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Fortified Wheat-Rye Bread: Investigating the Impact of Processing Purple Potatoes "Vitelotte" on Physicochemical and Sensory Attributes

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Abstract

Cereal products, including bread, are significant in global consumption, confirmed by their enduring presence in human diet. However, commonly consumed refined flour bread contains only small amounts of essential nutrients and bioactive compounds necessary for optimal health.

The study aimed to investigate the influence of the method of processing purple potatoes used as an addition to sourdough wheat-rye bread on its physicochemical properties. This study investigated the incorporation of purple potatoes into wheat-rye bread using three distinct processing methods: boiling, baking and raw (C, B, and R). Polyphenol content, crumb colour analysis, acidity determination, salt and sugar content quantification, porosity evaluation, moisture content determination, and bread volume were measured, and organoleptic assessment was also conducted. The highest content of polyphenolic compounds in bread (207.45 mg GAE/100 g of bread) was obtained by using roasted purple potatoes as an additive. The bread had suitable physicochemical parameters and was classified in the first group of bread quality in the organoleptic tests. The results highlighted the importance of potato incorporation in bread formulations, affecting both quality and nutritional attributes, thus offering promising avenues for developing functional foods.

Keywords: purple potatoes, Vitelotte, wheat-rye bread, sourdough

1. Introduction

Cereal products, especially bread, hold a prominent position in global consumption, after dairy and potato products. Bread, an enduring staple in human diet for millennia, has historically been revered as a quintessential, even sacred, food source (Pastor et al., 2023). Despite the shifts observed in dietary patterns during the COVID-19 pandemic, bread consumption has exhibited relatively minor fluctuations, emphasising its enduring significance in human dietary habits (Janssen et al., 2021).

Bread is a fundamental source of complex carbohydrates essential for sustaining energy levels and regulating blood glucose concentrations. Moreover, it is rich in low-fat vegetable proteins and a spectrum of vital nutrients, including B vitamins, vitamin E, and trace minerals such as iron, potassium, calcium, and selenium, all of which play pivotal roles in various physiological processes (Boukid et al., 2018).

Regrettably, the commonly consumed bread derived from refined flour is deficient in essential nutrients and bioactive compounds known for their health-promoting properties. These are crucial in mitigating the risk of civilization-related ailments and other conditions stemming from nutritional insufficiencies. Thus, it is widely recognised that, given its widespread consumption, bread requires fortifying with essential nutrients to uphold optimal health and nutritional balance in line with a sustainable health perspective (Kaim & Goluch, 2023).

Potatoes contribute essential nutritive compounds, minerals, and vitamins and are a valuable energy source, boasting easily digestible carbohydrates and approximately 2 g of protein per 100 g dry weight (DW). Notably, the protein in potatoes, with its amino acid composition, particularly lysine, is a valuable supplement for cereal products where lysine is often a limiting amino acid (Singh et al., 2020).

Nowadays, colour-fleshed potatoes, including the blue varieties, are of particular interest, presenting potential sources of bioactive compounds, especially anthocyanins. Anthocyanins (ACNs) are fundamental plant pigments centred around the flavylium (2-phenylchromenylium) ion structure. ACNs, primarily in plant cell vacuoles, exhibit diverse water-soluble colours such as red, purple, black, or blue. ACNs can exist as acylated or nonacylated forms, depending on the presence of acyl groups. These variations, including mono-, di-, tri-, and tetra-acylated anthocyanins, influence their stability and colour under pH, light, and temperature conditions (Mattoo et al., 2022). ACNs exert significant physiological effects due to their ability to modulate gut microbiota, mitigate oxidative stress and inflammation, and enhance neuropeptides such as IGF-1 and cGP. The burgeoning literature on anthocyanins underscores their potential in safeguarding organ structure and function (Panchal et al., 2022), thus presenting promising avenues for developing functional food products.

