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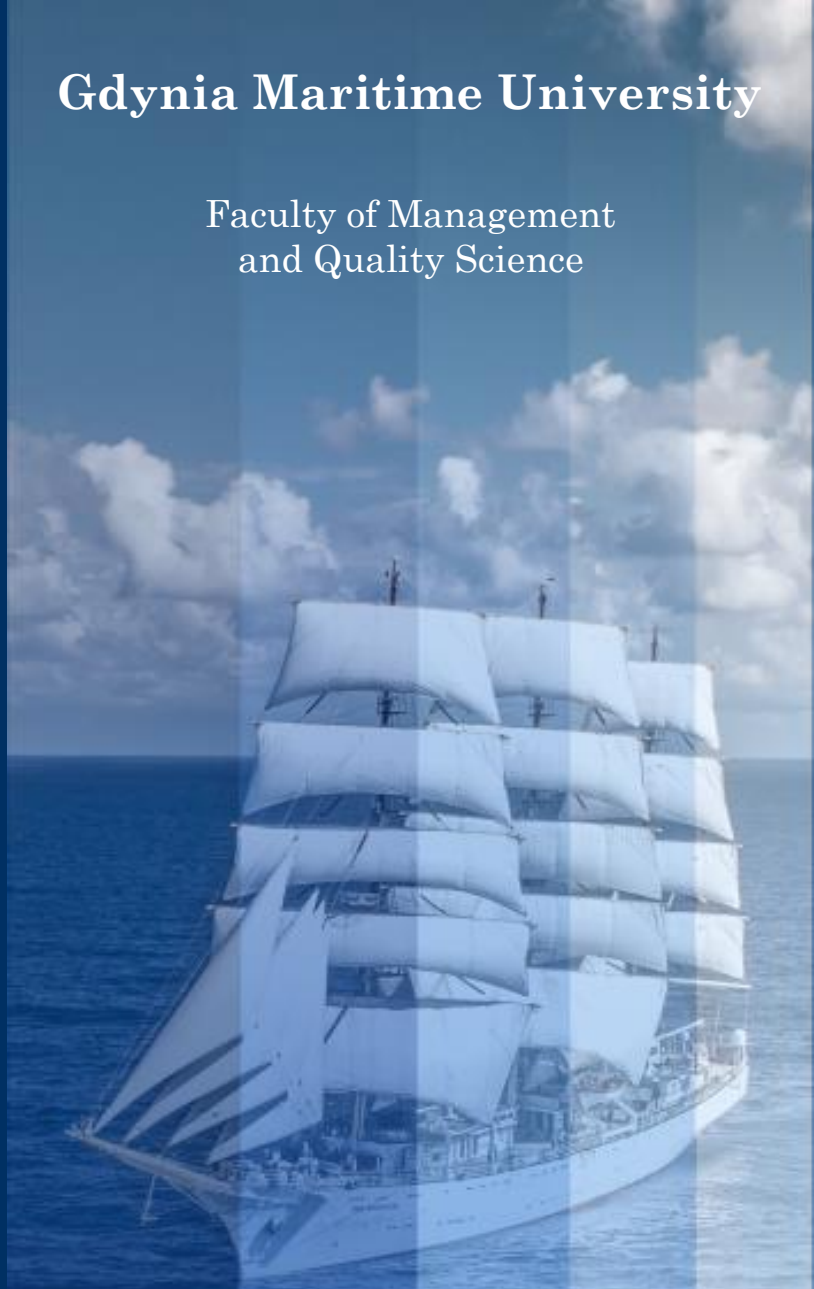

Quality and Safety of Products and Services

Jakość i bezpieczeństwo produktów oraz usług

Edited by Anita Kukułowicz, Agnieszka Palka

Gdynia 2025

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QUALITY OF PERSONAL BRAND AS A COMPONENT OF CONSUMER VALUE – CASE STUDY OF MAREK KAMIŃSKI

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Abstract

In knowledge-based and value-driven economies, personal branding has emerged as a key intangible asset that influences consumer perceptions, preferences, and purchasing behaviour. This study examines the quality of personal branding as a component of consumer value using the case study of Marek Kamiński, a renowned polar explorer, speaker, and founder of educational and psychological resilience programmes.

This research reviews the theoretical frameworks and classifications of consumer value, including its functional, emotional, symbolic, and social dimensions. Emphasis is placed on emotional trust, authenticity, and personal storytelling as strategic elements that distinguish personal brands from corporate entities, especially in the context of ambassadorial roles and influencer marketing.

The empirical section is based on an original survey instrument designed to assess brand awareness, trust, and perceived credibility associated with Kamiński's personal brand. This study investigated whether a celebrity's story and values affect the perceived value of products or services he might endorse, regardless of the respondent's prior interest in exploration or travel.

This study aims to examine whether and how the quality of Marek Kamiński's personal brand as a renowned explorer, speaker, and innovator generates consumer value in its functional, emotional, symbolic, and social dimensions. By analysing the case of Marek Kamiński, the authors assess the ambassadorial potential of his personal brand as a tool for enhancing the perceived value of products, services, and ideas among consumers.

Keywords: personal branding, consumer value, quality indicators in branding, knowledge-based economy, influencer marketing.

INTRODUCTION

In the contemporary landscape of knowledge-based and value-driven economies, brands are no longer confined to products, services, or corporations. Individuals, particularly those operating in public, educational, or mission-oriented spheres, are increasingly perceived as symbolic brands capable of generating substantial consumer value. Personal branding, once viewed primarily as a professional strategy, has evolved into a complex phenomenon that blends emotional resonance, ethical perception, and narrative coherence. This evolution has brought personal brands to the forefront of consumer decision-making, particularly in contexts where trust, authenticity, and symbolic alignment matter more than transactional utility.

As consumers grow more attuned to meaning-making in their consumption patterns, the role of the personal brand expands beyond visibility or popularity. It becomes a mechanism for identity anchoring, moral signalling, and social connection. The literature on consumer value reflects this shift, emphasising the multidimensional nature of value, functional, emotional, symbolic, and social, and the growing importance of values-based branding strategies. Within this paradigm, the personal brand is not merely a vessel for self-promotion, but a potential driver of public trust, psychological resonance, and civic engagement.

This study explores how the quality of a personal brand contributes to consumer-perceived value using the case of Marek Kamiński, a polar explorer, philosopher, motivational speaker, and founder of educational and psychological resilience programmes. As a public figure operating at the intersection of adventure, ethics, and personal growth, Kamiński represents a non-commercial yet highly recognisable brand identity. The central premise of the study is that the perceived quality of his brand, defined through dimensions such as authenticity, trust, competence, and consistency, shapes not only audience admiration, but also their perceived value of the initiatives and causes he represents.

To investigate this premise, the study draws on established theoretical models of consumer value and personal branding, bridging them with an empirical

exploration of audience perceptions. Through a mixed-method survey distributed among audiences familiar with Kamiński's work, this study examines how brand quality attributes translate into functional, emotional, symbolic, and social value. It also assesses whether these perceived values influence behavioural indicators such as willingness to follow recommendations, participate in events, or engage with affiliated missions.

By analysing Marek Kamiński's personal brand as a case study, this research contributes to ongoing scholarly discussions on the symbolic capital of personal branding, the role of ethical storytelling in value creation, and the strategic implications for mission-driven public figures. It also offers data-informed recommendations for enhancing audience engagement and optimising brand communication in ways that align with contemporary expectations for authenticity, impact, and purpose.

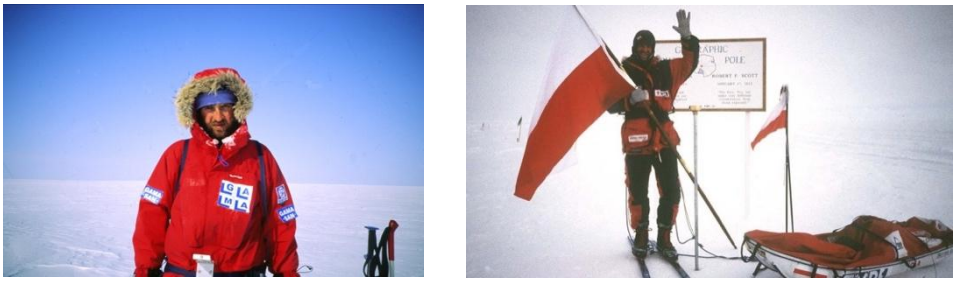

Figure 1. Marek Kamiński – polar explorer, author and founder

Source: Private archive of Marek Kamiński.

1. THEORETICAL FOUNDATIONS OF CONSUMER VALUE

In contemporary economies, the process of value creation has shifted beyond the transactional exchange of goods and services. Instead, value is increasingly co-constructed through experiences, meanings, emotions, and social affiliations. This evolution has elevated consumer-perceived value to a central concept in marketing, brand management, and consumer behaviour research. Understanding how value is defined, assigned, and experienced by individuals is crucial not only for evaluating purchasing decisions but also for exploring the influence of intangible brand assets, particularly in the context of personal brands.

Among the most cited definitions [Zeithaml 1988] describes consumer value as the individual's overall assessment of utility based on the trade-off between received benefits and perceived costs. Yet subsequent research has emphasised that value is not a singular or purely rational construct; rather, it is multidimensional and context dependent. Scholars such as Holbrook [1999], Sheth et al. [1991] and Sweeney & Soutar [2001] have proposed theoretical frameworks that distinguish between functional, emotional, symbolic, and social dimensions of value, all of which contribute to the subjective perception of what makes a brand, product, or individual meaningful [Akarsu et al. 2025; Luo et al. 2022; Singh et al. 2023].

This multi-dimensional approach is especially relevant in an era of personal branding, where individuals function as value carriers, influencers, and representatives of worldviews. A personal brand no longer exists solely as a projection of professional expertise or reputation; it operates as a complex symbolic construct that can inspire, guide, or mobilise audiences [Black & Veloutsou 2017; Shafiee et al. 2020]. In this context, the perceived quality of a personal brand, measured through attributes such as authenticity, trustworthiness, and competence, plays a critical role in determining the kind of value it generates for others.

This theoretical background provides the foundation for our empirical study of Marek Kamiński's personal brand. Kamiński is a well-known Polish explorer, philosopher, and speaker, whose public image blends adventure with ethical mission. The present research seeks to understand how audiences perceive the value embedded in his personal brand, functionally, emotionally, symbolically, and socially, and whether such value can be strategically leveraged for education, engagement, or commercial initiatives.

1.1. Personal brand quality as a driver of consumer value

In recent years, marketing research has increasingly positioned personal brand quality as a structured, measurable construct, analogous to product or corporate brand equity, that shapes consumer perception and behaviour [Black & Veloutsou 2017; Shafiee et al. 2020]. Its core dimensions include authenticity, competence, trustworthiness, consistency, and distinctiveness [Gong & Zhang 2011; Johnstone & Tan 2015].

Among these, authenticity, the alignment of internal values with external communication, is the most emphasised. It enables emotional connection and trust,

reinforcing symbolic value [Guèvremont & Grohmann 2016; Vahdat et al. 2020]. Competence, understood as expertise and reliability, supports both functional and symbolic value, while trustworthiness enhances consumer loyalty and long-term engagement [Kromalcas et al. 2024; Yang et al. 2021].

Consistency ensures clarity and reliability, and distinctiveness enables a brand to stand out in saturated attention markets. Together, these dimensions correspond to categories of consumer value: emotional (authenticity), functional (competence), symbolic (distinctiveness), and social (trust and consistency) [Draganska et al. 2014].

Ultimately, high-quality personal brands serve not only as recognisable personas but also as identity anchors, driving emotional resonance and meaning-making. When managed strategically, they become scalable tools for generating value in domains where individuals themselves are the interface with the audience [Black & Veloutsou 2017].

1.2. Conceptual framework and research assumptions

Considering the multidimensional nature of consumer value and the growing strategic role of personal branding, this study proposes a conceptual framework to examine how the quality of a personal brand contributes to audience-perceived value. Drawing from the literature on brand equity, influencer credibility, and value--based marketing, the framework bridges theoretical insights with an empirical investigation focused on Marek Kamiński, a public figure whose personal brand transcends commercial self-promotion and instead communicates mission-driven authenticity, ethical positioning, and symbolic resonance.

The conceptual model underlying this analysis assumes that personal brand quality can be operationalised through interrelated dimensions: authenticity, competence, trustworthiness, consistency, and distinctiveness [Yang et al. 2021]. These dimensions serve as cognitive and emotional cues that shape perceptions of functional, emotional, symbolic, and social value. Importantly, the value attributed to a personal brand is not viewed here as a static attribute, but as a relational outcome emerging through dynamic interaction between the brand's communication and the audience's needs, values, and experiences [Guèvremont & Grohmann 2016; Shafiee et al. 2020; Szántó et al. 2025; Vahdat et al. 2020].

This study positions the personal brand as a meaning-making mechanism, a mediator between the symbolic resources communicated by the individual and the interpretative processes of the audience. Such positioning is especially relevant in post-materialist economies, where identity, affiliation, and ethical alignment have become key drivers of consumer behaviour [Gajashree & Anand 2021; Jansi Rani et al. 2019]. In this sense, Marek Kamiński's brand, built around polar exploration, psychological resilience, environmental ethics, and public education, offers a unique case for examining how perceived quality translates into value creation.

This study assumes that the strength of a personal brand lies not merely in visibility or popularity but in its ability to consistently deliver meaning, trust, and identification across contexts. It is further assumed that individuals who demonstrate a credible alignment between their actions, messages, and declared values are more likely to elicit emotional loyalty, symbolic association, and value-based engagement [Hollebeek et al. 2023].

To structure this analysis, four research questions were formulated.

RQ1: Which attributes of Marek Kamiński's personal brand are most salient to his audience?

RQ2: How do these attributes influence consumers' perceptions of functional, emotional, symbolic, and social value?

RQ3: To what extent is personal brand quality a decisive factor in the brand's perceived ambassadorial or promotional potential?

RQ4: Can personal brands, such as Marek Kamiński's, enhance organisational missions or public engagement through symbolic or emotional alignment?

These questions reflect an interpretivist approach to value analysis, grounded in the belief that value emerges from subjective and contextual interpretations rather than from objective product features. By analysing audience perceptions and narrative alignment, the study seeks to uncover how quality-driven personal brands can act as value multipliers, particularly in fields where social trust, mission resonance, and symbolic credibility are more influential than product functionality or transactional appeal [Saroya 2024; Vultee 2015].

Ultimately, the conceptual framework advances the view that personal brand quality is not simply a personal asset but a strategic resource with measurable implications for brand co-creation, stakeholder engagement, and perceived societal contribution. This has relevance for individuals operating at the intersection of

business, culture, and social innovation, as exemplified by the case of Marek Kamiński.

2. METHODOLOGICAL FRAMEWORK

The methodological framework of this study was designed to align with its exploratory and interpretive aims, focusing on the subjective perceptions of consumer value ascribed to personal brands. Data were collected using the CAWI method (Computer-Assisted Web Interviewing) through an online questionnaire. The survey instrument was developed to investigate how the perceived quality of Marek Kamiński's personal brand translates into functional, emotional, symbolic, and social value. It included both closed- and open-ended questions and was informed by existing academic literature on personal branding, consumer-perceived value, and influencer trust and credibility.

The questionnaire was aligned with the four research questions articulated in the conceptual framework of this study. It sought to identify the most salient attributes associated with Kamiński's personal brand (RQ1), explore how these attributes are perceived across different value dimensions (RQ2), and assess their influence on the brand's ambassadorial potential and symbolic alignment with broader social or organisational missions (RQ3, RQ4). The quantitative items included Likert-scale statements measuring trust, authenticity, motivational impact, recommendation response, and perceived credibility. Additional multiple-choice and open-ended questions captured associations with emotions, values, and identity-related perceptions of the participants.

The survey was distributed online through social media platforms affiliated with the Marek Kamiński Foundation and Academy and shared via networks of respondents interested in exploration, education, and psychological resilience. A total of 306 valid responses were collected, primarily from Polish-speaking participants. The sample was non-random and self-selecting, consisting mostly of individuals with at least minimal familiarity with Kamiński's public persona. As such, this study does not aim for statistical generalisability but rather seeks to understand patterns of meaning-making among engaged or aware audiences.

The methodological approach was primarily quantitative, with qualitative elements used for the contextual interpretation. Quantitative data were used to

examine the strength and frequency of brand associations and to construct composite indicators of personal brand quality (e.g., through mean scores and PCA). Open--ended responses were subjected to preliminary thematic analysis using manual coding techniques in Excel. Recurrent themes were identified based on semantic similarity, symbolic resonance, and frequency of appearance. Coding criteria included emotional tone, value alignment, and brand-related associations. The process was conducted independently by two researchers to ensure reliability. The epistemological stance of this study is interpretivist, assuming that consumer value is co-constructed through individual perceptions, symbolic framing, and narrative positioning. Therefore, the focus lies not on aggregate brand popularity but on how personal brands are interpreted through the lenses of trust, values, and perceived meaning. This framing is particularly relevant for mission-driven individuals, whose influence may transcend commercial brand metrics.

Ethical considerations were addressed by ensuring informed consent, anonymity, and voluntary participation of the respondents. Participants were briefed about the purpose of the research, could withdraw at any stage, and their data were processed in accordance with the GDPR and institutional research guidelines.

These findings suggest that while Kamiński's brand is widely respected, this does not uniformly translate into ambassadorial behaviour or influence consumer decisions.

3. RESULTS

The findings of this study provide a multifaceted view of how Marek Kamiński's personal brand is perceived by his audience and how this perception relates to the creation of consumer value. Through quantitative analysis of five key indicators – trust, motivation, authenticity, recommendation response, and perceived credibility – insights were gathered regarding the quality of the personal brand and its links to functional, emotional, symbolic, and social value.

RQ1: Which attributes of Marek Kamiński's personal brand are most salient to his audience?

Descriptive statistics (see Table 1) indicate that the highest average scores were assigned to trust (M = 2.04), motivation (M = 2.01), and authenticity (M = 1.90). Although all indicators were measured on a 1–5 Likert scale (with lower scores

indicating stronger agreement), the medians for these three indicators were consistently low (Mdn = 2 or 1), confirming their centrality in the perception of Kamiński's personal brand.

Table 1. Descriptive statistics for personal brand quality indicators

Indicator	Mean	Median	SD
Trust	2.04	2	1.23
Motivation	2.01	2	1.25
Authenticity	1.90	1	1.33
Recommendation	2.47	2	1.23

Source: own study.

The correlation matrix (see Table 2) shows strong and significant positive correlations between trust, authenticity, motivation, and credibility ($r > 0.80$ in all cases), suggesting that these indicators form a coherent perceptual structure.

Table 2. Pearson correlations between brand quality indicators

Indicator	Trust	Motivation	Authenticity	Recommendation	Credibility
Trust	1	0.80	0.82	0.61	0.80
Motivation		1	0.86	0.58	0.82
Authenticity			1	0.58	0.87
Recommendation				1	0.57

Source: own study.

These findings support the interpretation that trust, motivation, and authenticity are the most salient and interrelated dimensions of the brand, forming the symbolic, and ethical core of Kamiński's perception.

RQ2: How do these attributes influence consumers' perceptions of functional, emotional, symbolic, and social value?

Although not measured through direct Likert items, the value dimensions were inferred from the responses to multiple-choice and open-ended questions. Participants most frequently associated the brand with values such as authenticity, courage, and determination, indicating strong emotional and symbolic resonance. These attributes also align with holistic concepts such as inspiration, mission, and inner journey, suggesting that the brand transcends mere functional appeal.

Social value was evident in the participants' willingness to engage with Kamiński in various capacities. Over 80% of respondents expressed a willingness to participate in events featuring him, indicating a perceived social benefit from proximity to the brand. Functional value was linked to familiarity with his books, programmes, and educational initiatives, as reported in follow-up items exploring exposure to his projects.

Although this portion of the analysis remains partially qualitative, these responses confirm that brand quality indicators map meaningfully onto the four types of consumer value. This conclusion will be further strengthened by the thematic analysis of open responses in the future stages of the study.

RQ3: To what extent is personal brand quality a decisive factor in the brand's perceived ambassadorial or promotional potential?

Despite high levels of trust and authenticity, only 19.28% of participants stated that they were likely to follow recommendations made by Marek Kamiński. This is reflected in the relatively higher average score on the recommendation item ($M = 2.47$), compared to other indicators.

This divergence was further analysed using Principal Component Analysis (PCA), which revealed two distinct latent factors. The first principal component (PC1) combined trust, motivation, authenticity, and credibility, representing a general reputation dimension. The second principal component (PC2), dominated almost exclusively by the recommendation indicator, captured an independent action tendency.

Figure 2. Relationship between reputation and action: PCA analysis of Marek Kamiński's personal brand indicators

Source: own study.

These findings suggest that while Kamiński's brand is widely respected, this does not uniformly translate into ambassadorial behaviour or influence consumer decisions.

RQ4: Can personal brands, such as Marek Kamiński's, enhance organisational missions or public engagement through symbolic or emotional alignment?

The survey revealed strong associations between Kamiński's brand and personal growth, psychological resilience, and ethical leadership. Respondents expressed high agreement with statements related to the relevance of their work to broader educational, ecological, and developmental missions.

Importantly, more than 80% of respondents indicated a willingness to attend an event led by Marek Kamiński or support initiatives endorsed by his foundation. This suggests a strong emotional and symbolic alignment that enhances their value as public figure capable of mobilising engagement.

The results further showed that women rated the overall quality of the personal brand slightly higher (M = 2.17) than men (M = 1.96), although the difference was not statistically significant (t-test p = 0.121). However, a Kruskal-Wallis test showed that age groups differed significantly in their evaluations (p = 0.0193), indicating that generational identity may shape brand resonance.

Table 3. Gender-based differences in brand perception

Group	N	Mean Brand Score
Women	127	2.17
Men	174	1.96

Source: own study.

Table 4. Statistical test results

Test	p-value
t-test (gender)	0.121
Kruskal-Wallis (age)	0.0193

Source: own study.

The results confirm that Marek Kamiński's personal brand is perceived as highly trustworthy, authentic, and motivational, attributes that are symbolically integrated into a coherent reputational structure. While this symbolic capital translates into emotional and social value, it does not automatically convert into consumer behaviour or product-related action.

The brand's strength lies in its moral authority, inspirational capacity, and ability to mobilise engagement in non-commercial, mission-driven contexts. Its ambassadorial potential is therefore better understood not in commercial terms, but as a means of promoting shared values, educational impact, and public trust.

4. DISCUSSION

The findings of this study offer a nuanced understanding of how personal brand quality contributes to perceived consumer value, with a specific focus on the case of Marek Kamiński. In alignment with the theoretical frameworks discussed earlier, the results confirm that consumer perception of personal brands is structured not merely around attributes such as trust or authenticity in isolation, but rather as integrated, symbolic systems of meaning.

The principal component analysis (PCA) revealed that the most salient brand attributes, authenticity, motivational capacity, credibility, and perceived integrity, cohere into a single latent construct. This confirms earlier literature on the symbolic and emotional foundations of personal branding [Zauner et al. 2015], particularly in the case of mission-driven figures operating in the public sphere. However, the clear segmentation between perceived quality and behavioural response (PC2) also echoes prior work in influencer marketing and trust theory, which suggests that emotional resonance does not always predict action [Zauner et al. 2015].

This discrepancy indicates a key area for strategic development. While Kamiński's brand is well-established as emotionally and symbolically credible, its potential to generate consumer engagement or mobilise audiences remains under--leveraged. This gap offers an opportunity to develop value-based participation mechanisms that are better aligned with the brand's core symbolic capital.

Several implications arise from this:

Audience segmentation and narrative anchoring

The emotional and symbolic nature of the brand aligns most strongly with audiences seeking guidance, meaning, and resilience, namely, younger adults (20–35) and professionals navigating transitional life phases. However, communication strategies remain largely generalised. To maximise perceived value, the brand should adopt differentiated narrative strategies tailored to specific audience identities and needs, which can be described as identity congruence in brand storytelling [Xi et al. 2022].

Strategic use of symbolic visuals

Respondents often associated the brand with qualities such as strength, clarity, and trust. While the semantic field was dominated by symbolic language, the visual branding of the foundation and related projects remains inconsistent. Drawing on

consumer psychology and colour theory, the brand's symbolic message can be reinforced through a consistent visual palette, for example, incorporating navy blue (trust, depth), white (authenticity), and green (resilience, ethics). These colours are also congruent with environmental themes associated with the brand's legacy.

Collaborative credibility building

Open-ended responses suggest that the perceived value of the brand would be strengthened by strategic associations with other credible figures in the Polish public space, particularly those perceived as similarly mission driven. Names such as Martyna Wojciechowska, Jakub Patecki, and Jacek Walkiewicz emerged frequently. Collaborations with these figures would not only increase visibility but also reinforce symbolic alignment, which the literature identifies as critical for sustaining consumer trust in prosocial or educational contexts [Xi et al. 2022; Kubiczek et al. 2024].

Experiential and participatory offerings

Given the limited consumer action observed (e.g., low rate of response to product recommendations), the brand's strategic growth appears to lie not in commoditising the figure of Kamiński, but in offering participatory experiences, such as curated expeditions, mental resilience workshops, or digital storytelling projects. These should be positioned not as products but as platforms for value co--creation [Tan & Chiu, 2024; Hussain et al. 2024]. The data suggest a readiness among respondents to engage emotionally and symbolically; the strategic task is to translate this into concrete avenues for action and affiliation.

Limitations of influence

Finally, the study points to a broader theoretical issue in personal brand research: the tendency to assume a linear correlation between brand admiration and behavioural responsiveness. Our findings challenge this assumption, suggesting instead a reputational-behavioural divide. This distinction warrants further empirical attention and may inform future conceptual refinements in the study of symbolic influence and brand-mediated trust.

CONCLUSIONS

This study set out to examine the role of personal brand quality in shaping consumer-perceived value, using Marek Kamiński as a case study. Rooted in the theoretical frameworks of value-based branding and identity signalling, the study confirmed that emotional and symbolic attributes, particularly authenticity, trust, and motivational resonance, are central to how audiences experience and assess the value of a personal brand.

Quantitative and qualitative data showed a coherent reputation profile, but also revealed a gap between symbolic admiration and behavioural activation. While audiences express strong emotional alignment, they do not always engage in action, such as following recommendations or participating in branded initiatives. This suggests that even high-quality personal brands require strategic support to convert meaning into measurable engagement.

The findings reinforce the idea that personal branding is not only a tool for visibility, but a mechanism for public trust, identity formation, and social participation. When managed with authenticity and relevance, personal brands like Marek Kamiński's can serve as powerful platforms for education, collaboration, and mission-driven communication.

Future brand development should focus on audience segmentation, co-creation with trusted partners, and stronger alignment between values and tangible offerings. This will not only strengthen the brand's presence, but also enhance its impact in fields where symbolic leadership and psychological resonance are key to long-term engagement.

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IMPACT OF DYNAMIC MECHANICAL LOADING ON BIOCHEMICAL COMPOSITION OF TOMATOES

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Abstract

This study examines the impact of dynamic mechanical loading on the biochemical composition of tomatoes, focusing on total soluble solids (TSS), reducing sugars, ascorbic acid, and lycopene. Tomatoes were exposed to different vibration frequencies (10–40 Hz) and times (3–12 hours). Results showed that vibration increased TSS and reducing sugars, with the highest increases at 20 Hz for 12 hours. Ascorbic acid content decreased with vibration, especially at higher frequencies. Lycopene content peaked at 30 Hz for 12 hours but declined at longer durations or higher frequencies. These findings highlight how vibrations affect biochemical changes in food during transport.
Keywords: food transport, ripening, tomatoes, vibration.

INTRODUCTION

Tomatoes (*Lycopersicon esculentum)* are among the world's most popular and frequently consumed vegetables. After potatoes, they are also the most commonly grown [Famuyini et al. 2020]. Tomatoes are grown in Europe in two different ways. The first is in Mediterranean countries, which have higher temperatures and more sunshine. The second is in colder countries where heating and artificial lighting are necessary during winter, so they are also very commonly transported [Torrellas et al. 2012]. In addition to their taste, tomatoes are a rich source of many essential minerals, making them an extremely valuable dietary product [Toor & Savage 2006; Wang et al. 2023]. The quality of tomatoes is assessed based on their weight, colour, firmness and taste [Pathare et al. 2021]. However, due to their climacteric nature,

delicate structure, and soft skin, they are very susceptible to damage after harvest, especially during transportation and reloading operations [Al-Dairi et al. 2021]. Transport, a crucial link in the supply chain, causes losses for this product. Improper conditions cause this during transport and distribution, such as failure to maintain refrigerated temperatures and unfavourable infrastructure, i.e. improper condition of roads, which generates mechanical damage to transported products [Kamhangwong et al. 2021; Park et al. 2024]. In particular, vibrations generated during transport are a huge problem, primarily concerning soft products such as tomatoes. The vibration level is influenced by road conditions, vehicle speed, driving style, and the packaging of transported products [Soleimani & Ahmadi 2015]. These factors directly affect external and internal changes in fruit, such as skin damage, reduced firmness, weight loss, changes in chemical composition, and degree of ripeness. Studies confirm the negative impact of vibrations on various fruits, e.g., strawberries, kiwi, and tomatoes, and shorten their shelf life [Kojima et al. 2001; Wei et al. 2019]. The quality of tomatoes is also affected by storage conditions, especially temperature. Higher temperatures accelerate respiration and ethylene production, which causes faster weight loss and firmness. Low temperatures, on the other hand, slow down life processes, affecting the freshness of food products. Therefore, post-harvest strategies are so important because they help maintain freshness for a more extended period, thus minimising losses and improving the commercial quality of tomatoes. The impact of real-time transport vibrations on tomato ripening acceleration has not been extensively studied. Ripening is known to cause items to spoil more quickly. This study aims to investigate the effect of simulated vibrations of different frequencies, within the range of those occurring in actual conditions, on physicochemical changes such as TSS, reducing sugars, ascorbic acid, lycopene, and visual changes in tomatoes, which may contribute to the development of strategies to improve post-harvest management while maintaining high tomato quality.

1. MATERIAL AND METHODS

1.1. Research material

The tomatoes *Hardy* variety used in this study were obtained from a single local farm (52°15′ N, 16°37′ E) and came from the same harvest batch, ensuring

uniformity in both variety and growing conditions. The tomatoes selected for the study were uniform in colour, size, weight, and firmness, devoid of defects, and harvested at a stage of partial ripeness suitable for consumption. They were loosely packed in recycled plastic containers measuring 400 x 300 x 150 mm, with each container holding approximately 30 tomatoes (weighing 4 kilograms) and stored at a temperature range of 12 to 15°C. A total of 5 containers of tomatoes were used for the study.

1.2. Measurement equipment

Experimental studies were conducted on a test stand consisting of a vibration simulator placed in a stationary car body with the possibility of temperature regulation. The vibration simulator allowed for changing the frequency in the range from 10 to 50 Hz. The following frequencies were used for the tests: 10, 20, 30 and 40 Hz. The selected frequencies are within the range of those occurring in actual road food transport [Idaszewska & Szymański 2020]. The vibration simulator consisted of two basic elements: a vibration forcing installation – a motor controlled by an inverter, elastic suspension, vibration isolation elements – and an integrated control system for the parameters of the station operation. The control of the station operation and ongoing supervision over the correctness of the controlled individual executive elements was carried out by monitoring mechanical quantities (vibration accelerations) in a feedback loop controlled by a PC.

1.3. The system of experiment

The following parameters were determined in tomatoes: total soluble solids (TSS), reducing sugar, ascorbic acid content, lycopene content, and visual changes. These measurements were made on tomatoes divided equally into three groups: zero test – tomatoes immediately after harvest; control test – tomatoes not subjected to vibrations but stored for 7 days; tomatoes subjected to vibrations at frequencies of 10, 20, 30, 40 Hz for 3, 6 and 12 hours and then stored for 7 days.

1.4. Analytical methods

Total soluble solids (TSS)

The Abbe refractometer was used to measure tomatoes' total soluble solids, which were expressed in Brix. One to two drops of tomato juice were placed on the prism. Before use, the refractometer was standardised by adding a few drops of distilled water.

Reducing sugar

Using dinitrophenol, which was reduced to a colourful product under an alkaline environment and high temperature, the G-26 test was used to detect the concentration of reducing sugars. By measuring the absorbance at $\lambda = 600$ nm, the concentration of this product was ascertained. The determinations were done using Talburt and Smith's methodology [Talburt & Smith 1987]. The results were expressed in the percentage of fresh mass.

Ascorbic acid

The ascorbic acid content was determined using Tillman's titration method of 2.6-dichloroindophenol [PN-A-04019; Food Products – Determination of Vitamin C Content. Polish Committee for Standardization 1998]. The results were expressed in mg/100 g.

Lycopene content

Lycopene was extracted from the homogenized tomato juice using a mixture of *n*-hexane, methanol, and acetone (2:1:1, v/v) supplemented with 0.5 g L^{-1} of butylated hydroxytoluene (BHT) as an antioxidant. The absorbance of the hexane phase was recorded at 502 nm using a UV/VIS spectrophotometer (Rigol Ultra 3660). The lycopene concentration was calculated using its specific extinction coefficient (E 1%, 1 cm) of 3150 [Alda et al. 2009]. The lycopene concentration was expressed as mg/100g product.

Statistical analysis

The statistical calculations were performed using Statistica 12 software (TIBCO Software Inc., Palo Alto, CA, USA). A one-way ANOVA was conducted

on the data, and multiple comparisons of means were carried out using the Tukey test for $p \leq 0.05$.

2. RESULTS

Table 1 presents summary results for tomatoes after harvest (zero test), stored (control test), and subjected to vibrations.

Table 1. The effect of vibration frequency and time on TSS, reducing sugar, ascorbic acid and lycopene

Vibration frequencies [Hz]	Vibration time [h]	TTS [0Brix]	Reducing sugar [%]	Ascorbic acid [mg/100 g]	Lycopene [mg/kg]
Zero test		5.42 ±0.37 ^{a}	2.40 ±0.06 ^{a}	20.85 ±3.88 ^{ab}	21.28 ^{a}
Control test		6.04 ±0.14 ^{ab}	2.84 ±0.06 ^{b}	22.03 ±2.42 ^{b}	32.58 ^{def}
10	3	6.80 ±0.09 ^{bcd}	3.04 ±0.09 ^{bc}	20.02 ±1.80 ^{ab}	32.9 ^{ef}
	6	6.77 ±0.38 ^{bc}	3.06 ±0.13 ^{bc}	20.23 ±1.56 ^{ab}	35.52 ^{fgh}
	12	7.12 ±0.5 ^{cd}	3.34 ±0.05 ^{cd}	21.98 ±6.85 ^{ab}	29.15 ^{cd}
20	3	7.27 ±0.48 ^{cd}	3.34 ±0.23 ^{cd}	20.07 ±1.47 ^{ab}	34.14 ^{fg}
	6	7.34 ±0.45 ^{cde}	3.48 ±0.19 ^{d}	21.08 ±3.13 ^{ab}	36.54 ^{gh}
	12	8.23 ±0.24 ^{e}	3.90 ±0.09 ^{e}	16.30 ±3.94 ^{ab}	29.2 ^{cd}
30	3	7.67 ±0.74 ^{cde}	3.47 ±0.17 ^{d}	16.72 ±3.16 ^{ab}	33.46 ^{fg}
	6	7.67 ±0.27 ^{cde}	3.48 ±0.13 ^{d}	18.12 ±1.21 ^{ab}	37.97 ^{h}
	12	7.72 ±0.55 ^{cd}	3.44 ±0.29 ^{d}	17.10 ±1.50 ^{ab}	26.87 ^{bc}
40	3	7.28 ±0.47 ^{cde}	3.56 ±0.21 ^{d}	16.58 ±2.36 ^{ab}	29.99 ^{cde}
	6	7.35 ±0.59 ^{cde}	3.48 ±0.16 ^{d}	16.73 ±1.11 ^{ab}	32.49 ^{def}
	12	7.03 ±0.58 ^{cd}	3.35 ±0.14 ^{cd}	15.82 ±0.73 ^{a}	23.52 ^{ab}

Explanation: Mean values sharing the same letter are not significantly different at $p = 0.05$ within the same sample.

Source: own study.

3. DISCUSSION

Total soluble solids (TSS) indicate the ripening stage and the concentration of soluble minerals and sugars in fresh produce, making it a key factor in evaluating the tasting quality of the product [Al-Dairi et al. 2021a]. Storage of tomatoes resulted in an increase in TSS from 5.42 to 6.04 °Brix. Exposure to vibration generally led to

further increases in TSS values, with the highest result observed at 20 Hz for 12 hours (8.23 °Brix), which was the only statistically significant increase ($p \leq 0.05$) compared to the control. In most other cases, increases in TSS with longer vibration times and higher frequencies were observed but not statistically significant. For instance, at 30 Hz, TSS values increased slightly from 7.67 °Brix after 3 hours to 7.72 °Brix after 12 hours; however, this change did not reach statistical significance and should be interpreted as a tendency rather than a confirmed effect. Similarly, at 10 and 40 Hz, the results followed the same trend of gradual increase, but without statistically significant differences. The observed tendency for TSS to increase may be attributed to enzymatic degradation of pectins and hemicelluloses to simple sugars, as well as water loss leading to a higher concentration of soluble components [Dumville & Fry 2000]. Similar findings were reported by Shonte et al. [2013], who observed an increase in TSS in tomatoes stored at room temperature, supporting the link between ripening and sugar accumulation. Conversely, at the highest tested frequency (40 Hz), a slight decrease in TSS after extended vibration was noted, possibly due to accelerated respiratory metabolism and oxidative degradation of sugars under excessive mechanical stress [Md. S Kabir et al. 2020; Md Shahjahan Kabir et al. 2024].

Sugar is crucial in tomatoes as it determines their sweetness and taste. Elevated sugar levels are necessary for optimal flavour. Tomato fruit primarily contains glucose, fructose, and small quantities of sucrose [Tagele et al. 2022]. The reducing sugar content significantly increased with vibration time and frequency, reflecting the metabolic changes induced by mechanical stress. At lower frequencies, such as 10 Hz, reducing sugar content rose gradually from 3.04% after 3 hours to 3.34% after 12 hours. A similar pattern was observed at 20 Hz, where the content increased from 3.34% to 3.90% over the same period. These results confirm that vibration accelerated tomato ripening because an increase in reducing sugars is associated with the ripening process, a finding confirmed by other work [Dabesor et al. 2022]. The same results were observed for blueberries in other studies [Idaszewska et al. 2024], confirming that mechanical stress accelerates the decomposition of starch into sugars, hence their higher content after subjecting the fruit to vibration [Costa et al. 2021].The increase in reducing sugar content was less pronounced at higher frequencies, such as 30 Hz and 40 Hz. For instance, at 40 Hz, the content stabilized at 3.48% after 6 hours and slightly declined to 3.35% after 12 hours. This slight decrease may be attributed to the consumption of sugars during respiration,

as observed by Azene et al. [2014], who highlighted that excessive stress conditions can enhance metabolic rates, leading to sugar depletion. Furthermore, the reducing sugar levels in the control test 2.84% were significantly lower than those in vibrated samples, highlighting the role of mechanical stimulation in enhancing carbohydrate metabolism. These findings suggest that moderate time of vibration (e.g., 3 to 6 hours) optimises reducing sugar content by promoting enzymatic activity without triggering excessive respiratory consumption or oxidative damage. Such insights align with prior studies, including Pathareet al [2021] and Al-Dairi et al. [2021b; 2022], who emphasised the balance between mechanical stress and metabolic processes in maintaining the quality of fresh produce.

All living things require ascorbic acid, a water-soluble antioxidant molecule. Since its discovery to prevent scurvy, ascorbic acid has been extensively studied in humans. Its function as a free radical scavenger is now considered crucial for preventing cancer, cardiovascular disease, cataracts, and other physiological disorders [Reang et al. 2021; Wang et al. 2024]. There is a significant variation in the amount of ascorbic acid within fruit species due to the fruit ripening stage [Arabia et al. 2024]. Across all treatments, ascorbic acid content decreased compared to the control test 22.03 mg/100 g. This decline was observed regardless of vibration frequency or time, indicating that exposure to vibrations consistently reduces ascorbic acid levels. The natural decrease in ascorbic acid content in tomatoes during storage may be related to increased ascorbate oxidase activity [Yahia et al. 2001]. The frequency of vibrations played a significant role in the extent of ascorbic acid degradation. At 10 Hz, ascorbic acid levels remained relatively stable across different vibration times, with only minor variations observed (20.02 mg/100 gat 3 hours vs. 21.98 mg/100 gat 12 hours). Higher frequencies, such as 20and 30 Hz, exhibited more pronounced reductions. At 30 Hz, the content dropped to 16.72 mg/100 g after 3 hours and 17.10 mg/100 g after 12 hours. At 40 Hz, a similar trend was observed, with a final value of 15.82 mg/100 g after 12 hours. Increased time of vibrations generally led to a more significant reduction in ascorbic acid content; for example, at 20 Hz, the concentration decreased from 20.07 at 3 hours to 16.30 at 12 hours. Similarly, at 40 Hz, the content fell steadily over time, reaching the lowest value of 15.82 after 12 hours. These findings indicate a clear relationship between vibration frequency, vibration time, and ascorbic acid degradation. Vibrations introduce mechanical stress, which may disrupt the molecular stability of ascorbic acid. Higher frequencies, such as 30 and 40 Hz, likely impart more energy

to the system, accelerating the degradation process than lower frequencies. Very similar observations were made at Kojima, where the level of ascorbic acid in strawberries before the study was 63.4 mg/100 g; then, due to storage, it dropped to 61.7 mg/100 g and, due to additional vibration, it finally amounted to 59.2 mg/100 g [Kojima et al. 1990]. Ascorbic acid decreases under vibration stress due to disrupted energy metabolism, which affects intracellular redox homeostasis and accelerates oxidative damage. The imbalance in reactive oxygen species metabolism and reduced ATP production promote senescence and weaken antioxidant defences, leading to ascorbic acid degradation [Shu et al. 2022].

Lycopene, a lipophilic carotenoid pigment naturally present in red to orange fruits and vegetables (e.g., tomatoes, melons, and papayas), has gained importance as a food-grade antioxidant for preventing lipid oxidation [Khan et al. 2021]. Lycopene content in the samples tested showed significant variations with vibration frequency and exposure time. Storage of tomatoes increased lycopene content from 21.28 to 29.15 mg/kg. This is confirmed by other studies that during storage, particularly at room temperature, lycopene and other carotenoid pigments increase significantly as ripening and maturation processes promote the transformation of chloroplasts into chromoplasts, leading to carotenoid accumulation [Al-Dairi et al. 2021a]. The application of 10 Hz vibration increased lycopene concentration with longer exposure time, reaching a peak of 35.52 mg/kg after 12 h. A similar pattern was observed at 20 Hz, where lycopene reached 36.54 mg/kg after 12 h. The highest lycopene concentration (37.97 mg/kg) was observed at 30 Hz for 12 h, suggesting that both frequency and duration play a synergistic role in increasing lycopene levels, potentially due to induced stress responses or structural degradation enhancing extractability. Interestingly, at 40 Hz, although 6 h exposure resulted in moderately elevated lycopene levels (32.49 mg/kg), a decrease was observed after 12 h (23.52 mg/kg), approaching the baseline values. In general, moderate vibration frequencies (20–30 Hz) combined with longer exposure times (12 h) seem to be most effective in increasing lycopene content, whereas excessively intense conditions (40 Hz, 12 h) may lead to degradation. Some research suggests that mechanical vibrations associated with long-distance transportation may accelerate ripening and enhance lycopene synthesis, although further studies are needed to confirm this relationship [Al-Dairi et al. 2021c]. These findings are important for optimising postharvest processing conditions for lycopene-rich products.

Visual changes

Figure 1 shows visual changes in tomatoes exposed to vibrations at a frequency of 10 Hz for 3, 6 and 12 hours. No changes were observed in tomatoes not exposed to vibrations (control test) and in tomatoes exposed to vibrations for 3 and 6 hours. In the case of tomatoes exposed to vibrations for 12 hours, a bruise was observed on the surface of one tomato.

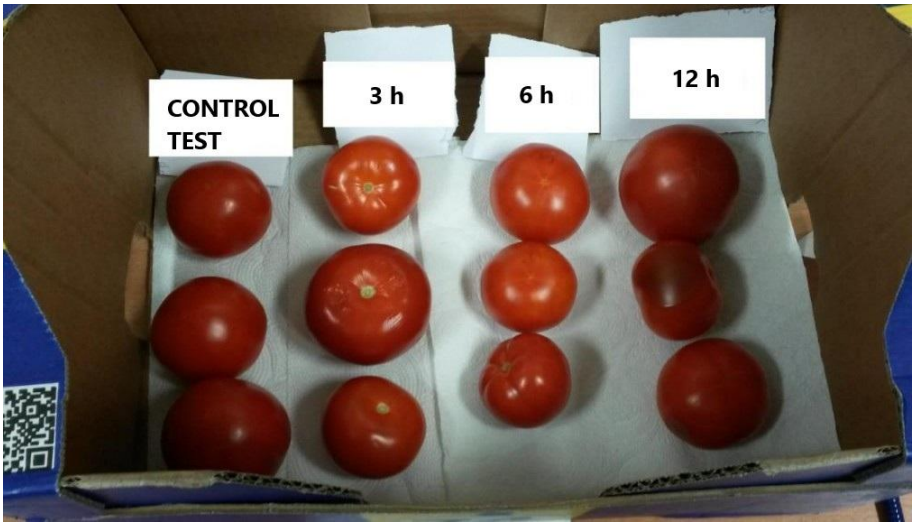

Figure 1. Visual changes in tomatoes exposed to vibrations at a frequency of 10 Hz for 3, 6 and 12 hours

Source: own study.

Figure 2 shows visual changes in tomatoes exposed to vibrations at a frequency of 20 Hz for 3, 6 and 12 hours. No changes were observed in tomatoes that were not exposed to vibrations (control test). In the case of tomatoes exposed to vibrations for 3 hours, wrinkling of the skin and minimal bruising were observed on the surface of 1 tomato, and those exposed to vibrations for 6 hours, on the surface of 2 tomatoes. For tomatoes exposed to vibrations for 12 hours, bruising of the surface of 1 tomato and molding of the second tomato were observed.

