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AN ASSESSMENT OF THE POSSIBILITY OF USING PLANT DRINKS IN A GLUTEN-FREE BREAD RECIPE

S u m m a r y

Background. A gluten-free diet is the only treatment for diseases related to gluten intolerance. Bread is the basic ingredient of any diet. In recent years, we have observed an increase in the availability of gluten-free products on the Polish market, but their quality still differs from traditional products. The production of gluten-free food is associated with many technological difficulties in ensuring that products have the appropriate consistency and texture. Lactose intolerance is also relatively common in people who are newly diagnosed with celiac disease. Therefore, it seems advisable to undertake research aimed at replacing milk with plant-based drinks in a gluten-free bread recipe. The aim of the study was to determine the effect of the addition of plant drinks on the quality of gluten-free bread. Milk, soy, almond and rice drinks were used for baking. Gluten-free bread was subjected to a sensory evaluation. The weight, specific weight, volume, moisture, texture and color of the bread were also tested.

Results and conclusion. The type of drink used affects both the taste, aroma, structure and texture. Breads with milk substitutes have a less noticeable taste of bread and yeast. However, in the assessment of sensory desirability, the best results were obtained in the case of gluten-free bread with the addition of a soy drink. It was found that the use of plant drinks did not significantly affect the weight after baking, specific weight and moisture. The use of plant-based drinks to obtain gluten-free bread may be an alternative for people on a vegan diet.

Key words: gluten-free bread, plant-based milk, texture, sensory analysis

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Introduction

Bread is one of the basic components of a daily human diet. It is the main source of carbohydrates and provides many valuable nutrients, including B vitamins and fiber to support the proper functioning of the intestines. Due to changing eating habits and an increase in various types of food allergies and intolerances, newer recipes and technological solutions are sought to expand the offer of products available on the market [13, 21, 28]. Demand for gluten-free products continues to grow, with a global market of $21.61 billion in 2019 and is projected to reach nearly $24 billion by 2027. Taking into account an upward trend in the value of the gluten-free market and consumer interest, it is important to ensure the availability and variety of this type of product [11].

Gluten-free bread is the basis of the elimination diet of patients suffering from gluten–dependent diseases, which include, among others: celiac disease, non-celiac hypersensitivity to gluten, Duhring's disease and wheat allergy [25]. According to research, celiac disease affects about 1 % of the population, and the incidence of this disease is gradually increasing. Failure to follow a strict diet ultimately leads to the disappearance of intestinal villi, which in turn results in malabsorption of nutrients from food. The limited absorption of ingredients necessary for the proper functioning of the body may cause various clinical symptoms [4].

In recent years, we can observe an increase in the availability of gluten-free products on the Polish market, but their quality still differs from traditional products. The production of gluten-free food is associated with technological difficulties in ensuring that products have the appropriate consistency and texture. Gluten-free food is also characterized by a lower nutritional value compared to products obtained from traditional cereals. The use of a gluten-free diet carries the risk of deficiency of many ingredients, therefore it should be varied and enriched with protein, fiber and macro – and microelements [2].

In order to improve the rheological properties of the dough, which will allow for the proper forming of the billets and obtaining the appropriate properties of the finished product, many studies are carried out to improve the recipes of gluten-free bread. In order to replace gluten, which is a structureforming factor, substances are used to support the proper development of the dough, emulsifiers, as well as texturing and thickening substances. The most commonly used are hydrocolloids, which include, among others, guar gum, xanthan gum, Locust bean gum, pectin, carboxymethyl cellulose and hydroxyethyl cellulose. These substances also have the ability to bind water, gel and act as stabilizers [5, 7, 16]. Enzymes (transglutaminases, amylases and proteases) and exopolysaccharides, which are produced by lactic acid bacteria, are also increasingly used, which allows the elimination of chemical substances that make up the structure [3, 8, 17, 19, 29].

