored in a laboratory at 23 ± 2 °C and relative humidity of 50 ± 5% for 28 days.

METHODS

The microstructure of the fillers and of the tested composites was studied by scanning electron microscopy (SEM) (Merlin, ZEISS) with a Gemini II column at an acceleration voltage of 7–10 kV, probe current of 46 – 71 pA and working distance of 8 – 13 mm. The samples were attached to carbon tape and they were not covered or polished.

The bulk density ρ_v [kg/m^3] of the gypsum materials was determined by a gravimetric method. The dimensions of test prisms were measured by digital calliper and the volume was calculated from the dimensions. The bulk density was determined from the volume of the sample and its mass in the dry state according as a ratio between the mass and volume of samples.

The specific mass ρ [kg/m^3] was determined by helium pycnometry (Pycnomatic ATC). The porosity p (%) was calculated from the bulk density and the specific mass according Eq. (2)

$$p = (1 - \rho_v/\rho).100 \quad (2)$$

The flexural and compressive strength were determined in accordance with standard ČSN EN 13454–2 [12] on standard test prisms. The experiment was performed as a common three-point bending test. The measurements were carried out 28 days after mixing. The compressive strength was measured on the halves of the specimens left over from the bending test.

Moisture content (by mass) of samples was determined by gravimetric method – wet samples were weighted and mass in wet state m_w [g] was obtained. Then the samples were

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dried at 40 °C and weighted again (m_d). The moisture w_m [wt.%) was calculated according Eq. (3).

$$w_m = \frac{m_w - m_d}{m_d} \times 100\% \quad (3)$$

RESULTS AND DISCUSSION

Microstructure

The shape and surface of particles of all fillers was examined and compared. The SEM images can be seen in Figure 1. There can be seen that the surface of the sand and expanded clay is rough and rather nonporous. The pores in the expanded clay particle are mostly closed. The particles of expanded perlite are mostly broken, with a lot of open pores, but the surface is smooth, because of glassy nature of perlite. The PUR particles are also smooth, but highly irregular and their structure is similar to the inner structure of perlite.

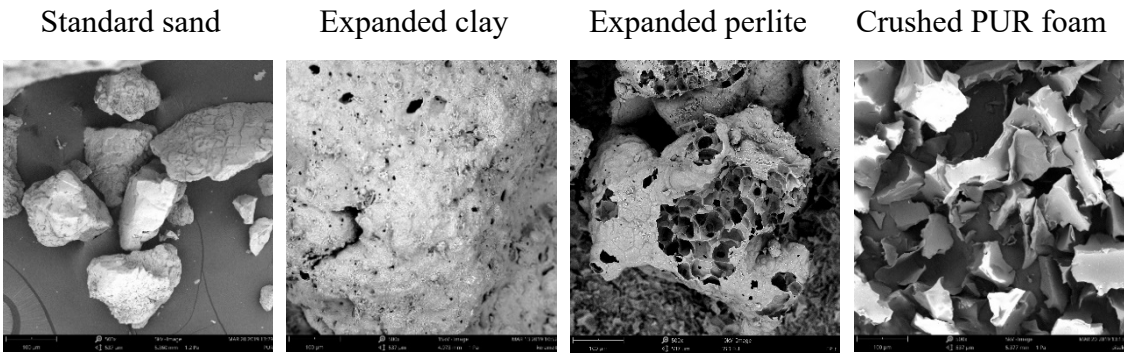


Fig. 1: SEM of particles (500 x magnification)

The structure of composites with different fillers is given in Figure 2. The filler particles, gypsum crystals and hydrated silicates in amorphous form can be found in each material. These phases were confirmed by EDS analysis. Interfacial transition zone between the binder and particles can be seen in materials with sand (C_{REF}) and with expanded clay (C_{EC}), but it is not very pronounced. In materials with expanded perlite (C_{EP}) and PUR (C_{PUR}) the gypsum crystals grow into the particles. The most significant difference is in the size and shape of gypsum crystals. The gypsum crystals in composite with silicate sand (C_{REF}) are substantially smaller but better formed than crystals in material with PUR. The crystals in C_{PUR} are thicker, but they are cracked and broken. Similar pattern can be seen also in the material with expanded perlite, while the crystals in C_{EC} are similar to the C_{REF}, but they are worse formed. This is given by the shape and structure of particles. In the presence of rougher and less porous particles the gypsum crystals are smaller, but better shaped, while in the presence of the particles with irregular shape and smooth surface the crystals are bigger, but not so well formed. This means, that the crystals in these materials were formed more quickly and therefore they had no enough time for better shaping.

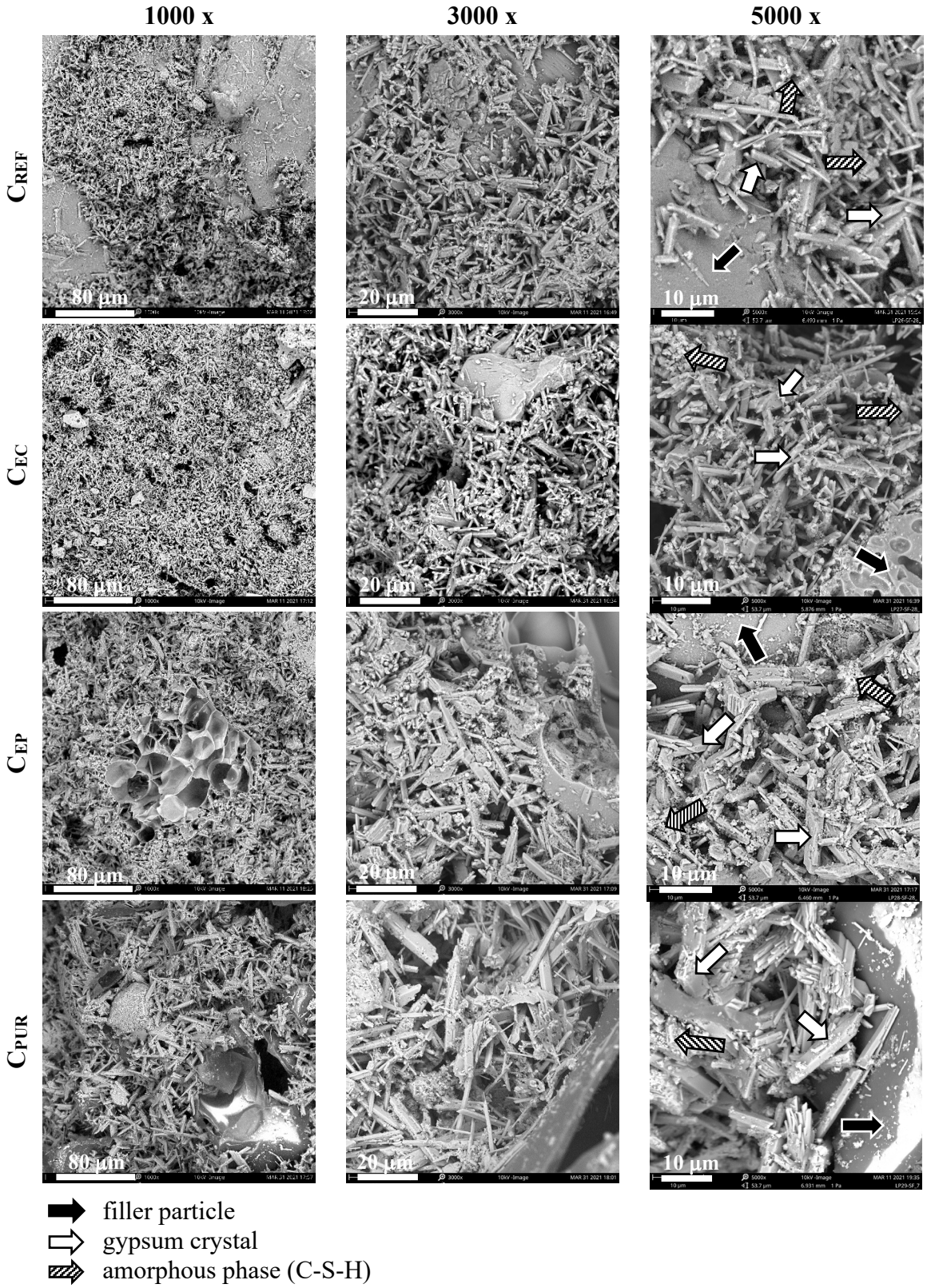
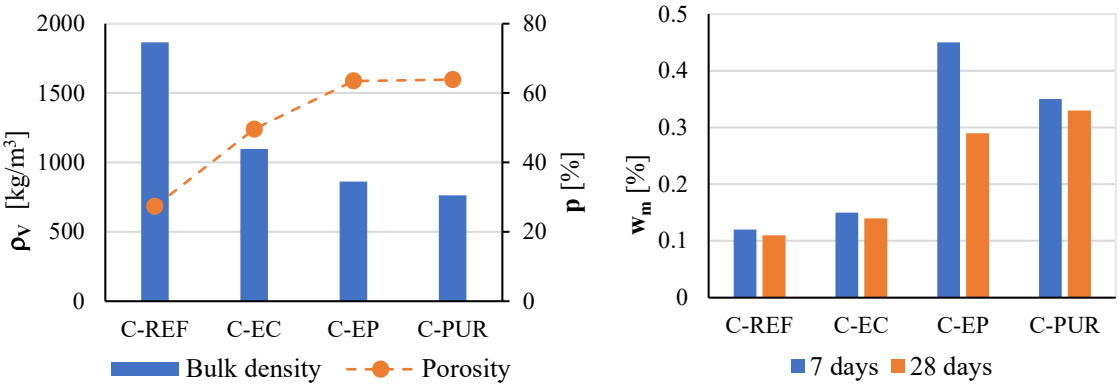


Fig. 2: SEM of composites

Physical properties

There were minimal changes in bulk density and porosity between 7 and 28 days, therefore bulk density and porosity at 28 days only are shown in Fig. 3a. There can be seen that the highest bulk density, 1881 kg/m3, had reference material with standard sand which was expected, because sand is non-porous and gypsum crystals in binder were smallest and therefore tightly packed. Interesting results were achieved for material with PUR, because the filler itself was not porous (as can be seen in Fig. 1), but PUR is lightweight itself and the porosity of binder was very high because of largest gypsum crystals. Similar results of bulk density and porosity were achieved for composite with expanded perlite, but in this case the porosity of particles contributed to the total porosity, while the porosity of binder was slightly lower because the gypsum crystals were smaller. The bulk density of composite with expanded clay was highest from all materials with lightweight fillers because the bulk density of expanded clay was high and gypsum crystals were small.

The moisture by mass in 7 and 28 days can be seen in Fig. 3b. There can be seen, that the moisture decreased only slightly for all materials with the exception of materials with expanded perlite. The longer drying of this material was caused by the moisture in the open pores of the particles, which needed more time to evaporate.



a) Bulk density and porosity b) Moisture by mass

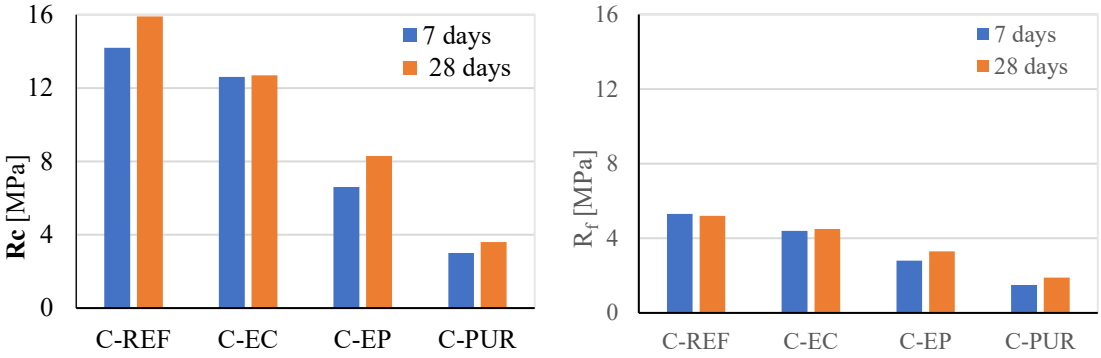
Fig. 3: Physical properties

Mechanical properties

The flexural strength and compressive strength of all materials is in Fig. 4 a) and b) respectively. The strength of the gypsum is achieved rather quickly (in the hours or few days), while the pozzolanic reaction lasts longer. As can be seen, strength mostly increased in all materials between 7 and 28 days, nevertheless the increase was not so steep, because the amount of pozzolana was less than 10% and the final strength of gypsum was already achieved. The compressive strength of the material with expanded clay was over 12 MPa, which is about 25% lower than strength of reference material, nevertheless still sufficient for building purposes. There was the smallest difference between the 7 and 28 days strengths in this material, which means, that the pozzolanic reaction in this material was fastest. The biggest increase in strengths was achieved in

the materials with expanded perlite and PUR. It means, that while the contribution of gypsum to the strength was finished rather early, the pozzolanic reaction continued more slowly. It can be confirmed by the shape of gypsum crystals in these two composites, which are worse shaped than crystals in composites with sand and expanded clay.

Even if the mechanical properties of the material with waste PUR were the lowest from all materials (flexural strength was 1.9 MPa, compressive strength was 3.6 MPa), they were still sufficient for less demanding purposes, as for the plasters and non-bearing construction. They were also most favourable from the ecological point of view, because of using waste material as a filler [8].



a) Compressive strength b) Flexural strength

Fig. 4: Mechanical properties

CONCLUSION

The influence of the fillers on the structure and properties of composites with ternary binder, composed from gypsum, silica fume and lime hydrate, was studied. The hydration of ternary binder was influenced by the type of the filler. Especially the process of gypsum crystallization differed significantly and therefore the properties of final material were changed accordingly.

It was found, that:

- The structure of the hardened ternary binder differs significantly with the type of the filler.
- The gypsum crystals are smaller but smooth and better formed in the materials with rough particles (composite with silica sand and with expanded clay).
- The gypsum crystals are bigger but cracked in the composites with smooth particles (composites with expanded perlite and waste polyurethane).
- The structure had impact on the mechanical properties of composites. The porosity of materials with bigger gypsum crystals was higher and their strength was lower.
- The best mechanical properties from composites with lightweight fillers achieved the material with expanded clay with compressive strength over 12.7 MPa and flexural strength 5.2 MPa.
- The mechanical properties of material with waste polyurethane were lowest, nevertheless its properties were sufficient for less demanding purposes. The environmental impact of this material was most favourable from all tested materials.

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INNOVATION IN VERNACULAR TRADITIONS: PRELIMINARY EXPERIMENTAL RESEARCH ON CLAY MIX DESIGN FOR DURABLE POURED EARTH WALLS

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ABSTRACT

Innovative construction materials and techniques can be sourced from natural resources and traditional methods, and applied to green housing concepts to enhance energy efficiency and occupant well-being. Innovation in vernacular traditions can be achieved by integrating the modern, current methods and techniques, materials and tools within local traditional technologies and associated natural raw materials (clay, sand, wood, straw, and wool) in order to enhance ecologic housing facilities with improved overall performance: structural, economic and sustainable. The current paper focuses on development of poured earth walls as an eco-friendly alternative to classic solutions (masonry, concrete walls, etc.), specifically on the clay-based mix design feasible for the poured earth technique. This technique resembles natural concrete, aggregate grains are bonded by clay particles instead of cement-based binding systems, and it offers environmental benefits such as facile recyclability, low impact, and effective hygrothermal regulation, but also brings consistent challenges regarding the proper clay-based earthen mix design. Preliminary and exploratory fresh-state testing is performed on several clayey mixes, in order to identify critical parameters with further relevance to the structural and durability performance, together with specific comparative evaluation and corresponding conclusions related to overall concept feasibility.

Keywords: vernacular architecture, clay, poured earth, walls, fresh state mix, durability.

INTRODUCTION

The earth constructions terminology refers to structures and buildings which are made mainly realised by using natural materials such as soil, clay, sand and organic materials (Iriarte et al., 2016). These materials are mixed, and compacted or even poured in formworks to form walls, floors and roofs. All around the world earth constructions have been used by different cultures throughout history and continue to be used nowadays. Among defining characteristics of earth constructions are their durability and low environmental impact. They imply the use of locally available materials which determines the reduction of material transportation (generally generating important construction costs) and minimize the carbon footprint associated with construction [1].

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Also, earthen buildings prove themselves versatile and suitable for various climates, due to their intrinsic ability to adjust to the existing environment and be able to regulate humidity and ensure thermal comfort [2]. The ability to absorb and store heat, necessary for maintaining the stability of indoor temperatures, is provided by the high thermal inertia of earth materials [1]. Another significant characteristic of earth constructions is their cultural and historical significance, as many earthen buildings own important shares of the cultural legacy of various areas and their communities, accurately reflecting traditional architectural styles and techniques [1]. These structures often have unique aesthetic qualities and are treasured for offering the strong link to local identity and history. This creates the proper context to valorise the vernacular building techniques as sustainable architectural solutions, inspired by local traditions, and capable of ensuring a cultural bridge among generations and communities and also the balance between energy efficiency and cultural specificity of various areas [3], [4], [5].
The increasing interest of the scientific community is related to the practical use of earth-based materials in construction, which is still limited so far by several factors: material intrinsic physical characteristics, associated construction techniques with severe structural and durability limitations, on one hand, and technical, organizational, political and socio-economic barriers, on the other hand [6]. Among the latest we mention the lack of harmonized international regulations concerning the design, execution and exploitation of these structures in accordance with the usual safety criteria in construction, as in the case of steel, concrete, and masonry buildings.

The current study focuses on the poured earth as technique for realization of wall elements (partition walls or even structural walls), as alternative to the rammed earth technique, more popular and more popular, but also presenting design, execution and exploitation lacks. The poured earth technique uses stabilized, fluid form earthen mixes, which is then poured into moulds to create durable earthen elements. The experimental programme uses local raw material, from two distinct sources of Timiș county of western part of Romania, a very rich area in earthen heritage building tradition.

CONTEXT AND OBJECTIVES OF INVESTIGATION

The current study is founded by previous research performed at NIRD URBAN-INCERC Timișoara branch, Romania in the topic of earthen structures, including a comparative analyses of rammed earth walls vs. poured earth walls [7].

The poured earth technique offers the benefit of improved workability and easier handling of the composition, both during mixing for uniformity—ensuring consistent moisture content and even distribution of grains or additives—and during the casting of the loam mixture into rigid horizontal formwork. The fluid nature of the material reduces casting time, allowing for a complete fill of the formwork. However, a significant drawback of this method is the substantial axial shrinkage, ranging from 3% to 6%, even when using loam with 10% to 15% cohesive clay content [8]. Increasing the clay content requires more water and results in greater axial shrinkage during the drying process. The addition of dispersed fibres, whether organic or inorganic, has been proved beneficial for enhancing both load-bearing capacity and reducing shrinkage and displacement [7]. According to the specified study [7] the poured earth specimens showed superior performance in comparison to the compressed earth ones, in both compressive strength and displacement control. However, the significant shrinkage of

the loam mixture poses a major drawback, along with the extended time required for the elements to fully dry.
The current research, as follow-up to the previous one, is focused on development and proper assessment of fresh state earthen mixes for direct use in the poured earth technique, in attempt to identify critical material characteristics and technological relevant aspects. The poured earth mixtures need to meet the following basic criteria in order to be considered suitable for the proposed technique:

- *Fresh state material:*

o They must have high fluidity which allows the material to be easily poured into the mould (pumpable mixtures with ideally self-compacting behaviour are also considered);

o When casted into moulds, they should exhibit a liquid-solid transition behaviour allowing the wall element to support its weight after a short drying period;

- *Hardened state material:* The minimum mechanical strength gained after the casting, in the wet state of the material, should be approximately 0.07 MPa in less than 24 hours [9].

Consequently, one major goal of the research is identifying a comprehensive approach for clayey mixtures design, their evaluation (initial and continuous) in terms of critical parameters and suitable mixing technology for direct use in the poured earth technique.

MATERIALS AND METHODS

1. Methodology for initial evaluation of a clayey material composition

The first step of the study refers to preliminary experimental investigations performed for a fast and potentially rough evaluation regarding the composition (clay content) and even physical properties of <earth>, as raw material considered for specific mixtures with particular use in earthen buildings. In order to be able to determine the range of use of a clay soil for a specific application, it is necessary to determine its composition, namely the amount of clay, the amount of sand, other materials (fibres, impurities), etc.

The proposed procedure is performed on local raw earthen material, extracted from two distinct quarries located in Timiș County, in the western part of Romania, C1 and C2 (Fig. 1). Some empirical (on site) investigations are proposed on earthen materials, in order to roughly determine their composition. Simultaneously, standardized laboratory determinations are performed on the same material sample, in order to compare the results and potentially validate the proposed empirical investigations.

a)  b)  c) 

Figure 1 Earthen material: a) C1 source; C2 source: b) raw state; c) after rough sieving

Empirical testing on earth material for rough assessment of material composition:

a. The Washing Test:

A moist soil sample is rubbed between the hands (Fig. 2). If the grains feel distinct, this indicates sandy or stony soil. If the sample is sticky, but the hands can be wiped clean

when dry, this indicates dusty soil. If the sample is sticky to the extent that water is needed to clean the hands, this indicates loamy soil (with increased clay content).

a)  b)  c)  d) 

Figure 2 The Washing Test: a), b) C1 material; c), d) C2 material

b. The Cutting Test:

A wet soil sample is shaped into a ball and cut with a knife. If the cut surface is shiny, the mixture has a high clay content; if it is dull, it indicates a high sand content.

c. The Sedimentation Test:

The soil sample is mixed with plenty of water in a glass jar. The larger particles settle at the bottom, the finer ones at the top. This stratification makes it possible to estimate the proportion of the constituents. This determination allows a rough assessment of the amount of clay, dust, sand or aggregate, depending on the height of each layer identified in the glass jar. (Fig. 3, a and b).

a)  b)  c)  d) 

Figure 3 The Sedimentation Test: a) C1 material; c) C2 material; The Ball Drop Test: a) C1 material; c) C2 material

d. The Ball Drop Test:

The sample should be as dry as possible, but wet enough form a 4 cm diameter ball, which is dropped from a height of 1,5 m onto a flat surface. If the ball flattens slightly and has few or no cracks, it has a high binding strength due to its high clay content (Fig. 3, c and d). This mixture should usually be diluted by the addition of sand.

e. The Consistency Determination Test:

The moist soil sample is shaped into a ball with a diameter of 2-3 cm. This ball is rolled in the palm of the hand into a thin 3 mm diameter thread. If the sample breaks before it is 3 mm in diameter, water is added until the breakage requirement is reached at ϕ3 mm. Further, a ball is formed in the palm with the soil sample at the same moisture content. If this is not possible, the sand content is too high or the clay content is too low. If the ball thus formed can be squeezed between thumb and index finger by pressing, the sample has a high clay content. If the ball crumbles slightly when pressed, the clay content is low.

a)  b)  c)  d) 

Figure 3 The Consistency Determination Test: the ϕ3 mm thread: a) C1 material; b) C2 material; the ball: c) C1 material; d) C2 material

Standardized laboratory testing on earth material for granular composition of C1 and C2 samples was performed by using a combined method in accordance to the following norms (national and European): EN ISO 14688-1:2018 Geotechnical investigation and testing. Identification and classification of soil - Identification and description; EN ISO 14688-2:2018 Geotechnical investigation and testing - Identification and classification of soil - Part 2: Principles for a classification; STAS 1913/5-85 (Romanian norm, withdrawn) Foundation soil. Determination of granulometry. The obtained results of granular composition, performed by sieving and also by sedimentation, allow C1 and C2 material positioning in the in the ternary diagram.

2. Clay soil mix Preliminary design for poured earth technique: fresh state material evaluation; fresh state mixture amelioration by specific addition

The preliminary compositions proposed in the preliminary experimental program aim to meet the S2/S3 slump class (concrete assimilation) as fresh state requirement, in order to obtain a material suitable to be cast in the formwork. Regarding the surface cracking pattern during the drying stage, surface cracks < 0.5 mm.

The materials used for proposed preliminary mixtures are:

a) The biding system: C1 and C2 clayey soil;

b) Aggregate: 0/1 fine sand; 0/4 mm alluvial silico-limestone; 4/8 mm gravel (from certified sources);

c) Specific additions:

i. dispersant addition (mix water reduction and crack widthstabilization): Sodium Tripolyphosphate, granular CARFOSEL 996, from Prayon S.A. was used;

ii. agents for improving viscosity, workability and compressive strength: Normal hydrated lime (HL) as primary additive; calcium lignosulfonate (CL), 48% concentration, as second addition.

d) Tap water for mixing sequences, with temperature ranging between 14 - 16 °C.

The experimental program contains two stages:

Stage 1: Clay soil mixture development (without using the dispersant addition)

Stage 2: Clay soil mixture amelioration by the use of the dispersant addition.

The first stage of the procedures includes development of 8 mixtures (R1 – R8) obtained by varying the binding material, in terms of type (C1 or C2) and their amount (percent

by mass) in relation to the aggregate (type and amount, percent by mass) (Table 1). No dispersant was used, only HL addition for two mixes (percent of total mass of the mix). The water amount was empirically established by mass, as time to time addition during the mixing sequences and considering the constrain condition of fresh state mixture slump ranging of 100-150 mm, corresponding to S3 slump class.

Table 1 Stage 1: R1-R8 mix design of clayey material for poured earth technique.

Mixture / **Material**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**
C1 (%)	-	75	47.5	35	40	-	45	50
C2 (%)	100	-	-	-	-	40	-	-
Sand 0/4 mm (%)	-	12.5	35	30	30	30	20	25
Gravel 4/8 mm (%)	-	12.5	17.5	30	30	30	25	25
Primary additive (%)	-	-	-	-	-	-	-	-
Secondary additives (%)	-	-	-	5 HL	-	-	10HL	-
Water %	35	25	25	30	20	20	25	20

The second stage of the procedures consist in compositional amelioration of previous mixes by using primary addition for water content reduction and by varying the aggregate ratio,the amount of water was established during mixing according to the consistency of mixing by recording the settling. The proposed mix design is presented in Table 2.

Table 1 Stage 2: R9-R15 - ameliorated mix design (W 18% by total mass)

Mixture / **Material**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**
C1 (%)	100	100	75	60	90	-	-
C2 (%)	-	-	-	-	-	18	25
Sand 0/4 mm (%)		-	25	40	10	-	75
Gravel 4/8 mm (%)		-	-	-	-	-	
Primary additive (%)	0.2	0.2	0.2	0.2	0.15	0.15	-
Secondary additives (%)		-	-	2CL			Straw 1%
Water %	50	30	24	22	22	22	13

The fresh state material evaluation is performed by the slump test, for R9 - R_{cam} mixtures.

RESULTS AND DISCUSSIONS

1. Initial evaluation of a clayey material composition

The empirical testing on earth material for rough assessment of material composition leads to the general result that both C1 and C2 materials are classified as "soils with high clay content": the washing test and the cutting test: C1 and C2 – High clay content; the sedimentation test: The C1 a layer of dusty sand can be distinguished at the top; The C2 no clear stratification of the sand or aggregate part can be distinguished; Both analysed samples C1 and C2 have a high content of dusty clay or clay dust; the washing

test and the cutting test: C1 and C2 – High clay content; the ball drop test and the consistency determination test: both samples have high clay content and can be used as rammed earth or poured earth.

Standardized laboratory testing on earth material of C1 and C2 samples, performed by sieving and also by sedimentation, show the granular composition presented in Table 3 allow C1 and C2 material positioning in the in the ternary diagram (Fig. 4).

Table 3 Determination of granular composition through sedimentation

Sample	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
C1	23,50	49,91	26,37	0,22
C2	40,00	56,34	3,66	0,00

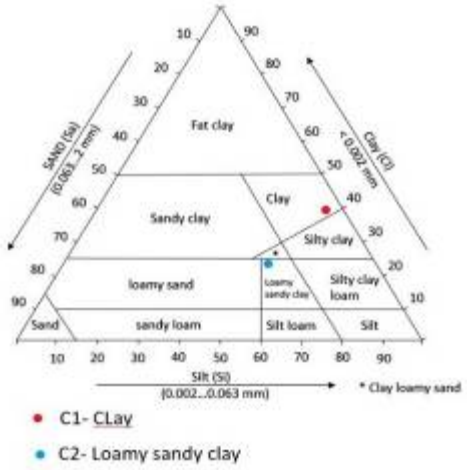


Figure 4 C1 and C2 material positioning in the ternary diagram

The results are emphasising the validation of simple (on-site) determinations for earth material; although not very accurate, they showed a good correlation with the standardized determinations performed in the laboratory. Also, the overall conclusion is that C1 and C2 materials posses a rich clay content, suitable for current research.

2. Initial evaluation of a clayey material composition

The slump test results (Table 4) indicate the efficiency of considered addition for the fresh state performance improvement (Fig. 5).

Table 3 Determination of granular composition through sedimentation

Sample	R9	R10	R11	R12	R13	R14	R15
Slump (mm)	240	165	110	150	280	30	70



Figure 4 Fresh state evaluation of the ameliorated preliminary mixtures by slump test

CONCLUSIONS

The preliminary experimental study proves the correlation of the on-site determinations, developed on the basis of centuries of experience in the handling of clays as a binder in the construction area, empirical in nature but with relevant results, with standardized, established laboratory tests. This stage of preliminary compositional development leads to conclusions on the next directions for further research on compositional improvement, based on the use of polymeric additives respectively dispersing agents with additive and strongly improving effect in the area of reducing the mixing water and implicitly the drying shrinkage, as forms of vulnerability of these materials.

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LEAN CONSTRUCTION AS A TOOL FOR CONSTRUCTION WASTE REDUCTION

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ABSTRACT

Architecture construction and engineering (ACE) is one of the most widespread industries in the world. At the same time, the construction industry consumes 50% of extracted primary sources of raw materials, 50% of energy consumption, 33% of water consumption and produces a third of the generated waste to create buildings and construction products. A lean construction represents an innovative approach in the construction industry that aims to maximize efficiency, minimize waste and improve the overall performance of construction projects.

The life cycle of buildings consists of four basic phases - building design, implementation, use and disposal of the building. The principles of lean construction can be applied in all production phases. The level of effectiveness of the lean construction application and, consequently, the effectiveness of the reduction of construction waste depends on the type of lean tools applied. The aim of the paper is to point out the possibilities and effectiveness of the application of selected tools of lean construction (prefabrication, lean layout and 5S method) for the reduction of construction waste. The research was processed through a case study. The object of the case study was the Allbelli residential building in Slovakia. It was confirmed that it is possible to significantly reduce the amount of construction waste generated by a suitable modern method of construction – prefabrication.

Keywords: lean construction, construction waste, reduction, prefabrication, 5S method

INTRODUCTION

The efforts of today's experts and society are directed towards sustainable construction, the implementation of the idea of a circular economy and the achievement of zero waste (zero waste strategy) in the construction industry. These incentives stem from general social pressure, initiatives and strategies of the European Union (EU), their transitions into national strategies and, last but not least, economic and competitive advantages.

The inevitable need for changes in the area of eliminating the negative impacts of the construction industry on the economic, ecological and social aspects of society resulted in a system of new paradigms, global and national policies, tools and innovation. The basic global strategy in the area of sustainability was defined through the document “Transforming our world: the 2030 Agenda for Sustainable Development” [1]. Agenda 2030 represents a set of 17 sustainable development goals (SDGs) divided into 169 sub-goals. One of the goals is to ensure sustainable production and consumption [1]. The members of the EU approached to holistic approach for sustainable development goals through the establishment of six program priorities [2], among which in the ecological field the European Green Deal is particularly important [3]. The principles of

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sustainability can also be integrated into construction and construction projects as a whole. General recommendations for sustainability in construction were defined by the European Union as a Level(s) European framework for sustainable buildings [4]. In a simple way, it provides an extensive evaluation system of the performance of buildings in the field of sustainability within the entire life cycle of the building, from its design to its disposal, or a new life cycle of recycled materials. The Level(s) sets macro goals in the area of resource efficiency and life cycle circularity of building materials as "optimizing building design to support lean and circular material flows", including:

- minimization of construction and demolition waste due to optimization of material use,
- changes in construction material cycles, including simple adaptability to project changes,
- preferring the deconstruction of buildings over the demolition of buildings [4].

One of the possible approaches to reducing of waste generation in the construction industry according to EU requirements is the implementation of lean construction principles. Lean principles make it possible to increase the production of the industry using less human effort, equipment, time and space, while getting closer to the goal of satisfying the exact needs of the customer [5]. Lean construction creates production systems that minimize waste of time, materials and effort in order to achieve the greatest value for the customer. The only way to achieve such an ambitious goal is to involve all stakeholders, including architects, engineers, builders, building managers and the customer, in the early stages of the project [6].

The benefits of lean construction are enormous, but the benefits can vary depending on the current state of operations, company size, project scope, and even geographic location. The most significant advantages of the lean construction idea application are: (i) improved productivity and increasing customer satisfaction; (ii) quality improvement; (iii) increasing security [7]. The main disadvantage of this concept is that it must always be implemented as a whole to achieve the desired improvement. If only limited units were applied, the effect of this application would not have a sufficient effect. In connection with the application, it is also necessary to take into account the possibility of a relatively long and demanding implementation, which could, in the absence of interest and motivation, cause problems. In order to obtain the desired improvement, it is necessary to involve all employees, including top management. The concept of lean production requires the support of management, which affects quality, flexibility, costs and also production [8]. Barriers to the implementation of lean construction have been classified by many authors. These barriers are categorized as management, process, people, resource, technology and other related barriers [9]. The commitment and support of top management is essential to achieve successful adoption and implementation of innovation strategies such as lean principles [8]. Currently, there are a number of more or less complex lean construction tools that affect various aspects of construction Waste reduction, mistake proofing, inventory management benefits can be achieved by applying lean tools such as 5S, LPS, Poke Yoke, VM. The lean tools the colour coding, standard signboards, Visual display boards and BIM support on-site management, timely completion of project, and reduction of variations aspects of construction. The minimum rework, standard schedule, and cleanliness of work place can be achieved through lean tools aimed on collaborative process mapping, Heijunka. Finally, the motivation of

employees and labour, timely completion of project, and minimum rework can be supported by big rooms, value system, continuous improvement lean tools [10], [11], [12], [13].

MATERIALS AND METHODOLOGY

Based on literature review, the research question and the aim of the paper were determined as: "to point out the possibilities and effectiveness of the application of selected tools of lean construction (prefabrication, lean layout and 5S methods) for the reduction of construction waste".

Research material

The research will be carried out through a case study. The object of case study is an Allbelli residential building which consists of five parts (A-E) (Fig. 1). The structural system of the building is a monolithic reinforced concrete skeleton of 4 to 12 storey buildings. The foundations of the building are made of piles, the vertical load-bearing structures are reinforced concrete walls and columns with a thickness of 350mm, 300mm a 200mm; and the horizontal supporting structures are made of reinforced concrete ceiling slabs with a thickness of 200 mm.

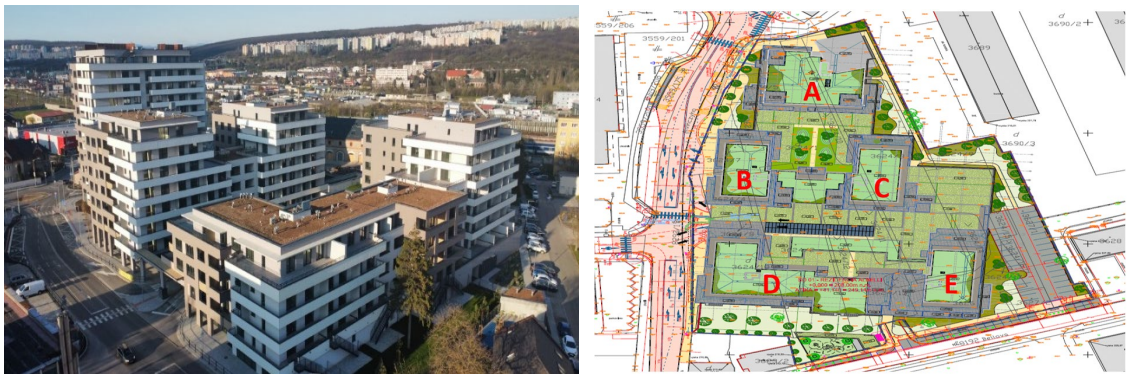


Fig. 1: Object of case study is an Allbelli residential building: on left - visualisation, on right - situation.

Research methodology

The theoretical knowledge and practical applications of lean construction and its tools were obtained through the research methods of analysis and synthesis. Considering that the Allbelli residential building was being built at the time of the research, it was possible to determine the possibilities and effectiveness of the application of lean construction tool using another scientific method, which is a comparison. Through analysis and synthesis, lean tools were selected and investigated. Subsequently, the effect of their application was compared with the traditional approach to the exhibition of the Allbelli residential building.

RESULTS AND DISCUSSION

Based on a detailed analysis of lean tools at lean construction, three lean tools were selected. It is necessary to realize that the lean idea can be applied during the entire construction life cycle, i.e. in the phase of design, implementation, use and demolition of construction. During the research, the effects of the application of three lean tools:

- prefabrication,
- lean layout,
- 5S method

were determined.

An awareness of the need to use lean construction tools is necessary already in the design phase. It is during the design of the project documentation that it is necessary to communicate with all construction participants about the possibility of their use, to point out the advantages and disadvantages of their use. Last but not least, reducing the amount of construction and demolition waste during construction is one of the benefits of using prefabrication of reinforced concrete structures. The solution of the case study was based on the comparison of the amount of construction and demolition waste (C&DW) generated during the implementation of load-bearing structures in the traditional way and using prefabrication. Given that the construction system of Allbelli residential buildings is a monolithic reinforced concrete structure, the traditional approach consists of construction processes - formwork, reinforcement, concreting and removal of formwork. During these processes, mainly construction waste - wood, concrete and steel - is created directly on the construction site. As part of the application of the lean principle of "prefabrication" in the construction of the Allbelli, it was proposed to apply filigree walls which in terms of static behavior show the same properties as a reinforced concrete wall made with traditional technology. These walls effectively transfer loads from higher floors and are able to withstand horizontal loads such as wind pressure.



Fig. 2: Lean tool – prefabrication: on left - filigree walls, on right - installation of filigree walls.

The advantage of prefabrication applying, i.e. elements that were manufactured in the factory and only assembled on site (Fig. 2), is also in the area of construction waste generation. By comparing the generation of construction waste in the traditional way and prefabrication, it is possible to claim that using prefabrication as one of the tools of lean construction, it is possible to reduce the generation of construction waste concrete by 50,06% and wood by 87,97% (Table 1).

Table 1: Comparison of the C&DW generation affected by the application of the lean construction tool

waste category	C&DW generation (m^3)		difference (%)
	traditional construction method	lean construction method – prefabrication	
wood	10,81	1,3	87,97
concrete	26,27	14,12	50,06

Another lean tool analysed in order to show its influence on the creation of construction and demolition waste is a lean layout. This approach is defined by systematic optimization of work procedures and effective management of material and human resources on construction sites. Work processes are redesigned to eliminate unnecessary steps, which significantly reduces the volume of waste and improves work efficiency. In general, lean layout in the construction industry is used to achieve a significant reduction in the wastage of resources and time, which leads to economic savings and supports the ecological sustainability of the construction process. This approach not only contributes to more efficient use of resources, but also to improving the working environment and increasing employee satisfaction.

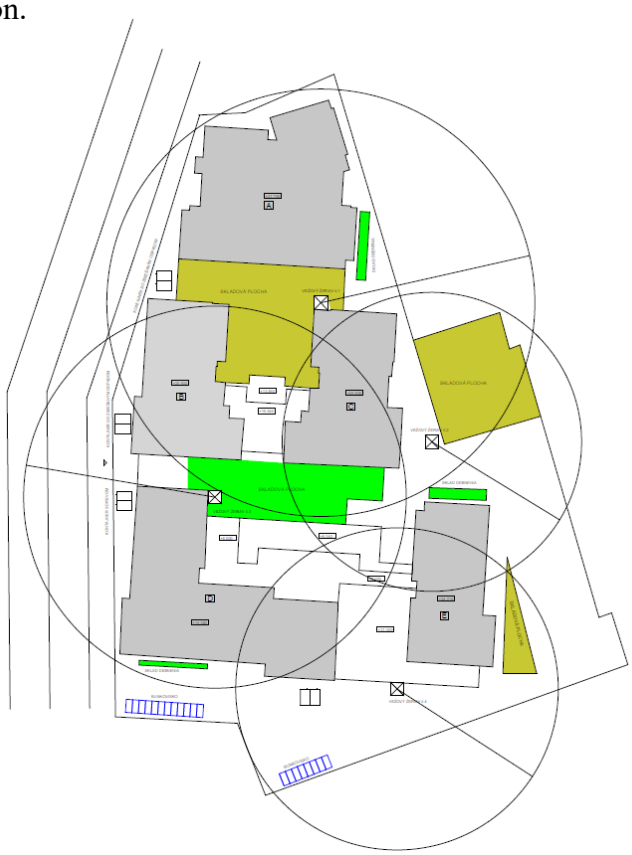


Fig. 3: Lean tool – lean layout: grey colour - proposed building, yellow colour - original storage areas, green colour - additional storage areas.

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The building materials, their types and quantities needed for the construction of the load-bearing structure of the Allbelli residential building were analysed using the lean layout tool (Fig. 3). There were three storage areas (yellow colour) on the construction site. A detailed study confirmed the need for the creation of additional storage areas (green colour) on the construction site, and the size of the construction site and the location of the facilities on the construction site made this possible.

The design of additional storage areas eliminated the transport of building materials on the construction site, which also eliminated situations where building materials could be damaged and thus the generation of construction waste was reduced. The efficient distribution of storage areas on the construction site is a fundamental element for construction waste reducing and improving the overall productivity of the project. Availability and accessibility of storage areas are key to minimizing complications that can lead to mishandling or damage to materials. The first step in effective allocation of storage area is careful planning of access routes for vehicles and handling equipment on site. These approaches must be designed to allow seamless access to materials, reducing the need for long or complicated transport routes. Such planning should take into account all aspects of the construction site, including topography, existing infrastructure and planned work operations. Implementation of lean layout requires detailed planning and coordination with all stakeholders involved on the construction site. After implementing the proposed changes, it is important to monitor key performance indicators such as time spent transporting materials, frequency of warehouse use, and overall worker satisfaction. This assessment will help identify additional areas for improvement and possibly adjust the storage area layout plan.

Last lean construction tool analysed was the 5S method. Sorting as the first pillar of the 5S method corresponds to the Just in time principle. There is only what is needed, in a certain amount and only when it is needed, at the workplace/construction site. The beginning of the process of implementing the 5S method on a construction site begins with a thorough analysis of all materials, tools and equipment that are on site. This step is essential because it provides a basic overview of the state of the workplace, allows the identification of possible areas where there is an excessive accumulation of unnecessary items, that is, it includes the identification of old, damaged or obsolete materials, tools and equipment that are no longer needed or do not fulfill their role in the current construction condition. During the construction of the Allbelli residential building, problems were identified with the lack of orderliness by workers on the construction site. There were rest of packaging materials at the construction site, indicating inadequate waste removal and ineffective management of waste streams. In addition to the remains of protective packaging, excessive remains of materials debris were also found, which indicates a lack of care in handling materials and inefficient use of materials. In this case, communication and training of workers about the importance and benefits of maintaining order on the construction site is important. If workers are not clearly informed about the standards and requirements for maintaining order on the construction site, inconsistent order to these rules and standards may occur. Workers should keep their construction site orderly. If the work environment is not arranged correctly, there is an accumulation of unnecessary items and misunderstandings. The implementation of the 5S method can also lead to a better understanding of work processes and the identification of areas where it is possible to minimize the excessive use of materials or create more efficient work

procedures. This can contribute to reducing waste and increasing the efficiency of construction work.

CONCLUSION

Nowadays, we are witnessing society's pressure to reduce the negative impacts of the construction industry (ACE). Reducing the amount of construction waste is a key point of the construction industry within the framework of sustainability and circular economy in the sense of Agenda 2030 and Green deal. The presented contribution points out that by simple application of selected lean construction tools - prefabrication, lean layout and 5S method, it is possible to achieve a reduction in the generation of construction waste. Of course, it is necessary to apply these approaches already in the initial phase of the construction life cycle (construction design) by specific construction participants (investor, designer, contractor). Through a case study, it was proven that by replacing the traditional lean construction method with an approach (filigree walls), it is possible to reduce the generation of wooden construction waste by 87,97% and concrete construction waste by 50,06%. On the other hand, however, it is necessary to admit that prefabrication cannot be used in the design and implementation of every building. Lean tools - lean layout and 5S method can always be used. Even with small changes in the management of the construction organization, it is possible to achieve a reduction in the generation of construction waste.

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NANOPARTICLES AND RECYCLABLE WASTE IN CONSTRUCTION MATERIALS. FROM PRACTICAL NECESSITY TO ADVANCED SOLUTIONS

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ABSTRACT

In an increasingly competitive economy, we are facing fierce competition in the construction materials industry, where the use of recyclable waste from demolitions has become more than a necessity. The compensation for the loss of certain properties, which could otherwise lead to a reduction in mechanical characteristics, has been achieved through the addition of nanoparticles with superior qualities. This paper will present the main nanoparticles introduced as subtle additives (ranging from 0.01 percent to a maximum of 1 percent) - currently limited due to manufacturing costs - into the formulations of construction materials such as nanocomposites, nanomortars, nanoconcretes, etc., as well as in sometimes substantial fractions of recycled aggregates, among others. Several types of nanoparticles will be discussed, starting with nanoclay, which improves strength and durability and carbon nanotubes, predominantly used in polymers for construction. In concrete, nano-silica can enhance compressive strength and reduce permeability, graphene oxide can improve mechanical properties and reduce weight and nano-metakaolin, being a pozzolanic material, contributes to long-term strength and durability. At the same time, an analysis will be conducted on some of the recyclable waste from construction, which, under certain conditions, can become integral parts of the formulations for new materials. In this way, we can address two societal issues: the first related to recycling demolition waste and the second to reducing pollution. Furthermore, we can highlight the circular economy, as these materials are reintroduced and repurposed in the creation of new advanced building materials.

Keywords: nanoparticle, recyclable demolition waste, new advanced buildings materials

INTRODUCTION

Research on the use of nanomaterials, mechanical properties, and the durability of cementitious materials is expanding year by year. These studies show that incorporating nanoparticles into cementitious materials can significantly enhance their characteristics, particularly in terms of strength and durability, while also identifying future research needs by uncovering unexpected features, such as self-cleaning capabilities or thermal conductivity improvements. Nanoparticles like nano-silica and carbon nanotubes are used

to modify the microstructure of cementitious materials, improving their density and reducing micropore formation [1, 4].

The introduction of nanomaterials in concrete increases mechanical strength and accelerates cement hydration, which is crucial for developing new cementitious materials with enhanced properties [2, 5]. Nanomaterials like TiO_2 and silver nanoparticles are also being explored for their photocatalytic and antibacterial properties, respectively, in geopolymer mortars, for example [6]. Adding nanoparticles to cementitious materials has demonstrated significant improvements in compressive strength and durability, which are essential for structural applications [3, 8].

Research indicates that materials like graphene and nano-silica can strengthen cement even at low doses, paving the way for more efficient concrete formulations. The mechanical properties of cementitious composites can be optimized through appropriate methods of nanomaterial dispersion, which remains an active area of research [2]. Incorporating nanoparticles into concrete also improves sustainability parameters, reducing the environmental impact of concrete structures [3, 4]. Nanomaterials help minimize porosity and enhance crack resistance, which is essential for the longevity of concrete structures [5, 7].

Nanomaterials can also be successfully used to improve the properties of foundation soils and asphalt mixtures [10], enabling the development of modern 3D printing technologies and opening new opportunities in the field [11]. Furthermore, new materials developed using recyclable waste and nanomaterials are significantly more efficient due to their reduced environmental impact [10]. Future research will focus on exploring new nanomaterials and their effects on the durability of cementitious materials while addressing current challenges in this field [1, 6].

MATERIALS AND METHODS

Nanotehnologii si nanoparticule

Nanotechnology is considered one of the main directions for the development of micro and nanosystems in recent decades, as well as new materials capable of incorporating elements into their structure that give them remarkable properties. It promises to revolutionize essential areas such as health, energy, environmental protection and the construction industry, but especially new materials. Through radical discoveries and innovations, nanotechnology [2, 7] can transform medical diagnosis and treatment, increase energy efficiency through advanced materials and renewable sources, reduce pollution and waste through green technologies, and improve industrial production through innovative processes adapted to market requirements and which are also sustainable. Potentially, nanotechnology [5, 7] could lead to a more efficient and sustainable use of resources and can have a beneficial impact on the vast majority of people around the world.

Nanomaterials are materials with a very small-scale structure (on the order of nanometers - 10E-9) that give them unique properties (superior mechanical resistance, photocatalytic properties, improved thermal conductivities) and diverse uses ranging from fields such as medicine (nanorobots that perform treatment tasks at the molecular level) or to nanosensors introduced into road layers, capable of monitoring their structural behavior in real time, including a multitude of functions.

There are numerous types of nanometric particles (metallic, oxide, polymer) used in medicine, catalysis, sensors with various uses, nanotubes (carbon, boron nitride) - very resistant and conductive or nanofibers used in filtration, textiles and composite materials or cementing, nanocomposites in hybrid combinations for increased durability, two-dimensional materials (graphene, MoS_2) that have the quality of being conductive and versatile. Nanoporous materials (aerogels) for insulation or fullerenes which are carbon molecules with multiple applications in energy and beyond.

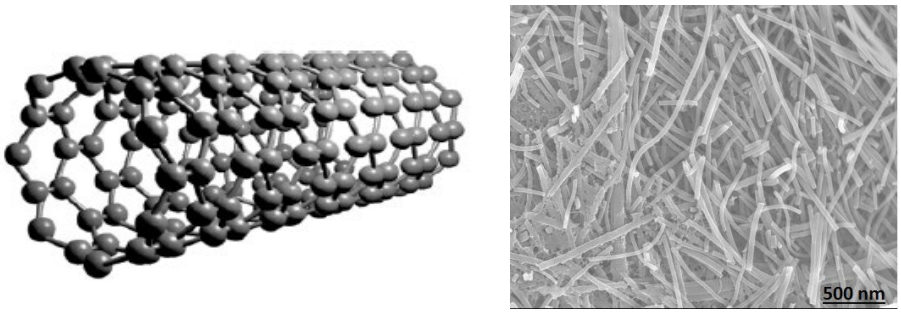
The most frequently used nanoparticles in civil engineering are those related to silicon dioxide nanopowder (Fig. 1 a,b) which improves the mechanical strength, durability and impermeability of concrete by reducing porosity.



a) Nanopoudre Dioxide de Silicon b) SEM for silicon nonopowder

Fig. 1. Silicon dioxide nanoparticles

Carbon nanotube (Fig. 2 a) or carbon nanofiber (Fig. 2 b) are particles that can contribute to an increase in the mechanical strength or conductivity of new composite cementitious materials.