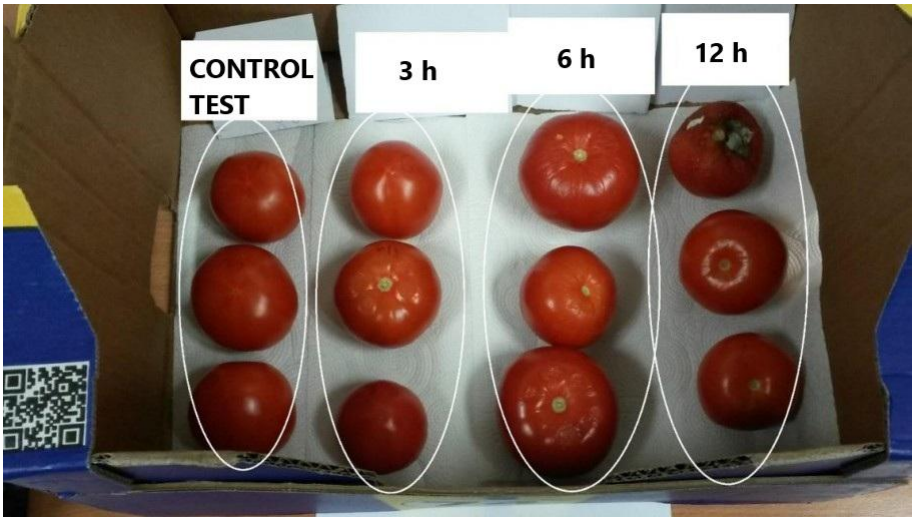

Figure 2. Visual changes in tomatoes exposed to vibrations at a frequency of 20 Hz for 3, 6 and 12 hours

Source: own study.

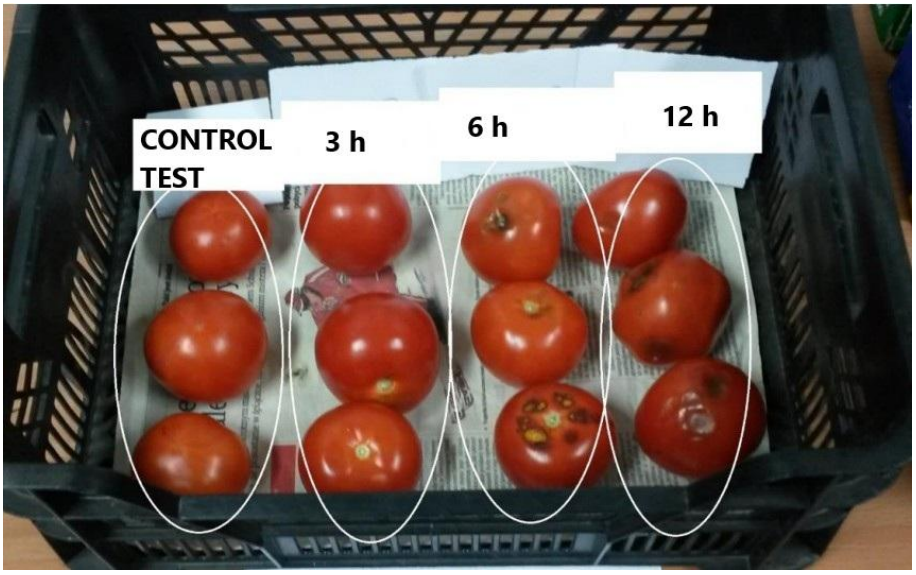

Figure 3. Visual changes in tomatoes exposed to vibrations at a frequency of 30 Hz for 3, 6 and 12 hours

Source: own study.

Figure 3 shows visual changes in tomatoes exposed to vibrations at a frequency of 30 Hz for 3, 6, and 12 hours. No changes were observed in tomatoes that were not exposed to vibrations (control test). In the case of tomatoes exposed to vibrations for 3 hours, minimal bruising was observed on the surface of 1 tomato. In the case of tomatoes exposed to vibrations for 6 hours, significant bruising was observed on the surface of 2 tomatoes, and in the case of tomatoes exposed to vibrations for 12 hours, three tomatoes.

Figure 4 shows visual changes in tomatoes exposed to vibrations at a frequency of 40 Hz for 3, 6, and 12 hours. Minimal changes were observed on the surface of 1 tomato in the case of tomatoes not exposed to vibrations (control test). Mold was observed in most tomatoes exposed to vibrations for 3, 6, and 12 hours.

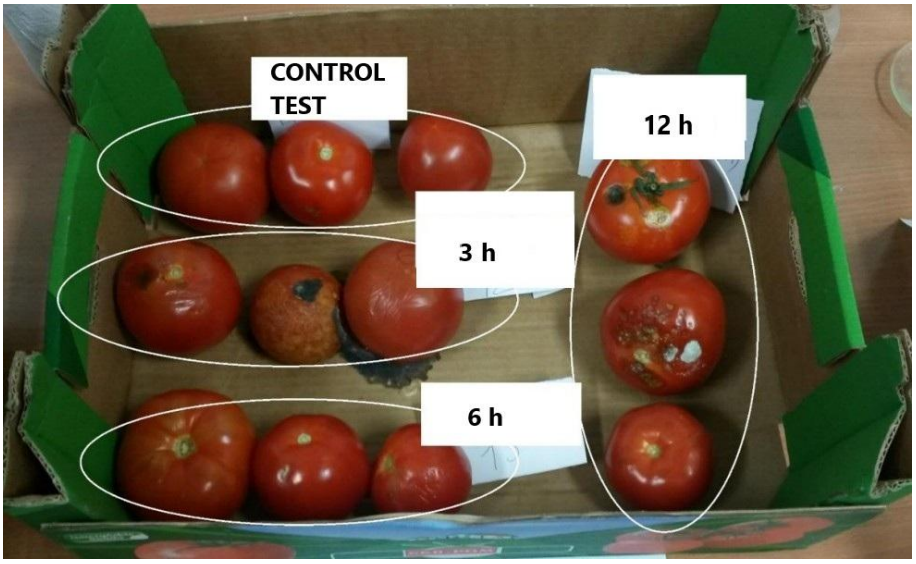

Figure 4. Visual changes in tomatoes exposed to vibrations at a frequency of 40 Hz for 3, 6 and 12 hours

Source: own study.

CONCLUSIONS

In this study, the effect of dynamic mechanical loading on the biochemical properties of tomatoes was investigated, in particular total soluble solids (TSS),

reducing sugars, ascorbic acid, and lycopene. TSS generally showed an increasing trend with higher vibration frequency and longer vibration duration. However, only the increase observed at 20 Hz for 12 hours was statistically significant. Reducing sugars also increased with vibration frequency and time, but the changes were more subtle than for TSS. The highest values of reducing sugars were recorded at 20 Hz and 12 h. Ascorbic acid tended to decrease at higher frequencies and longer vibration durations. Lycopene content increased with increasing vibration frequency and duration for the range 10-30 Hz. A decrease in lycopene was observed at 40 Hz. In all cases, exposure to vibration, compared to unexposed tomatoes, increased the effect on the parameters studied. It is important to emphasise that most results showed observable trends rather than statistically significant differences. This may be due to the experimental design, which used controlled, harmonic vibrations with a constant amplitude. In contrast, real transport conditions involve variable vibration amplitudes, multidirectional motion and may have more pronounced or different effects on fruit quality. Future studies should include more complex vibration profiles to better simulate real transport dynamics and assess their cumulative effects on biochemical and physical properties of fruit. These results contribute to the understanding of the balance between mechanical stress and metabolic processes, offering valuable information on post-harvest processing strategies to increase the quality and nutritional value of fresh produce. Care should be taken to minimise the negative effects of vibration during transport by using appropriate packaging, taking care of driving style, and perhaps improving load securing, regardless of the product's transport time.

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HEALTH POTENTIAL OF WHITE TEA

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Abstract

White tea represents the least processed form of tea, retaining high levels of bioactive compounds with broad health-promoting potential. The aim of this paper was to present the current state of knowledge regarding the health properties of white tea and to assess its relevance in the prevention of lifestyle-related diseases. The study discusses the major groups of chemical constituents present in white tea, including polyphenols (catechins, flavonoids, phenolic acids), polysaccharides, alkaloids, and the amino acid L-theanine, with emphasis on their biological significance.

Based on the analysis of the literature, it has been demonstrated that white tea may support cardiovascular function by lowering cholesterol levels, reducing blood pressure, and mitigating oxidative stress. Furthermore, numerous experimental studies confirm its anti-inflammatory, anticancer, and neuroprotective effects. Compounds found in white tea may inhibit the aggregation of pathological proteins in the brain, modulate the activity of enzymes and inflammatory pathways, and improve lipid and glycemic profiles. A beneficial influence of white tea on lipid metabolism and body-weight regulation has also been reported, which may be relevant for the prevention of metabolic syndrome and type 2 diabetes.

The collected evidence indicates that regular consumption of white tea may serve as a supportive element in the prevention of lifestyle-related diseases. However, further clinical studies are needed to determine the optimal intake and mechanisms of action of the active compounds contained in white tea.

Keywords: white tea, bioactive compounds, health-promoting properties, lifestyle-related diseases.

INTRODUCTION

Tea (*Camellia sinensis*) is one of the most widely consumed beverages worldwide, valued both for its sensory qualities and its potential health-promoting properties. Depending on the degree of leaf oxidation, six primary types of tea are distinguished: white, green, yellow, oolong, black, and dark tea. White tea is considered the least processed variety, produced from young buds and leaves without fermentation, which allows for the preservation of a high level of natural bioactive compounds [Jenny & Mao 2013; Lai et al. 2022; Tang et al. 2019].

The most important group of active compounds in white tea are polyphenols, primarily catechins (approximately 70% of all tea polyphenols), as well as flavonoids, anthocyanins, and phenolic acids. These compounds exhibit strong antioxidant, anti-inflammatory, anticancer, and antidiabetic properties, resulting from their ability to neutralise free radicals and modulate enzymatic activity [Guo et al. 2024; Zhang et al. 2017; Zhang et al. 2024]. In addition to polyphenols, white tea also contains polysaccharides, which may exert immunomodulatory and anti-obesity effects, as well as alkaloids – primarily caffeine, theobromine, and theophylline – which possess stimulating effects on the nervous and cardiovascular systems [Cai et al. 2025; Giles et al. 2017; Guo et al. 2024; Zeng et al. 2022; Zhou et al. 2023].

Another valuable constituent is L-theanine, an amino acid responsible for the characteristic mild flavor of the infusion and its potential neuroprotective and stress-reducing effects. Tea also contains terpenoids (including linalool, geraniol, and nerol), which contribute to its aroma and exhibit antioxidant activity, as well as numerous mineral components (potassium, magnesium, calcium, selenium, iron, manganese) and vitamins of the B, C, E, and K groups, which support the functioning of the nervous, immune, and metabolic systems [Bai et al. 2019; Deb & Borah 2024; Luo et al. 2024].

The richness of these compounds makes white tea a valuable source of biologically active substances with broad health-promoting potential. Therefore, the aim of this paper was to review and analyse the available scientific data on the health properties of white tea, with particular emphasis on its preventive and therapeutic

potential in lifestyle-related diseases. This work is a narrative review and includes a discussion of the chemical composition and biological mechanisms of action of white tea.

1. HEALTH POTENTIAL OF WHITE TEA

1.1. Effects on the cardiovascular system

Cardiovascular diseases are among the most common chronic conditions worldwide and represent a leading cause of mortality and disability. More than 75% of these diseases occur in low- and middle-income countries, where limited access to preventive care leads to delayed diagnosis and poorer outcomes. In recent years, growing attention has been directed toward the role of dietary components, including the bioactive compounds present in tea, in the prevention and progression of cardiovascular diseases [Gao et al. 2022; Gracia et al. 2017; Shang et al. 2021; Zheng et al. 2022].

White tea exhibits potential protective effects on the cardiovascular system, primarily due to the presence of polyphenols with antioxidant, anti-inflammatory, and hypolipidemic properties. These compounds reduce oxidative stress, endothelial dysfunction, and lipid peroxidation, which may help prevent the development of atherosclerosis and hypertension [Leopold & Loscalzo 2008; Wang et al. 2013; Yigit et al. 2024].

In preclinical studies, white tea extract (WTE) improved lipid profiles and liver function in ApoE–/– mice with atherosclerosis by lowering total cholesterol and triglyceride levels and reducing aortic intima thickness. Similar effects were observed in models of hypercholesterolemia, in which WTE and its catechins (EGCG, ECG) inhibited the expression of MTP and apoB, thereby decreasing VLDL lipoprotein synthesis and increasing LDL receptor expression. Additionally, an increase in HDL concentrations and inhibition of lipase activity were demonstrated, further supporting the hypolipidemic and anti-atherogenic effects of white tea [Luo et al. 2020; Sanlier et al. 2018; Tenore et al. 2013].

Clinical data indicate that regular tea consumption lowers blood pressure. In a meta-analysis of 10 studies involving 834 participants, Yarmolinsky et al. [2015] reported reductions of 2.36 mmHg in systolic blood pressure (SBP) and 1.77 mmHg

in diastolic blood pressure (DBP). Although the analysis did not specifically include white tea, its high catechin content suggests a similar hypotensive effect. In animal models, Fuente-Muñoz et al. [2025] confirmed that white tea extract reduces blood pressure, decreases infarct size, and attenuates cardiac oxidative stress. These effects were attributed to the activity of polyphenols, particularly EGCG. Furthermore, Xu et al. [2024] demonstrated a direct vasorelaxant effect of white tea through the inhibition of calcium and potassium channels, confirming its multidirectional and synergistic mechanism of action [Fuente-Muñoz et al. 2025; Xu et al. 2024; Yarmolinsky et al. 2015].

Available experimental and epidemiological data indicate that white tea may serve as a natural supportive agent in the prevention of cardiovascular diseases. Its effects include the regulation of lipid metabolism, improvement of vascular elasticity, reduction of blood pressure, and attenuation of oxidative stress and inflammation, which underscores its potential relevance as a component of functional foods and preventive dietary strategies.

1.2. Anti-inflammatory and anticancer effects

The bioactive constituents of white tea, particularly epigallocatechin gallate (EGCG), exhibit multifaceted anticancer and anti-inflammatory activities involving the modulation of numerous cellular pathways. EGCG interacts with transmembrane receptors and kinases, leading to the inhibition of proliferation and the induction of apoptosis in cancer cells. Cancer cells are particularly sensitive to its effects due to so-called oncogene addiction, characterised by the hyperactivation of signalling pathways essential for their survival. Inhibition of these pathways results in cancer cell death while exerting minimal effects on healthy cells [Yang et al. 2009].

In a study by Wang et al. [2024], a novel heteropolysaccharide (WTP) was isolated from white tea, composed primarily of arabinose, galactose, and glucose. WTP inhibited the proliferation of HepG2 and HCT-116 cancer cell lines and induced apoptosis through activation of the mitochondrial pathway. Additionally, it reduced the secretion of pro-inflammatory cytokines (TNF-α, IL-6), confirming its dual anticancer and anti-inflammatory activity [Wang et al. 2024].

Mao et al. [2010] demonstrated that white tea extract (WTE) inhibits the progression of non-small cell lung cancer (NSCLC) through the activation of PPAR-γ receptors and 15-lipoxygenase (15-LOX) enzymes, leading to suppressed

proliferation and the induction of apoptosis in cancer cells. Inhibition of PPAR-γ abolished the cytotoxic effect, confirming its central role. Simultaneously, the activation of 15-LOX indicates an anti-inflammatory mechanism that may limit the development of tumours driven by chronic inflammation [Mao et al. 2010].

In in vitro studies, white tea extract was shown to inhibit the proliferation of HT-29 colorectal cancer cells in a dose- and time-dependent manner, inducing apoptosis through caspase activation. Notably, it simultaneously protected healthy intestinal cells from oxidative damage induced by H_2O_2, as confirmed by the comet assay. This cytoprotective effect was attributed to the presence of catechins with strong antioxidant properties [Hajiaghaalipour et al. 2015].

In a skin wound model in rats, topical application of white tea extract was shown to accelerate the healing process by reducing inflammatory infiltration, stimulating fibroblast proliferation, promoting angiogenesis, and enhancing collagen synthesis. Histological analysis confirmed these findings – wounds in extract-treated animals closed more rapidly, and tissue regeneration was more complete. These effects are attributed to polyphenols with strong antioxidant and anti-inflammatory potential [Kouhihabibidehkordi et al. 2021].

Saral et al. [2019] described the anti-inflammatory effects of white tea in a model of cisplatin-induced nephrotoxicity. Supplementation with white tea reduced TNF-α levels and the activity of the transcription factor NF-κB, thereby decreasing inflammatory cell infiltration and improving nephron structure. These findings indicate the potential of white tea in mitigating drug-induced kidney damage of inflammatory origin [Saral et al. 2019].

The collected evidence confirms that white tea exhibits both anticancer and anti-inflammatory effects. These mechanisms involve the regulation of gene expression related to proliferation, apoptosis, and inflammatory responses, modulation of the PPAR-γ and NF-κB pathways, and the reduction of oxidative stress. The observed outcomes – including cytotoxicity toward cancer cells, protection of healthy cells, and support for tissue regeneration – make white tea a promising source of natural compounds with preventive and therapeutic potential.

1.3. Effects on the central nervous system

Neurodegenerative diseases (NDs) represent a complex group of disorders of the central nervous system (CNS), including Alzheimer's disease (AD), Parkinson's disease (PD), amyotrophic lateral sclerosis (ALS), frontotemporal dementia (FTD), and Huntington's disease (HD). They are characterised by progressive neuronal damage in various regions of the brain and spinal cord, leading to impairments in cognitive, motor, and neurological functions [Erkkinen et al. 2018; Temple 2023].

Despite intensive research efforts, the pathogenesis of NDs remains incompletely understood. The interplay of genetic, epigenetic, and environmental factors is considered fundamental. One of the proposed mechanisms underlying disease progression involves the transfer of misfolded proteins between cells in a manner reminiscent of prion-like processes [Dugger & Dickson 2017; Erkkinen et al. 2018].

Due to its minimal processing, white tea retains high levels of bioactive compounds with neuroprotective activity, particularly polyphenols, catechins (EGCG, ECG), and L-theanine. These compounds neutralise reactive oxygen species (ROS), reduce oxidative stress, and modulate inflammatory responses within the CNS. In in vitro studies, white tea extracts have been shown to inhibit acetylcholinesterase activity, protect neurons from oxidative damage, and regulate the secretion of pro-inflammatory cytokines (TNF-α, IL-6), indicating their potential in the prevention of neurodegenerative diseases [Dias et al. 2013].

Baranowska-Wójcik et al. [2020] evaluated the ability of different types of tea to inhibit acetylcholinesterase (AChE) activity. All analysed infusions exhibited inhibitory effects, with white tea demonstrating one of the highest levels of inhibition, regardless of brewing temperature and duration. These findings suggest that regular consumption of white tea may support cholinergic system function and alleviate symptoms of cognitive impairment [Baranowska-Wójcik et al. 2020].

The bioactive constituents of white tea, particularly EGCG and theanine, exhibit multifaceted neuroprotective effects confirmed in preclinical models. These compounds reduce the aggregation of neurotoxic proteins such as β-amyloid and α-synuclein, enhance neuronal survival, increase the activity of antioxidant enzymes (SOD, catalase), and decrease levels of oxidative stress markers. Additionally, theanine modulates the levels of neurotransmitters – including GABA, dopamine,

and serotonin – thereby supporting mood regulation and neuroplasticity [Chen et al. 2018].

The CNS is particularly vulnerable to oxidative stress due to its high oxygen demand, substantial content of polyunsaturated fatty acids, and the presence of redox-active metals (Fe, Cu). Excessive levels of ROS and RNS lead to neuronal damage and the progression of neurodegeneration. Polyphenols, including EGCG, exhibit strong antioxidant and anti-inflammatory properties that protect neurons from injury. In Parkinson's disease models, regular tea consumption has been shown to reduce the risk of disease development [Sanlier et al. 2018].

In a comparative study of various tea types, white tea extract was shown to most effectively inhibit amyloidogenesis – one of the key mechanisms in the pathogenesis of neurodegenerative diseases. The polyphenols it contains modulate cellular proteostasis, reduce the formation of pathological protein aggregates, and activate mechanisms responsible for the degradation of misfolded proteins, thereby promoting neuronal protection [Wan et al. 2021].

EGCG, the principal polyphenolic component of white tea, exhibits multi-targeted neuroprotective activity. It reduces the aggregation of pathological proteins such as tau and Aβ, enhances autophagy, and modulates key cellular pathways including Nrf2–ARE, NF-κB, and MAPK. EGCG mitigates oxidative stress, neuroinflammation, and mitochondrial dysfunction, thereby decreasing Aβ cytotoxicity and inhibiting fibrillogenesis. Preliminary clinical findings suggest potential improvements in cognitive and motor functions, although its therapeutic efficacy is limited by low bioavailability [Amin et al. 2025].

Additionally, the polyphenols in white tea activate autophagic processes, facilitating the removal of damaged organelles and pathological protein aggregates. EGCG also increases the expression of brain-derived neurotrophic factor (BDNF), thereby supporting neurogenesis and synaptic plasticity. Improvements in mitochondrial metabolism and the strengthening of the blood–brain barrier further enhance the neuroprotective efficacy of white tea *in vivo* [Hong et al. 2022].

The collected evidence indicates that white tea, owing to its high content of polyphenols, catechins, and theanine, exhibits pronounced neuroprotective potential. These mechanisms include the reduction of oxidative stress, inhibition of neuroinflammatory processes, modulation of neurotransmission, and prevention of neurotoxic protein aggregation. Regular consumption of white tea may therefore serve as a meaningful component in the prevention of neurodegenerative diseases.

1.4. Effects on metabolism and weight regulation

Obesity represents a global health challenge and a major risk factor for lifestyle-related diseases such as type 2 diabetes, hypertension, atherosclerosis, and certain cancers. According to data from the Global Burden of Disease Group, the prevalence of obesity has doubled since 1980 in more than 70 countries, and the number of individuals with excess body weight has exceeded 2 billion, accounting for approximately 30% of the global population. Despite preventive efforts, this trend continues to rise, including among children. The primary mechanism underlying the development of obesity is a persistent imbalance between energy intake and expenditure, resulting in a positive energy balance [Caballero 2019; Mayoral et al. 2020].

The polyphenols present in tea, particularly catechins, exert beneficial effects on lipid metabolism and weight regulation by reducing fat absorption, enhancing lipid oxidation, and increasing energy expenditure. These effects have been confirmed in both *in vitro* and *in vivo* studies. Owing to its high concentration of bioactive compounds, white tea demonstrates particularly strong hypolipidemic activity – it lowers total cholesterol, LDL cholesterol, apolipoprotein B, and triglyceride levels, which translates into reductions in body weight, BMI, and adipose tissue content [Abiri et al. 2023; Yilmaz & Acar-Tek 2023].

In a randomised clinical trial by Akyildiz et al. [2024] involving 91 obese individuals (BMI ≥ 30 kg/m²), it was demonstrated that 12 weeks of regular white tea consumption (2 cups per day) significantly improved metabolic parameters. Reductions were observed in body weight, waist circumference, and BMI, along with improvements in lipid profile (decreases in TC, LDL, and TG, and an increase in HDL). Fasting glucose levels, markers of oxidative stress (MDA), pro--inflammatory cytokines (TNF-α, IL-6, IL-1β, MMP-9), and appetite-regulating hormones (leptin, ghrelin, asprosin) were also reduced. These findings confirm the beneficial effects of white tea on weight control and metabolic regulation [Akyildiz et al. 2024].

In animal models, white tea extract (WTE) has been shown to beneficially modulate lipid and energy metabolism. In mice with non-alcoholic fatty liver disease (NAFLD), supplementation with WTE (500–1000 mg/kg) for 12 weeks reduced body weight and adipose tissue content despite similar food intake. A decrease in hepatic steatosis, reductions in ALT, AST, TG, and TC levels, and activation of

genes involved in oxidative phosphorylation and ATP metabolism were observed, accompanied by the inhibition of lipogenesis. This effect was further supported by the normalisation of mTOR and IDH2 protein expression [Li et al. 2022].

In a study by Salem et al. [2023], a tea nanoformulation containing white tea was administered to rats with diet-induced obesity. After four weeks, a significant improvement in metabolic profile was observed, including reductions in glucose, insulin, triglycerides, and total cholesterol levels. At the molecular level, activation of the AMPK pathway and increased expression of SIRT1, GLUT-4, and PPAR-γ were noted, promoting improved glucose utilisation and reduced lipogenesis. Concurrently, decreases in TNF-α and the lipogenic transcription factor SREBP-1c were observed, confirming the anti-inflammatory and antilipogenic effects of white tea [Salem et al. 2023].

Nunes et al. [2015] demonstrated that 60 days of supplementation with white tea infusion in rats with induced prediabetic status improved glucose tolerance and insulin sensitivity, thereby reducing hyperglycemia. In the brains of these animals, lower concentrations of lactate and alanine were observed, indicating improved energy metabolism, along with reduced expression of the glucose transporters GLUT1 and GLUT3 [Nunes et al. 2015].

In a study by Zhou et al. [2025] using an obese rat model, supplementation with white tea extract significantly reduced weight gain, improved lipid, and glycemic profiles, and promoted the balance of the gut microbiota. An increase in beneficial bacteria such as *Akkermansia muciniphila* and *Bacteroides* was observed, along with a reduction in metabolites associated with lipogenesis and inflammation. These effects were stronger than those observed for dark tea, indicating a greater potential of white tea in improving metabolic homeostasis [Zhou et al. 2025].

Sun et al. [2019] demonstrated that 28 days of white tea consumption modulate bile acid metabolism by increasing the concentrations of beneficial fractions (murocholic acid and glycocholic acid) while simultaneously reducing levels of unfavourable metabolites such as taurolithocholic acid. The modulation of these pathways may support lipid metabolism, improve insulin sensitivity, and promote the maintenance of healthy body weight [Sun et al. 2019].

The collected evidence indicates that white tea may support metabolic regulation through multiple mechanisms, including the modulation of metabolic gene expression, activation of the AMPK and SIRT1 pathways, improvement of lipid profiles, reduction of inflammation, and beneficial effects on the gut microbiota.

Consequently, it may serve as a supportive component in the prevention and management of obesity and metabolic syndrome.

CONCLUSIONS

White tea constitutes a valuable source of bioactive compounds, primarily polyphenols, which exhibit a broad spectrum of health-promoting activities. Its chemical composition depends on cultivar, environmental conditions, and processing technology; however, it consistently features high levels of substances with antioxidant and anti-inflammatory properties. Numerous experimental studies have confirmed that white tea extracts may positively influence cardiovascular, neurological, and metabolic functions – by lowering lipid and glucose levels, modulating enzymatic activity, and regulating the expression of pro-inflammatory cytokines.

The compounds present in white tea, including catechins, L-theanine, and caffeine, demonstrate cardioprotective, neuroprotective, and anti-obesity effects and may support the maintenance of oxidative homeostasis. These properties make white tea a promising component of functional foods and a supportive element in the prevention of lifestyle-related diseases.

Despite the encouraging results of preclinical studies, well-designed clinical trials are still lacking to clearly determine the efficacy and bioavailability of the active constituents of white tea. Therefore, further research is essential to fully elucidate its preventive and therapeutic potential.

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THE EFFECT OF PH ON THE PERCEPTION OF BITTER TASTE OF FOOD INGREDIENTS

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Abstract

This study is concerned with determining the effect of the pH on the interpretation of bitter taste stimuli based on a selected group of bitter food components. Investigations were conducted for a group of bitter compounds selected from flavonols, flavones, and quinoline and methylxanthine alkaloids. Using sensory testing, the intensity of bitter taste (IBTs) was determined for taste mixtures containing constant concentrations of the bitter stimulus in buffers with acidic, neutral, and basic pH. The results of the study show that the relationship between the intensity of bitter taste (IBTs) and the pH level of mixtures of bitter components can be described with sigmoidal and exponential curves. The study also reveals that the bitter taste is well-masked in acidic pH environments, which results in low IBTs values. The effect of bitter taste masking has a weakening tendency along with changes in pH from neutral to basic. The study provides evidence demonstrating that even slight changes in the pH level can have a major impact on the perception of bitter taste of taste food ingredients. The study also used a predictive model for bitter taste (a proprietary pharmacophore technique –the so-called Simple Pharmacophore Model) to determine the predicted values of bitter taste intensities (IBTp). The results of this study showed that the predicted bitter taste intensities of the tested bitter product ingredients (IBTp) are comparable to the average bitter taste intensities (IBTs) determined by sensory analysis for neutral pH levels.

Keywords: bitter taste perception, taste quality bitter food components, Labelled Magnitude Scale (LMS), sensory analysis, Simple Pharmacophore Model (SPM).

INTRODUCTION

The taste system plays a fundamental role in stimulating living organisms to consume foods which are rich sources of energy (caloric content), electrolytes maintaining fluid homeostasis and amino acids which are involved in biosynthesis processes [Li et al. 2024]. The human taste perception system is very complex, and its sensitivity is determined by the genetic inheritance of taste senses, changes in the natural environment, quality of available food, taste acceptance and preferences, and a range of other inter-individual factors including age, health status and level of social awareness [Kikut-Ligaj & Trzcielińska-Lorych 2015; Pallante et al. 2021]. The basic functions of bitter taste are to protect the organism against toxic food components [Behrens & Meyerhof 2013; Liu et al. 2013; Lu et al. 2021]. On the other hand, many of the bitter compounds (e.g., flavonoids, furochromones, methylxanthines) are natural metabolites, antioxidants, antimycotic, antiviral and antibacterial drugs and psycho- and neurostimulants [Behrens & Meyerhof 2013; Luo et al. 2025]. As a rule, humans accept or prefer diets with low to moderate levels of bitterness and avoid highly bitter foods [Jiao et al. 2021]. Recent studies show that bitter taste is detected by a family of approximately ~30 receptor proteins (TAS2Rs) located in the bitter taste receptor cells ($BTRC_S$) [Li et al. 2024; Liu et al. 2013; Yang et al. 2021]. New research indicates that a half of bitter chemical compounds are identified by three types of receptor proteins: TAS2R10, TAS2R14 and TAS2R46 [Meyerhof et al. 2010; Ziegler et al. 2023]. The gustatory signals generated into all $BTRC_S$ are transmitted to the same brain field (see Figure 1) [Liu et al. 2013].

The G protein-coupled receptor is activated in the extracellular space of the $BTRC_S$ by an external signal in the form of a ligand or another signal mediator. An agonist (ligand) blocks the interactions of helices TM_1, TM_2, TM_4 and TM_6 (Figure1) stabilising the resting state of the receptor (inactive GPCR), and thus initiates GPCR transition into the active state (active GPCR). Activation of the basic structure (inactive) of the receptor initiated by ligand binding leads to a number of conformational changes which promote G protein binding on the intracellular side of the cell, further signal transduction and transmission. Even though the TAS2R proteins allow the detection of multiple bitter compounds, they do not provide the capacity to differentiate between them [Yarmolinsky et al. 2009; Ziegler et al. 2023], which is why humans are unable to distinguish between various bitter substances (unlike with smell) and are only capable of identifying variable intensities of

bitterness. Impulses generated by structurally different bitter ligands (food components) are averaged, which makes it possible to develop a variety of acceptability profiles for bitter taste in food products.

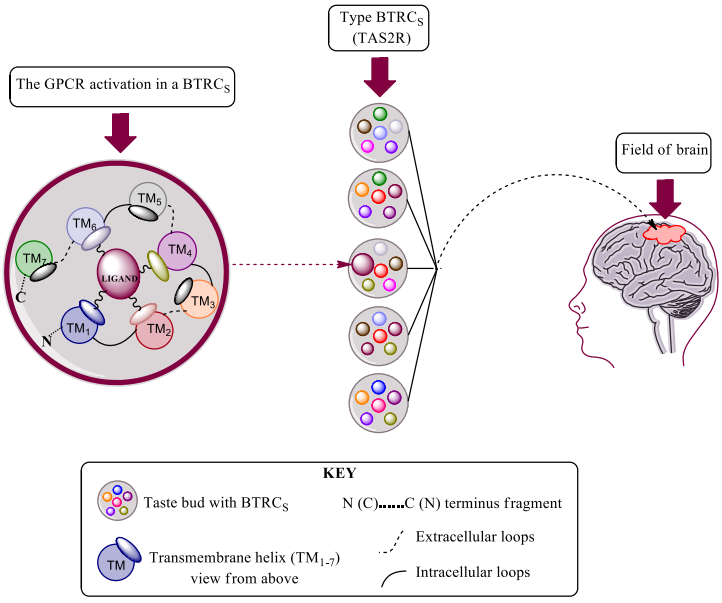


Figure 1. Transmission of bitter taste signals with TAS2Rs to the brain

Source: own study.

The intensity of bitter taste is particularly important for consumers since it determines their rejection or acceptance of foods, and thus allows for the differentiation between acceptable and potentially toxic taste compositions. Bitterness is a characteristic flavour quality of a variety of food products including beer, wine, citrus juices, tea, yerba mate, or chocolate. A multitude of chemical compounds (e.g., catechins, flavonols, or caffeine) [Gaudette & Pickering 2012; Soares et al. 2018] increase the functionality of food products; however high levels of bitterness minimise their acceptance by consumers [Lesschaeve & Noble 2005]. The situation has contributed to the development of a range of strategies (e.g., the addition of saccharose, cyclodextrins, or sodium chloride) aimed at improving the sensory profile (reducing bitter taste perception) of foods containing

an admixture of bitter taste, and thus increasing their acceptability to food consumers [Gaudette & Pickering 2012]. On the other hand, the consumption of foods containing excessive amounts of active and, at the same time, biotoxic compounds, and also NaCl, brings negative health effects. In view of the above, intentional supplementation of food products while maintaining their optimal sensory and health-promoting qualities is currently a major challenge faced by the food industry. The complexity of the perception of basic taste qualities (sweet, salty, sour, and bitter) in foods has contributed to the intensification of research focused on interactions existing between them in binary, ternary and quaternary mixtures [Choi et al. 2024; Green et al. 2010]. For example, investigations of two-component mixtures have shown that bitterness is suppressed both by sweet stimuli and sodium salts, whereas the sensation of sweetness can be suppressed both by sour and salty stimuli [Green et al. 2010].

Investigations of the course of psychophysical curves conducted by Keast show that an important property characterising taste-taste interactions are sigmoidal functions [Keast & Breslin 2002]. They hypothesised that the effect of mixing taste compounds are taste-taste interactions causing the suppression or enhancement of the intensity of the mixed taste quality. These interactions are characterised by the sigmoidally-shaped curve.

Sigmoidal curves can be constructed as three separate phases. Important modulators of sweet and bitter taste include organic and inorganic salts. The most recent studies have found that salts, i.e., magnesium sulphate, zinc sulphate, organic salts sodium acetate [Delompré et al. 2019], homoeriodictyol sodium salts – HED [Gaudette & Pickering 2012] – and inorganic sodium salts (sodium chloride), have a significant effect on the perception and reduction of bitter taste [Gaudette & Pickering 2012; Green et al. 2010]. The study of simple two-component (binary) and, in particular, complex ternary and quaternary mixtures conducted by Green et al. suggest that the suppression of negative taste stimuli (salty, bitter and sour) favours the perception of sweet carbohydrates in foods [Breslin & Beauchamp 1997].

The masking (suppression) of bitter taste and its associated enhancement of the sweet taste are experimentally verified facts which are underpinned by the need to supply the body with high-energy carbohydrates. An addition of sweet taste seems a key factor affecting the perception of multi-component taste mixtures. There is, however, a range of beverages (e.g., coffee, yerba mate, and various types of tea)

containing very low sugar concentrations and demonstrating a clear dominance of bitter taste over other taste qualities. The intensity of bitter taste (IBT) of such beverages depends primarily on the amount and composition of bitter components, and on the content of sodium salts.

In our view, the pH factor can also be a significant modulator of the intensity of bitter taste in such taste mixtures. The effect of the pH level on bitter taste perception can arise from the buffer characteristics of many sodium salts and their acids which are constituents of taste compositions. The hypothesis may be confirmed for taste mixtures containing constant concentrations of a bitter ligand over a range of buffer solutions with different acidic and basic pH values.

A second possibility for determining (predicting) the intensity of bitter taste (IBT) is provided by virtual screening techniques (VS) such as pharmacophore methods [Giordano et al. 2022]. Predicting to what extent product ingredients shape bitter taste is made possible by, among other things, the 3D pharmacophore technique [Seidel et al. 2018], referred to as the so-called Simple Pharmacophore Model (SPM) [Kikut-Ligaj & Ruda 2021].

SPM is a technique that compiles the affinity characteristics of groups of objects such as chemical compound molecules and transposes them into appropriate mathematical equations that verify quantitatively and qualitatively the occurrence of bitter taste activity [Kikut-Ligaj 2019; Kikut-Ligaj & Ruda 2021]. The models SPM--type disproportion (systematise) groups of bitter compounds in terms of taste intensity and, at the same time, verify which of the studied molecules do or do not exhibit bitter taste [Kikut-Ligaj 2019].

Using the author's SPM model, the intensities of bitter taste (IBT) were determined for the studied group of bitter food components in a neutral aqueous environment. The final result of the conducted research was the confirmation of the consistency of the results of sensory tests with the results of predictions obtained using the SPM model.

1. MATERIAL AND METHODS

1.1. Bitter compounds and biological activity

In addition to a large number of key dietary nutrients including proteins, lipids, carbohydrates, vitamins, and minerals, there is also a huge variety of non-nutritive biologically active and naturally bioactive components which contain a range of secondary plant metabolites such as inter alia, flavonoids, saponins, or terpenoids [Kumar et al. 2023]. Many of these groups of natural compounds exhibit bitter taste despite major differences in their chemical structure. In this study used six bitter compounds classified as flavanols (catechin, epicatechin), flavonols (quercetin), flavanones (naringenin), methylxanthine alkaloids (caffeine), and quinoline alkaloids (quinine) (see Figure 2).

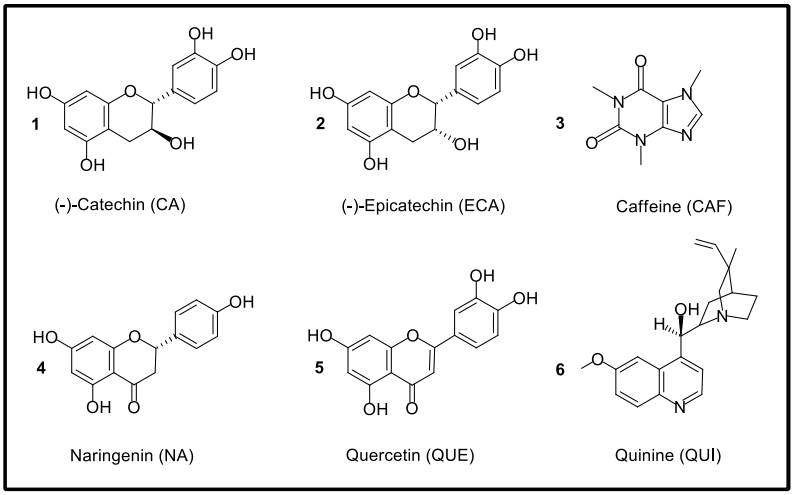


Figure 2. Structures of compounds under study (1–6)

Source: own study.

Compounds 1–6 used in the analyses were purchased from Sigma-Aldrich. All of the tested compounds have HPLC purity. The structures of the studied bitter ligands were prepared in ChemBioOffice.

1.2. Methodology for predicting of bitter taste activity

The structures of compounds 1-6have been optimised by the Density Functional Theory (DFT) method with B3LYP functional and 6–31G (2d, p) base [Biswas & Ganguly 2017; Kikut-Ligaj 2019; Tirado-Rives & Jorgensen 2008]. The presence of water as a solvent was stimulated with Conducting Polarized Continuum Model (CPCM) [Chen et al. 2010]. The obtained representative conformations (RC) of all structures of the studied compounds (1–6) were used by SPM pharmacophore analysis. In the pharmacophore analysis, the Gaussian and Ligand Scout programs were used.

The research procedure using the SPM model involved specifying the electronic characteristics and determining the individual pharmacophoric functions for the studied compounds. In this stage, the following pharmacophoric functions were determined: HBD – hydrogen bond donors, PI – positive ionization areas, HBA – hydrogen bond acceptors, NI – negative ionisation areas and π-electron subregions type aromatic-hydrophobic AR/H areas. All identified pharmacophore features were used in the descriptive analysis to determine the predicted intensity of bitter taste (IBT). The IBT values were determined as the sum of all characteristics pharmacophore such as: number of point interactions (NPI) represented by pharmacophore features and so-called the number of interactive stimulations (NIS) represented by three-centres pharmacophore representations [Kikut-Ligaj 2019].

1.3. Sensory analysis. Participants

The study involved a panel of fifteen expert sensory assessors (of both sexes) [EN ISO 8586:2023] having several years of experience in the assessment of a wide variety of food products [Le Berrre et al. 2013]. The panel's experts were selected and trained specifically with respect to their sensory ability, focusing in particular on the identification of bitter, sweet, salty, and sour taste [Le Berrre et al. 2013]. That is, the taste qualities that the vast majority of the products ingredients have. The panellists also received basic training in the identifying umami taste, metallic and aftertastes.

Moreover, the group of sensory panellists was previously involved in studies assessing the intensity of bitter taste in model sensory solutions of bitter taste and a range of other food products. Assessor selection was carried out using three types

of sensory tests such as the ability to recognise the quality of taste, to determine detection thresholds and difference thresholds. For the analysis of sensory data qualified candidates were selected who met the conditions of above tests in the range of sensory sensitivity. However, sensory sensitivity selected on the basis of tests and systematic training assessors is not a permanent feature. Therefore, every time before a sensory test requires monitoring. Monitoring for changes in taste perception was carried out through additional training (for the purposes of research, presentations of samples and uniform conditions for measurements), and every time quick questionnaire surveys (for the control preparation testers for sensory analysis) and the discussion of research results. The questionnaire on preparation testers included, among others, such declarations as: non-smoking of cigarettes; not using alcohol, a substance with a very intense smell (mainly cosmetics and food), strong coffee; being in a good mood and health, etc. The group of sensory panellists was tasked with ordering the study compounds on the basis of the perceived intensity of bitter taste (i.e., from not bitter –0 to strongest imaginable bitter –100). Sensory studies by the panel of testers were repeated fourfold in the development of the sensory evaluations taking into account the average values of the data obtained.

1.4. Sensory procedure

Sensory tests were conducted [ISO 3972:2011; ISO 6658:2017; ISO 8589:2007] with buffered solutions of the study compounds (1-6), using the sip-and--spit technique [Running & Hayes 2017]. All the analytical solutions used in tests contained the same and above-threshold amounts of the bitter ligands under study. Every analytical solution consisted of 0.014 g of a study ligands (1-6) dissolved in a mixture containing: 100 ml of an appropriate phosphate buffer (I-VI) and 900 ml of distilled water. The study ligands were used in very high sensory concentrations [Gaudette & Pickering 2012]. The buffers were used at appropriately low concentrations to minimise the detectability in the test solutions of other taste qualities (sour, salty) that could potentially interfere with the assessment of the intensity of bitter taste (IBT) of the study samples. Between tests of consecutive analytical samples there were breaks of several seconds during which the panellists rinsed their oral cavity with distilled water in order to eliminate aftertaste. The study was based on a hybrid scale, the so-called LMS (Labelled Magnitude Scale) [Green et al. 1996; Jones et al. 2017; Lim et al. 2009].

The presented scale is not a typical LMS scale (Figure 3). It contains a scale of categories established by Green [Green et al. 1996], however it differs in ranges of numerical values assigned to individual categories of bitter taste intensity.

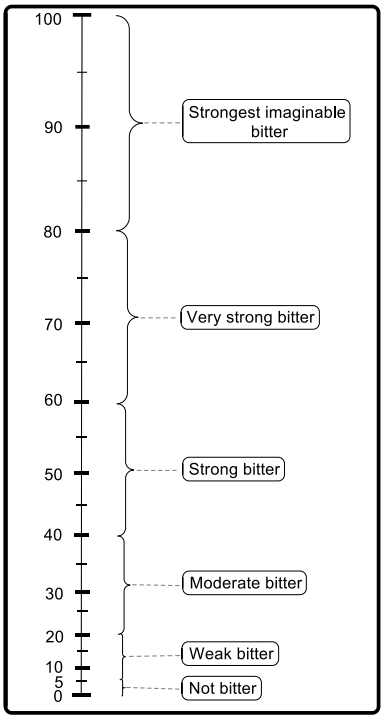


Figure 3. Structures of compounds under study (1-6)

Source: own study.

The adopted scale represents three different ranges: the strongest bitter stimuli for 40.1–100 points (strongest imaginable bitter, very strong bitter, and strong bitter), the weak and mild bitter stimuli for 5.1–40 points (weak moderate bitter and bitter), and the range of zero stimulus for 0–5 points (not bitter). The maximum verbal value (strongest imaginable bitter) was anchored at the numerical value of 90, and for successive categories a 20 point drop (identical in proportion) in the value of the stimulus was adopted (i.e. 70, 50, 30, 10). In these points, further verbal categories of bitter taste intensity were anchored. The numerical ranges for most categories were adopted at intervals of +10 points and –9.9 points from their anchoring places.

Exceptions are the weakest and the zero stimulus (weak bitter and not bitter). For the stimulus defined as 'not bitter', a range of 0–5 points (anchoring at 0) was designated, and for the 'weak bitter' category – a range of 5.1–20 points (anchoring at 10).

Verbal LMS values define areas of changes in the intensity of bitter stimuli, determining the correct ordering of analytical solutions. The LMS was adjusted so that the verbal ranges (with the exception of 'not bitter') corresponded to similar ranges of numerical values for the bitter stimuli. The sensory solutions were formulated using constant concentrations of bitter taste stimuli (1–6) with dynamically variable acidity. In this way, possible differences in the sensory perception of the bitter taste for acidic, neutral, and basic pH ranges of analytical solutions could be observed. For data analysis and professional graphing OriginLab software was used.

1.5. Preparation of analytical solutions

All analytical solutions were prepared with commercial phosphate buffers: KH_2PO_4 –Na_2HPO_4 and KH_2PO_4–NaOH (cf. Table 1). All the buffer solutions were diluted by adding 900 ml of deionised water to 100 ml of an appropriate phosphate buffer. As the next step, the pH level of prepared stock buffer solutions was checked three times using a pH meter (cf. Table 1).

Table 1. Stock phosphate solutions used in sensory tests

Sample No.	Type of buffer	pH_C of pure buffer	pH_R of diluted buffer (buffer /water – 1:9)	$\Delta pH = pH_r - pH_c$
I	$KH_2PO_4 - Na_2HPO_4$	5.8 ±0.02	5.97 ±0.02	+0.17
II	$KH_2PO_4 - Na_2HPO_4$	6.0 ±0.05	6.44 ±0.04	+0.44
III	$KH_2PO_4 - Na_2HPO_4$	6.8 ±0.02	7.02 ±0.02	+0.22
IV	$KH_2PO_4 - Na_2HPO_4$	7.0 ±0.05	7.04 ±0.05	+0.04
V	KH_2PO_4 – NaOH	7.2 ±0.02	7.31 ±0.00	+0.11
VI	KH_2PO_4 – NaOH	7.4 ±0.05	7.47 ±0.02	+0.07

Source: own study on the basis Kikut-Ligaj 2015.

The stock buffers were used to prepare six series of analytical solutions: CA1-CA6, ECA1-ECA6, NA1-NA6, QUE1-QUE6, CAF1-CAF6, QUI1-QUI6 (Table 2). Each test series contained a constant concentration (0.014 g/l) of one of the bitter compounds under study, i.e., catechin, epicatechin, naringenin, quercetin, caffeine, and quinine. All the test series were checked three times to verify their pH level (cf. Table 2).