Lactose intolerance is also relatively common in people with newly diagnosed celiac disease. Therefore, an increasing number of consumers are choosing plant-based drinks (milk) substitutes for medical reasons. Plant drinks substitutes or extracts are water-soluble extracts from legumes, oilseeds, cereals or pseudocereals that look like cow's milk [26]. Plant-based food is gaining more and more popularity. This trend is based on several factors such as lifestyle changes, interest in alternative diets, and growing awareness of sustainable production of food, especially protein. Plant-based drinks substitutes can serve as an alternative to traditional products [12]. Therefore, it seems advisable to undertake research aimed at replacing milk in the recipe of gluten-free bread with plant-based drinks.

Materials and methods

Gluten-free bread concentrates were used with following ingredients: corn starch (BogutynMłyn, Poland), potato starch (Melvit, Poland), corn flour (Kupiec, Poland), millet flour (Melvit, Poland), instant yeast (Lesaffre, Poland), sugar (SuedzuckerPolska Sp. z o.o, Poland), salt (Kłodawa S.A. Poland), hydrocypropyl methylcellulose (HPMC) (J. Rettenmaier&Söhne, Poland). The following ingredients were added to the concentrates: "Łaciate" milk (fat content 3.2 %, Mlekpol, Poland), soy, almond and rice plant-based drinks (Alpro, Poland), tap water.

The basis of gluten-free bread concentrates was corn starch. The same amount of potato starch, corn flour, instant yeast, sugar, salt, and hydroxypropyl methylcellulose (HPMC) was present in each of the samples. Only the amount of corn starch was changed. The concentrate recipes were established on the basis of our own research, in which the amount of ingredients needed to prepare the dough was determined. The loose ingredients, which were used to prepare the mixture, were weighed in accordance with the recipes on technical scales with a precision of 0.01. The recipe composition is given in Table 1.

Table 1. The recipe composition of gluten-free bread concentrates.
Tabela 1. Skład recepturowy koncentratów pieczywa bezglutenowego.

Ingredients / Składniki	Raw material content [%] / Zawartość surowca [%]
Corn flour / Mąka kukurydziana	30
Rice flour / Mąka ryżowa	35
Potato starch / Skrobia ziemniaczana	19
Sugar / Cukier	5.1
Salt / Sól	1.5
Yeast / Drożdże	2.4
Millet flour / Mąka jaglana	5
HPMC / Hydroksypropylometyloceluloza	2

All ingredients were mixed in a mixer for 5 min, and next the mixture was stored in a plastic bowl for 30 min at 40 °C. After 30 min, the dough was placed in shaped bowls where the fermentation process was continued for the next 10 min until the optimum volume was reached. The baking proceeded in a UNOX combi-steamer oven (XBC type, model: XBC 404) at 175 °C for 23 min, on a third level of vaporization. The refrigerated breads were packed using a polyethylene bag, they were stored at a temperature of 22 ± 2 °C. All measurements were repeated twice.

The bread volume was measured using the rapeseed displacement method 10-05. The bread moisture was determined according to the Approved method 44-15A [1].

Cubes with an area of 27 cm^3 were cut from the bread crumb and then weighed on technical scales with an accuracy of 0.01. Knowing the mass and volume, the specific weight was calculated.

The measurements of crumb hardness were done by using a texture Analyzer TA-XTplus (Stable Micro Systems, United Kingdom). Slices with a thickness of 20 mm were cut from the center of the analyzed loaves. Subsequently, the slices were squeezed and relaxed. As before, we used a cylindrical head with an attachment in the shape of a cylinder of a diameter of 36 mm. Measurements were done at the speed of movement of the head of 1 mm/s penetrating the sample to a depth of 10 mm with a charge cell of 250 N. An analysis of the moisture and hardness of the crumb was made after 24 and 48 hours after baking.

A sensory evaluation was carried out using the scaling method by a trained team of 10. The length of the scale segment was 100 mm, which corresponded to 100 conventional units. The evaluators marked the intensity of individual features for each of the loaves separately. The taste, smell, structure and texture of the crumb were assessed, as well as consumer desirability [22, 23].