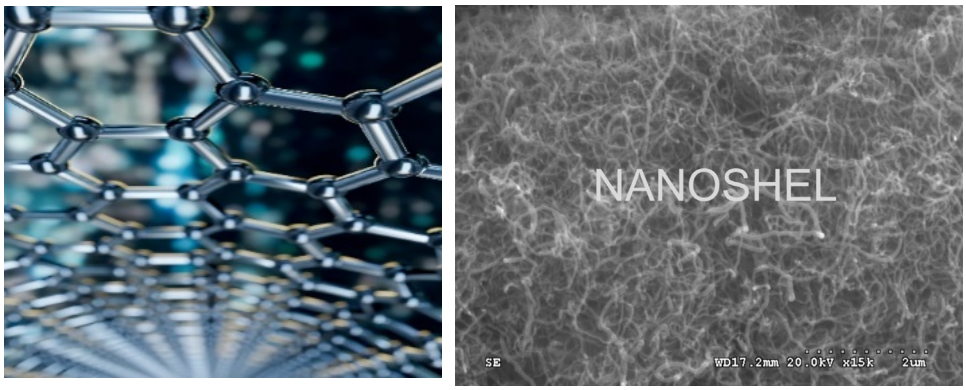
a) Carbon Nanotubes b) SEM for carbon nanofibers

Fig. 2. Carbon nanotubes and microstructural view of nanofibers

Graphene (Fig. 3), known for its exceptional mechanical, thermal, and electrical properties, has numerous promising applications in civil engineering, particularly for enhancing material performance and developing smart infrastructure and enhances the

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compressive and tensile strength of concrete, making structures more resilient to stress and reducing crack formation.



a) Graphene b) SEM for Single Walled Nano Tubes

Fig. 3. Graphene structure and SEM for Single Walled Nano Tubes (SWNT)

Recyclable waste in constructions

Demolition waste, especially from concrete structures (fig. 4), can be recycled and used to produce a new material that can also be concrete, thus contributing to reducing the environmental impact and reintegrating it into the economic circuit. This practice is part of the circular economy strategy and sustainable resource management.



a) Demolition processes b) Demolition processes c) Waste from demolition

Fig. 4. Recyclable waste of civil engineering sector

Demolition waste is multiple but those that can re-enter the recycling circuit are: recycled concrete (different sort aggregates or fines – Fig. 5), bricks and ceramic materials used as secondary aggregates in concrete but which can reduce the density of the concrete, making it suitable for non-load-bearing applications.



a) Recycled great aggregate b) Recycled medium aggregate c) Recycled fine aggregate

Fig. 5. Recyclable aggregate of civil engineering sector

Finely ground recyclable glass can be used as a pozzolanic binder or as decorative aggregate or asphalt waste added to improve the waterproofing properties of concrete but in limited quantities.

Advanced materials and their role in civil engineering

Advanced materials play a key role in achieving significant improvements in sectors such as aerospace, transport, construction and healthcare. They contribute to reducing carbon emissions and energy consumption, while facilitating efficient recycling and optimizing resource use through the rational and necessary use of construction waste [12, 13]. Another major advantage is the reduction of dependence on rare raw materials, particularly important for Europe, where they are available in limited quantities. By developing better performing, lighter, more durable and more sustainable materials, the transition to a green and circular economy is supported.

RESULTS and DISCUSSION

The use of nanomaterials in civil engineering

The use of nanomaterials in civil engineering [12, 13] opens new possibilities for improving the performance, durability and sustainability of structures and construction materials by increasing the physical and mechanical properties of concrete, reducing microcracks and permeability of materials, which makes them more resistant to corrosion, freeze-thaw and other degrading phenomena. Nanotechnology-based materials are used for thermal insulation and creating windows with self-regulating properties of light and temperature, can improve the thermal and fireproof performance of buildings but also for self-diagnosis and repair when smart concrete with nanotechnology-based sensors [14] allows real-time monitoring of cracks or stresses and even their self-repair by introducing nanogels into road structures.

Ecological curbs made from recyclable waste and nanoparticles [15] represent an innovative and necessary solution for building a sustainable future. The use of recycled materials in combination with nanoparticles not only offers significant environmental benefits, but can also contribute to increasing their physical and mechanical performance and improving the quality of urban and rural spaces, making them more attractive and sustainable in the long term.

Nanorobots in civil engineering [14] represent a fascinating and emerging technological advancement that could revolutionize the way infrastructures are built, monitored, repaired and maintained. These nanorobots could play a key role in infrastructure through predictive maintenance and real-time monitoring, performing nanoscale inspections inside materials, detecting defects invisible to the naked eye, which is impossible with traditional methods.

Compatibility of nanomaterials with concrete recipe and additions of recyclable waste

These solutions integrate advanced nanotechnologies and ecological materials, offering alternatives to, for example, traditional concrete or stone curbs. Thus, this involves optimizing the mixtures to obtain improved mechanical, chemical and ecological

properties. Nanomaterials must be integrated in such a way as to improve the properties of the concrete, without negatively affecting its homogeneity, workability or durability.

The compatibility of nanomaterials with concrete recipes and the integration of recyclable waste represent an innovative direction in the construction industry, with the potential to improve concrete performance and support sustainability. This is achieved by optimizing recipes and using advanced technologies to ensure appropriate mechanical, chemical and ecological properties.

DISPERSION

The dispersion of nanoparticles in different media is the process of uniformly distributing these particles in various matrices, such as liquids, gases or solids. This process is influenced by factors such as particle size, interactions between nanoparticles and the chosen medium, colloidal stability and physicochemical properties of the materials involved.

In liquid media, dispersion depends on surface tension, pH, ionicity and the use of dispersing agents (surfactants or polymers), while in the case of gases, dispersion stability is influenced by aggregation due to van der Waals forces, and for solid media, dispersion requires special technologies such as mechanical mixing or chemical treatment to prevent agglomeration of nanoparticles.

The goal of dispersion optimization is to maximize the unique properties of nanoparticles, such as electrical conductivity, optical properties or chemical reactivity, in applications such as medicine, industry and electronics.

The dispersion of the nanoparticles presented above can be done by several methods, such as in water (Fig. 6) using or not different dispersants (polyoxyethylene-alkyl phenol ether, surfactants (Fig. 6), silane-modified polycarboxylate, different types of cationic polycarboxylates, surfactants or others), mechanical mixing directly with the cement in different proportions (0.01% to 5%), with the help of ultrasound, the solvent evaporation method, electrostatic techniques, microfluidization or heating at high temperatures.



a) Water dispersion of silicon dioxide b) Water dispersion of carbon nanotubes

Fig. 6. Water dispersion of diferents nanoparticles

But each method has its advantages and limitations that make it optimal for use and we can remember here that ultrasonic dispersion (Fig. 7) brings a gradual and unwanted heating of the mixture due to molecular agitation so we had to control this phenomenon (Fig. 7) by maintaining them at low temperature,



a) Temperature method control b) Stability method control

Fig. 7. Water dispersion of silicon dioxide

The use of chemical dispersants (polymers or surfactants, stabilizing agents) that coat nanoparticles, reduce the attractive forces between them and prevent their agglomeration and lead to the stabilization of nanoparticles for longer or shorter periods depending on the type of dispersant and percentage, but unfortunately they can also modify the properties of nanoparticles or interfere with other substances/materials existing in the networks used in certain situations, which is less desirable.

CONCLUSIONS

The main topics addressed in studies on nanomaterials in cementitious materials include the use of nanomaterials to improve the mechanical properties and durability of cement-based materials. This research highlights the importance of innovation in nanotechnology to optimize the performance of construction materials while simultaneously addressing environmental and other challenges.

However, the production of nanomaterials is very costly on a small scale. Moreover, their tiny size and the associated handling difficulties can negatively impact human health and the environment. The implementation of nanotechnologies also requires adapting traditional construction processes, implying a complete shift in approach and the associated costs.

For instance, producing innovative curbs not only enhances the aesthetics and functionality of public spaces but also promotes sustainable and energy-efficient solutions. The use of recycled materials, intelligent nanotechnologies, and eco-friendly approaches contributes to creating more sustainable cities that are better adapted to future challenges.

Nanomaterials thus represent a promising solution for safer, more efficient, durable, and sustainable constructions, transforming civil engineering into a more innovative field.

Looking ahead, combining various dispersion methods based on their compatibility with cementitious material components is being considered to achieve a more homogeneous mix. This would also allow better control over the stability of the resulting materials.

ACKNOWLEDGEMENTS

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SEA GRASS POSIDONIA OCEANICA AS AN UNCONVENTIONAL THERMAL INSULATION

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ABSTRACT

The construction industry is one of the largest air polluters. This fact, along with the increasing demand for savings of heating energy, is leading to a growing interest in more eco-friendly materials for building thermal insulations. New thermal insulating material, prepared from the Posidonia Oceanica (commonly known as sea grass or Neptune grass) was prepared and studied. Posidonia Oceanica is an endemic plant that grows in large quantities in the shallow waters of the Mediterranean Sea. It is a protected species, but this protection does not apply to the non-living parts of the plant. Thermal insulating boards were made from dead Posidonia leaves bonded with plant-based epoxy. Bulk density of the boards ranged from 159 to 289 kg/m^3, and coefficient of thermal conductivity was between 0.054 and 0.076 W/m. K. Tensile strength of boards with bulk density 240 kg/m^3 and higher exceeded 2 MPa, which is sufficient for thermal insulation purposes. The ecotoxicity test showed that material is not ecotoxic for algae. The diffusion resistance of the boards was high (from 22 to 196 by wet cup method and 36 to 178 by dry cup method), because of the impermeable resin on the surface. The main problem of the Posidonia Oceanica boards was low mold resistance, which is common problem of most natural-based materials. This must be resolved, along with fire protection, before the material can be used in the buildings.

Keywords: thermal insulation, Posidonia Oceanica, Neptune grass, thermal conductivi

INTRODUCTION

According to the EU Directive 2010/31 [1] the construction industry is one of the largest polluters of the environment. Therefore, more eco-friendly alternatives to traditional thermal insulation materials are currently being sought. Conventional materials like fiberglass, polystyrene, or polyurethane often have energy-intensive production processes from non-renewable resources, and their disposal or recycling at the end of their lifespan is problematic. Using natural organic materials in insulation offers several benefits, concerning both environmental and technical aspects. These include the renewability of resources, low carbon footprint, biodegradability, and hygienic safety.

Some natural thermal insulations are used traditionally, such as wood fibre and particle boards, straw, sheep wool, cork, and similar materials. Currently, entirely new, previously unused biological sources are also being explored for producing these insulations, such as reed [2], mycelium [3], sugar beet pulp [4], rice and rapeseed straw [5,6] or new combinations of traditional materials, such as hempcrete.

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The international BIO4EEB project (BIO Insulation Materials for Enhancing the Energy Performance of Buildings), funded by the EU (Fig. 1), focuses on these unconventional thermal insulations. Within the project, several types of bio-material-based products are being developed for residential buildings. These include panels made from sea grass (Posidonia oceanica), polyelectrolyte complexes (PECs) for fire-resistant coatings, windows from bio-polyurethanes (bio-PUR), and thermal insulating foams from bio-polyurethane and polylactic acid (PLA).



Fig. 1: Logo of BIO4EEB project

The Czech participant in the project is involved in testing and verifying panels made from Posidonia oceanica, commonly known as sea grass or "Neptune grass." It is an endemic plant that grows in large quantities in the shallow waters of the Mediterranean Sea. This grass grows in sandy channels near the coast at depths of around 35 meters and can reach up to 1.5 meters in height. It is a protected species, but this protection does not apply to the non-living parts of the plant, which are washed ashore in the form of fibrous balls known as "Neptune balls" or as thick layers of dead leaves (Fig. 2). These are usually considered waste material and are disposed of in open landfills or composted.

Neptune balls can be shredded into fine fibers that can be used as thermal insulation in various forms. Loose fibers are already commercially available, for example for cavity filling. The bulk density of the fibers ranges from 17 kg/m³ to 155 kg/m³ (depending on compaction level), and their thermal conductivity ranges between 0.043 and 0.070 W/m·K [7]. Panels made from these fibers, bonded with epoxy resin (partially of natural origin), were tested. These panels, made from untreated fibers, had very low mechanical properties, and the authors recommended chemical treatment of the fibers (using sodium hydroxide and silanization) before use [8].

However, not much use has been found for dead sea grass leaves, and they have been only sporadically researched. For example, dry Posidonia leaves were experimentally used as insulation for flat roofs in 14 residential units on the Spanish island of Formentera. The thermal insulation layer made from Posidonia leaves had a bulk density of 185 kg/m³ and a thermal conductivity $\lambda = 0.044$ W/m·K [9].



Fig. 2: Neptune balls (left) and a layer of dead Posidonia leaves (right). Author: Lovina Fullgrabe, retrieved from https://seaescape.fr/blog/2020/10/20/banquettes-posidonie/

MATERIALS AND METHODS

Thermal insulating panels were produced by one of the project partners, company SOPHIA Hightech, Italy. Dead Posidonia leaves were collected at the Mediterranean coast in south Italy. Dry leaves were coated by plant-based epoxy resin and put into the moulds with the dimensions 300 x 300 mm. They were pressed to the desired thickness (150 - 300 mm). Eleven samples with different thicknesses and bulk densities were prepared (Fig. 3). The designation of each panel comprises of desired bulk density and thickness, but it was found that the real thickness and bulk density were slightly different. Designation, thickness and bulk densities of all samples can be seen in Table 1.

The bulk density ρ_v [kg/m^3] of the tested materials was determined by a gravimetric method. The dimensions of panels were measured by digital calliper and the volume was calculated from the dimensions. The bulk density was determined from the volume of the sample and its mass in the dry state as a ratio between the mass and volume of samples.

The flexural strength was determined by the three-point bending test according to the ČSN EN 310. The size of samples was 300 mm x 50 mm x thickness, 3 samples from each panel were tested and average value was calculated for each panel.

Water vapour diffusion resistance factor μ [-] was measured using the dry-cup and wet--cup method. At dry-cup method the test samples were placed on the sealed cups containing silica gel, at wet-cup method there was water instead of silica gel. Samples were put into the climatic chamber with 50% relative humidity and temperature 25 °C. They were weighted periodically and the water vapour diffusion resistance factor was calculated according to EN ISO 12572.

Preliminary test of ecotoxicity was made for 3 solid and 3 ground samples, taken from panels (10 g in 100 ml of distilled water for each sample), using the algae *Desmodesmus subspicatus*. The samples were exposed to the light for 30 days and after that the inhibition of the algae growth was evaluated according to the optical absorbance of the

solution. The values of absorbances were measured spectrometrically at a wavelength of 750 nm and average values of solid and grounded samples were compared with the control samples.

Mold resistance test was made according to ISO EN 846. Each sample was placed on an agar culture medium (5% maltose-dextrose agar) in Petri dishes. The dishes were left open during laboratory temperature for 3 hours (a non-specific airborne mold community was used as a test biological system). The dishes were then closed. The incubation proceeded at 25±1 °C for 28 days in a thermostat. The growth of mycelium on the top side of the samples was visually observed.



Fig. 3: Panels made from Posidonia Oceanica dead leaves

Table 1: Designation, thickness and bulk density of samples

Sample designation	Thickness [mm]		Bulk density [kg/m3]	
	Desired	Real	Desired	Real
P150/15	15	12.5	150.0	236.4
P150/20-1	20	18.0	150.0	159.0
P150/20-2	20	17.0	150.0	176.9
P200/20-1	20	17.1	200.0	219.7
P200/20-2	20	20.5	200.0	197.6
P200/30	30	31.0	200.0	189.2
P250/20-1	20	16.3	250.0	316.1
P250/20-2	20	19.6	250.0	238.4
P250/25	25	24.1	250.0	200.2
P300/20-1	20	20.4	300.0	286.6
P300/20-2	20	19.6	300.0	289.0

RESULTS AND DISCUSSION

The thermal conductivity λ [W/m·K] in the relation to the bulk density is given in Fig. 4. Thermal conductivity of all samples was under 0.1 W/m·K, which means that all materials can be considered as a thermal insulating materials. The value 0.1 W/m·K is generally considered as an upper limit for thermal insulations. The thermal conductivity ranged between 0.054 and 0.076 W/m·K with the bulk density between 159 and 289 kg/m³. There can be seen that thermal conductivity increases with bulk density, but the increase in thermal conductivity is only 42% with an 80% increase in bulk density, meaning that the thermal insulation capability remains effective even at higher densities.

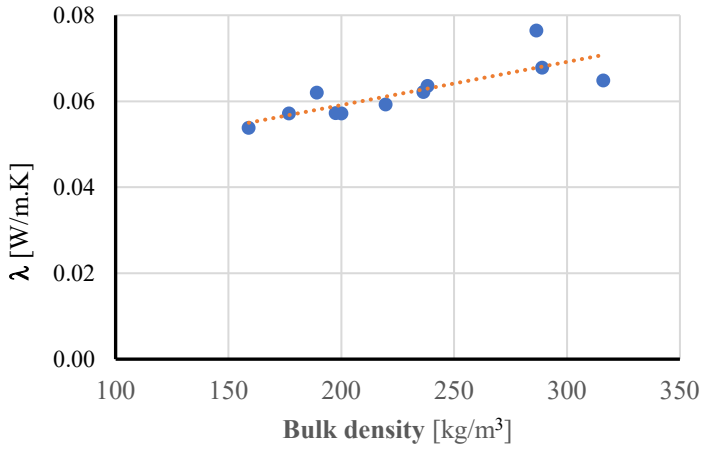


Fig. 4: Thermal conductivity of panels from Posidonia Oceanica

The tensile strength of the panels ranged from 0.7 to 2.8 MPa, as can be seen in Fig. 5. Strength increased with bulk density, and for panels with a bulk density of around 240 kg/m³ or higher, it exceeded 2 MPa, which is sufficient for thermal insulation materials.

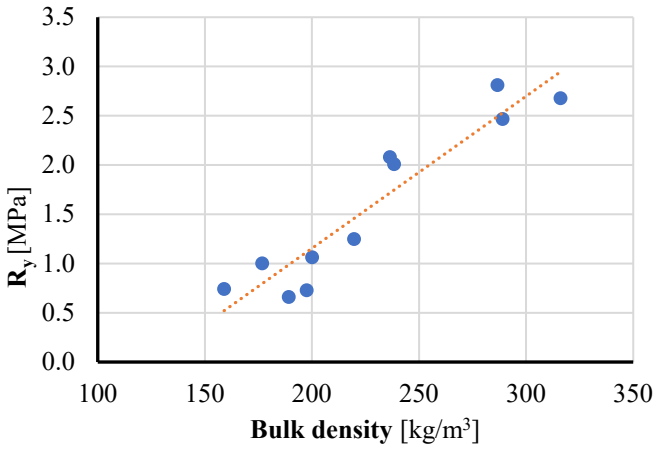


Fig. 5: Tensile strength of panels from Posidonia Oceanica

The diffusion resistance factor μ (Fig. 6) ranges from 22 to 196 (measured by wet cup method) and from 36 to 178 (dry cup method). The relatively high resistance to diffusion is primarily due to the layer of impermeable resin on the panel's surface. The μ-factor

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increases with bulk density. While for the panels with bulk density under 200 kg/m^3 is under 50, for the heaviest panels in exceeds 150. It is caused by the lower porosity of heaviest panels.

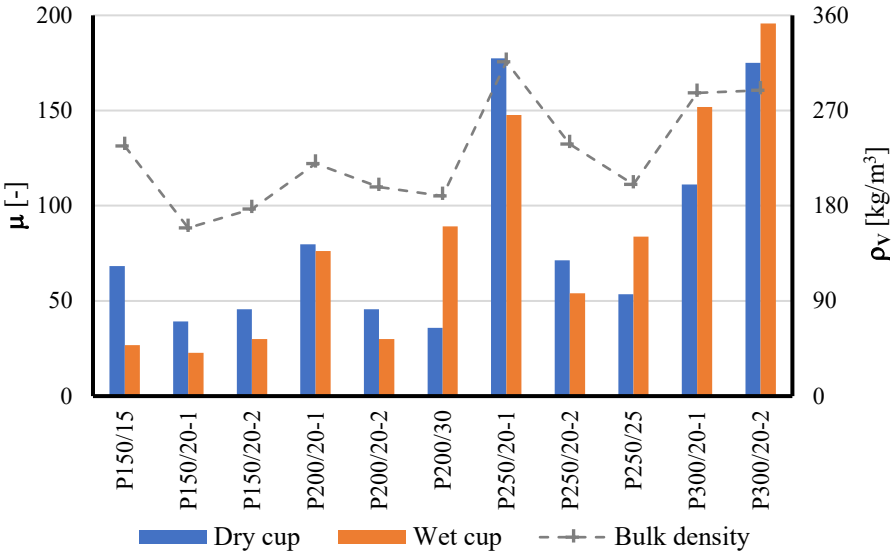


Fig. 6: Diffusion resistance factor of Posidonia Oceanica panels

The results of the preliminary ecotoxicity test are in Table 2. Negative value of inhibition means that samples stimulated the algae growth and therefore the material is not ecotoxic. The appearance of the samples after ecotoxicity test is in Fig. 7. Green color indicates algae growth.

Tab. 2: Ecotoxicity test results

Sample	Absorbency	Inhibition
solid	1.59	-57%
ground	1.24	-23%
control	1.01	0

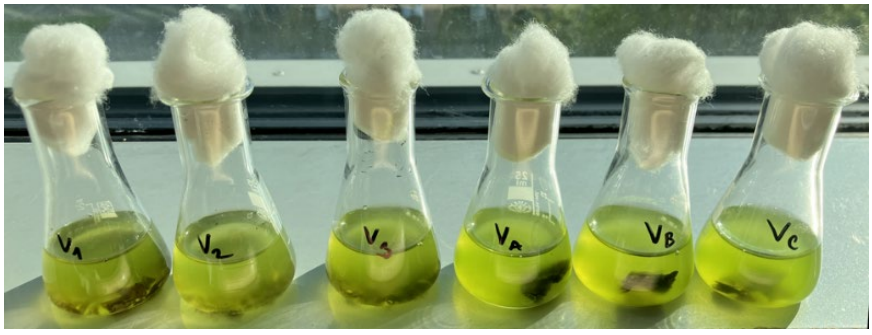


Fig. 7: Samples after ecotoxicity test

After the mold resistance test, all samples were covered by molds (controls without samples as well as agar in the Petri dishes with the samples), as can be seen in Fig. 8. The results indicated no difference between tested samples. However, molds did not cause biodegradation of materials as wood destroying fungi, it is mainly an aesthetic and health problem (possible production of spores).

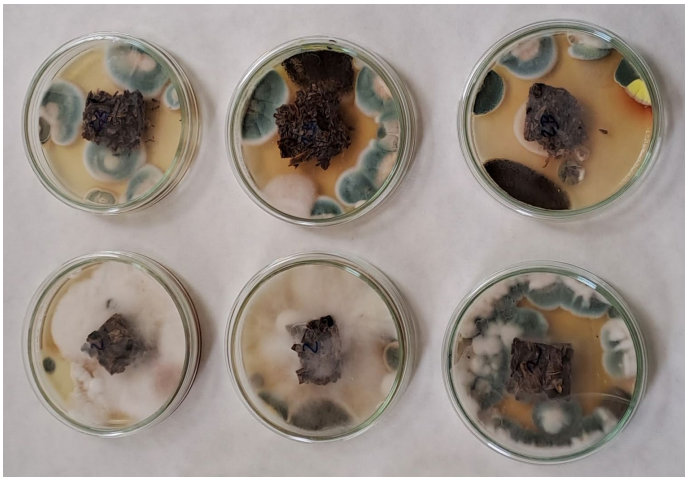


Fig. 8: Samples after mold resistance test

CONCLUSION

Panels made from Posidonia Oceanica dead leaves, bonded by plant-based resin have properties comparable to the commercially available wood fiber panels and can be successfully used for insulation either on their own or as a part of sandwich prefabricated panels. For practical use, panels with a bulk density of around 240 kg/m³ seem most suitable, as they have a tensile strength greater than 2 MPa, and their thermal conductivity is around 0.06 W/m·K.

Panels are protected on the surface against moisture, but when they are cut or broken, they are prone to the growth of mold and mildew on the unprotected side (as other plat-based materials), therefore they have to be properly installed and protected against moisture. The panels also need to undergo some treatment to enhance fire and pest resistance, but it is important to consider the types of treatments used and their potential impact on indoor air quality.

The use of this material is naturally expected mainly in the Mediterranean area (where sea grass is naturally found), but given the large volume of waste dead leaves of Posidonia Oceanica, testing this material in other climatic conditions also seems interesting, especially because thermal insulation materials are very important in colder regions.

ACKNOWLEDGEMENTS

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DISCLAIMER

Co-funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Health and Digital Executive Agency (HADEA). Neither the European Union nor the granting authority can be held responsible for them.

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SECTION GREEN DESIGN,

SUSTAINABLE CITIES AND ARCHITECTURE

ANALYSIS OF ERROR FACTORS IN REGIONAL GHG ESTIMATION BASED ON FUEL CONSUMPTION: FOCUS ON THE ROAD TRANSPORT SECTOR

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ABSTRACT

The climate crisis due to global warming is intensifying, and international cooperation to curb temperature rise is underway. South Korea has set GHG reduction targets, along with systems for implementation and assessment to achieve these goals. South Korea currently applies the IPCC-Tier2 method based on fuel consumption to estimate GHG emissions at the national level. Additionally, starting in 2024, it has begun estimating GHG emissions at the level of 17 local cities. However, applying the fuel consumption-based GHG estimation method at the local level can lead to errors, as it cannot accurately estimate GHG emissions from cross-regional traffic. Accordingly, this study conducted the following analyses to identify the error factors when applying the fuel consumption-based GHG estimation method at the local level. First, GHG emissions were estimated for 25 districts in Seoul, South Korea, based on fuel consumption and VKT (Vehicle Kilometers Traveled). After identifying the differences in emissions based on the estimation method, a regression analysis was conducted to determine the factors influencing these differences. The analysis showed that the errors in the fuel consumption-based GHG estimation method result from GHG emissions generated by commercial vehicles and freight trucks. Since commercial vehicles and freight trucks travel across multiple regions, it is likely that their refueling areas differ from their areas of operation, which may explain this outcome. This study analyzed the limitations and error factors when estimating GHG emissions at the local level based on fuel consumption. The analysis results suggest a necessity to develop methodologies for accurately estimating carbon emissions at the local level.

Keywords: Greenhouse-gas, MRV System, Road Transportation, Mileage-based

INTRODUCTION

As global warming accelerates, the damage caused by climate change is intensifying. GHG, the main cause of global warming, are increasing each year, and the global average temperature is also rising rapidly. International efforts to curb temperature rise are ongoing, with the Paris Agreement on climate change, adopted at COP 21 in 2015, being a prominent example (Kim, 2020). The Paris Agreement sets goals for climate change mitigation and adaptation. Article 2 defines the objectives for mitigating and adapting to climate change, and Article 7 outlines the specific principles, cooperation frameworks, plans, reporting and support mechanisms, and monitoring procedures needed to achieve

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the adaptation goals. These provisions include detailed regulations specifying National Adaptation Plans (NAPs) and the development of concrete national-level adaptation policies. Accordingly, the interpretation and implementation of the Paris Agreement provisions by each country have emerged as key policy issues, and the necessity of a comprehensive framework to guide the implementation process is increasing.

South Korea is also working to implement the Paris Agreement, aiming for a 24.4% reduction in GHG emissions from 2017 levels by 2030. Establishing a robust monitoring system is essential for evaluating target achievement. This will enable accurate estimation of GHG emissions and reductions. The Ministry of Environment of South Korea has established and is operating the National Greenhouse Gas Information Management System (GIR). The GIR provides a system for the systematic measurement and reporting of GHG-related data, publishing inventory reports at regular intervals.

South Korea currently assesses GHG emissions at the national level but is gradually transitioning to a Bottom-Up approach, aggregating GHG emissions from local units to estimate national emissions. This suggests the need for a method that can accurately estimate GHG emissions at the local level. However, applying a fuel consumption-based GHG estimation method at the local level may not be suitable, especially when estimating GHG emissions from the road transport sector.This occurs because the area where the fuel is purchased differs from the area where the vehicle operates. In other words, GHG emissions from specific vehicles may be estimated for areas where the vehicles did not actually operate. This issue poses difficulties in objectively assessing GHG emissions and reductions by region. Due to the aforementioned issues, GHG emissions estimated based on fuel consumption are expected to contain errors. Therefore, this study aims to analyze the main causes of these errors.

MATERIALS AND METHODS

The 2006 IPCC Guidelines recommend presenting a specified GHG estimation method rather than a total volume concept, defining this as good practice. Accordingly, various studies have been conducted to develop an activity data-based emission estimation methodology, moving away from the fuel consumption-based approach[1] presented and evaluated various models for estimating GHG emissions from road transport. The models presented here were structurally similar but showed considerable variation depending on input data and calculation processes. A key drawback of these models is their reliance on estimated traffic volumes collected through traffic models or traffic surveys. Such estimated traffic volumes may be over- or underestimated depending on the region, leading to errors in emission evaluations. This perspective is also found in the study by [2], which suggests that real-time data should supplement estimated data to overcome its limitations. It emphasized that in large cities with high traffic volumes and complex travel patterns, Intelligent Transportation Systems (ITS) should be utilized to accurately estimate GHG emissions.

With advancements in ITS and communication technologies and the accumulation of related data, research to accurately estimate GHG emissions has continued. [3] estimated GHG emissions using a model based on actual traffic volume (VKT). The VKT data was obtained from traffic databases analyzed by the Gyeonggi Province Traffic DB Center and Anyang City Hall. GHG emissions were calculated by multiplying VKT by the emission factor (EF) for each vehicle. However, the study identified a limitation in estimating emissions for roads without direct measurement, such as secondary roads

where ITS technology is insufficient. Advancements in technology and improvements in data processing capabilities have driven continued research to refine GHG emission estimation methodologies.

As shown in previous studies, efforts to accurately estimate GHG emissions in the road transport sector have been ongoing. Various attempts have been made to shift from fuel consumption-based to activity data-based emission estimation methods, but limitations due to technical constraints and restricted availability of data have been revealed. However, with GHG reduction designated as a national priority, there is a growing societal demand for accurate MRV, making the development of advanced GHG emission estimation methodologies essential. To this end, it is first necessary to analyze the issues and underlying causes associated with the current fuel consumption-based estimation method. In this study, GHG emissions were initially estimated based on fuel consumption and VKT data for the 25 districts of Seoul. After identifying the differences in emissions by estimation method, a regression analysis was conducted on these differences and their underlying factors to identify the causes of issues within the fuel consumption-based estimation approach. The overall analysis process is shown in Figure 1.

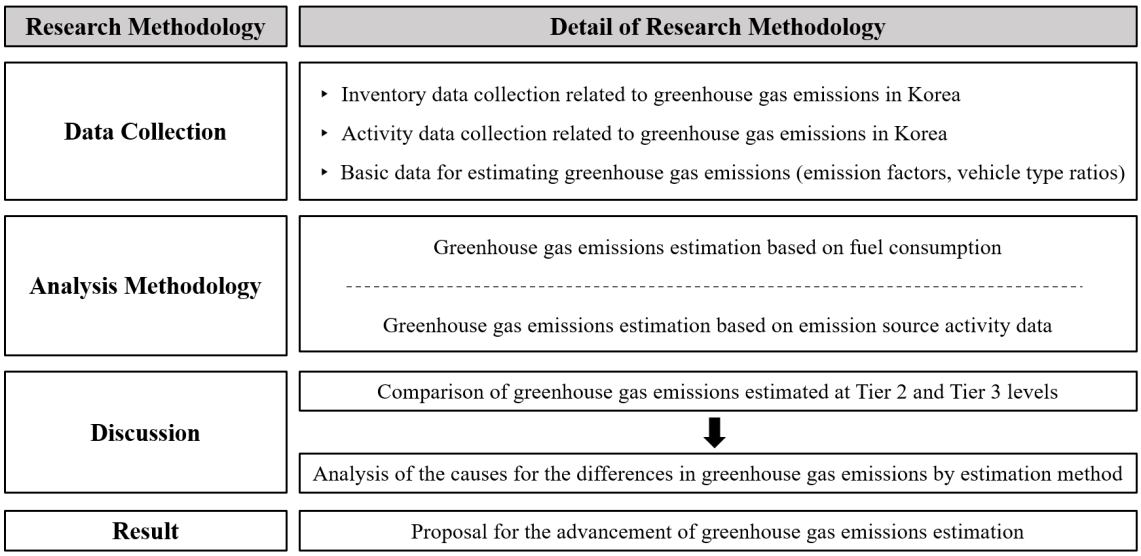


Figure 1. Research Flow

The annual GHG emission estimation formula based on fuel consumption (Eq. 1) and the data used are as follows.

$$\text{Emissions based on fuel consumption} = \sum (Fuel_{ijk} \times EF_{ij}) \qquad (1)$$

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In the above,

Fuel = Fuel consumption (TJ)

EF = Emission coefficient (kg/TJ)

i = Vehicle type

j = Fuel type

Data 1) "2022 Fuel Consumption in the Land Transport Sector in Seoul" from the 2023 Energy Statistics Yearbook [5]

Data 2) "National Calorific Value by Fuel Type" as specified under the *Energy Act*

The annual GHG emission estimation formula based on mileage data (Eq. 2) and the data used are as follows.

$$\text{Emissions based on activity data} = \sum (AM_{ijk} \times EF`_{ij}) \quad (2)$$

In the above,

AM = Annual Mileage (km)

EF` = Emission coefficient (kg/km)

i = Vehicle type

j = Fuel type

k = District

Data 1) "Average Vehicle Speed" presented in the 2022 Vehicle Speed Report by Seoul City [6]

Data 2) "Annual Vehicle Mileage by District and Vehicle Type" provided by the Seoul Open Data Plaza [7]

Data 3) "GHG Emission Factor for the Road Transport Sector" as specified under the *Framework Act on Low Carbon, Green Growth*

RESULTS

One can see below the results obtained (figure 2, figure 3)

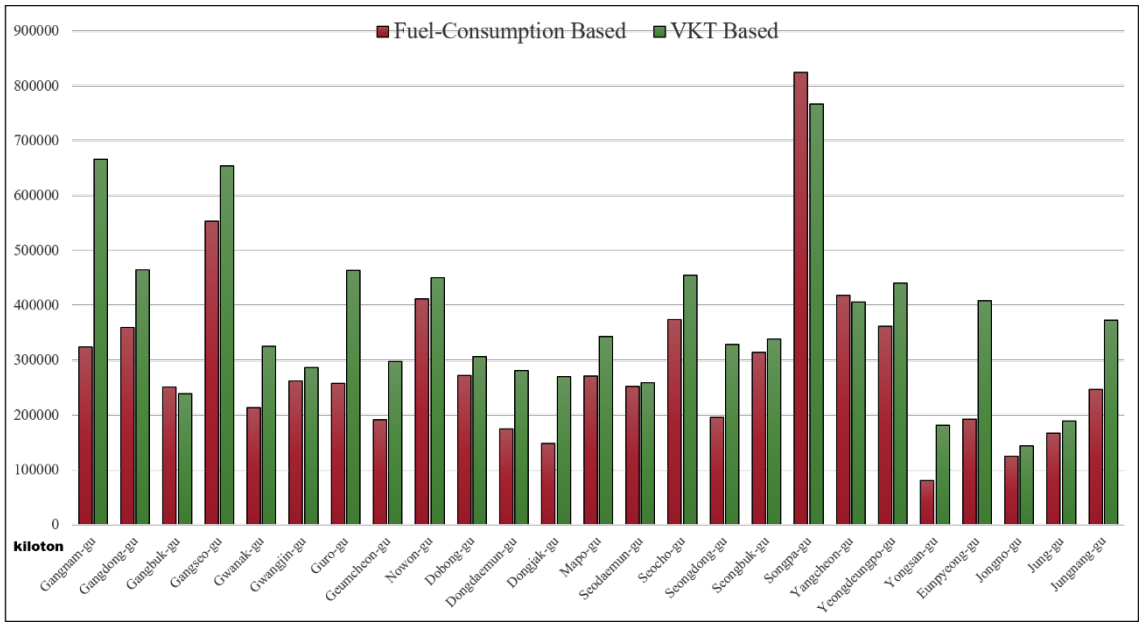


Figure 2. CO_2 Emissions Based on Fuel-Consumption & VKT method by Seoul Districts,

Source: Compiled by the authors

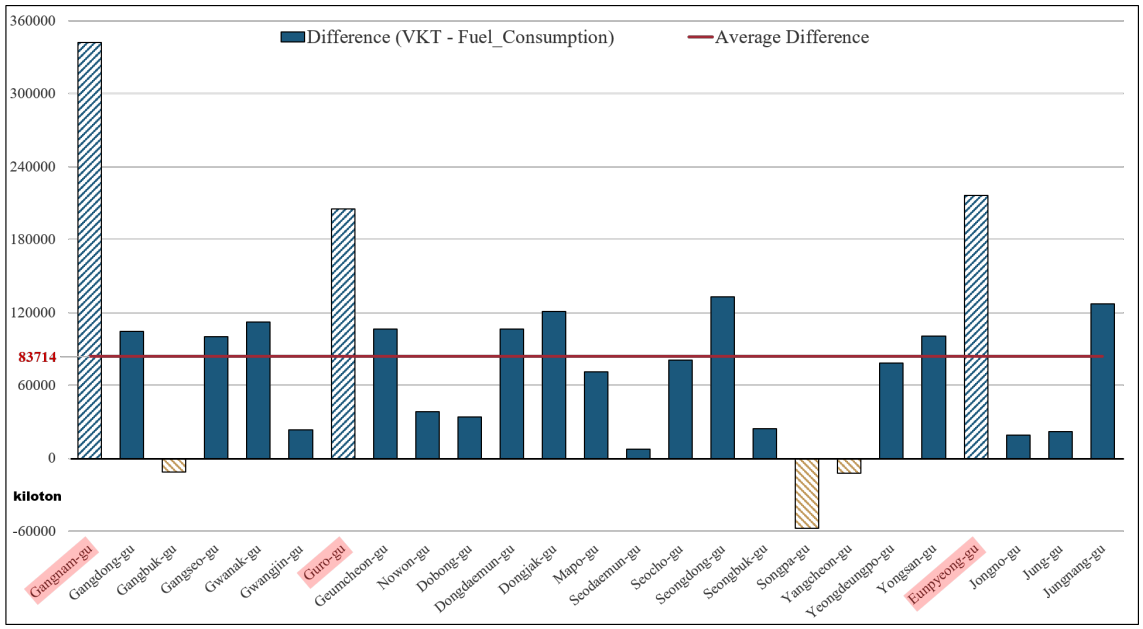


Figure 3. Difference of CO2 Emissions Between Fuel-Consumption & VKT method

Source: Compiled by the authors

https://doi.org/10.5593/sgem2024v/6.2/s26.31

Table 1. Summary Statistics of the Main Variables

	Mean	Std. Dev	Min	Max
	(1)	(2)	(3)	(4)
Difference by Emission Estimation Method	83,713.60	84,523.52	-57,354	341,962
Truck Registrations	12,908.24	5,182.07	5,050	29,466
Commercial Vehicle Registrations (Excluding Trucks)	5,878.88	4,267.02	1,127	20,552

Table 2. Summary of Regression Model Statistics

Variable	Coefficient	SE	t-value	p-value	R^2
Constant	80217.22	35839.23	2.24	0.04**	0.45
Truck Registrations	-7.16	3.18	5-2.25	0.04**	
Commercial Vehicle Registrations	16.33	3.87	4.22	0.00***	

※ The model demonstrated statistical significance, with an F-value of 0.00

DISCUSSION

The emissions analyzed using the fuel consumption and mileage-based estimation methodologies for the 25 districts of Seoul are shown in Fig. 2. GHG emissions calculated based on fuel consumption are represented by red bars, while emissions estimated using activity data are shown with green bars. In most districts, there is an observable difference in the lengths of the red and green bars, indicating discrepancies between GHG emissions estimated through fuel consumption versus mileage. Fig. 3 visualizes the differences in results based on the two GHG estimation methodologies. The average difference across all values is 83,714 kilotons, marked with a red line on the graph. This average represents approximately 25% of individual district emissions. In some districts, the difference noticeably exceeds or falls below this average, and these districts are marked with hatching on the graph.

The fuel consumption-based emission estimation method involves multiplying the total fuel consumption of each local government by fuel-specific emission factors. In contrast, the mileage-based emission estimation method calculates individual vehicle emissions by multiplying each vehicle's mileage by a unit emission factor, then summing the emissions of all vehicles passing through the given area. Based on this, it is anticipated that errors may arise in the fuel consumption-based estimation method when estimating emissions for vehicles whose refueling location differs from their area of operation (activity area). Consequently, a model was developed to identify error factors in the fuel consumption-based estimation method.

Initially, variables identified in previous studies as potential error factors were selected. The model was designed using latent variables, including incoming and outgoing traffic, the number of commercial vehicles, the number of freight trucks, road length, number of gas stations, and population for each district. After assessing model fit and the significance of each variable, "number of freight trucks" and "number of commercial vehicles (excluding freight trucks)" were selected as the final variables. Statistics for each variable and the model are provided in Table 1 and Table 2.

The model indicates that errors in the fuel consumption-based estimation method are influenced by the number of freight trucks and commercial vehicles. These vehicles are often registered in different locations from where they operate and typically travel across multiple regions, aligning with the anticipated issues in the fuel consumption-based method. Notably, districts with significant differences in estimated emissions, such as Guro-gu and Eunpyeong-gu, have large logistics and distribution centers. Additionally, Gangnam-gu and Guro-gu, with a high concentration of corporate headquarters, function as central business districts with substantial traffic inflows. These areas are also geographically on the outskirts of Seoul, experiencing high levels of through traffic and incoming/outgoing traffic, which reinforces the significance of these findings.

CONCLUSION

This study identified error factors in the fuel consumption-based estimation method. The root cause of these errors lies in applying this method at the local government level. As discussed in the introduction, the fuel consumption-based method is suitable for estimating GHG emissions at the national level, as it assumes that the total fuel consumed nationwide corresponds to the nationwide vehicle operation and GHG emissions. However, it is challenging to assume that vehicles operate and emit GHG in a specific region in proportion to the fuel consumed there. Since vehicles can freely cross regional boundaries, there is a high likelihood that the region where fuel is supplied does not match the region where the vehicle operates.

In this study, we aimed to identify factors influencing errors when applying the fuel consumption-based GHG estimation method at the local level. First, GHG emissions were estimated based on fuel consumption and mileage data for 25 districts in Seoul, South Korea. Next, differences in emissions based on the estimation method were examined, and regression analysis was conducted to derive factors influencing these differences. The analysis showed that the errors in the fuel consumption-based GHG estimation method stem from emissions generated by commercial vehicles and freight trucks. This finding suggests the need to adopt a mileage-based estimation method for accurate GHG emissions estimation at the local level, especially in regions with business, distribution, and tourism zones. Adopting a mileage-based method can significantly reduce measurement errors in such areas.

Since achieving carbon neutrality begins with accurately assessing GHG emissions, efforts to overcome the limitations of the fuel consumption-based estimation method must continue. While the mileage-based estimation method applied in this study may also contain some errors due to the use of average values and population estimation, transitioning to a mileage-based method is essential to address the inherent limitations of the fuel consumption-based method. With advancements in artificial intelligence and big data analysis, the accuracy of the mileage-based GHG estimation method will continue

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to improve. It is hoped that the findings of this study will serve as foundational data for developing policies and systems to support the advancement of GHG emissions estimation in the future.

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In the text, cite the literature in the appropriate places only by number:

/no more than 15-20 references for an 8-page article/

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BUILDING DESIGN ACCORDING TO THE GREEN BUILDING PRINCIPLES

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ABSTRACT

An ecological approach to construction and the Green Building concept force construction processes participants to meet specific requirements. In relation to designers and making designs of buildings, the requirements to be taken into account have also been defined. Above all, social, financial, and environmental benefits throughout the entire lifecycle of a building must be taken into consideration. It is significant to choose materials that ensure the safety and durability of the structure, as well as its thermal insulation up to the required level, and to use construction materials and products made from recycled raw materials. Green building is primarily about the efficient use of energy and resources, and automated construction technology, which should improve the comfort and functionality of buildings. When designing, the aim is to minimise interference with the natural landscape by fitting new buildings into the existing landforms and among adjacent buildings. An ecological building has an impact on both nearer and more distant surroundings, hence the right location is vital. Designing in accordance with the Green Building principles entails acknowledging the needs of society, such as ensuring accessibility for people with disabilities, creating social space and improving the quality of life of residents. The principles of sustainable development apply to both newly designed facilities and those undergoing thermal modernization. This article presents an example of a design made according to Green Building principles.

Keywords: green building, materials from recycling, sustainable development

INTRODUCTION

Architecture is currently undergoing a profound transformation. Green architecture and sustainable development have emerged as overarching facets in the construction industry, being driven by global fears about degradation of the natural environment, including excessive consumption of natural resources. Traditional architecture sought to consider three basic attributes of buildings: the form, function and construction, hence buildings were designed to be aesthetically pleasing, but also durable and functional. The 21st century, however, forces architects to take a more holistic approach to building design, in which responsibility for the environment, including the comfort of using a building, that is the indoor climate, is prioritised [3]. A solution that has gained much popularity is the Integrated Design Process (IDP), where each problem is approached from different points of view, by such stakeholders as the investor, architect,

construction engineer, site engineer, contractor, user, and this allows one to design a building that is optimal in terms of costs within the building's entire life cycle [4]. Designers of the building's architecture, construction and installations, building material manufacturers, and contractors should all be involved in efforts to achieve sustainable development goals, taking into account social, financial and environmental benefits throughout the whole life cycle of a building.

On 25 September 2015, the UN Sustainable Development Agenda called 'Transforming Our World: the 2030 Agenda for Sustainable Development', was adopted by 193 UN member states. It sets 17 goals, referred to as Sustainable Development Goals (SDGs), and associated targets, which are to be achieved by year 2030 [10]. The agenda focuses on 5 basic areas, 5xP: People, Planet, Prosperity, Peace, and Partnership. The issues related to sustainable construction are the responsibility of the Green Building Council, an umbrella name for non-governmental organisations whose main objective is to increase awareness of the need to design, build and use buildings in such a way as to minimise consumption of natural resources throughout the entire life cycle of a building. There are associations in UN member states dealing with sustainable building, for example the Polish Green Building Council in Poland (*Polskie Stowarzyszenie Budownictwa Ekologicznego*), whose four pillars are: climate change, circular economy, health and quality of life, and biodiversity.

In the context of sustainable construction, a holistic approach is as highly important as the inclusion of all aspects of a construction process, from making a design, through construction works, to the use and maintenance of a building. The basic premises of green building design are illustrated in fig. 1.

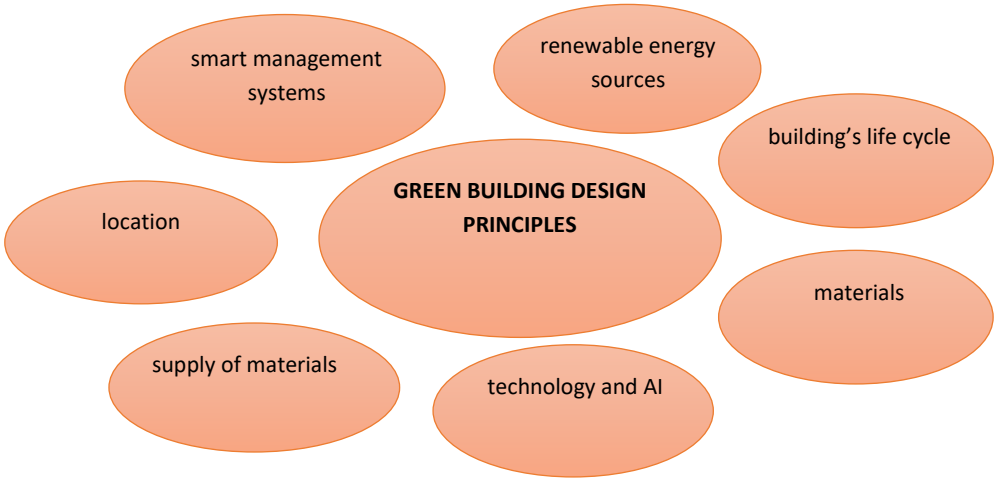


Fig. 1 Green Building design premises. *Source: the authors*

Sustainable design underlines the need to minimise the carbon footprint. Possible solutions are passive buildings, green roofs and efficient thermal insulation systems based on natural resources. Much emphasis is placed on natural recycled materials, and on state-of-the-art materials like bioconcrete and self-healing concrete. Other ecological materials include wood and aluminium. The latter material is gaining in popularity because of its increasingly common use for the production of window and door joinery, as a replacement of less ecofriendly PVC. Moreover, these materials can be recycled, which significantly helps to make energy savings and achieve close-loop targets. When selecting materials, it is also worthwhile to take into consideration their natural

composition, high durability, effect on air quality, availability, simplicity of use, and ease of disposal [13, 14]. While designing interiors, efforts are made to include as many materials with high heat capacity as possible, for example concrete or stone, which absorb, store and gradually release heat to the environment. This allows one to regulate temperature inside a building, minimizing temperature fluctuations, especially in changeable atmospheric conditions [1].

Decreased demand for energy can be achieved by tapping onto alternative energy sources. The inclusion of renewable energy sources such as solar panels, wind turbines, geothermal energy or bioenergy and other sustainable energy solutions in the building industry ensures energy self-sufficiency and contributes to reduced emissions of greenhouse gases [2, 8].

Smart HVAC (Heating, Ventilation, Air Conditioning) grids and systems, which have been gaining in popularity over the recent years, enable us to optimise energy efficiency in the entire life cycle of a building. To this end, roller shutters are fitted in windows to prevent the overheating of the building's interior, while the rooms are designed in such a way as to promote natural air flow and exchange. Monitoring systems and smart lighting are also installed. To maximise the use of natural light, automatic window shutters are designed with a built-in smart timer and controller that allow their automatic closing and opening, depending on the intensity of sunlight in different times of the day and seasons of the year. When choosing sanitary fixtures and fitting, it is a good idea to opt for ones which allow restricted water flow (e.g. taps with aerators, water saving toilet cisterns, etc.) [6, 11].

Passive design takes advantage of characteristics of the landscape, climate and materials in order to create an energy-saving space. It is important to position a building so as to allow it to harvest as much solar energy as possible in winter, but not to be exposed to excessive sunlight in summer, which can be helped by strategically placing windows, canopies and other elements, in order to focus or block the inflow of sunrays. The choice of a site should help to minimise the demand for transport, which is associated with a better access to public transport and services. Locating a building near public transport stops or stations is intended to encourage future inhabitants to use public transport, which reduces emissions of harmful substances to the atmosphere and consequently ensures cleaner air in the urban space. When designing buildings, it is also worth considering the natural relief of the terrain, and measures to protect the flora and fauna found there. This can be achieved by using natural slopes in the landscape, taking into account the existing plants, and adjusting the planned building to the ones already there, in its vicinity.