Blue-fleshed varieties, with a protein content comparable to traditional varieties, are deemed suitable for integration into various culinary products, including bakery goods. It is worth noting the favourable culinary profile of these potatoes, coupled with safe levels of anti-nutritive compounds such as glycoalkaloids (Pęksa et al., 2013).

Potato proteins have higher biological value than crops such as peas, wheat, or rice, nearing the nutritional value of animal proteins. The amino acid composition, featuring richness in essential amino acids such as aspartic, glutamic, leucine, valine, alanine, lysine, and arginine, enhances the nutritional profile of products incorporating potato-derived ingredients (Hussain et al., 2021). Recent studies confirm that including purple-fleshed potatoes in bakery products, such as bread, could positively increase the amino acid composition of bread and its nutritional value (Taglieri et al., 2021).

However, to date, there has been a lack of studies focusing on selecting the correct form of potato for bread formulas, especially traditional bread based on sourdough.

The aim of the study was to investigate the influence of the method of processing purple potatoes used as an addition to sourdough for wheat-rye bread on its physicochemical properties.

2. Materials and Methods

Bread preparation

The study investigated the production of wheat-rye bread incorporating purple potatoes, employing three distinct processing methods before baking. These methods were: M – cooking the potatoes unpeeled until soft, followed by mashing to achieve a mousse-like consistency after cooling; B – baking the potatoes unpeeled at 190°C, then peeling and pressing them after cooling; and R – utilising raw potatoes grated on a fine mesh grater. The "Vitelotte" variety of potatoes sourced from a farm in Podkarpackie Province, Poland, was selected for the study.

Wheat-rye breads incorporating potatoes were prepared utilizing a two-phase baking method. Initially, a sourdough was created by fermenting a blend of rye flour type 2000 and water (1:1, w/w) for 19 hours at a temperature range of 26-28°C. The dough formulation comprised 250 g of wheat flour type 750, 150 g of the previously prepared sourdough, 400 g of "Vitelotte" potatoes, salt at 2.3 g per 100 g of flour, and water at a ratio of 60 g per 100 g of flour. Fermentation of the dough occurred for 60 minutes at a controlled temperature of 30°C. Finally, each experimental variant resulted in duplicate bread loaves baked at 190°C for 50 minutes. Post-baking, the breads were cooled at room temperature.

Bread extract preparation

Extraction was carried out in an ultrasonic bath (Polsonic Sonic 6D, Poland); 10 ml of 80% methanol was added to the crumb samples (2 g), and the extraction took place under conditions at 80 kHz at 60°C for 30 minutes.

The samples were then shaken for 10 minutes and centrifuged in a laboratory centrifuge (Adverti MPW-54) for 10 minutes at 5800 rpm. Extraction was made in triplicate for each bread, and the resulting supernatants for each variant were combined and used for further analysis.

Polyphenol analysis

The total polyphenol amount was determined using the Folin-Ciocalteu spectrophotometric method (Prior et al., 2005). The absorbance was measured at 725 nm using a HachLange DR5000 UV-Vis spectrophotometer. The results were expressed as mg gallic acid equivalents (GAE) per 100 g of bread (mg GAE/100 g).

Quality assessment

Bread quality and organoleptic evaluation were carried out within 24 hours of baking.

The crumb colour was assessed utilising a Minolta Chroma Meter CR-200b colourimeter (Konica Minolta, Tokyo, Japan), employing the CIE Lab colour model encompassing three parameters: L*, a*, and b*. Measurements were made using the L*a*b colour scale. The range from black to white (brightness) was expressed by the L* parameter. The a* parameter allowed to determine the red (+a*) to green (−a*) colour balance, while the b* parameter determined the yellow (+b*) to blue (−b*) colour balance. The crumb colour difference ΔE was also calculated for all the analysed variants according to the formula: $\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$ and compared with commercial wheat-rye bread without additives. In developing the results of ΔE calculations, the International Commission on Illumination CIE criterion was used (Mokrzycki & Tatol, 2011).

All analyses were performed in triplicate.