The characterization of the gluten-free bread color was performed using the L*a*b* system [20]. All sampled gluten-free breads were analyzed in terms of the referred parameters using a Minolta CR-310 colorimeter (Konica-Minolta, Japan), which was calibrated a priori with a white standard tile. Each measurement was repeated five times.

A statistical analysis of the results obtained was performed applying Statgraphics Plus 4.1. The differences between the averages were estimated by conducting a multivariate regression analysis. The significance level (α) was set to 0.05 and the smallest statistically significant difference was chosen using Tukey's test. A PCA analysis was done using Statistica 13.3 software.

Results and discussion

The physical properties of bread, which include, among others, the volume and specific weight as well as the porosity, moisture and hardness of the crumb determine its quality, and the consumer's assessment [24].

Table 2. Volume and specific weight of gluten-free breads with the addition of cow's milk (GF milk), and plant-based drink: soy (GF soy), almond (GF almond) and rice (GF rice) drinks.
Tabela 2. Objętość i masa właściwa pieczywa bezglutenowego z dodatkiem mleka krowiego (GF milk), oraz napojów roślinnych: sojowego (GF soy), migdałowego (GF almond) i ryżowego (GF rice).

Sample / Próbka	Volume [cm^3/100 g] Objętość [cm^3/100 g]	Specific weight [g/cm^3] Ciężarwłaściwy [g/cm^3]
GF milk / Mlekokrowie	212.74 ± 1.69	0.21 ± 0.02
GF soy / Napój roślinny sojowy	243.27 ± 2.01	0.23 ± 0.02
GF almond / Napój roślinny migdałowe	162.32 ± 1.65	0.21 ± 0.02
GF rice / Napój roślinny ryżowe	143.59 ± 1.95	0.20 ± 0.03

The volume of the gluten-free breads made was in the range of 140 cm^3/100 g - 240 cm^3/100 g (Table 2). The gluten-free bread with the addition of a plant drink (240 cm^3/100 g) was characterized by the highest volume among the examined breads. The gluten-free bread with the addition of milk (210 cm^3/100 g) showed a similar volume. The gluten-free bread with the addition of rice drink was characterized by the smallest volume (140 cm^3/100 g). The gluten-free bread with almond drink (160 cm^3/100 g) showed a higher volume than the bread with the addition of rice drink. The volume of the bread with the addition of plant drinks was different compared to the bread with the addition of milk. The weight of the loaves immediately after baking ranged between 130.04 g - 133.42 g and did not differ significantly. The highest weight was observed for the bread with almond drink (133.42 g), and the lowest for the bread with soy drink (130.04 g). The gluten-free bread made in the work differed in terms of volume and weight from the results obtained by Gambuś [10]. This may be the result of using a different recipe composition. The specific weight of the gluten-free bread ranged between 0.21 g/cm^3 - 0.23 g/cm^{3}and did not differ significantly. The gluten-free bread with the addition of soy drink had the highest specific weight (0.23 g/cm^3). On the other hand, the lowest specific weight was shown by the gluten-free bread with the addition of rice drink (0.20 g/cm^3). Moisture shows the degree of freshness of the bread and affects the staling process, which adversely affects the changes in the sensory characteristics of the bread [9].