Table 2. Analytical series CA1-CA6, ECA1-ECA6, NA1-NA6, QUE1-QUE6, CAF1-CAF6, QUI1-QUI6 with the average pH values of the samples

Catechin		Epicatechin		Naringenin		Quercetin		Caffeine		Quinine	
Sample name	pH	Sample name	pH	Sample name	pH	Sample name	pH	Sample name	pH	Sample name	pH
CA1	6.13 ±0.02	ECA1	6.14 ±0.01	NA1	6.07 ±0.01	QUE1	6.07 ±0.00	CAF1	6.02 ±0.01	QUI1	6.15 ±0.02
CA2	6.54 ±0.01	ECA2	6.53 ±0.02	NA2	6.49 ±0.02	QUE2	6.47 ±0.02	CAF2	6.45 ±0.03	QUI2	6.61 ±0.02
CA3	7.12 ±0.03	ECA3	7.12 ±0.02	NA3	7.15 ±0.01	QUE3	7.10 ±0.02	CAF3	7.08 ±0.02	QUI3	7.19 ±0.00
CA4	7.17 ±0.03	ECA4	7.17 ±0.00	NA4	7.17 ±0.01	QUE4	7.11 ±0.01	CAF4	7.09 ±0.02	QUI4	7.18 ±0.01
CA5	7.41 ±0.03	ECA5	7.41 ±0.02	NA5	7.36 ±0.00	QUE5	7.35 ±0.02	CAF5	7.33 ±0.01	QUI5	7.49 ±0.02
CA6	7.56 ±0.02	ECA6	7.56 ±0.03	NA6	7.52 ±0.02	QUE6	7.50 ±0.01	CAF6	7.48 ±0.03	QUI6	7.55 ±0.01

Source: own study on the basis Kikut-Ligaj 2015.

The series of analytical solutions defined above (Table 2) were used in sensory tests performed using the sip-and-spit technique (rinsing the oral cavity with the analytical solution) to evaluate the intensity of bitter taste (IBT). The sensory evaluations of the test solutions were conducted at a constant room temperature (21–22°C).

1.6. Data analysis

The statistical analysis of study results was performed with Origin 10.0. The variation in pH measurements and sensory evaluations was analysed statistically with a one-factor analysis of variance (ANOVA). The significance level for pH measurements was set at $\alpha = 0.01$, and for sensory evaluation at $\alpha = 0.05$. The psychophysical (sigmoidal and exponential) curves and values of normative coefficients of determination (Adj. R-Square) were calculated with Boltzmann function using Origin 10.0.

2. RESULTS AND DISCUSSION

2.1. Study of the effect of pH level on bitter taste perception using sensory analysis

The results of the sensory studies of the six series of analytical solutions (catechin, epicatechin, naringenin, quercetin, caffeine, and quinine) are presented in Table 3. The presented value of intensity of bitter taste to individual samples are the mean of 15 sensory assessments. The average values of intensity of bitter taste correspond to the mean pH value of the analytical solutions.

Table 3. pH and sensory values of the intensity of bitter taste for analytical solutions studied, compounds 1–6

Sample Name	pH	Sensory values of the intensity of bitter taste	Sample name	pH	Sensory values of the intensity of bitter taste
Catechin			Epicatechin		
CA1	6.13 ±0.02	10.0 ±3.7	ECA1	6.14 ±0.01	7.1 ±1.9
CA2	6.54 ±0.01	7.5 ±3.9	ECA2	6.53 ±0.02	5.7 ±1.3
CA3	7.12 ±0.03	12.5 ±5.3	ECA3	7.12 ±0.02	27.1 ±2.9
CA4	7.17 ±0.03	55.0 ±3.3	ECA4	7.17 ±0.00	52.9 ±2.8
CA5	7.41 ±0.03	77.5 ±3.7	ECA5	7.41 ±0.02	70.0 ±4.4
CA6	7.56 ±0.02	77.5 ±5.2	ECA6	7.56 ±0.03	87.1 ±2.9
Quercetin			Naringenin		
QUE1	6.07 ±0.00	1.4 ±1.4	NA1	6.07 ±0.01	10.0 ±1.8
QUE2	6.47 ±0.02	8.6 ±1.4	NA2	6.49 ±0.02	17.2 ±1.9
QUE3	7.10 ±0.02	30.0 ±3.3	NA3	7.15 ±0.01	12.9 ±3.0
QUE4	7.11 ±0.01	70.0 ±6.2	NA4	7.17 ±0.01	60.0 ±2.9
QUE5	7.35 ±0.02	78.6 ±6.0	NA5	7.36 ±0.00	83.1 ±4.0
QUE6	7.50 ±0.01	71.4 ±5.9	NA6	7.52 ±0.02	86.7 ±4.0
Caffeine			Quinine		
CAF1	6.02 ±0.01	27.1 ±1.9	QUI1	6.15 ±0.02	22.4 ±1.7
CAF2	6.45 ±0.03	25.1 ±1.9	QUI2	6.61 ±0.02	28.0 ±1.9
CAF3	7.08 ±0.02	44.9 ±2.2	QUI3	7.19 ±0.00	41.4 ±2.1
CAF4	7.09 ±0.02	40.2 ±2.3	QUI4	7.18 ±0.01	40.4 ±2.3
CAF5	7.33 ±0.01	59.0 ±2.0	QUI5	7.49 ±0.02	61.4 ±2.8
CAF6	7.48 ±0.03	78.0 ±2.4	QUI6	7.55 ±0.01	78.6 ±2.8

Source: own study on the basis Kikut-Ligaj 2015.

2.2. Catechin and epicatechin

The test solutions containing catechin (CA1-CA6) and epicatechin (ECA1--ECA6) were subjected to sensory evaluation which made it possible to determine the mean values of the intensity of bitter taste (IBT). The mean IBT values obtained in this way were then compared with the mean pH values of the analytical solutions under study (Figure 4).

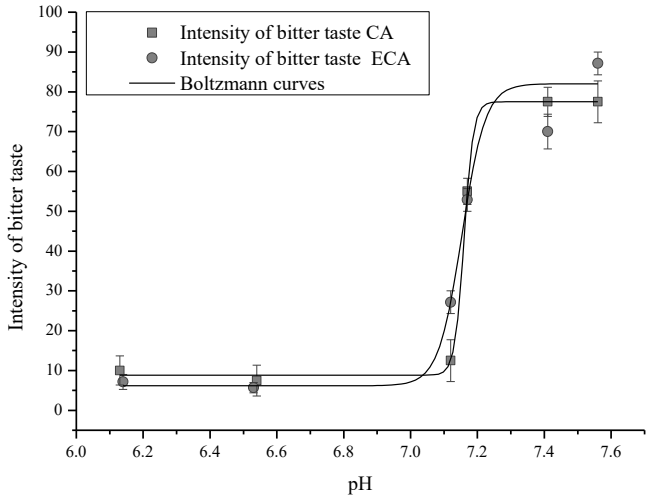


Figure 4. Sigmoidal psychophysical curves defining the correlation between pH and IBT for analytical solutions of catechin (CA) and epicatechin (ECA)

Source: own study.

The analytical solutions of catechin and epicatechin both gave rise to psychophysical curves described with Boltzmann sigmoidal functions. The plotted above psychophysical curves demonstrated values of normative coefficients of determination (Adj. R-Square) RS = 0.9984 for catechin and RS = 0.9717 for epicatechin.

2.3 Quercetin and naringenin

The mean values of the intensity of bitter taste (IBT) were determined for analytical solutions having the same concentrations of quercetin (QUE1-QUE6) and

naringenin (NA1-NA6). The comparison of the mean pH values with the mean IBT values obtained for the test solutions resulted in sigmoidal curves (Figure 5).

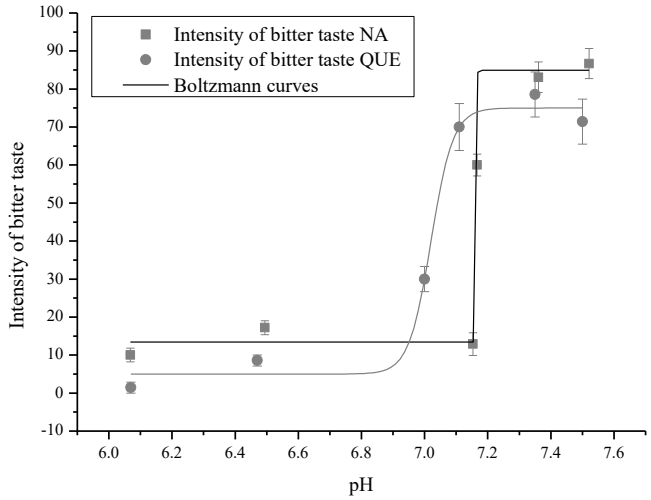


Figure 5. Sigmoidal psychophysical curves defining the correlation between pH and IBT for analytical solutions of quercetin (QUE) and naringenin (NA)

Source: own study.

The above psychophysical curves characterise the relationship of bitter taste and the pH analytical of the solutions described with Boltzmann functions. Normative coefficients of determination calculated for the above sigmoidal function models were for quercetin RS = 0.9185 and naringenin RS = 0.9704.

2.3. Caffeine and quinine

Analytical solutions containing a constant concentration of caffeine (CAF1--CAF6) and quinine (QUI1-QUI6) were subjected to sensory evaluation to determine the mean values of the intensity of bitter taste (IBT). The mean IBT values obtained in this way were then compared with the mean pH values of the analytical solutions under study (Figure 6).

The comparison of the mean pH values and the mean IBT values obtained for the test solutions is illustrated in the exponential curves shown in Figure 6.

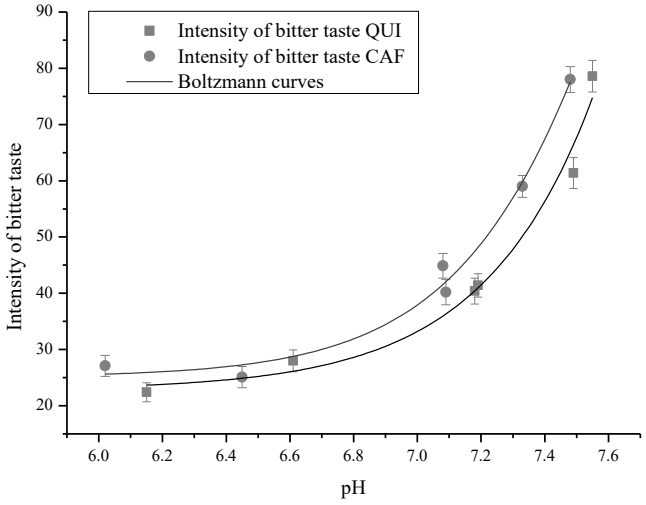


Figure 6. Exponential psychophysical curves defining the correlation between pH and IBT for analytical solutions of caffeine (CAF) and quinine (QUI)

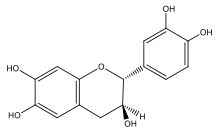
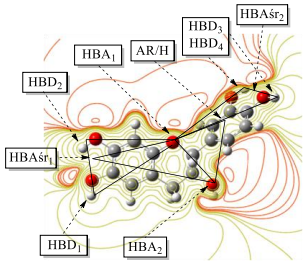
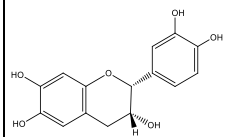
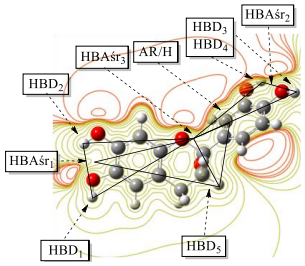
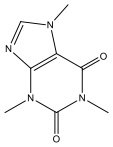
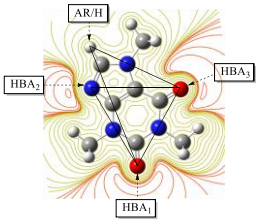
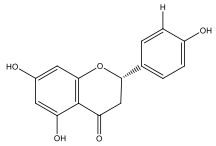
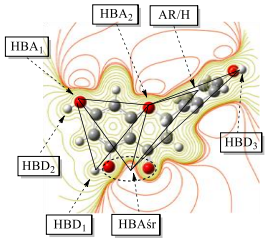
Source: own study.

The exponential curves (Figure 6) illustrate the relationship between bitter taste and the pH of the analytical solutions described with Boltzmann functions. Normative coefficients of determination for the above models of exponential functions (Figure 6) were for caffeine RS = 0.9721 and for quinine RS = 0.9576, respectively.

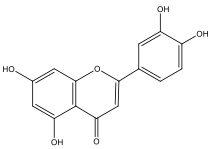
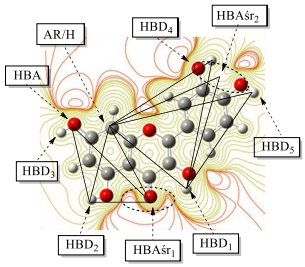
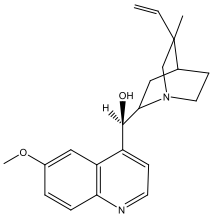
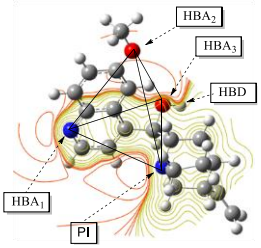
2.4. Prediction (SPM model) and sensorics values intensity of the bitter taste for studied compounds

The results of the prediction of bitter taste (IBTp) in a neutral aqueous environment, together with the values determined by the method sensory test (IBTs – average value for samples 3 and 4) for compounds 1–6 tested, are included in Table 4.

Table 4. Identification of pharmacophoric features and representations for studied compounds

Name and structure of bitter compound	Location pharmacophore features and electrostatic potential	Separated tree--centers pharmacophore representations	Sensory IBT_s and predicted IBT_P ($\sum NPI + \sum NIS$) x k) values
Catechin /1 		HBD_1-HBD_2-HBA_1 HBA_2-$HBAśr_1$-HBA_1 HBA_1-HBD_3-HBD_4 HBA_2-HBA_1-AR/H	33.75 ±4.27 (9 + 4) x 3.4 = 44.2
Epicatechin /2 		HBD_1-HBD_2-$HBAśr_3$ HBD_5-$HBAśr_1$-$HBAśr_3$ HBD_5-$HBAśr_3$-AR/H $HBAśr_2$-HBD_3-HBD_4	40.0 ±2.86 (9 + 4) x 3.4 = 44.2
Caffeine /3 		HBA_1-HBA_2-HBA_3 HBA_3-HBA_1-HBA_2 HBA_2-HBA_3-HBA_1 HBA_1-HBA_3-HBA_2 HBA_2-HBA_1-HBA_3 HBA_3-HBA_2-HBA_1 AR/H-HBA_1-HBA_3	42.55 ±2.23 (4 + 7) x 3.4 = 37.4
Naringenin /4 		HBAśr-HBA_1-HBA_2 HBAśr-HBD_2-HBA_2 HBD_1-HBA_1-HBA_2 HBD_1-HBD_2-HBA_2 HBAśr-HBA_2-AR/H HBAśr-HBA_2- HBD_3	41.43 ±5.22 (7+6) x 3.4 = 44.2

cont. Table 4

Quercetin/5 		HBAśr$_1$-HBD$_2$-HBD$_3$ HBAśr$_1$-HBD$_2$-HBA HBAśr$_1$-HBD$_2$-AR/H HBD$_1$- AR/H-HBD$_4$ HBD$_1$- AR/H- HBAśr$_2$ HBD$_1$- AR/H-HBD$_5$	50.0 ±4.74 (9 + 6) x 3.4 = 51
Quinine/6 		PI-HBA$_1$-HBD PI-HBA$_1$-HBA$_3$ PI-HBA$_1$-HBA$_2$ HBA$_1$-HBA$_2$-HBA$_3$ HBA$_1$-HBA$_2$-HBD PI-HBA$_2$-HBD PI-HBA$_2$-HBA$_3$	40.7 ±2.21 (5 + 7) x 3.4 = 40.8

Source: own study.

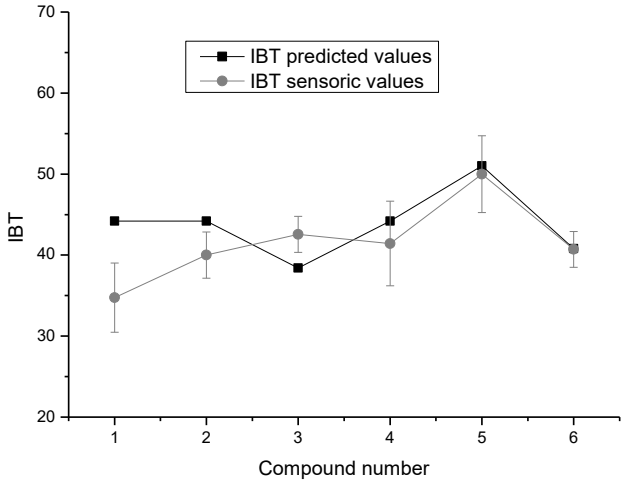


Figure 7. Predicted and sensorics intensity of the bitter taste values for studied compounds

Source: own study.

Illustrations of the changes in the predicted (IBTp) and sensory (IBTs) bitter taste intensity values are shown in Figure 7. The IBTp values included in Figure6were determined in a neutral aqueous environment and the sensory IBTs values represent the average value of the taste indices determined for the pH of samples 3 and 4 (close to neutral pH).

CONCLUSIONS

Differences in bitter taste perception for weakly acidic, neutral, and basic pH ranges were investigated for a group of bitter ligands belonging to flavonols, flavones, and quinoline and methylxanthine alkaloids. The relationship between the intensity of bitter taste (IBT) and the pH level of mixtures of these compound groups and appropriate phosphate buffers is described with sigmoid and exponential psychophysical curves. Studies show that buffered taste mixtures (in weakly acidic, neutral, and basic pH ranges) containing constant concentrations of a bitter stimulus and deprived of sweet taste stimuli demonstrate varying intensities of bitter taste. Generally, the results obtained in the study suggest that the pH level is a major modulator of the intensity of bitter taste (IBT) in taste mixtures containing phosphate buffers and bitter compounds. The buffer mixtures used are excellent at masking bitter taste when the pH level is acidic, giving rise to low IBT values. Neutral and weakly basic pH levels, however, produce multiple reinforcement of bitter taste intensity. The studies also show that taste mixtures containing constant concentrations of bitter ligands can be interpreted by the taste system as weakly, moderately, and strongly bitter depending on taste mixture composition. Even minor changes in pH level have a significant impact on the perception of bitter taste in mixtures of this type.

A moderate (average) IBT value characterises catechin, epicatechin, quercetin, naringenin, caffeine, and quinine solutions at neutral pH, as confirmed by both sensory tests and predictions obtained using the SPM method.

The study reported above provided valuable insights allowing the control of bitter taste in food products and beverages. Further research is necessary to fully elucidate relationships existing between pH levels of taste mixtures and the perception of bitter taste stimuli.

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SELECTED ASPECTS OF BOVINE MILK PRODUCTION

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Abstract

The aim of this study was to analyse selected aspects related to milk production in Poland, focusing on the structure of dairy farms in terms of land area, milk output, and the scale of milk collection, processing, and dairy consumption. Special attention was given to structural changes among milk producers in the Mazovian region between 2010 and 2020, as well as to the economic conditions influencing these activities, which are crucial for the sustainable development of the sector.

The study also considered the impact of two major events: the COVID-19 pandemic and the war in Ukraine highlighting the significant influence such occurrences have on milk production.

Keywords: bovine milk, milk production, dairy products, farm structure.

INTRODUCTION

Milk production represents one of the fundamental components of the agricultural sector in Poland, playing a significant role in both the national agri-food economy and the income structure of agricultural households. Poland ranks among the leading milk producers in the European Union, and the dynamic changes within this sector reflect not only global trends but also local economic, environmental, and technological conditions.

In the context of increasing consumer demands, tightening sanitary and hygienic standards, and the progressive mechanisation and automation of production, dairy farming is becoming increasingly complex and capital-

-intensive. Moreover, issues related to environmental protection and the concept of sustainable development are gaining importance, necessitating the modification of traditional livestock breeding methods and farm management practices.

An important component of the value chain in the dairy sector is the milk processing industry, broadly encompassing dairy products such as cheese, yogurt, kefir, butter, and powdered milk. The Polish dairy industry is characterised by a wide product assortment and growing export potential, which plays a crucial role in enhancing the sector's competitiveness on inter-national markets. The high quality of raw milk and the advancement of processing technologies contribute to the growth of added value and the increasing significance of processing within the overall structure of the dairy sector.

Between 2010 and 2020, significant transformations were observed in the structure of farms engaged in milk production, both at the national and regional levels. In the Mazowian Voivodeship, one of the most important dairy regions in Poland a clear consolidation of production occurred: the number of small farms declined, while the share of medium and large production units increased. This trend corresponds to the nationwide direction of changes driven by the pursuit of greater production efficiency and adaptation to the requirements of the European Union's Common Agricultural Policy. This process also brought about spatial, economic, and technological transformations within the regional milk production structure.

During the analysed period, the volume of milk production in the Mazovian region also underwent changes. Despite the decreasing number of farms involved in dairy cattle husbandry, the total milk production volume remained relatively stable or even showed an upward trend. This phenomenon resulted from increased productivity per cow, improved animal housing conditions, and wider adoption of modern technologies in feeding, genetics, and herd management. As a region with a strong dairy potential, Mazovian has maintained its significant role in Poland's milk production structure, exemplifying a successful modernisation process while adapting to evolving market conditions.

In the context of economic analysis, various factors determine the profitability of milk production. The most important include production costs (e.g., feed, energy, labour, infrastructure investments), purchase prices of milk, the availability of agricultural subsidies, and the efficiency of resource utilisation (land, capital, technology). Additionally, market variables such as domestic and foreign demand, raw material price volatility, and EU trade policy play a crucial role. An economic

analysis of milk production enables the assessment of farm profitability as well as their adaptive capacity to changing market and environmental conditions.

The objective of this study was to analyse selected aspects of milk production in Poland, in particular its production structure, economic efficiency, and the impact of environmental and regulatory factors on the functioning of the dairy sector. Special attention was paid to structural and quantitative transformations in milk production in the Mazovian region during the years 2010–2020, as well as to the economic conditions of this activity, which are of key importance for the sustainable development of the sector. The analysis was based on data published by the Central Statistical Office of Poland (GUS), including results from the Agricultural Censuses conducted in 2010 and 2020.

1. STRUCTURAL CHANGES IN FARMS IN THE MAZOVIAN REGION AGAINST THE BACKDROP OF POLAND IN THE PERIOD 2010–2020

Polish agriculture continues to evolve, yet improvements in production efficiency occur gradually. Globally, agricultural productivity has been stagnating due to a combination of traditional practices, climate change, and various socio-economic and environmental phenomena [Fróna et al. 2021]. Despite ongoing challenges in the agricultural product markets, farm owners strive to maximise yields and agricultural output, even as the total area of arable land increases only slightly.

According to preliminary data from the Agricultural Census conducted in 2020 by the Central Statistical Office of Poland (GUS), the total number of agricultural holdings in Poland amounted to approximately 1.317 million, marking a decrease of nearly 13% compared to the results of the 2010 Agricultural Census representing a reduction of around 190,000 farms [PSR 2010; PSR 2020].

As noted by Stańko and Mikuła [2016], the competitiveness of Polish agriculture is directly influenced by the size of the agricultural area owned by farms. The authors argue that the capacity for economic development increases with the expansion of farm size. However, they also observe that the structural shift toward larger farms is occurring more slowly in Poland than in many other EU member states.

An analysis of the average farm size across different voivodeships in Poland (Table 1) indicates that the national average farm size increased by 0.8 hectares

during the period 2010–2020, reaching 11.04 hectares. In the Mazowian Voivodeship specifically, the average farm size in-creased by 0.34 hectares, reaching 8.77 hectares [PSR 2020].

Table 1. Farm size in Poland in the years 2010–2020, in hectares

Voivodeship	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Lower Silesia	15.72	16.01	16.05	16.01	16.22	16.21	16.30	16.46	16.72	17.10	17.29
Kujawsko--pomorskie	15.01	15.04	15.04	15.14	15.30	15.40	15.51	15.77	16.14	16.43	16.58
Lubelskie	7.40	7.46	7.45	7.50	7.54	7.58	7.65	7.73	7.86	7.93	7.98
Lubuskie	20.32	20.82	20.78	20.75	20.92	20.94	21.14	21.18	21.52	21.90	22.29
Łódzkie	7.42	7.49	7.52	7.57	7.61	7.62	7.67	7.72	7.84	7.92	7.98
Małopolskie	3.83	3.86	3.88	3.92	3.95	3.98	4.02	4.04	4.10	4.13	4.16
Mazovian	**8.44**	**8.52**	**8.50**	**8.51**	**8.55**	**8.52**	**8.54**	**8.57**	**8.68**	**8.75**	**8.77**
Opolskie	17.83	18.00	17.99	18.12	18.22	18.21	18.30	18.51	18.69	19.02	19.16
Podkarpackie	4.47	4.54	4.56	4.60	4.63	4.71	4.73	4.77	4.83	4.90	4.94
Podlaskie	12.11	12.22	12.20	12.23	12.24	12.13	12.19	12.27	12.44	12.51	12.55
Pomorskie	18.84	19.00	18.94	18.95	19.00	19.02	19.09	19.16	19.42	19.58	19.62
Silesia	6.83	7.01	7.14	7.24	7.37	7.42	7.56	7.70	7.85	8.02	8.14
Świętokrzyskie	5.42	5.49	5.49	5.53	5.57	5.57	5.63	5.67	5.77	5.82	5.88
Warmińsko--mazurskie	22.95	23.07	22.88	22.90	22.92	22.76	22.70	22.79	23.05	23.25	23.25
Wielkopolskie	13.43	13.47	13.41	13.46	13.51	13.43	13.49	13.56	13.74	13.99	14.09
Zachodnio-pomorskie	30.30	30.70	30.67	30.20	30.29	30.00	30.20	30.35	30.78	31.44	31.75
Whole country	**10.23**	**10.36**	**10.38**	**10.42**	**10.48**	**10.49**	**10.56**	**10.65**	**10.81**	**10.95**	**11.04**

Source: ARiMR 2021.

The largest farms in terms of utilised agricultural area are located in the western and northern parts of the country. The highest average farm size is recorded in the Zachodniopomorskie Voivodeship at 30.30 hectares. The smallest farms are found in the Małopolskie, Podkarpackie, and Świętokrzyskie Voivodeships. In the Mazovian region, the average farm size remains below the national average.

According to Szymańska and Maj [2018], structural changes related to farm size are occurring slowly due to restrictive land use regulations governing agricultural land resources.

According to the European Farm Accountancy Data Network (FADN) [2021], in 2019, arable farms accounted for 43% of all agricultural holdings in Poland. Mixed farms engaged in both crop and livestock production represented the second largest group at 28%, followed by dairy cattle farms, which constituted 12% of all holdings.

An important factor for analysing changes in farm area is the distribution of farms according to the size of utilised agricultural area (UAA), presented in specific area groups (Figure 1). The most numerous categories of farms both in Poland as a whole and in the Mazovian Voivodeship are those with an area ranging from 5.00 to 9.99 hectares and from 10.00 to 14.99 hectares [PSR 2020]. According to Pawlak and Poczta [2010], this structural distribution remains a weakness of Polish agriculture. In their view, farm fragmentation is diminishing too slowly.

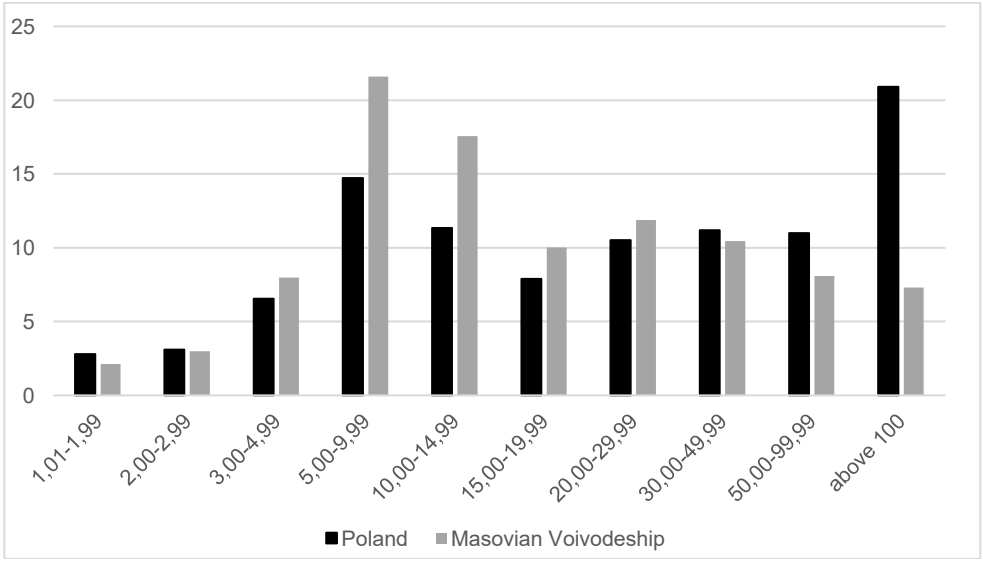


Figure 1. Percentage structure of agricultural area in 2019 by areagroup

Source: PSR 2020.

Although a decade has passed since the research by the aforementioned authors, a comparison of the data from the 2010 and 2020 Agricultural Censuses (PSR) reveals only a slight decrease approximately 16% in the number of farms with less than 15 hectares of UAA. At the same time, there was a marginal increase of about 6% in the number of farms exceeding 15 hectares of UAA [PSR 2010; PSR 2020].

A different perspective is offered by Krasowicz and Matyka [2021], who argue that even a modest increase in the number of medium and large farms contributes to improved efficiency in agricultural production.

2. CHANGES IN MILK PRODUCTION VOLUME IN THE MAZOVIAN REGION IN THE PERIOD 2010–2020

The United Kingdom's exit from the European Union contributed to Poland becoming the fourth-largest milk producer among EU countries, with its share increasing from 8.07% to 8.87%. According to research by Stanuch and Firley [2021], the average growth rate of milk production in Poland between 2015 and 2019 was approximately 2.3%. As reported by the National Support Centre for Agriculture (KOWR), Poland ranks among the top EU countries in terms of dairy cattle population following Germany and France [KOWR 2023].

Milk production also plays a significant role in national agricultural output. During the COVID-19 pandemic a particularly challenging period for the economy dairy production and milk procurement increased by approximately 3%, while dairy exports were maintained at levels comparable to the previous year. This growth in the dairy sector was observed despite an 8.2% decline in gross domestic product (GDP) in the second quarter of 2020 (compared to a 4.6% increase during the same period in 2019) [GUS 2021]. According to Rutkowski [2020], the resilience of the Polish dairy sector played a tangible role in mitigating the economic contraction of GDP.

Between 2011 and 2019, national milk production increased by 16.91%, corresponding to a growth of over 2 million litters of raw milk. For many years, the Mazovian Voivodeship has held a key position in Polish milk production. In 2019, compared to 2011, this region saw a substantial increase in raw milk output by approximately 0.75 million liters [GUS 2021]. The Podlaskie Voivodeship ranked second in terms of both milk production and dairy cattle population.

High-yielding dairy herds in this region contributed significantly to its production volumes. In 2019, the average milk yield per cow in Podlaskie was 6,497 liters annually, slightly higher than in the Mazovian Voivodeship, where the average yield per cow was 6,416 liters per year (Table 2) [GUS 2021].

Biological progress in dairy cattle breeding and technological advancements in feeding and animal husbandry have led to increases in milk yield per cow [Ziętara 2010]. Furthermore, the increase in milk production has been supported by a favourable euro exchange rate, stimulating export activity. The abolition of milk quotas, along with access to EU funds for farm restructuring and the rational use of farm resources, also contributed to the rise in raw milk output [Bórawski & Zalewski 2018].

Despite the general growth in national milk production, the scale of production at the individual farm level remains relatively small [Parzonko 2018]. In Poland, most milk is produced by farms with up to 10 cows [GUS 2021]; however, the number of such farms declined by 68% between 2002 and 2016. At the same time, the number of farms with more than 10 cows increased from 56,200 to 95,400 an increase of 52% [Bórawski & Zalewski 2018].

Table 2. Cow's milk production volume in 2011–2019 in terms of selected production parameters in terms of milk production volume in Poland

Area	Volume of milk production in thousand litres					Average number of dairy cows in heads	Average milk yield per cow in litres
Year	**2011**	**2013**	**2015**	**2017**	**2019**	**2019**	**2019**
Poland	**12052229**	**12347993**	**12859447**	**13304646**	**14089924**	**2200827**	**6402**
Lower Silesia	182566	189345	190620	180876	180657	25567	7066
Kujawsko-pomorskie	868598	871634	928277	934962	1055089	149375	7063
Lubelskie	721616	702533	782713	810135	807830	123020	6567
Lubuskie	118809	107929	85188	98457	84894	13100	6480
Łódzkie	957022	948549	981535	1032079	1096359	179444	6110
Małopolskie	347019	352257	324609	299815	285001	75802	3760
Mazovian	**2650313**	**2658480**	**2794268**	**2826162**	**3301849**	**514644**	**6416**
Opolskie	257193	246854	266570	277209	277422	38718	7165

cont. Table 2

Podkarpackie	253701	245249	230387	205806	160866	36858	4364
Podlaskie	2197602	2360786	2564834	2732153	2822924	434495	6497
Pomeranian	306778	358509	350396	362338	371826	57335	6485
Silesia	211519	241140	240806	259104	270178	43019	6280
Świętokrzyskie	383885	266444	256377	236475	217727	47644	4570
Warmińsko-mazurskie	941715	886685	959567	1075175	1031414	168116	6135
Wielkopolskie	1474354	1753273	1731166	1838398	1963651	269953	7274
Zachodniopomorskie	179539	158326	172134	135502	162237	23735	6835

Source: GUS 2019.

3. MILK PROCUREMENT PRODUCTION, AND DAIRY PRODUCT CONSUMPTION IN POLAND

Over the past decade, the value of agricultural product procurement in Poland has generally increased, with the exception of eggs (Table 3). The growth in milk procurement has been associated with the rising production of processed goods, including dairy products [Krasowicz & Matyka 2021]. To illustrate the market position of dairy products within the broader agricultural sector, the values of their procurement between 2010 and 2020 have been compared (Table 3).

A shift in the proportion between plant-based and animal-based product procurement was observed during this period. In 2010, the value of procurement for plant products was approximately twice that of animal products (ratio 1:2). However, by 2020, a clear shift occurred in favour of animal products, with the ratio increasing to 1:2.18 (Table 3). Among the animal-origin products on the agricultural market, milk recorded the highest growth in procurement value [Herbut & Walczak 2015]. According to Statistics Poland (GUS), the procurement of raw milk increased by over 30% in 2020 compared to 2010 (Table 3).

Table 3. Purchase value of selected agricultural products in 2010–2020

Specification	Unit of measurement	2010	2015	2019	2020
Purchase value of agricultural products (current prices)	PLN million	41324.5	57040.2	65594.6	67210.9
Products: plant	PLN million	13777.6	18600.1	19152.1	21124,7
Products: animal	PLN million	27546.9	38440.1	46442.5	46086.2
Slaughter livestock in terms of meat (including carcasses)	Thousand tonnes	3161.8	4083.4	4558.0	4678.0
Milk	Million liters	8760.9	10567.4	11827.9	12108.8
Consumer hen' seggs	Million pcs	1813.2	1079.2	823.2	525.0

Source: CSO 2021.

An increase in the procurement of raw milk did not directly translate into higher milk consumption. Within the dairy product category, consumption rose primarily for processed dairy goods such as yogurts, curd cheeses, aged cheeses, and dairy-based desserts, which was closely related to the growth in milk procurement [Woźniak 2018]. According to data from Statistics Poland (GUS) [2021], during the past decade there has been a significant decline in the consumption of milk as a standalone product 20% less in 2019 compared to 2010. As illustrated in Figure 2, an increase in milk consumption was observed only in 2010.

Komor et al. [2020] reported a downward trend in dairy product consumption in Poland between 2008 and 2017, identifying the following factors:

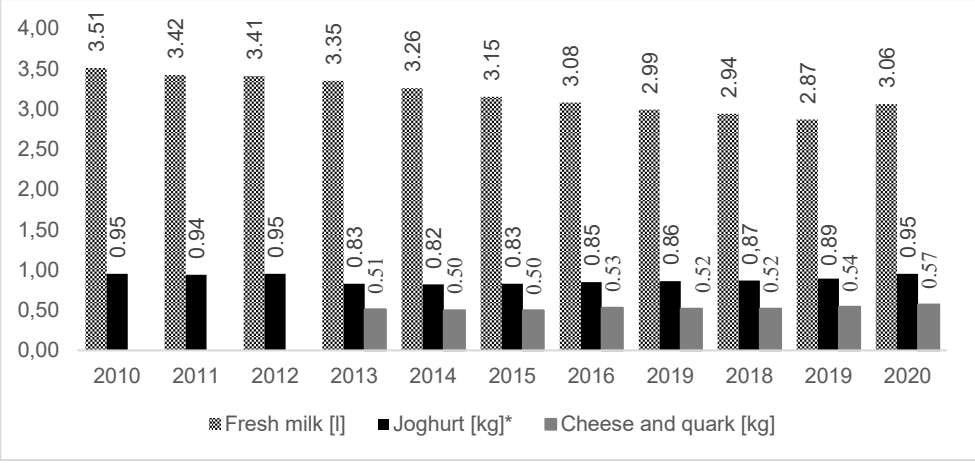
- Dairy consumption fell below the recommended daily intake levels.
- The variation in per capita consumption of dairy products depended on the number of persons in the household, namely the highest consumption was characteristic of one- and two-person households and gradually decreased as the number of persons in the household increased.
- Household income levels influenced dairy consumption; higher reported income was associated with higher dairy intake.

Similarly, in a study by Kwasek [2021], low levels of dairy product consumption among Poles were confirmed.

The decline in overall dairy consumption was closely linked to the reduced intake of drinking milk, which fell from 3.51 liters per person in 2010 to 3.06 liters per person in 2020. According to Figure 2, a slight increase in the consumption

of drinking milk was recorded in 2020 compared to the previous year. GUS statistics do not include the consumption of raw milk, which may account for a considerable portion of total milk intake and could offset the decline in reported drinking milk consumption. According to a study conducted by Matusiak et al. [2021] in the Łódź Voivodeship, 19.4% of respondents reported consuming raw milk, and over 80% of those who provided such a response resided in urban areas.

Among consumers, fermented dairy products are more popular than drinking milk or raw milk. Based on data from GUS [2021] (Figure 3), a modest increase in the consumption of yogurts and cheeses was observed over the past decade. Trajner [2018] confirmed that yogurts represented a significant share in the average diet compared to other dairy products. Since 2019, interest in cheese consumption has grown, following a period of relatively stable consumption levels in previous years [GUS 2021].



* up to and including 2012, CSO statistical data defined the yoghurt category as yoghurts and dairy drinks, therefore the chart presents data from 2013 onwards for the yoghurt category.

Figure 2. Average per capita consumption of selected dairy products 2010-2020

Source: GUS, 2021.

Milk production in Poland fully satisfies the domestic market's needs both in terms of human consumption and as animal feed. Between 2019 and 2022, the level of dairy product production remained above 120% of domestic demand [GUS 2023a]. As a result, exports of dairy products played a significant role in the milk

production sector, accounting for approximately one-third of total domestic milk production. According to the National Support Centre for Agriculture (KOWR) [2023], in 2022 compared to 2021, the export share of the following dairy products increased: skimmed milk powder by 36.1%, casein by 17.1%, condensed and powdered milk by 4.4%, and liquid milk and cream by 0.9%. At the same time, there was a notable decline in the export value of whey (by 19.7%), butter and fatbased products (by 16.7%), and ice cream (by 10.6%).

Overall, the share of exports in the dairy sector increased prior to the COVID--19 crisis, continued to grow during the pandemic, and remained strong thereafter. This trend has been confirmed by both academic research and government analyses. Stańko and Mikuła [2018] reported a 347% increase in the foreign trade balance of milk and dairy products from €154.7 million in 2000 to €691.7 million in 2016. According to calculations by the KOWR Bureau of Analysis and Strategy, based on data from the Ministry of Finance, the value of Polish dairy product exports reached €3.6 billion (PLN 16.8 billion) in 2022. This represents a 37% increase in the export share of milk and dairy products compared to 2021 [KOWR 2023].

In a study by Kobiałka and Nowak [2022], it was demonstrated that the dairy industry proved resilient during the recent pandemic crisis. At the same time, the authors pointed out that the war in Ukraine had a direct impact on export volumes. Prior to the outbreak of war in 2021, countries involved in the conflict namely Ukraine, Belarus, and Russia accounted for 5% of the total value of dairy exports, worth nearly €130 million. Additionally, the researchers emphasised the emerging challenges that the dairy sector will have to face, such as implementing the European Green Deal in agriculture and navigating the global economic crisis.

4. ECONOMIC ASPECTS OF MILK PRODUCTION

Milk production entails numerous costs, including feed production, veterinary care, maintenance and expansion of machinery, and investment in agricultural infrastructure. The main source of income for dairy farms is payment for milk, which depends on both the volume of milk produced and its quality parameters such as Total Bacterial Count (TBC) and Somatic Cell Count (SCC). Moreover, milk fat and increasingly also protein content are rewarded with price premiums, leading

to higher payments per liter of raw milk collected by processing plants. The higher the content of these nutritional components, the greater the income for dairy farms.

An additional source of revenue for these farms comes from the sale of calves and cows (Table 4) [Sznajder 1999].

Table 4. Economic aspects in milk production

Costs in terms of	Profits in
production or purchase of feed: • own roughage • own concentrated feed • purchased concentrated feed • feed additives, supplements • nutritional advice	milk sales- determinants of the milk price: • milk composition – fat content, protein content • microbiological and cytological quality of the milk • special premiums (volume of deliveries, membership of cooperative) • special deductions (inferior quality, cost of disposing of milk with antibiotics)
veterinary prevention and treatment	sale of calves
the operation of farm buildings and machinery (depreciation, renovation and repair costs, energy factors)	sale of cows
cow husbandry (maintenance of animals, insemination, certificates, union)	

Source: Sznajder 1999.

CONCLUSIONS

Milk production is a key element of the agricultural economy, with both economic and social importance. An analysis of selected aspects of this process reveals that technological development, evolving consumer demands, and increasing environmental awareness play a growing role in shaping modern dairy production methods. Therefore, factors such as sustainable development, technological progress, economic conditions, consumer preferences, global events, and changing climate and environmental conditions will always influence the production of this essential raw material.

It can be confidently stated that milk production today stands at the crossroads of tradition and modernity. Striking a balance between economic efficiency and social and environmental responsibility will thus be of key importance. Referring to

the two major events mentioned in this study, it must be noted that both the COVID-19 pandemic and the war in Ukraine significantly disrupted the functioning of the dairy sector in Poland. While the pandemic primarily challenged supply chain reorganisation and the need to adjust production to a changed demand structure, the war's effects were mostly cost and logistics related. In both cases, however, the sector demonstrated considerable flexibility and resilience, continuing production at a relatively stable level.

These events also accelerated modernisation processes, increased the importance of automation and digitisation, and intensified discussions on food security in Europe. When analysing the next decade of milk production i.e., the years 2020–2030 these events are expected to have a lasting impact on the behaviour and structure of Poland's dairy sector.

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NIR TECHNOLOGY FOR MONITORING THE QUALITY OF CHOCOLATES – PRELIMINARY STUDY

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Abstract

The aim of this study was to test NIR spectroscopy coupled with multivariate data analysis as a non-destructive tool to monitor selected chocolate quality parameters and to develop regression models to predict them. The analysed parameters were cocoa, sugar, and fat content. The research material were commercial chocolates (n = 35) with varying levels of cocoa mass. Pattern recognition techniques including principal component analysis (PCA) and partial least squares analysis (PLS) were used to classify the chocolates. The classification models distinguishing chocolates according to type and cocoa mass content was characterised by high classification performance. The model based on NIR spectra for prediction of sugar content showed good classification performance with errors at the level of 7.9% and 5.8% for validation and prediction, respectively. Proper models are also be found for cocoa mass and fat content in commercial chocolates. Overall, these findings highlight and prove the potential of NIR spectroscopy as rapid, robust, and non-destructive tools for screening quality in food.

Keywords: chocolates, quality control, non-destructive methods, PLS prediction, sustainable production.

INTRODUCTION

Chocolate is the world's most popular confectionery. This product, depending on its type, can be defined as a suspension of sugar, cocoa, and powdered milk dispersed in a continuous fat phase, obtained through different proportions of ingredients and various processes. The main parameters that vary among chocolate products are the amount of cocoa solids and sugar [Afoakwa 2016; Santos et al. 2021]. Europe is the world's largest chocolate producer and export market. In Poland, according to Euromonitor International [2023], chocolate consumption is forecasted to increase from 5.8 kg per capita in 2023 to 6.5 kg per capita in 2029. This places Poland in the middle of the European rankings.

Analysis by Euromonitor indicates that the global chocolate confectionery market has growth prospects, with the market value expected to exceed USD 189 billion by 2029. The primary ingredient for making chocolate is the cocoa bean, which comes from the cocoa tree (*Theobroma cacao L.*), grown in countries across Africa, South America, and Southeast Asia [Kongor et al. 2016]. Côte d'Ivoire was the largest producer of cocoa beans in the world according to the Wedel Lotto Report [2024], with a production of 2,175,000 tonnes in 2022–2023, followed by Ghana with 725,000 tonnes, and then Ecuador and Nigeria. Cocoa prices on international markets are quite volatile and can fluctuate significantly in the short term due to yield variability (affected by weather conditions), demand from chocolate manufacturers, and speculative trading on commodity exchanges.

The phytochemical, technological, and sensory characteristics of cocoa may facilitate adulteration of chocolate products. For example, the commercialisation of products with lower cocoa solids content than indicated on the label can lead to financial gains [Kongor et al. 2016; de Oliveira et al. 2018]. One objective of the sustainable food industry is to develop rapid, non-destructive methods for verifying authenticity, detecting adulteration, and controlling quality during storage. Optical techniques such as NIR, IR, and fluorescence spectroscopy have become valuable tools for identifying discrepancies between product labels and actual formulations [Krähmer et al. 2015; Quelal-Vasconez et al. 2018; Włodarska et al. 2018], adulterations [Turgut et al. 2025] and changes during storage [Włodarska et al. 2024]. The aim of this study was to evaluate and predict selected quality parameters of commercial chocolates using NIR technology as a fast and accurate tool for quality assessment.

1. MATERIAL AND METHODS

For this study, 33 commercially available chocolate products from various brands and product groups were purchased from the market during the period 2023–2024. Reference data for the nutritional parameters of the samples were obtained from the manufacturers' declared values, as presented on the product labels.