Several analytical methods were employed for each baked product to assess various parameters. The acidity was determined following the guidelines outlined in PN-A-74108:1996. The salt content was quantified using the Mohr method while reducing sugars, which was analysed using the Lane Eynon method. Porosity was evaluated using the Jacobi method, also in accordance with PN-A-74108:1996. Crumb scans were meticulously compared with photographs from the Dallman scale, and a porosity coefficient was then assigned. Crumb moisture content was determined through the drying method utilising a weighing-drying machine (MB25, OHAUS). Bread volume measurements were conducted with an SA-WY bread volumeter (ZBPP, Bydgoszcz, Poland), adhering to PN-A-74108:1996 standards. Additionally, an organoleptic assessment was carried out following the established Banecki method.

Statistical analysis

Statistical analysis was conducted using STATISTICA 13.3 (StatSoft, Kraków, Poland). One-way analysis of variance (ANOVA) followed by Duncan's post-hoc test were used to determine significant differences ($p < 0.05$) between the mean values. All the findings reported in this study are presented as the mean value of three determinations accompanied by their respective standard deviations.

3. Results and Discussion

The bread volumes of the investigated samples varied between 96.54 and 114.81 cm^3/100 g (Table 1). Notably, the addition of baked potatoes resulted in the highest volume. According to the Polish Standard (PN-A-74112:1997), bread is expected to exhibit less than 220 cm^3/100 g volume. The study's results indicate that the inclusion of potatoes significantly influences bread volume. This influence is likely attributed to modifications in dough structure and the fermentation process induced by the presence of potatoes. The observed lower-than-expected volume may be attributed to alterations in gluten structure and gas retention during baking. Given the product's unique nature, including the addition of potatoes and the voluntary adherence to Polish Standards (Dz.U. [Journal of Laws] from 2002, No. 169, item 1386, as amended), the assessment of bread quality characteristics proposed in this study is ultimately best left to consumers.

The bread volume is intricately linked to the presence of simple sugars within the dough, serving as substrates for fermentative microorganisms. Incorporating starch-rich potatoes into the dough augments the potential pool of simple sugars available for fermentation. Moreover, subjecting such raw material to heat treatment initiates starch gelatinisation, facilitating subsequent enzymatic hydrolysis during baking (Konkol, 2012). This research revealed that oven baking of potatoes yielded the most favourable outcomes in terms of achieving substantial bread volume. This observation remains in line with findings from Harris (1932), who conducted similar experiments by incorporating various proportions of mashed potatoes into bread formulations. The referenced study documented augmented gas production and enhanced dough volume proportional to the increment in potato content within the dough. In the subsequent phase of Harris' investigation, two batches of bread were baked utilising a blend comprising 50 g of flour and 50 g of potatoes. Notably, one batch received additional ingredients, including 1% diastatic malt and 0.001% $KBrO_3$, alongside the basic constituents. It was observed that loaf volume augmentation occurred not only with increased potato content but also made with flour possessing higher protein content.

Table 1. Physicochemical parameters of the tested breads prepared with: C – cooked potatoes; B – baked potatoes; R – raw potatoes

Tabela 1. Parametry fizykochemiczne badanych chlebów z dodatkiem: C – ugotowanych ziemniaków; B – pieczonych ziemniaków; R – surowych ziemniaków

	Variant/ Wariant		
	C	B	R
Volume [cm³/100g]/ Objętość [cm³/100g]	96.54[a] ± 5.64	114.81[b] ± 5.99	97.32[a] ± 3.86
Acidity [acidity degrees]/ Kwasowość [stopnie kwasowości]	3.7[a] ± 0.1	4.0[b] ± 0.1	3.8[a.b] ± 0.1
Salt [%]/ Zawartość soli [%]	1.44[a] ± 0.05	1.78[b] ± 0.03	1.79[b] ± 0.03
Sugar [wt%]/ Zawartość cukrów [% wag.]	4.12[a] ± 0.05	3.45[b] ± 0.15	2.20[c] ± 0.11
Porosity [%]/ Porowatość [%]	61.66[a] ± 0.15	54.03[b] ± 0.08	68.75[c] ± 0.13
Moisture [%]/ Wilgotność [%]	55.9[a] ±1.50	47.0[b] ± 1.63	45.44[b] ± 3.99
Crumb porosity coefficient/ Współczynnik porowatości miękiszu	20.00 ± 0.0	60 ± 0.0	70 ± 0.0