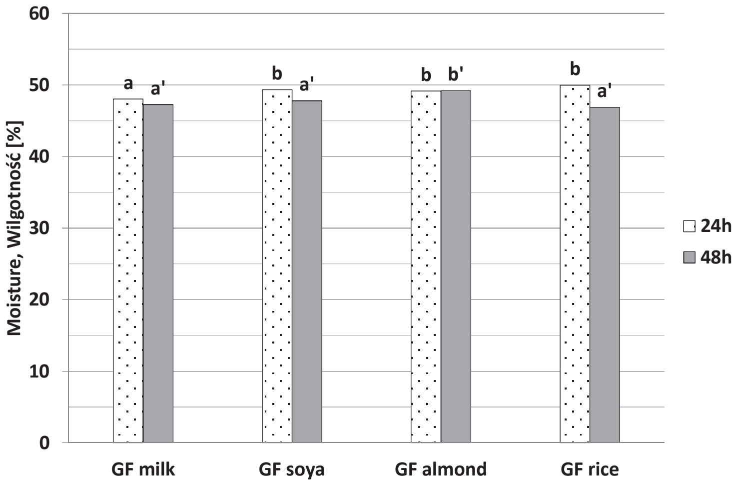

Figure 1. Moisture of gluten-free breads with the addition of cow's milk (GF milk), and plant-based drinks: soy (GF soy), almond (GF almond) and rice (GF rice) drinks.
Rysunek 1. Wilgotność pieczywa bezglutenowego z dodatkiem mleka krowiego (GF milk), oraz napojów roślinnych: sojowego (GF soy), migdałowego (GF almond) i ryżowego (GF rice).
Explanatory notes / Objaśnienia:
Values marked with the same symbols (a-b, a'b') mean no statistically significant differences (α = 0.05) / Wartości oznaczone tymi samymi symbolami (a-b, a'b') nie różnią się istotnie statystycznie (α = 0,05).

The moisture of the analyzed breads ranged from 47.53 ÷ 48.65 % after 24 hours and 45.98 ÷ 48.62 % after 48 hours (figure 1), which is consistent with Cacak-Pietrzak's research [3], according to which the moisture of a gluten-free bread should not exceed 53 %. An analysis of the moisture content of the gluten-free bread showed slight differences in the values 24 hours after baking among the gluten-free breads examined. There were also no significant differences in the bread moisture values after 24 and 48 hours of storage. The most noticeable decrease in moisture after 48 hours was observed in the gluten-free bread with the addition of rice drink. The moisture content of the gluten-free bread made at work is similar to the results obtained by Dłużewska and Marciniak-Lukasiak [8] and Gambuś [10]. Demirkesen [6], in his research on the moisture content of a gluten-free bread baked with rice flour and the addition of chestnut flour, showed that during the storage of bread, the process of staling occurs due to the migration of moisture from the crumb to the crust. As a result of this process, the ability to bind water by the crumb decreases, hence the lowest moisture losses in the bread are observed in samples stored for the shortest time. The use of vegetable drinks as a milk substitute did not increase the rate of loss of bread moisture during 48 hours of storage.

Color influences the positive or negative attitude of consumers to a given product [27]. When analyzing the results of the color parameters, it was found that they did not differ significantly (Table 3). The values of the L* parameter ranged between 72.43 ÷ 75.02. The highest value of the L* parameter was found for the bread with rice drink (75.02), and the lowest for the bread with milk (72.43). The values of the a* and b* parameters, showing the share of red and green, as well as blue and yellow, also did not differ significantly. All values of the a* parameter are negative, which proves the share of the green color. The highest proportion of green color was found in the case of the bread crumb with the addition of milk (-6.25), and the lowest for the crumb of the bread with the addition of almond drink (-5.39). The b* parameter values, indicating the share of yellow and blue colors, have positive values in each case. Positive values indicate the participation of the yellow color. Its largest share was observed in the case of the bread crumb with the addition of soy drink (27.32). On the other hand, the lowest share was seen in the crumb of the bread with the addition of rice drink (25.12). The obtained values of the L* parameter of the gluten-free bread crumb are similar to the values obtained by Krupa-Kozak [14], however, they differ in the proportion of yellow and green colors.

Table 3. The values of the color parameters of gluten-free breads with the addition of cow's milk (GF milk), and plant-based drinks: soy (GF soy), almond (GF almond) and rice (GF rice) drinks.
Tabela 3. Wartości parametrów barwy pieczywa bezglutenowego bezglutenowego z dodatkiem mleka krowiego (GF milk), oraz napojów roślinnych: sojowego (GF soy), migdałowego (GF almond) i ryżowego (GF rice).