Table 1 presents the general composition of the investigated product groups. The spectral data of the chocolate samples were recorded in the near-infrared range (12,500–3,800 cm^{-1}) using a Bruker MPA spectrometer (Bruker, Ettlingen, Germany) equipped with OPUS 7.2 software. Diffuse reflectance mode was used for non-destructive sample presentation. For each sample, five measurements were taken, with each spectrum averaged over 32 scans at a scanning speed of 10 kHz. The spectral resolution was set to 16 cm^{-1}.

Principal Component Analysis (PCA) was performed on the NIR spectra to identify interrelationships between the samples. The number of principal components was determined by evaluating the cumulative variance, selecting the first components that together accounted for more than 70% of the total variance. Partial Least Squares (PLS) analysis was then applied to extract new latent variables, providing an approach to model the covariance structure between the NIR spectra and selected quality parameters. After selecting the optimal number of latent variables, the resulting models were used to verify the authenticity of commercial chocolate samples. Multivariate data analysis was conducted using The Unscrambler version 9.7 (Camo, Norway).

Table 1. General composition of the samples according to the chocolate product group

	Dark chocolate	**Desert chocolate**	**Milk chocolate**	**White chocolate**
Energy [kJ]				
Average	2415	2154	2309	2313
Min	2020	2131	2216	2233
Max	2762	2180	2505	2383
Fat [g/100g]				
Average	43	30	35	31
Min	28	29	31	29
Max	54	32	47	32

cont. Table 1

Saturated fatty acids [g/100g]				
Average	25	18	22	18
Min	17	17	18	17
Max	34	19	29	19
Carbohydrates [g/100g]				
Average	30	52	51	59
Min	11	50	33	52
Max	54	54	58	65
Sugar [g/100g]				
Average	25	49	51	58
Min	0.5	47	31	52
Max	52	50	57	65
Protein [g/100g]				
Average	9.0	4.5	6.9	5.2
Min	4.6	5.0	5.9	4.2
Max	14.0	6.0	9.1	6.3
Salt [g/100g]				
Average	0.02	0.04	0.21	0.28
Min	0.01	0.01	0.14	0.19
Max	0.03	0.09	0.28	0.35
Cocoa content [%]				
Average	74	50	35	nd
Min	43	50	30	nd
Max	100	50	55	nd

Source: own study based on product labels.

2. RESULTS AND DISCUSSION

Figure 1 shows the examples of averaged spectra in NIR range (12500–4000 cm^{-1}) of different types of chocolates: white (Wedel), dessert (Terravita), milk (Milka), dark (Fin Carre 74%) and dark (95% J.D. Gross) (Figure 1a), as well as spectra of different brands dark chocolates with varying cocoa mass content (from 43% till 100%) (Figure1b).

The NIR spectra obtained (Figure 1a) revealed six main absorption bands corresponding to functional groups, with intensities varying according to the type of sample and cocoa mass concentration in the samples. These functional groups are typically associated with macromolecules, enabling compositional interpretation of the spectra.

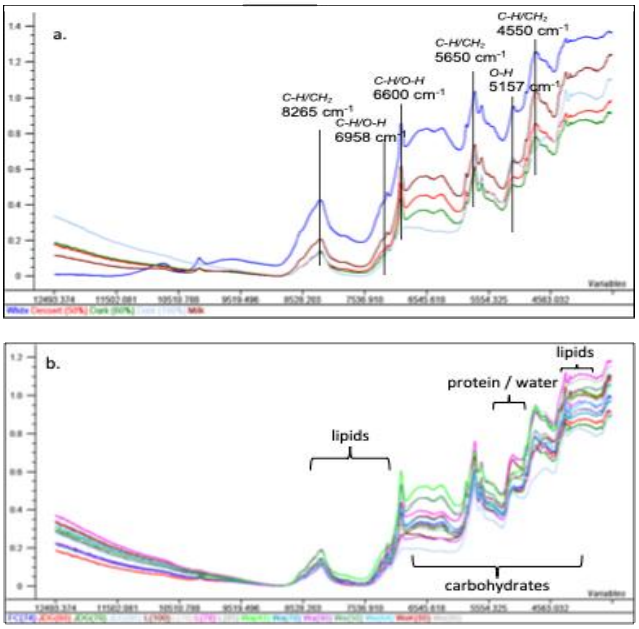

Figure 1. NIR spectra of different types of chocolates with marked bands indicating vibration types (a) and spectra of darkchocolates with different content of cocoa mass (45–100%) and with marked regions originating from water and nutrients (b)

Source: own research.

As shown in Figure 1b, increasing cocoa mass resulted in spectra with a consistent pattern; the primary difference was the increase in absorbance intensity. The observed bands were located in the following regions: lipids: 8264 cm^{-1}, 5650 cm^{-1}, and 4550 cm^{-1} (C–H and CH_2 vibrations), water and proteins: 5157 cm^{-1} (O–H vibrations), carbohydrates: 6958 cm^{-1} and 6600 cm^{-1} (C–H and O–H vibrations), likely due to the increase in cocoa solids and the corresponding decrease in sugar content in the formulations. These findings are consistent with the observations and analyses reported by Krähmer et al. [2015] and Santos et al. [2021].

To evaluate the differences between types of chocolates studied, an exploratory analysis was performed using principal component analysis. Analysis of PCA score plot revealed quite good separation between all range NIR spectra of types of chocolates products (Figure 2). The first two principal components explained 96% of the total variance in experimental data, in details PC1 accounted 87.93% and PC2 –8 % of the variance. PC1 distinctly differentiated the chocolates based on type of products and concentration of the cocoa solids. The samples were divided into three groups. Milk and white chocolates constitute separate groups, while dark and dessert chocolates did not show any visible grouping.

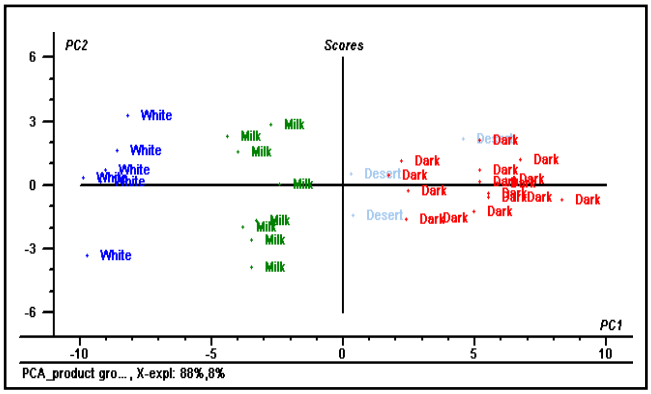

Figure 2. Principal component analysis of NIR spectra. Scores plot of PC1 *vs* PC2 with four types of chocolate products

Source: own research.

The Partial Least Squares (PLS) regression method was applied to quantitatively evaluate the concentration of nutritional elements, in chocolates based on their spectral characteristics. Different types of mathematical preprocessing were applied to the spectral data before building the model. Complete spectra were analysed in all the spectral regions and also relied on the chemical information concerning the occurrence of bands for individual compounds specific subregions were analysed. The linear calibration models that considered the test parameter variables obtained from the products labels, namely cocoa solids content, sugar content and fat content. Table 2 shows the characteristics of the models proposed for

the relationship between near-infrared spectral values and reference values for above parameters.

The PLS regression model for cocoa pulp content is characterised by accurate root mean square errors of validation (*RMSEV* = 4.101) and calibration (*RMSEC* = 2.982), as well as validation and calibration correlation coefficients of R^2 = 0.946 and R^2 = 0.969, respectively. This model was used to quantification of the cocoa mass content of a set of test samples (chocolate with no declared cocoa pulp content). The objective was to validate the best prediction model using a sample set not included in the calibration. All the results obtained for the test samples were within the expected range for the type of chocolate and did not deviate by more than 5% from the declared value. The exception was some milk chocolate samples, which deviated by 8.4%. The reliable literature contains information on highly robust calibration models for determining the content of individual chocolate components, particularly the cocoa mass content in relation to adulteration with carob flour [Quelal-Vasconez et al. 2018; Turgut et al. 2025], as well as the fat and sugar content [Benes et al. 2025; Krähmer et al. 2015]. Further research and development of data analytical methods for chocolate quality assessment is needed to improve the efficiency, accurate and speed of analysis. However, the implementation of such analytical solutions significantly reduces the amount of reagents and shortens the analysis time.

Table 2. PLS calibration parameters of the NIR spectra to predict the selected quality parameters of the products

Pre-processing, variable selection	Calibration		Validation	
	R^2	*RMSEC* [%]	Rv^2	*RMSEV* [%]
Cocoa solid content				
None + normalisation	0.971	2.85	0.954	3.77
First derivative	0.982	2.44	0.976	2.89
SNV	0.955	3.57	0.936	4.49
Sugar content				
None + normalisation	0.985	2.23	0.978	2.77
First derivative	0.985	2.23	0.979	2.74
Second derivative	0.989	1.88	0.959	3.80

cont. Table 2

MSC	0.976	2.85	0.969	3.31
SNV	0.976	2.42	0.965	3.06
Fat content				
None + normalisation	0.878	2.42	0.802	3.20
First derivative	0.958	1.44	0.909	1.18
SNV	0.966	1.29	0.945	1.71
MSC	0.959	1.42	0.935	1.85

R^2 – coefficient of determination, *RMSEC* – root mean square error of calibration, R_v^2 – coefficient of determination of validation, *RMSEV* – root mean square error of validation, *SNV* – Single Normal Variate, *MSC* – Multiplicative Scatter Correction.

Source: own research.

CONCLUSIONS

Near-infrared (NIR) spectroscopy proved to be a suitable and easily applicable method for fast, comprehensive quality analysis of chocolates, based on quantification of numerous nutritional parameters representing quality attributes. PCA was effective in identifying the characteristic behaviour of commercial chocolate samples according to product type and cocoa solids content. The application of PLS to the NIR dataset provided models with good predictive and generalisation capacity for chocolate samples. The models were analysed for cocoa mass, fat, and sugar content. This highlights the ability to quickly determine the cocoa mass content of commercial samples without any information being declared on the label. The low requirements for sample preparation in NIRS, coupled with the technical development of NIRS-based technology for analysis, offer new perspectives and solutions for fast, user-independent, reliable, and environmentally friendly quality and process control in the cocoa and chocolate industry.

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INFLUENCE OF DRY AGING TIME ON THE SENSORY ATTRIBUTES OF BEEF SIRLOIN

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Abstract

Meat seasoning is a key process that improves its quality in terms of taste, tenderness, and juiciness. Dry-aged beef is particularly popular among connoisseurs. However, this process leads to weight loss and is associated with high financial costs of specialist equipment and energy. The aim of the research was to determine the optimal seasoning time that allows for the best balance between improving sensory quality and energy costs. Beef sirloin was dry-aged for 12 weeks, with panelists assessing the sensory quality of the raw and fried meat every 7 days. The results indicate that the quality of the raw meat systematically deteriorates, while the sensory quality of the fried meat is best after 35 days of dry-aging.

Keywords: quality, beef, seasoning, dry aging, sensory analysis.

INTRODUCTION

The concept of beef quality is complex because it includes many features and properties that are influenced by many factors. These factors can be divided into those that affect pre-slaughter and those that shape quality after slaughter. Among the factors influencing pre-slaughter, both genetic and non-genetic conditions are of significant importance, such as sex, age, breeding system, nutrition, and pre--slaughter turnover. In addition to these aspects, natural differences between muscles resulting from their physiological function and structure also play a significant role in shaping meat quality. After slaughter, procedures related to handling carcasses and meat are of key importance. The most important post-slaughter factors include: cooling, cutting carcasses, packaging, storage, and maturation of meat. Each of these

stages can significantly affect the final quality of the product, determining its taste, texture, and shelf life. In the process of shaping meat quality, both appropriate pre-slaughter and post-slaughter management are important to ensure that the meat meets the high-quality standards expected by consumers [Cieślakowska 2021; Domaradzki et al. 2016; Kołczak 2008].

Among experts and beef connoisseurs, one factor is of particular interest – maturation occurring during seasoning (aging). Meat seasoning is a process of controlled maturation aimed at improving its quality by intensifying the taste, improving the texture, and increasing tenderness [Savell et al. 2005]. Enzymatic processes decompose proteins and fats to produce characteristic umami flavour notes. During seasoning, proteolytic enzymes decompose collagen fibers, of which beef has a large amount. This leads to an increase in the tenderness of the meat – it becomes more delicate and softer [Baird 2008]. Seasoned meat is characterised by a loss of moisture, but it is worth noting that during this process, proteins bind water in a more stable way. Seasoning also helps to get rid of undesirable aromas, i.e., the presence of blood and biochemical processes taking place in fresh meat may give it a metallic taste or sour smell. During seasoning, these substances naturally evaporate. When seasoning is carried out in appropriate conditions, the microflora develops in a controlled manner, it is possible to limit the growth of undesirable microorganisms and, additionally, to create a protective layer preventing meat from spoiling [Lepper-Blilie et al. 2012].

There are two main methods of meat maturation: wet aging and dry aging. Dry aging is a traditional technique that has been used for many years to obtain exceptional sensory qualities of beef. This process takes place in specially controlled conditions, where natural enzymatic and chemical changes occur. The maturation process, which takes place over a specified period of time, leads to the development of a unique flavour profile and changes in the meat structure [Dashdorj et al. 2016].

The benefits of dry-aging include [Kim et al. 2016; Lepper-Blilie et al. 2012]:

- intense, rich taste and aroma – compared to fresh meat, seasoned beef has a deeper taste,
- improved meat tenderness and structure – the enzymatic process significantly softens muscle fibers,
- natural meat preservation – the dry surface limits the growth of pathogens.

The disadvantages and challenges associated with dry-aging include [Kim et al. 2016; Lepper-Blilie et al. 2012]:

- weight losses and the cost of the process – meat loses 15 to 30% of its weight, which translates into higher production costs,
- long maturation time – full seasoning requires from several weeks to several months,
- technical requirements – the need to use controlled storage conditions is associated with additional financial outlays.

The basic factors that are crucial for proper seasoning are [Dashdorj et al. 2016; Kim et al. 2016, Savell 2008]:

- temperature: 1–3°C – maintaining a stable, low temperature prevents the growth of undesirable microflora, while allowing for slow enzymatic changes,
- relative humidity: 75–85% – the appropriate level of humidity prevents excessive drying of the meat and prevents the growth of bacteria and molds,
- air circulation: 0.2–0.5 m/s – constant air flow ensures even maturation and prevents the formation of microorganisms on the meat surface,
- seasoning time: 14–120 days – the maturation time depends on the expected effect; a standard period of 28–45 days is used, but in some cases the process may take longer, which leads to a deeper taste.

The information available in the literature on the optimal time for dry-aging of beef is inconsistent. Therefore, it was decided to undertake research to assess the impact of dry-aging on beef quality, with particular emphasis on changes in its sensory properties, in order to determine the optimal duration of the aging process. This research is important because seasoning is a long-term and expensive process. It leads to weight loss of the raw material but at the same time has a positive impact on its final quality and consumer acceptance. The conducted research will allow to determine the optimal time of the dry seasoning process, after which the sensory quality of the offered meat is the highest.

1. MATERIAL AND METHODS

The research material was obtained from a Polish company with many years of experience in beef production and processing. The process of seasoning and preparing the meat for sensory evaluation was conducted using professional

equipment used in the plant. The research material consisted of sirloin from Limousin cattle. The beef was divided into 11 samples weighing approximately 1 kilogram each. The pH level was determined in samples 1 to 10 and then they were placed in a special cabinet for meat dry seasoning. Sample 0 was the reference sample (fresh meat) that was immediately assessed. The seasoning scheme was as follows:

- sample 0 – fresh meat,
- sample 1 – meat seasoned 21 days (3 weeks),
- sample 2 – meat seasoned 28 days (4 weeks),
- sample 3 – meat seasoned 35 days (5 weeks),
- sample 4 – meat seasoned 42 days (6 weeks),
- sample 5 – meat seasoned 49 days (7 weeks),
- sample 6 – meat seasoned 56 days (8 weeks),
- sample 7 – meat seasoned 63 days (9 weeks),
- sample 8 – meat seasoned 70 days (10 weeks),
- sample 9 – meat seasoned 77 days (11 weeks),
- sample 10 – meat seasoned 84 days (12 weeks).

The conditions in the cabinet during seasoning: the storage temperature was around 2°C, which allowed for slowing down biochemical processes, limiting the growth of bacteria, and improving meat tenderness; humidity was maintained at around 80%, which prevented excessive drying of the meat and promoted the maturation process by controlling enzymatic changes. The use of a special cabinet allowed for ensuring proper air circulation, which was crucial for even aging and maintaining the quality of the product.

The sensory evaluation was carried out by a permanent team of five selected assessors with proven sensory sensitivity. The team consisted of two women and three men, all plant employees with many years of experience who evaluate beef on a daily basis. Additionally, for the purposes of the study, they were trained in the 5-point evaluation method. According to Turek et al. [2016], they could be described as specialized expert evaluators. The panellists used sight, smell, taste, and touch to assess individual features based on reference cards on a scale of 1 to 5, where 1 was insufficient and 5 was very good. The reference cards were prepared by authors based on literature data, own experience and after consultation with employees who have many years of experience in assessing beef, and in accordance with

PN-ISO 6658 and PN-ISO 4121. Each evaluation was carried out in controlled laboratory conditions, with appropriate lighting and a neutral sensory environment to limit the influence of external factors on the panellists' perception. The evaluation of the sample consisted of two stages: evaluation of raw meat and evaluation of fried meat. The raw meat was assessed immediately after the sample was taken out of the seasoning cabinet and trimmed of the dried skin. The following were rated: colour (in terms of uniformity, intensity, and possible signs of discolouration), smell (as pleasant and characteristic of meat or as deviating from the norm, e.g., sour) and consistency (taking into account the structure of the meat, its elasticity, moisture and hardness). The sample was then cut into slices approximately 2,5 cm thick and subjected to heat treatment on a grill plate Hendi 203163 heated to 200°C. During cooking, the meat was turned every 45 seconds. The evaluation of fried meat was carried out on a sample that had reached a final internal temperature of 65°C. The following were rated: smell, juiciness (based on the amount of juices released during biting), tenderness (in terms of ease of chewing and the structure of muscle fibers) and taste (taking into account the intensity and balance of flavours characteristic of seasoned meat).

The results of individual assessors were recorded in a table and the average values were calculated. Statistical analysis was performed using StatSoft Polska Sp. z o.o. 2025 software, scoring kit version 6.1.0. To determine whether the evaluated samples differed, the nonparametric Kruskal-Wallis test, which is an equivalent of one-way analysis of variance, was used. This test determined whether the difference between the tested samples was statistically significant. The level of significance for all statistical analyses was set at $P < 0.05$ [Naes et al. 2010].

2. RESULTS

The results of the sensory tests of raw meat are presented in Table 1, while those of the heat-treated – fried meat is presented in Table 2. They indicate that the meat seasoning process significantly affects its sensory quality.

Table 1. Results of raw meat sensory evaluation

Average ratings given by evaluators (raw meat)					
Feature	**Colour**	**Smell**	**Consistency**	**Arithmetic mean**	**Total score (weighted mean)**
Weighting factor	**0.3**	**0.4**	**0,3**		
Sample 0	4.8[a]	5.0[a]	4.8[a]	4.9	4.9[a]
Sample 1	4.0[b]	4.2[b]	5.0[b]	4.4	4.4[b]
Sample 2	3.8	4.6[c]	4.4	4.3	4.3[c]
Sample 3	4.4[c]	4.4[d]	4.2	4.3	4.3[d]
Sample 4	3.0	4.0	4.6	3.9	3.9
Sample 5	2.4	3.2	4.4	3.3	3.3
Sample 6	1.8[a c]	3.4	4.0[a b]	3.1	3.1[a]
Sample 7	2.0[a]	3.4	4.2	3.2	3.2
Sample 8	2.4	2.4[a c d]	4.4	3.1	3.0[a]
Sample 9	1.6[a b c]	3.0[a]	4.4	3.0	3.0[a]
Sample10	1.8[a c]	2.0[a b c d]	4.2	2.7	2.6[a b c d]

[a b c d] Means within a column with the same superscripts are different ($p < 0.05$).

Source: own study.

The dry seasoning process caused the sensory quality of raw meat to deteriorate over time. Statistically significant deterioration comparing to reference sample was observed after 56 days of dry aging. The feature that deteriorated the most was colour. It is worth noting that the smallest changes were observed in the case of consistency, which was assessed as good even in the final seasoning period.

Sensory evaluation of fried meat showed that until the 35th day of seasoning, the sensory quality improved, obtaining the highest score after this time, while further seasoning resulted in a gradual deterioration of sensory quality.

The exception was sample 6, aged for 56 days, which obtained a score of 4.8. However, until 11th week of aging the sensory quality remains good.

The basic effect of dry-aging is the gradual loss of water from the meat, which can range from 15 to 30% of the initial weight. This process concentrates the taste, which gives the meat intense umami notes and nutty accents. The activity of proteolytic enzymes such as cathepsins and calpains, which gradually decompose structural proteins, is of key importance for improving the tenderness of meat. Protein degradation contributes to the softening of muscle tissue, and lipid oxidation gives the meat a characteristic, deep flavour [Dashdorj et al. 2016; Kemp 2010; Kołczak 2008]. Longer maturation time leads to the intensification of the Maillard reaction, which is responsible for the development of a rich flavour bouquet. Lipid oxidation and the action of surface microflora promote the development of complex flavour notes that distinguish dry-aged meat from its fresh counterpart [Savell 2008].

Table 2. Results of fried meat sensory evaluation

Average ratings given by evaluators (fried meat)						
Feature	**Smell**	**Juiciness**	**Tenderness**	**Taste**	**Arithmetic mean**	**Total score (weighted mean)**
Weighting factor	**0.15**	**0.2**	**0.25**	**0.4**		
Sample 0	5.0^{a}	4.8^{a}	3.0^{acdf}	4.6^{f}	4.4	4.3
Sample 1	5.0^{b}	5.0^{b}	3.4^{bcd}	4.8^{a}	4.6	4.5$_{a}$
Sample 2	4.8	4.8^{c}	4.2	4.6^{f}	4.6	4.6^{b}
Sample 3	5.0^{c}	5.0^{d}	5.0^{abceg}	5.0^{bcd}	5.0	5.0^{c}
Sample 4	4.6	5.0^{e}	5.0^{abdeg}	3.8^{bce}	4.6	4.5
Sample 5	4.2	3.4	3.4^{cdef}	3.6^{bde}	3.7	3.6^{cd}
Sample 6	4.8	4.4	4.8^{afg}	5.0^{cdef}	4.8	4.8^{de}
Sample 7	4.2	3.8	4.2	4.2	4.1	4.1^{c}
Sample 8	4.4	4.0	4.2	4.2	4.2	4.2

cont. Table 2

Sample 9	4.4	3.4	4.2	4.6	4.2	4.2
Sample10	3.6^{abc}	2.4^{abcde}	3.0^{cdfg}	1.8^{abef}	2.7	2.5^{abce}

^{abcde} Means within a column with the same superscripts are different ($p < 0.05$).

Source: own study.

Analysing the results obtained for individual sensory quality features of fried beef, it is difficult to determine a clear trend of changes. Only in the case of tenderness can it be stated that it improves until the 35th day, maintaining the best quality for another week, and then gradually deteriorates.

3. DISCUSSION

The information on dry-aging available in the literature is very diverse, hence own research was undertaken. According to Perry [2012], the dry-aging time of beef should be from 50 to 80 days. A longer aging time does not increase the flavour of beef at the same level and may affect the intensification of biochemical changes. The Gudjónsdóttir et al. [2015], in their research, noticed that muscle fibers in meat that matures for at least 21 days undergo enzymatic degradation, significantly affecting the level of tenderness. In the discussed experiment, an improvement in tenderness was also observed after 21 days of seasoning, but the highest scores were obtained after 35 and 42 days. Longer aging time is associated with an increased risk of a large loss of total mass. The research results available in the literature confirm that meat subjected to the maturation process can lose from 10% to 35% of its mass after 21 and 120 days, respectively [Dashdorj et al. 2016].

Smith et al. [2008] noted that steaks that matured for 21 days were given the highest score for beef flavour. Lepper-Blilie et al. [2014] and Colle et al. [2015] also showed that the optimal maturation time for beef is 21 days. This is confirmed by other studies, in which extending the maturation time to 28 days did not result in further improvement of sensory quality [DeGreer et al. 2009]. Niedźwiedź et al. [2013] showed that a longer maturation time favours the development of a deeper aroma, a more attractive colour, and very good consistency and tenderness, however the maximum maturation time in their experiment was 14 days. Research of Colle et al. [2016] showed that extended to 63 days has positive effects on consumer perception of tenderness and overall acceptability.

Analysis of the results of own research indicates that the optimal time for dry--aging of beef is 35 days (5 weeks). After this period, the meat attains the highest sensory quality, achieving the best scores for all assessed features. However, it is important to remember about the limitations of the study (small number of evaluators, lack of instrumental tests, one batch of meat), although other studies also confirm that beef seasoned for 28-35 days is characterised not only by maintaining the appropriate moisture, but also by an increased concentration of flavour components, which affects the intensity and expressiveness of the beef flavour. Reduced water content in the meat changes the structure of the fibers. They are more brittle, which has a positive effect on the quality of the product [Terjung 2021].

Extending the maturation period beyond 36–42 days (5–6 weeks) leads to a gradual deterioration of key attributes such as taste and aroma, although juiciness and tenderness also received the highest rating after 42 days of seasoning. Kemp et al. [2010] showed that after 56 days (8 weeks), a clear degradation of quality begins to be felt, which manifests itself in the form of excessive drying, loss of juiciness, and changes in texture. Similarly, the loss of juiciness was observed in discussed research. Long maturation is therefore an economically unprofitable practice, as the product loses mass, becomes dry and hard, and therefore unattractive to consumers.

CONCLUSIONS

The research confirmed that seasoning plays a significant role in improving the quality of meat, especially in relation to sensory values such as taste, tenderness, and juiciness. The results of the studies indicate that the optimal time for dry seasoning of meat is about 5 weeks. Although the quality of raw meat was systematically deteriorating, after this time, fried meat was characterised by the best sensory properties, and longer seasoning lead to deterioration of the features, particularly in taste and smell. Therefore, due to both lower quality and higher costs, it is not justified to extend the maturation process.

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QUALITY ASSESSMENT OF SELECTED PLANT-BASED POWDERED BEVERAGES

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Abstract

In recent years, the market for plant-based products that serve as substitutes for animal-derived foods has been developing extremely dynamically. Among these, powdered plant-based beverages have gained a prominent position as an alternative to cow's milk. Therefore, the aim of the present study was to evaluate the quality of three selected powdered plant-based beverages: soy (I), coconut (II), and rice (III), with particular emphasis on their physicochemical and sorption properties.

As part of the research, the content of basic nutrients (protein and fat), water content and water activity, as well as colour parameters (L*, a*, b*) were determined for both the powdered form and the rehydrated beverages. In addition, bulk (loose and tapped) density, Hausner ratio, and Carr index were evaluated. To determine the hygroscopic properties influencing storage stability, sorption isotherms were determined within a water activity range of 0.11–0.98. Furthermore, sensory evaluation was conducted to assess consumer acceptability of the products.

The analyses revealed that the physicochemical properties and storage stability of powdered plant-based beverages were strongly influenced by the choice of raw materials and the production methods employed. All evaluated products exhibited favorable shelf-life characteristics and demonstrated promising potential as functional, stable alternatives to cow's milk in the food industry.

Keywords: powdered plant-based beverages, physicochemical properties, water activity, sorption isotherms, sensory evaluation.

INTRODUCTION

The dynamic development of the plant-based product market in recent years has been directly linked to growing consumer interest in plant-based diets, as well as health, ethical, and environmental concerns. Increasing awareness of the environmental impact of food production, along with food intolerances and allergies, is prompting consumers to seek alternatives to traditional animal-derived products [Aschemann-Witzel et al. 2021]. Among these alternatives, plant-based beverages represent a key product category and have become a popular substitute for cow's milk. Within this category, powdered plant-based beverages occupy a particularly important position. Due to their low water content, these products exhibit high microbiological stability, extended shelf life, and reduced transport weight, making them attractive for both consumers and the food industry [Brückner-Gühmann et al. 2019; Caporgno & Mathys 2018]. Moreover, the ability to prepare these beverages conveniently at any time and place enhances their usability and aligns with current trends in functional and convenient food products. However, the effective use of such powders in food processing requires a comprehensive quality assessment, including chemical composition, physicochemical properties, colour, and product behaviour under storage conditions. The study of sorption properties is of particular importance, as it enables the assessment of a product's susceptibility to moisture uptake and facilitates the prediction of its storage stability [Jiang et al. 2020].

Therefore, the aim of this study was to evaluate the quality of three selected powdered plant-based beverages: soy (I), coconut (II), and rice (III), with particular emphasis on their physicochemical and sorption properties.

1. MATERIAL AND METHODS

The research material consisted of three powdered plant-based beverages: soy (I), coconut (II), and rice (III), produced by the company Mogador s.r.o. (tř. Tomáše Bati 1664, 765 Otrokovice, Czech Republic). The products were purchased from both retail and online outlets, and the study included samples from two different production batches of each beverage, all within the declared shelf-life period. The raw material composition of the tested beverages varied depending on the primary ingredient: the powdered soy beverage contained 30% soy component, including protein and oil; the coconut variant contained 35% coconut oil; while

the rice variant included 12.8% rice flour supplemented with soybean oil and maltitol as a sweetening agent.

The nutritional values declared by the manufacturer are presented in Table 1. The highest energy value was recorded for the coconut beverage (556 kcal/100 g), and the lowest for the rice beverage (479 kcal/100 g). The highest protein content was observed in the soy beverage (5.2 g/100 g), whereas the highest fat content was found in the coconut beverage (35 g/100 g), of which 32 g were saturated fatty acids. Despite its lower caloric value, the rice beverage contained the highest amount of carbohydrates (68 g/100 g).

Table 1. Nutritional value of the analysed powdered plant-based beverages (per 100 g of product)

Nutrient	Soy beverage (I)	Coconut beverage (II)	Rice beverage (III)
Energy [kJ/kcal]	2141 / 512	2318 / 556	2008 / 479
Total fat [g]	27	35	23
of which saturated fatty acids [g]	3.6	32	3.0
Total carbohydrates [g]	62	59	68
of which sugars [g]	10	9.7	8.5
Protein [g]	5.2	1.2	2.5
Salt [g]	0.66	0.29	0.46

Source: own elaboration based on data from the unit packaging.

1.1. Research methodology

As part of this study, an evaluation of selected powdered plant-based beverages: soy (I), coconut (II), and rice (III) was conducted, encompassing an analysis of their nutritional value, physicochemical and sorption properties, as well as sensory evaluation. Protein content was determined using the Kjeldahl method in accordance with the PN-75/A-04018 standard, applying a nitrogen-to-protein conversion factor of 6.25. Fat content was measured by the gravimetric Weibull–Berntrop method using Soxhlet extraction, according to PN-ISO 8262-3:2011. Moisture content was determined by the drying method at 104°C until constant weight was achieved. Water activity (a_w) was measured using an AquaLab 4TE apparatus (Decagon Devices Inc., USA) at a temperature of 20°C (±2.5°C). Colour parameters of the products, in both powdered form and after rehydration, were evaluated

instrumentally in the CIE L*a*b*colour space using a Konica Minolta colourimeter. For comparative purposes, a sample of powdered cow's milk was also included in the sensory analysis as a representative of a traditional animal-derived product.

As part of the physicochemical property assessment, bulk and tapped density were determined in accordance with the PN-ISO 8460:1999 standard. Based on the obtained results, the Hausner ratio and Carr index were calculated [Abdullah & Geldart 1999; Samborska et al. 2011; Ruszkowska & Wiśniewska 2017].

Sorption properties were determined using the static desiccator method over a water activity range of a_w = 0.07–0.92 at a temperature of 25°C, for a period of 45 days. In desiccators with a_w > 0.69, thymol was added to inhibit microbial growth. Based on the obtained data, sorption isotherms were constructed using the BET model (1), and the specific surface area of sorption was calculated. All calculations were performed using Microsoft Excel 2010.

$$v = \frac{v_m C a_w}{(1-a_w)[1+(C-1)a_w]} \tag{1}$$

where:

a_w – water activity (–);
v – equilibrium moisture content (g H_2O/100 g dry matter);
v_m – monolayer moisture content (g H_2O/100 g dry matter);
C – energy constant.

Sensory analysis was conducted on beverages reconstituted from powders at a ratio of 25 g per 250 ml, following the manufacturer's instructions provided on the unit packaging. The evaluation was carried out in individual sensory booths, with the participation of a trained panel consisting of 20 members.

The obtained results of the physicochemical analyses were statistically processed using the Fisher-Snedecor F-test and post-hoc analysis with the least significant difference (LSD) test. The significance level was set at $\alpha = 0.05$, assuming that differences were considered statistically significant at $p \leq 0.05$ [Stanisz 2006]. Calculations were performed using Statistica 13.3 software [StatSoft, Poland].

2. RESULTS

2.1. Protein content evaluation

Protein is one of the fundamental macronutrients, playing a crucial role in tissue development and regeneration, enzyme synthesis, and the regulation of numerous metabolic processes in the human body. Its biological value is primarily determined by amino acid composition and digestibility, which in plant-based proteins may be lower than in animal proteins; however, appropriate combinations of raw materials can significantly enhance this value [Rutherfurd et al. 2015; van Vliet et al. 2015]. From a nutritional perspective, determining protein content in powdered plant-based products is essential for evaluating their nutritional value as well as for ensuring compliance with food labeling regulations, in accordance with Regulation (EU) No 1169/2011 of the European Parliament and of the Council. In the analyzed powdered plant-based beverages, protein originated exclusively from plant sources: soy, coconut, and rice.

Table 2. Protein content in powdered plant-based beverages

Product	Own research results [g/100 g]
I – Soy-based beverage	4.2
II – Coconut-based beverage	1.5
III – Rice-based beverage	2.7

Source: authors' own compilation.

Based on the conducted analyses, the soy-based powder beverage exhibited the highest protein content among the tested products (4.2 g/100 g), which is consistent with literature data highlighting the high nutritional value of soy protein [Messina 2016]. The lowest protein content was recorded for the coconut-based powder (1.5 g/100 g), which reflects the naturally low protein level in coconut (Table 2). When comparing the obtained results with the manufacturer's declared values, certain discrepancies were observed, particularly for the soy-based beverage. However, all measured values remained within the acceptable tolerance margin of ±2 g/100 g, as specified by EU legislation [Regulation (EU) No 1169/2011].

Overall, the soy-based powder beverage demonstrated the highest protein content and the greatest potential as a milk substitute among the products tested.

2.2. Fat content evaluation

Fat, as one of the main macronutrients in the human diet, plays a crucial role not only in terms of energy supply but also in its functional and sensory properties. It acts as a carrier of flavor compounds, improves texture, and enhances the bioavailability of fat-soluble vitamins. In plant-based products, fat may originate from natural raw materials as well as technological additives, such as vegetable oils added to achieve the desired texture or foaming properties, especially in "barista-type" variants [Chalupa-Krebzdak et al. 2018; Jeske et al. 2017]. In this study, fat content was determined using a reference method and compared with the values declared by the manufacturer. The results are presented in Table 3.

Table 3. Fat content in powdered plant-based beverages

Product	Own research results [g/100 g]
I – Soy-based beverage	27.3
II – Coconut-based beverage	34.0
III – Rice-based beverage	22.5

Source: own study.

The highest fat content was found in the coconut-based powder (34.0 g/100 g), most likely due to the naturally high lipid content in coconut pulp. The lowest fat level was recorded in the rice-based powder (22.5 g/100 g), while the soy-based beverage exhibited an intermediate value (27.3 g/100 g). A comparison of the results with the values declared by the manufacturer revealed a high level of consistency, with all deviations falling within the tolerance limits set out in Regulation (EU) No 1169/2011, which permits a ±20% margin for fat content in the range of 10–40 g per 100 g.

2.3. Evaluation of moisture content and water activity

Moisture content and water activity are key parameters determining the quality and shelf stability of powdered food products. Moisture content refers to the amount of bound and free water present in the product, while water activity (a_w) indicates the ability of the material to participate in physicochemical, microbiological, and enzymatic reactions. High moisture content may promote powder caking, reduce

flowability and accelerate undesirable chemical and microbiological changes [Bonczar et al. 2011; Dec 2011]. On the other hand, low water activity, typical of dried foods, increases storage stability and hygroscopicity [Ruszkowska et al. 2006].

Based on the conducted analyses, all tested powdered plant-based beverages were characterised by low moisture content and water activity, indicating their potential microbiological stability and good storage quality. The highest moisture content and water activity were observed in the rice-based powder, while the lowest values were found in the coconut-based product. When compared to literature data, these values were lower than those reported for similar products analyzed by Ruszkowska and Wiśniewska [2017], which was likely due to technological differences and the varying quality of the raw materials used.

Table 4. Initial moisture content and water activity in the tested powdered plant-based beverages

Product	Moisture content [g/100 g d.m.]	SD	Water activity (–)	SD
I – Soy-based beverage	2.584^{b}	0.062	0.2465^{a}	0.0031
II – Coconut-based beverage	2.461^{a}	0.026	0.2419^{a}	0.0008
III – Rice-based beverage	2.936^{c}	0.038	0.3101^{b}	0.0075

x – mean of three replications; SD – standard deviation; differences marked with different letters in columns are statistically significant at $p \leq 0.05$.

Source: own study.

Based on the conducted analyses, it was found that among the tested powdered plant-based beverages, the rice drink had the highest water content, reaching 2.936 g/100 g dry matter, while the coconut drink powder exhibited the lowest moisture level. According to the literature, in a similar study by Ruszkowska and Wiśniewska [2017], the water content in soy and coconut-based drinks was reported to be higher.

Another evaluated parameter was water activity, which plays a key role in assessing the microbiological stability of powdered food products. All measured values of this parameter were below 0.6, the threshold considered critical for the growth of most microorganisms, thus confirming the microbial stability of the tested plant-based beverages. Variations in the results may have been due to differences in drying conditions and the formulation composition.

2.4. Colour evaluation

The colour of a food product is a key quality attribute that significantly influences both sensory evaluation and consumer acceptance. In the CIE L*a*b* colour space, colour is defined by three coordinates: L* (lightness), a* (green-red axis), and b* (blue-yellow axis), which allow for an objective analysis of colour differences in food products in various physical states [Guan et al. 2020; Pathare et al. 2013;]. The analysed powdered plant-based beverages exhibited high L* values, indicating light colour for all investigated samples. The highest lightness was observed in the coconut beverage powder (L* = 98.36 ± 0.04), likely due to the naturally white coconut pulp and a low content of coloured compounds.

The soy and rice beverage powders showed slightly lower L* values, potentially resulting from the presence of natural phenolic compounds [Kaur & Singh 2017].

The a* values were negative, indicating a dominance of greenish tones. The coconut beverage powder showed the lowest red component (a* = –2.46), while the rice beverage powder exhibited the highest (a* = –1.67). Although statistically significant, these differences remained within the typical colour range for plant-based products [Cheng et al. 2018]. The b* parameter, indicating the intensity of yellow tones, was highest for the coconut beverage powder (b* = 19.16), possibly due to the presence of sugars and lipids prone to Maillard reactions during drying. The rice beverage powder had the lowest b* value, confirming its mildest yellow hue among the tested samples.

Upon reconstitution, all beverages showed a decrease in lightness, a typical phenomenon related to light scattering in liquids and particle hydration. Despite this reduction, the coconut beverage remained the brightest (L* = 85.28), although differences with other samples were minimal. The a* and b* values also decreased, likely due to pigment dilution in the aqueous medium and the absence of thermal processes [Guan et al. 2020]. All analysed beverages, in both powdered and liquid forms, exhibited colours characteristic of products without artificial colourants.

The observed differences among the samples were consistent with literature data concerning the colour of plant-based raw materials and rehydration processes.

Table 5. Color parameters of the analysed plant-based beverages in powdered form and after reconstitution (CIE L*a*b*)

Product	Form of the tested product	L* ± SD	a* ± SD	b* ± SD
I – Soy-based beverage	Powder	96.98^{b} ±0.03	-1.73^{a} ±0.03	18.71^{c} ±0.11
	beverage (reconstituted drink)	85.20^{a} ±0.10	-2.36^{b} ±0.03	7.92^{b} ±0.27
II – Coconut-based beverage	Powder	98.36^{b}±0.04	-2.46^{c} ±0.03	19.16^{d} ±0.36
	beverage (reconstituted drink)	85.28^{a} ±0.03	-2.68^{c} ±0.01	7.31^{b} ±0.05
III – Rice-based beverage	Powder	96.95^{b} ±0.05	-1.67^{a} ±0.02	17.47^{c} ±0.13
	beverage (reconstituted drink)	85.01^{a} ±0.05	-2.29^{b} ±0.03	6.90^{a} ±0.33

Differences marked with different letters in the rows indicate statistical significance at the significance level of $\alpha = 0.05$.

Source: own study.

2.5. Determination of bulk density (loose and tapped), Hausner ratio, and Carr index

Flow properties of powders constitute a crucial aspect in assessing their technological suitability, especially concerning unit operations in the food industry such as transport, mixing, dosing, and packaging. One of the fundamental parameters characterising the ability of powders to flow is bulk density, defined as the ratio of the mass of the loose material to the volume it occupies without external mechanical influence. This parameter reflects the natural arrangement of particles and the presence of interparticle voids [Jędra et al. 2015]. Complementing this is the tapped density, determined after controlled tapping, which compacts the powder by moving smaller particles into voids between larger ones, resulting in a reduced total volume [Turchiuli et al. 2005]. The bulk and tapped density measurements of the analysed plant-based powdered beverages are presented in Table 6. The highest bulk and tapped densities were observed in the coconut powder, while the lowest were found in the rice powder. These differences may be attributed to the particle morphology and surface properties of the respective raw materials [Guichard 2002].

Based on the obtained density values, the Hausner ratio was calculated, defined as the ratio of tapped density to bulk density, serving as a measure of powder flowability. Values below 1.2 indicate good flow properties, whereas higher values

suggest a tendency toward agglomeration and more difficult powder movement [Carr 1965; Hausner 1967; Peleg 1977]. The lowest Hausner ratio (1.20) was observed for the coconut powder, while the highest (1.23) was recorded for the rice powder, indicating poorer flowability characteristics for the latter.

An additional measure of powder flowability is the Carr's index, calculated based on the difference between tapped and bulk densities. Values below 15% indicate excellent flowability, while values above 20% suggest poor flow properties [Rhodes 2008]. In this study, the lowest Carr's index was observed for the coconut powder (15.87%), whereas the highest value was recorded for the rice powder (18.89%), confirming previous observations regarding the flow characteristics of this product.

Table 6. Physicochemical parameters of the analyzed plant-based powdered beverages

Product	Loose bulk density [g/cm³]	Tapped bulk density [g/cm³]	Hausner ratio (–)	Carr's index [%]
I – Soy-based beverage	$0.54^{b} \pm 0.01$	$0.64^{b} \pm 0.03$	$1.20^{b} \pm 0.02$	$16.38^{b} \pm 1.20$
II – Coconut-based beverage	$0.57^{c} \pm 0.02$	$0.68^{c} \pm 0.01$	$1.19^{a} \pm 0.02$	$15.87^{a} \pm 1.37$
III – Rice-based beverage	$0.50^{a} \pm 0.01$	$0.62^{a} \pm 0.01$	$1.23^{c} \pm 0.01$	$18.89^{c} \pm 0.84$

Differences marked with different letters in rows indicate statistically significant differences at a significance level of $\alpha = 0.05$.

Source: own study.

2.6. Evaluation of sorption properties

The characterisation of sorption properties is a key factor influencing the storage stability of powdered food products, especially those with low water activity and high hygroscopicity. Water vapor sorption from the environment is a dynamic process, the course of which depends on the type of raw material, powder structure, and environmental conditions [Bell & Labuza 2000; Mathlouthi 2001]. In the present study, empirical sorption isotherms were determined using the static-desiccator method over a water activity range of 0.07–0.92 at 25°C. The isotherms exhibited a characteristic sigmoidal shape, corresponding to Type II isotherms according to the Brunauer, Emmett, and Teller [1938] classification, typical for foods with a high content of low-molecular-weight substances and hydrophilic components [Domian & Lenart 2000].

According to Mathlouthi and Rogé [2003], sorption isotherms can be divided into three regions: (I) $a_w < 0.3$, corresponding to monolayer water strongly bound to polar groups of the matrix components; (II) $a_w = 0.3–0.7$, representing multilayer water with greater mobility; and (III) $a_w > 0.7$, free water available for microbial growth and enzymatic reactions. Based on the shape of the isotherms, it was observed that all tested products exhibited a high capacity for water vapor sorption, particularly at higher water activity levels, which is critical for designing appropriate packaging and storage conditions.

For the mathematical description of the sorption process, the BET model was applied, limiting the analysis range to water activity (a_w) between 0.07 and 0.33, corresponding to the monolayer sorption region. The model parameters are presented in Table 7.

Table 7. BET model parameters for the tested plant-based powdered beverages

Product	v_m [g H_2O/100 g d.m.]	c_e	R^2	SKO	SSA [m²/g]
I – Soy-based beverage	2.63	27.29	0.9905	2.08	92.37
II – Coconut-based beverage	2.15	41.89	0.9956	0.79	75.59
III – Rice-based beverage	2.62	37.40	0.9978	1.26	91.89

v_m – monolayer capacity; c_e – energy constant values; R^2 – determination coefficient; SKO – sum of squared deviations of the theoretical from empirical values; SSA – sorption surface area.

Source: own study.

The value of v_m, representing the monolayer capacity, is an important indicator of the shelf-life stability of powdered food products; higher v_m values suggest greater sorption capacity and improved microbiological stability under low relative humidity conditions [Ocieczek & Ruszkowska 2011; Ruszkowska 2012]. The highest v_m values were observed for the soy and rice drinks, which may indicate greater stability compared to the coconut powder. Despite its lower v_m, the coconut drink exhibited the highest BET constant (c_e), suggesting strong binding of water molecules within the monolayer range and possibly indicating the presence of more polar chemical groups in the product matrix. Based on the obtained v_m values, the specific sorption surface area was also calculated, reflecting the extent of the active surface available for water molecule sorption. The results are presented in Table 7. The soy drink powder demonstrated the largest specific sorption surface area, with the rice powder slightly lower. These values were comparable to those obtained for

other plant-based products, such as powdered milk or base blends for instant beverages [Ruszkowska & Palich 2016]. The relatively lower sorption surface area of the coconut drink may be attributed to its lipid structure, which potentially limits the accessibility of polar groups for water. The conducted study confirmed that the analyzed plant-based powdered drinks exhibited sorption properties typical of low-moisture foods, supporting their good storage stability. Differences in isotherm shape and parameters indicated a significant influence of raw material type and matrix composition on the sorption capacity of the products.