a, b, c – the same letters in rows mean that there is no statistically significant difference between the samples ($p < 0.05$)/ a, b, c – te same litery w wierszach oznaczają brak statystycznie istotnej różnicy między próbami ($p < 0,05$)

Source/ Źródło: own research/ badania własne.

During the bread-baking process, the degree of acidity plays a crucial role, influencing the condition and quality of gluten and the development and activity of yeast and lactic acid bacteria. The acidity of baking samples primarily hinges on the presence of organic acids synthesised through the fermentation of simple sugars, chiefly by lactic bacteria. The acids generated during fermentation inhibit the proliferation of putrefactive bacteria and *Bacillus mesentericus*, thus preventing the onset of the so-called potato disease (Cohn et al., 1918). According to the prevailing Polish Standard (PN-A-74112:1997), the acceptable acidity range for mixed bread (country bread) should not surpass 7°kw. The acidity values obtained for the examined crumbs (Table 1) align with this standard, ranging between 3.7 and 4.0°kw. The topic of acidity in baked goods incorporating coloured potatoes was addressed in a study focusing on the evaluation of anthocyanin and polyphenol content in Romanian purple potato varieties such as “Albastru-Violet de Gălănești” and “Christian” (Bădărău et al., 2016) which investigated the impact of varying proportions (5%, 15%, 30%) of potato varieties added to the dough on selected bread parameters. Preceding incorporation into the dough, the potatoes underwent boiling followed by grinding. The acidity levels (expressed as acidity degrees per 100 g of product) in bread containing purple potatoes exhibited elevation, notably registering 1.51 with 5% coloured potato paste addition and 2.065 with 30% purple potato paste addition, in contrast to bread devoid of added potatoes (1.38). Thus, the inclusion of potatoes potentially exerted a beneficial influence on the metabolic activities of fermentative microorganisms.

Salt serves multifaceted roles in bread baking beyond imparting flavour, acting as a gluten structure enhancer and a preservative. It also facilitates the efficient retention of carbon dioxide generated during fermentation. Inadequate salt levels in baked goods may result in structural looseness and weakening, potentially leading to diminished volume and shape distortion (Avramenko et al., 2018; Taylor et al., 2018). In line with World Health Organization guidelines advocating a reduced salt intake, it is recommended that adults consume less than 5 grams of salt per day (WHO, 2023). Approximately 25-40% of daily sodium chloride intake originates from bread and bakery products.

In the analysed bread samples, the salt content ranged from 1.44% (C) to 1.79% (R) (Table 1). Note that salt content varies across different types of baked goods. Dybkowska et al. (2015), for instance, reported a salt content ranging from 1.2% to 1.5% in various mixed, wholemeal, and choice breads. Similarly, He and MacGregor (2007) documented a 1.4-1.8% salt content in plain bread.

The salt content findings of bread containing purple potatoes obtained in this study coincided with those reported in the existing literature.

Substitutes for sodium chloride, such as potassium chloride, calcium chloride, or magnesium chloride, are commonly used to reduce sodium chloride levels in baked goods. An alternative strategy involves employing a dry sourdough starter to replace sodium chloride in confectionery baked goods. Scientific evidence suggests that dry sourdough can effectively mitigate the adverse effects of salt reduction on bread flavour while contributing to desirable sensory attributes and achieving an appropriate crumb texture (Voinea et al., 2020). Note that the salt content varies based on the type and origin of the product, ranging from 0.17% in bread with reduced salt content to 1.79% in bread incorporating potatoes, as observed in Romania.