Sample / Próbka	L*	a*	b*
GF milk / Mlekokrowie	$72.43^{a} \pm 0.55$	$-6.25^{c} \pm 0.07$	$25.91^{a} \pm 0.50$
GF soy / Napój roślinny sojowy	$73.25^{a} \pm 1.13$	$-6.24^{c} \pm 0.05$	$27.32^{b} \pm 0.64$
GF almond / Napój roślinny migdałowe	$73.35^{a} \pm 0.93$	$-5.39^{c} \pm 0.03$	$26.16^{ab} \pm 0.67$
GF rice / Napój roślinny ryżowe	$75.02^{a} \pm 0.67$	$-5.81^{c} \pm 0.02$	$25.12^{a} \pm 0.31$

Explanatory notes /Objaśnienia:
Values in columns marked with the same symbols (a-c) mean no statistically significant differences (α = 0.05). Wartości w kolumnach oznaczone tymi samymi symbolami (a-c) nie różnią się istotnie statystycznie (α = 0,05)

Texture proves the quality of food products. By analyzing the results of the texture parameters (Table 3), it was observed that the lowest value of the hardness parameter was found in the bread with the addition of milk. The hardness of this bread did not change during 48-hour storage. The gluten-free bread with the addition of rice drink was characterized by the highest value of the hardness parameter after 24 hours. In the case of the breads with the addition of soy and almond drinks, the hardness increased during storage. However, these values were not statistically significant. Similar relationships were observed by Kulczak [15], who assessed selected physical properties of a gluten-free bread with the use of instant pea flour and buckwheat products.

The value of the elasticity parameter ranged between 0.82 ÷ 0.89 after 24 hours of storage and 0.79 ÷ 0.86 after 48 hours of storage (Table 4). The gluten-free bread with the addition of rice drink was characterized by the highest value of the elasticity parameter, both after 24 and 48 hours of storage. No statistically significant differences were observed. In the studies by Marciniak-Łukasiak and Skrzypacz [18], in which the addition of amaranth flour was used, the elasticity increased during storage, which may be related to differences in the recipe composition.

Table 4. Hardness, Springness, Cohesiveness, Gumminess, Chewiness of gluten-free breads with the addition of cow's milk (GF milk), and plant-based drinks: soy (GF soy), almond (GF almond) and rice (GF rice) drinks.

Tabela 4. Twardość, sprężystość, spoistość, gumowatość, żujność pieczywa bezglutenowego bezglutenowegoz dodatkiem mleka krowiego (GF milk), oraz napojów roślinnych: sojowego (GF soy), migdałowego (GF almond) i ryżowego (GF rice).

Time [h] Czas [h]	Sample Próbka	Hardness [N] Twarodść [N]	Springness Sprężystość	Cohesiveness Spójność	Gumminess [N] Gumiastość [N]	Chewiness [N] Żujność [N]
24	GF milk	$15.89^{a} \pm 1.25$	$0.82^{a} \pm 0.12$	$0.26^{a} \pm 0.03$	$4.03^{a} \pm 0.93$	$3.33^{a} \pm 0.53$
	GF soy	$20.85^{c} \pm 1.42$	$0.84^{a} \pm 0.06$	$0.33^{b} \pm 0.04$	$6.90^{b} \pm 0.87$	$5.82^{b} \pm 0.42$
	GF almond	$18.96^{b} \pm 1.02$	$0.86^{a} \pm 0.21$	$0.43^{c} \pm 0.02$	$8.18^{c} \pm 1.02$	$7.03^{c} \pm 0.81$
	GF rice	$23.23^{d} \pm 1.43$	$0.89^{a} \pm 0.11$	$0.35^{b} \pm 0.03$	$8.13^{c} \pm 1.23$	$7.31^{c} \pm 0.60$
48	GF milk	$15.71^{a} \pm 0.97$	$0.83^{a} \pm 0.06$	$0.29^{a} \pm 0.03$	$4.60^{a} \pm 1.02$	$3.83^{a} \pm 0.62$
	GF soy	$21.68^{c} \pm 1.32$	$0.83^{a} \pm 0.09$	$0.32^{a} \pm 0.02$	$6.99^{c} \pm 1.21$	$5.81^{c} \pm 0.41$
	GF almond	$22.81^{c} \pm 1.25$	$0.79^{a} \pm 0.06$	$0.30^{a} \pm 0.03$	$6.91^{c} \pm 1.32$	$5.48^{c} \pm 0.52$
	GF rice	$17.84^{b} \pm 1.02$	$0.86^{a} \pm 0.05$	$0.31^{a} \pm 0.04$	$5.45^{b} \pm 0.82$	$4.71^{b} \pm 0.54$