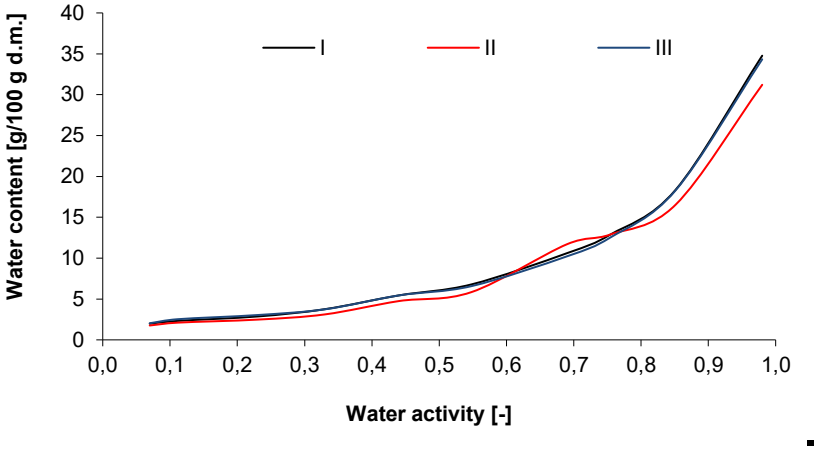

Figure 1. Sorption isotherm of the studied plant-based powdered beverages

Source: own study.

2.7. Sensory evaluation

Sensory evaluation constitutes a crucial step in the quality assessment of food products, allowing direct verification of their consumer acceptability. In this study, sensory evaluation was conducted on three powdered plant-based beverages: soy (I), coconut (II), and rice (III). The samples were reconstituted according to the manufacturer's instructions by dissolving 25 g of powder in 250 ml of hot water, then left to cool to room temperature. The reconstituted beverages demonstrated physical stability, exhibiting no signs of separation or visible sediment, an important attribute from the consumer's perspective. To facilitate comparison, reconstituted

powdered cow's milk was included as a conventional reference product. The evaluation employed a consumer test using a 5-point hedonic scale alongside a list of quality descriptors for aroma and taste. The sensory panel consisted of 20 trained participants (both women and men), aged 18–50, all with higher education and free from allergies or food intolerances, in accordance with good sensory testing practices [ISO 11136:2014].

Regarding aroma, the rice beverage and powdered milk received the highest acceptability scores (mean rating of 5), confirming their mild and neutral character. Participants described the rice beverage aroma as cereal-like and slightly sweet, while the powdered milk was characterised as creamy and typical of dairy products. The coconut beverage received lower aroma ratings, likely due to its more distinctive aromatic profile.

All beverages were positively rated for taste, with an overall mean score of 4 across the panel. The sensory panel most frequently identified characteristic flavor notes associated with the source material: cereal and mildly nutty for the soy beverage, lightly sweet for the coconut, and cereal for the rice beverage. Over 80% of respondents described the soy beverage as having a mild, slightly nutty aftertaste, and 90% identified the coconut beverage as slightly sweet.

In terms of texture, the soy beverage and powdered milk were rated highest (score of 5), suggesting uniformity and a pleasant mouth feel. The coconut beverage received a neutral score (3), indicating varied perceptions among participants. All beverages received high color ratings (mean score of 4). Overall acceptability scores were consistent across all samples (score of 4), indicating good sensory quality and promising market potential.

Table 8. Sensory evaluation of the reconstituted plant-based beverages (on a 0–5 scale)

Sensory evaluation Attribute	0 – Milk powder	I – Soy-based beverage	II – Coconut-based beverage	III – Rice-based beverage
Aroma	5	4	3	5
Taste	4	4	4	4
Consistency	5	5	3	4
Color	4	4	4	4
Overall acceptability	4	4	4	4

Source: own study.

Additionally, participants were asked about the perceived innovativeness of the products. As many as 80% of respondents considered the tested beverages to be moderately innovative, which may reflect the increasing presence of such products on the market. At the same time, 75% expressed a willingness to try similar beverages in the future, confirming consumer interest in alternatives to animal-derived milk.

Table 9. Aroma and flavor descriptors of the analyzed plant-based beverages

Attribute	0 – Milk powder	I – Soy-based beverage	II – Coconut-based beverage	III – Rice-based beverage
Description of aroma	Creamy, characteristic	Mild, plant-based	Slightly nutty	Cereal-like, mildly sweet
Description of taste	Creamy, milky, typical	Grainy, slightly nutty	Mildly sweet, coconut	Grainy, neutral

Source: own study.

Based on the conducted sensory analysis, it was concluded that the reconstituted plant-based powdered beverages exhibited a high level of acceptability, good physical stability, and clear identification of flavour and aroma characteristics. The results indicated strong consumer appeal of the tested products as functional alternatives to cow's milk, aligning with current trends in the development of the plant-based beverage market [McClements & Grossmann 2021; Sethi et al. 2016].

CONCLUSIONS

The conducted research enabled the quality assessment of three commercially available powdered plant-based beverages: soy (I), coconut (II), and rice (III), considering their nutritional value, selected physicochemical and sorption properties, as well as sensory evaluation. Based on the obtained results, the following conclusions were formulated:

1. The soy beverage stood out with the highest protein content, confirming its value as a plant-based protein source, whereas the coconut beverage, consistent with its

raw material profile, exhibited the highest fat content, corroborating the manufacturer's declarations.
2. All tested powders were characterized by low moisture content and water activity below 0.6, which supported their microbiological stability and shelf-life during storage.
3. Color parameters (CIE L*a*b*) indicated good uniformity and conformity with typical values for plant-based products; differences between the dry and reconstituted forms resulted from natural optical changes following hydration.
4. Flowability indices (Hausner ratio and Carr's index) confirmed good powder flow properties for all samples, particularly for the coconut powder, potentially facilitating their application in industrial settings.
5. Sorption property evaluation revealed that the powdered plant-based beverages exhibited type II isotherms, characteristic of foods with moderate hygroscopicity. Among them, the soy and rice powders showed the highest monolayer moisture capacity, indicating good water-binding ability. This feature may reflect higher sorption stability and suggest enhanced shelf-life under elevated humidity conditions, which favor recrystallisation and undesired physicochemical changes.
6. Reconstituted powdered plant-based beverages received high sensory scores, exhibiting distinct aroma and flavor profiles characteristic of the raw materials used. The soy beverage was described as mildly nutty, the coconut as slightly sweet, and the rice as cereal-like.
7. The results confirm that the analysed powders constitute a valuable alternative to cow's milk, especially in the context of products with extended shelf-life. Future research should focus on enriching the composition with functional components, improving sensory attributes, and optimising the reconstitution process, taking into account consumer needs and sustainable development principles.

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ASSESSMENT OF WOMEN'S KNOWLEDGE AND AWARENESS IN TERMS OF PRODUCTS CONTAINING FIBER AND FATS

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Abstract

Adequate nutrition is crucial for maintaining metabolic balance and preventing chronic diseases. This study assessed women's knowledge and awareness regarding dietary fiber and fats. A CAWI survey was conducted among 150 female respondents aged below and above 35 years. The results revealed significant differences in nutritional awareness between age groups, with younger women demonstrating lower understanding of recommended fiber intake and fat quality. Higher education correlated with better awareness of functional food and lipid composition. Findings highlight the need for targeted nutrition education promoting informed consumption of dietary fiber and healthy fats.

Keywords: nutrition knowledge, women, dietary fiber, fats, awareness.

INTRODUCTION

Proper nutrition is one of the fundamental determinants of human health and quality of life. A balanced diet containing adequate amounts of dietary fiber and fats plays a crucial role in preventing lifestyle-related diseases, including obesity, type 2 diabetes, atherosclerosis, and cardiovascular disorders [Gawęcki 2012; Jarosz et al. 2020]. Nutrition knowledge among consumers is a key factor shaping rational dietary behaviors; therefore, its assessment constitutes an important element of

research on public health awareness and dietary practices [Banach & Jezierska 2023; Kowalska et al. 2022].

Dietary fiber, an indigestible component of plant origin, exerts multidirectional health-promoting effects. It regulates gastrointestinal function, influences blood glucose and cholesterol levels, and supports the development of beneficial intestinal microflora [Ciborowska & Rudnicka 2018; Gawęcki 2012]. The recommended daily fiber intake for adults is 25–40 g; however, actual consumption levels in the Polish population are significantly lower [Jarosz et al. 2020; Traczyk & Jarosz 2012]. The insufficient supply of dietary fiber often results from limited knowledge about its sources and importance in the diet [Grafka et al. 2019].

Although fats are the most concentrated source of energy, they also perform essential structural and regulatory functions in the human body. They provide essential unsaturated fatty acids necessary for the proper functioning of the nervous, hormonal, and cardiovascular systems [Gawęcki 2012]. However, an improper ratio of saturated to unsaturated fats and an excessive total fat intake may contribute to the development of numerous metabolic diseases [Kałwa & Wilczyński 2017; Wilczyńska 2012].

1. MATERIAL AND METHODS

The survey was conducted from November 2024 to February 2025. A proprietary electronic questionnaire was used to collect data via the Microsoft Forms platform (CAWI – Computer-Assisted Web Interview).

A total of 150 women participated in the survey (detailed data are presented in Table 1). Three basic demographic variables were analysed, allowing for a detailed characterisation of the respondents: age, education level, and place of residence, taking into account the population size.

With respect to age, the study group was divided into two groups: women under 35 years of age constituted 51% of all respondents (n = 76), while women over 35 years of age constituted 49% (n = 74). This means that the sample was almost evenly distributed in terms of age, allowing for cross-group comparisons. In terms of education, the largest group consisted of those with higher education (46% n = 69), followed by those with secondary education (34% n = 51). Female

students constituted 12% (n = 18), and those with vocational education (8% n = 12). Individuals with only primary education did not participate in the study.

In terms of place of residence, respondents came from a variety of demographics. The majority of participants lived in cities with up to 50,000 inhabitants (31%, n = 46). Next, the largest groups were those living in cities with 150,000 to 500,000 inhabitants (23%, n = 35), followed by rural areas (15%, n = 22), and cities with 50,000 to 150,000 inhabitants (15%, n = 23). Women from the largest cities, with populations exceeding 500,000, constituted 16% of the sample (n = 24).

Table 1. Characteristics of the surveyed group of respondents

Variable		Number of indications (n)	[%]
Age	Under 35 years old	76	51
	Over 35 years old	74	49
Education	Primary	0	0
	Secondary	51	34
	Vocational	12	8
	Female students	18	12
	Higher	69	46
Place of residence – number of inhabitants	Countryside	22	15
	up to 50 thousand	46	31
	50–150 thousand	23	15
	150–500 thousand	35	23
	> 500 thousand	24	16

Source: own study.

2. RESULTS AND DISCUSSION

The study aimed to evaluate the level of knowledge and awareness among women concerning dietary fiber and fats – two macronutrients that play a fundamental role in maintaining homeostasis and preventing diet-related diseases. Results indicated that although most respondents demonstrated a general understanding of healthy nutrition principles, their detailed knowledge regarding the physiological role and sources of fiber and fats remained insufficient. Similar tendencies were observed in studies by Anderson et al. [2009] and Slavin [2013],

emphasising that while fiber is widely recognised as beneficial, the mechanisms behind its health effects are less understood among consumers.

Younger respondents (under 35 years) showed lower awareness of daily fiber intake recommendations, food sources, and the distinction between soluble and insoluble fiber. This corresponds to research by Karwowska and Majchrzak [2015], who demonstrated that consumer understanding of fiber composition remains limited, especially among younger adults and those with moderate education levels. Older women (over 35 years) displayed higher awareness, often motivated by health concerns or previous dietary counselling. All research results are presented in Table 2.

Table 2. Knowledge and awareness of women regarding dietary fiber and fats

Question / Indicator	Women under 35 years	Women over 35 years	Interpretation
Awareness of fiber definition and types	54% correctly identified soluble and insoluble fiber	72% correctly identified both types	Older respondents demonstrated more accurate conceptual understanding ($p < 0.05$)
Knowledge of recommended daily fiber intake (25–35 g/day)	41% aware	63% aware	General underestimation of dietary recommendations in both groups
Recognition of fiber-rich foods (whole grains, legumes, vegetables)	68% correct	81% correct	Indicates satisfactory awareness but limited translation into daily practice
Awareness of fat classification (saturated, MUFA, PUFA)	52% correct	70% correct	Younger group confused MUFA and PUFA; educational need identified
Knowledge of sources of unsaturated fats (olive oil, nuts, fish)	61% aware	85% aware	Older respondents more likely to associate olive oil and nuts with health benefits
Awareness of trans fats and processed foods	44% aware	67% aware	Trans fats remain underrecognised among younger women
Reading nutrition labels for fat and fiber content	39% frequently read	64% frequently read	Label literacy improves with age and education

cont. Table 1

Belief in importance of fiber for digestion and weight control	84% agree	92% agree	High general awareness but with limited practical adherence
Belief in need to limit all fats equally	57% agree	28% agree	Indicates persistent misconceptions among younger respondents

Source: own study.

Regarding fat consumption, both age groups recognised fats as an essential dietary component, but misconceptions persisted concerning the role of saturated and unsaturated fats. Many younger participants associated all fats with negative health outcomes, while older women more accurately identified olive oil, nuts, and fish as sources of beneficial unsaturated fatty acids. Comparable findings were reported by Thorning et al. [2016] and Wilczyńska [2012], who highlighted that public knowledge of fat quality often lacks nuance, particularly in distinguishing MUFA and PUFA from harmful trans fats.

Quantitative analysis revealed substantial differences in respondents' nutritional knowledge depending on age and education level. Women above 35 years generally demonstrated greater awareness of dietary recommendations, the role of fats and fiber in health maintenance, and the interpretation of food labeling. This trend supports previous observations by Gawęcki [2011] and Świątkowska et al. [2022], who noted that age and education significantly influence nutrition literacy.

Most younger respondents declared familiarity with the concept of "healthy eating," yet their practical understanding – such as identifying high-fiber foods or differentiating between saturated and unsaturated fats – remained incomplete. Similar findings were obtained in research by Godula et al. [2019], indicating that the ability to apply theoretical knowledge to daily dietary choices is often limited among younger consumers.

The results also highlighted discrepancies between attitudes and actual behaviors. While the majority of respondents expressed awareness of the importance of fiber and unsaturated fats, fewer consistently implemented these principles in their diet. A comparable inconsistency was observed by Kozłowska-Strawska et al. [2017], who emphasised the gap between declared and real food practices, even among individuals declaring pro-health attitudes.

The data reveal a clear relationship between age, education, and nutritional awareness. Older women, typically with more stable lifestyles and greater exposure

to health information, demonstrated higher levels of dietary knowledge and more rational attitudes toward fat and fiber consumption. These findings align with previous studies indicating that age is positively correlated with nutrition literacy [Anderson et al. 2009; Grajeta 2004].

Younger respondents tended to perceive "fat" as inherently unhealthy, reflecting a long-standing stereotype perpetuated by media and restrictive diet trends. This echoes the conclusions of Rybicka and Kowalczewski [2024], who noted that marketing messages emphasising "low-fat" products often distort consumer understanding of fat quality and nutritional balance. Similarly, Thorning et al. [2016] reported that simplistic public health communication may inadvertently encourage the avoidance of beneficial fats, such as omega-3 and omega-6 fatty acids.

Awareness of dietary fiber functions was relatively high but often limited to digestive benefits, without a clear understanding of its metabolic roles, such as regulation of blood glucose and cholesterol levels. Comparable results were found by Slavin [2013] and Galanakis [2019], who emphasised the need to strengthen public knowledge of fiber's prebiotic effects and its preventive role against metabolic disorders.

Moreover, both groups displayed gaps in knowledge about food labelling, suggesting insufficient ability to interpret nutrient composition. According to EFSA [2022] and BNF [2023], improving label literacy is crucial for promoting informed choices, particularly in populations with variable dietary awareness. In this study, only 39% of younger and 64% of older women regularly read labels for fiber and fat content, indicating an area for targeted education.

Education emerged as a key determinant of knowledge accuracy. Respondents with higher education levels were more likely to provide correct responses regarding fat classification and fiber types. These findings correspond with Świątkowska et al. [2022], who demonstrated that individuals with tertiary education are more responsive to nutritional campaigns and more capable of applying dietary recommendations.

Environmental factors, such as access to reliable information, lifestyle pace, and social influences, also played a notable role. Younger women, balancing professional and family responsibilities, often reported limited time for meal planning and reliance on convenience foods. Similar behavioral determinants were reported by Musioł et al. [2015], linking time scarcity and stress with suboptimal food choices and irregular eating habits. Conversely, older women tended to exhibit greater

dietary consistency, possibly reflecting a stronger orientation toward preventive health behaviors.

The observed patterns correspond to global research indicating that women generally show higher nutrition awareness than men but may still struggle to implement knowledge effectively [FAO 2021; WHO 2023]. In the European context, EFSA [2022] highlights a persistent gap between theoretical understanding and real dietary practices – particularly concerning fat quality, where misconceptions about "good" and "bad" fats remain widespread. The British Dietetic Association [2023] also emphasises that practical nutrition education should integrate both cognitive and behavioural components, encouraging mindful, label-based food choices.

The discrepancies observed between declared knowledge and actual behaviour underline a key challenge in public nutrition: awareness does not always translate into informed action. Although most respondents understood that fiber supports digestive health and fats are not uniformly harmful, their daily practices often contradicted this knowledge. This phenomenon, known as the knowledge–behaviour gap, has been described in several studies [Micha & Mozaffarian 2009; Wanders et al. 2011], indicating that cognitive understanding alone is insufficient to sustain healthy eating patterns.

From a behavioural perspective, the results suggest that emotional and situational factors – such as stress, convenience, and exposure to marketing – strongly mediate food choices. Younger women, in particular, reported a tendency to omit breakfast or snack irregularly, behaviours that can impair metabolic regulation and reinforce misconceptions about fat and calorie control. According to Gawęcki [2011] and Wilczyńska [2012], such patterns may contribute to energy imbalance and micronutrient deficiencies over time.

Older respondents' higher awareness likely stems from cumulative exposure to health information through traditional media, medical consultations, and life experience. This aligns with findings by Grajeta [2004], showing that preventive health awareness increases with age, especially among women. However, the persistence of partial misconceptions – even within the older group – suggests that educational interventions should not rely solely on age but also on personalised communication strategies.

Importantly, both groups recognised the importance of fiber in weight control and fat in maintaining energy and hormonal balance. Yet misconceptions persisted: more than half of younger participants believed that "all fats should be limited",

reflecting a reductionist interpretation of dietary guidelines. Public health programs should therefore emphasise the qualitative rather than quantitative aspects of fat intake – promoting the consumption of unsaturated fatty acids and discouraging industrial trans fats.

In practical terms, these results highlight the need for continuous nutrition education, tailored to demographic characteristics. For younger women, digital and social media platforms represent the most effective channels, as noted by recent WHO [2023] recommendations on health promotion through digital communication. For older consumers, community-based and institutional initiatives may yield better engagement. Combining both approaches could ensure broader reach and sustained impact.

Educational efforts should integrate theoretical and behavioural components, focusing on label reading, portion control, and product selection based on fiber and fat quality. According to EFSA [2022] and the British Dietetic Association [2023], effective interventions must move beyond information dissemination toward developing practical skills, such as interpreting nutrition labels, planning balanced meals, and recognizing misleading health claims.

CONCLUSIONS

The conducted study confirms that women's nutritional knowledge and awareness regarding dietary fiber and fats remain inconsistent and partially influenced by non-scientific sources. While younger respondents demonstrate higher engagement with nutrition content, this does not always translate into accurate understanding or healthy dietary behaviour. Older women tend to display more comprehensive and evidence-based knowledge, which more frequently results in appropriate dietary choices.

Based on the research conducted, the following conclusions were drawn:

1. The study confirmed that women's nutritional awareness concerning dietary fiber and fats is moderate, with significant variation by age and education level.
2. Older respondents demonstrated higher knowledge accuracy, particularly regarding fat quality and fiber function, while younger women displayed more misconceptions about dietary fat.

3. Despite high self-declared awareness, behavioural inconsistencies persist, underscoring the gap between knowledge and practice.
4. Targeted education – emphasising food label interpretation, fiber intake recommendations, and the role of unsaturated fats – is necessary to enhance dietary literacy and public health outcomes.
5. Future programs should adapt communication strategies to audience age and lifestyle, employing digital media for younger consumers and community education for older ones.

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JAKOŚĆ USŁUG ŚWIADCZONYCH PRZEZ PUBLICZNE I PRYWATNE PLACÓWKI MEDYCZNE W PERSPEKTYWIE KLIENTÓW

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Streszczenie

Jednym z najważniejszych czynników determinujących konkurencyjność placówek medycznych jest wysoka jakość świadczonych usług, ich ciągłe doskonalenie oraz dostosowanie do potrzeb klientów. Aby zwiększać zadowolenie swoich klientów z oferowanych usług, każda placówka medyczna powinna wdrażać działania mające na celu poznanie wymagań klientów związanych z usługą, a także badać ich satysfakcję ze spełnienia tych wymagań.

Celem badania była ocena postrzegania przez klientów jakości usług świadczonych przez publiczne i prywatne placówki medyczne. Badanie przeprowadzono z wykorzystaniem metody ankiety. W badaniu wzięło udział 262 respondentów. Stwierdzono, że respondenci postrzegają jakość usług świadczonych przez prywatne placówki medyczne oraz dostępność tych usług jako wyższą w porównaniu z jakością i dostępnością publicznych świadczeń medycznych. Do korzystania z usług świadczonych przez publiczne placówki medyczne respondentów skłania przede wszystkim ich bezpłatność, z kolei do korzystania z usług prywatnych – krótki czas oczekiwania na usługę oraz jakość tych usług. Wybierając placówkę medyczną, respondenci kierują się przede wszystkim czasem oczekiwania na usługę oraz kompetencjami i doświadczeniem pracowników placówki. Na postrzeganie jakości usługi medycznej przez respondentów ma wpływ przede wszystkim czystość i higiena pomieszczeń placówki, kompetencje personelu i profesjonalizm obsługi oraz czas oczekiwania na wizytę.

Słowa kluczowe: jakość usług, usługi medyczne, ocena jakości.

WPROWADZENIE

Konstytucja Rzeczpospolitej Polskiej ustanawia prawo każdego obywatela do ochrony zdrowia i wynikający stąd obowiązek państwa do zapewnienia odpowiednich standardów medycznych [Konstytucja 1997]. Usługi medyczne mogą być świadczone przez różne podmioty, w tym publiczne (finansowane ze środków publicznych) i prywatne placówki medyczne (finansowane z innych źródeł) [Smarżewska 2020; Ustawa 2011]. Oczekiwania współczesnego społeczeństwa związane z opieką medyczną są coraz większe i kładą szczególny nacisk na jakość udzielanych świadczeń. Dlatego bez względu na status prowadzonej działalności, jednym z najważniejszych wyzwań stojących przed każdą placówką świadczącą usługi medyczne jest zapewnienie wysokiej jakości tych usług, ich ciągłe doskonalenie oraz dostosowanie do potrzeb klientów [Bembnowska i Jośko-Ochojska 2015; Guzak i Rybka 2024]. Jakość usług przekłada się bowiem na bezpieczeństwo pacjenta, jego życie i zdrowie, a co za tym idzie na zadowolenie i zaufanie do placówki medycznej [Waszkiewicz i Białecka 2012]. Jest również jednym z czynników determinujących konkurencyjność placówek medycznych [Trela 2016; Trzcińska 2019].

Jakość usługi medycznej można zdefiniować jako świadczenie, które odpowiada określonym kryteriom i aktualnemu stanowi wiedzy medycznej w ramach posiadanych zasobów, zapewniających pacjentowi maksymalny zysk zdrowotny i minimalne ryzyko ochrony zdrowia [Pintal-Ślimak i in. 2018; Trela 2016]. Przy określeniu jakości usługi medycznej wyróżniane są jej trzy podstawowe kategorie: jakość struktury (w tym liczba i poziom wykształcenia personelu świadczącego usługę, infrastruktura i aparatura medyczna posiadana przez placówkę, struktura organizacyjna placówki, kultura organizacji oraz styl zarządzania placówką), jakość procesu (opieka nad pacjentem) oraz jakość wyników (efekty leczenia oraz zadowolenie pacjentów) [Gajewska 2019; Guzak i Rybka 2024; Pintal-Ślimak i in. 2019]. Zdaniem Gajewskiej [2019] oraz Stawickiej [2016] wśród stref, w których można analizować jakość usług medycznych, wyróżnia się jakość usługi – opieki medycznej (przeprowadzenie zabiegu zgodnie z najnowszą wiedzą medyczną), sferę informacyjną (skuteczna komunikacja między personelem medycznym a pacjentem związana z usługą), sferę techniczną (jakość i nowoczesność sprzętu stosowanego w diagnostyce i leczeniu), sferę zarządzania i ekonomiczno-administracyjną (właściwy sposób zarządzania placówką oraz zasobami finansowymi,

infrastrukturalnymi i ludzkimi) oraz sferę marketingu. Gajewska dodatkowo wskazuje, że na jakość usług świadczonych przez placówki medyczne składa się jakość techniczna i funkcjonalna. Jakość techniczna oznacza zgodność z normami i technicznymi wymaganiami stawianymi usługom medycznym (w tym zapewnienie standardów medycznych, nowoczesnej technologii oraz kompetencji personelu medycznego). Z kolei jakość funkcjonalna jest wynikiem subiektywnej oceny pacjenta. Pacjent będzie zadowolony z usługi medycznej wówczas, gdy nastąpi równowaga pomiędzy tymi dwoma wymiarami jakości [Gajewska 2019]. Z kolei Wiśniewska i Muraczewska [2015] oraz Rosak-Szyrocka [2016] wskazują, że na jakość usługi medycznej wpływa potencjał placówki, na którą składają się kompetencje personelu medycznego, nowoczesność sprzętu medycznego, którym dysponuje placówka, dostępność usług świadczonych przez placówkę, niezawodność, uprzejmość i wrażliwość personelu placówki wobec pacjentów (empatia i gotowość niesienia pomocy), wygląd placówki i jej pracowników, przejrzystość działań, odpowiedzialność personelu za realizowane działania, bezpieczeństwo pacjentów podczas świadczenia usługi, komunikatywność (przepływ informacji między personelem placówki a pacjentem), a także jakość kliniczna usługi (dostosowanie usługi do stanu zdrowia pacjenta).

Jakość usługi medycznej jest pojęciem złożonym i wielowymiarowym, a jej definiowanie zależy od punktu widzenia strony zainteresowanej, która ją ocenia, np. personelu medycznego, właścicieli placówki medycznej i zarządzających placówką, płatnika (Narodowego Funduszu Zdrowia) oraz pacjenta (klienta placówki) [Trzcińska 2019]. Jednakże analizując wymiary jakości usługi medycznej, najważniejsze jest jej postrzeganie z punktu widzenia pacjenta, który powinien być traktowany jako klient (podmiot) placówki medycznej o określonych potrzebach i oczekiwaniach, które powinny być spełnione. Jakości usług medycznych nie można rozpatrywać w oderwaniu od potrzeb i preferencji pacjentów co do atrybutów tych usług [Nadziakiewicz 2018]. Z punku widzenia pacjenta ważny jest nie tylko efekt, czyli wynik leczenia, ale także inne elementy wpływające na postrzeganie jakości świadczonych usług, tj. wystrój placówki, stosowana aparatura medyczna, płynność przepływu informacji pomiędzy personelem a pacjentem czy uprzejmość i empatia personelu [Trela 2016].

Wybierając placówkę medyczną, pacjenci oczekują nie tylko rzetelnego wykonania procedury medycznej, ale również odpowiedniej jakości obsługi, poszanowania własnej godności, rzetelnej i zrozumiałej informacji oraz właściwych

warunków świadczenia usługi [Guzak i Rybka 2024]. Dokonując wyboru placówki, pacjenci muszą polegać na swojej intuicji, opiniach znajomych oraz byłych pacjentów na jej temat [Guzak i Rybka 2024; Makieła i Przebinda 2015]. Opinie te są jednak często subiektywne i nie zawsze wiarygodne, ponieważ pacjenci dokonują oceny jakości usług świadczonych przez placówkę często na podstawie własnych, bardzo subiektywnych odczuć związanych z procesem świadczenia usługi medycznej [Guzak i Rybka 2024]. Ważną rolę w wyborze placówki pełnią również dotychczasowe doświadczenia pacjentów związane z korzystaniem z usług medycznych [Makieła i Przebinda 2015].

Potrzeby pacjentów, które inicjują świadczenie usług medycznych, są niezwykle trudne do przewidzenia [Detyna 2016]. Mimo tych trudności, placówki medyczne muszą nie tylko zrozumieć, jak ważne są poszczególne atrybuty świadczonych usług dla pacjentów i jak te atrybuty wpływają na ich decyzje związane z wyborem placówki, ale także wiedzieć, jak spełnienie wymagań w odniesieniu do każdego atrybutu wpływa na satysfakcję pacjentów [Malik i Sharma 2017]. Dlatego powinny wdrażać działania mające na celu poznanie wymagań klientów związanych z usługą, a także badać ich satysfakcję ze spełnienia tych wymagań, ponieważ jest to podstawą uruchomienia procesu doskonalenia jakości, a także skutecznego zarządzania w placówce medycznej [Bembnowska i Jośko-Ochojska 2015; Trzcińska 2019].

1. METODA BADANIA

Celem badania była ocena postrzegania przez klientów jakości usług świadczonych przez publiczne i prywatne placówki medyczne. Badanie zostało przeprowadzone z wykorzystaniem metody pomiaru sondażowego pośredniego on-line (CAWI). Narzędziem badawczym był zaprojektowany na potrzeby badania autorski kwestionariusz ankiety. Kwestionariusz zawierał 10 pytań zamkniętych jedno- oraz wielokrotnego wyboru oraz dwa pytania, w których zastosowano pięciostopniową skalę porządkową. Pytania zadane respondentom dotyczyły:

- częstotliwości korzystania z usług medycznych,
- powodów, dla których respondenci decydują się na korzystanie z usług świadczonych przez prywatne i publiczne placówki medyczne,
- determinant wyboru placówki medycznej,

– czynników wpływających na postrzeganie jakości usług medycznych,
– oceny dostępności oraz jakości usług medycznych.

Kwestionariusz ankiety został udostępniony respondentom za pomocą narzędzia Google Forms. Dobór próby miał charakter przypadkowy i wygodny. W badaniu wzięło udział 262 respondentów (tabela 1).

Tabela 1. Struktura respondentów

Cecha socjodemograficzne		n	[%]
Płeć	Kobieta	143	55
	Mężczyzna	119	45
Wiek	18–35	212	81
	36–60	41	16
	powyżej 60	9	3
Wykształcenie	Podstawowe	7	3
	Średnie	152	58
	Wyższe	102	39

Źródło: opracowanie własne.

Wyniki badania analizowano z wykorzystaniem metod statystyki opisowej, obliczając dla każdej odpowiedzi wskaźniki struktury. Wyniki opracowano w programie Microsoft Excel 2016.

2. WYNIKI

Większość, bo aż 96% respondentów, deklaruje korzystanie z publicznej służby zdrowia. Nieco mniej (89%) korzysta z usług świadczonych przez prywatne placówki medyczne (tabela 2).

Tabela 2. Częstotliwość korzystania przez respondentów z usług świadczonych przez publiczne i prywatne placówki medyczne

Częstotliwość korzystania	Publiczne placówki medyczne		Prywatne placówki medyczne	
	n	[%]	n	[%]
Bardzo często	41	16	34	13
Często	55	21	70	27
Rzadko	107	41	102	39
Bardzo rzadko	49	19	28	11
Nie korzystam	10	4	28	11

Źródło: opracowanie własne.

Analizując dane przedstawione w tabeli, można stwierdzić, że respondenci w podobnym stopniu korzystają z publicznych oraz prywatnych usług medycznych. Największa grupa ankietowanych deklaruje, że z obu rodzajów usług korzysta rzadko (odpowiednio 41% i 39%), natomiast druga pod względem liczności grupa badanych korzysta z nich często (odpowiednio 21% oraz 27%). Z usług świadczonych przez publiczne placówki medyczne bardzo często korzysta 16% respondentów, a z prywatnych usług medycznych – 13%.

Zapytani o powody, dla których korzystają z usług świadczonych przez publiczne placówki medyczne, respondenci wskazywali przeze wszystkim na czynniki ekonomiczne. Pytanie miało charakter wielokrotnego wyboru (tabela 3).

Tabela 3. Powody korzystania przez respondentów z usług świadczonych przez publiczne placówki medyczne

Powody korzystania z publicznych usług medycznych	n	[%]
Odprowadzam obowiązkowe składki na ubezpieczenie zdrowotne, dlatego należy mi się dostęp do publicznych usług	169	65
Nie dysponuję dostatecznymi środkami pieniężnymi na korzystanie z usług świadczonych przez prywatne placówki medyczne	100	38
W pobliżu mojego miejsca zamieszkania nie ma prywatnych placówek medycznych	28	11
Kompetencje i doświadczenie pracowników publicznych placówek medycznych są większe niż pracowników prywatnych placówek medycznych	11	4

cd. Tabeli 3

Jakość usług świadczonych przez publiczne placówki medyczne jest wyższa niż jakość usług świadczonych przez prywatne placówki medyczne	8	3
Mam większe zaufanie do pracowników publicznych placówek medycznych niż do pracowników prywatnych placówek medycznych	5	2

Źródło: opracowanie własne.

Respondenci deklarują, że korzystają z publicznych usług medycznych przede wszystkim z powodu uprawnień dostępu do takich usług wynikających z odprowadzania obowiązkowych składek na ubezpieczenie zdrowotne (65% wskazań) oraz braku wystarczających środków pieniężnych umożliwiających im korzystanie z usług świadczonych przez placówki prywatne (38% wskazań). Ponadto ankietowani wskazywali, iż w pobliżu ich miejsc zamieszkania nie znajdują się żadne prywatne placówki medyczne (11%), przez co są zmuszeni do korzystania jedynie z usług publicznych. Pozostałe czynniki (kompetencje i doświadczenie pracowników placówki, jakość świadczonych usług oraz zaufanie do pracowników placówki) w niewielkim stopniu determinują decyzje badanych dotyczące korzystania z publicznych placówek medycznych.

Respondentów zapytano również o powody, dla których korzystają z usług świadczonych przez prywatne placówki medyczne. Ankietowani mieli możliwość wskazania wielu odpowiedzi (tabela 4).

Tabela 4. Powody korzystania przez respondentów z usług świadczonych przez prywatne placówki medyczne

Powody korzystania z prywatnych usług medycznych	**n**	**[%]**
Czas oczekiwania na usługi świadczone przez prywatne placówki medyczne jest krótszy niż na usługi świadczone przez publiczne placówki medyczne	177	68
Jakość usług świadczonych przez prywatne placówki medyczne jest wyższa niż jakość usług świadczonych przez publiczne placówki medyczne	111	42
Prywatne placówki medyczne oferują szerszy zakres usług niż placówki publiczne	85	32
Kompetencje i doświadczenie pracowników prywatnych placówek medycznych są większe niż pracowników publicznych placówek medycznych	47	18
Mam wykupiony pakiet usług medycznych w placówkach prywatnych	45	17

Źródło: opracowanie własne.

Najczęstszym powodem, dla którego respondenci decydują się na wybór prywatnej placówki medycznej (68% wskazań), jest krótszy czas oczekiwania na usługę w porównaniu z usługami świadczonymi przez placówki publiczne. Badani wskazywali również na jakość tych usług, która w ich opinii jest wyższa w porównaniu z jakością publicznych usług medycznych (42% wskazań) oraz szerszy zakres usług oferowanych przez placówki prywatne (32% wskazań). Mniejsze znaczenie mają dla respondentów kompetencje i doświadczenie pracowników prywatnych placówek oraz wykupiony pakiet usług medycznych (odpowiednio 18% i 17% wskazań).

Ankietowanych poproszono także o wskazanie, w jakim stopniu określone kryteria determinują ich decyzje związane z wyborem placówki medycznej (tabela 5).

Tabela 5. Kryteria wyboru przez respondentów placówki medycznej

Kryterium wyboru placówki medycznej	Zdecydowanie nieważne	Raczej nieważne	Trudno powiedzieć	Raczej ważne	Zdecydowanie ważne	Średnia ocena
	(1)	(2)	(3)	(4)	(5)	
Czas oczekiwania na usługę	6 (2%)	7 (3%)	14 (5%)	63 (24%)	172 (66%)	4,48
Kompetencje i doświadczenie pracowników placówki	6 (2%)	5 (2%)	30 (11%)	90 (34%)	131 (50%)	4,28
Koszt usługi	7 (3%)	10 (4%)	34 (13%)	96 (37%)	115 (44%)	4,15
Zakres świadczonych usług	7 (3%)	15 (6%)	24 (9%)	107 (41%)	109 (42%)	4,13
Bezpieczeństwo pacjenta podczas świadczonej usługi	7 (3%)	14 (5%)	41 (16%)	79 (30%)	121 (46%)	4,12
Opinie o placówce	11 (4%)	15 (6%)	26 (10%)	102 (39%)	108 (41%)	4,07
Odległość placówki od miejsca zamieszkania	9 (3%)	33 (13%)	38 (15%)	94 (36%)	88 (34%)	3,84
Wyposażenie placówki	7 (3%)	28 (11%)	58 (22%)	97 (37%)	72 (27%)	3,76
Sposoby umawiania wizyty	19 (7%)	43 (16%)	60 (23%)	71 (27%)	69 (26%)	3,49

Źródło: opracowanie własne.

Wszystkie oceniane kryteria są dla respondentów ważnymi determinantami wyboru placówki medycznej (dla wszystkich kryteriów stwierdzono łącznie powyżej 50% wskazań: raczej ważne i zdecydowanie ważne). Większość z nich (6 z 9) uzyskała średnią ocenę powyżej 4, co świadczy o ich dużym znaczeniu dla ankietowanych. Wybierając placówkę medyczną, badani biorą pod uwagę przede wszystkim czas oczekiwania na usługę (4,48) oraz kompetencje i doświadczenie pracowników placówki (4,28). Ważnymi determinantami wyboru placówki przez ankietowanych są również koszt usługi (4,15), zakres świadczonych usług (4,13) oraz bezpieczeństwo zapewniane pacjentowi podczas świadczenia usługi (4,12). Najmniejszy znaczenie ma dla respondentów sposób umawiania wizyty (3,49).

Badanie miało na celu również ocenę wpływu cech usługi medycznej na postrzeganie przez respondentów jakości usług świadczonych przez placówki medyczne (tabela 6).

Tabela 6. Wpływ cech usługi medycznej na postrzeganie przez respondentów jakości usług świadczonych przez placówki medyczne

Cecha usługi medycznej	Zdecydowanie nie wpływa	Raczej nie wpływa	Trudno powiedzieć	Raczej wpływa	Zdecydowanie wpływa	Średnia
	(1)	(2)	(3)	(4)	(5)	
Czystość i higiena pomieszczeń placówki	1 (0%)	7 (3%)	7 (3%)	61 (23%)	186 (71%)	4,62
Kompetencje personelu i profesjonalizm obsługi	5 (2%)	5 (2%)	5 (2%)	59 (23%)	188 (72%)	4,60
Czas oczekiwania na wizytę	4 (2%)	9 (3%)	14 (5%)	53 (20%)	182 (69%)	4,53
Indywidualne podejście personelu do pacjenta	2 (1%)	9 (3%)	22 (8%)	69 (26%)	160 (61%)	4,44
Dostępność do usług	3 (1%)	7 (3%)	12 (5%)	93 (35%)	147 (56%)	4,43
Poszanowanie prawa do prywatności i intymności	5 (2%)	9 (3%)	16 (6%)	71 (27%)	161 (61%)	4,43
Dostępność i nowoczesność sprzętu medycznego	3 (1%)	6 (2%)	24 (9%)	107 (41%)	122 (47%)	4,29

cd. Tabeli 6

Kompleksowość usług	2 (1%)	10 (4%)	29 (11%)	96 (37%)	125 (48%)	4,27
Różnorodność sposobów umawiania wizyt	14 (5%)	39 (15%)	36 (14%)	80 (31%)	93 (35%)	3,76

Źródło: opracowanie własne.

W opinii badanych wszystkie oceniane cechy determinują postrzeganie przez nich jakości usług medycznych (dla każdej cechy stwierdzono łącznie powyżej 60% wskazań: raczej wpływa i zdecydowanie wpływa). Należy także zauważyć, że prawie wszystkie cechy (poza różnorodnością sposobów umawiania wizyt) uzyskały średnią ocenę powyżej 4, co świadczy o tym, że znacząco determinują opinię ankietowanych o jakości usług świadczonych przez placówki. Opinia respondentów o jakości usługi medycznej w największym stopniu zależy od czystości i higieny pomieszczeń placówki (4,62), kompetencji personelu i profesjonalizmu obsługi (4,60) oraz czasu oczekiwania na wizytę (4,53).

Jednym z wyróżników usługi medycznej, mającym wpływ na zadowolenie pacjentów, jest dostępność usługi. Autorzy publikacji poświęconych jakości usług medycznych wskazują, że dostępność tych usług jednym z poważniejszych wyzwań stojących przed współczesnym systemem ochrony zdrowia, a opinia pacjentów o dostępności usług jest negatywna [Kanownik 2017; Nadziakiewicz 2018; Sygit i in. 2017]. W tabeli 7 przedstawiono opinie respondentów na temat dostępności publicznych i prywatnych usług medycznych.

Tabela 7. Ocena przez respondentów dostępności usług świadczonych przez placówki medyczne

Opinia na temat dostępności usług	Publiczne placówki medyczne		Prywatne placówki medyczne	
	n	[%]	n	[%]
zdecydowanie pozytywna	7	3	43	16
raczej pozytywna	47	18	162	62
trudno powiedzieć	92	35	50	19
raczej negatywna	79	30	6	2
zdecydowanie negatywna	37	14	1	1

Źródło: opracowanie własne.

W przypadku publicznych usług medycznych największa grupa respondentów oceniła ich dostępność negatywnie (łącznie 44% wskazań: ocena raczej negatywna i zdecydowanie negatywna). Pozytywną opinię na temat dostępności tych usług wyraziła jedna piąta respondentów (łącznie 21% wskazań: ocena zdecydowanie pozytywna i raczej pozytywna). Należy również zauważyć, że duża grupa respondentów (35%) nie potrafiła wyrazić swojej opinii na ten temat. Z kolei opinia większości respondentów na temat dostępności usług świadczonych przez prywatne placówki medyczne jest pozytywna (łącznie 78% wskazań: ocena zdecydowanie pozytywna i raczej pozytywna). Tylko 3% respondentów negatywnie ocenia dostępność tych usług, z kolei 19% nie potrafiło wyrazić swojej opinii w tym zakresie.

Respondentów poproszono również o wyrażenie opinii na temat jakości usług świadczonych przez prywatne i publiczne placówki medyczne (tabela 8).

Tabela 8. Opinia respondentów na temat jakości usług świadczonych przez placówki medyczne

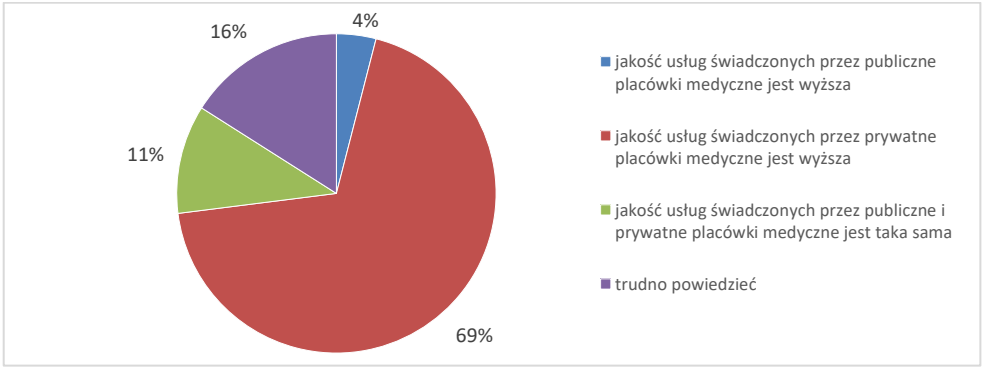
Opinia na temat jakości usług	Publiczne placówki medyczne		Prywatne placówki medyczne	
	n	[%]	n	[%]
zdecydowanie pozytywna	9	3	38	14
raczej pozytywna	81	31	159	61
trudno powiedzieć	104	40	60	23
raczej negatywna	67	21	3	1
zdecydowanie negatywna	25	5	2	1

Źródło: opracowanie własne.

Oceniając jakość usług świadczonych przez publiczne placówki medyczne, największa grupa respondentów (40%) nie potrafiła wyrazić swojej opinii. Pozytywną ocenę na temat jakości tych usług wyraziło 34% ankietowanych (wskazania: ocena zdecydowanie pozytywna i raczej pozytywna), z kolei 26% oceniło tę jakość negatywnie (wskazania: raczej negatywna i zdecydowanie negatywna). Z kolei w przypadku usług medycznych świadczonych przez placówki prywatne większość respondentów (75%) oceniła ich jakość pozytywnie (wskazania: ocena zdecydowanie pozytywna i raczej pozytywna), a tylko

2% negatywnie (wskazania: raczej negatywna i zdecydowanie negatywna). Pozostała grupa badanych (23%) miała trudności z wyrażeniem swojej opinii w tym zakresie.

Poproszeni o wyrażenie swojej opinii na temat różnic w jakości usług świadczonych przez publiczne i prywatne placówki medyczne respondenci w większości (69%) wskazywali, że wyższą jakość usług zapewniają placówki prywatne. Tylko 4% ankietowanych jest zdania, że wyższą jakość usług zapewniają placówki publiczne, a 11% nie zauważa różnicy między jakością usług świadczonych przez publiczne i prywatne placówki. Pozostała grupa respondentów (16%) nie potrafiła wyrazić swojej opinii w tym zakresie (rysunek 1).

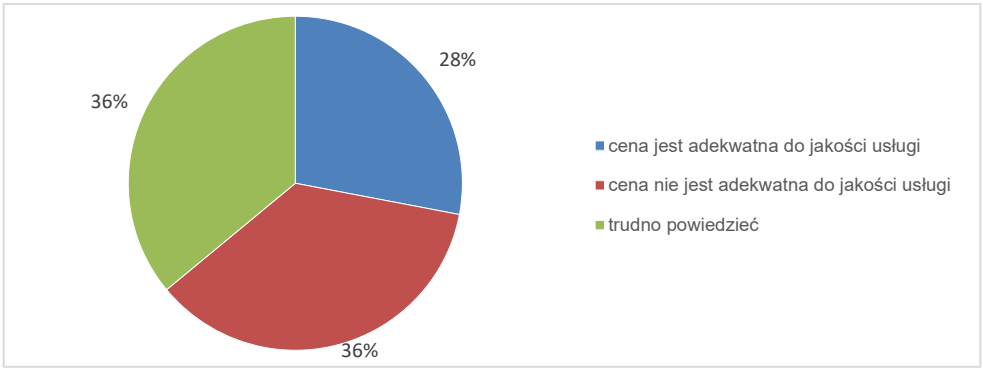


Rysunek 1. Postrzeganie przez respondentów jakości usług świadczonych przez prywatne i publiczne placówki medyczne

Źródło: opracowanie własne.