In a study by Taglieri et al. (2021), bread enriched with flour derived from boiled "Vitelotte" potatoes and citrus albedo was examined – the process involved peeling the potatoes after cooking, followed by slicing and freeze-drying. The resulting freeze-dried potato was ground into powder and incorporated into the dough. Comparative analyses were conducted between bread formulations enriched with and without the additives above, focusing on evaluating the efficacy of yeast and sourdough starter utilisation in baking. The authors conducted a comprehensive physicochemical and sensory evaluation of the bread samples. Despite the omission of added salt in the baked goods, the sensory panellists noted the presence of a discernible salty aftertaste in the crust and crumb of the sourdough bread. This phenomenon can be attributed to a synergistic interplay between the souring process and proteolysis facilitated by the enzymatic activity of lactic acid bacteria (LAB). Additionally, the inclusion of purple potatoes exerted a positive influence on the proliferation of lactic acid bacteria and yeast metabolism. This effect is likely attributable to the higher sugar content in purple potato flour compared to the control bread, which was solely composed of wheat flour. Note that bread featuring purple potatoes and sourdough exhibited heightened acidity and a more pronounced colour intensity when juxtaposed with bread prepared with yeast fermentation.

The sugar content within the dough profoundly influences the quality of the final baked product, impacting both dough aeration and the formation of characteristic breadcrumb structure (Sahin et al., 2019). The analysis in this study revealed that sugar content ranged from 2.20% to 4.12%, depending on the weight of reducing the sugars across the bread variants examined (Table 1). The highest content was observed in samples incorporating cooked potatoes, whereas the lowest was noted in samples containing raw potatoes. The method of potato processing exerted a significant influence on the levels of reducing the sugars present. Miśniakiewicz (2003) elucidated on the outcomes of organoleptic and physicochemical assessments conducted on the ten most renowned bread types in Kraków. Note that the results similar to those of this study were reported, with average reduced sugar contents ranging from 2.5% to 5% for individual baked goods and 2.8% for wheat-rye bread.

Porosity serves as a pivotal indicator of the dough fermentation process. Wheat bread typically exhibits porosity from 73% to 83%, whereas for rye bread this is from 55% to 70% (Ocieczek & Sepczuk, 2015). Bread porosity is ruled by the fermentation process's intricacies and the flour's baking characteristics (Besbes et al., 2013).

On examining the results of this study (Table 1), it becomes evident that the porosity of the examined bread ranged from 54% to 68.75%, in line with the reference range for rye bread. Note that the sample denoted as B, incorporating baked potato, exhibited the lowest porosity. Nevertheless, this finding closely approximated the results reported by Chen et al. (2021). In that study, the authors prepared bread using wheat flour, water, yeast, and salt, subsequently investigating structural alterations in the baked product over time, storing the bread at ambient temperature. Initial porosity following baking was recorded at 53.7%, increasing to 56.8% after approximately 14 days. The increased porosity over time can be attributed to gradually replacing water-filled pores with air as moisture content diminishes.

Moisture content significantly influences the textural properties of bread, impacting aspects such as crumb structure and the bread's blackening process. Ambroziak and Kolodziejski (1986) conducted a comparative analysis of the effects of various potato-derived additives on dough and wheat bread properties, including juice, puree, starch, and potato flakes. Their findings highlighted that incorporating potato products can enhance bread quality, with potato juice emerging as the most effective additive. Additionally, introducing other additives into the dough resulted in a notable increase in water absorption by 5% to 6%, thereby extending the bread's shelf life, augmenting carbon dioxide production, and consequently increasing bread volume. Furthermore, enhancements in aroma and taste were discerned in the baked goods.

The moisture content of the breads examined in by the authors ranged from 45.44% to 55.9%. Note that, in line with the standard (PN-A-74112:1997), mixed breads are recommended to possess moisture values of at most 55% post-production, and decrease to below 40% by the end of the storage period. Interestingly, the moisture content of all bread variants fell within the stipulated standard range.