Explanatory notes /Objaśnienia:
Values marked with the same symbols (a-e) mean no statistically significant differences ($\alpha = 0.05$) / Wartości oznaczone tymi samymi symbolami (a-e) nie różnią się istotnie statystycznie ($\alpha = 0,05$).

The gumminess of the bread made ranged between 4.03 ÷ 8.18 N after 24 hours of storage and 4.60 ÷ 6.99 N after 48 hours of storage (Table 4). The gumminess of all breads with the addition of plant-based drinks was greater than that of the bread containing cow's milk. These differences were statistically significant. The highest value of the gumminess parameter was found in the bread with the addition of almond drink (8.18 N). In the case of the gluten-free bread with the addition of almond drink and rice drink, the value of the gumminess parameter after 48 hours was lower than after 24 hours of baking. The chewiness of the breads after 24 hours of storage ranged from 3.33 to 7.31 N, while after 48 hours of storage it was from 3.83 to 5.81 N. Similar to gumminess, the chewiness values were higher for the breads with the addition of plant drinks. The chewiness parameter of the bread with the addition of rice drink 24 hours after baking was the highest and amounted to 7.31, and the smallest parameter of the bread with the addition of milk was 3.33. The chewiness parameter of the bread with the addition of almond drink and the addition of rice drink after 48 hours was lower than after 24 hours of baking.

Four types of gluten-free bread were subjected to a sensory evaluation. The taste, smell, structure and texture of the crumb were assessed, as well as consumer desirability. The bread taste was the most noticeable in the case of the gluten-free bread with the addition of milk and obtained the highest scores. The taste of this taste in gluten-free bread with the addition of soy drink was lower than in the case of the bread with the addition of milk (70 AU – an arbitrary unit). The bread taste in the gluten-free bread with the addition of almond drink was felt to a lesser extent than in the bread with the addition of soy drink (50 AU). The gluten-free bread with the addition of rice drink had the least noticeable bread taste and obtained 40 AU. The bread with milk is the most salty (70 AU). The saltiness of the breads with the addition of soy and almond drinks was assessed at the same level (30 AU) and it is noticeably lower than in the case of the bread with the addition of milk. The gluten-free bread with the addition of rice drink showed the least salty taste (20 AU).

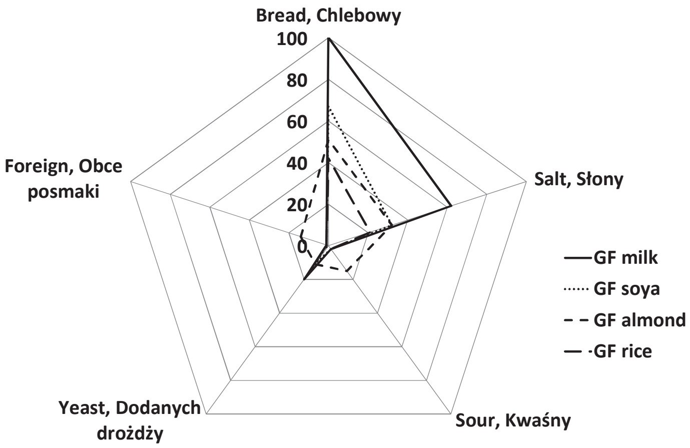

Figure 2. The taste of the gluten-free breads with the addition of cow's milk (GF milk), and plant-based drinks: soy (GF soy), almond (GF almond) and rice (GF rice) drinks.
Rysunek 2. Smak pieczywa bezglutenowego z dodatkiem mleka krowiego (GF milk), oraz napojów roślinnych: sojowego (GF soy), migdałowego (GF almond) i ryżowego (GF rice).