Badanie miało również na celu sprawdzenie, jak respondenci postrzegają cenę usług świadczonych przez prywatne placówki medyczne (rysunek 2).

Najmniejsza grupa ankietowanych (28%) jest zdania, że cena prywatnych usług medycznych jest adekwatna do ich jakości. Z kolei 36% badanych jest przeciwnego zdania i taka sama grupa uczestników badania nie potrafiła wyrazić swojej opinii.



Rysunek 2. Postrzeganie przez respondentów adekwatności jakości usług świadczonych przez prywatne placówki medyczne do ich ceny

Źródło: opracowanie własne.

3. DYSKUSJA

Z przeprowadzonego badania wynika, że większość respondentów decyduje się na mieszany model usług medycznych, obejmujący usługi finansowane zarówno ze środków publicznych, jak i własnych środków pacjentów. Badani korzystają z podobną częstotliwością z usług świadczonych przez publiczne, jak i prywatne placówki medyczne. Jak wskazuje Nadziakiewicz [2018], mimo przysługującemu każdemu pacjentowi prawa dostępu do bezpłatnych usług medycznych, rynek usług nieobjętych finansowaniem NFZ stale rośnie, a osoby, które polegają wyłącznie na publicznej opiece zdrowotnej, stanowią zaledwie kilka procent wszystkich pacjentów.

Ankietowani decydują się na korzystanie z publicznych świadczeń medycznych głównie ze względu na kwestie finansowe – najważniejszymi przyczynami determinującymi wybór tych usług są ich bezpłatność oraz brak dysponowania przez badanych środkami finansowymi umożliwiającymi im korzystanie z prywatnych usług medycznych. Z kolei w przypadku świadczeń zdrowotnych finansowanych ze środków własnych respondenci korzystają z nich przede wszystkim ze względu na krótki czas oczekiwania na usługę. Podobnie twierdzi Smarżewska [2020], zdaniem której Polacy coraz chętniej korzystają z rynku prywatnych usług medycznych, głównie ze względu na krótszy czas oczekiwania na usługę. Również Niedziakiewicz [2018] wskazuje, że głównym czynnikiem skłaniającym pacjentów

do wyboru prywatnego systemu ochrony zdrowia jest długi czas oczekiwania na wizytę w ramach NFZ. Zdaniem autorki znacznie krótszy czas oczekiwania to podstawowa zaleta komercyjnych usług medycznych.

Czas oczekiwania na wizytę, obok rozmieszczenia placówek medycznych, godzin otwarcia i liczby specjalistów, jest jednym z elementów składających się na dostępność usługi medycznej [Bojar 2010]. Jak zauważa Kanownik [2017] dostęp do publicznych świadczeń medycznych jest obecnie poważnym wyzwaniem stojącym przed decydentami ochrony zdrowia. Skargi pacjentów na braku dostępu do tych świadczeń stanowią ponad połowę wszystkich skarg rozpatrywanych przez NFZ. W wyniku badania przeprowadzonego w ramach pracy potwierdzono, że opinia większości respondentów o dostępności publicznych usług medycznych jest negatywna. Podobne wyniki uzyskała Nadziakiewicz [2018], która wykazała, że znaczna liczba klientów nie była zadowolona z wyznaczonych terminów przez daną placówkę medyczną. Również Sygit z zespołem [2017] wskazuje, że z punktu widzenia pacjenta największą słabością funkcjonowania podmiotów leczniczych jest dostępność świadczeń medycznych.

Decyzje respondentów dotyczące wyboru placówki medycznej są determinowane przede wszystkim czasem oczekiwania na usługę. Jednakże dla badanych bardzo ważne są również kompetencje i doświadczenie personelu placówki, koszty usługi oraz zakres świadczonych usług. Podobne wyniki uzyskała Czerwińska [2014], która wykazała, że wysoko wyspecjalizowana kadra medyczna, krótki czas oczekiwania na wizytę oraz zakres świadczonych usług, obok łatwego dostępu do placówki i pozytywnych opinii o placówce, są dla pacjentów ważnymi kryteriami wyboru placówki. Również Malik i Sharma [2017] wykazali, że wybierając placówkę medyczną, pacjenci szukają jak najlepszych specjalistów, dlatego do placówki pacjentów przyciągają przede wszystkim kompetencje personelu medycznego decydujące o skuteczności procesu leczenia.

Według Niedziakiewicz [2018] na wzrost popularności prywatnych usług medycznych ma wpływ m.in. umawianie wizyt przez Internet. Również Czerwińska [2014] dowiodła, że dla pacjentów bardzo duże znaczenie przy wyborze placówki medycznej mają czynniki informatyczne i możliwość rejestracji przez internet. Nie znalazło to jednak potwierdzenia w badaniu przeprowadzonym w ramach pracy – stwierdzono bowiem, że sposoby umawiania wizyt są dla respondentów najmniej ważnym kryterium wyboru placówki medycznej.

Jak wskazuje Rudzewicz [2008], usługa medyczna może być charakteryzowana przez wiele atrybutów – w obszarze technicznym (np. dostępność, skuteczność leczenia, kompetencje personelu, nowoczesność technologiczna), w obszarze pozamedycznym (np. czystość i wyposażenie placówki, indywidualne podejście do pacjenta, godziny pracy placówki), a także w obszarze relacji między różnymi wykonawcami usługi. W ramach badania wykazano, że największy wpływ na to, jak pacjent oceni jakość otrzymanej usługi medycznej, ma czystość i higiena pomieszczeń placówki, kompetencje personelu i profesjonalizm obsługi, czas oczekiwania na wizytę, indywidualne podejście personelu do pacjenta oraz dostępność usług.

Na podstawie wyników przeprowadzonego badania można stwierdzić, że w opinii respondentów jakość prywatnych usług medycznych jest wyższa w porównaniu z jakością usług publicznych. Podobne wyniki uzyskała Wyszkowska [2017]. Wynika to najprawdopodobniej z faktu, że generalnie opinia o publicznej służbie zdrowia jest w społeczeństwie negatywna [Sygit i in. 2017]. Może to być przyczyną rosnącego zainteresowania pacjentów usługami świadczonymi przez prywatne placówki medyczne. Respondenci korzystający z tego rodzaju usług mogą mieć poczucie, że większość ich wymagań jest spełniona w kontraście do publicznych świadczeń medycznych, w ramach, których placówka spełnia jedynie te, które są możliwe do realizacji w ramach finansowania usług ze środków publicznych. Biorąc pod uwagę, że ankietowani decydują się na korzystanie z publicznych świadczeń medycznych głównie ze względu na kwestie finansowe, warto zauważyć, że mimo wysokiej oceny jakości usług świadczonych przez prywatne placówki medyczne, tylko co trzeci respondent uważa, że ich cena jest adekwatna do ich jakości.

WNIOSKI

Jakość usług medycznych ma coraz większe znaczenie dla społeczeństwa, dlatego rozpoznanie oraz spełnienie wymagań pacjentów jest czynnikiem umożliwiającym placówkom świadczącym usługi z zakresu ochrony zdrowia zwiększanie ich konkurencyjności, a także osiąganie trwałego sukcesu. Bez względu na rodzaj finansowania (środki publiczne bądź prywatne) poznanie opinii pacjentów na temat usług medycznych pozwala na zdefiniowanie ich potrzeb i oczekiwań, co niesie

ze sobą możliwość doskonalenia jakości świadczeń zdrowotnych oferowanych przez placówki medyczne.

Na podstawie przeprowadzonego badania można sformułować następujące wnioski:

1. Respondenci postrzegają jakość usług świadczonych przez prywatne placówki medyczne oraz dostępność tych usług jako wyższą w porównaniu z jakością i dostępnością publicznych świadczeń medycznych.
2. Do korzystania z publicznych świadczeń medycznych respondentów skłania przede wszystkim ich bezpłatność, z kolei do korzystania z usług świadczonych przez prywatne placówki medyczne – krótki czas oczekiwania na usługę oraz jakość tych usług.
3. Wybierając placówkę medyczną, respondenci kierują się przede wszystkim czasem oczekiwania na usługę oraz kompetencjami i doświadczeniem pracowników placówki.
4. Na postrzeganie jakości usługi medycznej przez respondentów ma przede wszystkim czystość i higiena pomieszczeń placówki, kompetencje personelu i profesjonalizm obsługi oraz czas oczekiwania na wizytę.

Badana próba respondentów nie jest reprezentatywna, stąd też nie można uogólnić uzyskanych wyników na całą populację pacjentów korzystających zarówno z publicznych, jak i prywatnych świadczeń zdrowotnych. Jednakże uzyskane wyniki dostarczają orientacyjnych informacji na temat postrzegania przez klientów jakości usług oferowanych przez placówki medyczne oraz mogą być inspiracją dla kierownictwa placówek podczas określania potrzeb doskonalenia jakości świadczonych usług.

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NEUROTASTING, NEUROGASTRONOMY AND NEUROENOLOGY: SOME OF THEIR FINDINGS AND POTENTIAL IMPLICATIONS FOR FOOD QUALITY MANAGEMENT AND FOOD TECHNOLOGY

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Abstract

Application of neuroscientific methods to the food science helps for a better understanding of how the tastes and smells influence consumers in their eating choices, and also allows for a better investigation of the brain motivational processes towards the food: these findings could be used to improve the quality of food products and the quality of nutrition, making it more pleasant and healthy.

This work presents new neuroscientific discoveries related to the human primary gustatory cortex: its location in the brain and its connections with other senses and hedonic experience. It turns out that the smell, colour, shape, and packaging of a product can significantly change the way we perceive its taste. Therefore, it is particularly important to understand the neural mechanisms of this multisensory taste perception. A sixth taste (ammonium chloride receptor, discovered and reported in Nature Communications in 2023), and its meaning are also discussed.

We conclude that some recent discoveries made through the use of neuroscientific methods in food science open up many possibilities of their practical applications. This information could lead to understanding individual differences in consumer food preferences and taste perception, guide nutritional science, and even to food technology.

Keywords: gustatory cortex, neuroenology, neurogastronomy, neurotasting, taste.

INTRODUCTION

The new technological advances achieved during the last years allowed the scientific community to investigate and employ neuroscientific tools with their measures not only for strict research purposes but also for the study of human behaviour in real and daily life situations. Especially, a growing interest in the use of brain imaging (neuroimaging) techniques, for the analysis of brain responses to different contexts is observed. Generally, scientific development in recent years is characterised by an expansion in the application of different and multidisciplinary research modalities to answer various questions of a given scientific field. This boom refers also to growing use of neuroscientific methods to better understand human behaviour in various contexts [Cherubino et al. 2019]. Moreover, the neuroscientific approach has proven to be a truly powerful tool for studying unconscious responses and brain functioning in everyday life. It enables the study of how a person perceives, processes, evaluates, reacts, and utilises the external stimuli in the decision-making process in everyday activities and interactions [Gluth et al. 2012].

One of the most important questions in today's modern marketplace is what drives consumers to choose one product over another or why they decide to interact with a particular brand. It is no wonder, then, that interest in understanding how brain responses reflect consumer decision-making continues to grow. The practical application of tools in real-world contexts and for real-world stimuli, such as taste (the subject of this article), is referred to in the literature as neuromarketing. This term specifically describes a field of science defined as "the application of neuroscientific methods to the analysis and understanding of human behaviour in relation to markets and marketing exchanges" [Lee et al. 2007, p. 200]. Neuromarketing research aims to examine different brain areas during the experience of marketing stimuli in order to find and report the relationship between customer behaviour and neurophysiological system. Using knowledge and know-how from the human brain anatomy and knowing the physiological functions of brain areas, it is possible to model the neural activity underlying specific human behaviours. Using neuroimaging methods, scientists can compare the activation of different brain areas during a given task to develop models that not only describe the dynamics of human decision-making but also allow us to understand the typical discrepancies between consumers' thoughts and their actions [Jordao et al. 2017].

It should come as no surprise then that neuromarketing is also widely used in the food and beverage sector. For several years, researchers have focused their attention on applying neuroscientific methods not only to the external characteristics of food and beverage products (i.e., packaging, price, shape, colour, and texture), but also to their internal values: taste and smell [Cherubino et al. 2019]. This type of study, called neurotaste or neurotasting, includes concepts such as neurogastronomy [Shepherd 2011] and neuroenology [Shepherd 2016]. The taste is a vital sense in humans because of its active role in assessment of food quality [Di Flumeri et al. 2016]. Primarily, information conveyed through the sense of taste helps to quickly identify edible and nutritious foods (e.g., sweet taste), allows people to avoid many toxic substances (e.g., bitter or sour taste), and enables hedonic evaluation of nutrition that may occur before, during, or after consumption quality [Di Flumeri et al. 2016].

Application of neuroscientific methods to the food science helps for a better understanding of how the tastes influence consumers in their eating choices, and also allows a better investigation of the brain motivational processes towards the food: these findings could be used to improve the quality of the nutrition, making it more pleasant and healthy.

The aim of this article is to present the latest neuroscientific discoveries related to new disciplines such as neurotasting, neurogastronomy and neuroenology. The article was prepared using the narrative literature review method (presentation of the current state of research in a given field, identification of key concepts).

1. THE INTEREST IN UNDERSTANDING THE COGNITIVE PROCESSING RELATED TO THE HUMAN SENSE OF TASTE

Taste is the sensation produced as a response of the human gustatory system to molecules and ions from the ingested food dissolved in the saliva. The dissolved molecules and/or ions can bind to the surface proteins (taste receptors) distributed throughout the whole tongue or interact with pore-like proteins (ion channels), inducing electrical changes within the taste cells and subsequently chemical signals via the seventh, ninth and tenth cranial nerves to the brain where the perception of taste takes place [Roper & Chaudhari 2017].

Traditionally, it is believed that the perception of five basic tastes: sweet, salty, umami, sour, and bitter, as well as the oral sensation of fat, play a key role in determining consumer acceptance, preference, and choice of food. This process basically takes place in the subconscious (instinctively), which associates certain foods with pleasure and happiness and others with fear [Drewnowski 1997]. The pleasure we derive from eating, which provides us with the desire to consume food, is called hedonism. Interest in understanding the cognitive processing involved in the human sense of taste has grown over the past decades, not only in basic food and nutrition research but also in clinical applications and the consumer industry.

The sense of taste is not entirely determined by our genes but can be modulated by a number of biological (endogenous) and environmental factors, including body mass index and consumption of certain foods [Ileri-Gurel et al. 2012], smoking, and alcohol consumption [Pepino & Mennella 2007], aging [Bartoshuk et al. 1986], gender [Duffy 2007], and exposure to pathogens [Duffy 2007].

It should also be noted that "taste" is different from "flavour". Taste perception is based on gustatory responses triggered by water soluble substances via contacting sensory taste end organs in the oral cavity. Flavour perception combines sensory experience of olfaction and gustation. Olfactory signals are produced by neurons in a specialised patch of the nasal epithelium upon the exposure to volatile substances. Both gustatory and olfactory signals are integrated in the orbitofrontal and other areas of the cerebral cortex to generate the taste or flavour perception [Zhang et al. 2019]. More precisely, taste perception is defined as "those sensations that result from the direct simulation of the gustatory receptors localised on the tongue and occurring elsewhere in the oral cavity" [Spence et al. 2015, p. 248]. In contrast, according to the International Standards Organization [ISO 2008], flavour perception is defined as a "Complex combination of the olfactory, gustatory and trigeminal sensations perceived during tasting". Note, however, that in everyday language, taste is used interchangeably for flavour.

Motoki, Spence and Velasco [2023] presented a systematic review and the critical appraisal of multisensory taste/flavour perception, providing ample evidence that context dramatically influences what we taste. It would seem that taste is taste. Sometimes this is true, and sometimes not. It turns out that the colour, shape, and packaging of a product can significantly change the way we perceive its taste.

Colour and taste

Colour plays a significant role in shaping the taste of products. For example, the colour pink has been shown to increase perceived sweetness. Hidaka and Shimoda [2014] examined this by adding a pink colour to distilled water with sucrose. It was found that pink enhanced the perception of sweetness, while green did not have such an effect. Moreover, dark (vs. light) coloured beer was found to enhance the bitterness perception while light (vs. dark) coloured beer increased the perception of refreshment [Blackmore et al. 2021]. The saturation of colours can also alter the taste. More saturated colours are associated with tastiness, whereas less saturated colours are associated with healthiness [Motoki et al. 2023]. Marketers can use this principle in communication materials and packaging design. For example, why the chips department is so colourful? These brands want to activate associations with tastiness, and not necessarily with healthiness.

Shape and taste

The shape of the product also affects the taste. Yudi et al. [2022] described Cadbury, a brand that learned this the hard way. The company changed the shape of its chocolate bars – they made the corners round instead of angular. This way, 4% of the chocolate was saved on each bar. However, it turned out that after the shape change, complaints began to arrive. Brand-loyal customers were disappointed that their beloved chocolate bars now tasted much creamier than before – something they didn't like. Even though the recipe hasn't changed. So, chocolate bar shapes influenced creaminess perception of consumers. This concept (the influence of shape on taste) can be applied not only to the products themselves, but also to packaging. For example, yogurt served in a round container (cup) will taste creamier than in an angular shaped carton [Yudi et al. 2022]. How to increase sweetness? We might also benefit from using round shapes. Round shapes are naturally associated with sweetness (e.g., fruit), which in turn can make the taste perception a bit sweeter. When we're walking in a store, we have to pay attention to the candy department. Smart brands already use round-shaped fonts for sweet candies and angular-shaped fonts for their sour counterparts.

In general, we can conclude that taste is subjective and can be altered by many factors. In neuromarketing, it is important to pay attention to the tiniest details, even

such as product shape, packaging shape, and packaging design, because all of these will affect the taste of a given product.

"Neuromarketing Principle: Taste isn't just taste. External factors influence the taste of products drastically. Application: As a marketer, you want to pay close attention to the design and shape of your packages and communication materials, because it can enhance taste perceptions" [Van der Vleuten 2023].

Relationships between communication, perception, and consumer satisfaction

There are numerous neuroscientific studies investigating the relationships among communication, perception, and satisfaction experienced by consumers [Stasi et al. 2018]. Neuroimaging techniques such as fMRI (Functional magnetic resonance imaging) and MEG (Magnetoencephalography) have proven to be most useful in determining the dynamics of information processing from the taste system in the human brain. In particular, a brain structure called the insula has been linked to the initial sensory processing of taste sensations [Grabenhorst et al. 2007]. Therefore, it is commonly considered the primary taste area.

In turn, the orbitofrontal cortex (OFC) and prefrontal cortex (PFC) have been implicated in processing hedonic aspects of taste sensations [Kringelbach et al. 2004] and are often considered a secondary taste area. Studies based on less invasive tools, in particular fNIRS (Functional near-infrared spectroscopy) and EEG (Electroencephalography), have confirmed the earlier theory of the particularly important role of the PFC in decoding taste related information [Ohla et al. 2012]. All these findings are consistent with the widely accepted theory from the 1990s of a causal relationship between human PFC activity and motivational processes in response to sensory stimuli. According to this theory, increased activity in the left hemisphere of the brain is associated with an approach attitude, whereas increased activity in the right hemisphere of the brain is associated with a withdrawal attitude [Davidson et al. 1990].

It is worth noting that the first study using neuromarketing tools concerned taste was conducted in 2003. The aim of this study was to determine how taste perception affects consumer preferences for popular beverages such as Coca-Cola and Pepsi [McClure et al. 2004]. The authors used a brand experiment to demonstrate the dominance of the frontal lobe (specialised in executive function) over the limbic

system (responsible for emotional and instinctual behaviour) in the product choice. In this study, fMRI was used to find the neural correlates of consumer preferences for two popular and similarly flavoured sweetened beverages: Coca-Cola and Pepsi.

A group of 67 participants was divided into four groups; each group underwent a separate taste test outside the scanner and was instructed in the procedure for delivering the beverage while they were in the scanner. Before the taste test, participants were asked which drink they preferred, Coca-Cola or Pepsi, or whether they simply had no clear preference for either. The study found that different brain areas were activated depending on whether people were aware or unfamiliar with the proposed brand, and in this case, Coca-Cola, as a strong brand, had the power to own parts of the frontal cortex of its loyal consumers [Stasi et al. 2018]. However, the Coca-Cola and Pepsi study results discussed here have raised concerns about their potential power among many. Fears have been raised that such results contain a hidden code that changes consumers' perceptions below the level of awareness (in our opinion, this is not true).

In a study [Plassmann et al. 2008], participants have been scanned with an fMRI while they were performing a wine tasting and preference rating task. In other studies using an fMRI scanner, various foods and drinks, such as chocolate and coffee, were administered in liquid form because liquid products are particularly easy to administer using a computer-controlled pump attached to a tube that delivers carefully controlled amounts of liquid into the subject's mouth.

2. INTERACTION BETWEEN THE TWO SENSORY MODALITIES OF TASTE AND OLFACTION

In the last years, the phenomena called cross-modality has been receiving growing interest, it has been defined as sensory–sensory connectivity and influences of one modality over primary sensory cortex of another [Driver & Noesselt 2008]. This interaction between sensory modalities is studied similarly to synesthesia (i.e., the experience of feeling one sensation in response to another sensory stimulus) [Pearce 2007]. An interesting phenomenon is that odors and tastes can lead to specific memories: many people can associate certain odors with pleasant events, with friends, family members, or other close people, and these memories can be automatically triggered by a brief exposure to the same odor [Ramsoy 2015].

The importance of studying the interaction among sensory modalities becomes of clarity when applied to the study of a daily experience for humans: perception of food and for example wine. In fact, in the case of food, cross–modal interactions occur between aroma, taste, and texture [Poinot et al. 2013]. "Flavour is perhaps the most multi-modal of all of our sensory experiences" [Small 2012, p. 540], when flavour is defined as a perception including gustatory, oral somatosensory, and retronasal olfactory signals, arising from the mouth during foods and beverages consumption. For instance, for the wine tasting, sommeliers in addition to the use of the gustation, by the introduction of the wine into the mouth, employ the stimulation of the olfactory system both through a direct olfactory stimulation (by the nose) and a retro-nasal pathway (accomplished by air inhalation while swirling the wine around in the mouth) [Cartocci et al. 2017].

Therefore, to understand how the brain creates the taste of wine, one must appreciate both the gustatory system, responsible for taste, and the olfactory system, responsible for smell. The gustatory system is composed of taste cells in the mouth that respond to chemical compounds in the food and beverages consumed, and signal to the gustatory complex in the brain to create perception of flavour. These taste cells are responsible for sensing all five/six taste modalities.

Smell is a dual sense; odor stimuli can be delivered by breathing in (i.e., orthonasal olfaction) and breathing out (i.e., retronasal olfaction). Olfaction begins when odorant molecules enter the nasal cavity via inhalation through the nose or rising through the mouth from food or beverage. These molecules bind to receptors that signal to the olfactory bulb, which activates a broader cascade of neural signals responsible for smell recognition, memory, and emotion. The neural activity that represents the response of the brain to a particular odor constitutes an odor map or odor image [Shepherd 2006]. While odor patterns are highly complex and are registered unconsciously, their recognition is crucial for smell perception.

The distinction between these two olfactory stimulation modalities seems to be important. Evidences showed that in correspondence of congruent taste-odor pairs using the orthonasal route (implying subjects to sniff), neural suppression occurred in chemosensory regions [Small et al. 2004]. The convergence of taste and odor, firstly considered to occur only at the level of the orbitofrontal cortex, has been proven already at the insula [Small 2012] and piriform cortex [Maier et al. 2012] levels. Therefore, analysis of the contribution of olfaction to the process of tasting

wine and other products is the basis for studying taste perception [Cartocci et al. 2017].

The importance of smell during tasting has already been noticed, as people were advised not to drink wine when they had a cold (because a stuffy nose reduces the pleasure of drinking (in our opinion not only wine, of course). This common observation has also been empirically demonstrated in several scientific studies [Caratu et al. 2018; Cartocci et al. 2017; Cherubino et al. 2017]. The experimental protocol included the EEG index, adopted as an indicator of approach or withdrawal (AW) motivation (representing the cognitive activity in the brain) as proposed by Davidson et al. (1990) and an Emotional Index (EI), deriving from the matching of HR (Heart Rate) and GSR (Galvanic Skin Response) activities (representing the emotional activity in the brain, as proposed by Vecchiato et al. [2014]).

The experiments involved tasting two types of Italian wines (Sangiovese and Morellino di Scansano), and the process was also divided into two phases: smelling and tasting. Two different conditions were also included in the tasting phase: "with the nose open" and "with the nose closed". The results of both studies were the same and clearly showed the influence of the smelling phase on the emotional index (Figure 1) in comparison with the other two tasting phases (with and without the olfactory component). A greater tendency (approach motivation) to taste wine was also found in the presence of an olfactory component (compared to the other two conditions) (Figure 1).

The physiology involved in the wine tasting suggest as the wine volatile substances warmed by the hand in the glass before the degustation could target immediately the olfactory areas, by contributing to the formation of the taste sensation. However, it is a common experience that the wine tasting experience will be poor if the subject has a cold. In fact, data suggest a clear interaction between the two sensory modalities of taste and olfaction, since it was observed an increased emotional and cognitive appreciation of wine tasting experience "with the open nose" when compared to the "close nose" or cold condition [Cartocci et al. 2017]. Generally, the data suggest an interaction of the two sensory modalities influencing the emotional and the cognitive aspects of wine tasting experience in group of typical consumers (non-experts).

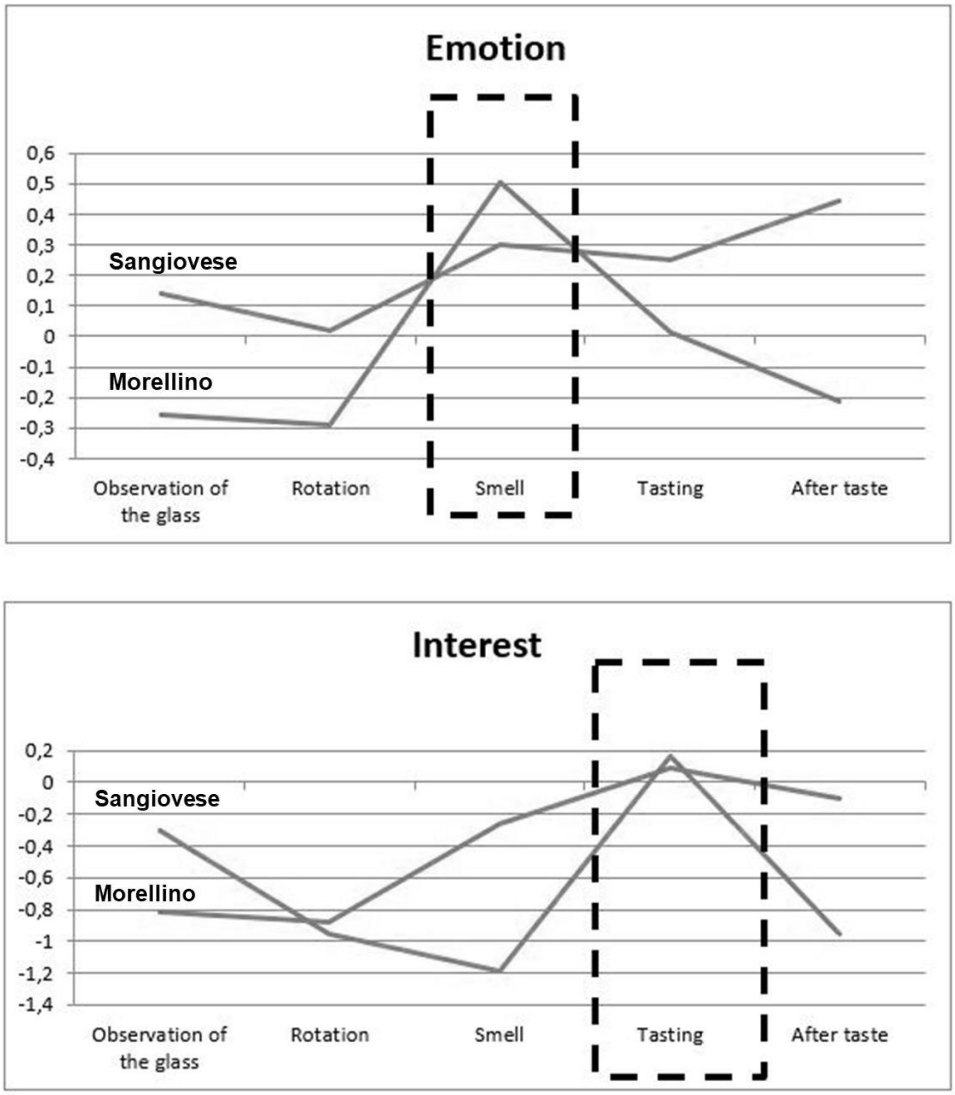

Figure 1. Results of the research showing a significant increase of the emotional values (EI, denoted as "Emotion") during the wine smelling phase, in comparison with the other two phases of tasting – with and without olfactory component – and a trend of major pleasantness (AW index, denoted as "Interest") in correspondence of wine tasting phase, with the combination of taste with the olfactory component

Source: https://www.brainsigns.com/en/company/c2/blog/neuro-taste-the-importance-of-olfaction-in-food-wine-tasting.

It is worth mentioning Cherubino et al. [2019] who suggest that these neurotechniques could be applied not to encourage highly processed foods addiction but to make healthy food more attractive, appealing, and thus more consumed.

As gustatory and olfactory cues add to our visual analysis, these sensory images condense into a central, neural representation of a wine flavour object. Evidently, the complex flavour of wine comes from much more than taste on our tongue. As stimuli in the language of the senses are translated into the language of the brain, our sensory systems condense our sensory experience and archive the information for future reference. Ultimately the messages and memories about smell and taste, old and new, that converge during the tasting experience that allow us to detect flavors in food or wine [Shepherd 2015].

The intricacies of the combined biomechanic and brain mechanisms responsible for the taste of wine are only just being elucidated in the interdisciplinary field of neuroenology [Shepherd 2015]. We conclude that the current interesting research results in the field of neuroenology can be practically used not only in winemaking but also in the case of some food products.

3. THE NEUROPHYSIOLOGY OF TASTE

How we know what flavours we love and what flavours we hate?

Taste is responsible for assessing the nutritional value of food, guiding basic behaviours that aim to prevent the consumption of toxic substances and help maintain a healthy diet. Taste buds detect different chemicals in our food that we recognise, such as, for example, bitterness or sweetness. Sweet and bitter are two of the most salient sensory percepts for humans as well for animals; sweet taste allows the identification of energy-rich nutrients whereas bitter warns against the intake of potentially noxious chemicals, for example toxic plant alkaloids. The information received by the tongue buds is transmitted through multiple neural stations to the primary gustatory cortex in the brain, and that is where the story of taste can really begin [Peng et al. 2015].

Some imaging studies have shown that sweet and bitter are represented in the primary gustatory cortex by neurons organised in a spatial map, with each taste quality encoded by distinct cortical fields [Chen et al. 2011]. Peng et al. [2015]

demonstrate that by manipulating the brain fields representing sweet and bitter taste we are able to directly control internal representation, sensory perception, and behavioural actions. These results confirm the segregation of gustatory features in the cerebral cortex, reveal the innate nature of appetitive and aversive taste responses, and illustrate the ability of the gustatory cortex to recapitulate complex behaviours in the absence of sensory input.

Umami taste

A good example of manipulating taste sensations are attempts to develop salt substitutes because excessive salt consumption in the diet is one of the global health problems. One study assessed the effect of sodium aspartate (Asp-Na) on salty taste perception using sensory tests [Nakagawa et al. 2014]. When NaCl and KCl were added to the mixture, Asp-Na significantly increased the salty taste perception of the mixture by 1.6 times compared to the control group. Interestingly, Asp-Na did not enhance the response to NaCl, nor did Asp-Na enhance the response to sour, bitter, or umami stimuli. The optimal concentration of Asp-Na to enhance the saltiness of the salt mixture was 1.7 mM. The greatest enhancement was induced when NaCl and KCl were mixed at equimolar concentrations. Asp-Na significantly suppressed the bitterness of quinine hydrochloride, suggesting that the bitterness of KCl in the salt mixture is suppressed by Asp-Na. The authors of the study suggest that a mixture of NaCl and KCl containing Asp-Na can be used as a salt substitute. In addition to demonstrating that Asp-Na enhances salty taste responses in experimental animals and humans, these findings provide clues to identifying elusive salty taste receptors [Nakagawa et al. 2014]. Another strategy being investigated for reducing sodium in foods is the use of salty and salty taste-enhancing peptides, which can reduce sodium intake without compromising taste or saltiness. The 2024 paper reviews the latest developments in these peptide purification and identification technologies and discusses methods for assessing their effectiveness in saltiness perception [Chen et al. 2024]. The work of Chen et al. [2024] is worth recommending to food designers and technologists because it is a current reference point for the development and use of salty and salty taste-enhancing peptides as sodium substitutes in low-sodium food formulas.

In 1908, Japanese chemist Kikunae Ikeda identified the chemical basis of a taste he called umami a meaty or brothy taste found in different foods. The word umami

can be loosely translated from Japanese as "a pleasant, savory taste", although there is no English word that truly captures its essence. It wasn't until decades later that the Western scientific community accepted that umami was an individual taste and salt (glutamate) in its own right, akin to sweet, salty, sour, and bitter. Umami was recognised as the fifth basic taste in 2002 (after salty, sweet, sour, and bitter) to describe a pleasant savory taste.

Umami ingredients may help to reduce the consumption of salts and fats in the general population and increase food consumption in the elderly [Diepeveen et al. 2022]. Analytical methods are available to determine the key contributors to umami and to predict taste intensity and active values [Moerdijk-Poortvliet et al. 2022]. A good taste is key in persuading the general public to accept novel food products and to start including it into their diets.

The history of umami taste suggests that achieving official status as a new, sixth taste may not be an easy feat.

Sixth primary taste?

In addition to sweet, salty, sour, bitter, and umami, a new study suggests the tongue might also detect ammonium chloride as a basic taste (sixth taste). A sixth zone (ammonium chloride as another primary taste) has recently been discovered, a discovery published in *Nature Communications* in 2023 [Liang et al. 2023]. The key to this discovery was a protein called otopetrin 1 (Otop1), which is found in cell membranes and creates a channel for hydrogen ions to move into the cell. This is the same receptor that picks up on acidity, which we taste as a sour flavour like lemon juice or vinegar. The researchers hypothesised that the Otop1 protein might also respond to ammonium chloride since it's related to acidity too. The tongue responds to ammonium chloride through the same protein receptor that signals sour taste.

Ammonium chloride is often an aversive taste and most likely evolved to help avoid harmful substances, since ammonia is noxious to humans and other animals. However, it is evident that humans can learn to enjoy it, just like how we've acquired a taste for spicy or acidic foods. The ammonium chloride flavour is prominent in salt liquorice candy, which is popular in Nordic countries, the Netherlands, and northern Germany. Wright [2023] in her paper published in *Nature Neuroscience* called receptor for ammonium chloride "Salty liquorice taste receptor". "Ammonium is

toxic at high concentrations, and most vertebrate species avoid the taste of it. However, small amounts of ammonium chloride (NH4Cl) lend a bitter, sour taste to salty liquorice, a popular confection in Scandinavian countries" [Wright, 2023, p. 1837].

Foods like fruits and vegetables that taste sour have a low pH, meaning they are high in acids, including citric acid for lemons, tartaric acid for grapes and acetic acids in fermented foods like vinegar. It has been recognised for more than a century that the low pH – which translates to high concentration of hydrogen ions (H^+) – in these foods generates a perception of sourness in humans. But how the tongue senses pH, and specifically what molecule constitutes the pH sensor, was not known.

Otop1 is a member of a class of molecules called ion channels, which allow charged ions to cross cell membranes. In the case of Otop1, the charged ion carried across the membrane is H^+. In 2018, Tu et al. [2018] published a study in *Science* that took a closer look at the sour taste sensor. Although the researchers identified Otop1 as a proton channel, they did not show that it was required for sour taste responses in an intact animal. The new study makes the first such discovery. One year later, the group led by Emily Liman have reported in *Current Biology* that Otop1 is a sensor for pH on the tongue "Otop1 forms a proton channel expressed in taste receptor cells that detect sour stimuli" [Teng et al. 2019, p. 3648].

Arguably, identifying specific molecules responsible for taste opens up the possibility of their wide application. This information could lead to understanding individual differences in consumer food preferences and taste perception, guide nutritional science, and even lead to new approaches to pest control. Professional tasters and chemists could use this information to manipulate tastes to make foods and even medicines more palatable. Or, household products containing toxic chemicals could be made less palatable, thus protecting against accidental ingestion.

Gustatory cortex: how the brain perceives taste?

It took many years of research for scientists to begin to understand the intricacies of how the brain perceives taste.

In 2011, neurobiologist Charles S. Zuker and his team published the first gustotopic map of the mammalian brain, using sophisticated neuroimaging techniques to show how different parts of the cortex respond to specific tastes [Chen et al. 2011]. The authors examined the logic of taste coding in the brain, examining

how sweet, bitter, umami, and salty are represented in the primary gustatory cortex. Striking topographic segregation has been demonstrated in the functional architecture of the gustatory cortex. It turned out that each taste quality is represented in a separate cortical field, which reveals the existence of a gustotopic map in the brain.

Following on from Chen et al. [2011], a study published in *Nature* [Peng et al. 2015] confirms the segregation of taste features in the cortex, reveal the innate nature of appetitive and aversive taste responses, and illustrate the ability of the gustatory cortex to recapitulate complex behaviors in the absence of sensory input. It is worth quoting briefly the leader of this research group, Charles S. Zuker, about the conclusions of the study: "Taste, as you and I think of it, ultimately resides in the brain". "Specialised taste receptors on the tongue detect sweet or bitter, etc., but it is the brain that assigns meaning to these chemicals. The results simply show that responses to sweet and bitter tastes are hardwired into the brain" [Wein 2015].

Such findings are consistent with the results of a later study, from which we learn that the cortical representation of taste propagation in the right primary taste cortex appears to follow an ecological goal of enhancing the discrimination of safe nutrients from harmful substances – an evolutionarily old hedonic compass for what and what not to ingest [Prinster et al. 2017]. Furthermore, the authors considered it interesting to examine whether this spatial pattern of human taste organisation in the primary taste cortex (PTC) is maintained or altered in pathologies such as eating disorders or taste deficiencies.

Other groups continued to investigate, but it wasn't until 2019, that scientists pinpointed the human brain's taste center much more precisely in *Nature Communications* [Chikazoe et al. 2019]. In the study distributed multivoxel activity patterns (fMRI experiment at 3 T) was used to identify regions with patterns of activity differentially sensitive to sweet, salty, bitter, and sour taste qualities. These were found in the insula and overlying operculum, with regions in the anterior and middle insula discriminating all tastes and representing their combinatorial coding. These results were replicated using more advanced neuroscientific tool, very high--field fMRI at 7 T with a variety of sweet and bitter taste types, suggesting taste specificity rather than chemical or receptor specificity. The results thus provide evidence that the human gustatory cortex is really located in the insula. So, it was only after using new techniques to analyse fine-grained patterns of activity that it was discovered that a particular part of the insula cortex – the older cortex in

the brain hidden behind the neocortex – represented distinct tastes [Chikazoe et al. 2019].

In fact, however, it has long been hypothesised that the human primary gustatory cortex is located in the insular cortex [Small & Faurion 2015]. However, tastes evoke activity in multiple regions in the human brain, including the insula, frontal operculum, parietal operculum, and orbitofrontal cortex [Veldhuizen et al. 2011]. These regions also tend to show similar responses to different taste types [Small & Faurion 2015], with any observed differences reflecting hedonic experience rather than differences in taste quality. Although representations of hedonic value are found in many regions in the brain [Small et al. 2003], classification of basic tastes and thus relative taste specificity should be the defining feature of gustatory cortex and its boundaries in the human brain. The insula refers to is an unassuming structure buried deep within the fissure of the lateral sulcus. The insular cortex, which separates the frontal and temporal lobes, has long been thought to be the primary sensory area for taste (Figure 2). It also plays a role in other important functions, including visceral and emotional experience.

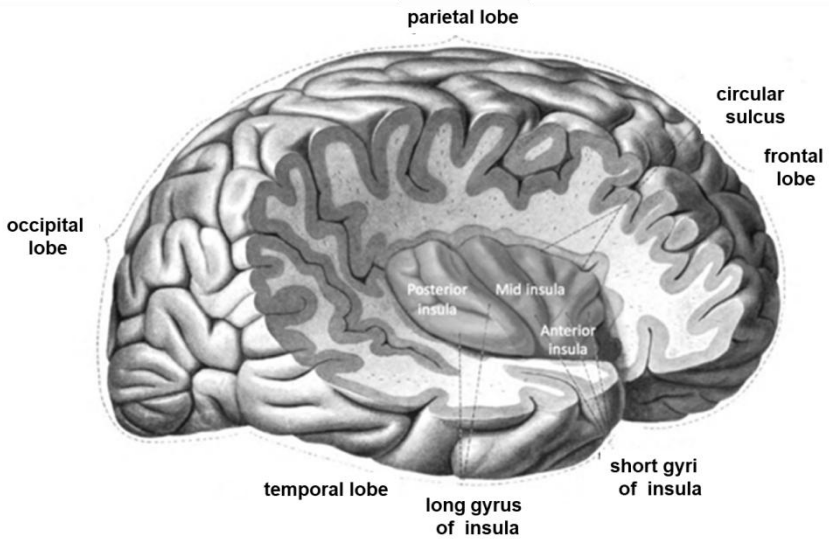

Figure 2. The insula is hidden in one of the deep grooves on the surface of the brain, but cutting out the outer layer reveals its structure

Source: https://www.iflscience.com/the-neurology-of-taste-how-your-brain-perceives-flavor-71159.

To find out what people really taste, we need to consider not only where in the insula it is stimulated, but also how. One of the difficulties of studying the brain-taste connection is that tastes are associated with strong hedonic responses, e.g., sweet tastes good and bitter tastes bad. Therefore, we do not know whether these taste areas are actually devoted to taste or rather to hedonics or taste palatability. Fortunately, Chikazoe et al. [2019] also identified patterns distinguishing liking from disliking in the insula that were distinct from those representing taste quality. By comparing different compounds that produce a similar taste quality, such as the sweetness of glucose versus sucralose, the study also found that the insula represents a taste quality, i.e., simply sweet, and not just specific chemicals. The identification of a specific region in the insula that differentiates basic tastes from each other as well as subjective likes and dislikes provides strong evidence of where and how taste is represented in the human brain.

The map of taste perception in the human brain is probably more complex than what we currently know, but there is one part of the insula where all the different taste areas can be found, and that is the gustatory cortex, as shown by Chikazoe et al. [2019].

In our opinion, the current state of knowledge about the taste system will open up new avenues of research in neurotasting due to the ability to observe pure sensory experiences (in the insular cortex) and separate accompanying hedonic experiences distributed across numerous cortical regions.

It is likely that we will obtain an answer to the question of whether brand awareness of a beverage actually influences taste sensations, but this time observed in the older cortex in the brain hidden behind the neocortex – insula cortex.

One may ask how do 5 (or 6) basic tastes transform into the countless complex taste sensations we experience when eating (sometimes multi-course meals)? Smell has already been shown to play an important role in taste perception, as do vision and touch. Of course, gustatory information is combined with information from other sensory systems in the orbitofrontal cortex located in the frontal lobe. This region is considered important for the pleasurable and rewarding aspects of eating. Moreover, as taste is processed in higher-order regions of the CNS (Central Nervous System), information is combined using population coding mechanisms [Hedges 2022, p. 373].

In traditional survey research, consumers declare a subjective assessment of their sensory experiences, whereas the current level of development of

neuroscientific methods allows for their disentangling (the influence of various factors contributing to a generalised subjective experience) by observing the activity of different brain regions. Therefore, we encourage the conduct of exemplary new studies that combine traditional surveys with advanced neuroscientific research tools and methodologies. For example, we could replicate the study by McClure et al. [2004], which aimed to assess how taste perception influences preferences for Coca-Cola and Pepsi beverages. It is likely that we will obtain an answer to the question of whether brand awareness of a beverage actually influences taste sensations, but this time observed in the primary gustatory system (in the insular cortex).

Similarly, it may be interesting to examine the impact of consumer knowledge of a product's price (low vs. high) on taste perception (unpleasant vs. delicious) during tasting. Therefore, another example experiment worth replicating is the neuroenological study by Plassmann, O'Doherty, Shiv and Rangel [2008], which found that increasing the price of wine increases subjective experiences of pleasantness and also increases activity in the medial orbitofrontal cortex – an area that is widely thought to encode for experienced pleasantness during experiential tasks. But will increasing the price of the same wine increase observable activity in the primary taste system? We likely don't know yet.

Neurogastronomy

Interest in food tastes and flavours is expanding rapidly, driven by a widening interest in food and concerns about the rising incidence of obesity and diseases related to unhealthy eating. While most interest was focused on the food, its composition, and the perceptions that it brings forth, this has left large gaps of knowledge about the specific brain systems that create the perceptions. Just such approach to taste/flavour through brain mechanisms has been termed neurogastronomy (a term that was only coined in 2006) [Shepherd 2015]. More precisely, neurogastronomy is considered as an interdisciplinary field that, in addition to neuroscience, also incorporates elements of psychology and gastronomy to better understand how consumers experience and enjoy food. The main goal of neurogastronomy is to understand the neural mechanisms underlying taste perception, appetite regulation, and food intake [Drewnowski 2015; Small 2014].

However, research in the neurogastronomy has also been expanding to include more areas, such as the role of emotions, culture, and the environment in food

perception and intake. As a result of studies, it has been shown that the perception of taste is mediated by specialised receptors on the tongue, gut and nose, which send signals to the brain, where they are processed and integrated to create the perception of taste [Drewnowski 2015; Small 2014]. Moreover, it was also found that the hypothalamus, insula, and the prefrontal cortex play a critical role in regulating hunger and satiety [Murphy 2018].

The pursuit of a better understanding of the complex multisensory nature of taste has required expansion into many other research areas, which has led to the birth of a new branch of science called neurogastronomy. Going beyond neurotasting and neuroenology, neurogastronomy also has important implications for the food industry and for public health. For example, understanding the neural mechanisms underlying taste perception can help food scientists develop new flavors and textures that are more appealing to consumers [Rolls 2016]. Moreover, studying the brain's role in regulating appetite and food intake may lead to new strategies for preventing and treating obesity and other eating disorders [French 2016].