Another important target is to shorten supply chains. Here, the choice of suppliers matters. One should consider both logistical issues (e.g. distance), which affect the carbon footprint left, and the quality of goods. A shorter supply chain means lower environmental costs of transport, that is less pollutants emitted to the atmosphere by vehicles transporting materials and other elements to a construction site. It is worth asking potential partners about certificates and any other documents attesting to their reliability and adherence of the green development requirements.

Green building design and modelling is an important aspect of ecological construction because it employs software tools and methods to analyse, simulate and optimise the environmental efficiency of a building being designed. The use of IT instruments

facilitates daily work done by all participants of a building process and minimises the risk of potential errors. Automated generation of drawings, reports, analyses, timetables, and other essential information about the building under construction eliminates the risk linked to the so-called human error.

The application of building information modelling (BIM) enables the user to create a database of materials with detailed information about them. By carefully calculating amounts of materials needed, it is possible to minimise the waste, while precise localisation of all elements of a building eliminates collisions between supplies. BIM also ensures a more rapid transfer of information between different divisions in the construction industry. Designing and modelling with the use of modern tools can help to identify potential problems and threats, as well as to provide solutions and recommendations to improve the design. Finally, it allows documenting and verifying the results of the design process, and assists in obtaining a green building certificate [16]. By performing an analysis of the design building's life cycle assessment, it is possible to optimise design and material solutions, which may have an adverse impact on the environment [12]. BIM facilitates the acquisition of data at every stage of a design process. Based on the analyses made, it can be concluded that a building's life cycle assessment should be made right from the start of a design process in order to achieve optimisation, that is the attainment of the best possible final results [7].

The review of the literature and interviews with engineers, as well as seminars dedicated to the above problems, confirm the authors' belief that it is of utmost importance to systematise construction design principles in terms of sustainable development. Hence, the aim of this article has been to present the basic design aspects according to the Green Building concept and to illustrate them with practical examples in order to gain better understanding of the Green Building approach, to learn about the benefits derived from sustainable construction, and to identify the challenges that must be overcome for these principles to be implemented in practice.

MATERIALS AND METHODS

The first step in our study was the perusal of source literature, and an analysis of the source materials and information (stage 1 in figure 2). The materials for the study were extracted from interviews with engineers and from seminars organised for contractors of construction works. With this information, we were able to summarise the data concerning the approach to building design in line with the Green Building principles. This allowed us to define the research problem. Finally, a study case of a building designed according to the sustainable development framework was presented.

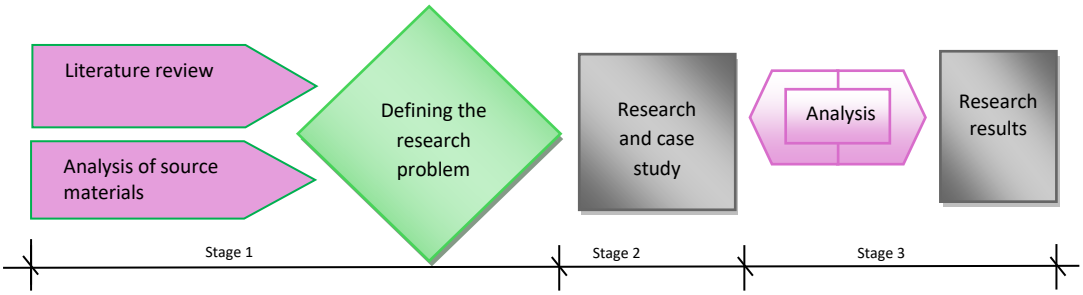


Fig. 2 A flow chart illustrating the research methodology and scope. *Source: the authors*

RESULTS

Having analysed the Green Building principles, a comparison was made between some design aspects for a traditional building and one designed in accordance with the provisions of sustainable development.

Two single-family, one-storey houses with a habitable attic and a similar building area (approximately 150 m^2) and cubage, both situated in a rural area, were selected for comparison. Building number 1 was designed in a traditional way, on a rectangular plan and covered with a gable roof. It was built with the traditional brick technology with reinforced concrete tie beams and ceilings. The building is connected to the municipal heating and ventilation network, including hot water supply, and with no alternative energy sources.

Building number 2, consistent with the Green Building principles, was situated on a land parcel in such a way as to harvest the maximum solar energy – it has large south-west facing windows with roller shutters and open space rooms. The northern part of the building, which is a cool zone, has no windows and is divided with partition walls. The walls of the house were made of expanded clay blocks, which provide an additional benefit of providing high accumulation mass. The gable roof is traditional but with three-layer insulation of the total thickness of 45 cm. Certified window and door joinery was used. To minimise water consumption, rainwater and grey water recovery systems were created. Mechanical ventilation with heat recovery as well as photovoltaic panels and a heat pump were designed. A comparison of the selected solutions is presented in table 1.

Table 1 Comparison of traditional building no 1 and building no 2 raised according to Green Building principles

Factor	Traditional building	Building raised according to Green Building principles
Building materials	Conventional materials, e.g. concrete, steel, brick	Ecological, renewable materials, with small impact on the environment, e.g. expanded clay, wood; and technologies reducing the carbon footprint (prefabrication)
Energy saving	No advanced insulation solutions or efficient energy management systems were used	Strong emphasis on energy savings, by using effective insulation materials, mechanical ventilation with heat recovery, and renewable energy sources (photovoltaic panels, heat pumps)
Water management	The building was not optimised for water savings	The building uses water collection systems, water saving devices, and technologies which minimise water consumption
Impact on the environment	It can lead to a higher pollution level during construction and after its completion	The design comprises processes that minimise the environmental impact, for example by using low emission materials, or design reducing the carbon footprint
Sustainable development and health	It may not take into account aspects related to the residents' health, such as indoor air quality, access to daylight or ecological materials	It focuses on promoting health and comfort of residents, by using ventilation systems, low-toxic materials and natural light
Life cycle of a building	It may generate higher maintenance costs in the long term due to higher water and energy consumption	A sustainable design envisages a longer life cycle of a building, lower maintenance costs and easier adaptability to changing needs

Source: the authors

https://doi.org/10.5593/sgem2024v/6.2/s26.32

DISCUSSION

Case studies from the real world offer a valuable insight into the practical application of the design techniques presented above. The analysis of the two compared designs of houses attested to the presence of sustainable development trends, which was described in this paper on the basis of a review of the literature and interviews and seminars with experts. It is worth noticing that visually similar buildings can play their functions in an entirely different manner, and have a different impact on the environment and comfort of users. Traditional construction focuses on functional and aesthetic expectations of the investor, on the use of standard materials, methods and practices in design that are well known. It also tends to generate more waste and emissions of harmful substances. In contrast, green building creates many benefits for the environment, economy and society. It contributes to reductions in amounts of greenhouse gases, CO_2 emissions and water consumption. It has a beneficial effect on the health and well-being of residents by providing them with ample natural light, ventilation, thermal comfort, and good quality indoor air, while reducing noise. Our comparison of two variants of single-family houses demonstrated lower maintenance costs of building no 2, and its greater market appeal to investors owing to the compliance with certification standards. The implementation of new design principles calls for a well-integrated and well-thought-out system so as to ensure effective control and management. The initial costs of green building solutions can be challenging to investors; however, the long-term savings can offset these costs, which is proven by analyses of the life cycle of buildings. Our analyses and interviews show how important it is to disseminate the sustainable development building trends, and - in the context of future studies – to acquire information about potential challenges and ways to deal with them [5, 9].

CONCLUSION

The article focuses on significant aspects of making sustainable building design. The main aim is to acquaint the reader with specific practical guidelines that can help architects and building designers in their daily work. The analysis of actual designs allows us to understand how design techniques are transmitted from theory to practice, shaping a sustainable environment. Based on our study, we can conclude that integration of ecological solutions in a building design process contributes to reducing the negative impact of construction on the natural environment. The right approach to building design can have a beneficial influence on nature as well as generating economic benefits and improving the quality of life of the building's residents. When adopting these principles, it is worth bearing in mind that the sustainable development design guidelines allow the designer to shape a building's surroundings in a way that not only satisfies current expectations but also creates a sustainable future for next generations. Observing the horizon of trends in building design, it can be seen that green architecture is advancing towards a harmonious combination of modernity, functionality and environmental management. There are numerous challenges that green building is faced with, hence the key importance of environmental education of the society, because the demand for green buildings increases as the public awareness of this approach to design grows.

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CYCLING TOWARDS SUSTAINABLE TOURISM AND MOBILITY: INSIGHTS FROM THE CZECH REPUBLIC

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ABSTRACT

The purpose of this article is to explore the role of cycling tourism in promoting sustainable urban mobility and environmentally friendly tourism practices, with a focus on the Czech Republic. The study investigates the motivations, behaviors, and preferences of cycling tourists, particularly in the post-COVID-19 context. Findings reveal that relaxation and exploring new destinations are primary motivations for cyclists, who favor dedicated cycling paths over mixed road traffic. Generation Z tends to use bicycles for leisure activities with friends, rather than for long-distance touring. Contrary to expectations, the availability of charging stations for e-bikes is not yet a significant factor influencing cycling route choices in the country.

The results also show that, during long-distance cycling trips, tourists tend to prefer local guesthouses or alternative forms of accommodation over hotels. Cyclists also prioritize routes that are close to amenities such as dining facilities, highlighting the importance of accessible infrastructure. Furthermore, after the pandemic, there has been a shift towards active forms of mobility, such as walking and cycling, over the use of public transport.

This study provides valuable insights into how cycling tourism can contribute to sustainability goals by promoting eco-friendly travel options and encouraging urban planners to develop cycling-friendly infrastructure. The findings suggest that cycling tourism is an important driver of sustainable urban mobility, offering a model for integrating tourism with broader urban development strategies focused on reducing environmental impacts.

Keywords: cycling, sustainability, tourism, urban mobility

INTRODUCTION

Tourism is a dynamic and fast-growing industry with the potential not only to create employment opportunities but also, especially after the COVID-19 pandemic, to focus on sustainable practices across many countries worldwide, as the industry carries some negative impacts on society [1]. Transportation is a crucial component of tourism, and without its development, expanding this sector would be challenging [2].

Sustainability has become a key issue across all sectors, including tourism [4]. It is defined by three main principles: economic, social, and environmental, with a need to find a balance between them [2]. Properly developed and regulated tourism activities can significantly contribute to achieving all 17 Sustainable Development Goals (SDGs) [7]. However, various forms of tourism can have negative effects on destinations and local communities [4]. Achieving sustainability in tourism depends on awareness, political support, promotion, and the engagement of all stakeholders. It is vital to

monitor the impacts of tourism and stakeholder behavior, implementing measures to mitigate negative environmental consequences in the long term [2].

On the one hand, sport and tourism are two separate sectors, but on the other hand, they are interconnected, and it is even possible to talk about the fact that tourism activities are often carried out at the same time as sport. This close relationship is evidenced by, among other things, the infrastructure facilities built such as accommodation, catering and transport [6]. Sports tourism is a form of tourism where participants travel to engage in sports activities or attend sports events [7]. Conditions for sport and recreation in each country can support tourists' active lifestyles, safety, and the sustainability of the area [8].

Tourism is closely linked to the movement of tourists, showing the interdependence between travel and mobility systems. However, with the expansion of tourism and mobility, the issue of excessive greenhouse gas emissions has emerged [5]. Currently, tourism development is driven by the growth of various transport modes, including those under the category of micromobility. Micromobility comprises bicycles, scooters, walking, and other means of short-distance transport, which offer the advantages of speed and smart solutions. These transport modes encourage sustainable behavior, contributing to the principles of sustainable tourism [3], [10]. Cycling, in particular, has gained popularity as both a means of transport and a leisure activity, with interest in it continuing to rise [6]. Micromobility options, including cycling, represent a group of eco-friendly transport modes that help reduce environmental impacts, making destinations more attractive and allowing them to stand out competitively [10].

The development of cycling tourism relies heavily on built infrastructure like designated cycle paths [3]. Paths without road traffic and intersections enhance safety and promote sustainable travel, which can also help manage seasonality fluctuations in the demand for sports tourism [3], [8]. Additionally, nearby dining or lodging facilities, such as hotels, guesthouses, or bed and breakfasts, can make these routes more appealing to certain traveler segments [3]. In particular, the climate of an area or the quality and desirability of natural landscapes are important elements of cycling development [8].

The COVID-19 pandemic has highlighted the need for sports tourism to adapt to new demands [6]. Since the pandemic, many people have shifted their lifestyles, placing greater emphasis on sustainable behavior. This trend is evident in the growing interest in sports tourism, particularly cycling [9]. This study focuses on a target group of cyclists across the Czech Republic, exploring their perceptions of cycling in the context of sustainability and urban mobility following the COVID-19 pandemic.

MATERIALS AND METHODS

A questionnaire survey targeting all age groups was conducted to study the behavior and preferences of cyclists in the Czech Republic. The survey consisted of eight closed questions, including a set of statements designed to gather data on specific behaviors in certain situations. Initially, the research focused on determining whether respondents actively use bicycles and whether they cycle alone, with a partner, with friends, or with family. These questions helped identify the target group of cyclists.

The survey also explored whether cyclists were more likely to be day-trippers, engage in multi-day cycling trips, or how frequently they rode during the main cycling season

(April to September) in the Czech Republic. This information helped clarify whether participants cycled recreationally, used bicycles primarily as a mode of transport, or considered cycling a passion.

Following this, respondents were presented with statements and asked to indicate their level of agreement. The statements were designed to reflect current trends in sustainability, urban mobility, and changing lifestyles following the COVID-19 pandemic. They were based on findings from scientific studies on cycling behavior in Italy and other countries, allowing for a comparison of Czech cyclists' behaviors with those of cyclists abroad.

The final section of the questionnaire gathered demographic information, including the respondent's region in the Czech Republic, gender, age, and education level.

The research questionnaire was created electronically using Google Forms and distributed across the Czech Republic via social media. Additionally, it was made available at the reception desk of a three-star hotel located in Hranice, Olomouc Region, near the popular Bečva cycle path, and distributed to hotel clients. The survey was conducted from early June to September 2024. The goal was to capture the preferences of cyclists by collecting relevant data from a suitable target group, including those who utilize accommodation facilities during their cycling trips. A total of 201 respondents took part in the survey, 70 of whom said they were active cyclists.

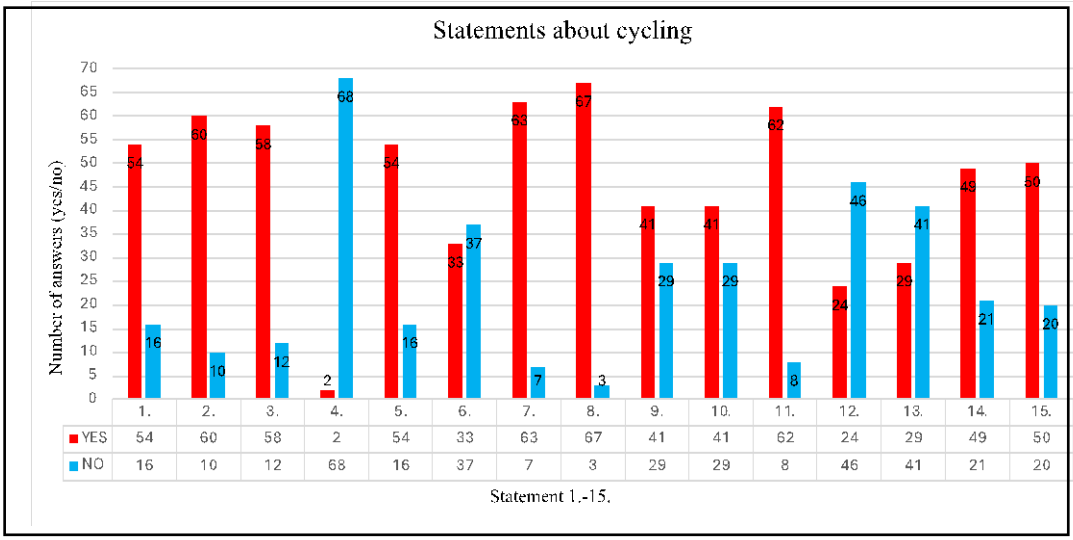
RESULTS

The first part of the questionnaire focused on gathering basic information about respondents from the Czech Republic. Most cyclists reported cycling with their family (partner and children). Interestingly, the second largest group consisted of those who cycle with their partner. As shown in Figure 1, a total of 50 cyclists either rarely or often take multi-day cycling trips during the season, representing the majority of respondents. The largest age group among the respondents was between 46 and 60 years old. Cyclist behavior was further analyzed through the statements provided below.

Attributes		Number of respondents
Cyclist		70
He/she rides a bike most often with ...	Family	24
	Partner	23
He/she goes on multi-day cycling trips	During the season often	20
	Rarely	30
Gender	Female	35
	Male	35
Age	18-25 years	7
	26-33 years	13
	34-45 years	18
	46-60 years	24
	61 years and older	8

Figure no. 1: Results of closed-ended questions of questionnaire (source: own elaborating)

The second part of the questionnaire survey was focused on more detailed specifications of cyclists' behavior in the Czech Republic. The following graph (Graph no. 1) presents the results of the statements listed below the graph.



Graph no. 1: Results of statements about cycling (source: own elaborating)

Statements:

1. I use my bicycle for bicycle trips rather than as a means of transport (to work, school).
2. I tend to do my bike tours in the country I come from.
3. The main motive for cycling for me is the need to relax [4].
4. During a bike tour I look for charging stations for electric bikes [6].
5. The development of cycling supports the achievement of sustainable tourism (protection of the environment) [5].
6. After the COVID-19 pandemic, I look for means of active mobility (walking, cycling) rather than public transport [5].
7. When cycling I prefer dedicated cycle paths rather than mixed traffic on the road [5].
8. I'm willing to travel a longer distance on a dedicated bike path than when riding in mixed traffic on the road [3].
9. When I cycle, I tend to choose a cycle route that is close to accommodation or catering facilities [3].
10. Generation Z (born 1997-2012) uses bicycles for leisure time with friends rather than for long bicycle trips [6].
11. On long bike rides I prefer to stop at a catering facility where I expect to be able to refresh myself [6].
12. When I cycle, I usually stay overnight in some accommodation for at least 1 night.
13. During a cycling holiday I prefer to stay in a hotel [4].
14. I use a bicycle as a secondary means of transport, i.e. I use private or public transport to get to a given place and then make daily trips by bicycle [4].
15. Within the framework of cycling, I explore rather unvisited cities and monuments.

A more detailed analysis of cyclists' behaviour leads to the following conclusions. It can be seen that around 77 % of respondents use a bicycle for cycling trips rather than as a means of transport. This is confirmed by statement 3, where 82 % of respondents' main motive for cycling is relaxation and exploring undiscovered places. However, it can be observed that 97 % of the cyclists surveyed do not look for charging stations for e-bikes on their routes. It can be seen that 77 % of respondents are aware of the implications of sustainable transport and therefore use a bicycle. Statement 6 presents the results of the lifestyle changes after the COVID-19 pandemic and it is therefore evident that 47 % of cyclists are looking for means of active mobility. The vast majority of respondents indicated a preference for dedicated cycle paths over mixed traffic on the road. Generation Z is also more likely to use the bicycle as a means of spending leisure time with friends. As many as 96 % of respondents also indicated that they prefer to stop at a lodging or dining facilities during their bicycle trips. In contrast, when cyclists undertake multi-day cycling holidays, they prefer to stay in other types of accommodation rather than in a hotel. Moreover, if we take into account the data from the Figure 1 above, we can conclude that people whose main motive is relaxation often travel with their family or partner and their age ranges from 34-60 years. Thus, this is a target group of middle-aged or later people who perceive the importance of sustainable modes of transport and their environmental consequences. It can also be noted that this target group is looking for infrastructure for cyclists, such as cycle paths and nearby social facilities (accommodation, restaurants). Interestingly, this target group does not use accommodation in hotels during cycling holidays, which often provide a total comfort of services for cyclists. The results of the survey therefore reflect the current situation regarding cycling in the Czech Republic.

DISCUSSION

The research findings reveal similarities between the behavior of cyclists in the Czech Republic and those abroad, highlighting key patterns that inform the development of sustainable mobility. One notable observation is that, unlike their counterparts in other countries, cyclists in the Czech Republic do not yet seek out charging stations for e-bikes, suggesting a lower adoption rate of e-bikes. This could indicate an opportunity for growth in e-bike usage, provided that supporting infrastructure, such as charging points, is developed to encourage broader adoption. Additionally, the survey results reflect a positive shift toward active mobility, such as walking and cycling, among Czech cyclists following the COVID-19 pandemic. However, this shift appears less pronounced than in other countries, suggesting that there is room to further promote and encourage active, sustainable modes of transport. Campaigns to raise awareness about the benefits of cycling, combined with investments in infrastructure, could play a crucial role in bridging this gap. The data underscores a significant potential for developing cycling infrastructure in the Czech Republic. The majority of cyclists expressed a preference for designated cycle paths and the availability of nearby accommodation and dining facilities. This points to a growing demand for integrated infrastructure, particularly in urban areas and along major cycle routes connecting cities. Prioritizing the development of such infrastructure can encourage more individuals to adopt cycling not just for leisure, but as a practical, everyday mode of transport. Despite the majority of respondents perceiving cycling as a sustainable mode of transport, the findings reveal a disparity between this perception and actual usage, as cycling is predominantly seen as a leisure activity. This suggests that while the benefits of cycling are recognized, more

efforts are needed to position it as a viable alternative to other modes of transport, particularly for daily commuting. Developing supportive infrastructure, such as safe cycle paths, secure parking, and urban bike-sharing systems, could make cycling a more attractive option for regular use. Interestingly, the research also shows that while multi-day cycling trips are popular, cyclists tend to avoid hotel accommodations, indicating a preference for other forms of lodging, such as campsites or short-term rentals. This behavior suggests an opportunity for the tourism and hospitality sectors to adapt and cater to the specific needs of cyclists, thereby enhancing the appeal of cycling tourism. Overall, the results confirm that there is significant potential for promoting sustainable mobility through cycling in the Czech Republic. Investment in infrastructure, coupled with initiatives to raise awareness and integrate cycling into urban transport planning, could play a critical role in fostering a culture of sustainable mobility. Expanding designated cycle paths, improving access to facilities, and supporting the adoption of e-bikes would not only encourage greater usage but also align with broader goals of reducing carbon emissions and promoting healthier lifestyles.

CONCLUSION

The study aimed to investigate the behavior and preferences of cyclists in the Czech Republic, with a particular focus on sustainable modes of transport. The findings reveal both opportunities and challenges for promoting cycling as a practical, everyday means of transportation. Although cycling is a popular activity in the Czech Republic, it is primarily seen as a leisure pursuit rather than a sustainable mode of transport. This perception suggests a need for a cultural shift, where cycling is embraced not just for relaxation but also as a viable and eco-friendly alternative for daily commutes.

The research identified several key areas for development. First, there is significant potential for expanding infrastructure to support cycling, including designated cycle paths, bike parking, and facilities such as e-bike charging stations. The data showed that, unlike in some other countries, cyclists in the Czech Republic are not yet actively seeking out e-bike charging infrastructure, which may indicate a lower adoption of e-bikes. Addressing this gap could encourage more widespread use of e-bikes, supporting sustainable urban mobility. Furthermore, the study highlights the importance of support from cities and municipalities in promoting sustainable transport. Investments in infrastructure, such as cycle paths connecting urban centers and integrating cycling facilities with public transport, can make cycling a more attractive option for residents. This is especially relevant given the post-COVID-19 trend towards active mobility, which has had a positive impact on both the environment and public health. However, the proportion of Czech cyclists opting for active transport remains lower than in other countries, suggesting a need for further promotion and education.

A surprising finding was that cyclists tend not to use hotel accommodations when taking multi-day cycling trips, preferring other forms of lodging. This presents an opportunity for the hospitality sector to adapt and cater to the needs of cyclists, offering specialized services that align with the growing trend of sustainable tourism.

The results underscore the need for further research, particularly into daily transport habits, such as commuting to work or school. Understanding these patterns could help in designing more effective strategies to encourage sustainable travel within towns and cities. There is also a notable opportunity to improve the perception of cycling as a

sustainable mode of transport among younger generations, especially Generation Z, who currently use bicycles more for leisure.

The study has several limitations that should be acknowledged. The sample may not fully represent the broader cycling population in the Czech Republic due to potential regional bias and the reliance on online distribution and a specific hotel location. Moreover the scope of questions was limited, providing a general rather than detailed understanding of cycling sustainable habits.

Overall, this study provides a comprehensive overview of the current state of cycling in the Czech Republic, identifying critical areas for infrastructure development and policy support. It outlines a framework for integrating cycling and sustainable mobility into broader urban development strategies, promoting a shift towards greener, healthier, and more sustainable cities. Encouraging the perception of cycling as not just a recreational activity but as a practical, everyday mode of transport is essential for achieving long-term sustainability goals.

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DEVELOPMENT PERSPECTIVES OF URBAN AGRICULTURE IN THE PROMOTION OF URBAN SUSTAINABILITY IN LATVIA

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ABSTRACT

In 2015, the United Nations set 17 sustainable development goals to be achieved by 2030. Among them, the 11th goal is – sustainable cities and communities. Taking into account such factors as increasing urbanization, challenges of well-being in the urban environment, the imbalance of resources, the issue of sustainability of urban areas is becoming more and more relevant. It requires solutions that balances sustainable development in economic, environmental and social dimensions. Urban agriculture is a practice with a wide functionality, simultaneously impacting several challenges, such as the crisis of social cohesion, provision of resources, awareness of food systems, etc. In Latvia, agricultural practice is based on traditions and is widespread among the population, but in urban areas it is practiced mostly in the scale of micro-farming for self-consumption. However, taking into account the global experience of urban agriculture, it is relevant to assess the development perspectives of the practice's potential in Latvia as well. Therefore, the aim of this study is the assessment of urban agriculture development scenarios in Latvia. The development scenarios are subordinated to the dimensions of sustainable development and the potential of urban agriculture in promoting the urban sustainability. The method of the analytic hierarchy process was used to evaluate the development scenarios. As a result of the research, the most suitable urban agriculture development scenario in Latvia is based on the social dimension, where urban agriculture is creating a socially active and involved society.

Keywords: urban agriculture, sustainable development, sustainable cities, Latvia, analytic hierarchy process

INTRODUCTION

The relevance of urban agriculture as an object of research in various fields of science has significantly increased in the 21st century. The research activity and its dynamics confirm the growth of the role of practice in modern society, especially in the promotion of urban sustainability. The definition of the concept of urban agriculture is complicated by different scales, territorial understanding, practice approaches, goals, etc. aspects. However, in both the short and extended versions of the definition, the Food and Agriculture Organization of the United Nations emphasizes the aspects of food cultivation, identifying in the short version of the definition that urban agriculture "can be defined as the production of food and other outputs and related processes, taking place on land and other spaces within cities and surrounding regions" [1]. Although agriculture is not only a food-producing sector, in the context of urban agriculture, emphasizing this aspect is essential, as it justifies the multifunctionality of the practice [2].

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Historically, the relevance of urban agriculture has been variable – initially it started as a practice for the security and independence of the city's food resources, but in the 21st century it is a practice for obtaining food resources, environmental diversification, educational functions and recreation [3]. Urban agriculture has become a supporting tool for urban sustainability and regeneration. Agricultural practice in cities is primarily associated with the promotion of various aspects of sustainability, however, the dominant dimensions in the development of the practice differs in regions and countries. Taking into account its versatile functionality and differences in approach and scale in different countries, urban agriculture research is essential for the determination and analysis of the specifics of not only global regions, but also national and even organizational levels.

Urban agriculture in Latvia is influenced by a set of several factors, highlighting social potential and economic risks, but the multifunctionality of the practice, including the promotion of urban sustainability, determines the relevance of its development. Although urban agriculture in Latvia has sufficient development experience, the determination of development perspectives has not been carried out so far. In order to determine the most appropriate development perspective, the research has chosen the analytic hierarchy process (AHP) - method developed by the American professor Thomas L.Saaty. AHP is a multi-criteria decision-making method that transforms the investigated problem situation into a hierarchical criteria model and provides a systematic approach to the hierarchical arrangement of problem or goal elements [4].

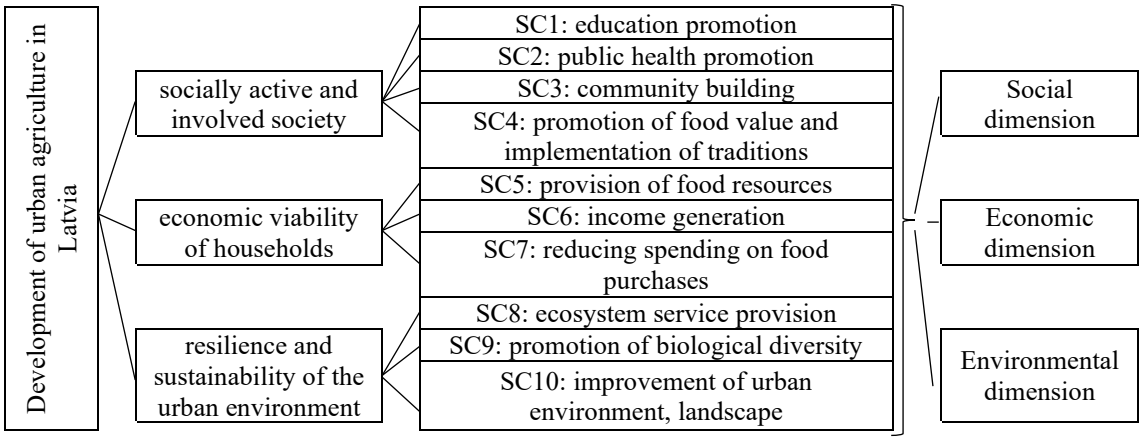
MATERIALS AND METHODS

Several data were used in the development of the research and the application of the AHP method. First of all, the previous studies on the specifics of urban agriculture in Latvia (multifunctionality of the practice [2], analysis of the motivation of the practice [5], the socio-economic specificity of the practice [6]). Secondly, the existing studies on urban agriculture in other countries were used, the focus of which is the analysis of the dimensions of sustainable development, in order to form a description of the development perspectives in Latvia. In the result, by summarizing the results of research on urban agriculture in Latvia and the results of research in other countries on the implementation of sustainability dimensions in practice, the AHP method with a four-level approach was developed in this research (Fig.1).

At the ***first level***, the general goal is identified - determining the most suitable perspectives for the development of urban agriculture in Latvia. In the ***second level***, three groups of criteria are classified: 1) socially active and involved society; 2) economic viability of households; 3) resilience and sustainability of the urban environment. The criterion of a *socially active and involved society* is justified by the functionality of the practice in various aspects of welfare development, such as education, health, cohesion, involvement and co-responsibility, etc. [2]. The criterion for ensuring the *economic viability of households* is subordinated to the specifics of urban agriculture in Latvia – both the case analysis [6] and the results of the population survey [5] show that the practice is primarily implemented in households, much less often in community gardens and businesses. Therefore, the development of urban agriculture in Latvia is primarily influenced by the criterion of the economic viability of households. The criterion of *resilience and sustainability of the urban environment* is justified by the functionality of agriculture in the urban environment, where the practice provides not only food resources, but also a direct impact on the urban ecosystem and environmental quality [2; 7].

In the ***third level***, the sub-criteria are defined for the identified three groups of criteria. The sub-criteria are determined according to the functions of the practice in Latvia [2], the case analysis and its SWOT analysis [6] and the results of the population survey [5].

At the ***fourth level***, scenarios for achieving the overall goal are determined. Urban agriculture has a certain role and potential in promoting the sustainable development of cities [2; 3; 9], therefore the approach of classifying the dimensions of sustainable development is often used in the research of various aspects of urban agriculture, both the specifics of the practice and the impact in sustainability analysis [7; 8; 9]. In order to determine the development perspectives of urban agriculture in Latvia and its driving scenario, this study analyzes which dimension of sustainable development is dominant in achieving the general goal. Therefore, three alternatives of development perspectives have been determined for the development of urban agriculture in Latvia: development driven by the social dimension, the economic dimension or the environmental dimension.



Source: authors' construction

Fig. 1. **Hierarchy of evaluation criteria for evaluating the development perspectives of urban agriculture in Latvia**

In this research an expert analysis approach is used to evaluate criteria and alternatives. In the selection of experts in the AHP method, the relevance of the experts' knowledge and experience in the analyzed problem must be primarily taken into account - by primarily determining the sufficient coverage of the experts' knowledge and experience in the criteria and competences to be evaluated in the scenarios to make a decision, not a certain number of experts [10]. In this research, as the primary criterion in the selection of experts was set the choice from representatives of various dimensions influencing the development of urban agriculture. The ***experts*** involved in the research are: *Rita Vectirane* (Deputy Chairperson of the Jelgava City Council in the program of social affairs, health protection, culture, education and sports issues, Chairperson of the Education and Culture Committee of the Latvian Association of Municipalities); *Dace Silina* (Dr.agr., associate professor of the Latvia University of Life Sciences and Technologies, leading researcher of the Institute of Soil and Plant Sciences); *Anita Villerusa* (Dr.med., professor of Riga Stradins University, leading researcher of the Institute of Public Health, representative of the European Association of Public Health Schools (ASPHER) in Latvia); *Una Ile* (Dr.arch., associate professor of the Latvia University of Life Sciences and Technologies, leading researcher of the Department of Landscape Architecture and Planning).

RESULTS

Three development scenarios were created to evaluate the development perspectives of urban agriculture in Latvia, describing the functions implemented in the scenario and drivers of development for each. The results of urban agriculture studies in Latvia and the regions of the Global North have been used to develop the characteristics of the scenarios.

The development of urban agriculture based on the **social dimension** is driven by social sustainability. The social dimension justifies the implementation of *functions* such as the promotion of education, especially in the aspects of awareness of the value of the environment and food [7; 8; 11], involvement of society in urban planning and social development issues [12], promotion of physical and psychological health [2] and co-responsibility [7; 8], promoting social well-being by reducing social alienation [11] and restoring the human-nature connection and cultural traditional activities [8; 9; 12]. In this urban agriculture development scenario the *drivers* in Latvia are individuals as initiators. However, in the fulfilment of a full-fledged social dimension, the activity and involvement of the community and the support of the local government are essential, because the functions of the dimension can be realized most widely in the form of gardens of community and educational institutions – and that implementation requires the systemic support of local governments.

The **economic dimension** in the development of urban agriculture focuses on the aspects of resource balance and provision. It ensures *functions* in two main directions: the provision of food resources and aspects of financial sustainability [7; 8; 12]. Growing food at the household level provides food resources, potentially reduce food purchase expenses, generate income and promote employment [2]. The *drivers* of the economic dimension depend on the practice volumes. But since it can be identified in the research of urban agriculture in Latvia that it is practiced mostly in households, in small quantities and mainly for self-consumption [5], then in the assessment of the development scenarios of the practice in the economic dimension, the activity of households is primarily evaluated. In this context, dimension drivers are individuals.

Urban agriculture, based on the **environmental dimension**, develops and improves the resilience, diversity and sustainability of the urban environment [7], providing *functions* such as mitigating the negative consequences of climate change with aspects of ecosystem service [8; 12] and creating a recreational environment [2]. The *drivers* of this scenario are representatives of all levels, starting from individuals, greening and diversifying the environment around them at the household level, up to the national level, where the processes of urban greening and biodiversity promotion affect climate neutrality, sustainable cities, etc. the strategic goals of national development.

In the case of Latvia, in order to determine the most appropriate scenario, the experts evaluated the mutual importance of criteria and sub-criteria and their role in the implementation of various dimensions (scenarios) of the development of urban agriculture. The results of the expert assessment are summarized in Table 1.

Table 1

Weight of AHP criteria, expert assessment

Criterion	Criterion weight	Sub-criterion	Sub-criterion weight	Dimensions		
				S*	E*	En*
socially active and involved society	0.43	SC1	0.28	0.53	0.14	0.33
		SC2	0.22	0.38	0.21	0.41
		SC3	0.34	0.56	0.19	0.25
		SC4	0.17	0.40	0.22	0.38
economic viability of households	0.29	SC5	0.49	0.34	0.39	0.27
		SC6	0.33	0.34	0.46	0.20
		SC7	0.18	0.24	0.43	0.32
resilience and sustainability of the urban environment	0.28	SC8	0.20	0.33	0.23	0.44
		SC9	0.35	0.27	0.15	0.58
		SC10	0.45	0.35	0.15	0.50

** S – social; E – economic; En - Environmental*

Source: authors' construction and calculations based on AHP method

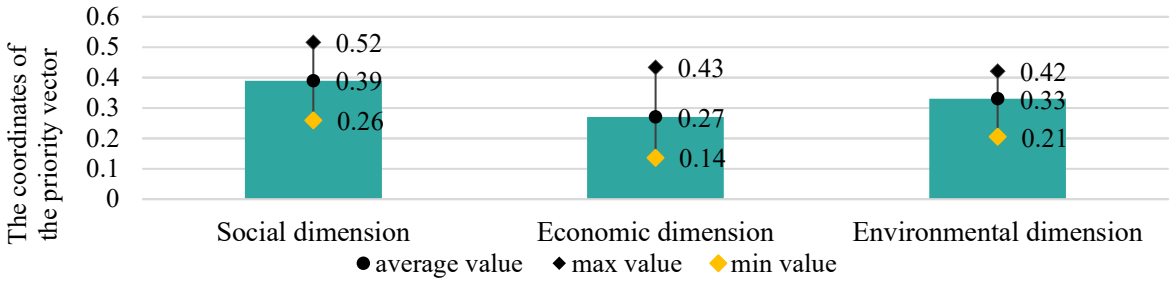
At the first step, the criteria were compared in relation to the general goal of the research – the development of urban agriculture in Latvia. Summarizing experts' assessments, it can be concluded that the development of urban agriculture in Latvia can primarily ensure a *socially active and involved society* (experts' average assessment: 0.43).

In the second step of experts' evaluation, the sub-criteria of each group were compared (Fig.1). Urban agriculture in Latvia is able to create a *socially active and involved society* if it fulfils such functions as education promotion (SC1), public health promotion (SC2), community building (SC3), implementing food values and growing traditions (SC4). According to the assessment, the formation of a socially active and involved society is primarily influenced by the potential of urban agriculture in community formation – it has the greatest impact, promoting both social cohesion and communication, as well as involvement in community activities and development-related issues.

Urban agriculture in Latvia contributes to the *economic viability of households* if it fulfils such functions as provision of food resources (SC5), generates income (SC6) and reduces the expenditure on food purchases (SC7). The opinion of experts prevails that urban agriculture is primarily able to fulfil the provision of food resources for households. However, 3 out of 4 experts emphasized that at the household level, the provision of food resources is primarily possible, and not the generation of income, emphasizing relatively small production volumes. All experts rate the household viability criterion "reduction of food purchase expenses" as the lowest – the consensus of the assessment is also emphasized by the comments of all experts during the interviews regarding the high cost of food growing practices when all resource costs are taken into account.

Urban agriculture in Latvia contributes to the *resilience and sustainability of the urban environment*, if it fulfils such functions as providing ecosystem services (SC8), promoting biological diversity (SC9) and improving the urban environment and landscape (SC10). The experts' assessment is dominated by the potential of practice to improve the city environment and landscape. The result also indicates that the environmental specificity of Latvia's cities and low pollution (compared to metropolitan cities) reduce the potential of urban agriculture in providing ecosystem services. The experts particularly emphasized the functionality of urban agriculture in greening the environment.

In the final step of the AHP method, experts evaluated the comparative role of three development perspectives in the development of urban agriculture in Latvia (Fig. 2). As a result of the evaluation of alternative dimensions in the achievement of the general goal (development of urban agriculture in Latvia), the experts evaluate the ***social dimension*** as the dominant one with a global priority vector of 0.39. Taking into account the assessment of experts, the most important thing for the development of urban agriculture in Latvia is to promote the social dimension, which is a priority in the group of criteria for a socially active and inclusive society (Table 1). But for the social dimension, the global priority vector is also high for the sub-criteria of other groups, such as "improving the urban environment" (0.35), "providing food resources" (0.34) and "generating income" (0.34). This shows the integrity and influence of the social dimension also in the criteria of the economic viability of households and the sustainability of the urban environment. Therefore, according to experts, the perspective of the social dimension is a priority for the development of urban agriculture in Latvia.



Source: authors' construction

Fig. 2. **Evaluation of the perspectives of development of urban agriculture in Latvia**

The assessment of the environmental dimension is also relatively high, which dominates the sub-criteria "promoting biodiversity" (0.58), "improving the urban environment" (0.50) and "providing ecosystem services" (0.44) in the experts' assessment, and is relatively significant also in criteria such as promotion of food value and cultivation traditions (0.38) and education promotion (0.33). The interaction of social and environmental dimensions is essential in the development of sustainable cities, as they are characterized by the provision and balance of natural resources and social development that protects and develops the urban environment and mitigates its risks. Both the global priority vector of the economic dimension and the assessment of household viability criteria are relatively the lowest in the experts' assessment, which indicates that the economic dimension is not decisive in the development of urban agriculture in Latvia.

DISCUSSION

Urban agriculture is a tool for developing sustainability of cities, but the practice differs in regions and countries, so differs also the dominant dimensions of the sustainability that drives the development of urban agriculture. The involvement of individuals and households, as well as the community, municipality and the state, is essential in the fulfilment of the social dimension that determines the development of urban agriculture in Latvia. Urban agriculture has the potential to build social cohesion, civic participation and communication, shaped by the social dimension of the practice. But for its successful implementation, the promotion of community activity and the involvement of local

governments are important to ensure access to unused city areas or those whose use can be supplemented with agricultural practices.

Three the most important activities can be identified for developing social scenario of this research. First, *community gardens* need to be developed more widely. It requires multilateral involvement. Taking into account the potential of the social dimension, cooperation between activists and the municipality is necessary. Since the practice of growing food in cities is hindered by the cost of resources, the municipalities of national cities need to identify and evaluate the availability and transfer of unused or functionally complementary areas for the creation of community gardens with land use regulations that should prioritize the social and environmental dimensions of the practice. The experience of community gardens in Latvia so far shows that the management of community gardens works by handing over their supervision to interested communities and activists. However, the experience of leading urban gardens in Europe, such as Lisbon, Paris, London, etc. shows that local governments can carry out systemic coordination more effectively. Community gardens restore social ties, build community involvement and cooperation in shaping the urban environment, and initiate the creation of a unified community culture [8]. Learning the experience of existing community gardens and involving researchers is relevant for determining the interest and willingness of the city's residents to get involved.

Second, the *expansion of household practices*. Fulfilment of the social dimension at the household level determines the implementation of active practices for health promotion and transmission of traditions. The population survey [5] shows that the involvement of the population of Latvian national cities in practice activities is high. Their promotion at the household level primarily takes place under the influence of the motivation of family traditions and habits, which is supplemented by the relevance of urban agriculture as a social and modern trend. And third, the *inclusion of urban agriculture practices in the education system*. The practice of growing food contributes not only to the understanding of food products and their cultivation, but also to their value, the importance of food systems and environmental sustainability, and the problem of food waste, thus developing social capital. Although these aspects are important at all levels of education, this research's experts emphasize the role of pre-school educational institutions, which have better management monitoring opportunities due to a relatively smaller number of pupils. However, for the full inclusion of urban agriculture in pre-school educational institutions, the involvement of not only schools, but also municipalities and the state is important, ensuring systemic provision of information and resources and motivation.

CONCLUSION

The role of urban agriculture in the development of cities has historically changed, reaching wide multifunctionality and potential in promoting urban sustainability in the 21st century. Although the practice is widespread in Latvia, especially at the household level, its research has so far not paid attention to the identification and evaluation of development perspectives.

In order to evaluate the development of urban agriculture in Latvia, three development perspectives have been described in this study – development driven by social, economic and environmental dimensions in promotion of urban sustainability. Although currently urban agriculture in Latvia is primarily practiced in households, the results of the study show that the perspective of promoting the economic viability of households is relatively

unimportant for the development of the practice. The perspective of the development of urban agriculture in Latvia is shaped by the environmental dimension, especially in the aspect of greening the urban environment and creating a diversity of green areas.

But in the Latvian situation, the social dimension is decisive, which directs the urban agriculture functions of promotion of education and public health, community building and implementation of traditions. For the fulfillment of the social dimension as a tool for urban sustainability, it is important to develop public involvement in community and school urban gardens, ensuring informational, consultative and resource support of the municipality.

In order to be able to cooperate in different levels for the development of the social dimension of urban agriculture in Latvia, it is essential in future research to carry out studies that would evaluate the quality indicators of various products, the implementation of technological innovations and the analysis of economic benefits and expenses in the context of various Latvian municipalities.

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ENVIRONMENTAL SAFETY IN THE DIGITAL AGE: SCIENTIFIC AND PRACTICAL ASPECTS OF IMPLEMENTING THE SUSTAINABLE DEVELOPMENT GOALS

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ABSTRACT

The article aims to develop the concept of environmental safety as a science and practice in the digital era in accordance with the goals of sustainable development. The scientific novelty of the study lies in the analysis of the development of new models for predicting environmental risks based on machine learning and artificial intelligence algorithms. This includes forecasting climate change, air, water and other ecosystems pollution. Using the methods of systematic analysis and modelling of environmental safety as a complex social and economic phenomenon and a dynamic process, the article considers the ways of using risk assessment methods to identify potential threats and vulnerabilities related to environmental safety in the digital era. These methods can be used both separately and in combination to conduct a deep and comprehensive analysis of the topic of environmental security in the context of the rapid development of digital technologies. Research results: 1. The article presents an analysis of environmental safety as a field of science and practice in the digital era in accordance with the goals of sustainable development. 2. The concept of environmental safety as a field of science and practice in the digital age in accordance with the goals of sustainable development has been formulated. These concepts and trends are combined to create an integrated approach to environmental safety as a new discipline, including the development of new approaches to regulation and control, taking into account digital innovations. The practical significance of the study is to overcome key challenges and use opportunities for further development of environmental safety, which eliminates harmful environmental impact and maintains a balance between natural and anthropogenic components of the natural environment. Environmental safety restores the broken relationship between humans and nature and harmonises their coexistence.

Keywords: environmental safety, digital technologies, environmental threats, digital transformation, risk minimisation, sustainable development goals.

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INTRODUCTION

Environmental safety is a state of the environment that ensures the protection of humans, society and nature from possible harmful effects of natural and anthropogenic factors. It is a complex, interdisciplinary field that combines environmental, economic, social, philosophical and technological aspects to ensure sustainable development. Environmental safety is the key to preserving our planet for future generations. It requires a responsible attitude to natural resources and the introduction of the latest technologies aimed at minimising the negative impact of human activity on the environment. In the digital era, environmental safety is gaining new opportunities and challenges, and the integration of digital technologies into this area allows for more efficient monitoring. Digital technologies and innovations determine environmental safety in the modern world, as environmental safety is gaining new opportunities and challenges in the digital age. Integration of digital technologies into this area allows to increase the efficiency of monitoring, management and response to environmental threats, providing a set of actions and a set of appropriate measures that ensure the ecological balance on the planet and in different regions, at a level to which people can adapt physically, without losses (political, economic, social). Digital technologies continue to evolve, opening up new opportunities for environmental safety, and they facilitate technology integration, global cooperation, and innovations in the renewable system. Among them are: the creation of unified platforms that combine different technologies for integrated environmental risk management; the use of digital technologies for data exchange and coordination of environmental efforts at the international level; and the further development of technologies for the efficient use of renewable energy sources. Together, these technologies contribute to creating a safer and more sustainable environment, helping to address today's complex environmental challenges. The digital transformation of environmental safety is opening up new horizons for environmental protection and sustainable development. Innovative technologies make it possible to monitor ecosystems more effectively, predict changes and prevent environmental disasters. However, in order to successfully implement these opportunities, it is necessary to take into account the challenges related to data security, technology integration and training. Overall, the digital age offers powerful tools for ensuring environmental sustainability, which, if used correctly, will help preserve our planet for future generations. Digital technologies and innovations, which define environmental sustainability in the modern world, are key tools for sustainable development and environmental protection. Environmental security should be cultivated in connection with the challenges and prospects posed by climate change and pollution as permanent threats to the environment. Climate change, which poses a challenge to the entire world, requires joint efforts to reduce greenhouse gas emissions and adapt to new conditions; pollution, as a constant threat, requires the introduction of new technologies and approaches to waste management. Therefore, it is necessary to promote the integration of environmental approaches into all spheres of the economy and society and to introduce environmental safety as a field of science and practice in the digital age. The purpose of the study: to develop the concept of environmental safety as a field of science and practice in the digital age in accordance with the goals of sustainable development. Research objectives: 1. To present an analysis of environmental safety as a field of science and practice in the digital era in line with the Sustainable Development Goals. 2) Analyse the benefits and challenges of digital technologies in the field of environmental safety, which open up new horizons for

environmental protection and sustainable development in the context of overcoming the environmental crisis as a factor in achieving economic sustainability in the context of the European Green Deal [1].

MATERIALS AND METHODS

In the digital age, the concept of environmental security becomes particularly important for both science and practice. The materials and methods used to develop the concept of environmental security as a field of science and practice in the digital age in line with the Sustainable Development Goals may include a variety of philosophical, economic and social approaches, which indicate a transdisciplinary approach. An overview of possible materials and methods that can be used to develop a vision of the concept of environmental security as a field of science and practice in the digital age: 1) The method of systemic analysis and synthesis, aimed at studying the interaction between the elements of environmental security and identifying the best strategies for sustainable development. 2) Informatics method, including Big Data and analytics, which includes collecting and analysing large amounts of environmental data to identify trends and predict future changes; using machine learning algorithms to improve the accuracy of forecasts and ecosystem modelling; ensuring the security and confidentiality of environmental data, protecting them from cyber threats. 3) Monitoring through the use of modern sensor technologies, IoT (Internet of Things) and drones to collect data on the state of the environment, which allows obtaining accurate information on air, water, soil pollution, etc. Big Data analysis, including processing of large amounts of data to identify trends in climate change, detect environmental crises and assess the impact of human activity on natural resources; use of AI to predict environmental crises, develop strategies to minimise the impact of human activity on the environment, and automate 4) Digital technologies in green technologies, including the development of new environmentally friendly technologies, such as renewable energy and green production technologies, which help reduce emissions and negative environmental impact. 5) The axiological method, which is based on education and information through digital means, the use of digital technologies to raise environmental awareness of the population, and teaching sustainable consumption and resource conservation. All of these methods allow scientists, NGOs and governments to interact more effectively in the fight against environmental problems in the digital age, which is a key aspect of ensuring sustainable development and preserving the environment for future generations. Environmental Safety in the Digital Age: Implementing the Sustainable Development Goals is a comprehensive approach that includes the use of digital technologies to ensure environmental safety and achieve the Sustainable Development Goals (SDGs), which is important for Ukraine in the context of overcoming the problems of food and environmental security of Ukraine [2].