Table 2. CIE L*a*b* colour parameters of the bread crumbs
Tabela 2. Parametry barwy miękiszu chlebów

Variant/ Wariant	L*	a*	b*	ΔE*
Control/ Próba kontrolna	64.54^{a}±0.35	2.13^{a}±0.15	18.28^{a}±0.13	–
C	63.34^{b}±0.20	6.34^{b}±0.08	8.05^{b}±0.16	11.13^{a}±0.20
B	52.29^{c}±0.08	6.55^{c}±0.04	13.37^{c}±0.07	13.92^{b}±0.07
R	57.75^{d}±0.22	5.95^{d}±0.04	11.69^{d}±0.16	10.21^{c}±0.02

Control – wheat-rye bread without potatoes; C – cooked potatoes; B – baked potatoes; R – raw potatoes/ Próba kontrolna – chleb pszenno-żytni bez dodatku ziemniaków; C – ugotowane ziemniaki; B – pieczone ziemniaki; R – surowe ziemniaki; a, b, c, d – the same letters in individual columns mean that there is no statistically significant difference between the sample ($p < 0.05$)/ a, b, c, d – te same litery w kolumnach oznaczają brak statystycznie istotnej różnicy między próbami ($p < 0,05$)

Source/ Źródło: own research/ badania własne.

The incorporation of purple potatoes into the bread dough significantly influenced the crumb colour of wheat-rye bread (Table 2). The crumb brightness of the control sample, devoid of additives, averaged 64.54, whereas the addition of potatoes induced a notable darkening of the crumb in both baked and raw potato-enriched samples. At the same time, the inclusion of purple potatoes led to a reduction in the yellow hue – denoted by a decrease in the parameter b* value – and an augmentation of the red colour proportion in the crumb – signified by an increase in the parameter a* value compared to the additive-free bread crumb. The most substantial absolute difference in crumb colour (ΔE*), relative to the control sample, was observed in bread containing baked potatoes (13.92). Nonetheless, across all the test samples, ΔE* exceeded 5, indicating perceptible changes in crumb colour discernible to the human eye and highlighting disparities between the control sample and the potato-enriched bread crumbs.

Polyphenolic compounds incorporated into the bread-making process augment the wheat bread's antioxidant capacity, potentially enhancing specific dough properties such as elasticity and strength. Adding polyphenolic compounds to the dough aims to offset the loss of these compounds incurred during the milling and purification of flour, which removes valuable germ and bran components (Czajkowska-González et al., 2021).

The substantial anthocyanin content inherent in purple potatoes influences the total polyphenol content, underscoring the significance of potato processing methods before their incorporation into the dough to mitigate excessive colour loss. Note that the variant employing baked potatoes (variant B) exhibited the highest polyphenol content at 207.45 mg GAE/100 g of bread, a statistically significant disparity compared to other variants. These findings underline the significant impact of purple potato processing methods on the polyphenol content of the resultant bread formulations (Figure 1).