Chikazoe et al. [2019] found the sweet spot in the insula – a specific area where a large ensemble of neurons respond to sweetness stimulation on the tongue. Interestingly, although a potential sweet spot has been identified in the insula cortex, its exact location varies across individuals, and the same spot responds to different tastes but with different patterns of activity. We conclude that this information could lead to understanding individual differences in consumer food preferences and taste perception, guide nutritional science, and even to food technology.

CONCLUSIONS

The purpose of this article is to review and present selected latest research results obtained using neuroscientific methods and tools in emerging disciplines such as neurotasting, neurogastronomy, and neuroenology. All of these disciplines share an interest in the sense of taste and its connections with other senses and hedonistic experiences. These three disciplines assume that context dramatically influences what we taste and they are interested in brain activity during taste experience, and even how and where the brain perceives taste.

Simply put, neurotasting is mainly interested in the influence of marketing stimuli (e.g., price, brand, colour, shape, aroma, texture, packaging, etc.) on

the perception of the taste of various food products, while neuroenology limits this focus to wines. Going beyond neurotasting, neurogastronomy has been expanding to include more areas, such as the role of emotions, culture, and the environment in food perception and their impact on consumption.

Interest in food tastes and flavours is expanding rapidly, driven by concerns about the rising incidence of lifestyle diseases. Understanding the disturbing phenomenon of the increasing incidence of obesity, eating disorders and diet-related chronic diseases requires a new approach to taste/flavor. Therefore, the main goal of neurogastronomy is to understand the neural mechanisms underlying taste perception, appetite regulation, and food intake.

We consider the most significant achievements in taste research to be the discovery of the ammonium chloride (NH_4Cl) receptor [Liang et al. 2023] as the sixth basic taste and the identification and precise localisation of the primary taste center in brain – in the insula cortex – the older cortex in the brain hidden behind the neocortex – represented distinct tastes [Chikazoe et al. 2019].

The practical implications of the discovery of the NH_4Cl receptor are difficult to predict beyond (perhaps) rewriting some textbooks and scripts. Because small amounts of NH_4Cl lend a bitter, sour taste to salty licorice, a popular confection in Scandinavian countries, it is possible to consciously (scientifically) use this tradition and design new products with a wide range of specific taste/flavour sensations.

Identifying and precisely localising the truly primary sense of taste in the brain could even change the methodology of consumer preference research. Observing the activity of the relevant taste region in the brain could allow for disentangling consumers' subjective multisensory experiences (declared by consumers in interviews and surveys) and separating pure taste sensations from the influence of other senses, marketing stimuli, emotions, memories, expectations, etc.

The sweet spot discovered in the insula cortex [Chikazoe et al. 2019], which responds to sweetness stimulation on the tongue, varies in its exact location between individuals, and the same spot responds to different tastes but with different activity patterns. We believe that comparing the activity of this point in the insular cortex among consumers could lead to a deeper understanding of individual differences in consumer food preferences and taste perception, guide nutritional science, and even food technology, more than traditional consumer surveys.

The identification of new, specific molecules which give an umami taste/flavour to certain foods, salty taste-enhancing peptides, and the discovery of the sixth basic

taste (NH_4Cl) open up the possibilities of their wide application and will likely inspire practitioners: food technologists and producers, food quality managers, and dietitians. Umami ingredients may help to reduce the consumption of salts and fats in the general population and increase food consumption in the elderly. Professional tasters and chemists could use this information to manipulate tastes to make foods, and even medicines, more palatable, because good taste is key to convincing the general public to accept novel food and incorporate them into their diets.

Future neuroscientific research can be expected to elucidate how consumers derive pleasure from food and beverages and what factors play a role in shaping this pleasure.

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QUALITY ASSESSMENT OF DIFFERENT RICE VARIETIES IN TERMS OF MINERAL CONTENT AND NUTRITIONAL VALUE

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Abstract

Rice (*Oryza sativa* L.) is one of the most important cereals for human nutrition and is consumed by around 75% of the world's population. Rice and wheat are the two most important cereals as leading food sources. This study aimed to determine the Fe, Cu, Mn, Zn, Ca, Na, Mg and K content of eight types of rice available on the Polish market, and to compare the nutrient content and type of plastic of portion packs and the colour of these types of rice.

Red and parboiled rice had the highest iron content, brown and black jasmine rice – magnesium content but red rice manganese. Wild rice was rich in zinc and copper. The portioned packages were made of high-density polyethylene (HDPE) film. The colour of the tested rice varieties differed depending on the variety and processing method.

Keywords: types of rice, micro and macronutrients, colour, portion pack.

INTRODUCTION

Production and trade

Rice is one of the staple crops for food security in the most populous countries – including China and India. World rice production in 2023/24 rose to a record 522 million tonnes, driven by higher yields in Far East Asia (including India) and the Americas. In Africa, the largest production is concentrated in Nigeria, Egypt, and

Madagascar. In South America, it is Brazil, Colombia, and Uruguay, and in North America, apart from the USA, also Nicaragua and Mexico (however, in the case of the Americas, Brazil and the USA are the clear leaders in rice production) [Bogacz 2023].

India will remain the world's largest supplier of rice, and shipments could reach 16.4 million tonnes, due to an increase in basmati and parboiled rice exports'. Another rice producer, Thailand's supplies were forecast at 8.7 million tonnes. Rice supplies from Pakistan and the USA could reach 5.7 million tonnes and 3.2 million tonnes respectively.

Rice imports to Poland in January-May 2024 were more than 98,000 tonnes, up 19% at $78 million. Myanmar (Birma), Italy and Pakistan are among the main suppliers of rice to Poland [Bogacz 2023]. In Europe, Spain, Italy, and Lithuania also produce rice. Vietnam and China are also mentioned on the packaging of the main grain trading companies (Kupiec and Cenos).

Rice species and types

The seed rice is (*Oryza sativa L*) and its subspecies Indian (*Oryza sativaindica*) and Japanese (*Oryza sativa japonica*) is an annual cereal plant in the panicle family (*Poaceae*), formerly called grasses (*Gramineae*). It is native to south-east Asia.

Rice is distinguished by the treatment used: parboiled and polished rice. In terms of the type of grain, short-grained, medium-grained, and long-grained, and the types of variety rice by place of origin or cultivation are black, red, basmati, jasmine and black jasmine rice. In addition, there is golden rice, a variety of seed rice (*Oryza sativa* L.) obtained by genetic engineering methods that synthesises β-carotene in the endosperm of the seeds. The cultivation of golden rice was intended to provide nutrient-rich food to the poor populations of developing countries. The project was humanitarian in nature from the outset. It was introduced in China, the Philippines, Bangladesh, and Vietnam [Tang et al. 2012]. Currently, this project is controversial, and cultivation has been suspended in the Philippines.

There is also wild rice (*Zizania aquatica*) on the market – this is a plant species also in the panicle family (*Poaceae*) native to North America. It is recognised by the name water oat. As a plant that grows under natural conditions without the need for artificial fertilisers, it retains a high concentration of micro- and macronutrients, e.g., phosphorus, zinc and manganese [Cwynar-Baran 2021]. Various species of wild rice

are grown around the world. Among them are: Manchurian wild rice, Northern wild rice Texas wild rice [Surendiran et al. 2014].

It should be mentioned that nowadays, rice is not only cultivated with the wet method, but also with the dry method (more often in Europe), as well as the fact that drained – deprived of water – fields after rice cultivation release the highest amount of methane into the environment, increasing the production of the so-called greenhouse gases. This is a result of the anaerobic decomposition of organic matter. Micro-organisms, known as methanogens, convert organic matter into methane (CH_4) in a water-rich environment with low oxygen concentrations. Rising temperatures and additional carbon dioxide in the atmosphere affect rice crops and the amount of methane (CH_4) released [van Groenigen et al. 2011].

The nutritional value, vitamin and macro and micronutrient content is influenced by the type or variety of rice, the way it is processed and its origin and method of cultivation. The nutrient content of rice is strongly influenced by environmental factors [Wu et al. 2018].

In recent years, there has been a debate about the increased arsenic content in food products, especially rice. This element, in its inorganic form (arsenite As(III) and arsenate As(V)), is harmful and can cause many diseases, including cancer [Kulik-Kupka et al. 2016]. Consumption of large amounts of rice containing this element can cause poisoning [Hojsak et al. 2015]. The inorganic arsenic content in raw rice ranges from 0.1 to 0.4 mg/kg of dry matter. These values are significantly higher than in other cereals [Hassan et al. 2017; Mania et al. 2017]. The arsenic content in rice depends on: the areas where it is grown, the type and method of processing. In 2023, Commission Regulation (EU) 2023/465 of 3 March changed the limits for the maximum permissible levels of arsenic in certain foodstuffs. For unpolished rice (polished or white rice) – 0.15 mg/kg of fresh weight, parboiled rice, husked rice and rice flour – 0.25 mg/kg, and for rice intended for the production of food for infants and young children – no more than 0.10 mg of arsenic/kg of product weight [Wolska 2023]. Due to the more complex methodology of measuring arsenic content in food products, it was not measured in these studies.

The aim of this study was to compare, in terms of nutritional and mineral content, several types of rice available on the Polish market and to compare type of plastic of portion packs and the colour of these types of rice.

1. MATERIAL AND METHODS

Eight types of rice available on the Polish market were used for the study. These were products offered by three trading companies: Kupiec, Cenos, and Sonko, imported from different countries of the world. Samples were portioned in plastic bags of 100g. The carton packs contained 400, 300 or 200 g of product. Two cardboard packages of rice were purchased. Before starting the tests, the samples from the 100 g packages were mixed within the same type of rice. The types of rice for the trials were:

- white rice, 4 x 100 g,
- parboiled rice, 4 x 100 g,
- jasmine rice, 4 x 100 g,
- basmati rice, 3 x 100 g,
- brown natural rice, 4 x 100 g,
- wild rice, 2 x 100 g,
- red rice, 2 x 100 g,
- jasmine black rice, 2 x 100 g.

Samples of different types of rice were analysed for minerals, seed colour after milling and nutritional composition.

The analysis of the content of selected elements: Cu, Zn, Mn, Fe, Ca, Mg, K, An MPAES – emission spectrometer was used for the tests, with prior mineralisation of the samples using a wet method with 65% HNO3 acid in the microwave oven Mars 6. It was carried out using emission atomic spectrometry in an MP-AES spectrometer, where the plasma is excited by microwaves. MP-AES is characterized by high sensitivity, with a detection limit below ppb levels. The analysis was performed on the basis of two reference curves. All analyses were performed in three replicates and the results were averaged. The results obtained were subjected to analysis of variance (ANOVA, post hoc Tukey tests). The results of the calculations were verified at a significance level of $p \leq 0.05$. Statistica 13.0 software was used. Differences were considered statistically significant at $p \leq 0.05$.

In the C.I.E. system, it is possible to determine the brightness of an image using the L* parameter, and chromaticity using the a* and b* parameters. The device was calibrated against a white standard prior to testing.

In order to determine the colour differences between the different types of rice, colour measurements were taken CIE L*, a*, b* using a Minolta Chroma Meter

CR-300. All analyses were performed in three replicates. Additionally, in order to compare the visual quality of the samples, the whiteness index W.I. was calculated, which allows for the assessment of the brightness of the product. A higher index value indicates greater whiteness. The values were calculated according to the formula [Le Thanh-Blicharz 2018]:

$$W.I. = 100 - \sqrt{(100 - L)^2 + a^2 + b^2}[\%] \quad (1.1)$$

where:

L* – brightness,
a* – chromatic component from green to red,
b* – chromatic component from blue to yellow.

The packaging of 100 g portions of rice was tested to determine what type of plastic was used in the packaging of all types of rice. A Jasco Fourier Transform Infrared Spectrometer (FT/IR-4X) with an ATR attachment was used for the test.

The purpose of the test was to determine whether film used for food packaging could pose a real risk to human consumption and the normal functioning of the human body.

In order to assess the value of the valuablea nutrion velue a comparative analysis was carried out of the nutritional value and origin of rice, the required heat treatment time based on the information provided on the collective packaging, as well as the purchase prices of the products converted to one serving – 50 g.

1.1. General characteristics of the different types of rice

[1] There are several types of rice. We categories rice according to its size, colour and how it is processed. Depending on their country of origin, the composition of different types of rice can also vary. This includes vitamins, minerals, protein, and starch. Below is a general overview of the most popular rice variety in Poland.

[2] White rice (*Oryza sativa*) is the most popular variety in the world, including in Poland. It is produced during a process known as polishing, whereby the husk,

bran, and germ are removed. Such rice is poor in nutrients, but has a longer shelf life, a delicate flavour, and a short cooking time [Kitchens of the World 2024].

[3] Parboiled rice – this has undergone a parboiling process, which involves soaking, subjecting the grains to twice the action of superheated steam and drying them. Thanks to this treatment, the rice has more nutritional value, is not sticky and has increased protection against pests and microorganisms. This treatment can be applied to different rice varieties to obtain, for example, parboiled basmati rice.

[4] The moisture content of parboiled rice grains is reduced to 10–11%, which allows for longer storage [Luh & Mickus 1991]. The parboiling process also causes starch retrogradation in rice [Ali & Bhattacharya 1976].

[5] Flavour is considered one of the most important quality characteristics of rice grain, as it is a key determinant of market price and is linked to both local and national identity [Fitzgerald 2009; Kovach et al. 2009]. Two types of aromatic rice, namely Basmati and Jasmine, can be distinguished based on grain dimensions such as length, width, and length-to-width ratio, as well as physicochemical properties, including amylose content and grain elongation ratio after cooking [Prodhan 2024]. Gene Badh 2.1, is the predominant allele in virtually all fragrant rice varieties today, including the widely recognized basmati and jasmine types [Kovach et al. 2009].

[6] Jasmine rice is a white, slightly elongated variety of rice originating from Vietnam and Laos. It has a floral aroma and sweetish taste and contains the aromatic compound 2-acetyl-1-proline. The grains become stickier during cooking [Go4taste 2024]. PhkaMalis jasmine rice from Cambodia has repeatedly been named the best rice in the world due to its taste and nutritional value (e.g., its glycaemic index). To harvest jasmine rice, the long stalks are cut and threshed. The rice can then be left in its husked form, known as paddy rice, shelled to produce brown rice, or milled to remove the germ and some or all of the bran, producing white rice [Kossow 2015]. The cooking time is slightly longer (20 min) than traditional white rice and should be soaked for 10 minutes first [Go4taste 2020].

[7] Basmati rice is an aromatic long grain rice, its grains are long, gently curved and slender. The name basmati comes from Hindi and means ‘queen of fragrance’ or ‘fragrant earth’. It has a relatively low glycaemic index compared to some rice varieties [Krukam 2024]. Basmati rice has a unique aroma, sweet

flavour, and a soft texture when cooked. It has a medium amylose content which causes it to swell slightly during cooking. Superior quality basmati rice is characterised by its unique features, including elongated, slender grains with a translucent endosperm, a sweet flavour, and a dry, airy, and tender texture when cooked. It also has a delicate curvature, a low amylose content, and a medium-low gelatinisation temperature. During cooking, it elongates 1.5 to 2 times in length but does not swell significantly in width; the rice also remains tender [Prodhan et al. 2024].

[8] Wild rice (*Zizania aquatica*) is another plant species of the family. It is a plant species of the panicle family (*Poaceae*) native to North America. It is recognised by the name water oat. Wild rice is not directly related to domesticated rice (*Oryza sativa*). The grains of wild rice have a brown casing with a tender inner grain that has a slightly vegetal flavour. The plants grow in shallow water in small lakes and slow-moving streams. The grain is also eaten by wild ducks and other aquatic animals. As a plant that grows under natural conditions without the need for artificial fertilisers, it retains a high concentration of micro- and macronutrients, e.g., phosphorus, zinc, and manganese [Cwynar-Baran 2021]. Wild rice grains contain 10–18% protein. Its value is twice that of brown rice [Surendiran et al. 2014; Zdrojewicz et al. 2017].

[9] Black jasmine rice is grown in Thailand. It is a whole grain with the husk. It has a slightly nutty aftertaste, and the jasmine variety is reminiscent of the very smell of this flower. When cooked, it is quite powdery and hard and turns purple in colour. Unlike other rice varieties from Asia, it is not sticky or rough. Contains one of the highest levels of anthocyanin pigment found in food [Yao et al. 2013]. Its dark purple colour is primarily due to its anthocyanin content and antioxidants like triacine, ferulic, vanillic, and humic acid and tocopherols and tocotrienols [Zdrojewicz et al. 2017]. The grain has a similar amount of fiber to brown rice and like brown rice, has a mild, nutty taste [Oikawa et al. 2015].

[10] Red rice is a variety of wild rice (i.e., *Zizania aquatica*) and has a low yield. Red rice comes in many forms. The reddish colour is the result of the natural anthocyanin content. It is often unpolished or partially polished rice, retaining the red bran layer. The grain is eaten with the husk. Some of the varieties encountered are short-grained and sticky, while some are long-grained. It has a nutty flavour and contains higher amounts of vitamin B6 [Fasahat et al. 2013].

The fiber and antioxidants in red rice may help lower cholesterol and reduce the risk of cardiovascular disease [Ling et al. 2001]. It is grown in Europe, Southeast Asia, and South America [Go4Taste 2024a].

[11] Brown rice has brown grains with an elongated shape. After harvesting, it is hulled manually or mechanically from the outermost inedible layer [Salagram 2024]. Brown rice has a higher vitamin, mineral, and fibre content than white rice. It is very slowly digested and has a low glycaemic index. Brown rice is rich in vitamins B, E, thiamine, niacin, riboflavin, folates. Brown rice can contain up to 10–20 times more arsenic than white rice [Sohn 2014]. Arsenic accumulates mainly in the husks of the grain, so removing them and polishing the rice reduces the content of this compound in the product. Interestingly, cooking in more water (ratio 5:1) or rinsing the rice before cooking can significantly reduce the arsenic content by up to 30–70% [Menon 2021]. The B vitamins contained in rice affect metabolism, increase excretion in urine, but also reduce the toxic effects of arsenic [Argos et al. 2010].

2. RESULTS AND DISCUSSION

The analysis of mineral components was performed by emission spectrometry after wet mineralisation. Four microelements and four macroelements were determined in the tested rice varieties. The results are presented in Table 1 and 2.

The analysed rice samples were tested for zinc (Zn), copper (Cu), manganese (Mn) and iron (Fe) content. The results obtained indicate that the content of microelements varies significantly depending on the type of rice, which may be due to both the botanical variety and the degree of grain processing.

The highest zinc content was found in wild rice (4.17 mg/100 g), which significantly distinguishes this variety from the others. In the case of other types of rice, the Zn content was relatively uniform and amounted to approximately 1.2–1.3 mg/100 g, with the lowest value recorded for brown rice (1.03 mg/100 g). A study by Ortiz-Cámara et al. [2019] showed that the zinc content of different rice varieties ranged from 8.82 to 12.9 mg/kg, which is consistent with our results after unit conversion. Copper is an essential element for many enzyme functions in the body. Its daily requirement is low and is approximately 0.9 mg/day for an adult [Rychlik et al. 2025]. The copper content in the rice samples tested was highest in

wild rice (0.63 mg/100 g). As in the case of Zn, the highest Cu content was found in wild rice.

Manganese was the most variable element among the microelements. The highest values were found in red rice (4.02 mg/100 g), black jasmine rice (2.93 mg/100 g) and brown rice (3.48 mg/100 g). Significantly lower Mn levels were found in white rice and jasmine rice (1.73 mg/100 g), which again highlights the impact of the cleaning and processing process on the loss of minerals. According to the USDA 2023, manganese was tested less in red rice i.e. 2.63 mg/100g, in brown rice 2.7 mg/100g and in long grain white rice only 0.98mg/100g.

The iron content was highest in red rice (2.62 mg/100 g), parboiled rice (2.47 mg/100 g) and wild rice (1.75 mg/100 g). The lowest Fe concentration was found in jasmine rice (0.75 mg/100 g). Iron is an essential element for oxygen transport in the body and the daily requirement is about 14 mg for an adult. The content of micro and macro elements in rice can vary and also depends on the processing conditions. It is worth noting that parboiled rice, although white, has a fairly high iron content. Lower iron values have been obtained for jasmine and basmati rice.

Table 1. Results of microelement content in different types of rice [mg/100g]

Microelement content in different types of rice in [mg/100g]				
Type of rice	**Zn**	**Cu**	**Mn**	**Fe**
white rice	1.289+/–0.055^{a**}	0.548+/–0.091 $^{a, b}$	1.737+/–0.097^{a}	1.512+/–0.097 $^{a, b}$
parboiled rice	1.169+/–0.021 ^{a}	0.390+/–0.082 $^{a, b}$	2.825+/–0.143^{b}	2.469+/–0.138 ^{d}
jasmine rice	1.255+/–0.072 ^{a}	0.344+/–0.039 ^{a}	1.723+/–0.011^{a}	0.753+/–0.162 ^{c}
basmati rice	1.214+/–0.242 ^{a}	0.387+/–0.082$^{a, b}$	1.837+/–0.036 $^{a, b}$	1.195+/–0.145 $^{a, c}$
wild rice	4.165+/–0.222^{b}	0.629+/–0.054 ^{b}	2.150+/–0.054 ^{b}	1.754+/–0.186 ^{b}
jasmine black rice	1.233+/–0.165 ^{a}	0.399+/–0.139 $^{a, b}$	2.935+/–0.049 ^{c}	1.534+/–0.188 $^{a, b}$
red rice	1.262+/–0.047 ^{a}	0.365+/–0.047 $^{a, b}$	4.018+/–0.044 ^{e}	2.623+/–0.124 ^{g}
brown rice	1.028+/–0.049 ^{a}	0.365+/–0.047 $^{a, b}$	3.481+/–0.222 ^{d}	1.459+/–0.126 $^{a, b}$
RDA [mg/day]*	M –11, F – 8	M, F – 0.9	M – 2.3, F – 1.8	M, F – 10

* M – male, F – female.
** a, b, c, d, e – average values marked with different letters differ statistically significantly ($p < 0.05$) between different types of rice.

Source: own study.

An analysis of the macroelement content (magnesium, calcium, potassium, sodium) in eight types of rice showed significant differences between the samples tested (Table 2). Among the samples analysed, the highest values for most elements were found in brown and wild rice, black jasmine rice and red rice, while the lowest values were found in white and jasmine rice.

The magnesium content ranged from 10.84 mg/100 g (jasmine rice) to 106.37 mg/100 g (brown rice). White and jasmine rice contained several times less magnesium than unpolished varieties (wild, red, and black jasmine rice), which confirms the impact of the polishing process on the reduction of mineral content. Similar magnesium values in whole grain rice were reported in a study by Tegegne et al. [2020], where the Mg content in NERICA rice was approximately 110 mg/100 g. The high magnesium content (and other macroelements) in whole grain rice may be related to the presence of this element in the outer layers of the grain, which are removed during the polishing process of white rice [Bisratewongel 2019].

Table 2. Results of macroelement content in different types of rice [mg/100g]

Macroelement content in different types of rice [mg/100 g]				
Type of rice	**Mg**	**Ca**	**K**	**Na**
white rice	10.925+/– 0.481^{a}	27.802+/– 5.727^{a}	74.163+/– 2.309^{a}	74.163+/–2.309^{a}
parboiled rice	62.341+/–3.180^{b}	36.164+/–3.749$^{a\ b}$	164.972+/–12.626^{b}	164.972+/–12.626^{b}
jasmine rice	10.839+/– 0.074^{a}	28.686+/–1.262^{a}	69.286+/– 0.694^{a}	69.286+/–0.694^{a}
basmati rice	11.681+/–0.251^{a}	37.117+/–0.888$^{a\ b}$	62.020+/–0.801^{a}	62.020+/–0.801^{a}
wild rice	90.157+/–1.167^{b}	89.274+/–2.928^{c}	258.733+/–0.469^{d}	258.733+/–0.469^{d}
jasmine black rice	102.796+/– 1.806$^{b\ c}$	40.419+/–3.588^{b}	206.519+/–5.608^{c}	206.519+/–5.608^{c}
red rice	95.504+/– 0.740$^{b\ c}$	29.787+/– 0.721$^{a\ b}$	170.281+/– 6.104^{b}	170.281+/–6.104^{b}
brown rice	106.369+/– 5.917^{c}	30.402+/–1.688$^{a\ b}$	208.642+/–0.904^{c}	208.642+/–0.904^{c}
RDA [mg/day]*	M – 420, F –320	M – 100, F –1200	M, F – 3500	M, F – 1500

* M – male, F – female.
** a, b, c, d, e, f – average values marked with different letters differ statistically significantly ($p < 0.05$) between different types of rice.

Source: own study.

The calcium content was generally lower than that of other elements, but also showed significant differences between samples. Wild rice contained the most calcium (89.27 mg/100 g), while white rice contained the least (27.80 mg/100 g).

Relatively high Ca content was also found in basmati rice (37.12 mg/100 g) and parboiled rice (36.16 mg/100 g). But in USDA 2023 data on black rice indicates a calcium content only 14 mg/100 g, wild rice approximately 8 mg/100 g, and long–grain white rice only 4 mg/100 g. Calcium is an element whose content in rice is relatively low, but whole grain rice can be an important source of it in the diet. The highest potassium content was found in wild rice (258.73 mg/100 g) and brown rice (208.64 mg/100 g).

Potassium was present in the highest amounts among the analysed elements. The richest source of potassium was wild rice (258.73 mg/100 g), followed by brown rice (208.64 mg/100 g) and black jasmine rice (206.52 mg/100 g). The lowest potassium content was found in jasmine rice (69.29 mg/100 g). Like other minerals, potassium is found in the outer layer of the grain, the bran.

The sodium content was highest in brown rice (187.97 mg/100 g) and red rice (182.17 mg/100 g), while the lowest was in white rice (111.30 mg/100 g). Although sodium is not typically expected to be present in high concentrations in natural plant products, its presence may be due to cultivation or processing conditions.

Parboiled rice, which contains quite a lot of potassium, magnesium, and iron, is also noteworthy. Because it undergoes a preliminary steaming process, it retains a lot of minerals compared to white, jasmine or basmati rice. The high iron content in red rice may indicate the potential of this variety as a source of this element in the diet, especially in plant–based diets, where the risk of iron deficiency is greater.

Colour parameters ground rice sample

The colour parameters marked in the L*a*b* system refer to L – lightness, a – a coordinate indicating the shift on the colour palette from red to green, and b* – the shift from yellow to blue. The results obtained from the measurement were converted presented in Figure 1 and Table 3. The whiteness index W.I. was calculated, which allows for the assessment of the brightness of the product. A higher W.I. in [%] value indicates a more intense whiteness. As shown after calculating the L*a*b* parameters according to the formula, it can be seen in Figure 1 that the two brightest rice varieties were jasmine and basmati, followed by brown rice, with parboiled rice coming in fourth. White rice did not show an intense white colour

after grinding, and the L brightness parameter was not the highest for this sample among the samples tested. Red, black, and wild rice, due to their flavonoid content, differed significantly in brightness as well as in the a* and b* parameters indicating red and blue colours.

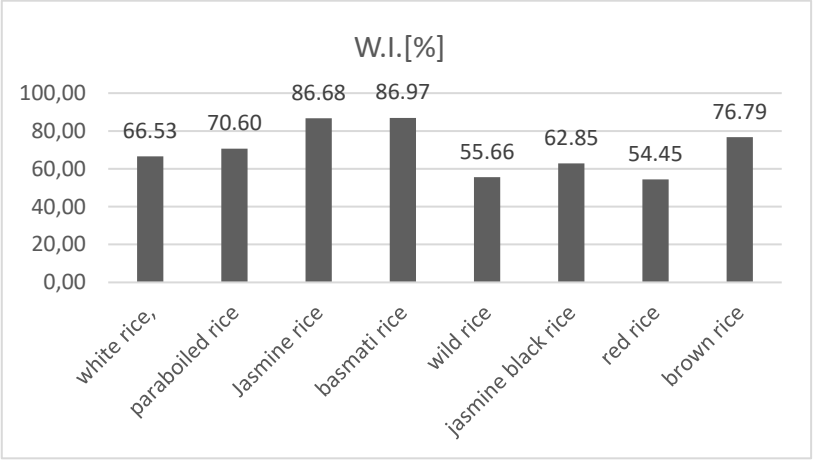

Figure 1. The whiteness index W.I. was calculated to probe rise [%]

Source: own study.

Table 3. Light parameters in rise sample aftergroundand whiteness index W.I.[%]

Sample No.	Parameters	L*	a*	b*	W.I.%
0	standard white	97.44	0.12	2.61	
1	white rice,	86.91	–6.5	31.48	66.53
2	parboiled rice	75.33	0.86	15.96	70.60
3	jasmine rice	89.99	–0.63	8.76	86.68
4	basmati rice	88.98	–0.39	6.95	86.97
5	wild rice	57.52	1.41	12.63	55.66
6	jasmine black rice	64.89	7.01	9.9	62.85
7	red rice	54.75	2.29	4.7	54.45
8	brown rice	80.46	1.12	12.47	76.79

Source: own study.

Identification of packaging film

To clarify what material was used to produce the 100 g portion bags, an IR analysis was performed. Spectra were obtained and compared with the database available in the device.

Polyethylene (PE) is a commonly used plastic that belongs to the polyolefin group, i.e., polymers composed of carbon and hydrogen. The density of this type of polyethylene ranges from 0.942 to 0.965 g/cm^3. The density of polyethylene affects its physical and mechanical properties. HDPE is a highly crystalline, tough and durable material. HDPE is widely recycled and is numbered '2'. It is a flexible, transparent, and thermoplastic material. It is not polycarbonate (PC). His makes it a safer option for food and beverage packaging compared to other plastics like polycarbonate, which can contain BPA. As different plastics have distinguishable light absorption spectra, the most direct means of identification of polymers is accomplished by FTIR spectroscopic technique. The Fourier transform infrared spectra have been recorded in the range 4000–400 cm^{-1} using spectrophotometer Jasco. Using FTIR, the molecular structure of the repeating unit -(CH_2-CH_2)n- of HDPE has been studied. The characteristic PE absorbance bands are located at 2918 cm^{-1}, 2849 cm^{-1}, 1472 cm^{-1} and 718 cm^{-1}.

It was found that high-density polyethylene film was used to package all types of rice. It is a flexible, transparent, and thermoplastic material known for its wide range of applications, both in everyday life and in industry. High-density polyethylene does not contain Bisphenol A, so it is not toxic even after prolonged cooking at 100°C. Not all cardboard packaging rice provided information about the type of film used for packaging individual portions.

Comparative evaluation of the nutritional value of the tested rice samples

Table 4 presents a summary of the nutritional values listed from the packaging as well as information on the country of origin, unit price per package, and information on cooking time.

Natural brown rice has the highest energy value per 100 g of dry product (370 kcal), while Basmati and white rice have the lowest (344 kcal). At the same time, natural brown rice has the highest fiber content (8.7 g). In terms of carbohydrate content, the highest value was determined for parboiled rice (80 g), while white, brown, jasmine, basmati, and wild rice had approximately 77 g/100 g.

Only black and red jasmine rice had less than 70 g of carbohydrates per 100 g of product. In terms of protein content, the highest values were found in black and red rice, at around 9 g/100 g. Wild and parboiled rice also have a similarly high protein content. However, this also depends on the method of calculation and measurement. The content of individual nutrients is, of course, influenced by the method of cultivation and location, as well as atmospheric factors. According to the U.S. Department of Agriculture Department of Agriculture, dry red rice contains 8.56 g of protein, 3.44 g of fat, 4.2 g of fiber, and 76.2 g of carbohydrates, including 70.8 g of starch [USDA rice red 2024]. In the case of black rice, the difference in fiber content is twice as high, while it similarly contains protein - 7.57 g [USDA rice black 2023]. In many dietary documents, the protein content of white and parboiled rice is stated as lower than on the labels of purchased samples, and is only 2.91 g/100 g, while the carbohydrate content is 26.05 g (as calculated) [ile-kalorii.pl 2017]. The values provided by the USDA for wild rice were very similar to those on the packaging, which also indicated that the rice originated in the US. The visible differences were in the protein content of 4.2 g and the Mg content – in the USA it was 108 mg/100 g. in our measurements, it was 90.16 mg Mg/100 g rise. This value was similar to the values indicated on the packaging of wild and red rice.

Table 4. Nutritional value, minerals, and number of portions along with the price for carton packages of rice

Distinguish	White rice	Parboiled rice	Jasmine rice	Basmati rice	Wild rice	Jasmine-black Rice	Red rice	Brown natural rice
Energy value [J/kcal]	1460/ 344	1548 /365	1469/ 346	1458/ 344	1470/ 346	1486/ 352	1485/ 351	1566/ 370
Fat [g]	0.7	1.0	0.5	0.6	1.3	3.6	3.0	1.9
Fatty acid [g]	0.2	0.5	0.2	0.2	0.3	1.0	0.8	0.5
Carbohydrates (starch) [g]	77	80	77	78	75	66.7	69.4	76.8
Fiber [g]	2.4	1.6	1.5	2.4	6.2	8.0	5.2	8.7
Protein [g]	6.7	8.1	7.6	6.5	8.6	9.1	9.0	7.1
Salt [g]	0.02	< 0.01	<0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.01
Mg [mg]	–	–	–	–	93	104	91,6	69
Zn [mg]	–	–	–	–	3.7	2.1	1.8	–
Cr [ug] /Fe [mg]	–	–	–	–	–	12 µg Cr	7,5 mg Fe	–
Price PLN	4.89	6.59	5.39	7.59	22.31	11.72	8.10	4.95

cont. Table 4

Portions in box	4 x 100	4 x 100	4 x 100	3 x100	2 x 100	2 x 100	2 x 100	4 x 100
Price per portion 50 g [PLN]	0.61	0.82	0.67	1.26	5.57	2.93	2.03	0.61
Marka	Kupiec	Kupiec	Cenos	Kupiec	Kupiec	Sonko	Sonko	Kupiec
Importer country	Vietnam	Italy	Vietnam	Pakistan	USA	Thailand	Cambodia	Italy
Cooking time	15 min	12 min	15 min	15 min	30 min	25 min	25 min	30 min

Source: own study.

CONCLUSIONS

The study aimed to determine the content of minerals in different types of rice and compare their nutritional value and competitiveness on the market. It was found that the varieties that were cleaned and polished contained fewer minerals but at the same time had a higher carbohydrate content. White parboiled rice, after water-pressure processing, did not lose its mineral content or nutritional value. The price of a portion of white parboiled rice is slightly higher than white, brown, or jasmine rice, but lower than less processed rice. Wild rice, black jasmine, and red rice contained the most minerals, the nutritional value of these types of rice was similar. Black jasmine and wild rice are the best in terms of nutrition and mineral content, but their price is significantly higher than white rice. Brown rice deserves attention, as it has a high content of minerals but also an appropriate nutritional value. It can potentially be advertised as dietary rice. White rice didn't show an intense white colour after grinding, and the L brightness parameter was not the highest for this sample among the samples tested. Red, black, and wild rice, due to their flavonoid content, differed significantly in brightness. The work confirmed the type of film used for individual packaging – it is HDPE film, suitable for recycling and free of Bisphenol A.

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GENERAL PRODUCT SAFETY REGULATION (GPSR) – EVOLUTION OR REVOLUTION IN PRODUCT SAFETY REGULATIONS

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Abstract

The dynamic development of information technology (IT) and the growing importance of e-commerce have led to increasing gaps in the European Union (EU) regulations on general product safety, which were introduced over 20 years ago by Directive 2001/95/EC. The lack of effective control in e-commerce and threats from the technologies related to artificial intelligence and the augmented reality have accelerated work on new regulations.

In 2023-2024, there was a twofold increase in alerts related to unsafe non-food products noted on the EU market. Frequent cases of low-quality products sold online also demonstrate the need for more effective controls. Regulation (EU) 2023/988 of the European Parliament and the Council provided a new version of the General Product Safety. So-called GPSR rules have significantly influenced the level of consumer products' safety, especially those offered online. Manufacturers and importers must assess the risk posed by the goods they place on the market. Consumers have gained a more extensive warning system (Safety Gate portal).

GPSR has a big influence on the availability of product information and increases the responsibility of e-commerce platforms. It is an evolution of general product safety rules and their implementation shouldn't be a revolution in the responsibilities of producers and distributors.

Keywords: General Product Safety Regulation (GPSR), responsible trade.

INTRODUCTION

The European Union (EU) comprises today 27 member states and is the largest single market in the world with the number of citizens (and potential consumers) equal to approximately 450 million people, and a gross domestic product (GDP) of 16 trillion euros [Macchi 2025]. The introduction of non-food products on the EU market requires compliance with fundamental principles that are intended to ensure the safety of products, as well as freedom of product movement within the single market of goods [Biznes.gov.pl 2024a]. The specific product requirements involve either harmonised or non-harmonised legislative scope, depending on the type of product itself, its method of production, or properties that may be related to health, safety, and environmental protection [Howells 2024]. The harmonised rules are applied to the groups of goods, the usage of which may be dangerous or create some risk. This includes, for example, cosmetics, toys, construction goods, explosives, personal protective equipment, electrical equipment, and machinery [Biznes.gov.pl 2024b]. All products subject to harmonised legislation must bear the CE mark before being placed on the EU market, which confirms that they comply with EU safety, health, and environmental protection requirements.

Establishing general rules of product safety is particularly important because the EU market is governed by the principle of mutual recognition [Eur-lex 2015]. If any product is legally on sale in one EU country, it can by definition be sold in other EU countries (unless there are important reasons to limit this trade, e.g., for public health reasons). The goods for which no common EU requirements have been specified must comply with the requirements specified in national legislation, but the free movement of goods in the non-harmonized area is ensured by the application of the principle of mutual recognition [Biznes.gov.pl 2024c].

The overall safety of non-food products placed on the EU market has become the main objective of Directive 2001/95/EC on general product safety, which was approved by the European Parliament and the Council on 3 October 2001 [Directive 2001/95/EC]. A safe product must bear information enabling its tracking and if necessary for its safe use, it must provide warnings and information about any inherent risk [Eur-lex 2015]. First of all, a safe product must meet specific national requirements or general EU standards. When such references are not available, the product safety assessment must be based on other UE Commission guidelines, best practices in the sector concerned, state-of-the-art technology, or reasonable

consumer safety expectations. The Directive 2001/95/EC introduces also a rapid information exchange system (so-called RAPEX) that enables national authorities to alert their counterparts immediately to any product posing a serious threat to consumers' health or life [Safety Gate Report 2025].

Over the past 25 years, the realities of ensuring the safety of non-food products have changed and the general principles introduced by Directive 2001/95/EC have begun to be insufficient [Eur-lex 2023]. A large part of modern products is related to augmented reality and the use of artificial intelligence in interactions with consumers. Online sales have become one of the most important distribution channels (especially during and after the COVID-19 pandemic). The system for notifying and withdrawing products from the market and the standardisation of requirements also require improvement. According to European Commission experts the costs of accidents related to unsafe products are estimated at 11.5 billion euros per year for the EU market [European Commission 2023]. The value of unsafe products that had to be withdrawn from the EU market in 2021 was estimated at 19.3 billion euros. In 2023 and 2024, there was a significant increase in the number of alerts related to unsafe non-food products introduced onto the EU market (Figure 1). In 2024, the notification system featured the highest number of alerts validated since the system was created (4 137 alerts), which was almost double the number in 2022.

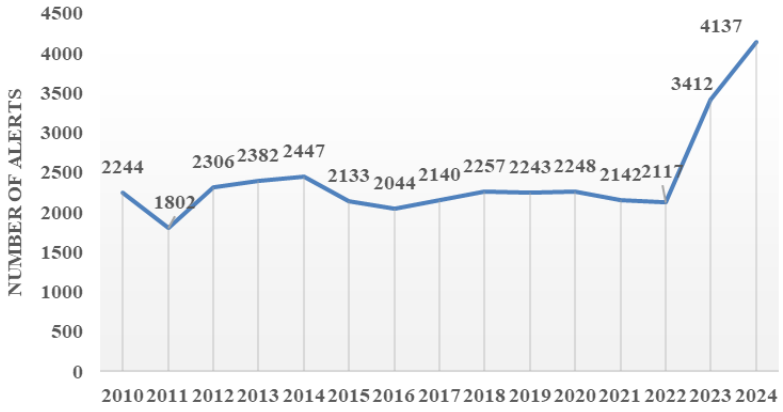

Figure 1. Number of alerts recorded in rapid alert system for unsafe non-food products in 2010–2024

Source: Safety Gate Report 2025.

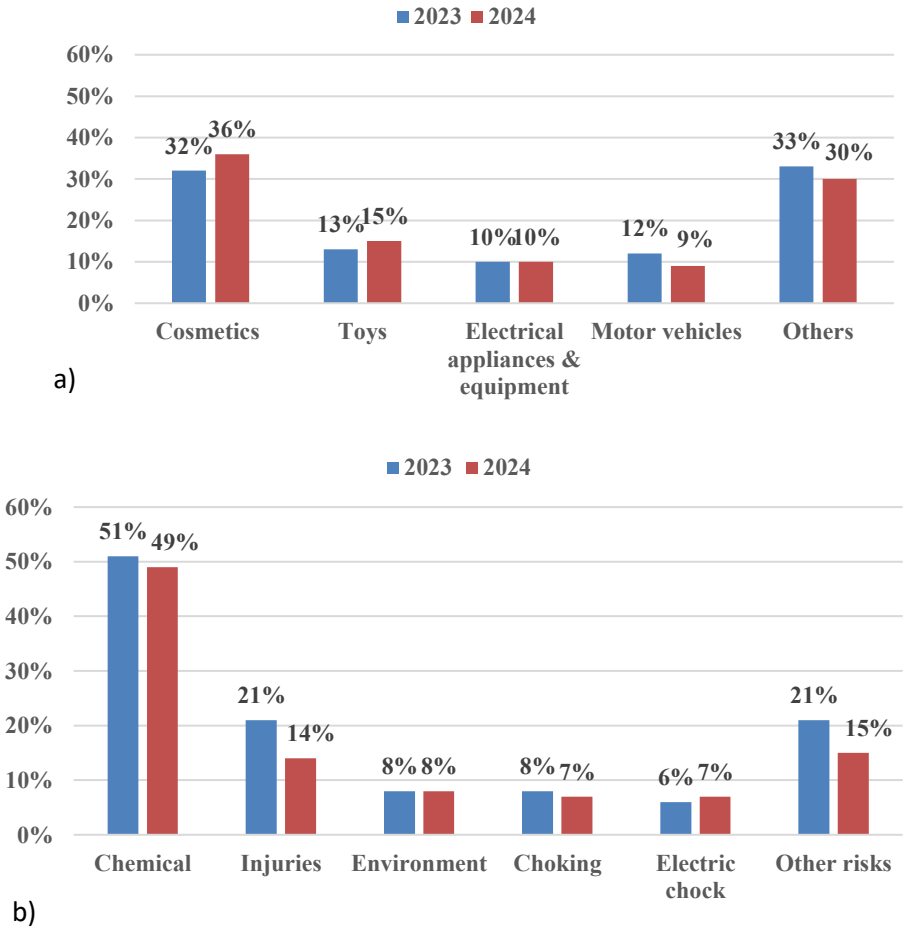

Figure 2. The percentage of most frequent alerts by product category (a) and types of risk (b) in rapid alert system for unsafe non-food products in 2023 and 2024

Source: Safety Gate Report 2025.

The increased number of alerts in recent years is the result of the constantly growing amount of threats related to cosmetic products, which constitute just over one third of all notifications (Figure 2a). The next most frequently reported product groups (toys, electrical appliances, and equipment, and vehicles) remain at the forefront, which demonstrates the importance of monitoring the quality and

safety of these product categories introduced to the EU market [Safety Gate Report 2025].

The most common type of risk validated for non-food products was of a chemical nature, often concerned cosmetic products and the detection of substances banned from the EU market [Safety Gate Report 2025]. The most frequent identified unsafe products also posed a risk of injuries, electric shock, choking with small parts or they were a threat to the environment (Figure 2b).

In addition to reports resulting from formal surveillance, there are also notifications coming directly from the market. For example, the European and local (e.g., Polish) consumer organisations have published reports indicating health risks and non-compliance with EU product safety regulations by Asian e-commerce platforms Temu and Shein [BEUC 2025; Federacja Konsumentów 2025]. The aforementioned report noted that more than half of the products tested contained dangerous heavy metals, considered carcinogenic and allergenic. Online platforms responded quickly and published appropriate statements assuring the safety of the products they offer [Shein 2025].

Listening to all the above-mentioned premises, the EU legislator came to the conclusion that the existing regulations should be updated. The effect of the legislative work undertaken was the Regulation (EU) 2023/988 of the European Parliament and of the Council on general product safety (so-called GPSR or General Product Safety Regulation), which became directly applicable in all EU countries on 13 December 2024 [Regulation (EU) 2023/988]. The GPRS Regulation aimed at more future-proof product safety rules concerning a new reality of EU consumers, dealing with the safety of online sales, direct imports, or new technology products [European Commission 2023]. Additionally, it is estimated that the introduction of new general product safety principles should reduce consumer detriment due to unsafe products and provide real financial benefits of 1 billion euros in 2025 and around 5.5 billion euros over the next decade. The article is a concise presentation of the key assumptions and rules introduced by the new General Product Safety Regulations (GPSR), and the expected effects on the safety and quality of non-food products available on the EU market.

1. GPSR OBJECTIVE AND SCOPE

The General Product Safety Regulation is supposed to be a new cornerstone of the European Union's consumer protection framework, designed to ensure that all non-food products placed on the market are safe for consumers [Ciechański 2024]. This guideline has undergone significant developments with the Regulation (EU) 2023/988.

The General Product Safety Directive broadens consumer protection and focuses on the following goals:

- covering the safety of all non-harmonized products,
- dealing with all types of safety risks (closing gaps in EU harmonisation legislation),
- setting the minimum safety obligations for all businesses,
- ensuring the same level of safety of non-food product sold online as offline,
- ensuring precautionary principles,
- improving enforcement by aligning the market surveillance regime,
- addressing the effectiveness of product recalls [EU Justice and Consumers 2025].

The GPSR rules have a broad range and apply to almost all consumer products placed on the EU market. Only products subjected to specific EU regulations are excluded from its scope. In particular, the following product groups should be given special attention for safety:

- toys – must be precisely described in terms of the materials used, risk warnings (for example, due to the presence of small parts), and information about the age of the child allowed to use the product,
- products intended for children – such as car seats or feeding accessories, which must meet strict safety standards and contain appropriate markings,
- chemical products – including household chemicals and cosmetic products, which require detailed information on ingredients, potential hazards, and methods of safe use,
- electronic equipment – requires comprehensive instructions on installation, use, and warnings about electrical hazards,
- clothing and textiles – must contain information on material composition, potential allergens, and product care instructions [Marszycki 2024].

Product safety requirements are the same for traditionally distributed goods and those sold online. The GPSR requirements apply to products made available on the market, whether new, used, repaired, or refurbished. Products for professional use that will later reach consumers should also meet the general safety requirements [UOKiK 2025a].