RESULTS

1. Environmental security in the digital age: realising the Sustainable Development Goals.

Environmental safety is crucial for the sustainable development of the digital society in the 21st century, and governments should pay great attention to it. Environmental security is an interdisciplinary science that is developing among the natural and social sciences. The concept of environmental security means: 1) the health, integrity and

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sustainability of ecosystems; 2) ecosystem services that contribute to human well-being. Environmental security has the characteristics of global nature, irreversibility of environmental damage and environmental restoration. Secondly, the progress of research in the field of environmental health safety, ecosystem integrity and resilience, ecosystem services, and environmental safety analysis and assessment. Currently, there is no universally accepted concept of environmental security, and new methods for analysing and assessing environmental security have been lacking. We identify three main theories of environmental security development: 1) assessment of ecosystem health and environmental risk; 2) national interests in the field of environmental/ecological security; 3) the concept of environmental law and legal practice. Therefore, it is necessary to develop a concept of environmental safety; build a theory of the subject of environmental safety; develop research methods; and develop a decision support model for sustainable development of the region. Environmental security is an important pillar and component of national security. This means that it is not affected by the problems of environmental degradation, that ecosystem services can effectively support economic and social development and protect human well-being, developing the philosophical foundations of the organisation's digital strategy as an axiological and ontological dimension [3,7,8].

Environmental safety includes natural resources, water bodies, as well as ecological and biological safety. It is both a goal of sustainable development and a dynamic system prone to continuous development. As an important component of national security, environmental security is a prerequisite for political, military and economic security and affects public welfare, sustainable economic and social development and long-term stability. It is one of the foundations of the entire national security system. Environmental security includes natural resources, water bodies, as well as ecological and biological security. It is both a goal of sustainable development and a dynamic system subject to continuous development. As an important component of national security, environmental security is a prerequisite for political, military and economic security and affects public welfare, sustainable economic and social development and long-term stability. It is one of the foundations of the entire national security system and the development of flexible governance structures in the context of the digital transformation of the 5G industry [4].

Thus, scientists have developed strategies for assessing environmental security, focusing on the problems of environmental degradation and ecosystem services that reflect the main content of environmental security. They create a system of indicators with the characteristics of relativity and dynamics of development, putting forward a certain indicator in a certain period of development. We put forward some specific prospects for further progress in environmental security: 1) improvement of the system of indicators and synthesising method for assessing environmental security; 2) studying the interrelationships between ecosystem services and economic and social development with the definition of environmental security for human well-being; 3) concern for scientific forecasting of environmental security for the future.

Common to these definitions are three main components that encompass the principles of human security and help to explore the value of this concept in more depth. Firstly, human security is a response to emerging threats that may become transnational in scope. Secondly, human security requires an expanded understanding of security, namely the protection and empowerment of people as the basis and goal of security.

Third, human security aims to develop strategies that are people-centred, inclusive, socially responsible and preventive.

Table 1 Integration with the Sustainable Development Goals (SDGs):

	Development area
SDG 6- Clean water and sanitation	Internet of Things (IoT), which is based on the use of sensors to monitor the environment, air, water and soil quality. This helps to identify and respond to environmental threats in a timely manner
SDG 7 - Accessible and sustainable energy	Use of digital technologies to improve the efficiency of renewable energy sources such as solar and wind power plants and create smart energy grids.
SDG 11 - Sustainable development of cities and communities	Implementation of smart city solutions such as intelligent transport management, waste management and air quality monitoring to create comfortable and environmentally friendly cities.
SDG 13 - Climate change action	Use of digital technologies to monitor and model climate change, develop adaptation strategies and reduce climate impact.
SDG 15 - Conserve terrestrial ecosystems	Aims to protect, restore and promote the sustainable use of terrestrial ecosystems, including forest management, combating desertification, halting and reversing land degradation and conserving biodiversity.

Overall, digital technologies are becoming a key tool in achieving environmental safety and sustainable development goals, contributing to a more sustainable and secure world. Digital innovations, such as the Internet of Things (IoT), big data, artificial intelligence (AI) and geographic information systems (GIS), allow for effective monitoring, analysis and management of environmental resources, reducing the negative impact on the environment, as evidenced by the 11th Global Food Security Index, which shows a deterioration in the global food environment for the third year in a row, threatening food security [5].

2. The place and role of digital technologies in ensuring environmental safety and sustainable development of society.

Digital technologies play an important role in ensuring environmental safety. They contribute to more efficient management of natural resources, environmental monitoring and rapid response to environmental problems. The use of digital technologies in these areas can significantly improve the effectiveness of environmental protection measures and ensure the sustainable development of society. Let us highlight the key aspects where digital technologies are used to improve environmental safety (Table 2).

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Table 2 - Specific examples and latest developments in the use of digital technologies in environmental safety.

Environmental monitoring	Development direction
Sensors and the Internet of Things (IoT)	Sensors for real-time monitoring of air, water and soil quality
Satellite photos and drones	Satellite imagery and drones are used to monitor changes in ecosystems, such as deforestation or water pollution.
Data analysis and forecasting: Big Data	Collecting and analysing large amounts of data to identify patterns and predict environmental risks.
Machine learning and artificial intelligence (AI)	Using AI algorithms to model environmental scenarios and optimise management decisions.
Digital platforms and apps	Developing platforms for efficient water, energy and waste management.
Blockchain Technology	The use of blockchain technology to track supply chains and ensure transparency in environmentally sensitive industries.
Mobile apps and online platforms	Develop educational applications to raise environmental awareness; report environmental issues and receive recommendations for action in the event of a disaster.
Social networks	Use of social media to disseminate information about environmental issues and initiatives.
Mobile apps for environmental action	Apps that encourage citizens to participate in environmental activities, such as litter picking, tree planting, or participation in recycling programmes.
Geographic information systems (GIS)	Using GIS for mapping environmental data and conducting environmental audits, which allows us to identify problem areas and plan measures to address them.
Virtual and augmented reality (VR/AR)	Use of VR and AR to model the environmental impacts of various projects, which helps to make informed decisions in the planning and construction process
Intelligent waste management systems	Introduce systems that automatically determine the best routes for waste collection, reducing carbon emissions and fuel consumption.
Smart Grids	Integration of renewable energy sources (solar, wind) into smart grids that optimise energy distribution and increase the reliability of electricity supply.
Energy efficient buildings	Use of energy monitoring and management systems in buildings to reduce energy costs and greenhouse gas emissions.
Energy storage facilities	Use of energy storage technologies to ensure the stability of electricity supply and maximise the use of renewable energy sources.
Electric vehicles and charging stations	Expanding the network of charging stations for electric vehicles and introducing smart charging management systems.

These activities are aimed at supporting sustainable development, reducing greenhouse gas emissions, improving air quality and creating more environmentally friendly transport. Examples of digital technology implementation: 1) Expanding the network of electric vehicle charging stations, in which the infrastructure for charging electric vehicles with smart charging management systems contributes to reducing greenhouse gas emissions and achieving SDG 11 (Sustainable Cities and Communities) and SDG 13 (Combat Climate Change). 2) Water management systems, which rely on IoT to monitor and manage water supply, supporting SDG 6 (Clean water and sanitation). 3) Smart agricultural technologies: The adoption of precision agriculture technologies to optimise resource use and reduce environmental impact contributes to SDG 2 (End hunger) and SDG 15 (Conserve terrestrial ecosystems). Digital technologies are a key factor in creating a more sustainable world, helping to achieve the environmental and social goals set out in the Sustainable Development Goals in the context of the environmental and economic adaptation process [6].

CONCLUSIONS

The study of this topic combines knowledge of ecology, information technology, economics and social sciences, contributing to the development of new theories and methodologies for analysing and solving environmental problems. The study of the impact of digital technologies on ecosystems and the environment contributes to the development of models for predicting environmental changes and evaluating the effectiveness of various management strategies. Theoretical research contributes to the development of new approaches and strategies for environmental decision-making based on scientific data and analysis. Theoretical models and analytical tools help assess the environmental impact of policy decisions, technologies and infrastructure projects. Developing and implementing new digital technologies for monitoring and managing ecosystems to improve the effectiveness of environmental protection measures. Researching the impact of digital technologies on the socio-economic development of regions and countries, including employment, education and economic growth. Using digital technologies to monitor air, water and soil quality helps prevent environmental threats and reduce their negative impact on human health. The introduction of smart technologies in urban management helps to improve the quality of life in cities by reducing pollution and increasing the efficiency of resource use. Digital systems for monitoring and managing water resources contribute to their rational use and protection from pollution. Precision farming technologies optimise the use of fertilisers and water, reducing the negative impact on the environment and increasing yields. The use of digital technologies to optimise energy consumption and waste management helps reduce greenhouse gas emissions and other pollutants. Innovative approaches to restoring degraded land and protecting biodiversity are based on the use of modern digital tools and methods. Digital technologies ensure transparency and accountability in decision-making related to environmental protection and natural resource management. Thus, digital technologies play a crucial role in ensuring environmental safety and achieving sustainable development goals by combining theoretical knowledge with practical measures to create a sustainable and secure world.

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GEOVISUALIZATION OF BORONGAJ CAMPUS IN MOBILE AUGMENTED REALITY

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ABSTRACT

This paper explores the application of augmented reality (AR) in spatial data and 3D model visualization, particularly in the context of smart cities and campuses. The term "smart city" refers to the concept of urban planning that optimizes city space by applying digital technologies to improve the quality of life. Smart cities include innovative solutions in traffic, urban planning, energy, communications and digital management of the city and buildings to provide efficient and sustainable development.

We developed a mobile AR application that integrates the 3D model of the Borongaj Campus, allowing users to visualize and interact with the model through the use of markers. The application provides an interactive environment where users can engage with the spatial data, enhancing their understanding of the campus layout and structure. Visualizing the 3D model in AR creates a dynamic and immersive experience, contributing to the growing adoption of AR in geovisualization of urban landscapes.

The paper also discusses the technical aspects of integrating AR with spatial data, highlighting the challenges and solutions involved in the process. In conclusion, we evaluate the advantages and limitations of the created model, the software tools used, and mobile AR as a medium for visualizing spatial data, providing insights into the potential of this technology for future applications in smart campuses and cities.

Keywords: 3D model, augmented reality, smart campus, Unity, Vuforia

INTRODUCTION

Even though the real world is three-dimensional, it has traditionally been represented on two-dimensional surfaces, like printed maps or computer screens. The effectiveness of reading and interpreting maps isn't solely determined by their design; a user's prior knowledge and experience also play a significant role in how well they understand the information presented on a map.

Augmented reality (AR) offers a major advancement in how we visualize, analyze, and utilize spatial data. With the rapid development of AR technology and the growing accessibility of devices such as smartphones, tablets, and AR glasses, new possibilities are emerging for integrating spatial data into everyday life and professional tasks [1].

The implementation of AR for spatial data visualization aims to provide a more intuitive and user-friendly interaction with 3D spatial data. By incorporating a third dimension through AR, spatial analysis and planning become more intuitive [2] especially as concepts like the smart city gain popularity. A smart city refers to innovative urban

planning that optimizes space using modern technologies and organizational principles [3]. Spatial information has become a key driver for successful development and decision-making within smart cities [4]. On a smaller scale, smart campuses apply these principles to promote environmentally friendly, energy-efficient, and sustainable development.

AUGMENTED REALITY TECHNOLOGY

The concept of the reality-virtuality continuum, also known as Milgram's continuum, helps us understand how different types of reality coexist and overlap in today's technological world and provides a framework for systematizing different forms of reality [5]. Reality refers to the physical world around us, where all objects and events are real and tangible. This is the starting point on Milgram's continuum (Figure *1*). Virtual Reality (VR) is at the opposite end of the continuum. It represents a completely synthetic world, created by a computer, in which the user can immerse himself and interact with it using specialized devices such as VR glasses and controllers. Mixed Reality (MR) lies in between, blending real and virtual elements. Augmented Reality (AR) and Augmented Virtuality (AV) are both part of this category, combining aspects of both the real and virtual worlds.

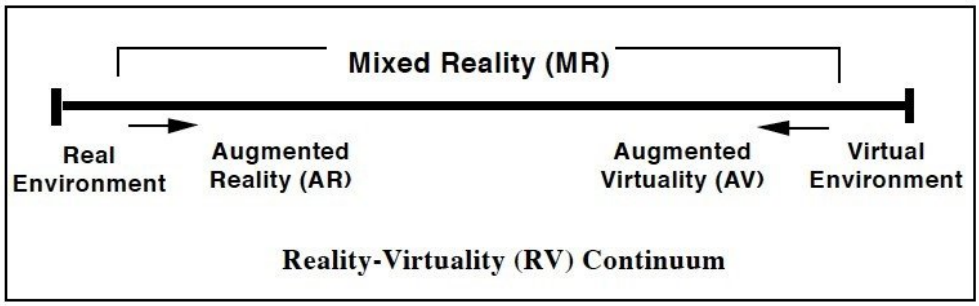


Figure 1 Reality-Virtuality Continuum [6]

AR combines elements of the real and virtual worlds by adding digital information or objects to the real world. It can be categorized by how it places digital content in the physical world. The main division includes location-based, marker-based and markerless AR. Marker-based AR relies on marker identification, and determining the marker's position and orientation triggers the display of virtual content in augmented reality.

SPATIAL DATA IN AUGMENTED REALITY

Conventional 2D display devices, such as screens, often lead to ambiguity and confusion in the display of multidimensional data due to the lack of true depth cues. Even with the help of powerful 3D rendering software, complex data patterns or 3D objects displayed on 2D screens still cannot correctly and efficiently provide spatial relationships or depth information. A 2D display device must rely on the ability of humans to compose a 3D representation of images. Despite the impressive mental capacity of the human visual system, its visual perception is not reliable if certain depth cues are missing [7].

As an answer to the mentioned challenges, AR evolved into an augmented virtual environment (AVE) and augmented geographic reality (AGR) by joining the concept of geography to the “virtuality continuum”. [8] suggest that AGR should be categorized into augmented reality environments (AREs) and augmented maps (AMs), based on the two ways in which users cognize geographic environments, i.e., based on field experiences

and maps, respectively. In AREs, visual information is primarily added to objects in the real world to realize functions such as navigation and illustration. In this way, it is possible to visualize landscapes and other cartographic items in a graphically attractive and flexible way.

These authors believe that the problem of classical maps lies in their static nature. The map cannot react to user behaviour. There is no real interaction between the user and the map. Possible operations with analogue maps are limited to moving, rotating and zooming (zooming in / out). Combining dynamic changing digital data with classic maps leads to richer visualization.

Geovisualization refers to the visual representation of geospatial data and the use of visual tools to interpret spatial patterns and relationships within complex datasets [9]. It has revitalized traditional cartography by introducing interactive elements. Moreover, there is a growing need for innovative tools to effectively communicate spatio-temporal phenomena to audiences. The integration of AR further enhances this by enabling the creation of more realistic 3D objects. Incorporating AR into cartographic products offers a new way to display and better understand geographic phenomena [2].

SMART CAMPUS

There is no universally accepted definition of a smart city, and the term takes on different meanings in different environments [4]. The term "smart city" refers to the concept of urban planning that optimizes city space by applying digital technologies to improve the quality of life. Smart cities include innovative solutions in traffic, urban planning, energy, communications and digital management of the city and buildings to provide efficient and sustainable development. The key element of this model is modern technologies that facilitate city management and provide a wide range of services. University campuses, as places of education and innovation, can be an excellent example of the application of smart technologies through the integration of educational, accommodation and public services [3].

The smart campus concept is based on the efficient use of resources to provide high-quality services to the university community while reducing costs. The benefits of a smart campus include an interactive environment, smart energy management, real-time monitoring and incident alerts. The basic goal of the concept is environmentally friendly, energy-efficient and sustainable development. Smart campuses play a key role in the digital transformation of universities, encouraging innovation and better organization [3].

With the development of technology, the lifestyle and work habits of people have experienced significant changes, which have also affected the ways of learning. The smart campus, as an advanced form of education system, is becoming a global trend that improves services, decision-making and sustainability of universities. Key technologies supporting a smart campus include cloud computing, the Internet of Things (IoT), AR, and artificial intelligence (AI) [10].

As a next-generation interface, AR provides a different way to interact and gain experiences to enhance the educational environment. Models created in the form of digital twins are often visualized using AR technology. A digital twin is a mirror image of a physical process that is articulated with the process in question and usually exactly matches the action of the physical process in real-time [11]. The smart campus system based on digital twin technology mainly has the following functions: campus navigation,

campus data visualization, augmented reality campus, and virtual simulation teaching [12]. Virtual reality technology allows users to experience the campus through virtual tours, while augmented reality provides smart navigation and augmented reality maps.

MATERIALS AND METHODS

The Borongaj Scientific-Educational Campus consists of ten former military buildings repurposed for academic use in Zagreb, Croatia. Alongside the renovation of these faculty buildings, upgrades included the reconstruction of the student restaurant, improvements to the surrounding environment, the establishment of IT infrastructure, and the introduction of a new bus line serving the campus. These factors make the Borongaj campus an ideal candidate for implementing the smart campus concept.

For developing an augmented reality (AR) visualization application, Unity (version 10-22-5) was selected in combination with the Vuforia Engine. Together, these tools provide a comprehensive solution that facilitates both the visualization and interaction with a 3D model in augmented reality.

The input data was sourced from a dataset used in a thesis on smart solutions for university campuses [3], with the 3D model exported in. fbx format. Setting up the Unity project and configuring the Vuforia AR package involves several steps.

To download the Vuforia package, it's necessary to create an account on the Vuforia Engine developer portal [13]. Vuforia's database, accessible via its web portal, allows for the creation and management of markers. To create a marker, dimensions are defined, and the desired image is uploaded in .jpg or .png format. A digital orthophoto map of the campus area at a 1:2000 scale was downloaded from the Spatial Planning Information System of the Ministry of Spatial Planning, Construction, and State Property [14]and printed in A3 format.

In Unity, the Vuforia features can be loaded using the command Assets→Import Package→Custom Package. The main camera must be replaced with an AR camera to enable augmented reality viewing, and a Vuforia license must be added to the project to unlock its features and connect to the database.

To add a marker to the object hierarchy, it is necessary to call Image Target from the Vuforia package. The next step is to add a 3D model of the area. To add a model, it needs to be added as a Prefab marker, thus achieving a parent-child relationship. Since the image marker is of a fixed scale, the Scale Tool was used to change its dimensions (Figure *2*).

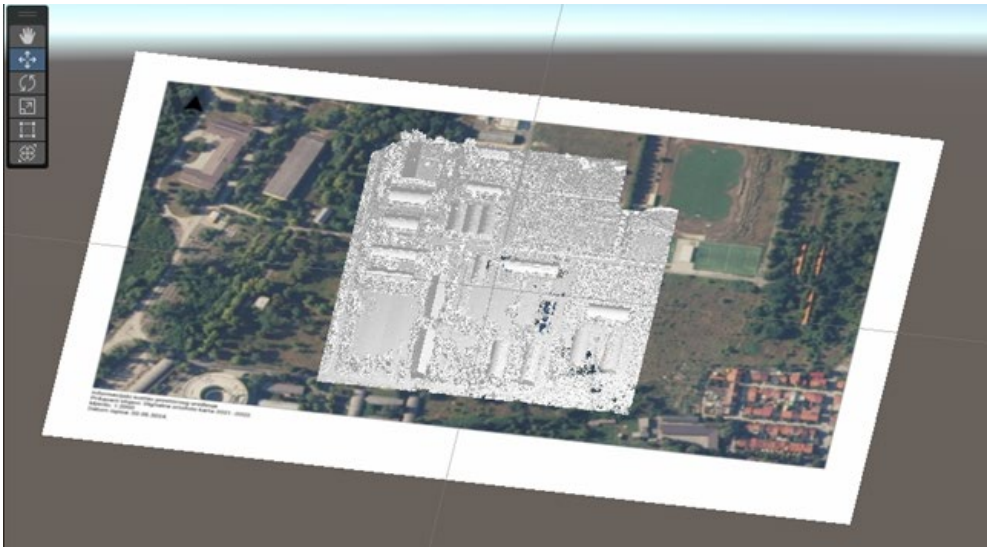


Figure 2 Scene view with loaded marker and model

The loaded mesh of the model is sufficient to describe the shape, while materials are used to define the appearance of the surface [15]. In this process, the 3D model did not retain the original colours, so the original pixel values had to be returned to the model. To create a new material in the project, select Assets→ Create→ Material from the main menu. The script used to get the original pixel values of the model was added via Assets→ Create→ Shader→ Standard Surface Shader. The task of the shader (that is, the created script) is to download colour information from the network vertices and tint it with a specific colour in the Unity editor.

To provide the application user with information about each faculty in the campus area, faculty labels have been introduced into the scene. In order to distinguish different faculties from each other, each faculty is shown with a different colour label.

Handling objects in Unity requires careful planning and optimization in various aspects of development. Too many objects can negatively affect memory, scene rendering, and application performance in general. Merging tags with the same values into a single object has a positive effect on application performance and facilitates future manipulation of the same. Also, by reducing the number of active objects in the scene, a clearer impression is created in the hierarchical display. In this case, a Mesh Combiner was used to combine several objects into one.

After combining the tags into one GameObject, applying the Mesh Combiner script resulted in the creation of a unified object, which is placed in the hierarchy of objects as a successor object of the 3D campus model.

In addition to overlapping virtual content and reality, AR aims to provide the user with the ability to interact with the content. The goal is to define how the input data changes the properties of the displayed virtual objects. The most common manipulations of objects in augmented reality refer to displacement, rotation and resizing. In this case, touch manipulation of the device screen was chosen for further development of the application. Sudden movements and rotations of the device can potentially cause marker recognition problems and the model to disappear.

Given that the model shows the entire campus area, introducing the ability to scale the model would provide the user with a clearer view of the area of interest.

This is made possible by using Lean Touch, a free tool that simplifies the process of implementing touch controls. In this case, it was used to scale objects using a pinching motion.

The Lean Touch component is added to the scene with the command GameObject→ Lean→ Touch. Lean Selectable and Lean Pinch Scale scripts have been added to the 3D Model Inspector using the Add Component command. Lean Selectable allows an object to be selected on interaction and is used so that all objects with the same configuration do not react at the same time. Lean Pinch Scale is used to scale an object using a pinch gesture with Lean Touch. When using these functions, it is necessary to turn on the Relative setting, so that the scaling is carried out concerning the touch point of the screen. Due to the hierarchical relationship of the campus model and faculty labels, faculty building labels follow the area model when interacting.

Unity UI is a tool for developing user interfaces of applications. Buttons are a fundamental element when creating interactive user interfaces in Unity. They are added to the scene via Canvas. The canvas is added to the scene with the command UI → Canvas. Render Mode allows you to choose between rendering elements in screen space or the real world. The button is added to the scene by selecting the canvas object and calling the UI→Button command. Five of them were added to the scene. The textual components represent the names of the faculties, in the color corresponding to the previously added labels. Scripts have been added to the buttons to control the activity of tags in the scene. Running a script on a button click is enabled using the On Click() component. Also, the possibility of restarting the scene has been added, and it is defined by commands in the "Scene_Manager" script (Figure *3*).

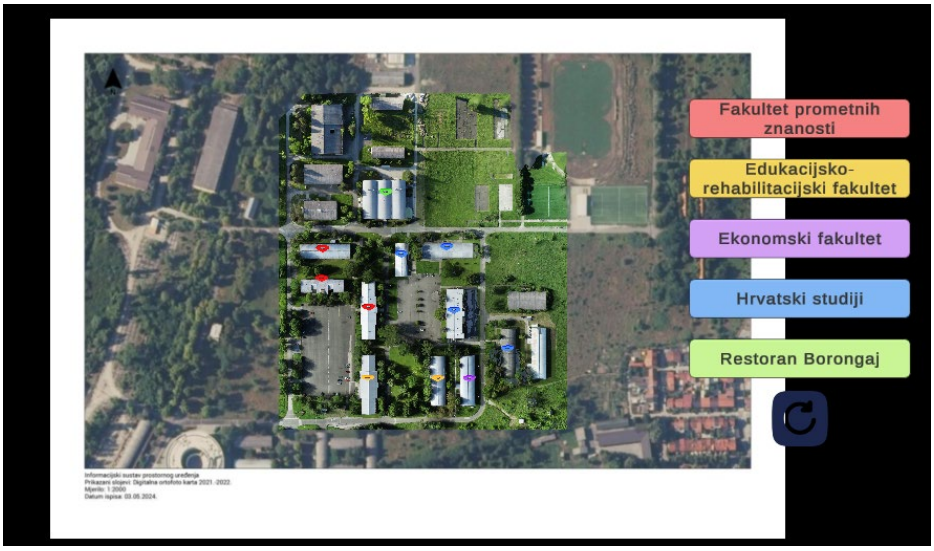


Figure 3 Final result – 3D model overlayed on marker with interactive possibilities

The application export configuration is located in the menu Edit → Project Settings → Player. The Other Settings menu contains basic settings unique to each application. Package Name serves to uniquely identify the application on the device, in the format “com.CompanyName.AppName”. The version represents the number of iterations of the

package. The version code of the package is not visible to the users of the application but is used by the authors for easier orientation between different versions. The minimum API level indicates the lowest version of Android on which the application can run. Target API Level indicates the version of Android for which the application is optimized.

The application is exported in the File → Build Settings menu. It is necessary to select the desired scenes and define the desired platform (in this case Android) with the Switch Platform command. After selecting the configuration for Android, the creation of the application was started with the Build and Run command.

RESULTS

The application file has been successfully downloaded and installed on the Xiaomi Redmi 10C device, occupying 1.52 GB of the device's internal memory. DOF printed on A3 paper was used as a marker, which application successfully recognizes and automatically activates the display of the 3D model of the campus in AR. Within the app, users can interactively manipulate the model through touch gestures. Successfully loaded buttons allow the display of additional objects, such as faculty or student restaurant labels, that integrate into the campus view. The labels are coordinated with the colour of the buttons that activate them, which enables faster orientation and easy differentiation of different objects. The model is responsive to user interactions. The user can manipulate the model using the pinch gesture, thereby changing the model view. At the end of the manipulation, the model can be returned to its original position by pressing the reset button.
The app is easy to use while allowing users to view the campus from multiple angles with additional information on key locations within the campus. Although all functions of the application work successfully, it may occasionally experience slow operation. This delay can be caused by several factors, such as the specifications of the device itself or the level of detail of the 3D model. Despite this, most of the functionality remains stable and the app continues to provide an interactive and rich augmented reality experience.

CONCLUSION

The visualization of spatial data in augmented reality represents progress in the way we perceive, analyze and use this data. With the development of AR and the increasing availability of devices that support this technology, such as smartphones, tablets and AR glasses, new opportunities are opening up for the integration of spatial data in everyday life and professional activities.

Using Unity and Vuforia SDK, an application was developed that enables the display of a 3D model of the Borongaj campus in augmented reality using markers. The tools used are easy to use, and much of the process is automated through various commands and plugins. Unity offers a wide range of functions and module libraries for different uses. However, it differs from classic GIS programs, which are a popular option for visualizing spatial data. There is a clear lack of projection systems and tools for the transformation or conversion of coordinates. Despite this, the application finds purpose in visualization of spatial data.

Although the software used is relatively affordable and easy to use, it requires a strong operating component. Unity uses a single file to store all project data, which takes up a large amount of memory, and for this application, it is 20GB of memory. It is crucial to consider these hardware limitations when defining the scope of similar projects.

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GREEN CITIES AS BIODIVERSITY HUBS

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ABSTRACT

Global biodiversity decline is dramatic. Urbanization is a global trend that is often driving biodiversity loss. At the same time urban green spaces can maintain high levels of biodiversity. However, for urban Nature-based Solutions to maintain biodiversity they have to be designed and managed with this goal in mind. Furthermore, there are certain risks to biodiversity associated with the urban green infrastructure. These risks merit consideration when urban planning is undertaken. Approaches to green infrastructure planning and design can differ depending on whether it is being integrated into existing cities or into new cities at the planning stage. Social and economic considerations can play an important role in determining whether the Nature-based Solutions projects are sufficiently supported in order to be capable of maintaining biodiversity. The presence of both ecosystem services and disservices can shape public attitude towards the solutions. This is a multi-dimensional question requiring thorough consideration to inform policymakers. Here we conduct a multi-factor analysis and based on it propose recommendations to policymakers and practitioners.

Keywords: green infrastructure, landscape ecology, Nature-based Solutions, nature conservation, sustainable development.

INTRODUCTION

Biodiversity loss is a pressing global problem that needs urgent action. Urbanization is among the causes of this problem. However, growth and emergence of cities can have both positive and negative impacts on biodiversity. Thus, the objective is to maximise the former and minimise the latter. Indeed, empirical evidence suggests that urban and peri-urban green infrastructure can maintain high levels of biodiversity [1]. It is, however, important to understand that implementation of urban green infrastructure per se does not guarantee biodiversity benefits. The green infrastructure can take different forms, including for instance parks, urban forests, green roofs, green walls, alleys and green lanes, community gardens, urban wetlands, rain gardens, vegetation filter strips, greenways, and green corridors. The infrastructure may vary in terms of its shape, size and composition. Green elements may or may not be combined with blue infrastructure. Urban green spaces may be connected or isolated from peri-urban ecosystems. These and other factors may determine capacity of the infrastructure to maintain biodiversity.

Along with capacity of urban green infrastructure to maintain biodiversity, it is important to consider benefits and risks associated with the development of green spaces. It is well established that urban green infrastructure delivers a range of important ecosystem services, which can strongly improve the quality of life of the city dwellers [2]. Positive health effects of contact with nature are well documented [3].

Furthermore, presence of the green spaces can buffer city dwellers from negative effects of changing climatic conditions, protecting them from harmful health effects of overheating or disasters such as flooding [4, 5]. In fact, urban green infrastructure is often considered a good example of Nature-based Solutions, which are intended to "address societal challenges through actions to protect, sustainably manage, and restore natural and modified ecosystems, benefiting people and nature at the same time" [6]. It is important to remember that urban green infrastructure may also be associated with ecosystem disservices, i.e. harmful effects on human well-being [7]. For instance, grasses, trees and shrubs can produce allergenic pollen. Presence of green spaces may increase crime levels in the urban areas. Green infrastructure may also impede some urban functions or become a source of invasive species [8]. Maximizing capacity of urban Nature-based Solutions to maintain biodiversity may be associated with some of these ecosystem disservices. This in turn may shape public attitude towards implementation of the projects. It is, therefore, important to make sure that not only the green infrastructure can maintain high levels biodiversity but also that it delivers ecosystem services and does not cause flow of disservices.

When urban Nature-based Solutions projects are being implemented the biodiversity and ecosystem service outcomes are often uncertain, especially in the context of global environmental change. There is an ongoing debate in scientific literature on whether urban green spaces should be designed and managed as natural habitats or as "novel ecosystems" [9]. Novel ecosystems often consist of non-native species assemblages, making the ecosystems potentially more resilient to environmental change. This assumption, however, is not strongly supported by empirical evidence, given the fact that in order to test green infrastructure resilience to changing conditions long-term observational studies are needed. At the same time, it is possible that if urban Nature-based Solutions are designed and managed mimicking natural ecosystems that are prevalent in a particular region, they may turn out to have a better adaptive capacity than the "novel ecosystems". Taking all above considerations into account it is essential to develop a holistic approach to design and planning of urban green infrastructure in order to turn the modern cities into biodiversity hubs. To reduce the uncertainty surrounding complex issues and to facilitate decision-making processes we conduct a system structural analysis and, based on the results, propose initial recommendations to policymakers and practitioners that might facilitate a holistic perspective and successful integration of green spaces into urban landscapes.

MATERIALS AND METHODS

In order to initially understand the dynamics of urban settings with respect to biodiversity, we selected a set of 10 variables that would represent both system services and disservices. These variables are not intended to be comprehensive or absolutely most important, since this first analysis will itself help identify the importance of the chosen variables and needs for altering the selection. Our selection was based on literature and the experience within the co-author group. Testing the methodological approach is also necessary for further development, including the iteration and increasing documentation and detail that would decrease subjectivity and focus on more specific sub-systems.

The system structural analysis done here uses a 0-4 relative scale to specify the impacts of each individual variable on the others, based on theoretical and actual urban land-use

relationships to environmental responses. The values were separately estimated by the co-authors and then averaged. From this impact matrix, the "causes" (row sums) impacts and "effects" (column sums) are then summarized to describe the overall system dynamics, while the individual impact relationships are useful for explaining possible driving factors, such as feedback loops. In-depth methodological descriptions are given by Scholz & Tietje [12].

The generalized character of the variables and the estimated impacts is recognized as an uncertainly and necessary to address in more detailed analyses. At the same time, a major advantage of our approach is its transparency and the increased communication between evaluators allowing them to appreciate perspectives and clarify terminology. This also facilitates stakeholder interactions in connection with possible implementation in the future.

RESULTS

The system service and disservice variables used in our system structural analysis are shown in Table 1. The row sums give the total impact of each variable on the left and the column sums indicate the impact of other variables on each column variable. These sums are often termed "Cause" and "Effect", and they are plotted in Figure 1. The variables in blue are mainly providing system services and those in red have system-disservice effects.

Table 1. Interaction (impact) matrix for the initial variables selected for a system structural analysis of the urban setting and in connection with biodiversity. There are 5 system services (black) and 5 disservices (red). The relative impact scale is 0-4. Positive impacts have black integers, and the negative impacts are red.

	Div Hab	Cli adapt	Connect	Wellbe	Disaster	Alergies	Invasive	U Space	Urb func	Crime	sum
Diverse habitats		4	3	3	2	2	2	2	1	2	21
Climatic adaptation	3		2	3	3	0	1	4	1	0	17
Connectivity	3	4		2	2	0	2	3	2	2	20
Social wellbeing	2	2	1		2	2	0	3	1	2	15
Natural disaster mitigation	3	3	3	3		0	1	2	3	2	20
Human alergies	0	0	0	2	0		0	2	0	0	4
Invasive species	3	2	2	1	1	2		1	1	0	13
Uban space requirements	3	4	4	3	3	2	1		3	3	26
Disrupting urban functions	2	2	2	2	2	0	0	2		2	14
Crime/security issues	0	0	1	3	1	0	0	1	2		8
sum	19	21	18	22	16	8	7	20	14	13	158

It can be noted that all of the service variables are actively involved in the system dynamics, meaning that their change significantly influences other variables and are themselves impacted by changes elsewhere in the system. They plot toward the upper right corner of the Cause-Effect diagram (Figure 1).

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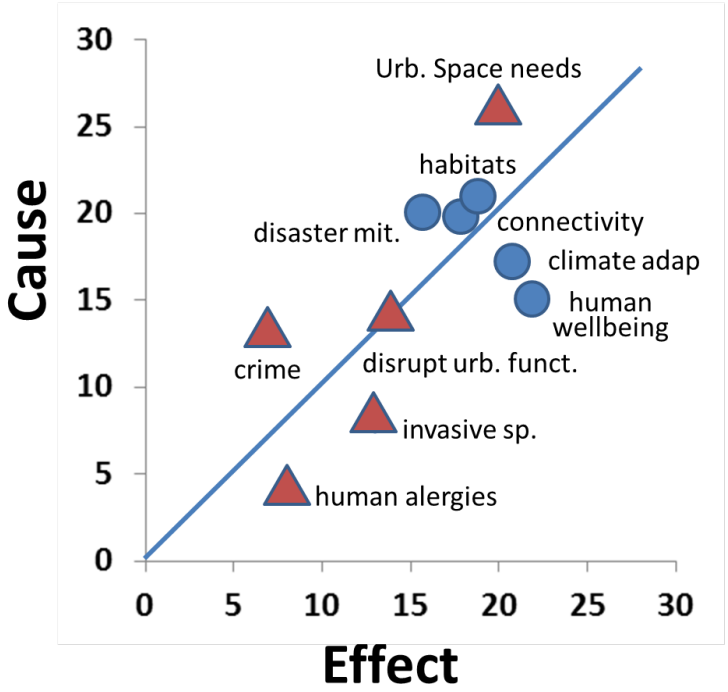


Figure 1. The Case-Effect relationships summarized from Table 1. The blue circles are system services, and the red triangles are disservices.

The disservice variables are less influential, except for "urban space needs", which has the greatest impact of all variables on the other system variables. Most disservice variables plot toward the lower left corner. Although not as active, they may have an important buffering effect on the system dynamics.

Individual associations can be identified and evaluated from the impact matrix (Table 1). The system-service variables tend to have positive impacts, meaning that their increase induces increases in other variables. Negative impacts are most common with the disservice variables, meaning that their increase can lead to decreased values in other variables. Positive feedback loops between the variables can make the system unstable and facilitate continued change. This can be an advantage if the variables in positive loops are favorable for biodiversity or other desired qualities in the system. Negative feedback loops tend to make the system more stable, but more inert and harder to change if this is a management goal. In this system it might be considered good that disservice variables, except for urban space needs, do not have a very active role in the system dynamics. However, "urban space requirements" is a disservice variable that is very highly active, and this motivates particular attention in the discussion below and in further system modeling.

System structural analysis is an analytical modelling procedure with the overall purpose of understanding internal relationships and dynamics between the selected variables. This step does not predict scenarios related to specific issues, which is often the goal for management support in constructive (synthesis) modelling. Ideally, the predictive synthetic modelling is done separately following the analytical step. Therefore, the role that each variable may have regarding environment changes and management questions is not indicated.

DISCUSSION

Our findings suggest that urban green infrastructure is logically associated with variables favouring biodiversity and human well-being. There are, however, trade offs and the most significant one appears to be “urban space needs”. This can be explained by the fact that certain aspects of human welfare, such as economic activity, real estate and energy efficiency tends to be dependent to some extent on concentration of buildings and efficient urban infrastructure. Given the scarcity of space in urban environments, green spaces are often reduced. For instance, a recent global study by Husqvarna [13] has revealed that global urban green areas the size of 7700 football fields were lost just in one year. These findings are astonishing and merit urgent action. A deeper look into ecosystem services and disservices associated with urban green infrastructure could help decision makers to fully understand the important role of green spaces in city environments.

A range of disservices associated with the green infrastructure [14], including human allergies, potential increase in crime, risk of invasive species spread, and disruption to urban functions (such as blocking drainage or increasing driving risks associated with fallen leaves), tend to be much less interactive within the system than ecosystem services (Figure 1), which are crucial in urban Nature-based Solutions. Indeed, positive impacts of the urban Nature-based Solutions that foster human health and well-being, disaster risk reduction, and climate adaptation can deliver the value equivalent to millions of dollars [15]. The potential contribution of green spaces to biodiversity conservation further enhances their value, offering positive effects that extend far beyond city borders. This includes provision of habitats within urban landscapes and enhanced landscape connectivity at a landscape and regional scales. In fact, urban green spaces can serve as biodiversity hubs, supporting species assemblages in the surrounding landscapes. At the same time, the role of urban Nature-based Solutions is associated with delivery of ecosystem services and ecological resilience.

Biodiversity values, however, should not be taken for granted. This can be illustrated by the following discussion of selected ecosystem conditions and processes, which are not easily understood without a system perspective that addresses the complexity of the urban-biodiversity system. For instance, the fact that plants are used as “construction materials” in the Nature-based Solutions, making them different from gray infrastructure, does not necessarily achieve biodiversity benefits. For urban green spaces to be capable of maintaining biodiversity they should have characteristics appropriate for the specific ecological systems of that site and region. This fact may easily be overlooked, resulting in lost opportunities to support biodiversity conservation and harness associated ecosystem services. One such characteristic is landscape connectivity. Urban green spaces if isolated from surrounding natural/semi natural landscapes can have a very low capacity to support biodiversity conservation. Such spaces, even if consist of suitable habitats in their territory, may not be colonized with species as the colonization tends to happen from natural ecosystems. The green spaces are also unlikely to contribute to biodiversity conservation beyond their borders. Thus, urban green infrastructure planning should consider connecting urban green areas with peri-urban natural/semi-natural ecosystems. This can be achieved through development of green corridors or green veining within urban landscapes. Increased connectivity may, to some extent, increase the risk of invasive species spreading from the city parks into the wild. However, these risks can be reduced by thorough planning.

In addition to landscape connectivity, it is important to consider the quality of habitats within urban green spaces. It is essential to integrate resources that can support the wildlife that is likely to inhabit the urban ecosystems. The taxonomic groups that tend to benefit from urban green spaces are birds and insects (especially insect pollinators). Indeed, urban ecosystems are found to be capable of maintaining highly diverse assemblages of these taxonomic groups [16, 17]. It is, therefore, important to consider habitats and resources essential for the local species from these taxonomic groups when planning the urban green infrastructure.

An opinion exists that use of native vegetation in urban landscape design is more beneficial to biodiversity conservation than application of exotic species. At the same time, it is very common to use non-native and often ornamental vegetation in urban design. Some evidence suggests that use of exotic species in urban environments can be justified and even more effective than native vegetation as the environmental conditions within the cities tend to differ from the surrounding landscapes [18]. Non-native species may be more resilient to higher temperatures and often fulfill important ecological functions, such as air purification, better than native species. The approach considers urban green species to be "novel ecosystems" [18]. Still, the evidence on benefits of novel ecosystems is scarce. Application of native vegetation can reduce the risk of invasive species spread. Furthermore, in some cases native vegetation may deliver ecosystem services more consistently than exotic species. For instance, in northern countries, native conifer tree species tend to provide human well-being benefits year-round, unlike many exotic deciduous tree species. It is also important to recognize that costs associated with use of local vegetation can be significantly lower than application of exotic species. Having said that, it is highly unlikely that urban green spaces will be designed using only native or only exotic species. The species mixes in most cases are likely to consist of both. It is therefore important to consider local context, keeping in mind the overarching goal to increase capacity of the green infrastructure to maintain biodiversity.

A holistic approach to design and planning of urban green infrastructure is essential to maximize benefits associated with the urban green spaces. The spaces should be considered as Natre-based Solutions and designed as ecosystems capable of maintaining biodiversity. This requires seeing each individual green area as a part of larger landscape, integration of the area into green networks ensuring high levels of landscape connectivity, and considering habitat quality within each area. A critically important factor is connecting the green spaces with natural/semi-natural ecosystems within the wider landscape, as with each other within the cityscape. It is also essential to consider green and blue infrastructure, and topography together as parts of the urban ecosystems. This would allow maximizing the capacity of the ecosystems to maintain biodiversity and resilience to changing environmental conditions, thereby sustaining the flow of ecosystem services. The approach should be widely implemented across urban areas in order to turn modern cities into biodiversity hubs and simultaneously foster the well-being of the city dwellers. Still, there is a clear need for future research into the role of urban green spaces as "novel ecosystems" in order to inform and facilitate Nature-based Solution design.

CONCLUSION

This study aimed to explore the interrelationships between variables with connection to both system services and disservices. These variables are related to the infrastructure and goals of urban development. The role of cities in biodiversity conservation be maximized for human well-being as well as economic sustainability if the dynamics of the system are understood and applied toward urban management and biodiversity. This is a challenging goal as tradeoffs exist between the two. Nevertheless, a closer look at urban systems allowed us to conclude that the implementation of urban Nature-based Solutions have multiple benefits and, hopefully, outweigh the costs. For this to happen, however, it is essential to consider biodiversity when the urban green infrastructure is being planned. This requires a holistic approach based on integration of the green areas into networks of green and blue infrastructure and topography. Quality of the habitats with the urban ecosystems is critically important. Still, current knowledge gaps do not allow for making confident decisions on whether urban green spaces shod be treated as "novel ecosystems" or should be designed resembling native habitats. Our study is an initial modelling phase aimed at understanding the urban system as a whole. For decision support, it is motivated to consider future synthesis modelling that can build predictive scenarios to test the alternative adaptations to combine urban functionality with the ecosystem services, turn modern cities into biodiversity hubs that could maximize human well-being in the cities and species survival chances in the region.

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GREEN FACTORY DESIGN WITH SMART MULTI LAYER

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ABSTRACT

Even today, factories and production systems are primarily planned using established methods from lean production, developed in the 1990s, which only partially address sustainability. Industrial production significantly impacts climate change; in Germany, for instance, 70% (9.1 million TJ) of the primary energy requirement of 13 million TJ comes from industry, and around 28% of annual new land use is attributed to industrial expansion and new construction.

This situation is no longer viable, given the European Commission's energy efficiency targets for 2030 and the roadmap to achieve no net land take by 2050. Additionally, traditional planning methods struggle to tackle pressing challenges such as a shortage of skilled workers, the need for greater flexibility, and increasing productivity. Therefore, new design principles are essential to harness this potential and create sustainable factories for the future.

The authors aim to demonstrate that enhancing energy and area productivity is crucial for a holistic improvement in sustainability and to identify additional design principles stemming from this focus. This includes extending factory planning into a third axis, emphasizing the strict separation of human-manual and automated subsystems, as well as distinguishing value-adding from supporting activities. These principles have been implemented in the innovation factory at TZ PULS as a proof-of-concept, exemplifying a sustainable production system of the future.

The proposed Smart Multi Layer Production System addresses key contemporary challenges and significantly reduces energy and land consumption. This approach presents a unique opportunity to align social, economic and ecological goals, establishing foundational design principles for sustainable and green factories

Keywords: Green Design Principles, Green Factory, Smart Factory, Area Productivity, Land Consumption, Lean Production

INTRODUCTION

The primary objective of factory design is to plan production facilities in such a way that they can economically implement the designated production processes over the long term. [1] For this reason, the principles and methods used cannot be static but must continuously adapt to current challenges, new legal frameworks, or global megatrends. [2] In factory design, it is essential to identify and adequately consider these external influences to ensure future viability. [3] The respective production system provides a framework to which factory planning must adhere. [4]

In the last decade of the 20th century, beginning with the publications from MIT (The Machine That Changed the World), the western world became aware of the efficient

production systems initially exclusively implemented in Japan. The so-called Lean Production achieved results in automotive manufacturing that must have been "declassifying" in terms of quality and productivity for western companies at that time. The rapid dissemination of the insights from that publication within the industry led to countless adoptions of large parts of the Toyota Production System (TPS), which was also leading in Japan. Later, production systems emerged that integrated western innovations and developed into a universally applicable, holistic approach: Lean Production Systems (LPS).

Today, LPS are widely standardized, as exemplified by regulations such as VDI 2870 in Germany, and are prevalent in most industrial enterprises, having become the standard for factory design [5] [6]. However, factory planning that relies on principles and methods which have, at best, evolved only partially over the past 30 years still fails to fully address sustainability: The concept of sustainability gained global significance only gradually in the 1990s, following its introduction in reports by the Club of Rome and the Brundtland Commission. As a result, it was only partially incorporated into emerging LPS. Initially, the economic dimension was prioritized and integrated as an extension of the concept. However, a comprehensive integration of all dimensions of sustainability has largely been lacking. [5] While LPS primarily originate from the so-called Industry 3.0, the focus of Industry 4.0 was primarily on the integration of intelligent, networked systems and digitalization. The focus will not be on sustainability until the 5th industrial revolution, which is only just beginning. The EU refers to a significant transformation towards a sustainable green European industry within the framework of Industry 5.0 [7] For green factory design, clear, coherent, and holistic design principles are required in order to accurately reflect the increasing importance of sustainability.

CHALLENGES IN FACTORY DESIGN

The development of the new design principles and the establishment of their model implementation were preceded by extensive literature research as well as numerous workshops and discussions with companies.

The UN's Agenda 2030, with its 17 Sustainable Development Goals (SDGs), serves as a global plan for creating holistic sustainability worldwide and were therefore used as a regulatory framework and reference point for the classification of the principles to be established. [8]

Among the 17 UN Sustainable Development Goals, there are some—such as those addressing global conflicts, inflation, and health crises like the COVID-19 pandemic—that lie largely outside the direct influence of individual companies. However, SDGs 7, 8, 9, 11, 12, 13, and 15 are particularly pertinent to factory planning, as they focus on topics where businesses can directly contribute, including clean energy, sustainable growth, industrial infrastructure, sustainable settlement areas, responsible production, climate action and life on land. When these in part abstract and broadly defined goals are combined with various statistics on concrete current drivers affecting the industry in Europe such as [9] [10] [11], the following challenges in factory design emerge: land consumption and decarbonization, energy (costs), difficulties on the labor market (skilled labor shortages), and the necessity for sustainable growth.

Although there is hardly any comparable data across Europe, there is an urgent need for action in almost all EU countries to reduce **land consumption** [12]: While over 1,000

km² of land is still being sealed every year across the EU, new land sealing must be entirely avoided from 2050 onward [13]. The current problem of land waste is particularly evident in buildings that are often planned with minimal height utilization. The necessary warehouse and production areas are arranged side by side and connected with forklifts. The transport routes required thus usually occupy 25 to 45% of the area of a production building [14]. This land waste continues at workplaces. For ergonomic reasons, only the area between 0.9 and 1.6 meters in height is used value-adding; everything above and below remains unused.

The industry remains a main consumer of **energy**. While approximately 25% of energy flows into the industry across Europe, in Germany, 70% (9.1 million TJ) of the primary energy demand of 13 million TJ is attributed to the industry [15]. Considering that 40–60% [16] of this energy in manufacturing companies is used for lighting, cooling, and heating, this presents a significant leverage point in factory design—especially regarding the European Commission's energy efficiency targets for 2030.

The **shortage of skilled labor** is increasingly proving to be a major driver of the need for productivity increases in companies. Although it is already a dominant issue in the European economy, this shortage is expected to become significantly more acute in the coming years. Currently, an annual economic loss of approx. 80 billion € is estimated in Germany alone [17]. A study has found that skilled labor shortages affect 85% of profess-sions across Europe [18]The efficient utilization of the limited pool of skilled workers is crucial for companies, requiring optimal support through technological systems.

However, **sustainable growth** increases can be achieved not only through automation, which goes hand in hand with mitigating the effects of the skilled labor shortage: Principally, employee productivity is primarily impaired by waste. The currently extensive distances in the layout lead to long driving and walking distances. If workers' areas are not appropriately separated from automated areas, this often results in waiting times and other inefficiencies in the workflows of personnel.

NEW DESIGN PRINCIPLES DERIVED FROM SMART MULTI LAYER

New design principles have been derived from these challenges and the associated factors, which have hardly been addressed in factory design to date, to facilitate the planning and sustainable operation of factories in line with environmental objectives. They were determined prototypically on the so-called Smart Multi Layer production system with vertical material flow (or simply SML, formerly: Z-Production). [19]

It has been developed at the Technologiezentrum TZ PULS as a completely novel concept for material flow control in production, addressing key challenges that future-proof production systems must overcome and integrates positive impacts across nearly all of these fields. In SML, factory planning—which, according to the state of the art, is typically planned solely in the horizontal plane—is expanded to include a third dimension. The following figure shows the proof of concept implementation at TZ PULS, also schematically illustrating the SML concept.