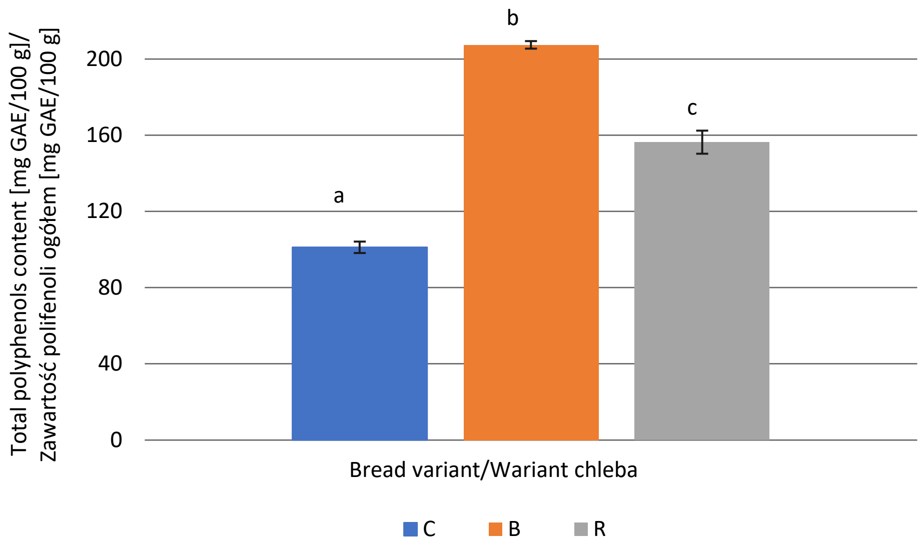

Fig. 1. Total polyphenol content in bread prepared with: C – cooked potatoes; B – baked potatoes; R – raw potatoes [mg GAE/100 g]
Rys. 1. Zawartość polifenoli ogółem w chlebie z dodatkiem: C – ugotowanych ziemniaków; B – pieczonych ziemniaków; R – surowych ziemniaków [mg GAE/100 g]

a, b, c – the same letters in individual bars mean that there is no statistically significant difference between the samples ($p < 0.05$)/ a, b, c – te same litery nad słupkami oznaczają brak statystycznie istotnej różnicy między próbami ($p < 0,05$)

Source/ Źródło: own research/ badania własne.

The polyphenol content in potatoes with yellow flesh typically averages 176 mg/100 g f.w., whereas varieties with coloured flesh contain 6-9 times more (Wierzbicka et al., 2015; Zarzecka et al., 2023). Taglieri et al. (2021) compared the total polyphenols in sourdough wheat bread with and without freeze--dried purple potatoes. Significantly higher labelled compound levels were observed in the enriched bread, nearly doubling the recorded content. The incorporation of purple potato flour and albedo significantly enhanced the phytochemical profile of the bread. Note that the total polyphenol content in sourdough bread surpassed that of yeast bread, highlighting the potential benefits of sourdough fermentation in enhancing the polyphenol content. This emphasises the enzymatic activity of lactic acid bacteria in catalysing the hydrolysis of complex phenols and their glycosylated forms into phenolic acids (Zarzecka et al., 2023).

Each bread variant underwent comprehensive evaluation, encompassing both qualitative assessments and sensory analyses that encompassed scoring based on flavour, texture, and the inner and outer layers of the bread. The evaluation outcomes are presented in Table 3. Breads with baked and raw potatoes were classified in the first group of bread quality, whilst bread with cooked potatoes was classified as the third class (satisfactory quality).

Upon assessing the volume and shape of the bread, all the baked goods received 4 points, indicating their well-risen nature and characteristic shape consistent with mixed bread varieties. Regarding the colour of the crust, each sample received 2 points, reflecting the correct appearance of the crust without any signs of burning. Furthermore, the thickness of the crust and other relevant characteristics of the tested breads obtained a score of 4.0 points, indicative of well-baked bread quality.

The crumb elasticity of the samples was notably commendable, characterised by plumpness and a slight moistness upon touch; in particular, breads denoted as B and R exhibited well-formed and evenly distributed porosity. However, bread incorporating boiled potatoes displayed a crumb typified by medium-sized and unevenly distributed pores and a several-millimetre layer of crumbliness.

Table 3. Results of organoleptic evaluation of bread performed by Banecki’s method
Tabela 3. Wyniki oceny organoleptycznej pieczywa wykonanej metodą Baneckiego

Bread characteristics/ Cechy pieczywa			Bread variants/ Wariant chleba		
			C	B	R
I	volume and shape/ objętość oraz kształt		4	4	4
II	crust/ skórka	colour/ kolor	2	2	2
		thickness/ grubość	4	4	4
		others/ pozostałe	4	4	4
III	crumb/ miękisz	flexibility/ elastyczność	3	3	3
		porosity/ porowatość	4	5	5
		others/ pozostałe	–16	2	2
IV	Taste and aroma/ Smak i aromat		6	6	6
Total/ Suma			11	30	30

Source/ Źródło: own elaboration based on the scheme for evaluation according to Banecki/ opracowanie własne na podstawie schematu do oceny według Baneckiego.