1.1. Product Safety Assessment

General Product Safety Regulation extends the criteria for assessing product safety specified in Directive 2001/95/EC [Regulation (EU) 2023/988]. According to the new regulation, the determining product safety includes evaluation:

- product properties and its impact on other products,
- the way the product is presented (including marking and instructions, durability, location, and legibility of warnings),
- categories of consumers at risk when using the product, in particular children and the elderly,
- product appearance – in particular, if the appearance of the product may suggest another use, it must have information about not using it in a manner inconsistent with its intended use [Biznes.gov.pl 2024a].

Taking into account the development of information technologies and the use of artificial intelligence the level of cybersecurity of selected products is also assessed. IT-advanced products should be resistant to external influences, including malicious third parties, where such influence could impact the security of the product or/and loss of connection. Special attention was also paid to evolving, learning, and predictive product features [EUR-lex 2023].

1.2. Distance selling

The importance of e-commerce sales in the European market is growing steadily year by year. Taking into account data from 38 European countries, the total business-to-consumer (B2C) European e-commerce turnover amounted to 870 billion euros in 2023 and was forecast to reach almost 960 billion euros in 2024 [Weltevreden 2024]. The number of low-value parcels (i.e., products with a value not exceeding €150) purchased online and reaching the EU market amounted to

approximately 4.6 billion in 2024 (twice as much as in 2023 and three times as much as in 2022) [European Commission 2025]. These statistics illustrate how important it is to ensure the quality and safety of goods sold online.

The GPSR rules require that offers for the sale of a product at a distance contain key data identifying the product and the entity responsible for placing it on the market, including:

- the name, registered trade name or registered trademark of the manufacturer and the postal and e-mail address at which it can be contacted,
- name, postal, and e-mail address of the responsible person (if the manufacturer is not resident or established in the Union),
- product identification information, including product image, type, and other product identifiers,
- any warnings or safety information required to appear on the product or on its packaging, or in an accompanying document, in accordance with this GPSR Regulation or with applicable UE harmonisation legislation, in a language that can be easily understood by consumers.

The new regulations expand the group of entities responsible for product safety to include online shopping platforms [UOKiK 2024]. Previously, this obligation rested mainly with manufacturers and importers. This means that platforms such as Allegro, Amazon, Temu, etc. can no longer act as mere intermediaries, but must actively participate in ensuring the safety of products sold through them. E-commerce services are required to monitor offers and remove those that do not meet safety requirements. The providers of online trading platforms must also register on the Safety Gate portal, designate a point of contact, respond to notices regarding the safety of products offered, and undertake the removal of a given product from the offer upon an order issued by supervisory authorities.

In response to new regulatory requirements, sales platforms are introducing solutions that help sellers adapt their e-stores. The platforms publish detailed manuals for users on how to meet GPSR requirements and support them with IT solutions, introducing functionalities such as visibility of the manufacturer's contact details, posting safety warnings and information on standards and certificates met [Allegro 2025; Amazon 2025].

2. GPSR OBLIGATIONS FOR INDIVIDUAL ENTITIES IN THE SUPPLY CHAIN

The GPSR establishes a broad obligation for producers, importers, and distributors to ensure that their products are safe for consumers. This requirement is not limited to specific types of products but applies to all consumer goods, except for those covered by sector-specific regulations. The regulation mandates that products must not pose any risks to the health and safety of consumers under normal or reasonably foreseeable conditions of use [UOKiK 2025b].

2.1. Producers

A producer is not only someone who manufactures a product but also anyone who acts as its manufacturer, branding the product with their name, trademark, name, etc. A person who repairs or remanufactures a product will also be considered a producer [UOKiK 2025b].

In the light of GPSR regulations, the manufacturer is obliged to:

- ensure products are safe by design,
- carry out internal risk analyses and draw up relevant technical documentation,
- act immediately and inform consumers and national authorities, through the Safety Business Gateway, if they believe a product on the market is dangerous,
- share information on accidents,
- provide essential product safety and traceability information on products or their packaging,
- provide contact details to receive complaints, investigate them and keep an internal register of complaints received [EUR-lex 2023].

GPSR regulations allows the manufacturer to appoint his authorized representative, at the same time indicating in the authorisation the tasks assigned to him, which include at least informing about the suspected danger of the product and contacting the supervisory authorities [UOKiK 2025b].

2.2. Importers

The importer, although he has no physical influence on the product, is obliged to verify the product's compliance with safety requirements. In the event of non-

compliance, he must inform the manufacturer and market surveillance authorities via the Safety Business Gateway [Eur-lex 2023].

The importer has to ensure products comply with the GPSR regulation's and must provide manufacturer data, product identification data, and instructions and safety information. It also ensures that the transport and storage conditions of the product do not jeopardise the product's compliance with these requirements [UOKiK 2023]. If the importer finds or has reason to suspect that a product is unsafe, he shall not place it on the market, immediately inform the manufacturer and ensure that corrective measures are taken, including those necessary to withdraw or recall the product. At the same time, it notifies national market surveillance authorities, through the Safety Business Gateway and ensure the public is alerted.

2.3. Distributor

A distributor is anyone who mediates the product's journey from the manufacturer to the consumer [UOKiK 2023]. The distributor is obliged to check the product safety before it is placed on the market, including by checking whether the manufacturer and importer have fulfilled their obligations (especially in terms of product identification). If the product does not meet the requirements for labelling and doesn't have instructions or appropriate warnings, the distributor shall not make the product available until it complies with the requirements. The distributor ensures appropriate transport and storage conditions of the product so that they do not threaten the product's compliance with the GPSR requirements.

3. ENHANCED MARKET SURVEILLANCE AND WARNING EFFECTIVENESS

The new obligations imposed by the GPRS Directive on manufacturers should not pose a problem, as they have the technical and administrative resources to comply with more detailed care for product security. Experts providing legal advice on trade in goods in the EU, however, point to the need to change the approach to ensuring product safety [Ciechoński 2025].

To increase the effectiveness of the early warning system, GPSR obliges the Commission to continuously develop the Safety Gate early warning system (replacing RAPEX 3) and maintain the Safety Business Gateway online portal

[European Commission 2025]. The Safety Gate system (previously known as the Rapid Alert System for dangerous non-food products, RAPEX) was created to ensure a high level of protection of consumer health and safety within the European Union Single Market. The early warning system for dangerous non-food products should be an accessible platform, within which national market surveillance authorities and the European Commission can exchange information on such products [UOKiK 2023]. In addition, the Safety Gate online portal was developed to inform the public and notify the European Commission about products that may pose a risk to the health and safety of consumers. The third tool is the Safety Business Gateway web portal, which helps companies fulfill their obligation to inform authorities and consumers about dangerous products and accidents involving such products.

The European Commission has developed a special website, where it explains the obligations of entrepreneurs in the event of detecting dangerous products among the products offered. It also provides a template for the warning that is applicable in such situations [Safety Gate 2025].

CONCLUSIONS

The General Product Safety Regulation is a comprehensive framework that is pivotal role in protecting consumer safety within the European Union. Its key provisions, including the general safety requirement, risk assessment, market surveillance, product recall, and liability rules, work together to create a robust system that minimizes the risks associated with consumer products. By harmonising standards, promoting transparency, and ensuring accountability, the GPSR not only safeguards consumers but also fosters trust in the internal market. As the regulatory landscape continues to evolve, the GPSR remains a cornerstone of EU consumer protection, ensuring that safety remains a top priority for producers and consumers.

The changes introduced by GPSR Regulation should be assessed as both evolutionary and revolutionary in the approach to product safety with expected benefits for consumers. At the same time, these are quite demanding changes from the perspective of producers, importers, and distributors. They were obliged to verify the safety of offered products in the light of new GPSR criteria, review the information provided to consumers during the sale of goods (also online), implement

new procedures for managing consumer notifications, and take into account the use of the Safety Gate system in their business activity.

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BEZPIECZEŃSTWO ŻYWNOŚCI W KONTEKŚCIE WYNIKÓW KONTROLI URZĘDOWYCH – STUDIUM PRZYPADKU

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Streszczenie

Praca dotyczy roli Państwowej Inspekcji Sanitarnej w zapewnieniu bezpieczeństwa żywności na podstawie wyników przeprowadzanych kontroli urzędowych. Omówiono system nadzoru nad bezpieczeństwem żywności, uwzględniając unijne i polskie regulacje prawne, działalność inspekcji oraz przeprowadzane kontrole.

Celem badania była ocena wyników kontroli przeprowadzanych w latach 2022–2023 przez Powiatową Stację Sanitarno-Epidemiologiczną (PSSE) znajdującą się w jednym z miast w północno-zachodniej Polsce oraz wskazanie najczęściej powtarzających się przyczyn negatywnych wyników kontroli w zakładach branży spożywczej. Stwierdzono, że najczęstszymi naruszeniami były niewłaściwe warunki sanitarno-higieniczne. Większość decyzji administracyjnych wydawanych przez PSSE nakazywała usunięcie stwierdzonych uchybień w określonym terminie. Wyniki badania potwierdziły, że największe problemy dotyczą magazynowania, transportu i dystrybucji żywności, co może prowadzić do zagrożenia zdrowia konsumentów.

Słowa kluczowe: Państwa Inspekcja Sanitarna, kontrole urzędowe.

WPROWADZENIE

Żywność jest jednym z najistotniejszych elementów w życiu każdego człowieka, wobec czego ciągła kontrola oraz sprawdzanie jej stanu jest kluczowe

na różnych etapach obrotu. Zapewnienie bezpieczeństwa żywności ma istotne znaczenie dla zdrowia oraz ogólnego dobrostanu społeczeństwa z wielu powodów, w tym występujących zagrożeń wynikających zarówno ze skażenia (chemicznego, mikrobiologicznego i fizycznego), jak i fałszowania żywności [Mańkowski 2018; Sygida & Wojtyła 2008; Urbanek 2020]. Jak wynika z Raportu „Stan sanitarny kraju w 2023 r.", nadzorem Państwowej Inspekcji Sanitarnej objęto ponad 560 tysięcy zakładów branży spożywczej, a liczba ta wzrosła o ponad 17 tysięcy w porównaniu z rokiem poprzednim, co potwierdza rosnącą skalę działań kontrolnych w tym obszarze [GIS 2024]. Identyfikacja tychże zagrożeń na stosunkowo wczesnym etapie umożliwia podjęcie działań zapobiegających ich przekształceniu się w poważne ryzyko. Co więcej, może również zapobiec dalszemu rozprzestrzenianiu się ustalonego zagrożenia [FAO 2023]. Zgodnie z Codex Alimentarius, który zawiera międzynarodowe wytyczne dotyczące higieny żywności, bezpieczeństwo żywności oznacza zapewnienie, że nie spowoduje ona negatywnych skutków zdrowotnych dla konsumenta, gdy jest przygotowywana i/lub spożywana zgodnie z jej przeznaczeniem [FAO i WHO 2023]. Natomiast w polskim prawie bezpieczeństwo żywności rozumiane jest szerzej – jako ogół warunków i działań, które muszą być spełnione i podejmowane na wszystkich etapach produkcji i obrotu żywnością, w tym m.in. w zakresie stosowania dodatków, poziomów zanieczyszczeń, pozostałości pestycydów czy cech organoleptycznych – w celu ochrony zdrowia i życia człowieka [Dz.U. z 2023 r. poz. 1448]. Obie definicje są zgodne co do celu, ale różnią się zakresem i szczegółowością ujęcia.

W większości krajów na świecie bezpieczeństwo żywności jest gwarantowane z mocy prawa oraz jest niezbędnym warunkiem wejścia produktu na rynek [Kwiatek & Patyra 2021]. Z racji przynależności Rzeczypospolitej Polskiej do Unii Europejskiej, polityka dotycząca bezpieczeństwa żywności opiera się na przepisach unijnych, w których kluczową rolę odgrywa Europejski Urząd ds. Bezpieczeństwa Żywności (European Food Safety Authority – EFSA). Jest on kluczowym organem Unii Europejskiej powołanym na mocy Rozporządzenia (WE) Nr 178/2002 Parlamentu Europejskiego i Rady z dnia 28 stycznia 2002 roku do działań związanych z oceną ryzyka, doradztwem naukowym i edukowaniem [Chatzopoulou et al. 2020]. Rozporządzenie (WE) Nr 178/2002 i inne rozporządzenia w dziedzinie bezpieczeństwa żywności (m.in. Nr 852/2004, Nr 853/2004, Nr 2017/625) kompleksowo regulują kwestie bezpieczeństwa żywności w Unii Europejskiej oraz określają główne zasady i wymagania prawa żywnościowego, w tym urzędowych

kontroli na różnych etapach produkcji, dystrybucji i sprzedaży żywności [Dz.U.UE.L.2002.31.1, Dz.U.UE.L.2004.139.1, Dz.U.UE.L.2004.139.55, Dz.U.UE.L.2017.95.1].

Na poziomie krajowym aktualnie obowiązującym aktem prawnym określającym wymagania i procedury niezbędne dla zapewnienia bezpieczeństwa żywności i żywienia jest Ustawa z dnia 25 sierpnia 2006 roku o bezpieczeństwie żywności i żywienia [Dz.U. z 2023 r. poz. 1448]. Wszelkie ustawy krajowe, jak i unijne, nakładają na przedsiębiorców w branży spożywczej wiele obowiązków w zakresie zapewnienia bezpieczeństwa żywności. Jednym z podstawowych wymagań jest wprowadzenie systemu HACCP (Hazard Analysis and Critical Control Points), czyli Systemu Analizy Zagrożeń i Krytycznych Punktów Kontroli, którego działanie koncentruje się z jednej strony na identyfikacji wszelkich zagrożeń, które mogą w sposób negatywny wpływać na zdrowie konsumenta, z drugiej natomiast na zastosowaniu metod eliminacji lub ograniczenia zagrożeń do akceptowalnego poziomu [Awuchi 2023]. Wymagania, które muszą spełniać przedsiębiorstwa branży spożywczej, kontrolowane są przez odpowiednie organy.

W Polsce urzędową kontrolą i nadzorem nad żywnością zajmuje się równolegle kilka instytucji. Od lipca 2020 roku głównymi podmiotami systemu krajowej urzędowej kontroli żywności są: Państwowa Inspekcja Sanitarna (PIS), Inspekcja Weterynaryjna (IW), Inspekcja Jakości Handlowej Artykułów Rolno-Spożywczych (IJHARS) i Państwowa Inspekcja Ochrony Roślin i Nasiennictwa (PIORiN) [Wiśniewska & Kowalska 2022].

Państwowa Inspekcja Sanitarna (PIS) jest instytucją państwową, regulowaną licznymi aktami prawnymi, poprzez które określa się powierzane jej zadania. Podstawowym aktem prawnym, na którym opiera się działalność PIS, jest Ustawa z dnia 14 marca 1985 roku o Państwowej Inspekcji Sanitarnej [Dz.U. z 2024 r. poz. 416]. Określa ona zakres działania PIS, a dokładniej państwowych inspektorów sanitarnych działających przy pomocy stacji sanitarno-epidemiologicznych będących publicznymi zakładami opieki zdrowotnej. Nadrzędnym celem działalności PIS, wynikającym z zapisów tejże ustawy, jest zatem ochrona zdrowia ludzkiego przed niekorzystnym wpływem szkodliwości i uciążliwości środowiskowych oraz zapobieganie powstawaniu chorób, w tym zakaźnych i zawodowych, polegająca m.in. na przeprowadzaniu badań laboratoryjnych oraz kontroli [Kucharski 2015; Kuś 2018; Posobkiewicz et al. 2015; Seweryn 2015; Wardzyńska 2017].

Głównym narzędziem każdego z poszczególnych organów Państwowej Inspekcji Sanitarnej (PIS) są kontrole urzędowe. Rozumiane są one jako czynności, których celem jest ustalenie stanu rzeczywistego oraz stwierdzenie, czy stan ten jest prawidłowy wobec przepisów prawa sanitarnego, a w konsekwencji zapobieżenie lub wyeliminowanie stanu niezgodnego z wymaganiami higienicznymi i zdrowotnymi lub stanu zagrażającego życiu i zdrowiu ludzi [Posobkiewicz et al. 2015; Seweryn 2015].

W przypadku wystąpienia jakichkolwiek niezgodności podczas czynności kontrolnych wyciągane są wobec przedsiębiorców konsekwencje, które muszą być dostosowane do charakteru stwierdzonych naruszeń i ich wpływu na zdrowie lub życie ludzi. Państwowy Inspektor Sanitarny może prowadzić postępowanie mandatowe, wydawać polecenia, jak również nakazywać, w drodze decyzji administracyjnej, usunięcie w ustalonym terminie stwierdzonych uchybień. Jeżeli natomiast naruszenie wymagań spowodowało bezpośrednie zagrożenie życia lub zdrowia ludzi, inspektor sanitarny nakazuje bezzwłoczne unieruchomienie zakładu pracy lub jego części [Dz.U. z 2024 r. poz. 416; Kucharski 2015].

Celem badania była ocena wyników kontroli przeprowadzanych przez Powiatową Stację Sanitarno-Epidemiologiczną (PSSE) znajdującą się w jednym z miast w północno-zachodniej Polsce oraz wskazanie najczęściej powtarzających się przyczyn negatywnych wyników kontroli w zakładach branży spożywczej. W związku z tym postawiono następujące pytania badawcze:

1) W jakim stopniu organizacje branży spożywczej spełniają wymagania dotyczące bezpieczeństwa żywnościowego?
2) Jakie są najczęstsze przyczyny negatywnych wyników kontroli przeprowadzanych przez PSSE?
3) W jakich obszarach stwierdzanych jest najwięcej niezgodności i jakie skutki administracyjne się z tym wiążą?

1. PRZEDMIOT BADANIA I METODY

Próbę badawczą stanowiły wyniki wszystkich kontroli zakładów należących do różnych grup obiektów w latach 2022–2023, które zostały przeprowadzone przez Sekcję Higieny Żywności, Żywienia i Przedmiotów Użytku Powiatowej Stacji Sanitarno-Epidemiologicznej. Przeanalizowano raporty z każdego roku w okresie

2019–2023. Jako próbę badawczą wybrano jednak raporty z lat 2022–2023, ponieważ wcześniejsze lata obejmowały okres pandemii. W tym czasie czynności kontrolne nie były prowadzone regularnie, co wpływało na wiarygodność uzyskiwanych danych.

W ramach badań zastosowano metody analizy danych oraz statystyki opisowej, opierające się na wynikach kontroli PSSE z wybranego okresu. Wykorzystano także analizę dokumentacji administracyjnej, decyzji pokontrolnych oraz wywiady z inspektorami sanitarnymi, co pozwoliło na identyfikację kluczowych czynników wpływających na wyniki inspekcji.

Stacja Sanitarno-Epidemiologiczna, zgodnie z posiadanymi kompetencjami, nadzoruje zakłady zlokalizowane na terenie powiatu, w tym:

1) zakłady produkcji żywności: piekarnie, ciastkarnie, wytwórnie lodów, zakłady wyrobów garmażeryjnych, przetwórnie owocowo-warzywne, zakłady przemysłu zbożowo-młynarskiego,
2) zakłady obrotu żywnością: sklepy spożywcze, w tym markety, kioski spożywcze, magazyny hurtowe, środki transportu żywności,
3) zakłady żywienia zbiorowego typu otwartego: restauracje, bary, zakłady małej gastronomii, ruchome obiekty gastronomiczne,
4) zakłady żywienia zbiorowego typu zamkniętego: stołówki szkolne, przedszkolne, w żłobkach, domach opieki społecznej, stołówki w szpitalach, zakładach pracy, bursach, internatach, zakłady usług cateringowych,
5) zakłady produkcji i obrotu materiałami i wyrobami przeznaczonymi do kontaktu z żywnością: wytwórnie oraz sklepy.

Liczbę zakładów objętych nadzorem PSSE oraz liczbę przeprowadzonych kontroli w latach 2022–2023 przedstawiono w tabeli 1.

Z analizy uzyskanych danych wynika, że w latach 2022–2023 największą grupą nadzorowanych zakładów przez PSSE były zakłady obrotu żywnością, które stanowiły 61% w 2022 roku i 59% w 2023 roku wszystkich nadzorowanych zakładów. W sumie analizie poddano 914 raportów zawierających wyniki wszystkich kontroli nadzorowanych zakładów przeprowadzonych przez PSSE w latach 2022–2023.

Tabela 1. Liczba zakładów objętych nadzorem wraz z liczbą przeprowadzonych kontroli przez PSSE w latach 2022–2023

Lp.	Grupa zakładów	2022		2023	
		Liczba zakładów objętych nadzorem	Liczba kontroli	Liczba zakładów objętych nadzorem	Liczba kontroli
1.	Zakłady produkcji żywności	136	25	139	54
2.	Zakłady obrotu żywnością	639	266	618	241
3.	Zakłady żywienia zbiorowego typu otwartego	143	80	161	80
4.	Zakłady żywienia zbiorowego typu zamkniętego	108	77	107	81
5.	Zakłady produkcji i obrotu materiałami i wyrobami przeznaczonymi do kontaktu z żywnością	22	5	24	5
Suma		**1048**	**453**	**1049**	**461**

Źródło: opracowanie własne.

2. WYNIKI

Stan sanitarny nadzorowanych obiektów był oceniany przez pracowników PSSE zgodnie z jednolitymi procedurami urzędowej kontroli żywności. Ocenie podlegały również materiały i wyroby przeznaczone do kontaktu z żywnością, przy uwzględnieniu obowiązujących przepisów w zakresie wymagań higieniczno-sanitarnych. Liczbę przeprowadzonych kontroli w poszczególnych grupach zakładów, w tym liczbę oraz rozkład procentowy kontroli z niezgodnościami w latach w 2022 i 2023 ujęto w tabeli 2.

Z analizy uzyskanych danych wynika, że w badanym okresie w 11% przeprowadzonych kontroli stwierdzano nieprawidłowości (odpowiednio w roku 2022 – 6% i w 2023 roku – 16%). Należy zauważyć, że procentowa liczba kontroli z niezgodnościami w nadzorowanych zakładach w 2023 roku wzrosła w stosunku do roku 2022 o 10%. Dla porównania, w skali ogólnokrajowej – według danych zawartych w Raporcie Głównego Inspektoratu Sanitarnego „Stan sanitarny kraju w 2023 r." – średni odsetek działań administracyjnych (decyzji i mandatów) w stosunku do liczby przeprowadzonych kontroli wyniósł w latach 2022–2023 około 24% [GIS 2024].

Tabela 2. Liczba kontroli przeprowadzonych przez PSSE wraz z liczbą i rozkładem procentowym kontroli z niezgodnościami w latach 2022–2023

Lp.	Grupa zakładów	2022			2023		
		Liczba kontroli	Kontrole z niezgodnościami		Liczba kontroli	Kontrole z niezgodnościami	
			Liczba	[%]		Liczba	[%]
1.	Zakłady produkcji żywności	25	3	12%	54	9	17%
2.	Zakłady obrotu żywnością	266	12	5%	241	39	16%
3.	Zakłady żywienia zbiorowego typu otwartego	80	11	14%	80	17	21%
4.	Zakłady żywienia zbiorowego typu zamkniętego	77	2	3%	81	10	12%
5.	Zakłady produkcji i obrotu materiałami i wyrobami przeznaczonymi do kontaktu z żywnością	5	0	0%	5	0	0%
Suma		**453**	**28**	**6%**	**461**	**75**	**16%**

Źródło: opracowanie własne.

Na podstawie danych z analizy dokumentów oraz informacji uzyskanych w trakcie wywiadu z pracownikami PSSE ustalono, że rodzajem najczęściej stwierdzonych niezgodności w poszczególnych grupach skontrolowanych obiektów w latach 2022–2023 były:

1. Zakłady produkcji żywności:
   - niewłaściwy stan sanitarno-higieniczny (brudne powierzchnie urządzeń, sprzętów i wyposażenia zakładów, niedoczyszczone powierzchnie, zawilgocenia, zapleśnienia na powierzchniach, takich jak podłogi, ściany i sufity, pajęczyny przy sufitach, nieporządek),
   - niewłaściwa jakość zdrowotna lodów z automatu z powodu nadmiernego wzrostu mikroflory z rodzaju *Enterobacteriaceae* w pobranych próbkach, co wskazuje na niezadowalającą jakość lodów, zgodnie z wymaganiami rozporządzenia Komisji (WE) Nr 2073/2005 z dnia 15 listopada 2005 r. w sprawie kryteriów mikrobiologicznych dotyczących środków spożywczych [Dz.U.UE.L.2005.338.1] – automaty do lodów,
   - brak opracowanych lub/i wdrażanych procedur GHP i HACCP,
   - obecność szkodników lub ich pozostałości,

- niewłaściwy stan sanitarno-techniczny (powierzchnie ścian, sufitów, podłóg oraz wyposażenia zakładów niegładkie, z ubytkami, odpryskami, trudne do utrzymania w czystości, zniszczone wyposażenie i sprzęt produkcyjny);

2. Zakłady obrotu żywnością:
   - brak aktualnych orzeczeń lekarskich do celów sanitarno-epidemiologicznych, wydanych dla pracowników wykonujących prace, w trakcie których istnieje możliwość przeniesienia zakażenia na inne osoby,
   - niewłaściwa jakość zdrowotna wprowadzanych do obrotu produktów spożywczych,
   - wprowadzanie do obrotu środków spożywczych po upływie terminu przydatności do spożycia lub daty minimalnej trwałości,
   - niewłaściwe przechowywanie produktów spożywczych, niezgodne z zaleceniami producenta, brak zachowania ciągłości łańcucha chłodniczego,
   - niewłaściwy stan sanitarno-higieniczny (brudne powierzchnie urządzeń, sprzętów i wyposażenia zakładów, niedoczyszczone powierzchnie podłóg, ścian i sufitów, nieporządek w pomieszczeniach magazynowych),
   - niewłaściwy stan sanitarno-techniczny (powierzchnie ścian, sufitów, podłóg oraz wyposażenia technologicznego zakładów niegładkie, z ubytkami, odpryskami, trudne do utrzymania w czystości; zniszczone wyposażenie i sprzęt produkcyjny);
3. Zakłady żywienia zbiorowego (typu otwartego i zamkniętego):
   - niedopełnienie obowiązku opracowania i wdrożenia systemu HACCP wynikającego z art. 5 ust. 1 rozporządzenia (WE) Nr 852/2004 Parlamentu Europejskiego i Rady z dnia 29 kwietnia 2004 r. w sprawie higieny środków spożywczych,
   - niewłaściwy stan sanitarno-higieniczny (brudne powierzchnie urządzeń, sprzętów i wyposażenia zakładów, niedoczyszczone powierzchnie podłóg, ścian i sufitów, nieporządek w pomieszczeniach zaplecza produkcyjnego), brak bieżącej ciepłej wody,
   - brak aktualnych orzeczeń lekarskich do celów sanitarno-epidemiologicznych, wydanych dla pracowników wykonujących prace, w trakcie których istnieje możliwość przeniesienia zakażenia na inne osoby,
   - brak informowania konsumentów o substancjach alergennych zawartych w przygotowanych potrawach / daniach,

– niewłaściwa jakość zdrowotna przygotowywanych i oferowanych do konsumpcji potraw/dań.

Stan sanitarno-higieniczny nadzorowanych przez PSSE obiektów żywności i żywienia był bardzo zróżnicowany. Na podstawie przeprowadzonego wywiadu stwierdzono, że na terenie nadzorowanego powiatu działają zarówno obiekty nowoczesne, jak i stare oraz obiekty małe (sklepy w rejonach wiejskich) i bardzo duże (typu super i hipermarkety).

Kompetencje Powiatowej Stacji Sanitarno-Epidemiologicznej obejmują także urzędową kontrolę i monitoring produkowanej i wprowadzanej do obrotu żywności pochodzenia niezwierzęcego oraz produktów pochodzenia zwierzęcego znajdujących się w handlu detalicznym. Liczbę pobranych przez PSSE próbek produktów żywnościowych wraz z liczbą i rozkładem procentowym zakwestionowanych próbek w latach 2022–2023 przedstawiono w tabeli 3.

Tabela 3. Liczba pobranych przez PSSE próbek produktów żywnościowych wraz z liczbą i rozkładem procentowym zakwestionowanych próbek w latach 2022–2023

Lp.	Grupa zakładów	2022			2023		
		Liczba próbek	Zakwestionowane próbki		Liczba próbek	Zakwestionowane próbki	
			Liczba	[%]		Liczba	[%]
1.	Zakłady produkcji żywności	14	0	0%	46	6	13%
2.	Zakłady obrotu żywnością	163	11	7%	142	7	5%
3.	Zakłady żywienia zbiorowego typu otwartego	18	10	55%	26	10	39%
4.	Zakłady żywienia zbiorowego typu zamkniętego	7	0	0%	2	0	0%
5.	Zakłady produkcji i obrotu materiałami i wyrobami przeznaczonymi do kontaktu z żywnością	4	0	0%	2	0	0%
Suma		**206**	**21**	**10%**	**218**	**23**	**11%**

Źródło: opracowanie własne.

Z analizy wynika, że liczba pobranych i zakwestionowanych próbek w latach 2022 i 2023 była na podobnym poziomie. Najwięcej próbek zakwestionowano w zakładach żywienia zbiorowego typu otwartego, takich jak bary czy zakłady małej gastronomii. Raport Głównego Inspektoratu Sanitarnego „Stan sanitarny kraju w 2023 r." także wskazuje, że właśnie w tej grupie obiektów najczęściej występowały nieprawidłowości, zwłaszcza w sezonie letnim [GIS 2024].

Pobrane próbki były badane w następującym zakresie: mikrobiologia, substancje dodatkowe, metale, kryteria czystości, azotany, pestycydy, skażenia promieniotwórcze, wartość odżywcza posiłku (wartość energetyczna, białko, węglowodany, tłuszcz), gluten, mykotoksyny, akryloamid, bakterie zoonotyczne i komensalne, alkaloidy tropanowe, WWA, jod w soli, karbaminian etylu, furan, zawartość histaminy, obecność soi, ocena znakowania, organoleptyka, badania materiałów i wyrobów przeznaczonych do kontaktu z żywnością. Ze wszystkich 206 pobranych próbek w 2022 roku, 21 zostało zakwestionowanych, w tym:

- 20 próbek lodów z automatu – ze względu na nadmierny wzrost mikroflory z rodzaju *Enterobacteriaceae*, co wskazuje na niezadowalającą jakość lodów, zgodnie z interpretacją wyników rozporządzenia Komisji (WE) Nr 2073/2005 z dnia 15 listopada 2005 roku w sprawie kryteriów mikrobiologicznych dotyczących środków spożywczych. Zakwestionowane lody były pobrane u czterech przedsiębiorców w zakładach, takich jak:
  - sklepy spożywcze – 10,
  - mała gastronomia i żywienie zbiorowego typu otwartego – 10.
- 1 próbka płatków jaglanych pobrana w magazynie hurtowym – ze względu na przekroczenie najwyższego dopuszczalnego poziomu pozostałości pestycydów – glifosatu, którego najwyższy dopuszczalny poziom został określony w Rozporządzeniu (WE) Nr 396/2005 Parlamentu Europejskiego i Rady z dnia 23 lutego 2005 roku w sprawie najwyższych dopuszczalnych poziomów pozostałości pestycydów w żywności i paszy pochodzenia roślinnego i zwierzęcego oraz na ich powierzchni, zmieniającego Dyrektywę Rady 91/414/EWG [Dz.U.UE.L.2005.70.1]. Zgodnie z obowiązującymi przepisami produkt został zgłoszony do Systemu Wczesnego Ostrzegania o Niebezpiecznej Żywności i Paszach (RASFF).

W 2023 roku pobrane próbki były badane w identycznych kierunkach jak w roku poprzedzającym. Ze wszystkich 218 próbek pobranych w 2023 roku

23 zostały zakwestionowane. Podobnie jak w 2022 roku, zdecydowana większość dotyczyła lodów z automatu ze względu na nadmierny wzrost mikroflory z rodzaju *Enterobacteriaceae*. Dane z Raportu Głównego Inspektoratu Sanitarnego „Stan sanitarny kraju w 2023 r." potwierdzają, że dominującą przyczyną zakwestionowania próbek był nadmierny wzrost *Enterobacteriaceae* w lodach z automatu [GIS 2024].

Jak wynika z analizy dokumentacji kontrolnej oraz sprawozdawczej PSSE, wobec podmiotów, u których stwierdzano niezgodności z obowiązującymi przepisami prawnymi, stosowano postępowanie administracyjne i egzekucyjne, przymuszające do wykonania wydanych zaleceń, z czym były związane przeprowadzane kontrole sprawdzające. Tabela 4 przedstawia postępowanie administracyjne i egzekucyjne PSSE wobec podmiotów skontrolowanych w latach 2022–2023, w których stwierdzono niezgodności z przepisami prawa żywnościowego.

Tabela 4. Zestawienie prowadzonego postępowania administracyjnego i egzekucyjnego PSSE w latach 2022–2023

Lp.	Grupa zakładów	Liczba decyzji administracyjnych		Liczba nałożonych mandatów		Liczba wniosków o ukaranie	
		2022	2023	2022	2023	2022	2023
1.	Zakłady produkcji żywności	3	6	1	6	0	0
2.	Zakłady obrotu żywnością	11	26	2	20	1	2
3.	Zakłady żywienia zbiorowego typu otwartego	6	12	2	7	0	0
4.	Zakłady żywienia zbiorowego typu zamkniętego	1	8	2	4	0	0
5.	Zakłady produkcji i obrotu materiałami i wyrobami przeznaczonymi do kontaktu z żywnością	1	0	0	0	0	0
Suma		**22**	**52**	**7**	**37**	**1**	**2**

Źródło: opracowanie własne.

W latach 2022–2023 w przypadku stwierdzenia nieprawidłowości organy PSSE podejmowały działania – zgodnie z kompetencjami i obowiązującymi przepisami prawa – mianowicie:

- wydały ogółem 74 decyzje administracyjne, nakazujące wyeliminowanie nieprawidłowości w zakładach produkcji żywności, zakładach obrotu żywnością, zakładach żywienia zbiorowego typu otwartego, zakładach żywienia zbiorowego typu zamkniętego oraz zakładach produkcji i obrotu materiałami i wyrobami przeznaczonymi do kontaktu z żywnością,
- w poszczególnych grupach zakładów ogółem nałożono 44 grzywny w drodze mandatu karnego za uchybienia higieniczno-sanitarne,
- w przypadku stwierdzenia w trakcie kontroli naruszenia przez przedsiębiorców przepisów art. 103 ust. 1 ustawy z dnia 25 sierpnia 2006 roku o bezpieczeństwie żywności i żywienia Państwowi Powiatowi Inspektorzy Sanitarni skierowali do Państwowych Wojewódzkich Inspektorów Sanitarnych 3 wnioski o nałożenie kar pieniężnych.

Z analizy wynika, że wzrost liczby kontroli w 2023 roku, w wyniku których stwierdzono niezgodności, generuje większą liczbę wydanych w tym roku decyzji administracyjnych, nałożonych mandatów karnych oraz wniosków o ukaranie. Liczba ta w stosunku do 2022 roku, analogicznie jak w przypadku kontroli z niezgodnościami, wzrosła.

3. DYSKUSJA

Na podstawie analizy otrzymanej dokumentacji (raportów, sprawozdań) oraz przeprowadzonych rozmów z pracownikami PSSE można stwierdzić, że w wielu zakładach powiatu północno-zachodniej Polski stan sanitarny ulega systematycznej poprawie. Można przypuszczać, że wynika to m.in. ze wzrastającej świadomości przedsiębiorców w zakresie obowiązujących wymagań oraz wdrażania i stosowania zasad dobrej praktyki higienicznej (GHP), dobrej praktyki produkcyjnej (GMP), a także wprowadzania procedur opartych na zasadach systemu HACCP. Potwierdzają to też dane z Raportu Głównego Inspektoratu Sanitarnego „Stan sanitarny kraju w 2023 r.", zgodnie z którymi w skali całego kraju zasady GHP/GMP wdrożono w 484 812 zakładach, natomiast system HACCP wprowadzono w 276 525 nadzorowanych zakładach. Wynika to z tego, że w części zakładów spożywczych,

korzystając z ułatwień przewidzianych przez Komisję Europejską dla małych przedsiębiorstw, uznano, że przestrzeganie zasad GHP i GMP jest wystarczające do kontroli najważniejszych zagrożeń dla bezpieczeństwa żywności. Raport wskazuje, że dotyczy to zwłaszcza punktów małej gastronomii, które bazują na półproduktach i produktach gotowych [GIS 2024]. Jednakże, jak co roku, co wynika z analizy dokumentacji PSSE, organy Państwowej Inspekcji Sanitarnej stwierdzały pewne niezgodności. Niezgodności te we wszystkich grupach obiektów były rozłożone w czasie, nie miały charakteru cyklicznego, zasadniczo nie obserwowano związku między rodzajem niezgodności a ich występowaniem w czasie. Wyjątkiem były obiekty gastronomiczne prowadzące działalność sezonową, w których występowanie niezgodności nasilało się w okresie letnim, co było związane ze zwiększonym ruchem turystycznym, wyższą temperaturą otoczenia, czy większą liczbą spotkań rodzinnych (święta, przyjęcia, wesela). Zwiększenie występowania niezgodności zaobserwowano głównie w obiektach małej gastronomii, a także miejscach, w których sprzedawano lody z automatu. Dotyczyły one głównie nieprzestrzegania zasad dobrej praktyki higienicznej i produkcyjnej, braku udokumentowania realizacji systemu opartego na zasadach HACCP oraz niewłaściwego stanu sanitarno-technicznego pomieszczeń. Zgodnie z raportem Głównego Inspektoratu Sanitarnego, w skali całego kraju w sezonie letnim 2023 roku odnotowano wzrost liczby interwencji w obiektach gastronomicznych w sezonie letnim. Najczęściej stwierdzano nieprawidłowości dotyczące higieny sprzętu, warunków przechowywania surowców oraz braku dokumentacji HACCP, co znajduje potwierdzenie w uzyskanych wynikach [GIS 2024].

Ustalono, że przyczyną występowania niezgodności w odniesieniu do placówek szkolno-wychowawczych oraz małych zakładów produkcyjnych było usytuowanie bloków żywienia oraz pomieszczeń produkcyjnych w budynkach funkcjonujących wiele lat, adaptowanych bez możliwości rozbudowy, ograniczających ich przestrzeń roboczą, z nieprawidłowym rozmieszczeniem pomieszczeń, często skutkującym krzyżowaniem się dróg technologicznych tzw. „brudnych” i „czystych”. Zgodnie z raportem Głównego Inspektoratu Sanitarnego, w 2023 roku w ponad 1600 placówkach oświatowych stwierdzono uchybienia w zakresie warunków sanitarno-technicznych, w tym niewystarczającą powierzchnię kuchni, przestarzałe wyposażenie oraz brak możliwości zapewnienia właściwego podziału stref, co potwierdza skalę problemu w skali kraju [GIS 2024]. Jak wskazali pracownicy PSSE, w wielu przypadkach poprawa stanu sanitarno-technicznego pomieszczeń, wyposażenia

i sprzętu wiązałaby się z istotnymi nakładami finansowymi, których brak przekładał się na wydłużenie terminów realizacji wyżej wymienionych potrzeb. Trudna sytuacja finansowa zmuszała również niektórych małych producentów, szczególnie z terenów wiejskich, do wstrzymywania inwestycji bądź całkowitej rezygnacji z nich, a także redukcji zatrudnienia, co zwykle skutkowało pogorszeniem się warunków produkcji w zakładzie. Niezgodności w tych miejscach dotyczyły głównie opracowywania oraz wdrażania systemów kontroli wewnętrznej, niskich kwalifikacji pracowników, małej dostępności szkoleń, braku wdrożenia systemu HACCP oraz zasad dobrej praktyki higienicznej i produkcyjnej. W raporcie Głównego Inspektoratu Sanitarnego podkreślono również, że w małych zakładach produkcyjnych i punktach żywienia zbiorowego często występowały problemy z zapewnieniem odpowiednich warunków lokalowych i kadrowych, co przekładało się na liczne niezgodności w zakresie higieny procesów i dokumentacji [GIS 2024]. Stosunkowo często zdarzało się, że pracownicy zatrudnieni przy produkcji nie posiadali orzeczeń lekarskich z badań do celów sanitarno-epidemiologicznych, co stanowi potencjalne źródło przenoszenia chorób zakaźnych, a w konsekwencji może zagrażać zdrowiu i życiu konsumentów. Niezgodności wynikały również z dużej rotacji personelu, braku szkoleń pracowników, nieznajomości przepisów prawnych dotyczących bezpieczeństwa żywności. Ponadto wielu przedsiębiorców nie jest w stanie dostosować standardu swoich obiektów do obowiązujących wymagań sanitarnych poprzez kompleksową modernizację zakładu. W związku z tym stosowane przez nich rozwiązania w celu zapewnienia bezpieczeństwa żywności często mają charakter prowizoryczny. Przeprowadzane są tylko doraźne remonty, których zakres ogranicza się wyłącznie do zaleceń wydawanych przez inspekcję sanitarną.

Analiza dokumentacji w zakresie nieprawidłowości i niezgodności w zakładach produkujących środki spożywcze pozwoliła stwierdzić, że wymagania prawa żywnościowego w pełni spełniały duże firmy, o ugruntowanej pozycji na rynku. Firmy te, ukierunkowane na jakość produktu i zadowolenie klienta, wdrażają systemy zarządzania jakością we wszystkich obszarach działalności. Produkując duże partie środków spożywczych, są świadome, że brak dbałości o zapewnienie warunków dla bezpiecznej produkcji mógłby narazić je na duże straty finansowe. Ponadto z analizy dokumentacji wynika, że najwięcej niezgodności i nieprawidłowości wymagających poprawy stwierdzano w obiektach zajmujących się obrotem żywnością, w szczególności w małych sklepach o niewielkiej powierzchni, które wprowadzają do obrotu szeroki asortyment środków spożywczych, często również artykuły

przemysłowe i chemii gospodarczej. Zgodnie z raportem Głównego Inspektoratu Sanitarnego, w 2023 roku w ramach nadzoru nad handlem detalicznym przeprowadzono w całym kraju ponad 130 tysięcy kontroli, z czego w blisko 10% przypadków stwierdzono nieprawidłowości, głównie dotyczące warunków przechowywania, oznakowania produktów oraz przeterminowanej żywności [GIS 2024].

Na podstawie raportów i sprawozdań PSSE podsumowujących poszczególne lata 2022 i 2023 wynika, że najczęściej stwierdzanymi nieprawidłowościami w nadzorowanych zakładach żywnościowo-żywieniowych były:

- niewłaściwy stan sanitarno-techniczny pomieszczeń, urządzeń i wyposażenia,
- niewłaściwe warunki przechowywania środków spożywczych – niezgodne z deklaracją producenta,
- wprowadzanie do obrotu środków spożywczych po upływie terminu przydatności do spożycia bądź daty minimalnej trwałości,
- brak lub nieprawidłowe oznakowania wprowadzanych do obrotu środków spożywczych,
- nieprzestrzeganie procedur opartych na zasadach HACCP,
- nieprawidłowe przechowywanie i usuwanie odpadów, w tym brak segregacji,
- brak właściwego zabezpieczenia przed dostępem szkodników.

W przypadku pobranych próbek żywności, przyczyny niezgodności wynikały z:

- braku właściwej kontroli wewnętrznej,
- nieprawidłowo prowadzonych zabiegów mycia i dezynfekcji urządzeń do produkcji lodów,
- słabego przygotowania organizacyjno-technicznego,
- braku środków finansowych na modernizację.

Zarówno analiza dokumentacji PSSE z północno-zachodniej Polski, jak i dane ogólnokrajowe wskazują, że najczęstsze nieprawidłowości w zakładach żywnościowo-żywieniowych dotyczą przede wszystkim uchybień sanitarno-technicznych, błędów w przechowywaniu i znakowaniu żywności oraz niewystarczającego wdrażania systemów kontroli wewnętrznej, co znajduje potwierdzenie w wynikach nadzoru przedstawionych w Raporcie Głównego Inspektoratu Sanitarnego [GIS 2024].

WNIOSKI

Działania PSSE na terenie powiatu w północno-zachodniej Polsce, objętego nadzorem sanitarnym w zakresie urzędowej kontroli żywności, mają na celu zapewnienie odpowiedniego poziomu bezpieczeństwa żywności produkowanej i wprowadzanej do obrotu. Na podstawie przeprowadzonego badania, obejmującego analizę danych oraz statystykę opisową wyników kontroli PSSE, uzyskano wnioski dotyczące przestrzegania przepisów prawa żywnościowego oraz głównych przyczyn uchybień:

1. Kontrolowane obiekty spełniały wymagania wynikające z prawa żywnościowego – wyniki kontroli wskazują, że większość zakładów spełnia określone normy sanitarne i higieniczne, choć zdarzają się przypadki niezgodności (średnio 11% kontroli, w czasie których stwierdzono niezgodności w badanym okresie).
2. Najczęstsze przyczyny negatywnych wyników kontroli dotyczyły niewłaściwego stanu sanitarno-higienicznego – głównymi niezgodnościami były zaniedbania w zakresie higieny personelu, czystości urządzeń oraz warunków przechowywania żywności.
3. Najczęstsze decyzje administracyjne w wyniku negatywnych kontroli dotyczyły poprawy stanu sanitarno-technicznego – większość decyzji wydawanych przez PSSE nakazywała usunięcie stwierdzonych uchybień sanitarno-technicznych w określonym terminie.
4. Etapami, w odniesieniu do których było stwierdzanych najwięcej niezgodności, jest magazynowanie, obrót oraz produkcja żywności – największa liczba uchybień dotyczyła obiektów zajmujących się przechowywaniem i dystrybucją żywności, co podkreśla konieczność zwiększonego nadzoru w tych sektorach.
5. Wnioski z poziomu lokalnego są spójne z tendencjami ogólnokrajowymi – najczęściej stwierdzane niezgodności w powiecie północno-zachodniej Polski pokrywają się z danymi ogólnopolskimi, które wskazują na problemy w zakresie higieny, przechowywania, oznakowania oraz braku wdrożenia systemów HACCP, co potwierdza konieczność dalszego wzmacniania nadzoru i edukacji w tych obszarach.

Podsumowując, Państwowa Inspekcja Sanitarna, poprzez swoje struktury, w tym Powiatowe Stacje Sanitarno-Epidemiologiczne (PSSE), odgrywa kluczową rolę w monitorowaniu i kontrolowaniu przestrzegania przepisów dotyczących bezpieczeństwa żywności. Mimo spełniania wymagań przez większość kontrolo-

wanych obiektów, wskazano na istotne problemy i wyzwania związane z przestrzeganiem norm sanitarnych. Zbieżność wyników uzyskanych na poziomie powiatowym z danymi ogólnokrajowymi wskazuje na systemowy charakter problemów, wymagających skoordynowanych działań nadzorczych i edukacyjnych. Wdrożenie skuteczniejszych mechanizmów kontroli oraz programów edukacyjnych w zakresie higieny może przyczynić się do poprawy sytuacji w przyszłości.

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