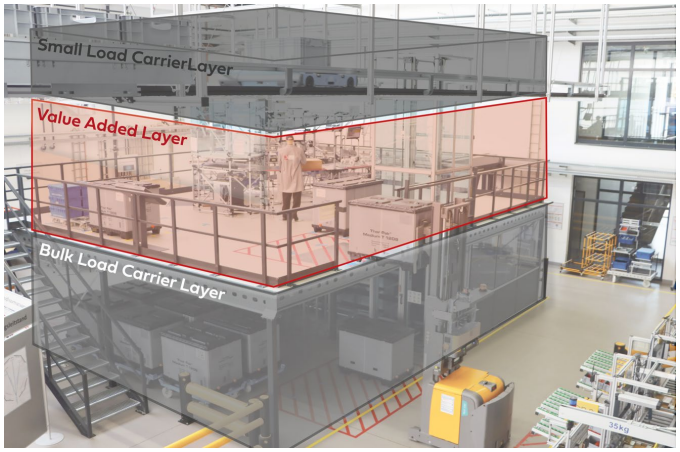


Figure 1: Smart Multi Layer implementation at TZ PULS [own research]

With the SML approach, workplaces and production areas are actively planned in the Z-axis and arranged across multiple levels, meaning they are partially shifted up one level or stacked—intentionally not in the conventional, rigid floor construction method, but in flexibly designed layers. This leads to a 40–60% reduction in the required area of a production facility while maintaining the same output, thereby significantly increasing area productivity. Additionally, this reduction in space also enables a substantial increase in energy productivity. For the first time, a clear distinction is made between manual human tasks and automated processes. These purely logistical and automated levels are neither heated nor cooled, thereby reducing the area to be climate-controlled to 33% of the original volume. The separation of value-adding and non-value-adding activities enables effective automation, especially of non-value-adding tasks, and facilitates the expansion of production in the third dimension.

All peripheral functions, particularly material storage and delivery, are concentrated in the levels above and below (as well as in corresponding cross-level transfer points/interfaces). Consequently, the center of the production system remains the human-dominated zone, where individuals perform complex assembly tasks (and thus value-adding activities) according to their core competencies, while material supply - from incoming goods to the worker - is fully automated (see the following figure).

SML represents a new type of assembly factory. The innovation of SML lies in the fact that the separation into layers is not based on production stages such as pre-manufacturing, final assembly, and storage, but rather on function.

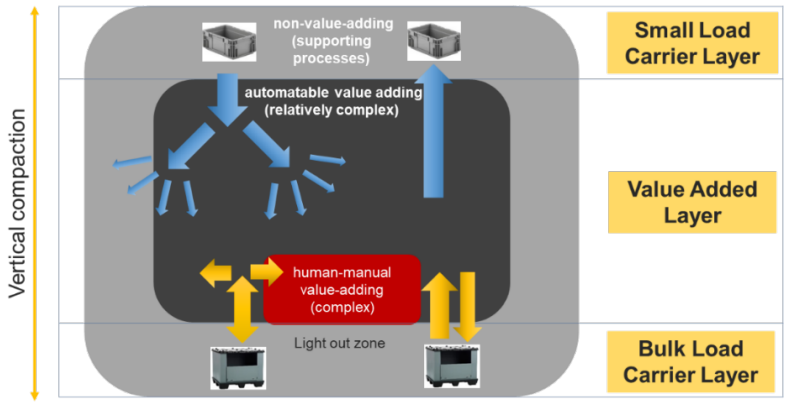


Figure 2: Layers and function separation of SML [19]

At TZ PULS, this production system is partially implemented as a proof of concept within the innovation factory. Various case studies have shown a significant increase in sustainability, along with a boost in output from 180,000 to 350,000 units per year, all while maintaining the same levels of personnel and resources.

The principles [19] resulted from this structure are illustrated in the following figure, with their relationship to the seven relevant SDGs [8] outlined above.

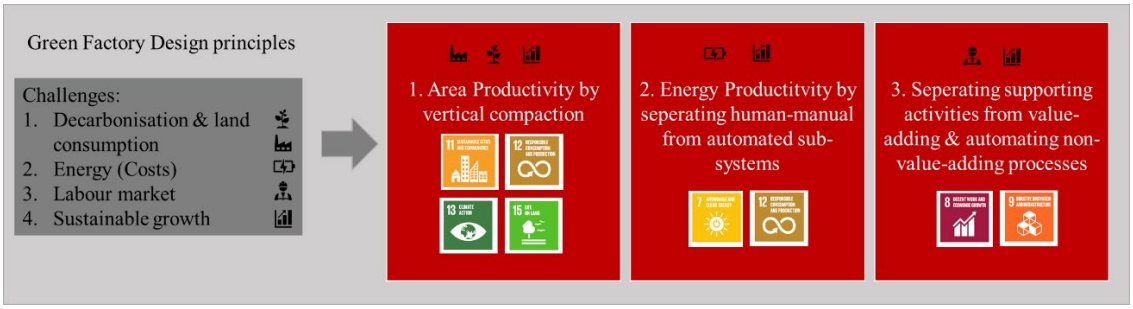


Figure 3: Green Factory Design principles [19; own research]

In the chapter on results, the principles are clarified and their relationship to holistic sustainability, including in the sense of the SDGs, is discussed in particular.

RESULTS

The first principle of area productivity calls for an expansion of factory planning into a third dimension, i.e., upwards. By significantly densifying the factory structure in the vertical plane, the built area and, consequently, land consumption can be substantially reduced while maintaining the same usable area. This effect is evident on a smaller scale by utilizing areas that cannot be used for ergonomic reasons, such as in assembly as storage or buffer zones, as well as on a larger scale across the entire factory structure through its layout over multiple levels.

A more productive use of area, which is directly linked to Goals 11, 12, 13 and 15, aims to achieve a broad range of sustainable objectives in all three dimensions of sustainability. These has already been demonstrated by the authors in a literature study, which was published in relevant scientific literature after peer review at the end of 2023. [20] The corresponding figure provides a concise overview of these points.



Figure 4: Impacts of less land consumption [own research]

https://doi.org/10.5593/sgem2024v/6.2/s26.38

Increasing **area productivity by vertical compaction** reduces land use, making a significant contribution to multiple SDGs by enhancing resource efficiency, preserving natural ecosystems, and strengthening climate resilience. It directly contributes to SDG 11 (Sustainable Cities and Communities) by mitigating urban sprawl and creating space for more sustainable urban development. Additionally, it supports SDG 12 (Responsible Consumption and Production) by optimizing resource use, particularly energy, and reducing the need for land-intensive production, which in turn lowers environmental impact. It also aids SDG 13 (Climate Action) by reducing CO_2 emissions and preserving natural carbon sinks such as forests and wetlands. The preservation of natural landscapes further regulates the microclimate and stabilizes the water balance, helping to mitigate climate risks. Moreover, the reduction of land use contributes to SDG 15 (Life on Land) by preserving biodiversity and protecting valuable habitats for flora and fauna. This helps prevent land degradation and loss of ecosystems, which are essential for maintaining ecological balance and supporting human livelihoods. Furthermore, the reduction of land use brings economic benefits, such as lower construction costs, reduced follow-up costs after extreme weather events, and decreased climate adaptation expenses. It also supports agricultural self-sufficiency. Overall, this integrated approach addresses multiple dimensions of sustainability and contributes to global decarbonization efforts.

When it comes to **energy productivity**, the energy required for product manufacturing is largely determined by product design rather than factory planning. However, significant potential lies in reducing "wasted" energy, particularly through efficiency improvements in heating, cooling, and lighting. This can be achieved by separating manual and automated areas: automated zones require less energy for climate control. This approach directly supports SDG 7 (Affordable and Clean Energy) by improving energy efficiency. Separating areas for human labor and automation reduces the space that needs climate control, cutting energy consumption and CO_2 emissions and promoting more sustainable energy use in production. It also contributes to SDG 12 (Responsible Consumption and Production) by optimizing resource use. This supports more sustainable, resource-efficient production practices.

By **separating value-adding and supporting activities**, routine tasks can be automated. Automation in particular counteracts the enormous challenge of the shortage of skilled workers. [21] This supports SDG 8 (Decent Work and Economic Growth) by enabling workers to focus on higher-value, complex tasks such as joining components in assembly while automation handles repetitive ones like logistics. It is contributing to SDG 9 (Industry, Innovation, and Infrastructure) as well through more efficient industrial processes and innovation. The consistent separation of human and machine roles, coupled with the key insight from numerous automation projects—that processes designed for humans should not be directly replicated in automation, but instead rethought from the perspective of automation's strengths—forms an innovative and targeted approach. Rethinking workflows from an automation perspective, rather than simply replicating human tasks, helps increase productivity and fosters innovation—key elements of both SDG 8 and SDG 9.

DISCUSSION

Factory design is still based on outdated assumptions today. It is therefore necessary to integrate new principles to address current challenges and enhance sustainability. The presented principles illustrate how factory design can be made more environmentally

friendly. In the practical implementation of the Smart Multi Layer production system, these principles have been validated, and their mutually beneficial relationships have been identified.

The principles have been intentionally formulated in a somewhat broader manner to maximize their general applicability within the wide field of factory design. While they could certainly be stated more concretely, doing so would necessitate re-evaluating their suitability for each individual planning project.

It is important to ensure the efficient use of area through vertical densification and that energy is conserved by separating automated areas, while also automating supporting tasks. The presented SML production system does not claim to be universally applicable. Rather, the authors hope to have effectively validated the principles and their multiple connections to the SDGs and therefore sustainability through the concluding part of a concrete exemplary implementation.

CONCLUSION

To meet the challenges of the future, factory design must evolve to become more sustainable. Novel principles were derived from current challenges and aligned with the UN's SDGs. Based on a real-world proof of concept, the Smart Multi Layer production system represents a cutting-edge approach to sustainable factory design, providing practical solutions that optimize resource use while maintaining high productivity.

According to the proposed principles, green factory design requires an efficient use of area and energy, as well as a functional separation of working areas to conserve resources and maintain productivity. These principles not only address the immediate needs of industry but also align closely with the UN's SDGs, making them a comprehensive framework for green factory design. By demonstrating the feasibility of these principles through a proof-of-concept, SML production systems show how sustainable and future-oriented production facilities can be achieved. A critical application in a real-world private-sector factory planning project would be a valuable point of connection.

Given the broad alignment of these principles with multiple SDGs that can be mapped in factory design, they can be regarded as holistic guidelines for creating green, sustainable factories. Ultimately, this approach offers a comprehensive solution for building factories that are economically, ecologically, and socially sustainable—laying the groundwork for a more resilient and sustainable manufacturing future.

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IMPACT OF URBAN VEGETATION ON SOLAR IRRADIANCE: A COMPARATIVE STUDY IN THE CITY OF ZAGREB

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ABSTRACT

Urban areas are characterized by very intense and complex interactions between built objects and natural elements, especially in terms of the impact they have on the local microclimate. One of the most important aspects of this interaction is the way in which vegetation influences incident solar radiation, which has a major impact on energy consumption, comfort and the overall sustainability of urban areas. In this study, we focus on the city of Zagreb, where we conduct a detailed analysis of the impact of urban vegetation on solar radiation, comparing areas with and without high vegetation. For this purpose, we calculated a digital surface model (DSM) from high-resolution LiDAR data. LiDAR technology enables very good mapping of both the terrain and above-ground features such as buildings and vegetation. The creation of two different DSMs - one with high vegetation and one without - allows us to isolate the specific effects of vegetation on solar radiation.

The analysis was performed in WhiteboxTools using the TimeInDaylight command, which calculates the daylight in a landscape over a given period of time. This command takes into account the position of the sun and topographic features in the DSMs for accurate modeling of solar radiation.

The result shows that solar radiation is different in areas with and without dense vegetation. The study found that tall vegetation, such as trees, greatly reduces solar radiation on the ground and surrounding buildings. A reduced impact of solar radiation can lead to cooler surface temperatures and a lower cooling demand in summer, contributing to higher thermal comfort in urban areas. Without vegetation, radiation would be much higher, increasing heat build-up and thus the extent of the urban heat island.

Keywords: timeindaylight, whiteboxtools, LiDAR, DSM, high vegetation

INTRODUCTION

The urban climate in densely populated urban areas is influenced by various effects that have an impact on the quality of life, e.g. on energy consumption and the environment. One of the worst effects in urban areas are urban heat islands (UHI), which are often caused by human activities, such as the combination of urbanization and construction, as well as deforestation of trees and urban greenery. One of the most important aspects in reducing UHI is urban vegetation, especially tall trees, which can reduce direct solar radiation to the ground or other surfaces such as buildings and houses, thus lowering the temperature of the local environment [1]. Various studies have shown that vegetation

plays an important role in reducing solar radiation, resulting in lower surface and air temperatures in dense urban areas [2].

Previous research on the effects of vegetation on urban microclimate has approached the problem using a variety of different methods. For example, Shashua-Bar et al. [1] found that urban vegetation reduces solar heat gains in buildings and open spaces, which improves thermal comfort and reduces energy requirements for cooling. On this aspect, Ali-Toudert and Mayer [2] found that a dense canopy not only protects the surface from solar radiation, but also serves to reduce peak temperatures at the surface, thus dampening the intensity of the UHI effect. According to Wong et al. [3], green infrastructure cools urban heat. Green spaces around buildings are therefore strategically placed to limit temperature fluctuations and thus contribute to a more stable urban heat environment. These studies emphasize the need for very precise, site-specific information about vegetation and its spatial relationship to buildings in order to expect an optimal cooling effect of green spaces.

Advanced geospatial technologies have enabled the acquisition of high-resolution three-dimensional data of terrain and urban features such as buildings and vegetation through active remote sensing systems such as Light Detection and Ranging (LiDAR). Digital surface models created from LiDAR data provide an effective way to analyze the spatial pattern of vegetation and its effects on solar radiation. Studies by Lingfors et. Al [4] and Bognar et al. [5] tested how DSMs derived from LiDAR data can provide a fairly accurate quantification of shading by vegetation on solar radiation in urban areas, which is very useful for informed urban planning.

The main objective of this research is to determine the impact of urban vegetation, especially tall vegetation, on solar radiation in densely populated areas.

MATERIALS AND METHODS

The study area is the city of Zagreb, the capital and largest city of the Republic of Croatia. Zagreb is located in the northwestern part of the country, at the foot of the Medvednica Mountains and along the Sava River. With an area of 641 km2, the landscape of Zagreb is very varied. It includes both the urban and suburban parts of the city, but also rural parts of Zagreb, forests, rivers and mountains in its area. The climate in Zagreb is humid continental all year round with warm summers and cold winters. The average annual rainfall is 840 mm. -0.5° C in January and 22.3° C in July are the temperature extremes. Total duration of sunshine is about 1800 to 1900 hours per year. The sunniest period is in summer months – June, July, August, with an average of 8 hours of sunshine, while in winter months – December, January, there is about 2 sunshine hours per day. This results in a combination of climate and topography that provides an ideal environment for the study of environmental variables such as solar radiation.

The LiDAR data used in this work was acquired within the project entitled Multi-sensor Aerial Survey of the Republic of Croatia for Disaster Risk Reduction Assessment, which was financially supported by the European Regional Development Fund. LiDAR data was collected as part of the aforementioned project in order to gather the necessary information on the territory of the Republic of Croatia for disaster risk assessment and analysis. These LiDAR data were pre-processed into following classes: unclassified, soil, low vegetation, medium vegetation, high vegetation, buildings, noise, water and bridges.

We created two digital surface models with a spatial resolution of 25 cm. The first model contained the ground, buildings, low, medium and high vegetation, while the second model contained only the ground and buildings. Then both DSMs were analyzed using WhiteboxTools - a geospatial data analysis software. In particular, we use the Timeindaylight tool in WhiteboxTools to calculate how much the vegetation cover affects solar radiation over time. These analyzes were done twice, once by considering and once without. The comparison of these two results gave us a clear indication of the contribution of vegetation, especially tall vegetation, to the distribution of sunlight in Zagreb.

RESULTS

The result of this study shows that exposure to solar radiation depends on the surrounding objects. The hypothesis of this study is that vegetation, especially tall vegetation, influences solar radiation on the ground. Although we analyzed vegetation, iIn this study, the surrounding buildings were one of the most influential components.

On the left side of the Figure 1. are results of daylight in Zagreb area without vegetation. On the right size of Figure 1. are results of daylight with vegetation. The areas with red color represent low amount of daylight, while blue color represents high amount of daylight.



Left size of Figure 2. shows the digital ortophoto, while the right side shows the lidar data for the same area. Figure 3. shows the difference in the time a site is in daylight between

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DEM with and without vegetation. It shows that between buildings facing north to south, there is much more daylight in the tree canopy during the day than on the ground between the buildings.

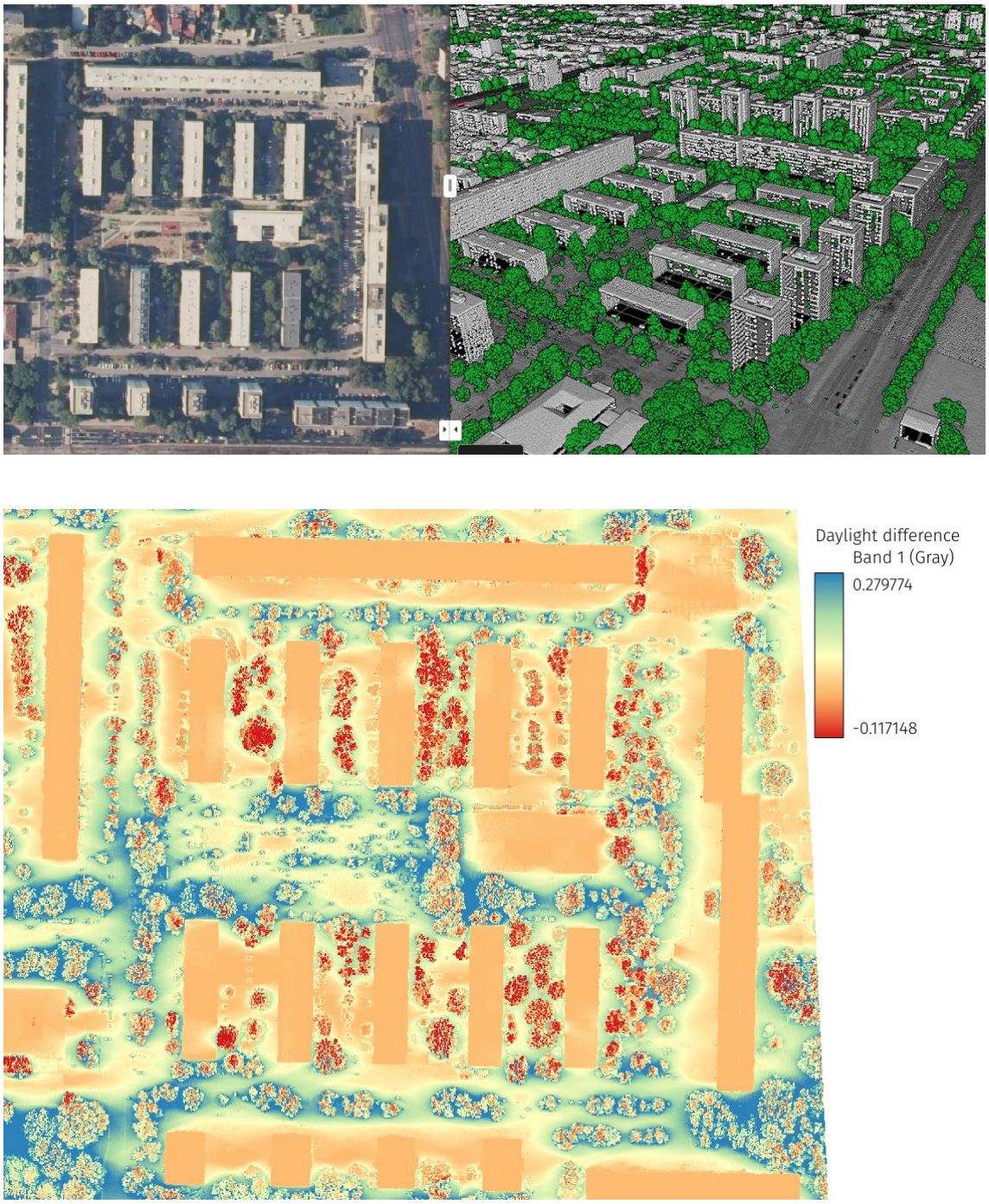


Figure 3. Difference of daylight between DSM generated with vegetation and DSM generated without vegetation

Blue color in Figure 3 represents the area where we would have much more daylight if the vegetation wasn't present. Yellow and brown color represents almost the same amount in daylight with and without vegetation. On the other hand, red color represents the areas where there is much more daylight with than without vegetation.

DISCUSSION

In this study, we focus on the city of Zagreb to assess the specific role of urban vegetation in attenuating solar radiation. Using DSMs created from high-resolution LiDAR data, we developed two models — one with high vegetation and one without — to isolate and quantify the effects of greenery on solar radiation patterns. We used the TimeInDaylight command from Whitebox Tools, which allows us to accurately assess how vegetation density and distribution affects solar radiation in urban landscapes.

The results of this study show that high and dense tree canopies reduce solar radiation in the urban area of Zagreb. It also shows that daylight in the parks is blocked by three tree canopies, which significantly reduce the amount of daylight reaching the ground which is shown in Figure 3 with blue color. In contrast, the influence of vegetation and tree canopies is significantly lower in the narrow areas between the buildings, especially in the north- and south-facing buildings. The result shows that these areas receive little daylight due to the shadows cast by the surrounding buildings, even without vegetation which is shown in red color in Figure 3. The presence of trees between the buildings therefore only has a minor influence on the reduction in daylight. The benefit of vegetation between the densely packed buildings therefore lies more in cooling through evaporation and air quality than in the reduction of sunlight.
The results of this research are similar to previous studies that have investigated the role of urban vegetation in reducing solar radiation and UHI [1,2]. Our research can contribute to the strategic placement of green infrastructure such as trees and shrubs to improve shading and thermal stability, as Wong et al. (2014.). The use of dense LIDAR data can improve the understanding of how different high elements such as buildings and high and medium vegetation can influence different phenomena such as shade and daylight at the local scale.

CONCLUSION

This study has thus shown, based on the analyzed data, the enormous contribution of urban vegetation to the reduction of solar radiation, especially in an urban environment such as Zagreb. The results show significant differences in solar radiation between areas with and without tall vegetation, with dense vegetation significantly reducing solar radiation on the ground and surrounding structures. These results confirm that high tree canopies effectively reduce ground-level solar radiation in open spaces, which can certainly help to reduce ambient temperatures and combat the effects of the urban heat island. However, in heavily built-up areas, vegetation has the least effect on incident solar radiation as the area is already shaded due to the buildings. This study therefore shows that vegetation can be integrated into urban areas in certain ways to take full effect in cool spaces and increase the climate resilience of cities.

Further research could build on improving LiDAR technology to capture a finer structure of vegetation and interactions with other urban features and develop advanced algorithms to assess seasonal variations and integrate solar potential maps with real-time LiDAR data.

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IMPROVING EDUCATIONAL BUILDING ENVIRONMENTS: A FOCUS ON COMFORT AND ENERGY

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ABSTRACT

This study investigates the relationship between users' comfort and energy consumption in an educational building located in a humid continental climate.

Through a year-long monitoring program, we collected data on indoor temperature, humidity, lighting levels, CO_2 concentrations, and natural gas consumption. Our analysis revealed that during the heating season, the average indoor temperature was 24.03 degrees Celsius while natural gas consumption reached 41.71 megawatt-hours (MWh). By analyzing the relationship between indoor environmental factors and energy consumption, we have identified a simple, yet very efficient passive strategy to improve building performance. By reducing indoor temperatures by just 1 or 2 degrees Celsius, we can significantly cut energy use. It's a simple step that can make a big difference.

Furthermore, this research emphasizes the importance of educating occupants on energy-saving behaviors to complement building-level improvements. By combining these strategies, educational institutions can achieve substantial energy savings while maintaining a comfortable indoor environment.

The insights from this research can guide building managers, architects, and policymakers in creating healthier and more sustainable educational spaces.

Keywords: educational building, thermal comfort, air quality, energy consumption

INTRODUCTION

With escalating global temperatures, the built environment faces increasing vulnerability to extreme weather events. To mitigate these risks and address climate change, the construction industry, known for its relatively low productivity, must prioritize building decarbonization.

Over the past decade, energy demand in buildings has exhibited a steady annual increase of slightly over 1%. Electricity's role in building energy consumption has expanded from 30% in 2010 to 35% in 2022. Although there has been a transition from fossil fuels toward electricity and renewables, fossil fuel usage within buildings has still grown at an average annual rate of 0.5% since 2010 [1].

Buildings were responsible for more than one-third of global energy use and carbon dioxide emissions related to energy and manufacturing in 2022. While energy intensity has decreased slightly since 2021, overall energy demand and carbon emissions for energy have risen, surpassing pre-pandemic levels. In 2022, buildings consumed approximately 30% of the total final energy used, dedicated to operational energy needs

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like heating, cooling, water heating, lighting, and cooking. Buildings' energy consumption and its operational carbon emissions can be reduced in time by using energy performant systems, green technologies and renewable sources of energy [2,3].

In Romania's building services sector, namely natural gas used for space heating and hot water demand accounts for the highest share of energy use. From the non-residential sector, the educational units are the biggest energy consumers – approx. 354 kWh/m2/year [4,5]. In 2022 the number of educational units for the pre-university level in Romania was 6682, while the number of public university educational units was 88 [4]. Given the standardized design of many school and university buildings, demonstrating their potential to become net-zero or even positive energy buildings is crucial for advancing decarbonization efforts.

Educational buildings accommodate on an average from 6 to 8 hours per weekday a high population density, therefore providing a good Indoor Environment Quality (IEQ) is essential for occupants' health, productivity and well-being [6-8]. Due to this high density and in the absence of a proper ventilation the air temperature rises and a significant quantity of CO2 emissions are released in the indoor environment leading to occupants' discomfort and a poor Indoor Air Quality (IAQ) [9]. The review and analysis performed by the Buildings Performance Institute Europe shows that within the 20°C÷26°C range, every 1°C reduction in temperature increases student learning performance by 2.3%, while every 100 ppm decrease in CO_2 concentrations is associated with a decline of 0.5% of absences from school due to illness [10].

Existing scientific literature often lacks a comprehensive approach that simultaneously examines energy efficiency, occupant comfort, and user's understanding of responsible energy practices in educational building. This study aims to bridge a knowledge gap by comprehensively examining the interrelationship between building energy consumption, IEQ, users thermal comfort and their awarness about the responsible use of energy. By investigating these factors in tandem, we seek to uncover the complex interplay that influences overall building performance and occupant well-being.

MATERIALS AND METHODS

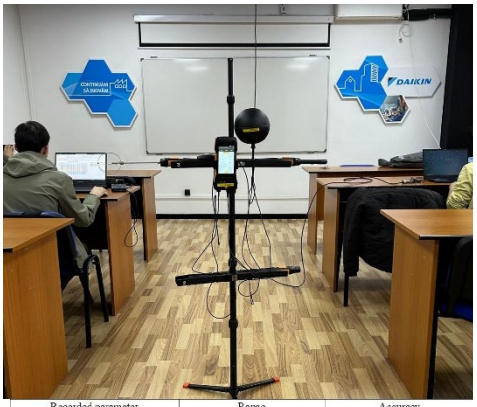
A year-long monitoring program was conducted within a selected educational facility at the Technical University of Cluj-Napoca, Romania, specifically the Faculty of Building Services Engineering (Figure 1). This educational building, constructed in the early 1960s, underwent a major renovation between 2005 and 2008. The building incorporates natural ventilation, a centralized heating system powered by natural gas, fluorescent and LED lighting fixtures.

To gain a comprehensive understanding of the building's energy performance and IEQ, an extensive investigation campaign was conducted throughout an academic year, spanning from October 2023 to September 2024. During this period, meticulous data collection was carried out, focusing on key IEQ parameters such as indoor and radiant temperature, humidity, air velocity, lighting levels, and CO2 concentrations with a Testo 400 instrument. The field measurements involved examination of several classrooms distributed throughout the educational building. The measuring instrument was positioned centrally within the occupied space at a height of 1.1 meters. To minimize local interference from the measuring equipment, a separation of at least 1 meter was maintained from all potential sources, including individuals, walls, and windows.

Environmental readings were captured every 3 minutes. A description of the equipment used and its position inside a classroom is provided in Figure 2.



Figure 1. Faculty of Building Services Engineering



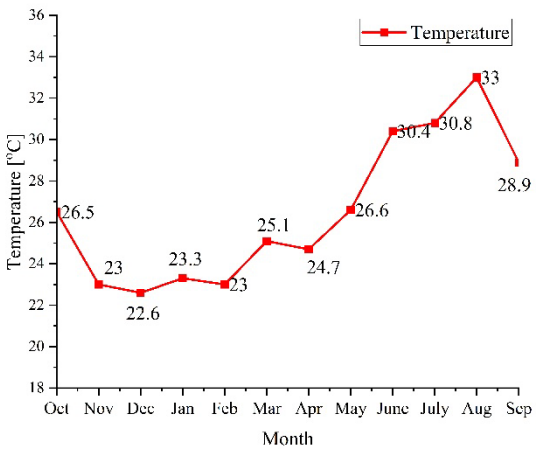
Recorded parameter	Range	Accuracy
Air temperature	0 ÷ 50°C	±0.5 °C
Radiant temperature	0 ÷ 120°C	-40 to +1000°C
Relative humidity	0 ÷ 100% RH	±1.8% RH
Air velocity	0 ÷ 5 m/s	±0.03 m/s
CO2 concentration	0 ÷ 5000 ppm	±75 ppm
Illuminance	0 ÷ 99999 Lux	±3 Lux

Figure 2. Testo 400 placement and technical specifications

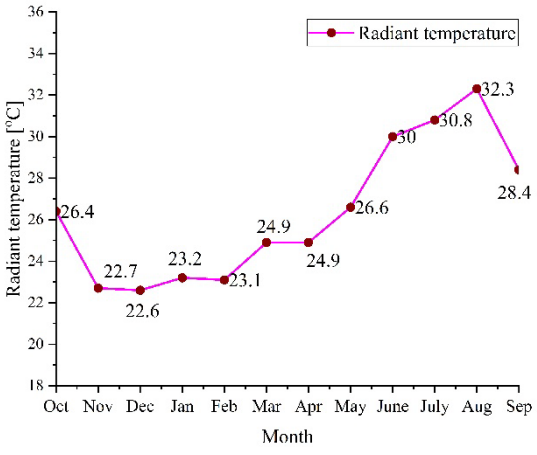
In addition to the indoor parameters' recordings, natural gas consumption was carefully monitored by analyzing the detailed data provided on the utility company's bills. This involved closely examining the consumption patterns over time, identifying any fluctuations or anomalies.

RESULTS

Figure 3 provides a comprehensive analysis of the monthly average values for the indoor thermal parameters, the lighting levels, and the CO2 concentrations measured within the study area during the research period.



a.



b.

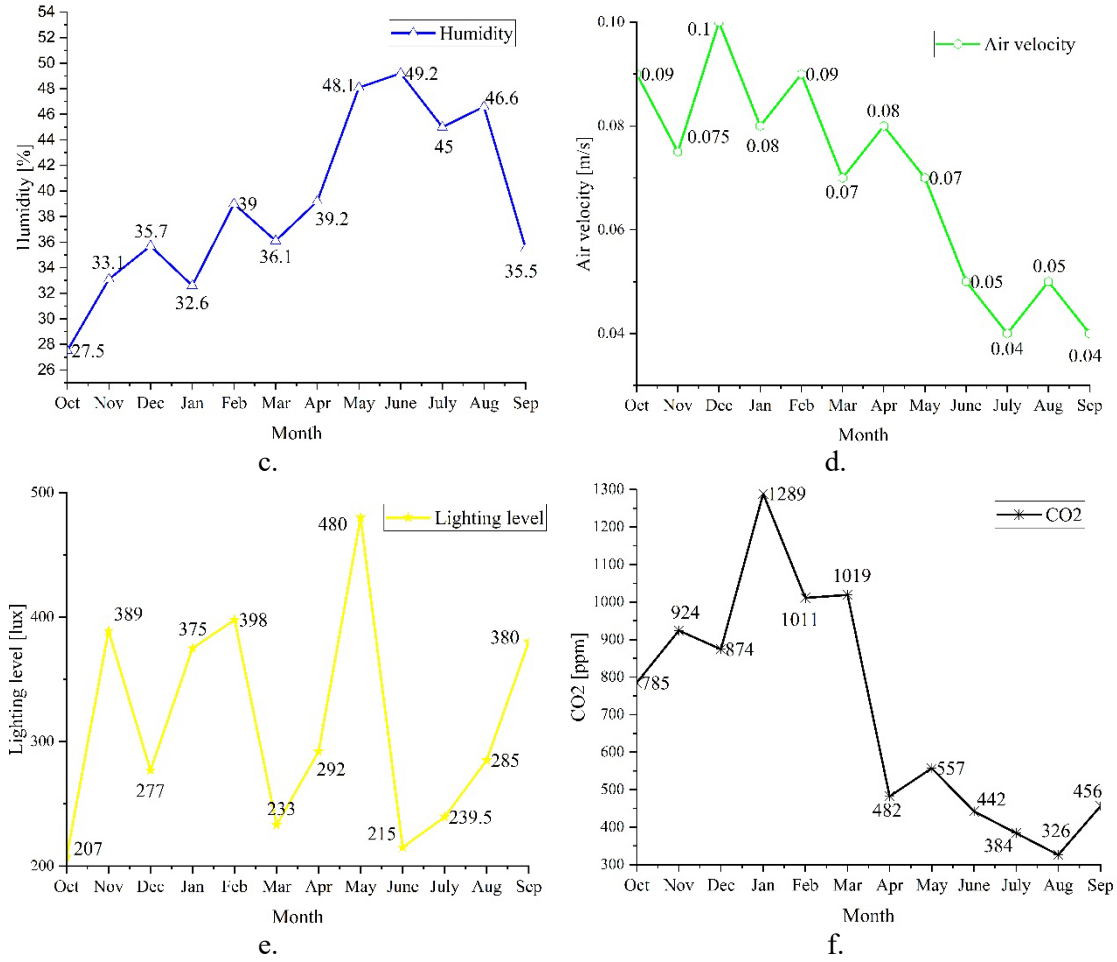


Figure 3. Mean values of the IEQ parameters (a – indoor temperature, b – radiant temperature, c – humidity, d – air velocity, e – lighting level, f – CO2 concentration)

Figure 4 illustrates the monthly natural gas consumption for heating and hot water production for the educational building.

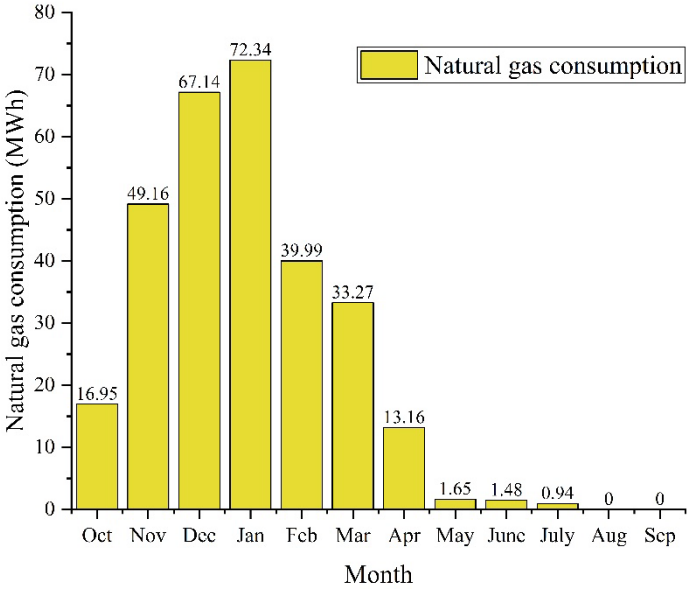


Figure 4. Monthly natural gas consumption within the educational building

To assess occupants' thermal comfort and predict their dissatisfaction towards the environmental conditions the Predicted Mean Vote (PMV) and the Predicted Percentage of Dissatisfied (PPD) equations outlined in ASHRAE Standard 55 [11] were used. Given the lack of an air conditioning system in the educational building, interventions to enhance occupant comfort during summer are not possible. Figure 5 graphically depicts the relationship between PMV and PPD during the heating season, providing insights into the thermal comfort experience of building occupants.

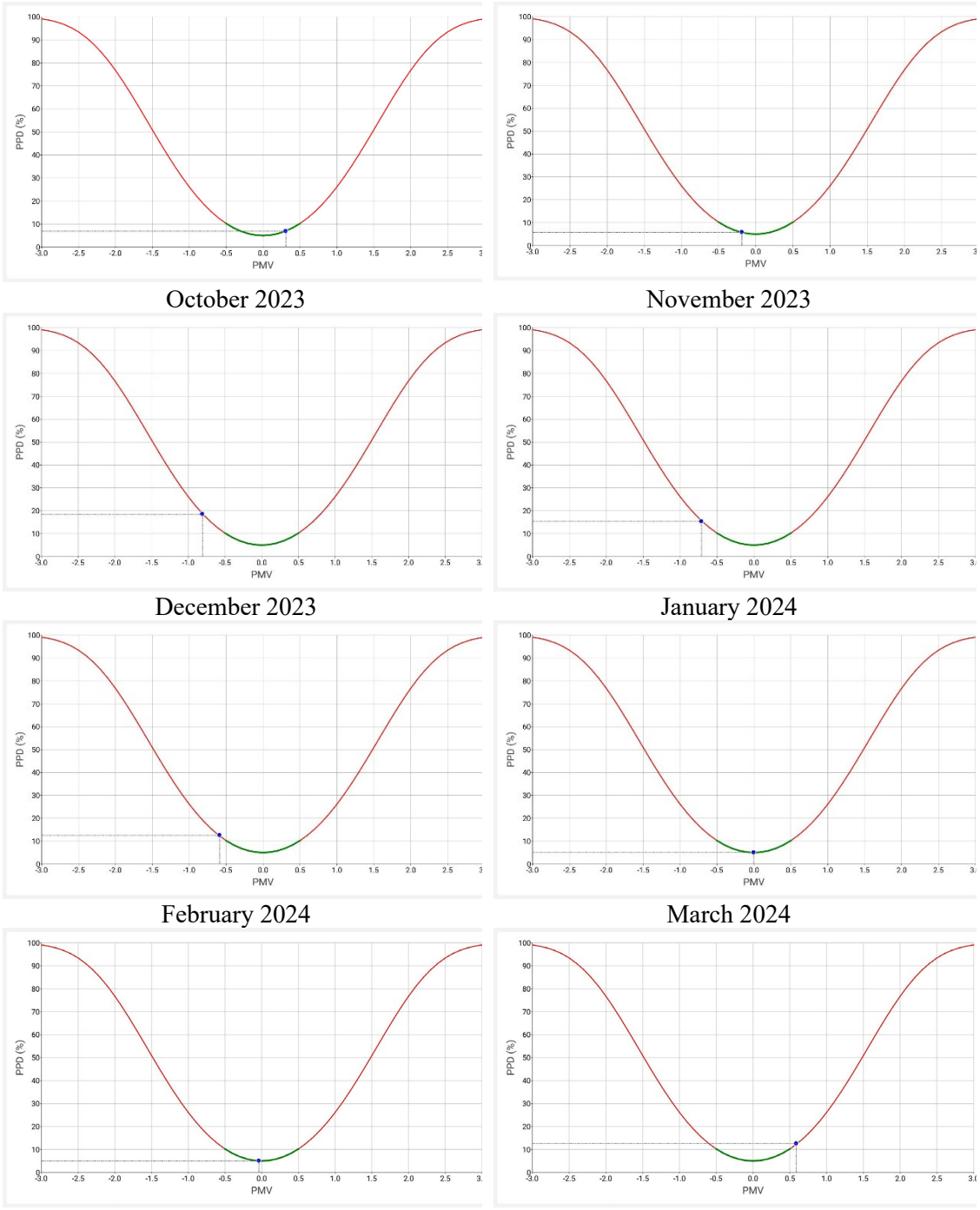


Figure 5. Relationship between PMV-PPD during the heating season

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DISCUSSION

Maintaining a proper indoor environment quality is crucial for both occupant well-being and building energy efficiency, especially during the heating season.

In general, the IEQ conditions observed during our field study in the educational building from October 2023 to September 2024 was in line with the thermal comfort criteria, for the heating season, established by international and national regulations [11,12], where temperatures typically should range from 20°C to 24°C, relative humidity from 30% to 70%, air velocity remained under 0.2 m/s, CO2 concentrations under 1000 ppm, and lighting levels around 300 lux.

The results of the investigation revealed that the mean indoor air temperature during the 7 months of heating (October 2023 – April 2024) was 24.03°C with a standard deviation (SD) of 1.43°C. This value is slightly higher than the recommended range of temperature according to standards [11,12]. The mean relative humidity was 34.74% with a SD of 4.09%, which is within the recommended range. The mean air velocity was 0.08 m/s with a SD of 0.01 m/s, indicating that the air movement is in line with the standards. The mean lighting levels were 310.14 lux with a SD of 77.63, which is generally considered adequate for classrooms.

In terms of IAQ, the average CO2 concentration measured was 912 ppm, with a SD of 246.98 ppm. Although this value falls below the recommended threshold of 1000 ppm, the elevated CO2 levels within the building are indicative of inadequate ventilation. As a naturally ventilated structure, the building relies exclusively on window openings and infiltration for air circulation. This suggests that a mechanical ventilation system is necessary to ensure a proper IAQ during the heating season.

The PMV-PPD method, a widely employed tool in thermal comfort research, assesses the suitability of environments for healthy adults. By quantifying PMV values between -0.5 and +0.5 and PPD values below 10%, the method determines adherence to the ASHRAE 55 Standard, ensuring a thermally comfortable and acceptable indoor environment. As depicted in Figure 5, the thermal comfort levels generally align with standard recommendations, with three notable exceptions occurring during the coldest months (December, January and February). However, when examining Figure 3a, it becomes evident that the average temperatures during these months exceed 22.6°C, suggesting a potential discrepancy between standards. Given that PMV is influenced by six factors – four environmental and two personal – more in-depth subjective investigations are warranted to fully understand the discrepancy between the measured temperatures, the thermal comfort assessment and the perceived thermal comfort.

The mean natural gas consumption during the heating season was 41.71 MWh with a SD of 22.88 MWh. This corresponds to an energy consumption of 63.17 kWh/sqm/year of the building. The energy consumption is similar compared to previous studies or benchmarks for similar buildings in the region.

Several studies examining various building types have demonstrated that reducing indoor air temperatures by just one degree can result in energy savings of 7% annually for heating [13,14]. Additionally, research has shown that students can effectively adapt to cooler environments during the winter months [15]. Given the average indoor temperature of 24.03°C during the heating season, it is crucial to implement strategies to reduce energy consumption. By adjusting indoor temperatures, it is possible to significantly decrease natural gas consumption, thereby enhancing the overall energy efficiency of the building.

Implementation of any energy saving actions cannot fully be reached if the building users are not integrated. The behavior and actions of the building users can lead to an increase in the total energy use. Promoting energy aware behavior in buildings are important aspects for the transition towards net-zero or positive energy buildings. Instead of seeing building's occupants as a problem, it is of significance to see them as part of the solution. The relationship between users behavior and building is complex and multidimensional, with many factors still not fully understood.

CONCLUSION

The comprehensive study undertaken in the educational building evaluated IEQ conditions, thermal comfort levels, and energy consumption throughout an academic year. While the majority of IEQ parameters complied with recommended standards, several notable exceptions were observed.

The average indoor temperature during the heating season reached 24.03°C, surpassing the recommended standards by a slight margin. Concurrently, CO2 levels consistently exceeded the acceptable threshold, averaging 912 ppm. These elevated CO2 levels underscore the need for a mechanical ventilation system to enhance indoor air quality.

The building's energy consumption of 63.17 kWh/m²/year was on par with similar structures in the region. By implementing a modest reduction in indoor temperatures of 1 to 2 degrees Celsius, the building could potentially achieve energy savings of 7% up to 13% without compromising occupant comfort.

To gain a deeper understanding of the complex interplay between measured temperatures, thermal comfort evaluations, and individual perceptions, further subjective investigations are warranted. Moreover, recognizing the substantial influence of building occupants' behavior on energy consumption, fostering energy-conscious practices is essential for advancing building energy efficiency.

Educational institutions possess a significant opportunity to decrease energy consumption, enhance indoor environmental quality, and foster a healthier, more sustainable learning environment for both students and staff.

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INTEGRATING GEOLOGICAL ELEMENTS INTO URBAN LANDSCAPES

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ABSTRACT

Urbanization is an ongoing trend. It causes various negative issues, including strain on human health and biodiversity. Cities are often subject to negative effects of climate change. Currently green and blue infrastructure are often seen as potential solutions for these problems. However, integration of topographically diverse sites and geological elements into urban landscapes is rarely considered as an important measure for addressing societal and environmental issues in cities. This can lead to lost opportunities. Poor protection of geo-heritage and low awareness of the geological values among city dwellers is also likely. The geological elements can be integrated into urban landscapes in a variety of ways. Here we discuss these opportunities and present the potential approaches to practical implementation of the integration. We explore opportunities to harness both existing geological elements and topography engineering to enhance effectiveness of Nature-based Solutions. We also highlight the values and costs associated with the approach and provide suggestions to policymakers and practitioners. In addition to well-known cultural, educational, scientific, and economic benefits of the proposed approach, we discuss less straightforward ones that are often overlooked by relevant stakeholders but still hold significant importance for the well-being of city dwellers. Given the fact that this is a novel research area, conceptual research methodology is applied here.

Keywords: geo-heritage, geo-diversity, sustainable development, Nature-based Solutions.

INTRODUCTION

More than a half of global population now lives in cities and the urbanization is expected to continue in upcoming decades [1]. Although the trend in general has led to an increase of human well-being, city dwellers face a broad range of challenges. In addition to the negative impacts of climate change (such as overheating or flooding), air and water pollution and diseases are clear risks for urban populations. For instance, infectious diseases will spread more easily due to high population densities non-infectious diseases, such as, respiratory and other diseases associated with pollution are more likely. High levels of stress and lack of physical activity contribute to obesity, mental, and cardio-vascular diseases. Recent research indicates that it is possible to address both climate related and health challenges through application of urban Nature-based Solutions [2, 3]. Indeed, “Nature-based Solutions address societal challenges through actions to protect, sustainably manage, and restore natural and modified ecosystems, benefiting people and nature at the same time” [4] and can be specifically designed to address societal challenges, such as those mentioned discussed above. The

urban Nature-based solutions are predominantly based on application of green and blue infrastructure. The role of topographic diversity and other geological elements in this context, however, does not seem to receive due attention.

Topography is closely related to age, composition and structure of regional soil and bedrock formations. It is further dependent upon the climatic and tectonic processes that create uplift and erosion that shape the landscape. Therefore, we will use the term "geo-diversity", which is connected to both topographic and strictly geological elements. Geo-heritage also includes mineral and fossil assemblages, stratigraphic and tectonic structures, and features that demonstrate specific events and developments during geologic history. Although these elements do not directly impact the landscape, they provide insight into the regional geological past and present and help illustrate the evolution of both physical and biological environments. Additionally, the naturally aesthetic value of geological elements is of value itself.

Geo-diversity, characterized in this way, can potentially deliver important benefits to the society complementing green and blue infrastructure. Indeed, topographically diverse sites can have higher climate-change resilience than the habitats located on the plain terrain. This is due to diverse micro-climatic conditions in such ecosystems. In addition, such sites can harbour highly biodiverse species assemblages due to increased diversity of ecological niches. Geo-diversity is also related to cultural heritage and local societal values and geo-diversity adds aesthetical value, potentially reducing levels of stress for residents and visitors. Although there is a substantial lack of empirical studies on potential health effects of topographically diverse sites, the fact that sites with diverse terrain tend to maintain healthy ecosystems [5] may indicate that this aspect can have positive human health effects, although more research is needed here.

Despite the fact that benefits of geo-diversity, this aspect is not explicitly integrated into urban landscape planning. Lack of attention to the geological and topographic elements may be a result of not recognising their value and a potential role as Natre-based Solutions. It is also possible that recognition of ways in which the geological elements can be integrated into urban landscapes may be lacking. In addition to that, lack of collaboration between landscape designers, urban planners, conservation specialists and geologists may hamper adoption of the approach. Willingness to integrate the topographic and geological elements into urban landscapes may be undermined by the costs associated with design and conservation strategies incorporating these elements. To foster adoption of the approach it is essential to understand the ways in which these elements can be integrated into urban landscapes. Thorough analysis of benefits and costs associated with integration of topographically diverse ecosystems into urban landscapes is essential, too. Finally, current knowledge gaps associated with the approach should be explored. We do discuss all this in the present study and provide recommendations for practitioners and policymakers.

MATERIALS AND METHODS

The present study employed a conceptual research methodology. The methodology is based on application of interdisciplinary research to search for solutions to real-world problems. Key strategies in conceptual research include theory synthesis, theory adaptation, typology, and modelling. We selected theory adaptation approach as it allows exploring concepts not explicitly discussed in existing literature and proposing novel insights. The approach integrates evidence and theoretical knowledge from

various fields to enhance current practices. In the present article, conceptual research is applied at the disciplinary interfaces between spatial ecology, sustainability science, landscape science, biodiversity science, and geology.

WAYS OF INTERATION

The first question that emerges when considering maximizing the value of geo-diversity in urban landscapes, such as utilization of their topographic diversity, is how this can be implemented in practice. Urban landscapes often possess unique geological features which are part of their geo-heritage [6]. The heritage objects are often discovered in the process of urban expansion and road construction [6]. Not only the important geological features may be present and discovered in the cities but also sites with high biodiversity may exist [7]. Such sites often are not given due attention and may be destroyed in the process of construction or development due to scarcity of valuable land in urban areas, and because of an unwillingness to make changes in ongoing construction projects, potentially increasing their costs or due to lack of public recognition and support [7]. Integration of these elements into an urban fabric may be problematic especially when they are discovered during construction. Nevertheless, the potential for geo-diversity to support Nature-based Solutions needs to be recognized. This can help offsetting the costs of their preservation. In addition, their cultural value and potential to increase tourism is important [6, 7] and can help justifying costs associated with changes to construction projects. The best approach here would be to undertake thorough geological assessments during the planning stage, before the construction works are started. The fact that the location geological elements cannot be changed should make their consideration an obvious part of the early planning process and other elements of urban grey, green and blue infrastructure should be designed considering the location of geological elements. In fact, geology and terrain as a basis for the planning processes is being promoted in nature conservation as a part of a landscape approach that considers conservation of the "nature`s stage" to protect ecosystem integrity and the "actors" inhabiting them [8]. This idea, however, does not seem to be adopted in urban planning yet.

When considering the potential role of specific geologic elements and, most importantly, geo-diverse sites in urban landscapes it is important to take a holistic view. In this case urban green and blue spaces need to be connected to or integrated with these sites. This is important first because this helps protect urban biodiversity and makes the associated flow of ecosystem services more resilient toward the negative impacts of climate change. Secondly, human exposure to and benefits from these ecosystems can be enhanced. Such planning pattern would resemble natural environments and ideally could turn urban landscapes into integrated holistic and resilient ecosystems.