All samples were deemed aromatic and pleasant regarding taste and aroma, warranting a score of 6 points. Note that bread with the addition of boiled potatoes received the lowest rating. The presence of a roux was identified as the critical detracting factor, adversely impacting the organoleptic qualities of the samples. This inadequacy suggests that the baked product is unsuitable for commercial production or consumption. Similar findings, leading to the disqualification of baked goods, were reported by Borkowska and Łagowska (2014) in their study examining bread quality from both ‘ordinary’ and organic bakeries. Negative assessments were attributed to selected bread from both bakery types, justified by inappropriate, excessively dark colouration and undesirable features such as numerous cracks in the baked product.

Bread incorporating either baked or raw potatoes (B and R) achieved the highest scores in the evaluation using Banecki’s method. None of these samples received negative assessments, indicating their superior quality. An evaluation of physicochemical parameters further supports this conclusion, indicating that these breads exhibit superior quality compared to the C sample. Whether baked or grated, the incorporation of potatoes facilitates the production of bread with desirable characteristics such as softness, fluffiness, and porosity. Additionally, the acidity of these samples, attributed to proper sourdough fermentation, is expected to have a positive impact on the shelf life and freshness of bread. Baked potatoes are recommended for bread production to optimise the bioactive compound content.

4. Conclusions

1. The processing method employed for incorporating purple potatoes into bread dough plays a pivotal role in determining the quality of the final product. Notably, it impacts on the crumb characteristics of wheat-rye bread.
2. The addition of purple potatoes, along with the chosen processing method, exerts a substantial influence on the polyphenol content of the resultant bread. Baking is the optimal method for preparing potatoes to maximise the polyphenolic compound content in bread formulations.
3. Wheat-rye bread emerged as a favourable matrix for integrating the addition of purple potatoes, offering a promising avenue for developing health-enhancing and functional food products enriched with bioactive compounds. Such formulations have the potential to augment the nutritional profile and confer health benefits associated with the consumption of sustainable health-promoting foods.

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Wpływ obróbki fioletowych ziemniaków „Vitelotte” na właściwości fizykochemiczne i sensoryczne wzbogaconego chleba pszenno-żytniego

Streszczenie

Produkty zbożowe, w tym chleb, odgrywają znaczącą rolę w światowej konsumpcji, o czym świadczy ich stała obecność w diecie człowieka. Jednak powszechnie spożywany chleb, produkowany z rafinowanej mąki, zawiera niewielkie ilości niezbędnych składników odżywczych i związków bioaktywnych.

Celem pracy było zbadanie wpływu sposobu obróbki fioletowych ziemniaków stosowanych jako dodatek do chleba pszenno-żytniego na zakwasie na jego właściwości fizykochemiczne. Zastosowano ziemniaki gotowane, pieczone i surowe. Dokonano analizy zawartości polifenoli ogółem, barwy miękiszu, oznaczenia kwasowości, ilości soli i cukru, oceny porowatości, określenia wilgotności oraz objętości chleba. Dokonano także punktowej oceny jakości pieczywa.

Najwyższą zawartość związków polifenolowych w chlebie (207,45 mg GAE/100 g chleba) otrzymano, stosując jako dodatek pieczone fioletowe ziemniaki. Chleb ten charakteryzował się dobrymi parametrami fizykochemicznymi i zakwalifikowano go do pierwszej grupy jakości pieczywa w badaniach organoleptycznych.

Analizując uzyskane wyniki, można stwierdzić, że włączenie fioletowych ziemniaków do receptur pieczywa pozytywnie wpłynie na jego właściwości odżywcze, oferując w ten sposób obiecujące możliwości opracowywania żywności funkcjonalnej.

Słowa kluczowe: fioletowe ziemniaki, Vitelotte, chleb pszenno-żytni, zakwas