Areas with natural geo-diversity, however, do not naturally occur in every city. This is especially true for regions with low-relief terrain. At the same time the topographic diversity may be essential for ensuring climate resilience and other benefits associated with geo-diverse landscapes. The question then is whether it is possible and essential to artificially integrate some sort of topography diverse sites into urban landscapes? This is a complex question with conflicting points of view. Opinion exists that urban green infrastructure should resemble natural ecosystems in surrounding landscapes [9]. A contrasting point of view considers urban green infrastructure as novel or designed ecosystems that can be different from natural habitats as long as they deliver ecosystem

services and support biodiverse species assemblages [10]. Given the fact that urban landscapes are designed by humans and in most cases both green and blue infrastructure fully, or at least partially, manmade, it is possible to consider engineering approaches for diversifying the topography. The approach is used in landscape design and Land Art where sculpting earth is sometimes implemented for aesthetic and artistic purposes. However, it is important to consider engineering approaches to topography formation from an ecological perspective, taking into account its role in climate change impact mitigation and maintenance of biodiverse species assemblages. Ideally, design and planning of the green infrastructure and urban Nature-based Solutions should start with assessment of opportunities to diversify the topography. This should be done taking into account landscape scale climate resilience of urban ecosystems.

COSTS

Preservation of the geo-heritage and geo-diverse areas in urban areas may incur significant costs. These costs can be associated with the need to change construction plans in such a way that the infrastructure does not transgress the geo-diverse areas and geo-heritage sites. This may require, for instance, construction of longer roads or elevated highways, increased length of underground infrastructure, increased volume of raw materials, working time and additional groundworks. Construction of some buildings may need to be relocated or even cancelled due to spatial constraints, which may incur costs of lost opportunities to sell or let the premises. In addition, costs may arise due to inefficiencies associated with less concentrated location of buildings, which, for instance, may result in higher energy consumption.

In contrast to sites with existing geo-heritage and geo-diversity, the location of Nature-based Solutions in urban areas often can be selected and topographic diversity engineered, avoiding some costs associated with modification of construction plans. However, topography engineering often includes groundworks and may require drainage construction, both of which are expensive. These costs could largely be spared if Nature-based Solutions are implemented without diversifying the topography, which may be tempting for stakeholders. This approach, however, is likely to result in loss of opportunities to harness ecosystem services, resilience and human well-being benefits associated with diverse terrain. The costs associated with preservation of geo-heritage and geo-diverse areas or with topography engineering are likely to be offset when considering associated benefits.

BENEFITS AND VALUES

The values that are most straightforwardly associated with geo-heritage and geo-diverse landscapes include cultural, scientific, educational, and recreational ones. Some of these values can deliver associated financial benefits, such as recreational value, which can often be harnessed for development of geo-truism. There are, however, other less straightforward benefits associated with geo-diversity and diverse topography, which may be easily overlooked. These include, as noted above, contribution of the sites to climate adaptation, human welfare and biodiversity conservation. These benefits may be particularly important in urban landscapes subject to heat stress, vulnerability to extreme weather events and other natural disasters, and conditions harmful to human health and hostile for biodiversity. In recent decades climate change has accelerated the rate of extreme weather conditions such as draught and flooding, exposing urban

environments to high risks for human health and even survival. Green and blue infrastructure are recognized as a means of mitigating the negative effects and applied as Nature-based Solutions. Although this trend is becoming widespread in urban environments, the role of induced or natural geo-diversity is yet to be fully recognized.

Geological elements geo-diverse sites can provide relevant measures to address the issues currently faced by city dwellers. The role of sites with diverse topography in climate adaptation has been proven throughout the history of our planet, as they served as climatic refugia during major climate shifts over geologic epochs, preserving biodiversity and serving as its recovery hubs [11]. This ability of the geo-diverse sites is to a large extent associated with a diversity of micro-climatic conditions within the ecosystems, buffering species from adverse impacts of changing climate [12]. In addition, diversity of ecological niches can positively contribute to the capacity of these habitats to maintain biodiversity for relatively long periods [13]. These factors can help to sustain the flow of ecosystem services under changing climatic conditions.

The positive contribution of geo-diversity to human welfare is multi-faceted. As mentioned above, cultural and aesthetic value of geo-heritage and topographically diverse landscapes can play an important role in the well-being of the city dwellers. Some evidence also suggests that topographically diverse landscapes can have both physical and mental health benefits. For instance, diverse terrain often promotes hiking, walking and other physical activities beneficial for human health, especially cardiovascular, respirational and general strength. In addition, geo-heritage, geo-diverse landscapes are often picturesque, which was found to have positive impacts on mental health, reducing level of stress, evoking positive emotions and even improving cognitive function [14]. Diverse terrain may contribute to reduced exposure to air pollution due to improved air circulation, thereby positively impacting on human respiratory system [15]. The link between geo-diversity and biodiversity can also have indirect positive impacts on human health as environments with diverse species assemblages were found to enhance human health [15].

RECOMMENDATIONS

Each Nature-based Solutions project is unique and therefore it not possible to generalize on associated costs and benefits. However, it is important to make sure that relevant practitioners and policymakers are aware of ways to integrate geo-heritage sites, geo-diverse areas and diverse topography into urban Nature-based Solutions. The stakeholders need to understand benefits associated with the geological and topographic characteristics of the solutions. Furthermore, climate adaptation, biodiversity and human health and well-being benefits should be considered with a long-term perspective and should not be directly compared with short-term costs or savings.

Ideally, considerations of geo-heritage and geo-diversity integration needs to be conducted at the planning stages, before city zoning or city expansion has started. This would allow avoiding costs associated with implementation of changes in ongoing or completed projects. The geological and topographic considerations need to encompass collaboration among multiple relevant specialists across a range of disciplines. For instance, the involvement of city planners, landscape architects, engineers, geologists, health and culture specialist involvement and cooperation would greatly benefit Nature-based Solutions projects to optimize the value of geodiversity. These considerations should be integrated into blue and green infrastructure planning and seen as

implementation of Nature-based Solutions. In fact, the holistic approach to city planning as a single ecosystem would be especially beneficial although this is not always feasible, especially in cases when the city already exists or when city expansion is being planned. To further advance this field it is essential to conduct more research on potential values of the geological and topographic diversity of urban landscapes. Indeed, there are significant knowledge gaps on the links between the topography, geo-heritage and geo-diversity and their contribution to human well-being, indicating an urgent need for further research. Land-use policies also need to be adjusted to accommodate these considerations and naturally integrate them in urban planning and development processes. The most straightforward way to do this would be to build upon existing green and blue infrastructure regulations and guidelines and integrate the geological and topographic considerations into them.

CONCLUSION

The aim of this study was to explore the potential role of geo-heritage, geo-diversity and diverse topography in urban ecosystems. Our study suggests that integration of geological elements into cities can have significant benefits, which most likely are not fully recognized in most cases. Despite the shortage of empirical studies on this subject, it is highly likely that geological and topographic diversity can address numerous challenges currently faced by the city dwellers. Furthermore, significant benefits to human wellbeing and biodiversity can be associated with the elements. In order to take a full advantage of integration of the geological elements into urban landscapes and minimize associated costs it is essential to conduct planning of urban green, blue and grey infrastructure considering opportunities for preservation of the geological elements and topography diversity. Cross disciplinary collaboration, future research and policy adjustments are essential to foster these developments. Holistic consideration of biodiversity, geo-diversity and human well-being can allow for sustainable development of modern cities. Long-term perspectives are essential for evaluation of associated costs and benefits.

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METHODOLOGY FOR THE DESIGN OF A CATALOG OF BUILDING ELEMENTS WITH POTENTIAL FOR REUSE IN THE REDEVELOPMENT OF UNIVERSITY CAMPUSES' OUTDOOR SPACE

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ABSTRACT

This article arises from a joint project between the universities of Jaen and Malaga (Spain), which are developing outdoor prototypes at the University Campus -called *Smart-Trees*- to improve the quality of exterior spaces for the university community.

The starting point for creating these outdoor canopies is using recycled material and elements from other buildings, such as from demolition or disassembly operations.

The first prototype was developed at the Malaga University Campus, and the second at the two campuses in Jaen and Linares.

Before the design process, the team needed more time to identify the materials and elements in some different locations. So, to implant this recycling initiative as a standard construction process, it needs to systematize the registration of materials from construction sites, warehouses, local industries, and scrapyards, aiming at the elements with the potential to be recycled to promote the reuse of traditionally discarded resources. To encourage collaboration between nearby universities or other institutions, creating a network for exchanging and optimizing materials is crucial, and integrating recycling practices in the design and architectural construction of the university urban spaces themselves is essential.

Establishing a methodology for creating an open catalog of reusable materials is necessary to promote sustainability in constructing new urban and social spaces in the university environment.

The open catalog would not only allow the identification, classification, and sharing of information on the availability of these resources. Besides, this open register would encourage research into new uses and applications of recycled materials in creating sustainable urban spaces. This interdisciplinary and collaborative approach contributes to reducing the environmental impact of construction, promotes the circular economy, and reinforces the role of universities as agents of change in the sustainable transformation of their environments.

Keywords: re-naturalization; circular economy; reusing materials; university inventory

INTRODUCTION

The climate has undergone great changes throughout history, due to natural causes. But the climate crisis we are currently experiencing is very different from previous ones [1].

Climate change, together with episodes of extreme weather, are the main risks for the Planet, taking into account the level of impact on society and its degree of probability [2].

Furthermore, with the progressive urban growth, the increase in university students and the lack of outdoor coworking space in the university areas of Malaga [2] led a group of researchers from multidisciplinary fields from the University of Malaga to develop a project of Smart-Tree which sought to enable quality spaces for teachers and students of the Teatinos University Campus, where a large part of the centers and departments of the University of Malaga are located [3].

The Smart-Tree project is located within Smart Campus, which aims to achieve a more comfortable, sustainable and intelligent campus. Being a Smart allows you to experiment and innovate in search of increasingly sustainable solutions for our planet. This proposal allows working on a small scale and can be extrapolated to a larger scale or areas. The Smart-Tree is located on Boulevard Louis Pasteur, behind the Faculty of Sciences. It is located in a place that was disused with the intention of creating an outdoor “co-working” space creating a microclimate of environmental and sensory comfort [4].

The project focuses primarily on two aspects of the Sustainable Development Goals (SDGs). First, it aims at urban greening (SDG 13) and integrating waste design and management (SDG 12). The goal is to incorporate a model that reduces the environmental impact caused by the extraction of new raw materials. For this reason, the application of the circular economy principle is proposed for the design of outdoor spaces.

The project started with initially mapping the materials available in the University's warehouses to source materials that required the least manipulation and transformation. Among the potentially reusable materials was a three-dimensional structure that had served as a "pergola" in the courtyard of the Faculty of Fine Arts (BBAA) on the El Ejido Campus (Malaga), which had been sent for recycling as a result of ongoing rehabilitation work on the building [2].

The project is based on an initial mapping of the materials that the university had in its warehouses in order to obtain materials that needed the least manipulation and transformation possible. Among the potentially reusable materials was a three-dimensional structure that served as a canopy in the courtyard of the Faculty of Fine Arts (BBAA) on the El Ejido Campus (Málaga) that had been sent for recycling as a result of the rehabilitations that were carried out were taking place in the building [2].

The Malaga Smart-Tree, built in 2020, covers an area of 48 m², of which 36 m² are under a methacrylate cover and 12 m² are uncovered. The landscaped area surrounding it measures 522 m² [2].

A pedestrian path crosses the central garden area and connects the Smart-Tree to the boulevard, which serves as the central communication axis of the University of Malaga campus [2].

The space has sensors to monitor and collect data on variables such as soil conditions, air quality, meteorology, and comfort levels. Since the project includes covered and open areas, sensors have been placed in both spaces to enable comparative analyses.



Fig. 1. Dismantling, relocation, and construction process of the structure of Smart-Tree in Malaga

The design of this space not only revitalized a previously unused area but also gave a second life to materials that had become obsolete after their initial use in partially demolished campus buildings. The selection of materials involved months of work, including searches through numerous university warehouses, reviews of ongoing construction projects to identify materials intended for disposal, explorations of local industrial waste, and even visits to scrapyards. This exhaustive process highlighted the need for a catalog to document all potentially recyclable materials and existing inventory in university warehouses to facilitate future Smart-Tree developments.

As of 2024, two additional Smart-Trees are being developed for the University of Jaen, one located in the municipality of Linares and the other in Jaen, both within university areas.

The Smart-Tree Linares is situated on the Scientific-Technological Campus of Linares, next to the Higher Polytechnic School (EPS) and the Classroom building. Following mapping reusable materials in the university's warehouses, a structure of metal arches, used initially to stabilize mining tunnels, was repurposed. These cold-curved profiles were mounted parallel to the ground. Additionally, high-resistance industrial shelving was incorporated.



Fig.2. Infographic of the Smart-Tree on the Linares campus

https://doi.org/10.5593/sgem2024v/6.2/s26.42

Together, these elements form the Smart-Tree Linares, with furniture sourced from the warehouses in Malaga.

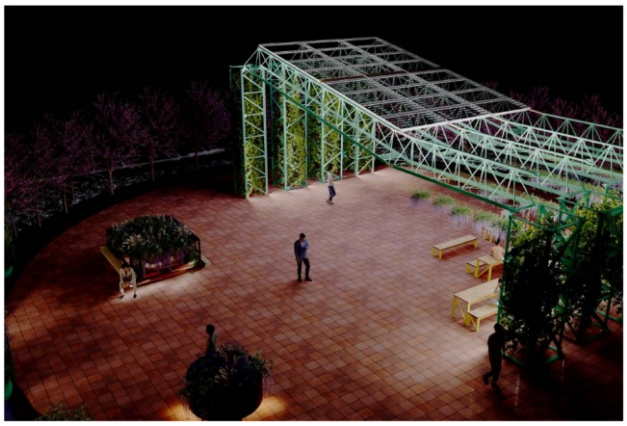


Fig. 3. Infographic of the Smart-Tree on the Jaen campus.

The Smart-Tree Jaen is located on the Jaen University Campus, near the Arqueodromo and the Cesareo Rodriguez Aguilera Classroom. As in previous cases, the university's warehouses were mapped. However, materials were scarce to create a structure suitable for a co-working space. In this instance, an old crane discovered in the Alcala scrapyard was repurposed. The crane was divided into four parts to shape the final structure. The furniture used was also sourced from the University of Malaga's warehouses.

A technical datasheet was created for the materials, including detailed drawings of the elements, an image, and a record containing an identifier, dimensions, material type, location, origin, condition, stock number, cost, and description. Below is an example of the datasheet for the structure used in the Linares Smart-Tree

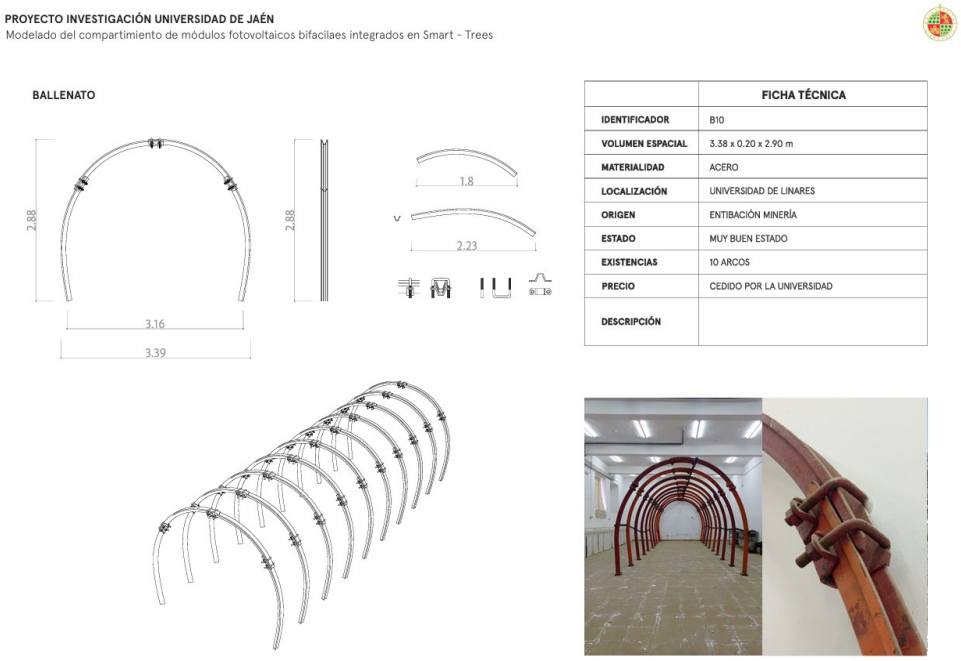


Fig. 4. Technical datasheet created to register the reusable materials. Author: Pablo Hernandez-Vilchez

MATERIALS AND METHODS

Given the need to inventory potentially recyclable materials, a review of the state of the art was conducted to determine whether previous studies had focused on developing a catalog for recyclable materials. Initial searches were performed using the Web of Science database. The first search, using the terms *campus (Abstract) AND materials (Abstract) AND inventory (Abstract)*, yielded 99 results. However, a preliminary review of the

abstracts revealed that most articles were unrelated to the research objective. Consequently, the term *materials* was replaced with terms more closely aligned with reuse and recycling, particularly within the circular economy context. A second search using the terms *campus (Abstract) AND circular economy (Abstract) AND inventory (Abstract)* yielded only two results.

Both of these articles directly addressed the creation of a catalog for construction materials; one article, titled *Creating a Green Chemistry Lab: Towards Sustainable Resource Management and Responsible Purchasing* was found to be particularly relevant. This study focuses on achieving and maintaining order while maximizing efficiency in teaching laboratories and warehouses within the Chemical Industry and the Department of Environmental Engineering at the Faculty of Engineering of Vitoria-Gasteiz. It employs the 5S methodology to optimize resource management [5].

Given the limited results, further searches were conducted on Google Scholar without restrictive terms. This broader search aimed to identify documents not indexed in Web of Science that could provide insights from other universities. During this process, a document titled *Characterizing the Materials Footprint of a University Campus: Data, Methods, Recommendations* was identified. This document is notable for defining universities as significant consumers and disposers of materials. It highlights that while universities often collect data on material consumption, only some focus on strategies for reuse and management. The article uses material flow analysis (MFA) to characterize and quantify material flows at the Massachusetts Institute of Technology (MIT). Chapter 2 of the study outlines their classification process, though construction materials are grouped into a broad category. This article provides a basis for proposing the development of a more detailed inventory for such materials.

The absence of articles detailing the creation of inventories, including methodologies for their development, underscores the need to design a standardized approach for universities. This approach would aim to create an open catalogue of reusable materials, fostering sustainability in constructing new urban and social spaces within the university environment. Such a catalogue would document the materials available at universities and standardize, organize, and classify storage spaces across different warehouses.

Drawing from the experiences gained through the Smart-Trees projects—which emphasized the importance of creating such a catalogue—a structure with five sections is proposed, as detailed below:

Section 1: Introduction and objectives

As it is a catalogue that aims to be open and issued among universities, it would have a first section explaining the purpose of the catalog for all new universities that want to adopt this new work methodology where the circular economy stands out. the search to reduce waste and encourage the reuse of materials in university urban design. Also a subsection describing what types of materials would be included and finally another subsection explaining how the information that comprises it is collected, such as inspections of the state of the materials, measurements and technical analyses.

Section 2: General classification of materials

This section allows you to organize the materials according to a taxonomy that facilitates their identification. The classification that makes it up would be the following:

- Material by type: It consists of grouping them by physical and composition characteristics. They can be classified as: concrete and derivatives; wood and derivatives; metals; glass and ceramics; plastics and polymers; textiles; others (composites, etc.).
- Material by origin*:* allows you to organize materials based on their origin. Material by origin. The classification that makes it up would be the following: building, civil works, industrial waste or urban environments.
- Material for its potential use: It allows materials to be classified according to the specific applications they may have. The classification that makes it up would be the following: structural elements, finishes, decorative components or urban infrastructure (benches, tables, curbs, trash cans, etc.).

Section 3: Materials technical sheet

Each material must have its technical sheet structured as indicated in a standard technical sheet, which will include:

- Identification: It will be assigned a unique code that will be assigned to the common and technical name with a registration date and the current location in the warehouses.
- Physical and mechanical description: dimensions, available quantity (with unit), weight, texture, color and mechanical properties will be indicated.
- State and conditions: the level of deterioration will be indicated, if it has any contaminants or damages such as rust or cracks; and finally some conservation observations.
- Origin and provenance: the source will be indicated, such as the work or project from which it comes and the approximate year of manufacture. Images of the material removal process will be attached in the case of new material and if there are materials that are already in the warehouses.
- Compatibility and potential uses: the parts of the project where it could be reused will be indicated, if it requires any type of transformation, storage conditions and finally indicate restrictions or recommendations.
- Photographs and diagrams: make images of the material from different angles and technical diagrams, if applicable.

Section 4: Selection and evaluation criteria

This section allows you to indicate selection and evaluation criteria that establish parameters to ensure suitability for specific projects and their alignment with sustainability and architectural functionality objectives. The criteria would be the following:

- Environmental impact: evaluate the carbon footprint of the material in its initial production and the potential for waste reduction when reusing it. This section would allow us to assign a recycling index to each project with which we could measure the volume of material that has been reused.
- Technical feasibility: ease of handling and transforming the material and compatibility with other materials.
- Architectural value: allows evaluating the aesthetic and functional potential in urban spaces.

Section 5: Experiences

To conclude the catalog would have the development of all the projects that have included a reuse process so that other universities can learn from the entire process with which the University of Malaga began and which the University of Jaén continued. These projects will be accompanied by images of the materials, before, during and finally in the project. You will also be given a final recycling rate.

This inventory will allow the creation of a standardized digital consultation tool so that all universities could know both the materials they have and the materials the closest universities have, allowing the creation of a network for exchange. The query tool would consist of an index with filters where a search can be carried out by type of material, origin, location, status and images of the selected material.

RESULTS

During the development of the 3 Smart-Tree it has been demonstrated that recycled materials can be effectively integrated into the design of university urban spaces. The need to generate a catalog that allows inventory of the different materials found in warehouses with the aforementioned information sections would allow having the necessary information for the development of these urban projects and the standardization of the process to promote external collaborations between universities.

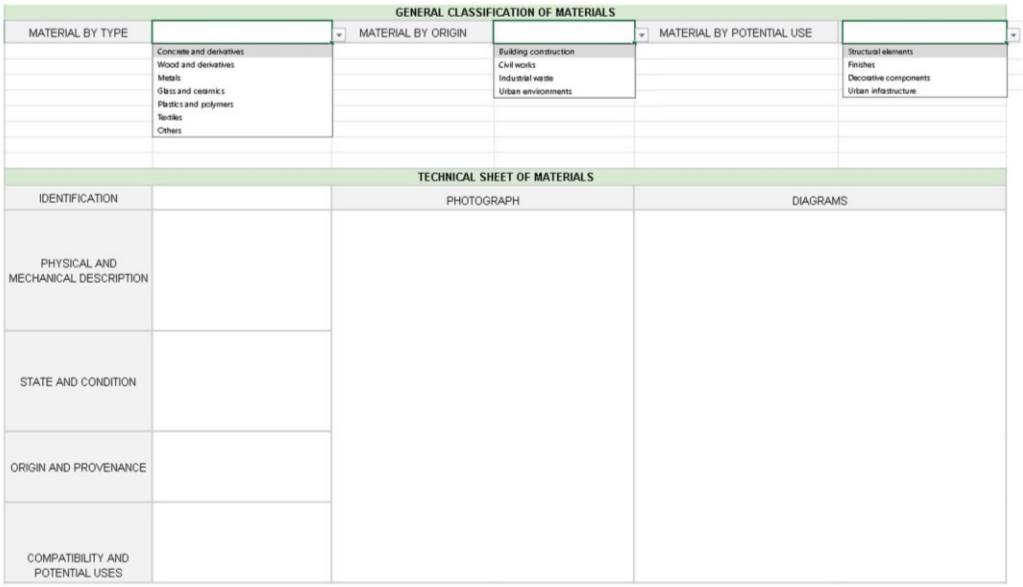


Fig. 5. Data matrix designed to register the materials and elements with reusable potential.

DISCUSSION

The resource of the tool is exposed, but it has limitations that can be exposed on three scales: physical storage space - technical support - and network. Firstly, the storage of construction materials requires considerable space, meaning that universities need spaces that can be used solely for their storage. Do university warehouses have capacity? Secondly, the development and maintenance of the tool require continuous technical and economic resources to ensure its operation. Who pays for it? Who leads it? Finally, universities must monitor the materials and commit to updating the information.

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CONCLUSIONS

The proposed matrix is presented as a necessary tool for managing and reusing recycled materials in the development of university spaces. This matrix articulates data at three interconnected scales: physical storage spaces (warehouses), digital infrastructure (software), and network connectivity (open catalog). This approach allows for standardized classification, monitoring, and optimization of the resources available in university environments. This matrix not only facilitates the inventory of materials through criteria such as their origin, type, or potential use but also incorporates specific indicators to evaluate their condition and viability in reuse projects.

One of the most notable aspects is its ability to centralize and systematize information, allowing resource management and reducing environmental impact. However, the effectiveness of this tool depends on adequate and continuous maintenance over time, the participation of trained personnel for data collection, and planning regarding storage.

Integrating a tool would allow access to a network where users can consult, analyze, and collaborate on projects from anywhere. This system promotes the reuse of materials and fosters a culture of circular economy within university communities. In conclusion, this matrix is positioned as a necessary and replicable management model that strengthens the university infrastructure, aligning with the global objectives of sustainability and regenerative design.

ACKNOWLEDGEMENTS

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OPERATIONAL CHARACTERISTICS OF A DC ISLANDED MICROGRID FOR GREEN HYDROGEN PRODUCTION

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ABSTRACT

This paper explores the operational characteristics of a DC islanded microgrid engineered to produce green hydrogen, utilizing power sourced from a solar array complemented by an energy storage system. The model simulates a one-week evaluation period, incorporating comprehensive analyses of electrical, thermal liquid, and thermal gas domains. By examining the interactions between the solar array, energy storage, and electrolyzer, the study provides a detailed assessment of system performance under varying conditions. Key metrics such as hydrogen production rates, energy efficiency, and thermal management are evaluated to identify optimal operational strategies. The insights gained from this study aim to enhance the efficiency and reliability of renewable energy systems, offering practical solutions for improving the stability and sustainability of green hydrogen production. The findings contribute to advancing the integration of renewable energy sources in microgrid configurations, promoting a more sustainable energy future.

Keywords: Green hydrogen, Solar energy, Electrolyzer, Energy storage, Carbon emissions.

INTRODUCTION

The shift towards renewable energy sources is crucial for combating climate change and reducing our reliance on fossil fuels. Among the various renewable energy technologies, green hydrogen production is emerging as a highly promising solution due to its high energy density and its capacity to generate zero carbon emissions. Green hydrogen is produced through the electrolysis of water, where electricity from renewable sources, such as solar and wind power, is used to split water molecules into hydrogen and oxygen. This method of hydrogen production is both environmentally friendly and sustainable. However, it requires a reliable system for converting and storing energy, particularly because renewable energy sources are often intermittent [1].

Islanded microgrids, which operate independently of the central power grid, represent a viable option for localized energy generation and storage. These microgrids can efficiently harness and utilize renewable energy on a smaller scale. A DC islanded microgrid, in particular, offers several advantages over its AC counterparts [2]. For instance, DC microgrids experience lower conversion losses, which enhances overall system efficiency. Furthermore, they are better suited for integration with modern energy

storage systems and DC-powered electrolyzers, which are essential for optimizing hydrogen production [3].

This paper focuses on the design and implementation of a DC-landed microgrid specifically aimed at producing green hydrogen using solar power in conjunction with an energy storage system. By examining this system, we aim to explore the potential benefits of DC microgrids in the context of renewable energy and hydrogen production. Key considerations include the efficiency of energy conversion, storage solutions, and the overall feasibility of deploying such systems on a local scale [4].

The analysis presented will detail the technical aspects of integrating solar power with energy storage and electrolyzers within a DC microgrid framework. It will also address the challenges associated with maintaining a stable and efficient energy supply, given the variable nature of renewable energy sources. Ultimately, the goal is to demonstrate how DC-landed microgrids can offer a sustainable and scalable approach to green hydrogen production, contributing to the broader transition towards cleaner energy systems [5].

MATERIALS AND METHODS

The microgrid system under investigation consists of three primary components, each crucial for the production of green hydrogen. These components are the solar array, energy storage system, and electrolyzer. To understand and optimize the interactions among these components, we employ a MATLAB software model.

1. Solar Array

The solar array serves as the primary source of electrical energy by converting sunlight into electricity through photovoltaic cells. The performance of the solar array is influenced by factors such as solar irradiance, temperature, and shading. Solar irradiance impacts the amount of electricity generated, requiring continuous monitoring and adjustment to account for daily and seasonal variations [6]. Temperature fluctuations and shading from surrounding objects also affect the array's efficiency. The MATLAB model simulates these variables to accurately predict the energy output of the solar array under various conditions. The power generated by the solar array is given by the equation:

$$P_{Solar} = \mu_{Solar} \times A_{Solar} \times I_{Solar} \quad (1)$$

where:

μ_{Solar} is the efficiency of the solar panels, A_{Solar} is the area of the solar panels, and I_{Solar} is the solar irradiance.

2. Energy Storage System

The energy storage system, consisting of batteries or other storage technologies, captures excess energy generated by the solar array. This stored energy is crucial for maintaining a steady power supply to the electrolyzer during periods of low solar output, such as cloudy days or nighttime. The MATLAB model integrates the energy storage system to simulate its performance and assess its ability to balance energy supply and demand [7]. By modelling the storage system's dynamics, we can optimize its design and capacity to ensure reliable operation of the microgrid. The energy stored in the system at time t+1 is given by the equation:

$$E_{Storage}(t+1) = E_{Storage}(t) + [P_{Solar}(t) - P_{\text{electrolyzer}}(t) - P_{Load}(t)] \times \Delta t \quad (2)$$

where:

$P_{\text{electrolyzer}}(t)$ is the power consumed by the electrolyzer at time t, $P_{Load}(t)$ is the load demand, and Δt is the time step.

The rate at which hydrogen is produced is given by the equation:

$$H_2 = \mu_{\text{electrolyzer}} \times (P_{\text{electrolyzer}}/E_{\text{water}}) \quad (3)$$

where:

$\mu_{\text{electrolyzer}}$ is the efficiency of the electrolyzer, and E_{water} is the energy required to split water into hydrogen and oxygen

3. Electrolyzer

The electrolyzer converts electrical energy into chemical energy by splitting water into hydrogen and oxygen through electrolysis. Its efficiency depends on the quality of the input power and the operating conditions, including voltage stability, current density, and the temperature of the electrolytic solution. The MATLAB model includes detailed simulations of the electrolyzer's performance, allowing us to evaluate how variations in input power affect hydrogen production and identify optimal operating conditions [8].

The MATLAB software model developed for this study integrates these components and simulates their interactions over a one week. It encompasses various domains, including electrical, thermal liquid, and thermal gas, to capture the complex dynamics of the system. This comprehensive modelling approach provides valuable insights into the operational efficiency of the microgrid, helping to identify potential areas for improvement and optimization. The use of MATLAB enables detailed analysis and visualization of the system's performance, facilitating a deeper understanding of how the solar array, energy storage system, and electrolyzer work together to produce green hydrogen effectively [9]. By leveraging MATLAB's capabilities, we can explore the behaviours of the microgrid under different scenarios, assess its reliability, and refine its design to enhance overall performance. The overall efficiency of the system is given by the equation μ_{system}:

$$\mu_{\text{system}} = H_2 \times E_{H_2}/(P_{Solar} \times P_{Storage}) \quad (4)$$

where:

E_{H_2} is the energy content of the produced hydrogen, and $P_{Storage}$ is the power from the storage system.

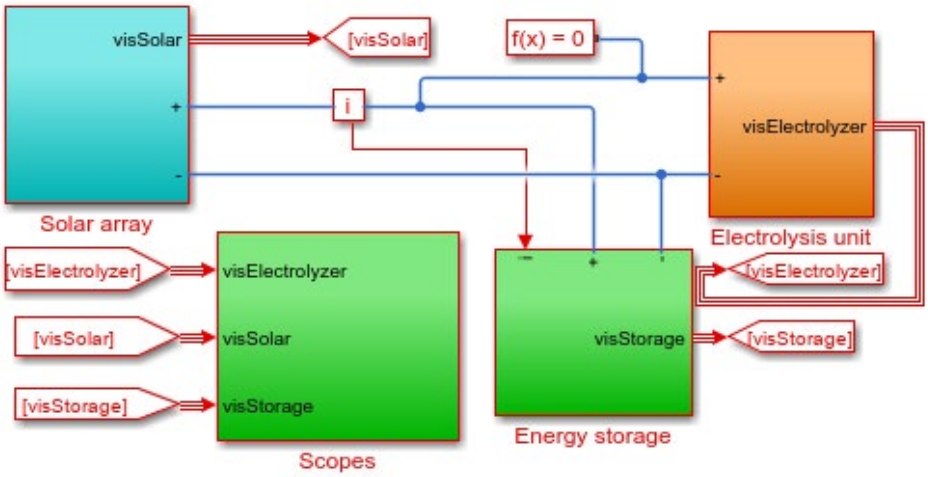


Figure 1. Overall System Diagram

Methodology

This study utilizes a simulation-based approach to assess the performance of a DC-islanded microgrid designed for green hydrogen production. The methodology involves varying key parameters, such as solar irradiance, temperature, and load demand, to evaluate their effects on system efficiency and hydrogen output. The simulation model is structured around three primary domains:

Electrical Domain: This component of the model simulates the power generation from the solar array, the dynamics of the energy storage system, and the power consumption by the electrolyzer. It captures the flow of electrical energy through the system, providing insights into how effectively solar energy is converted and utilized for hydrogen production [10].

Thermal Liquid Domain: The model includes a thermal liquid domain to represent the heat exchange processes within the system, with a specific focus on the electrolyzer. Effective heat management is essential for maintaining the electrolyzer's optimal performance and ensuring stable operation. This domain helps in understanding how thermal conditions impact the efficiency of electrolysis [6].

Thermal Gas Domain: This domain addresses the thermal properties and behaviours of the gases produced during electrolysis, namely hydrogen and oxygen. It models the heat generated and transferred by these gases, which can influence the overall system performance and the efficiency of the hydrogen production process.

To ensure that the simulation accurately reflects real-world operating conditions, data from actual weather patterns and load profiles is incorporated. This approach allows the model to simulate practical scenarios and assess the microgrid's performance under varying environmental and operational conditions [11].

Key performance metrics analyzed in the study include:

Energy Efficiency: Evaluates how effectively the system converts and utilizes solar energy to produce hydrogen.

Hydrogen Production Rate: Measures the amount of hydrogen generated over time, providing insight into the system's productivity.

System Reliability: Assesses the overall dependability and stability of the microgrid, including its ability to maintain consistent operation and performance.

By analyzing these metrics, the study aims to identify potential areas for optimization and improvement, ultimately enhancing the efficiency and effectiveness of the DC-landed microgrid for green hydrogen production [12].

RESULTS AND DISCUTIONS

The study reveals the significant potential for efficient green hydrogen production using a DC-islanded microgrid. The key findings from the simulation and analysis are as follows:

Solar Array Performance: The efficiency of the solar array is markedly influenced by weather conditions. The system achieves peak performance on clear, sunny days, where maximum solar irradiance is available. Conversely, during cloudy or shaded conditions, the energy output from the solar array diminishes considerably [2]. This variability highlights the importance of accounting for weather patterns in optimizing solar energy utilization.

Energy Storage Utilization: The energy storage system is crucial for balancing energy supply and demand. Effective management of stored energy is vital for maintaining

continuous hydrogen production, particularly during periods of low solar irradiance or nighttime [13]. The simulation demonstrates that well-optimized storage solutions can significantly enhance the reliability of the microgrid, ensuring a steady supply of power to the electrolyzer.

Electrolyzer Efficiency: The performance of the electrolyzer is closely tied to the stability of the input power. Variations in power supply can impact the efficiency of the electrolysis process, affecting the rate of hydrogen production and the overall efficiency of the system. Stable and high-quality power delivery is essential for maximizing electrolyzer performance and ensuring consistent hydrogen output [7].

The results also lead to several optimization strategies aimed at improving the system's performance. These include:

Advanced Control Algorithms: Implementing sophisticated control algorithms for energy management can enhance the efficiency of energy storage and distribution. Such algorithms can optimize the use of stored energy, minimize power fluctuations, and improve overall system stability [5].

Component Technology Improvements: Potential upgrades in component technologies, such as more efficient solar panels, advanced energy storage solutions, and high-performance electrolyzers, can further boost the system's efficiency and reliability. Continuous advancements in these technologies will contribute to better integration and performance of the microgrid [1].

The study underscores the effectiveness of the DC islanded microgrid for green hydrogen production and identifies key areas for further enhancement. By addressing the challenges related to solar array performance, energy storage management, and electrolyzer efficiency, the microgrid can be optimized to achieve higher efficiency and more reliable hydrogen production. The table 1 presents the substance's thermophysical properties at different temperatures, including enthalpy, which indicates the energy content; viscosity, which measures flow resistance; conductivity, which shows heat transfer efficiency; and specific heat, which represents the heat required to change its temperature [9].

Table 1. Hydrogen Properties

Temperature (K)	Enthalpy (kJ/kg)	Viscosity (s*uPa)	Conductivity (mW/kg/K)	Specific Heat (kJ/kg/K)
198.15	2532	6.77	132.4	13.57
223.15	2875	7.34	146.8	13.87
248.15	3224	7.88	160.5	14.08
273.15	3578	8.42	173.4	14.23
298.15	3936	8.94	185.6	14.33
323.15	4295	9.44	197.5	14.40
348.15	4655	9.93	210.1	14.45
373.15	5017	10.41	222.0	14.47

Figure 2 depicts the voltage levels of a battery and the grid. Initially, the battery voltage is lower than the grid voltage. Over time, the battery voltage decreases, whereas the grid voltage remains relatively stable with minor fluctuations. This suggests that the battery might be discharging to supply power, while the grid maintains effective voltage

regulation. However, the short timeframe and lack of specific voltage values limit the analysis, and current measurements would provide additional insights.

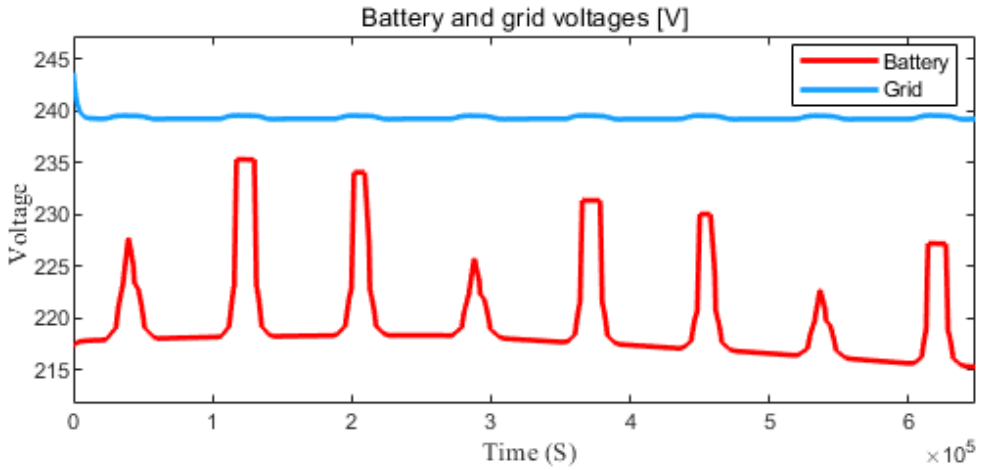


Figure 2. Battery and Grid Voltage Over Time

Based on figure 3, the system appears to function as follows:
Solar Power Generation: During daylight hours (approximately 6-18 Pm), solar power production rises, reaches a peak, and then declines as the sun sets.
Electrolyzer Operation: When solar power production surpasses immediate demand, the surplus energy is used to power an electrolyzer, which converts water into hydrogen for storage.
Energy Storage: The energy stored, likely in the form of hydrogen or batteries, is then utilized to supply power during periods of low solar generation.

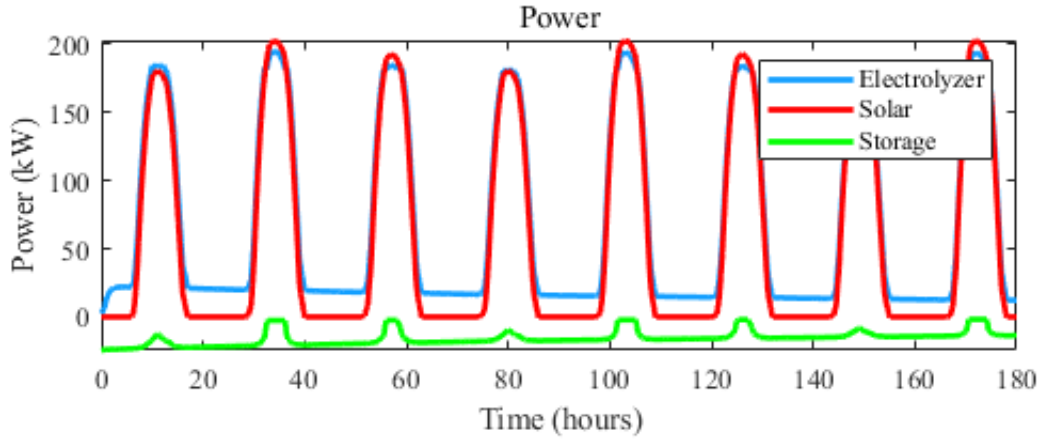


Figure 3. Power Production over time

The table 2 outlines critical design elements of the system, including the plate dimensions, which define their size; the number of electrode pairs and cells, which influence functionality; the membrane's area and thickness, which impact performance and durability; and the resistances, which affect electrical and heating processes.

Table 2. Electrolyzer Unit

Parameter	Value	Unit
Plate X	50	cm
Plate Y	100	cm
Plate Z	100	cm
Number of Electrode Pairs	3	
Number of Cells	100	
Membrane Area	(Plate.Y * Plate.Z) * Np_electrodes	cm^2
Membrane Thickness	2.0	cm
Resistance	0.25	Ohm
Heating Resistance	25	Ohm

Figure 4 illustrates the state of charge (SOC) of a battery over time, with the vertical axis representing the SOC in percentage (0% to 100%) and the horizontal axis showing time in hours. The graph reveals a general downward trend in SOC, with the rate of discharge varying over time. This could suggest that the battery is discharging steadily to power a load, that the discharge rate fluctuates due to changing load conditions, or that the battery's capacity is decreasing over time.

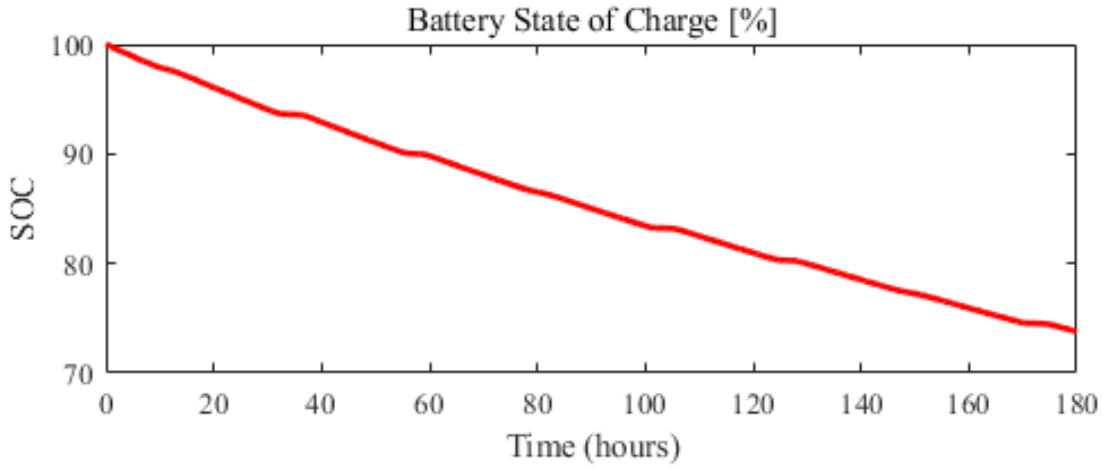


Figure 4. Battery state of charge over time

Figure 5 presents the cumulative amount of hydrogen produced over a period of 180 hours, with the vertical axis representing the total mass of hydrogen in kilograms (kg) and the horizontal axis showing time in hours. The graph indicates a steady increase in hydrogen production, suggesting a continuous production process, with the production rate appearing relatively constant based on the slope of the line.

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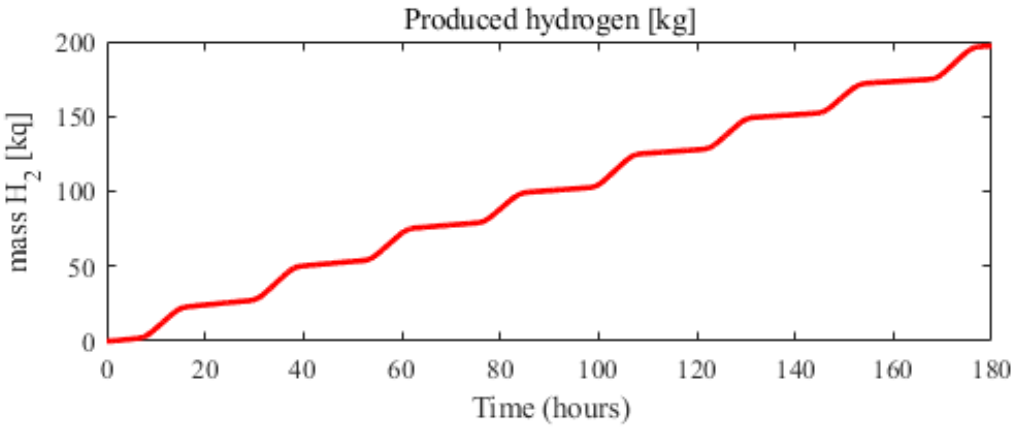


Figure 5. Hydrogen production over time

Figure 6 illustrates the energy consumption required to produce one kilogram of hydrogen over time, with the vertical axis representing energy consumed in kilowatt-hours (kWh) and the horizontal axis showing time in seconds. The graph reveals a general downward trend in energy consumption, indicating potential advancements in hydrogen production technology or process optimization.

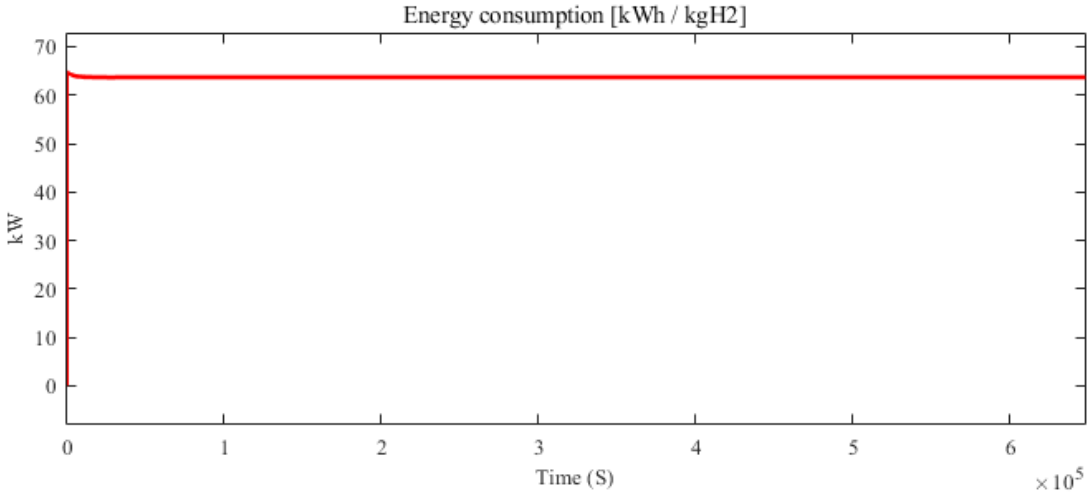


Figure 6. Energy consumptions

The table 3 details the hydrogen tank's surface area, its total volume, and the storage temperature, essential for ensuring proper storage and efficiency of hydrogen.

Table 3. Tank Data

Parameter	Value	Unit
Tank Area	(Plate.X * Plate.Y) * Np_electrodes	cm^2
Hydrogen Tank Volume	1000000	cm^3
Storage Temperature	273.15	K

The table 4 summarizes essential details of a battery, including its capacity (how much charge it holds), internal resistance (which affects efficiency), and operating voltage (which determines the power it can deliver).

Table 4. Energy Storage

Parameter	Value	Unit
Nominal Capacity (Qn)	50000	mAh
Initial Charge (Qinit)	50000	mAh
Half Capacity (Q1)	25000	mAh
Series Resistance (Rs)	0.2	ohms (Ω)
Nominal Voltage (Un)	240	volts (V)
Minimum Voltage (U1)	210	volts (V)

CONCLUSION

This study offers significant insights into the design and operation of a DC-landed microgrid dedicated to green hydrogen production. By effectively integrating solar power, energy storage, and electrolysis, the microgrid demonstrates the potential for achieving high efficiency and reliability in renewable energy systems.

Key findings emphasize that optimizing each component solar array, energy storage system, and electrolyzer is crucial for maximizing the system's overall performance. The solar array's efficiency is notably affected by weather conditions, underscoring the need for strategies to mitigate variability and ensure consistent energy supply. The energy storage system proves vital for balancing supply and demand, particularly during periods of low solar irradiance. Meanwhile, the electrolyzer's performance is heavily influenced by the stability of the input power, highlighting the importance of maintaining a stable and high-quality energy supply for effective hydrogen production.

The study underscores the importance of optimizing the integration of these components to enhance renewable energy utilization and hydrogen production. Advanced control algorithms and improvements in component technologies are identified as potential avenues for further increasing the system's efficiency and reliability.

Looking ahead, future research will focus on broadening the model to incorporate additional renewable energy sources, such as wind or biomass, to create a more comprehensive and adaptable microgrid. Additionally, exploring long-term operational strategies will be crucial for scaling the system to meet larger energy demands and ensure sustainable, large-scale implementation. This continued exploration will contribute to advancing the development of robust and efficient microgrid systems for green hydrogen production, supporting the transition to cleaner energy solutions.

ACKNOWLEDGEMENT

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OPTIMIZING SOLAR THERMAL SYSTEMS FOR DOMESTIC HOT WATER: A CASE STUDY ON LOW-FLOW TECHNOLOGY

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ABSTRACT

This paper presents an in-depth analysis of a residential solar thermal system designed for domestic hot water (DHW) production in a single-family dwelling located in Mangalia, Romania. Positioned at a latitude of 43.894° and a longitude of 28.422°, Mangalia benefits from an annual global irradiation of 1403 kWh/m², providing favorable conditions for solar energy utilization.

The study evaluates the system's performance over the course of a year, focusing on energy consumption, solar fraction, and environmental benefits. The solar thermal system in Mangalia achieves a performance ratio of 2.02, indicating that each unit of auxiliary energy input generates over two units of useful thermal energy. Notably, 64.3% of the household's total energy demand is met through solar energy, significantly reducing the reliance on conventional energy sources.

Further analysis reveals that the system produces a total annual thermal output of 2661 kWh, with energy savings reaching 2801 kWh per year. These savings correspond to a reduction of approximately 1502 kilograms in CO_2 emissions, underscoring the environmental advantages of solar thermal technology in this region.

By integrating detailed operational data, this paper highlights the system's efficiency in harnessing solar energy, particularly in the context of Mangalia's climatic conditions. The findings emphasize the potential for optimizing system design to maximize energy efficiency and reduce environmental impact. The paper concludes with recommendations for enhancing the adoption of solar thermal systems in residential settings across similar geographical locations, contributing to the global transition toward sustainable energy solutions.

Keywords: Energy Efficiency; CO_2 Emissions Reduction; Residential Heating; Renewable Energy; Mangalia, Romania.

INTRODUCTION

In the quest for more sustainable energy solutions, residential solar thermal systems have gained prominence as an effective method for reducing energy consumption and environmental impact. This study focuses on a solar thermal system installed in Mangalia,

Romania, a location well-suited for solar energy utilization due to its favorable climatic conditions. The system is designed to provide domestic hot water (DHW) for a single-family home, leveraging solar thermal technology to harness the sun's energy for heating purposes. To thoroughly evaluate the system's performance and operational efficiency, the study employs Polysun software for simulation and analysis. Polysun is a sophisticated tool that models and simulates the behavior of solar thermal systems, offering detailed insights into their performance under various conditions. By integrating this software, the study can accurately predict energy yields, optimize system design, and evaluate the impacts of different operational scenarios [1].

The core of this system consists of a solar collector field, which captures solar radiation and converts it into thermal energy. The collected energy is then used to meet the household's hot water needs, significantly reducing reliance on conventional energy sources such as fossil fuels or grid electricity. By integrating this solar technology, the system aims to enhance energy efficiency and decrease the overall energy footprint of the home [2].

The primary objectives of this study are to evaluate the performance of the solar thermal system in terms of its efficiency and effectiveness in meeting energy demands. This includes assessing how well the system converts solar energy into usable heat and how much of the household's hot water needs are satisfied through solar power. Additionally, the study examines the environmental benefits of the system, such as reductions in greenhouse gas emissions and energy savings, providing a broader perspective on its impact [3].

By analyzing the system's operational data and performance metrics, this research seeks to demonstrate the viability and advantages of solar thermal technology in residential settings. The goal is to offer insights into how such systems can be optimized for better performance and to encourage their adoption in similar regions [4]. This analysis contributes to the ongoing effort to develop sustainable energy solutions and promote environmental stewardship using renewable energy technologies [5].

MATERIALS AND METHODS

The study involves a residential solar thermal system installed in Mangalia, Romania. This system is designed to provide domestic hot water (DHW) and is comprised of the following key components:

1. Solar Collectors: The system includes a solar collector field with a total area of 4 square meters. These collectors are responsible for capturing solar radiation and converting it into thermal energy. The collectors' performance is evaluated based on their total annual thermal output and efficiency [6].

2. Heat Storage and Distribution: The thermal energy collected by the solar collectors is stored in a thermal storage unit and distributed for domestic hot water use. The system's design ensures that the stored heat is effectively utilized to meet household hot water requirements.

3. Auxiliary Heating System: In cases where solar energy alone is insufficient to meet the hot water demand, an auxiliary heating system is integrated. This system provides additional heating through conventional energy sources, ensuring consistent hot water availability throughout the year [7].

4. Monitoring and Control Equipment: The system is equipped with sensors and monitoring devices to track various performance metrics, including solar energy input, energy output, and operational efficiency. This equipment allows for precise measurement and evaluation of the system's performance.

Data Collection

1. Energy Consumption Measurements: Total energy consumption encompasses the entire energy use of the system, including both the solar thermal energy generated and the energy inputs from auxiliary sources. Specific measurements are taken for the electricity used by the system's pumps and other operational needs. Additionally, data is collected on the total fuel and electricity consumed by the auxiliary heating system during periods when solar energy is insufficient [8].

2. Solar Energy Measurements: Irradiation data measures the amount of solar radiation incident on the collector area to evaluate the potential solar energy available. The solar thermal output records the total thermal energy produced by the solar collectors throughout the year, providing a basis for assessing the system's performance.

3. Performance Metrics: The performance ratio is calculated by dividing the useful thermal energy output by the auxiliary energy inputs, which indicates the system's overall efficiency. The solar fraction measures the percentage of the total energy demand met by solar thermal energy, assessing the contribution of solar energy to the household's energy needs [9].

4. Environmental Impact Assessment: CO_2 emissions reduction is calculated by determining the decrease in CO_2 emissions resulting from the use of solar thermal energy, thereby highlighting the environmental benefits of the system [10].

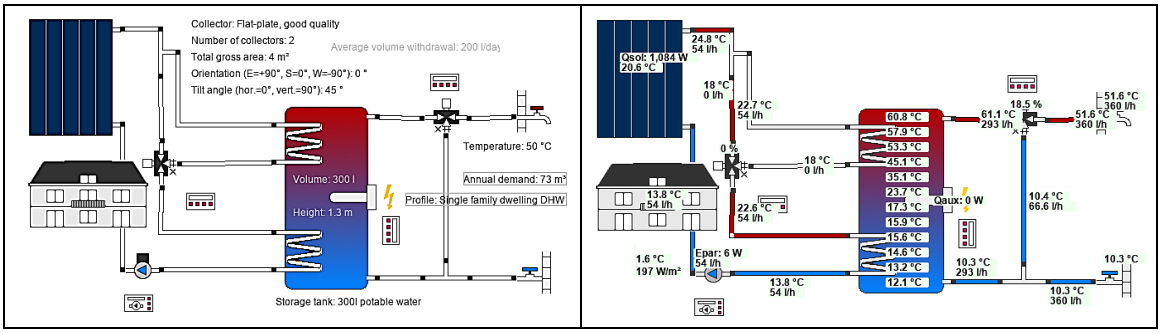


Figure 1. Overall System Diagram

The solar thermal collectors used are high-quality flat-plate models, with data sourced from SPF. The system includes 2 collectors arranged in a single array. The collectors cover a total gross area of 4 square meters, with both the aperture and absorber areas measuring 3.6 square meters. They are tilted at a 45-degree angle to optimize solar energy capture and oriented directly south to maximize exposure to sunlight [11].

Throughout the year, these collectors produced a total of 2661 kWh of thermal energy from an overall solar irradiation of 5712 kWh received on their surface. The efficiency of the collectors in converting solar energy into useful thermal energy is 46.6%. Additionally, after adjusting for the angle of incidence, the direct solar irradiation

received by the collectors was 3255 kWh, while the diffuse solar irradiation was 2151 kWh.

The following table 1 provides an overview of the system's location and the relevant meteorological data that influence its performance.

Table 1. Location of the system and Meteorological Data-Overview

Longitude	28.422°	Average outdoor temperature	12.3 °C
Latitude	43.894°	Global irradiation, annual sum	1403 kWh/m²
Elevation	46 m	Diffuse irradiation, annual sum	612 kWh/m²

The figure 2 illustrates the proportion of the total energy demand that is met by solar energy, providing insight into the solar fraction of the system.

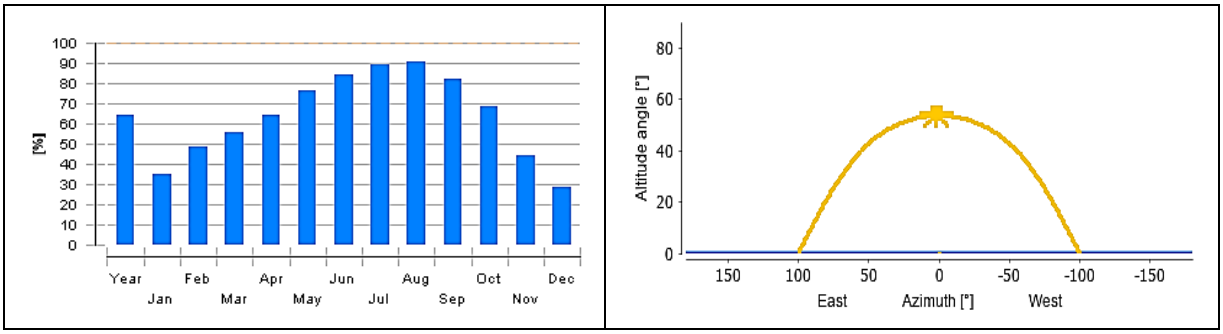


Figure 2. Solar fraction: fraction of solar energy to system [SFn]

RESULTS AND DISCUTIONS

1. Efficiency and Performance Analysis: The performance of the solar thermal system is analyzed by comparing the amount of thermal energy produced to the energy inputs required for operation. This analysis includes evaluating the performance ratio and solar fraction to determine how effectively the system utilizes solar energy.

2. Economic and Environmental Impact: The study assesses the economic benefits of the system, including energy savings and reductions in energy costs. Additionally, the environmental impact is evaluated by calculating the reduction in CO_2 emissions associated with the use of solar thermal energy [12].

3. Data Interpretation: Data from energy consumption, solar radiation, and system performance are analyzed to provide a comprehensive understanding of the system's efficiency and effectiveness. The findings are used to identify opportunities for optimization and to make recommendations for improving the system's performance.

Through these materials and methods, the study aims to provide a detailed evaluation of the solar thermal system's performance, efficiency, and impact, contributing valuable insights into the application of solar energy in residential settings [13].

System Overview (Annual Values)

Total fuel and/or electricity consumption of the system E_{tot}*:* The total amount of fuel and electricity consumed by the entire system over the year is 1570 kWh.

Total electricity consumption E_{cs}*:* The amount of electricity consumed by the system specifically for cooling and storage purposes is 1570 kWh per year.

Total energy consumption Q_{use}: The overall energy consumption of the system, including all sources, is 3173 kWh annually.

System performance: The performance ratio of the system, calculated as the ratio of useful energy output (including invested energy) to auxiliary and parasitic energy inputs, is 2.02. This indicates that for every unit of energy input, the system provides 2.02 units of useful energy.

Primary energy factor: The factor representing the efficiency of converting primary energy into usable energy is 0.89. A value less than 1 indicates the system is relatively efficient.

Comfort demand: The energy demand required to meet the comfort levels (such as heating or cooling) is fully covered by the system.

Overview of Solar Thermal Energy (Annual Values)

Collector area: The solar thermal collector field has a total area of 4 square meters.

Solar fraction total: The portion of the total energy demand that is met by solar energy is 64.3%. This means that 64.3% of the system's energy needs are provided by solar power.

Total annual field yield: The total amount of thermal energy generated by the solar collector field over the year is 2661 kWh.

Collector field yield relating to gross area: The annual energy yield per square meter of the collector's gross area is 665.2 kWh/m²/year, showing how much energy each square meter of the total area produces.

Collector field yield relating to aperture area: The energy yield per square meter of the collector's aperture area (the area that absorbs sunlight) is 739.2 kWh/m²/year, indicating the effectiveness of the solar collectors.

Maximum energy savings: The potential maximum savings in energy consumption due to the use of solar thermal energy is 2801 kWh per year.

Maximum reduction in CO_2 emissions: The estimated maximum reduction in CO_2 emissions resulting from the use of solar thermal energy is 1502 kilograms annually, reflecting the environmental benefits of the system.

The following figure 3 presents the daily maximum temperature recorded by the collector, highlighting the temperature variations experienced throughout the day.

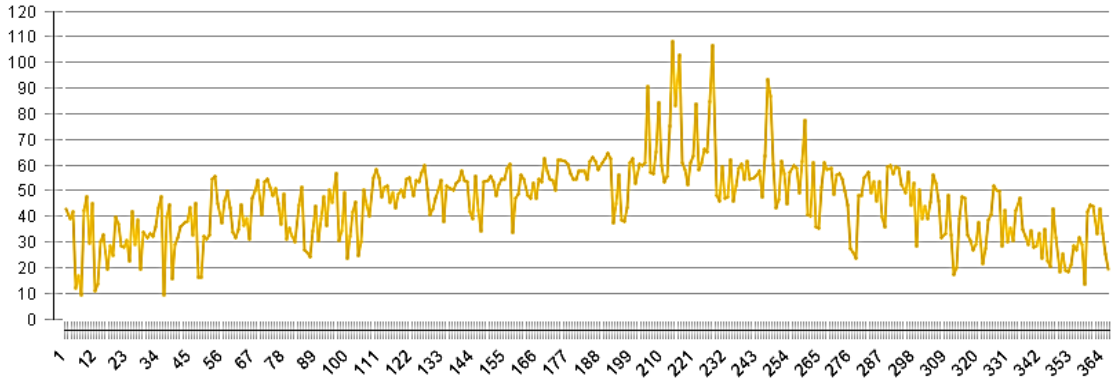


Figure 3. Daily maximum temperature [°C] of Collector

https://doi.org/10.5593/sgem2024v/6.2/s26.44

Figure 4 depicts the annual energy flow within the system, illustrating how energy is distributed and utilized over the year. It shows that the solar thermal system supplies 2661 kWh of thermal energy. To supplement solar energy, the heat generator consumes 1556 kWh of fuel and electricity. Additionally, the pumps use 14 kWh of energy to circulate fluids. The system meets a total of 3173 kWh for domestic hot water needs. There are heat losses amounting to 124 kWh each to the surroundings and to the indoor room, highlighting the inefficiencies in heat retention.

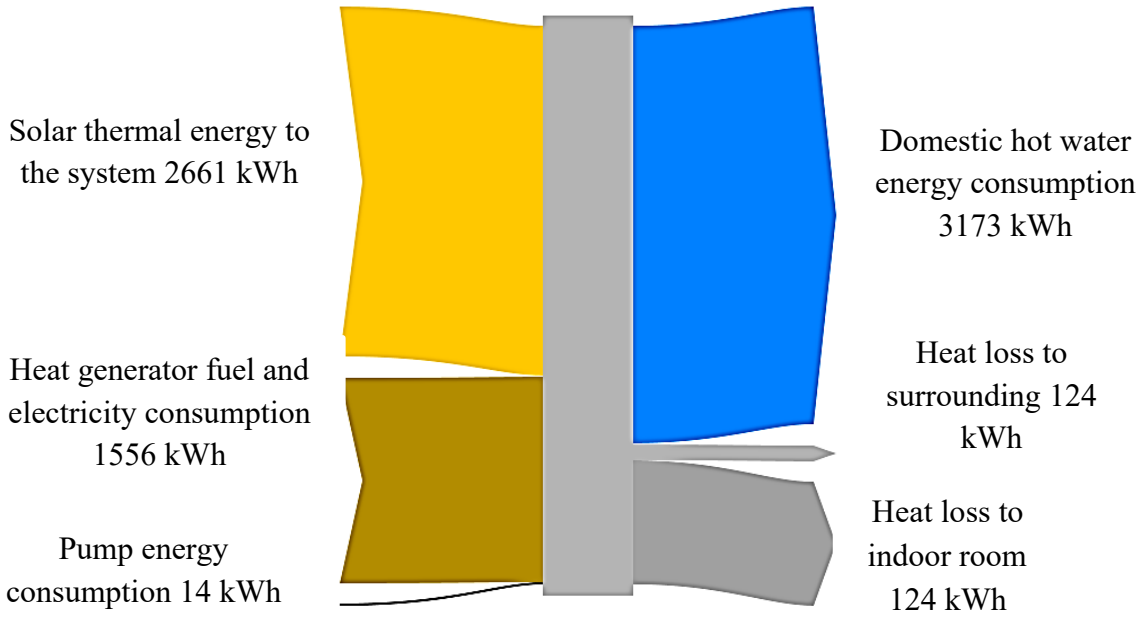


Figure 4. Energy flow diagram (annual balance)

The table 4 the solar thermal system consists of two flat-plate collectors arranged in one array, covering a gross area of 4 m², with an aperture and absorber area of 3.6 m² each. Installed at a 45-degree tilt facing directly south, the collectors are optimized for capturing sunlight throughout the year.

The system receives 5712 kWh of solar energy annually, out of which it converts 2661 kWh into usable thermal energy, achieving a collector efficiency of 46.6%. This efficiency reflects the system's capacity to convert both direct (3255 kWh) and diffuse (2151 kWh) solar irradiation into heat, even after adjusting for the angle of sunlight incidence.

Table 2. Monthly Performance Metrics of the Solar Thermal Energy System

	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Solar thermal energy to the system [Qsol]													
kWh	2661	118	154	200	228	280	300	324	321	274	231	139	90
Heat generator energy to the system (solar thermal energy not included) [Qaux]													
kWh	1479	222	167	163	129	88	57	41	35	61	109	177	229
Heat generator fuel and electricity consumption [Eaux]													
kWh	1556	234	176	172	136	93	60	43	37	64	115	186	241
Solar fraction: fraction of solar energy to system [SFn]													
%	64.3	34.7	48	55.1	63.9	76.1	84.1	88.7	90.1	81.8	67.9	44.1	28.3
Total fuel and/or electricity consumption of the system [Etot]													
kWh	1570	235	177	173	137	94	61	45	38	66	116	187	242
Irradiation onto collector area [Esol]													
kWh	5712	278	356	457	520	604	618	652	650	564	482	307	224
Electricity consumption of pumps [Epar]													
kWh	13.9	0.8	0.8	1.1	1.3	1.5	1.4	1.5	1.4	1.3	1.2	0.9	0.7
Total energy consumption [Quse]													
kWh	3173	286	265	294	279	276	255	252	246	238	252	254	275
Heat loss to indoor room (including heat generator losses) [Qint]													
kWh	935	57	56	67	72	86	92	102	104	92	83	66	57
Heat loss to surroundings (without collector losses) [Qext]													
kWh	124	7	9	11	12	13	12	12	13	12	11	8	6
Total electricity consumption [Ecs]													
kWh	1570	235	177	173	137	94	61	45	38	66	116	187	242

CONCLUSION

This study demonstrates the significant potential of solar thermal systems for enhancing energy efficiency and reducing environmental impact in residential applications, specifically in the context of Mangalia, Romania. The system analyzed in this case study was shown to be highly effective, meeting 64.3% of the household's total energy demand through solar energy alone, and achieving a commendable performance ratio of 2.02. These results highlight the system's ability to generate more than twice the amount of useful thermal energy relative to its auxiliary energy input.

The substantial reduction in CO_2 emissions, totalling 1502 kilograms annually, underscores the environmental benefits of adopting solar thermal technologies in regions with similar climatic conditions. Furthermore, the system's annual energy savings of 2801 kWh illustrates the economic advantages for homeowners, as reliance on conventional energy sources is significantly decreased.

The findings of this study suggest that with proper design and optimization, solar thermal systems can play a crucial role in sustainable energy strategies for residential buildings. It is recommended that further research focuses on optimizing collector efficiency and system configuration to enhance performance even further. Additionally, policies that support the adoption of solar thermal technologies could accelerate their integration into

residential energy solutions, thereby contributing to global efforts to reduce carbon footprints and promote energy independence.

The successful implementation and operation of the solar thermal system in Mangalia serve as a model for similar regions, demonstrating that solar energy is a viable and effective solution for meeting domestic hot water needs while also advancing environmental sustainability.

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SUSTAINABLE ARCHITECTURE OF THE PAST: THERMAL ENVIRONMENTS OF VERNACULAR HOUSE FLOORS, DIYARBAKIR, TURKIYE

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ABSTRACT

Increasing energy efficiency and reducing carbon emissions are among the objectives of sustainability. Sustainable design aims to conserve natural resources, reduce pollution, and obtain self-sufficiency by utilizing environmentally friendly materials. This study aims to research sustainable architecture from the perspective of vernacular houses. Designing buildings to suit the climate is an old tradition used in vernacular architecture. Historic buildings are characterized by low energy consumption, and sustainable societies must preserve the benefits of the past for future generations. This study examines the role of the thermal environment in earth-contact solutions in keeping the temperature sufficiently low in the summer in a hot and dry climate via ventilation, evaporative cooling, and earth cooling. Among the solutions utilized in sustainable architecture, ventilation plays a large role in response to arid climate conditions. The architectural design of the vernacular houses in Diyarbakir minimizes heat gain in the summer in different ways. Pools and water trickling down walls were used for evaporative cooling in low-humidity areas. The earth cooling technique is also very effective in dry climates. One of the most effective types of self-sufficient cooling in vernacular houses is ventilation on ground floors. Diyarbakir is located in southeastern Türkiye and has a hot arid climate populated with traditional houses. The study focused on the envelope design of the vernacular architecture and showed how it contributes to cooling via elevated ground floors. This study highlights the need for researchers to consider the energy efficiency benefits obtained in past solutions for use in future works in this area.

Keywords: Sustainability, Indoor Thermal Environment, Vernacular Houses,

INTRODUCTION

Sustainability means meeting the needs of the current generation without compromising future generations. A sustainable society preserves and enhances the benefits of life for future generations [1]. The differences in the vernacular architecture designs can be explained by their response to the climate. Sustainable designs are necessary, as we are using up resources without regard to the needs of our children [1]. In hot and dry climates, the thickness of the walls of historical assets is important. The exterior surfaces of houses are usually composed of a mixture of black basalt stone and white calcar stone to minimize the absorption of solar radiation. This historical asset design can minimize heat transfer in bottom components such as ground floors and walls. Owing to the low amount of rainfall, the roofs are flat and serve as sleeping areas on summer nights. Sustainability focuses on energy efficiency, pollution reduction, and waste reduction in the use of historical assets [2].

Historic buildings are low-energy consumers, so the lessons can be learned from them that can benefit future designs [3]. Vernacular houses are constructed to work harmoniously with the local weather conditions. Diyarbakir is located in southeastern Turkiye and has a hot arid climate populated with traditional houses that utilise thermal architectural solutions [4]. The aim of this study was to analyse how traditional Diyarbakir houses use the ground floor effect to respond to the hot and dry climate. In the region, examples of traditional and civil architecture are abundant, and the traditional, organic street texture has survived. Climatic data come first among the data that constitute the unique architecture in Diyarbakir, as the city is among the hottest cities in Türkiye. The climate in this city involves hot and dry summers and mild winters. Because of the hot and dry climate, measures were taken in Diyarbakir traditional houses to combat the heat; summer and winter sections were oriented according to the sun, basement floors were raised, and ventilation was provided with window openings (Figure 1). In the vernacular houses, water, shade devices, semi open areas, and floors raised from the ground with basements play active roles in the design. This paper aims to present the advantages found in vernacular houses inspired by the fact that eco-friendly and green design are important directions in contemporary architecture.

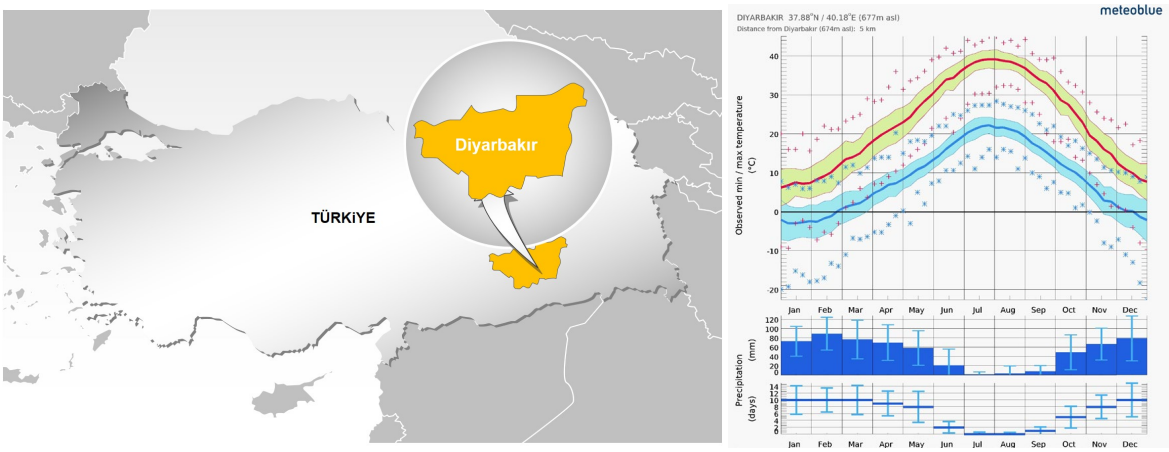


Figure 1. Diyarbakir on the map of Türkiye and its climatic data

MATERIALS AND METHODS

This study is based on an investigation of the vernacular houses in Diyarbakir in southeastern Türkiye and aims to determine how their basement floors impact the quality of their indoor thermal environmental. The methodology was developed to investigate the use of passive cooling systems to sustainably adapt to climate changes in the hottest city in Türkiye.

DESIGN STRATEGIES FOR THERMAL ENVIRONMENTS

Green and sustainable buildings are designed and maintained via environmentally responsible energy-efficient practices [5]. Sustainable buildings aim to provide productive environments for inhabitants. To achieve an appropriate design strategy in semiarid dry climates, in vernacular houses, the priorities are to build clustered houses to minimize the number of walls exposed to solar radiation. Vernacular houses use shading devices and exterior colors to mitigate heat from the sun [1]. The other most

effective parameters used in vernacular houses are i) evaporative cooling, which is effective in houses with courtyards that have self-shading; ii) ventilation; and iii) earth cooling (Figure 2). Pools and water trickling down walls are used for evaporative cooling, which are very effective techniques in low-humidity areas. The earth cooling technique is very effective in dry climates. The temperature of the soil near the surface is close to the temperature of the air, but the temperature decreases as the soil depth increases [1].



Figure 2. Elevated basement floor in the hot semi-arid region of Diyarbakir.

Placing buffer spaces such as underground floors that have low temperatures between living spaces can help achieve passive cooling. Passive cooling refers to a system that keeps the temperature sufficiently low in the summer, including the use of ventilation. The ground floor temperature is always below the maximum air temperature. Ashrae defines ventilation as the movement of air into or out of a space through openings such as doors and windows [6]. Using living spaces with floors elevated from the ground increases the wind velocity.

Climate, the condition of the thermal environment external to vernacular houses, is a very important parameter for low energy consumption and high-comfort design processes [7]. Owing to its location in southeastern Türkiye, Diyarbakir has a predominantly hot and dry climate influenced by Basra low pressure [4]. This area is characterized by extremely high temperatures and strong solar radiation. Humidity ranges from 40–60% annually, and rainfall rarely occurs in the summer. Rainfall occurs mainly in the winter. There is almost no rain in the summer and sunshine is plentiful throughout the year. Around buildings, the wind speed is less than 5 m/s at a height of 1.5 m.

ARCHITECTURAL APPROACH

The word vernacular stems from the Latin word varnaculus, which means domestic, native, and indigenous [5]. This architecture is based on localized needs and construction materials, reflects local traditions, and has good potential to provide thermal comfort. Vernacular architecture is recognized as a source of inspiration that could provide an effective solution for humans [8]. Vernacular dwellings are among the most important pieces of tangible cultural heritage [9].

The historical features of the city include castles, narrow streets, and climate-friendly traditional houses with courtyards. These buildings are constructed of stone and are well-built structures, most of which are local landmarks.

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Designing buildings to suit the microclimate is an old tradition used in vernacular architecture. The climate of the region is characterized as extremely hot and dry in the summers and moderately cold in the winters. The architectural design of the vernacular houses in Diyarbakir minimizes heat loss in the winter and minimizes heat gain in the summer in different ways. The semiarid and dry climate creates design priorities such as keeping heat out during the summer and using natural ventilation to cool buildings. To keep buildings cool, stone-built architecture was used in a clustered form in the old city, where basalt stone and sometimes limestone were intensely used to minimize the absorption of solar radiation (Figure 3). Deciduous plants, high courtyard walls, and blocks oriented along different axes shade the structure on summer days. Opening the building to the outdoors, such as through the use of courtyards, creates maximum contact with the outdoors.



Figure 3. Stone built architecture in dry and hot summers of Diyarbakir

The low humidity in summer facilitates the use of evaporative cooling. Vernacular houses are cooled through the use of courtyards, pools in the basement floors, and recesses. The water spray in the courtyard is held by the poriferous basalt stone, which dramatically reduces the temperature in dry climates.

Traditional architecture in dry climates often includes elevated structures, numerous openings, and thick insulated walls shaded by courtyards to combat hot and arid conditions. In hot regions, elevating a building's ground level is an effective building strategy to obtain ventilation. This allows air to flow beneath the structure, facilitating the removal of heat from the building's interior [8]. Underground spaces are effective at implementing night ventilation patterns. The elevated ground floors provide thermal indoor comfort areas due to increased wind speed above the ground. Under this elevated area is the basement floor, which is used as a cellar, that included opening to the courtyard to vent the air out. In vernacular architecture, ventilation openings near the tops of walls are common and are often called breathing envelopes (Figure 4). They were used to keep food and drinks cold without window joineries called lattice screens.

Lattice screens are used in vernacular architecture to cover openings. The lattice design contributes to creating consistent and controlled indoor airflow and provides control over the amount of light allowed to enter [8]. These basement floors are called serdaps (cold water) in middle east vernacular houses, and they are relatively large and sometimes have domed or vaulted ceilings or ceilings with wooden beams. Generally, the basement is elevated from the courtyard by at most 5–6 rows of stones nearly 150 cm in size.

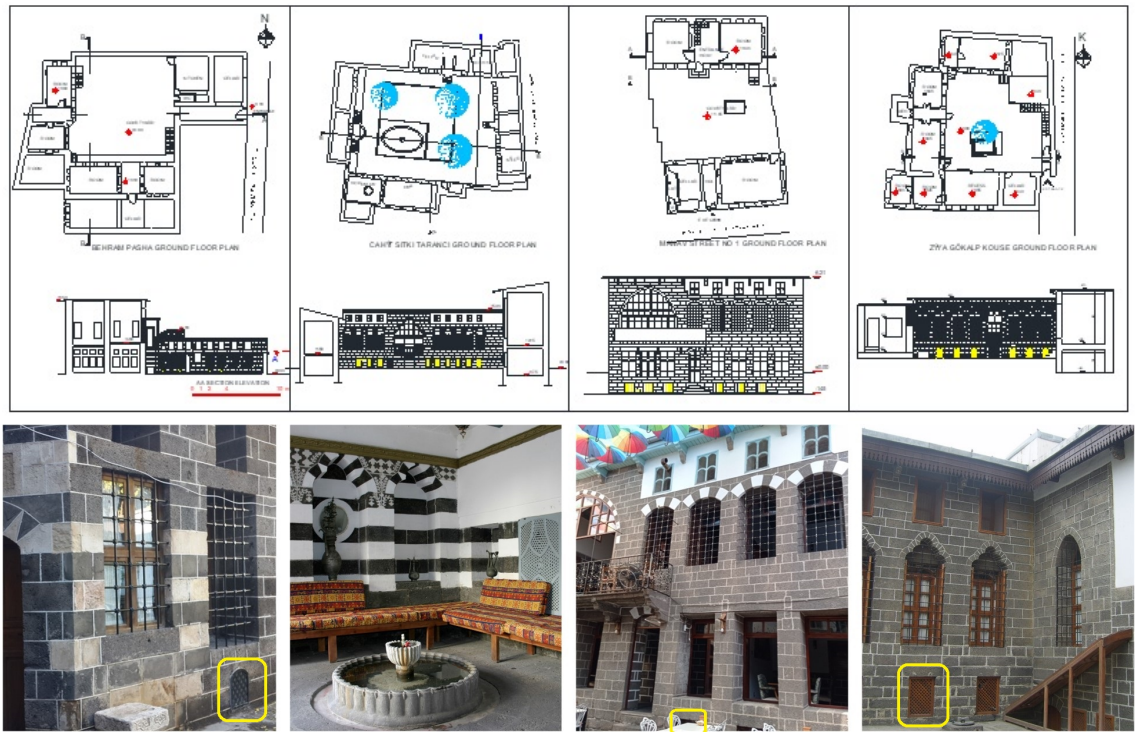


Figure 4. Plans and section elevations of vernacular houses in Diyarbakir

There are examples where there is no basement under the ground floor or where only a section is used, mostly in the southern blocks. The basement floor is assessed by three or four steps down and the assess point is located in the southern block looking to the north side of the courtyard to avoid exposure to the sun's rays or radiation. Ventilation is provided by a few small windows, and the space receives only dim light. Fountain pools are sometimes included inside and are used for relaxation on hot and dry days and provide evaporation and ventilation. The air rising from the basement floor provides coolness to the living space above.

CONCLUSION

In this paper, self-sufficient vernacular houses of Diyarbakir, Türkiye from the past within a hot and dry climate that used passive cooling were introduced. Ventilation is utilized in vernacular houses to regulate the indoor thermal environment also in the basement floors. The study findings point out the parameters of passive cooling in vernacular Diyarbakir houses emphasizing the indoor thermal environment of basement floors of ventilation. According to the results obtained in this study the vernacular architecture satisfies the indoor thermal environments.

Vents in the upper parts of the walls exhaust the hottest air from the structures enhancing the night ventilation and radiative cooling by lattice screens without glass. Evaporation is mostly used in hot and dry climates, in courtyards, in semi-sunken basement floors where water footprint was found as a pool inside that regulates the air to have indoor comfort environments.

Excluding the heat from outdoor environments by shading with courtyard, and improving the air flow with the vents in the upper parts help to enhance the comfort. Besides providing the air quality, the basement floors were used to keep the kitchen supplies fresh and the ground floor above cool by ventilation.

The aim of sustainable design is to conserve natural resources, reduce pollution and obtain self-sufficiency by utilizing environmentally friendly materials. The design strategies of ventilation rooted from the vernacular houses can be implemented in various new designs in hot and dry climates.

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SUSTAINABLE CITIES AND GREEN BUILDINGS VALUATION: THE APPLICATION OF DISCRETE CHOICE EXPERIMENTS IN PROPERTY APPRAISAL

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ABSTRACT

For the purpose of achieving a sustainable city, there has been a significant increase in the construction of green buildings in recent years. Since these are properties with characteristics that differ from those of ordinary buildings and, therefore, few transactions of comparable properties can be collected in the market area in which they are located, it is very difficult to apply the Revealed Preference Methods for green buildings appraisal.
These cases produce the same conditions common to industrial products, where it is necessary to estimate goods that have never been traded previously or have little historical data regarding potential consumers' expectations. Usually, the techniques to use here are based on surveys and hypothetical markets, which consider a range of possible scenarios to estimate the value of goods through the preferences stated by the market operators. It may be assumed that resorting to Stated Preference Techniques in special contexts it is preferable to use alternative methods that produce reliable opinions of value.
The paper proposes a property appraisal procedure that, by applying Discrete Choice Experiments, allows selecting the alternatives that are most likely to meet the market's preference and estimating: a) the incidence of the characteristics in market price formation both for consumers and producers; b) the market share of possible alternative properties, derived from different combinations of the characteristics and the best marketability alternative; c) the hypothetical market price associated with possible alternative options. After outlining the key elements of the issue, the main methodological and operational aspects of the proposed methodology are described.

Keywords: Sustainable cities, Green building valuation, Real estate appraisal, Stated Preference Techniques, Discrete Choice Experiments.

INTRODUCTION

A green building represents a building designed, constructed, and operated in a sustainable and efficient manner that is compatible with the requirements of ecology. The purpose of a green building is to produce no damage to the environment by significantly reducing, or eliminating, the negative impact of buildings on the environment and inhabitants, harmonizing with the context [1, 2]. Such structures contribute to the realization of a sustainable city and therefore, there has been a significant increase in the construction of green buildings in recent years. This situation significantly affects the real estate market and the appraisal practice. Since usually green building can be considered special properties in terms of intrinsic characteristics, which are not commonly traded in the real estate market, it is very difficult to collect

historical market data for the appraisal; counting on very few or no comparable properties, the valuation is rather uncertain [3]. In such situations, using historical data for appraisal would result in forced valuations based on false objectivity, which would produce worse effects that valuations based on hypothetical conditions. Thus, in this case the application of Revealed Preference Methods of appraisal [4] would be impossible or otherwise lead to an unreliable estimate. This situation is very similar to that of newly created industrial products, never placed on the market, for which it is necessary to estimate the most likely selling price. Usually, for such estimates we rely on hypothetical markets surveys and detect the expressed preferences of market participants. This is why an extensive literature developed on the survey methods aimed at valuating the individual willingness to pay in lack of observations in the actual market; these approaches to the valuation are called Stated Preference Techniques (SPTs)[5]. As opposed to statistical-mathematical models, the SPTs provide answers from the operators who are really interested in a given operation; moreover, the estimates based on stated data have a dynamic character, in that they take into consideration the way in which human actions and choices evolve.

Even though there may be some critical issues and difficulties connected with the application of the SPTs to real estate appraisal [6], it may be assumed that resorting to such methods in special contexts, where the real market does not allow to resort to consolidated appraisal techniques, may allow for valuation that is more consistent with the possibility of foreseeing future market conditions. In situations where the market is not explicit and cannot provide reliable historical data for real estate appraisal, it is usually allowed to refer to substitute methods that allow to come to reliable valuations and opinions.

To this aims, the paper proposes a property appraisal procedure, stated preferences based, that allows selecting the alternatives that are most likely to meet the market's preference and estimating: a) the incidence of the characteristics in market price formation both for consumers and producers; b) the market share of possible alternative properties, derived from different combinations of the characteristics and the best marketability alternative; c) the hypothetical market price associated with possible alternative options. After outlining the key-elements of the methodology, the operational aspects of the proposed procedure are described and discussed.

MATERIALS AND METHODS

Within the family of SPTs a distinction may be made between direct method, or Contingent Valuation Method (CVM), and indirect methods, or Choice Modelling Techniques (CMTs) [7]. The CVM allows to estimate the overall value of a good, directly asking people their willingness to pay (WTP) or to accept (WTA); conversely, it does not provide any indications regarding the value of the different characteristics the good is made up of. The CMTs allow to look into the attributes of the good and the effects of the variations in such attributes. This has particular importance when the decision is based on level variations in the attributes. They provide a fuller description of the implicit comparison among characteristics that individuals use in the market. They differ from the CVM in that the CMTs ask the respondent a choice among alternatives, a rank or a score instead of values. CMTs, then, may avert some of the problems connected with CVM, in that people may find it easier to attribute a score or a rank position without the need of thinking in monetary terms. Nevertheless, CMTs are

used to derive economic values through a monetary indicator (a price, charge or tax) that is a characteristic of each option.

CMTs can provide information on which attributes significantly determine the value people attribute to goods, the implicit importance of such attributes among the consumers, the value connected to the variation of an attribute and the total value of a good. CMTs may be divided into four main categories, which reflect the differences in the theoretical assumptions, in the analysis methods and in the experimental design procedures. In terms of practical application, the academic literature of the recent past mostly converges on the Discrete Choice Experiment - DCE since it better describes individual behaviours in the actual market [8]. In DCE the respondents are presented a basic scenario corresponding to the status quo and different alternative options in which attributes are specified with different levels. The attributes that must be included may be determined by means of focus groups. The selected attributes should include a monetary value that, as for the CVM, represents the payment vehicle. The number of attributes should be limited in order to ensure its suitability to be managed by the respondents. The respondents is asked to state their choice between a set of alternative options or none of them. To state 'none' means that the benefits with regard to the status quo are not guaranteed. Every respondent can be asked to repeat the choice experiment several times, with different characteristic levels based on an experimental design. As regards the theoretical foundation, DCE provides information regarding the chosen alternative only. Hence, the data are considered weakly ordered [9].

In order to analyse DCE data and obtain the mean and median WTP, it is necessary to refer to an econometric model that, in turn, may be used to describe the discreet choice behaviour. This refers to the Random Utility Theory [10] deriving from the economic assumption that a rational individual, given a series of options, will chose the one providing the highest expected utility. Moreover, it is theorised that the utility of an individual depends on the attribute level provided in every option and the price required to supply it. The level of utility associated with an option will vary among the different attributes [11].

The first step in determining the econometric model is to specify an indirect utility function generating a relation among all attribute levels, prices and individual characteristics with the levels of enjoyed utility. The analysis of DCE data aims at determining the parameters of this function based on the analysis of how individuals have made the choice among the options. The indirect utility function used by the analyst is merely an approximation of the actual indirect individual utility function. Hence the utility estimated through this model will not be 100% of the real utility. In order to complete the econometric model, it is necessary to add a random element to the indirect utility function of the analyst. This error component keeps into account the difference between the true utility of an option and what is estimated with the model. The inclusion of such random element explains the title “Random Utility Model”. Since there is a part of error in the utility function, the analysis becomes a probabilistic choice. The likelihood of a given respondent to prefer an option over another may be expressed as the likelihood that the utility associated to that option, according to the model, exceeds the one associated to all the other options [12].

RESULTS

The proposed appraisal procedure is designed to be used in such situation when it is not possible to resort to the actual market data due to a lack of the transactions and information, such as in the case of green building valuation. Based on the preference stated by a statistically significant sample of potential consumers and producers, by applying DCE, the procedure allows selecting the alternatives of a green building project that are most likely to meet the market's preference and estimating:

- the incidence of the characteristics in market price formation both for consumers and producers;
- the market share of possible alternative properties, derived from different combinations of the characteristics and the best marketability alternative;
- the hypothetical market price associated with possible alternative options.

Resorting to the DCE is mostly due to the purpose of valuation: the goal is to select the most preferable alternative for consumers and producers; as such, it is enough to select, among a set of given alternatives, the preferable one instead of the rank of the alternatives or the score attributed to each one of them. Moreover, the DCE is simpler for the respondent and best simulates the market behaviour of the subjects (among different, replaceable alternatives, one must choose the most preferable, based on its ability to meet the minimum requirements that drive the choice).

The main phases the procedure focus on:

1. Defining the appraisal question: what is the subject of valuation, what methods are to be used and how are the surveys going to be administered.
2. Sample selecting: identifying, first, the sample population and the sample frame and, subsequently, selecting two samples, one including potential consumers and the other potential producers who would operate in the future market area.
3. Designing the DCE through: a) the Qualitative study, targeted at defining the potential alternative options, the list of attributes and the respective levels; one of the attributes is the market price, expressed as maximum WTP for consumers and minimum WTA for producers; b) the Experimental design, consisting of detecting the number of alternatives resulting from the combination of different levels of attributes and selecting the alternatives (choice set) to be submitted in the questionnaire.
4. Carrying out the DCE: the respondents are informed about the purposes of the questionnaire and the structure of the task they are asked to perform; the alternatives are described, together with the attributes and the relevant attribute levels, then the questionnaire is submitted.
5. Analysis of the collected data through the DCE, structured as follows:
   - Choice of the indirect utility model to analyse the data;
   - Detection of the incidence of the characteristics on the price according to the consumers;
   - Identification of the consumers' market share;

- Detection of the best marketability alternative according to the consumers (C*);
- Detection of the incidence of the characteristics on the producers' price;
- Identification of the producers' market share;
- Identification of the best marketability alternative according to the producers (P*).

The individuals selected to compose the sample are contacted to arrange for a place and a date to carry out the interview. In the meantime, the comprehensive documentation explaining the theme of the interview and providing a detailed description of the valuation subject is sent to the respondents.

The respondents are informed about the purpose of the questionnaire and the structure of the task they are asked to complete. The first part of the questionnaire measures the involvement of the respondent in problems inherent to the good to be valued, the familiarity and use of the asset. The central part includes a description of the scenario and the measurement of personal preferences. The alternatives, attributes and attributes' levels are described. The choice matrix is presented, followed by a question aimed at detecting the preference. The last part of the questionnaire focuses on the social and economic characteristics of the respondent in order to verify the suitability of the sample to be representative and to look into any possible correlations between the choices and the social and economic variables (income, education, etc.).

In order to analyse DCE data, it is necessary to resort to an econometric model suitable to describe the behaviour of the discrete choice. In formulating a Random Utility Model, two important issued must be agreed upon:

- the functional form of the indirect utility function: the option is usually extremely simple indirect utility function specifications; for most applications the utility of an option is modelled as a simple linear combination of prices and attributes.
- the random element probability distribution: in this case, a likely distribution is Gumbel distribution or extreme value distribution, which is similar to normal distribution with the exception of having mathematical elements that are easier to process; the probability of a given choice to be made may also be expressed in terms of logistical distribution [13].

The first data analysis phase concerns with the econometric analysis estimate of the incidence the characteristics have on price (expressed as WTP/WTA of the attributes or implicit characteristic prices) through: a) valuing how respondents' utility would change if the attributes were changed from the current level (status quo) to another level (the levels set by the options being analysed); b) the expression of this utility variation in monetary terms.

The second information derived from the analysis of collected data is the market share (the potential market share for each possible alternative) for the consumers and producers and, from these, the selection of the best marketability alternative for the consumers and the producers (respectively referred to as C* and P*). The partial utilities, previously estimated through indirect utility models, are used as an input to estimate the product's market share, which allows to foresee the amount likely to be potentially sold or realised for each alternative.

As regards the utility theory, the price associated with the best marketability option will indicate the minimum WTP for the consumers and the maximum WTA for the producers.

DISCUSSION

As opposed to the applications performed in international real estate operations where reference is made solely to potential demand preferences, the described procedure takes into account also the producers' expectations, for the purposes of considering the conditions that generally occur in the actual real estate market. Because of such aspects, the proposed procedure represents a fundamental tool in green building appraisal and production process [14]; indeed:

- it allows to theorise different scenarios and forecast the values connected with the different project hypotheses, thus allowing the estimate of possible revenues through reliable hypothetical market values for long-term operations, which in the current valuation practice, in turn, are derived exclusively by projecting the conditions detected in past markets to the future;
- by detecting consumers' and producers' preferences, it allows to acquire instrumental information to the design, especially in the devising and proposal phases, becoming a fundamental tool to stimulate and elicit the detection of alternative and creative solutions;
- it consents to size real estate interventions by detecting both the amount of real properties to put into the market and the characteristics of such assets as a function of the appreciation of the different attributes in the market;
- it allows to produce market estimates in contexts where the green buildings have never been exchanged.

Moreover, deriving the implicit prices of real estate characteristics may become a fundamental element of reference for the adjustment procedures that apply to transaction prices, market leases and capitalisation tests in traditional real estate appraisal methods (e.g., Sales Comparison Approach and Income Capitalization Approach).

CONCLUSION

In conditions where the market is not explicit and cannot provide reliable historical data for real estate appraisal, the reference to surrogate methods that allow to come to reliable valuations is generally admitted. In order to operate in conditions where it is not possible to rely on real market data, the research suggests to refer, also for the valuation of exclusive real estate properties, to the DCE, valuation approaches of an asset that are based on hypothetical markets through procedures allowing to detect the preferences stated by the market subjects.

As opposed to mathematical-statistical models, DCE provides a response from operators who are truly interested in a given operation; the estimates based on stated data have a dynamic nature, in that they keep account of the way human actions and choices evolve; moreover, the operators are also asked to state their preference for hypothetical alternatives that include different characteristics and different levels to the same

characteristics, thus allowing to foresee the variation of a single element to the value of a good.
The proposed valuation procedure represents a starting point for further research developments for the purposes of expanding the experimental approach and improve those aspects that to date have limited the application of the DCE in the real estate industry.

The possible developments have mainly to do with those aspects connecting with the way the surveys are carried out and the level of information of the respondents. The reliability level of the results obtained through interviews depends for the most part on the ability of the interview to simulate similar conditions to those that occur in the market, i.e. the ability to provide similar information to those generally available in an actual market, which sometimes may derive from different sources and be influenced by the role of the intermediaries. It would be advisable, then, to test how complete initial information, may affect the WTP and WTA stated during the survey.

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THE ISSUE OF BLUE-GREEN INFRASTRUCTURE IN CITIES IN THE PAST AND TODAY

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ABSTRACT

Cities in the Czech Republic and nearby Central Europe usually have a very long tradition. This post shows changes in the long run in the scope and function of green and water areas in selected municipalities. Most of the cities in the region were founded in the Middle Ages, from the 10th to the 13th century. At this time, the issue of water and green cities was directed purely at the utility function of drinking water and food supply. The exception at this time was only the gardens of noble and tin buildings. Over time, the towns focused more on public greenery and water infrastructure for ornamental and recreational purposes. This phenomenon was most significant during the time of the Austria-Hungarian monarchy, from the mid-19th century to the First World War. The post-war period was marked by the return to utilitarian values of public space, and the blue-green infrastructure was again pushed to the edge of interest. Municipalities are resorted to the restoration or creation of new areas of green and water elements in connection with climate change.

Keywords: blue-green infrastructure, central Europe, public space

INTRODUCTION

Blue-green infrastructure is an approach to urban planning and landscaping that combines water features (blue infrastructure) and natural or vegetated features (green infrastructure) to improve environmental quality and increase urban resilience to climate change [1]. This approach combines ecosystem services such as stormwater management, flood protection, temperature reduction and air quality improvement to create healthier and more sustainable urban environments [2].

Blue infrastructure: Includes watercourses, ponds, canals, retention basins, wetlands and stormwater retention and use systems. The aim is to reduce the risk of flooding, promote natural processes of water infiltration into the soil and improve water quality [3].

Green infrastructure: Includes vegetated features such as parks, trees, gardens, green roofs and facades. These elements improve air quality, provide shade and cool cities in the summer months [4]. Vegetation also helps to bind rainwater and promotes biodiversity [5].

Modern examples include green roof systems, retention basins for rainwater harvesting, and revitalization of urban streams. In European cities such as Copenhagen and Hamburg, blue-green infrastructure has become a key part of urban planning. In the

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Czech Republic, similar elements are being introduced in cities such as Prague and Brno, where, for example, green roofs and parks linked to water systems are being built [6].

MATERIALS AND METHODS

This paper focuses on the original medieval towns across Central Europe. Cities such as Vienna, Prague, Budapest and Krakow were chosen as examples for the different stages of the development of blue-green infrastructure.

These cities were then examined in terms of the evolution of blue-green infrastructure throughout their development. The main data sources are individual documents from the history of the selected cities and freely available map and image sources. From these sources, the characteristics of the selected periods were subsequently compiled. The medieval period and the early post-establishment period of the towns were chosen as the three key milestones, followed by the period of the Austro-Hungarian monarchy in the second half of the 19th century and the post-World War II period after 1945 as the third period.

RESULTS AND DISCUSSION

Blue-Green Infrastructure in Medieval Towns of Central Europe

In the medieval period, towns across Central Europe, including regions like modern-day Germany, Austria, the Czech Republic, and Poland, were often shaped by natural elements, particularly rivers and forests. The term "blue-green infrastructure" (BGI) refers to the combination of water management systems (blue) and green spaces (green) that work together to sustain urban environments. While medieval towns did not consciously design these systems with ecological goals in mind, their layouts were inherently sustainable, shaped by necessity, geography, and local resources. This review explores how medieval towns in Central Europe integrated blue and green infrastructure into their urban landscapes, setting the stage for practices that have relevance to today's environmental challenges.

Water was central to the establishment and development of medieval towns in Central Europe. Rivers such as the Vltava in Prague, the Elbe in Dresden, and the Danube in Regensburg were crucial lifelines. These waterways not only provided transportation and trade routes but also ensured access to fresh water for drinking, agriculture, and industry. One of the most striking examples of blue infrastructure in Central Europe was the network of urban watercourses that evolved for flood control, water supply, and sanitation. In Prague, for instance, a sophisticated system of artificial channels, ponds, and mills developed along the Vltava River. These channels directed water for industrial purposes such as dyeing, milling, and brewing, while also acting as defensive features by diverting water around city walls.

In many Central European towns, water management also took the form of reservoirs and moats. For example, Nuremberg had an intricate system of wells and canals that supplied water to the growing population. Additionally, moats—originally designed for defense—often doubled as reservoirs that could store rainwater and help mitigate the risk of flooding. Medieval engineers, inspired by Roman aqueducts and local hydrological knowledge, developed systems to ensure a steady water supply for urban

centers. These systems, while rudimentary by modern standards, laid the foundation for sustainable urban water management in Central Europe.

Green infrastructure in medieval Central Europe was deeply rooted in the region's agrarian economy. Towns were surrounded by forests, meadows, and agricultural lands that not only provided food but also served as an integral part of daily urban life. These green spaces were essential for the survival of medieval populations, and their role extended beyond mere sustenance. Many medieval towns, like Kraków, Brno, and Bamberg, were planned with agricultural spaces both within and outside the city walls. Urban gardens, orchards, and vineyards were common, often located in courtyards, near monasteries, or on city outskirts. In the case of monastic settlements, gardens were carefully cultivated to provide medicinal herbs, vegetables, and fruits, forming a vital part of local green infrastructure. Forests surrounding Central European towns also served important functions. They provided wood for construction, fuel, and raw materials for industries like charcoal production and metalworking. The importance of these forests was often formalized in town charters, which regulated the use of common lands to ensure sustainability. Some towns even had early forms of forest management, aiming to balance the use of resources with the need for long-term preservation.

The layout of many Central European medieval towns reflects an organic integration of blue-green infrastructure. The towns were not strictly planned in the way modern cities are, but their designs evolved to incorporate natural elements for practical reasons. Rivers often acted as natural barriers and trade routes, while green spaces within the towns served both agricultural and recreational purposes. A notable example is the town of Český Krumlov in the Czech Republic, which developed around a bend in the Vltava River. Its urban design is a perfect blend of blue and green infrastructure, with the river playing a central role in both economic activities and defense, and the surrounding hills and forests providing natural fortifications and resources. In other towns, such as Freiburg im Breisgau (Germany), natural watercourses called "Bächle" ran through the streets, providing water for residents and livestock, as well as cooling the air in the hot summer months. This simple, yet effective system represents an early form of climate adaptation using natural water flows, and these Bächle remain a beloved feature of Freiburg to this day.

Medieval Central European towns, though not designed with modern sustainability principles, nonetheless displayed a form of environmental resilience through their integration of water and green spaces. The close relationship between townspeople and their natural environment fostered a culture of resource conservation, particularly in the use of forests and rivers. Town charters often included strict rules about the use of water and woodlands to prevent overexploitation. For example, in many German towns, the right to use water from nearby rivers for mills or industries was tightly regulated. These regulations helped maintain water quality and flow, which were vital for both drinking water and agriculture. Additionally, common lands and forests were often communally managed, ensuring that resources were shared and preserved for future generations.

Despite these early forms of sustainable practices, medieval Central European towns also faced significant challenges. Over time, growing populations put pressure on both water systems and green spaces. Pollution of water sources became a serious problem, as towns discharged waste directly into rivers, leading to contamination and outbreaks of diseases like cholera and dysentery. Flooding was another persistent issue. While

some towns, like Regensburg and Passau (Germany), were able to mitigate flood risks with embankments and floodplains, many others were not as fortunate. Periodic flooding, particularly in riverine towns, often caused significant damage, highlighting the limitations of medieval flood control methods.

Changes in Blue-Green Infrastructure in Central European Cities During the Austro-Hungarian Empire

The Austro-Hungarian Empire (1867–1918) was a period of profound urban transformation in Central Europe, marked by modernization and the influence of Enlightenment ideals. The blue-green infrastructure (BGI) that had served medieval towns was increasingly adapted to the demands of industrialization, urban growth, and changing social priorities. A key shift during this period was the rise of public green spaces, which reflected new urban planning philosophies and the empire's emphasis on public health, social welfare, and civic pride. In medieval times, green spaces in Central European towns were primarily utilitarian—gardens for food, forests for resources, and open commons for livestock. However, by the late 19th century, these cities underwent a reimagining of green infrastructure, as industrialization led to crowded and polluted urban environments. The expansion of cities during the Austro-Hungarian Empire required a rethinking of urban layouts, particularly regarding public health and quality of life. The rise of urban planning as a formal discipline saw green spaces shift from purely functional to aesthetically and socially significant. Inspired by the broader European park movement, Central European cities began incorporating public parks, tree-lined boulevards, and formal gardens into their designs. These spaces were meant to serve as "lungs" for the city, providing fresh air, recreation, and a visual counterbalance to dense, industrial urban centers.

Vienna, the imperial capital, exemplified this transformation. One of the most iconic urban projects of the Austro-Hungarian era was the creation of the Ringstraße (Ring Road) in the 1860s. After the demolition of Vienna's medieval fortifications, the city repurposed this space for a grand boulevard lined with monumental buildings, parks, and gardens. The Ringstraße's layout was revolutionary for its time, blending public buildings, cultural institutions, and green spaces into a coherent urban framework. Prominent parks like the Stadtpark, opened in 1862, became the first public park in Vienna, offering spaces for leisure and recreation to all citizens, regardless of class. Its ornamental design, combined with natural landscapes, reflected the city's growing appreciation for urban greenery as a place for both aesthetic enjoyment and public well-being. The park also symbolized a shift toward democratization of green spaces, as these areas were no longer limited to the aristocracy but were open to the broader public. The Danube River, which runs through Vienna, was also subject to significant modification during the empire's reign. The Danube regulation project (1870–1875) aimed to control flooding while creating new land for urban expansion. The development of the Donauinsel (Danube Island) as a flood control measure later became one of Vienna's largest recreational areas, combining blue and green infrastructure.

Budapest, the co-capital of the Austro-Hungarian Empire, also saw significant changes to its blue-green infrastructure. One of the most notable developments was the regulation of the Danube River, which flows through the heart of the city, separating Buda from Pest. The riverbanks were transformed into promenades, with green spaces and pathways designed to provide both flood protection and scenic public spaces. The

creation of Margaret Island (Margit-sziget), a large green island in the middle of the Danube, was a hallmark of Budapest's approach to combining water management with public greenery. Once a private royal estate, the island was opened to the public in the late 19th century and transformed into a major park with walking paths, gardens, and recreational facilities. Its development highlighted the empire's focus on creating accessible green spaces for all residents. Budapest's other major public park, Városliget (City Park), was established in the mid-19th century as one of the first public parks in Europe. Designed to provide recreational space for the burgeoning population, it became home to various cultural institutions like museums and a zoo, blending greenery with civic pride and education.

Prague, another major city within the Austro-Hungarian Empire, also witnessed significant developments in its blue-green infrastructure during this period. The Vltava River, central to the city's identity since medieval times, continued to play a key role, but new public parks and green spaces were introduced to serve the expanding population. The creation of parks such as Letná Park and Stromovka reflected the changing attitudes toward urban green spaces. Letná Park, originally the site of royal vineyards, was transformed into a public park in the late 19th century, offering sweeping views of the city and a space for leisure activities. Stromovka, a former royal game reserve, was opened to the public, becoming one of Prague's largest green spaces. These parks embodied the Austro-Hungarian ideals of providing open, recreational areas for city dwellers, particularly as Prague industrialized and became more densely populated.

In Kraków, a city with deep historical roots, the Austro-Hungarian period brought significant urban changes. The demolition of Kraków's old city walls allowed for the creation of the Planty Park, a green belt surrounding the historic center. This transformation of fortifications into a public park was emblematic of the period's approach to integrating green spaces into urban life. The Planty provided a peaceful promenade for residents while preserving the historical layout of the medieval town. Kraków's Austro-Hungarian planners also focused on the preservation of natural landscapes, such as the Wolski Forest, which was maintained as a green space outside the city. This attention to both urban and suburban greenery underscored the importance of balancing urban expansion with the conservation of natural environments, a key feature of blue-green infrastructure during this era.

The expansion of public green spaces during the Austro-Hungarian Empire was not merely a practical or aesthetic decision; it was a reflection of changing social values. Urban parks and tree-lined promenades became places for citizens to gather, exercise, and enjoy nature. This was part of a broader movement toward improving public health and well-being, as industrial cities were increasingly seen as unhealthy, polluted environments. Green spaces became a marker of modernity and progress, with cities across Central Europe using parks to project an image of sophistication and civic pride. These areas also played an important role in fostering a sense of community, as they provided spaces where people from different social classes could come together in a shared public realm. Parks and gardens were designed not only for leisure but also for cultural events, such as concerts and festivals, which were often held in these new green spaces.

Changes in Blue-Green Infrastructure in Central Europe During the Post-War Period

The post-World War II period brought drastic changes to the blue-green infrastructure in Central Europe, as the region was divided by the Iron Curtain into socialist Eastern Bloc countries and capitalist Western Europe. Urban planning, particularly in relation to green spaces and water management, was heavily influenced by the contrasting political ideologies and economic systems of the Cold War era. In socialist countries like Poland, East Germany, and Czechoslovakia, rapid industrialization and urbanization transformed the use of green and blue spaces, often prioritizing industrial expansion over ecological concerns. Meanwhile, in capitalist countries such as West Germany and Austria, the focus remained on preserving public green spaces and modernizing infrastructure in line with environmental conservation principles. This text explores the divergent paths of blue-green infrastructure development in these two contexts, highlighting the utilitarian approach to spaces in socialist cities and the continued importance of public greenery in capitalist areas.

After World War II, the Eastern Bloc nations, under the influence of the Soviet Union, embarked on large-scale industrialization projects to rebuild their economies and strengthen socialist ideals. The focus was on rapid urbanization, heavy industry, and mass housing, which fundamentally altered the landscape and the use of natural resources. Blue-green infrastructure in these countries was primarily shaped by the need to support industrial production and accommodate the influx of workers into urban centers. In socialist cities, such as Warsaw, East Berlin, and Prague, green spaces were often repurposed or diminished to make way for housing blocks, factories, and industrial facilities. The emphasis on creating new housing districts to accommodate workers led to the construction of massive prefabricated housing estates, known as paneláks or Plattenbau, which dominated the urban landscape. While some green spaces were retained, they were typically small, utilitarian courtyards or strips of greenery between apartment blocks. These areas were more about providing functional open space for workers than about fostering ecological balance or recreational enjoyment.

Water management also changed significantly in socialist countries during this period. The rivers and water bodies that had historically been vital to urban life were increasingly seen as resources for industrial use. Rivers like the Vistula in Poland, the Elbe in East Germany, and the Danube in Hungary were harnessed for hydropower, irrigation, and waste disposal from factories. Environmental degradation became a widespread issue as heavy industry polluted rivers and lakes with untreated waste and chemicals, leading to severe ecological damage. For example, in the industrialized regions of Czechoslovakia and East Germany, rivers such as the Oder and the Elbe became severely contaminated. The industrial focus left little room for concerns about sustainability or the preservation of blue infrastructure as a natural resource. In many cases, rivers and waterways became secondary to industrial priorities, leading to long-term ecological damage. Despite the overwhelming emphasis on industrialization, socialist governments recognized the need for green spaces, at least to some extent, as a part of their broader goal of promoting the collective welfare of the working class. Public parks and spaces were often created in new socialist housing developments, but these spaces were designed more for utilitarian purposes rather than aesthetic or recreational enjoyment. For example, in Warsaw's large post-war housing districts, small public parks were incorporated into urban plans, but they were generally minimalist, providing basic amenities such as playgrounds and sports fields rather than

expansive green landscapes. These green areas served a dual purpose: offering residents a limited space for physical activity and promoting the socialist ideal of collective use of land. However, they lacked the lushness, diversity, and historical character of pre-war parks or those in Western Europe. Large-scale projects like the Letná Park in Prague were repurposed to fit socialist ideology. For instance, Letná Park housed massive monuments like the statue of Joseph Stalin (later dismantled), transforming what had once been a recreational green space into a symbol of socialist triumph.

In contrast, in capitalist countries like West Germany and Austria, blue-green infrastructure during the post-war period focused on reconstruction and restoration of public spaces, with an emphasis on enhancing the quality of life for urban populations. The preservation and expansion of public parks, gardens, and water systems reflected the broader Western values of environmental stewardship, public health, and recreation. In cities like Vienna and Munich, which had been heavily damaged during the war, the post-war era saw major efforts to rebuild and expand public green spaces as symbols of recovery and civic pride. Vienna, which had been divided during the Cold War, remained a center for cultural preservation and modernization, with the city investing heavily in maintaining its public parks, including the iconic Stadtpark and the Prater. These parks were restored and expanded as public recreation spaces, emphasizing access to nature, beauty, and leisure in the urban environment. In West Germany, public green spaces were seen as critical components of urban regeneration. Cities like Munich, Frankfurt, and Hamburg invested in revitalizing their historical parks and creating new ones to cater to the needs of growing urban populations. The post-war reconstruction era was marked by an effort to incorporate green spaces into modern urban planning, ensuring that these areas provided social, cultural, and ecological value to the population. In capitalist countries, there was also a strong emphasis on restoring and preserving blue infrastructure, especially as environmental consciousness grew in the 1960s and 1970s. Rivers that had been damaged or neglected during the war were cleaned up, and new flood control systems were introduced that often incorporated natural landscapes. For example, in West Germany, the Rhine River, one of the most important waterways in Europe, became the focus of extensive environmental cleanup efforts, especially in regions like the Ruhr Valley, where industrial pollution had taken a heavy toll. Vienna also embarked on major water management projects, such as regulating the Danube to prevent flooding while creating the Donauinsel (Danube Island), a massive recreational space that combined flood protection with green public areas. This was emblematic of how capitalist cities were able to combine technical infrastructure with public amenity, reflecting a more integrated approach to blue-green infrastructure. Unlike the utilitarian green spaces of socialist cities, the parks and public spaces in capitalist Central Europe were designed to enhance the quality of life and reflect civic pride. Urban parks became central to the post-war identity of these cities, with green spaces functioning as symbols of cultural preservation, freedom, and modernity.

Today situation in cities

Today, blue-green infrastructure (BGI) in Central Europe reflects a growing emphasis on sustainability, resilience, and urban livability. Cities in both former socialist and capitalist regions are actively reversing the industrial-era damage by focusing on ecological restoration, green space expansion, and integrated water management. In former Eastern Bloc cities, there is a renewed push to rehabilitate polluted rivers and

expand public parks, with a focus on creating healthier, more resilient urban environments. Western cities, meanwhile, continue to prioritize preserving and modernizing their green spaces while incorporating climate adaptation strategies. Urban planners now embrace BGI as essential for addressing climate change, managing flood risks, and enhancing biodiversity. Projects like Vienna's Donauinsel and Budapest's revitalized Margaret Island highlight this trend, combining ecological goals with public recreation. Overall, the current approach prioritizes reconnecting cities with their natural landscapes, blending green and blue spaces to improve urban quality of life and sustainability.

CONCLUSION

The legacy of blue-green infrastructure in medieval Central European towns still influences urban planning today. Many cities, such as Prague and Kraków, retain the original layout of their medieval cores, with rivers and green spaces still integral to their identity. Modern urban planners increasingly look to the past for lessons on how to integrate natural systems into city planning in a way that enhances resilience and sustainability. Medieval towns in Central Europe provide a fascinating example of early blue-green infrastructure. Though not designed with modern environmental awareness, the integration of water systems and green spaces helped these towns manage their resources and build resilient urban environments. While there were limitations and environmental challenges, many of these practices still offer valuable lessons for modern urban planning. Today, the blending of historical preservation with ecological principles can help cities develop sustainable infrastructures that balance development with environmental care.

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THE MANAGEMENT OF SYSTEMATIC CADASTRE WORKS IN ROMANIA FOR SUSTAINABLE DEVELOPMENT

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ABSTRACT

Experiences made until present time have demonstrated that shaping sustainable cities is hardly possible without a comprehensive understanding of the changing natural environment and without monitoring the impact of human activities by integrating both virtual representations of real estate and natural environments. It is without doubt that cadastre has an important role in shaping sustainable cities. Cadastral systems should be developed for different jurisdictions in order to solve important land management problems, promote social and economic development and protect environment.

At this moment, in Romania it is desired the introduction of the systematic cadastre and, with it, the completion of specialized cadastres.

The cadastral works are carried out in order to provide realistic and complete data related to real estate to the interested persons, at all times, and is finalizing with the registration into the Land book of the respective real estate.

The management of systematic cadastre works is important to establish a comprehensive and reliable land registry system. This facilitates the effective use of land resources, ensures secure property rights, and supports sustainable land management practices.

By providing accurate land data, it helps in urban planning, environmental protection, and infrastructure development, while also promoting economic growth and social stability. Additionally, it contributes to reducing land-related disputes and improving governance, which are essential for achieving long-term sustainability goals.

Keywords: Systematic Cadastre, Sustainable Development, Real Estate, Land Book

INTRODUCTION

Experiences made until present time have demonstrated that shaping sustainable cities is hardly possible without a comprehensive understanding of the changing natural environment and without monitoring the impact of human activities by integrating both virtual representations of real estate and natural environments. It is without doubt that cadastre has an important role in shaping sustainable cities [1], [2].

The management of systematic cadastre works is important to establish a comprehensive and reliable land registry system. This facilitates the effective use of land resources, ensures secure property rights, and supports sustainable land management practices.

For each jurisdictions should be developed Cadastral systems in order to solve important land management problems, promote social and economic development and protect environment.

RESEARCH

Starting with the "Declaration Concerning the Cadastre" in 1994 and the Bogor, Indonesia Declaration in 1996 up to the "First EU Cadastre Congress" in Spain (2002), the unanimous trend and the conclusions of all these meetings, all emphasize the importance and the necessity of a modern cadastre within every country's sustainable development and environmental protection activities [4].

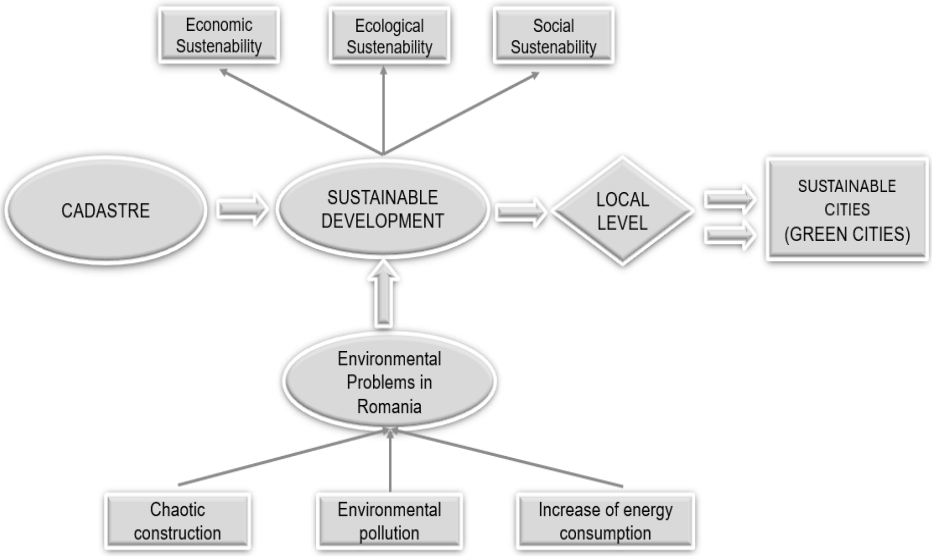


Fig. 1 The role of Cadastre in Sustainable development in Romania

By providing accurate informations about land and real estates, it helps in urban planning, environmental protection, and infrastructure development, while also promoting economic growth and social stability. Additionally, it contributes to reducing land-related disputes and improving governance, which are essential for achieving long-term sustainability goals.

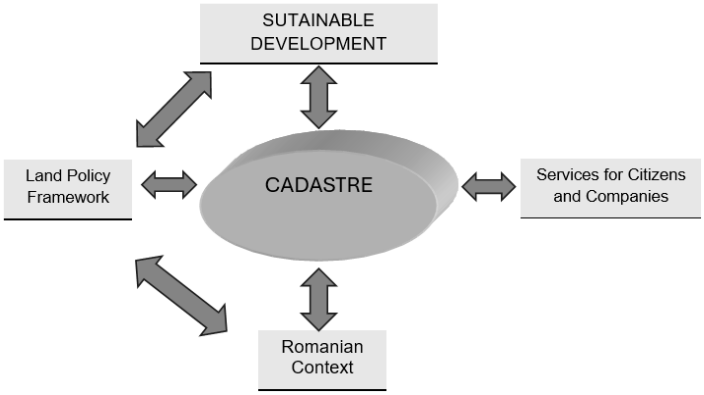


Fig. 2 Land management vision

RESULT AND DISCUSSION

At this moment, in Romania it is desired the introduction of the systematic cadastre and, with it, the completion of specialized cadastres.

The realization and the management of systematic cadastre is the exclusive attribute of the Romanian State, through the National Agency for Cadastre and Real Estate Advertising (ANCPI) within the National Cadastre and Land Book Program (PNCCF).



In 2015, in Romania, in the field of cadastre, the situation was catastrophic: from the total number of real estates, over 40 million, only 7.4 million were registered into the Land Book.

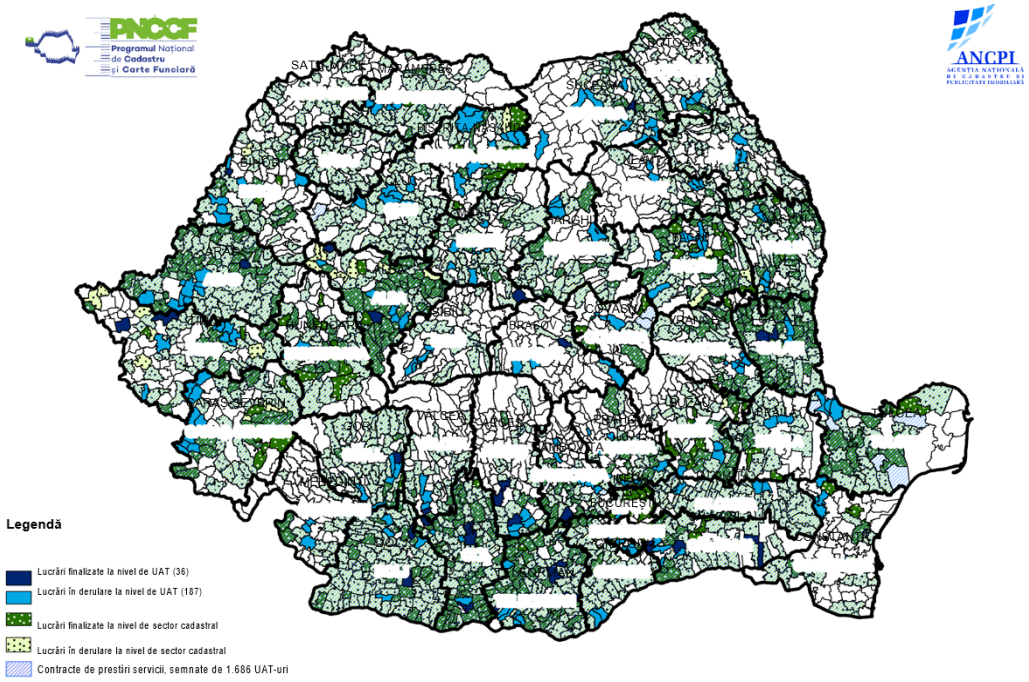
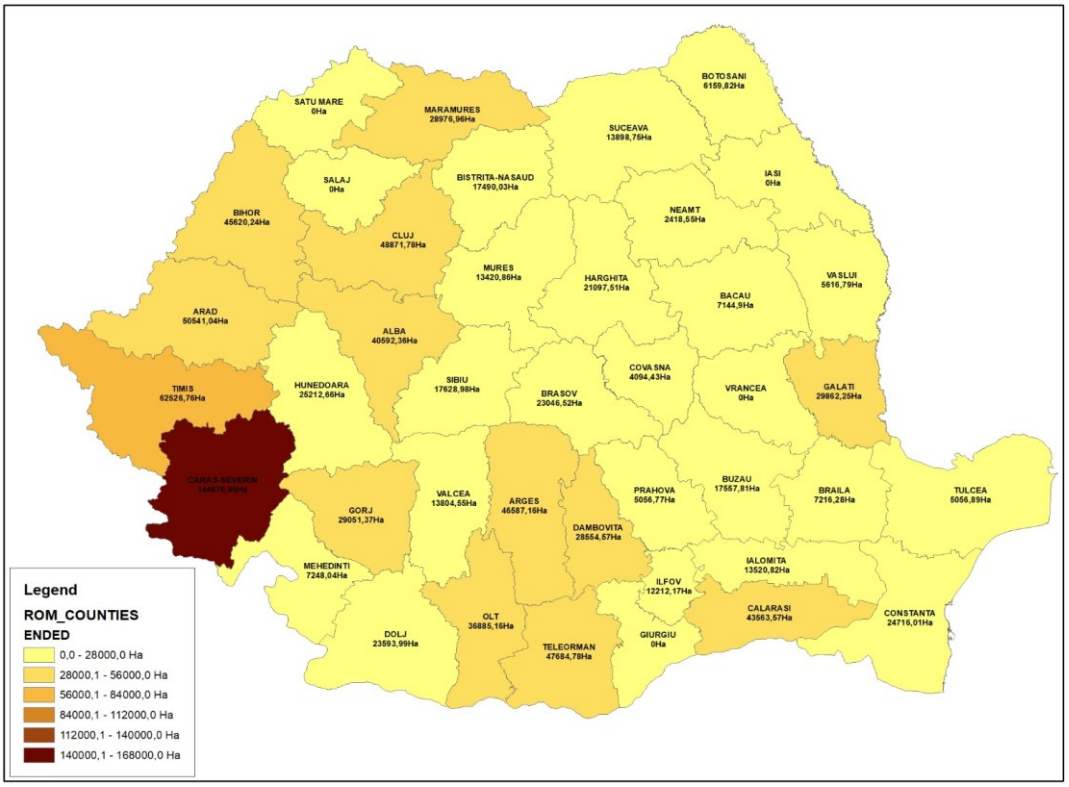


Fig. 3 The stage of the National Cadastre and Land book program at the end of 2016, after [7]

Out of a total of 3,181 Administrative Territorial Units (ATU) in Romania, at 30-th of September 2024, the systematic cadastre works have been completed in 273 ATU (of which 229 ATU were fully completed and 44 ATU partially completed), as well as in cadastral sectors, covering a total area of 6,014,080.27 hectares.



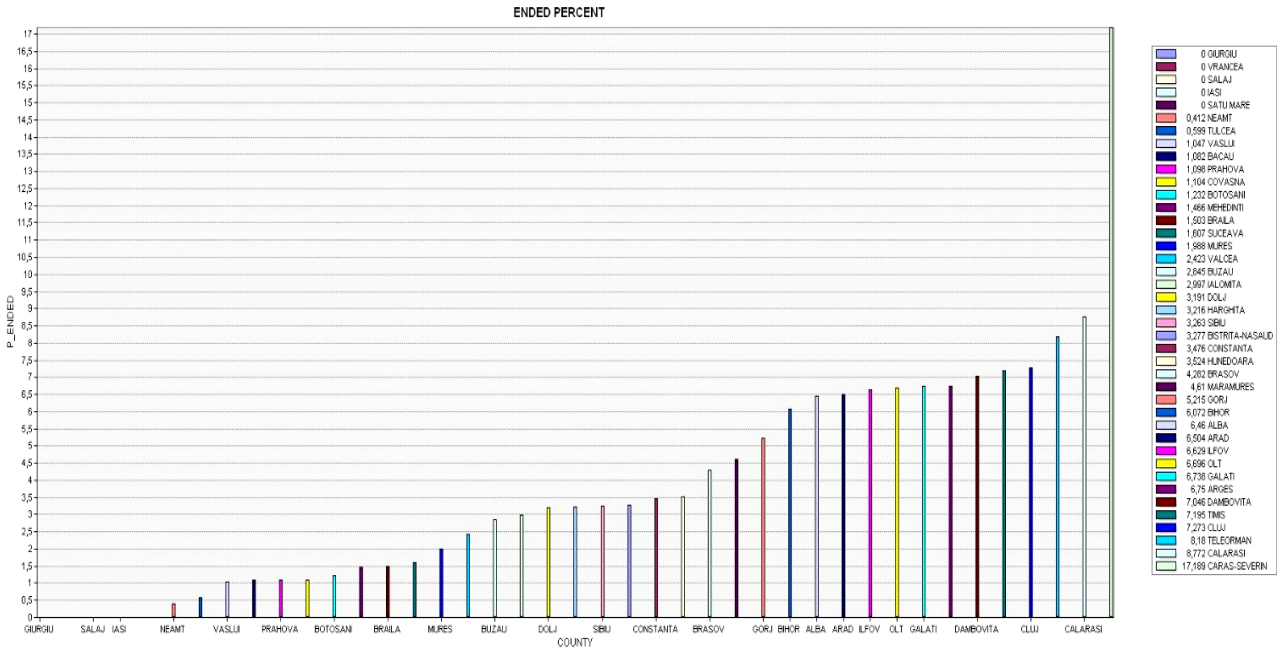


Fig. 4 Systematic cadastre works completed at county level at 30.09.2024

At 30-th of September 2024, systematic cadastre works are in progress in 2,026 ATU, with an estimated area of 6,595,982.19 hectares.

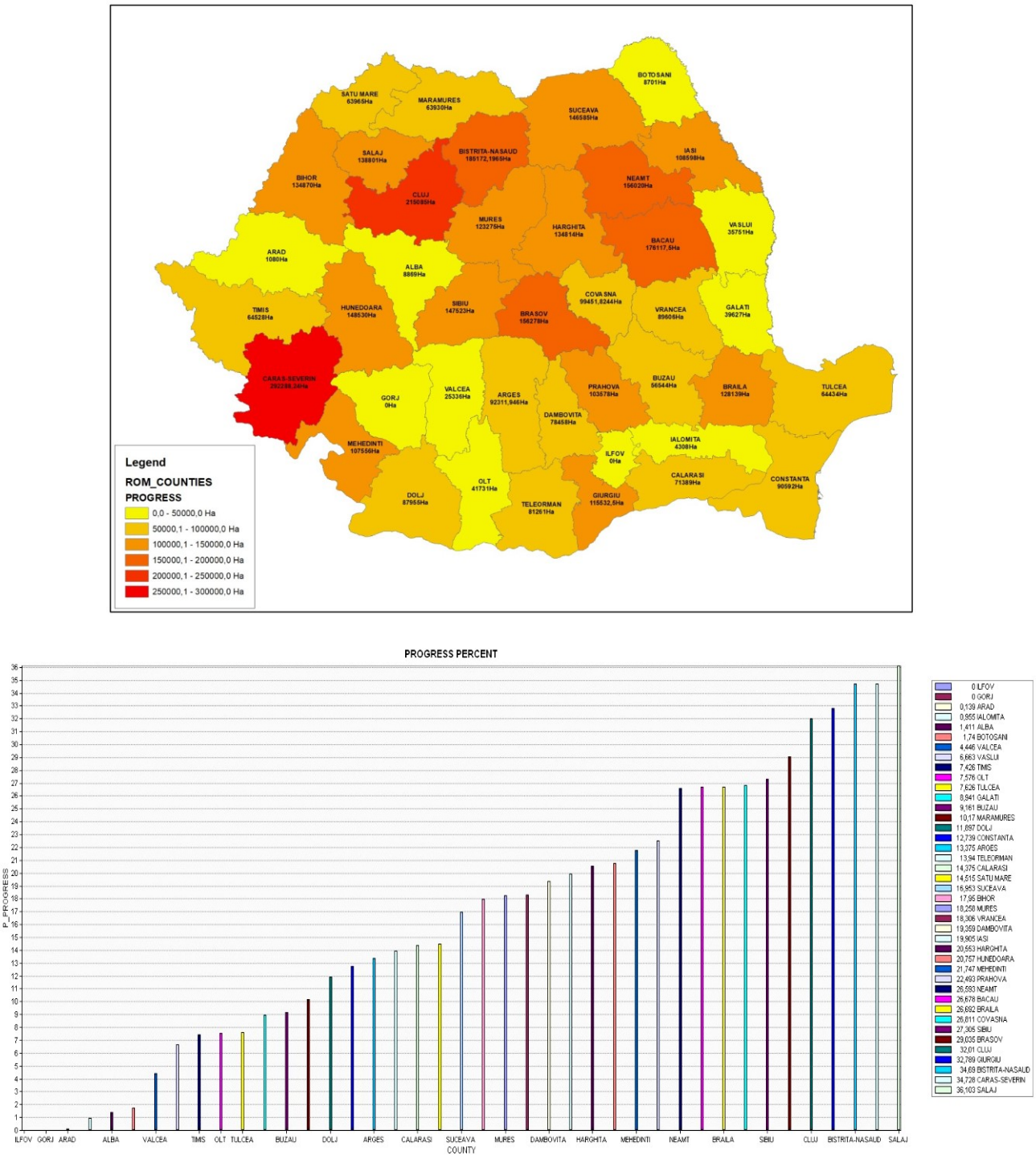
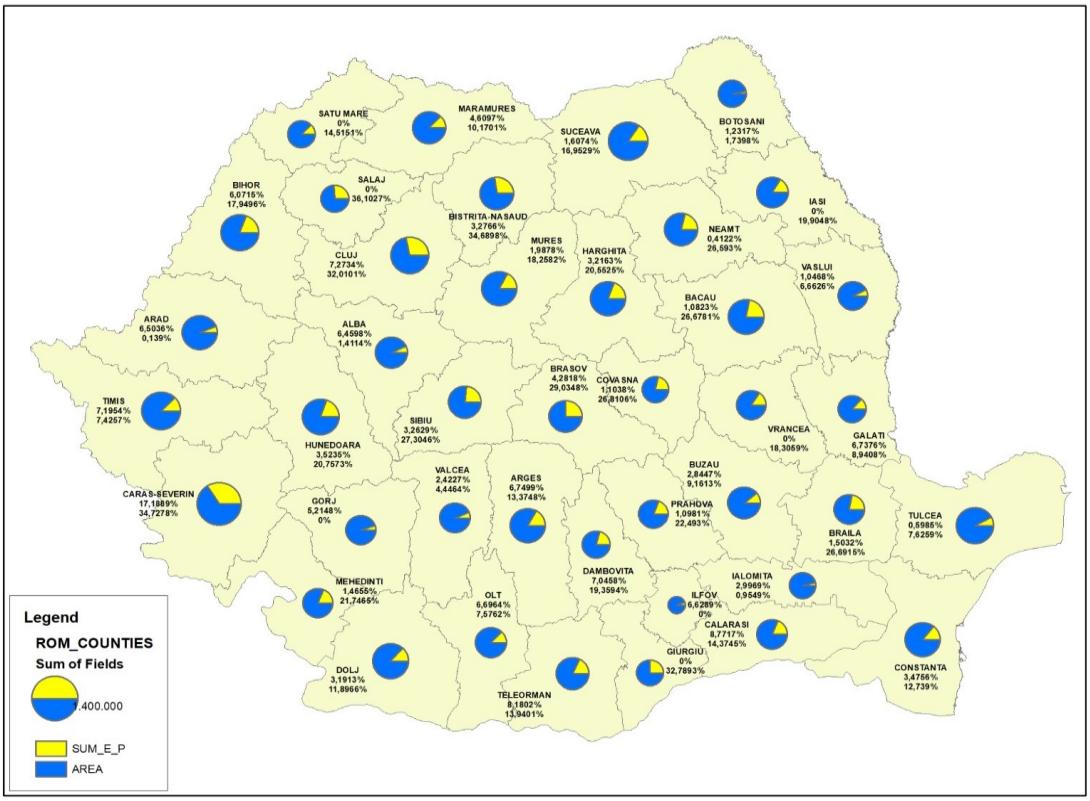


Fig. 5 Systematic cadastre works in progres at county level at 30.09.2024

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The ratio between the area registered in to the Land Book and the total area of the county in %

CADASTRE AND SUSTAINABLE DEVELOPMENT

The basic premise of sustainable development is to do things differently. This process begins with a change of values of each individual and continues by transferring these into all other walks of life. However, balance must be maintained in this process between using, saving and restoring all our resources and understanding that the future generations will largely depend on our present activities. Due to the changes in our lifestyle, we become and will become increasingly dependent on the system that provides us with information, especially spatial information, in order to create the conditions for making correct decisions. It is a complex process of change that will go on for years and affect government authorities, organizations, private sectors, industry and all individuals. The cadastre is one of the major stakeholders of the spatial data so it is necessary to involve it in this process [5].

The cadastre can provide the institutional, administrative, and technical basis to ensure the national consistency of content to meet user needs in the context of sustainable development. It provides a comprehensive record of land ownership, boundaries, usage, and value, which are critical for effective land management and resource allocation.

Here are the main ways in which cadastre supports sustainable development:

- supports land tenure security and property rights;
- enables efficient land use planning;

- facilitates land and property taxation;
- promotes agricultural productivity and food security;
- supports environmental protection and conservation;
- facilitates disaster risk management and climate resilience;
- improves access to information and transparency;
- fosters social equity and reduces poverty.

CONCLUSION

The management of systematic cadastre works is important to establish a comprehensive and reliable land registry system.

A well-maintained and accessible cadastre contributes to sustainable development by promoting land security, improving land management, and supporting environmental, social, and economic goals. With accurate, up-to-date cadastral data, countries can achieve a balanced approach to growth, reducing environmental degradation while advancing economic and social equity.

For each jurisdictions should be developed Cadastral systems in order to solve important land management problems, promote social and economic development and protect environment.

This facilitates the effective use of land resources, ensures secure property rights, and supports sustainable land management practices.

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USE OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES TO ACHIEVE THE GOALS OF ENVIRONMENTALLY SUSTAINABLE DEVELOPMENT

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ABSTRACT

This article aims to develop a concept for utilizing artificial intelligence (AI) technologies to achieve environmentally sustainable development goals, leveraging a suite of technologies for environmental protection and natural resource management in the digital age. The study employs risk-oriented approaches, system analysis, and modeling to explore the application of AI in attaining environmental sustainability objectives. Research Results: 1.The study presents an analysis of AI technologies applied to achieving environmentally sustainable development goals. 2. It formulates a concept for the role of AI in ensuring these goals are met. The research highlights AI's emerging role as a crucial tool in achieving sustainable development goals (SDGs). It underscores the importance of exploring innovative AI approaches to sustainable development. AI's capability to integrate vast datasets, such as satellite imagery, sensor data, and social media inputs, is proven to facilitate the creation of complex models and forecasts. Deep learning techniques are applied to analyze intricate environmental data, including climate change modeling, pollution detection, and biodiversity monitoring. Additionally, AI is used to develop intelligent ecosystem management systems that can adapt in real-time to environmental changes. The study addresses key challenges and opportunities for advancing the use of AI technologies in achieving environmentally sustainable development goals. AI holds significant potential to accelerate progress toward the SDGs, although it necessitates careful consideration of associated risks and challenges.

Keywords: artificial intelligence (AI), environmentally sustainable development, concept of AI technologies, digital technologies, sustainable development goals.

INTRODUCTION

The relevance of studying AI arises from several factors that highlight its significant impact on various aspects of human life and activity. Scientists have increasingly focused on AI due to its rapid development, which presents new opportunities and challenges and necessitates the formulation of strategies for developing superintelligence. It is crucial to investigate how these technologies can be integrated into society, the economy, and diverse industries.

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AI has the potential to dramatically reshape the labor market, foster economic growth, and boost productivity. However, it also poses the risk of job displacement and shifts in professional requirements. Research in this field aims to maximize the economic benefits of AI while minimizing its adverse effects.

AI is transforming everyday life, influencing social interactions, access to information, and educational opportunities. Studies help to understand how these changes can enhance quality of life and promote social equality. The application of AI in critical systems, such as healthcare, transportation, energy, and defense, necessitates a high level of safety and reliability. Research focuses on preventing errors and safeguarding against cyber threats.

AI can address significant environmental issues, including climate change, natural resource management, and pollution reduction. Research in this domain seeks effective methods to leverage AI for sustainable development. Leading in AI development and implementation also presents new international challenges and opportunities.

The relevance of AI research for sustainable development lies in its potential to ensure a more efficient, equitable, and sustainable future, enhancing the positive impact of technology on society and the environment while minimizing risks and negative consequences. This involves assessing positions and developing strategies to maintain competitiveness.

In Ukraine, the primary challenges of utilizing AI technologies in priority economic sectors include the imperfect identification of AI technologies aligned with sectoral needs and requirements, the lack of criteria for assessing the outcomes and threats of AI technology applications, and the absence of a conceptual framework for state policy on AI development in key economic sectors. These issues are addressed in the concept of the State Targeted Scientific and Technical Programme for the use of AI technologies in priority economic sectors up to 2026.

MATERIALS AND METHODS

We have used a risk-based approach to the analysis of artificial intelligence (AI), which involves assessing and managing potential risks that may arise during the implementation and use of AI. This approach allows minimising negative consequences and ensuring the safety and efficiency of technologies. The main components of the risk-based approach include: 1) Identification of possible risks associated with the use of AI. These may include technical risks (system failures, cybersecurity), ethical risks (bias, privacy), and social risks (impact on jobs, social inequality). 2) Analysis of the probability of occurrence and potential impact of the identified risks. This includes both quantitative and qualitative assessment methods to understand the extent of possible impacts. 3) Development of measures to minimise, control or eliminate risks. This may include technical measures (data protection, algorithm validation), policies and procedures (ethical standards, regulation), as well as educational and training programmes for AI users. 4) Continuous monitoring of AI systems to identify new risks and check the effectiveness of the implemented measures. Adapt risk management strategies in response to changes in the technological environment or new threats. 5) Ensure transparency in AI-related decision-making processes and accountability of responsible persons. This helps to increase trust in technology and reduce fears about its use. 6) Consideration of ethical principles and compliance with applicable laws when

developing and implementing AI. This includes ensuring data privacy, preventing discrimination, and maintaining fairness. A risk-oriented approach allows for safer, more responsible and efficient use of AI, which is key to its sustainable development and acceptance by society. The method of using forecasting and analysis of various development scenarios can be used to assess the potential impact of AI on society and the economy. This helps to develop adaptation and change management strategies. Involvement of the public and stakeholders in the process of AI development and implementation. This allows for the consideration of different points of view and ensures wider support and acceptance of technologies. The application of these methods allows for a more comprehensive and balanced approach to the analysis and management of AI, which is taking place in the context of the evolution of society from 4G to 5G and contributes to its sustainable and safe development [2].

RESULTS

1. Research on AI technologies for achieving environmentally sustainable development goals.

AI technologies can create smart cities and low-carbon cities to achieve a circular economy and more efficient use of resources. AI smart grids can combine electricity demand with green energy (e.g. solar or wind power) to improve energy efficiency. Large-scale data analysis using AI technology can help formulate a coordinated action plan. For example, AI technology can deepen scientists' understanding of climate change and facilitate further modelling of climate change. AI technology can also be used to increase the speed of satellite image recognition, timely predict the spread of desertification, and assist in land prevention and control, which can assist in green governance, so AI technology is of great importance for achieving the goals of environmentally sustainable development, which requires the digital transformation of education based on artificial intelligence [3].

Table 1. Artificial intelligence (AI) technologies for achieving the goals of environmentally sustainable development

The challenge	The way to solve the problem with the help of AI technologies
AI energy efficiency	AI systems can require significant computing power and, consequently, energy, which is why we are developing more energy-efficient algorithms and hardware solutions that reduce energy consumption and carbon footprint.
Integrating AI with renewable energy sources	The use of AI to optimise the production and consumption of energy from renewable sources such as solar and wind power, which helps to increase the efficiency and reliability of energy systems, contributing to sustainable development.
Natural resource management	AI can be used to monitor and manage natural resources, such as water, forests, and agricultural land, to conserve resources and prevent their depletion.
Climate change modelling	AI helps to create accurate models of climate change, which allows us to predict its effects and develop effective adaptation and mitigation strategies. This includes predicting extreme weather events and their impact on ecosystems and human communities.

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Waste reduction and recycling	AI can be used to improve waste sorting and recycling processes, which helps to reduce the amount of waste that ends up in landfills and increase the amount of recyclable materials.
Waste management	AI can improve waste sorting and recycling processes, which will reduce the amount of waste that ends up in landfills and increase the amount of recyclable materials.
Development of "smart" cities	AI can contribute to the creation of smart cities with efficient infrastructure, reduced greenhouse gas emissions, and improved management of urban resources. This includes optimising transport, building management, and lighting, which contributes to sustainable urban development
Health and welfare	AI can help in monitoring public health, predicting epidemics, and developing personalised healthcare solutions, which contributes to a better quality of life and community resilience.
Preserving biodiversity	AI is used to monitor species populations and their habitats, helping to develop strategies to preserve biodiversity and prevent species extinction
Education and professional development	AI can help to create adaptive educational programmes that take into account the individual needs of students and promote the development of skills necessary for sustainable development. This includes training for new professions that are emerging as a result of AI.
Data monitoring and analysis	AI can analyse large amounts of environmental data (e.g. satellite imagery, air and water quality data) to identify trends, anomalies and predict environmental problems.
Development of environmental technologies	AI can promote innovation in the creation of new environmentally friendly technologies, such as alternative energy sources, biodegradable materials, etc.
Urban and transport planning	AI can be used to develop efficient public transport systems and urban infrastructure planning, which will reduce greenhouse gas emissions and contribute to sustainable urban development.
Climate modelling	AI helps to create accurate models of climate change, which allows for informed decisions on measures to reduce greenhouse gas emissions and adapt to climate change.
Protecting biodiversity	Through the analysis of data on species populations and their habitats, AI can help develop strategies to preserve biodiversity and prevent species extinction.
Optimisation of resources	AI can help to optimise the use of natural resources such as energy, water and farmland, which helps to reduce waste and increase efficiency.
Global cooperation	AI research fosters international cooperation to address global challenges such as climate change, food security and healthcare. This includes sharing knowledge, technology and best practices between countries and organisations.

2. Forming the concept of AI technologies in ensuring the goals of environmentally sustainable development

Artificial intelligence (AI) can play a significant role in the development of environmentally sustainable solutions by influencing various aspects of environmental management and planning. Let us highlight the main areas of AI that can contribute to environmentally sustainable development. Artificial intelligence that benefits society can advance sustainable development goals. Artificial intelligence can allocate resources in real time by means of satellite mapping and data analysis of the current poverty situation. Predictive analysis using aerial photography and satellite imagery can increase agricultural productivity. Currently, up to 50% of crops and 78% of livestock production is wasted due to culling, overconsumption and inefficient production. Technological breakthroughs made possible by artificial intelligence are significantly improving preventive services and diagnostics. New technologies can be used to treat cancer, diabetes, and provide remote care for chronic diseases. Once the Internet of Things (IoT) and sensors feed information into AIoE, they can predict hygiene and consumption patterns, thereby improving the supply of water treatment and sanitation equipment. Thanks to real-time AI analysis, power generation and the efficiency of various clean energy sources can be continuously improved. The expansion of human potential brought about by the use of AI devices can simultaneously provide super-sensing and knowledge of the inner and outer world, improve human fitness and correct disabilities, thereby creating a more equal and inclusive society. Thanks to the ubiquity of the Internet of Things, smart devices and wearables, AIoT and digital artificial intelligence networks can influence the development of smart cities. The introduction of artificial intelligence into the analysis of climate change data and climate models allows predicting problems and disasters associated with the development of flexible governance structures in the context of the digital transformation of the 5G industry [5].

Table 2. Place and role of artificial intelligence in ensuring environmentally sustainable development

The direction of AI	Conditions for the implementation of AI
Environmental monitoring and data analysis	Using AI to analyse data from satellites, drones and sensors to monitor the environment; AI can help predict natural disasters such as floods, fires and hurricanes, allowing for timely response.
Using AI for environmental monitoring	AI can help detect water, air, and soil pollution; use drones and satellites to collect data and analyse it with AI.
Optimising resource use	Use of AI to optimise the use of water, fertilisers and pesticides, which reduces the negative impact on the environment; AI can improve energy efficiency in buildings and industry, helping to reduce greenhouse gas emissions.
Optimising energy consumption using AI	Using AI to improve the efficiency of renewable energy sources; intelligent energy management systems in buildings and industry.

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Waste management	The use of robots and machine learning for automatic waste sorting, which increases recycling efficiency; analysis of consumption and production data to develop strategies to reduce
Developing new environmentally friendly materials with the help of AI	Using machine learning to create new materials that are safe for the environment. Optimisation of material production processes with environmental aspects in mind.
Innovative technologies	Using AI to create new materials that are more environmentally friendly and recyclable; optimising the operation of solar and wind power plants using AI.
The role of AI in the development of smart cities	The use of artificial intelligence to manage transport systems, which reduces pollution; integration of environmentally friendly technologies into the urban environment.
The use of AI in agriculture and the path to sustainable development	Precision farming and resource management using AI; yield forecasting and pest management using AI.
Applying AI to biodiversity conservation	Monitoring and protection of rare and endangered species using AI technologies; analysis of ecosystems to identify threats and develop conservation measures.
Raising awareness and education	Use of AI-based interactive learning platforms to raise awareness of environmental issues among the public; use of social media and other online platforms to engage the public in environmental initiatives.
Artificial intelligence in the fight against climate change	Use of AI to model climate change and predict its consequences; development of climate change adaptation strategies using AI.
Ethical aspects of using AI for sustainable development	Identification of ethical standards and regulations for the use of AI in environmental projects; discussion of potential risks and benefits of AI for sustainable development.

Artificial intelligence has great potential to contribute to environmentally sustainable development by improving resource efficiency, reducing pollution and waste, and raising public awareness. However, to achieve the maximum effect, it is necessary to integrate AI with other technologies and approaches to ensure responsible regulation and ethical standards, which requires the development of human-compatible AI and the resolution of AI control issues [6].

CONCLUSIONS

As a result of our research, we have come to the conclusion that the use of artificial intelligence (AI) technologies to achieve the goals of environmentally sustainable development is an important and relevant topic. The development of AI models requires significant amounts of computing resources, which leads to high energy consumption. The carbon footprint caused by data centres is becoming an increasingly serious problem. The development of AI technologies is important for optimising the use of natural resources such as water and energy, which helps to reduce costs and minimise waste; for monitoring the environment and detecting changes in real time; for developing smart city models using AI to manage energy consumption and waste

management; for improving the efficiency of urban systems through automation and data mining; for using drones and sensors for precision agriculture, which reduces the cost of farming; and for the development of new technologies to help reduce the carbon footprint of the economy. In general, AI can play a key role in achieving the goals of environmentally sustainable development, but it is important to take into account the ethical, environmental and social aspects of its use, to create precision agricultural systems that optimise the use of water, fertilisers and pesticides, reducing the negative impact on the environment. The development of interdisciplinary research that combines knowledge from ecology, computer science, engineering, and social sciences to create integrated solutions will contribute to further scientific developments to accelerate the achievement of the SDGs through AI.

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