The breads with the addition of milk, soy and rice drinks do not taste sour. The sour taste was felt only in the bread with the addition of almond drink (10 AU). The taste of added yeast was not observed in the case of the bread with the addition of rice drink (AU). For the breads with the addition of soy and almond drinks, added yeast was tasted to a lesser degree (10 AU). The bread with the addition of milk had the most perceptible taste of added yeast (40 AU). No foreign aftertaste was noted in the breads with the addition of milk, soy drink and rice drink (0 AU). Only the bread with the addition of the almond drink had a slightly perceptible foreign aftertaste (10 AU) (Figure 2). A smell analysis showed that each of the gluten-free breads assessed did not have any foreign smells. The breads with the addition of milk, soy and rice drinks were characterized by the smell of bread felt at the same level. Only in the case of the bread with the addition of almond drink, the bread smell was much more intense, which translates into a sensory evaluation. The smell of added yeast was the most pronounced in the bread with the addition of milk (100 AU). Yeast added to the gluten-free bread with the addition of soy drink was felt strongly (90 AU).

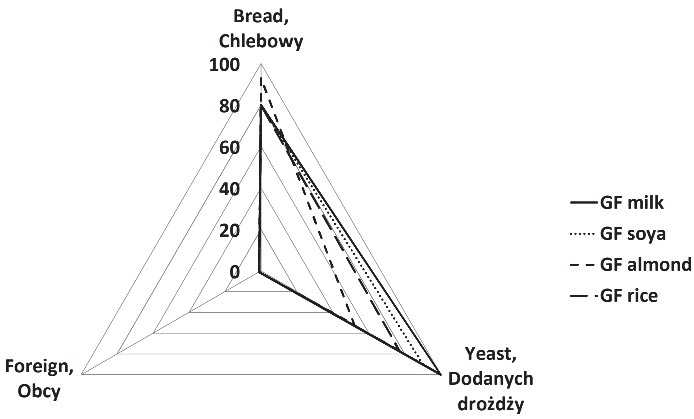

Figure 3. The smell of the gluten-free breads with the addition of cow's milk (GF milk), and plant-based drinks: soy (GF soy), almond (GF almond) and rice (GF rice) drinks.
Rysunek 3. Zapach pieczywa bezglutenowego z dodatkiem mleka krowiego (GF milk), oraz napojów roślinnych: sojowego (GF soy), migdałowego (GF almond) i ryżowego (GF rice).

The yeast flavor in the bread with the addition of rice drink was less pronounced than in the bread with the addition of soy drink (70 AU). The bread with the addition of almond drink was characterized by the least perceptible smell of added yeast (50 AU) (Figure 3). An analysis of the structure and texture showed that the gluten-free bread with the addition of rice drink was the most brittle, compact and hard, and obtained 90 AU in each feature (Figure 4). The gluten-free bread with the addition of milk showed the same crispness as the bread with the addition of rice drink (90 AU). The bread with the addition of soy drink (80 AU) was less tender. The bread with almond drink was the least brittle, hard (40 AU) and compact (50 AU). The breads with the addition of milk and soy drink were characterized by a strongly compact structure (70 AU), and also showed high hardness. The gluten-free bread with the addition of milk was harder (60 AU) compared to the gluten-free bread with the addition of soy drink (50 AU). The highest level of consumer demand was observed for the gluten-free bread with the addition of soy drink (70 AU) (Figure 5). The gluten-free bread with milk (60 AU) and the gluten-free bread with almond drink (50 AU) were highly coveted among consumers. The least desired bread was the gluten-free bread with the addition of rice drink (40 AU).

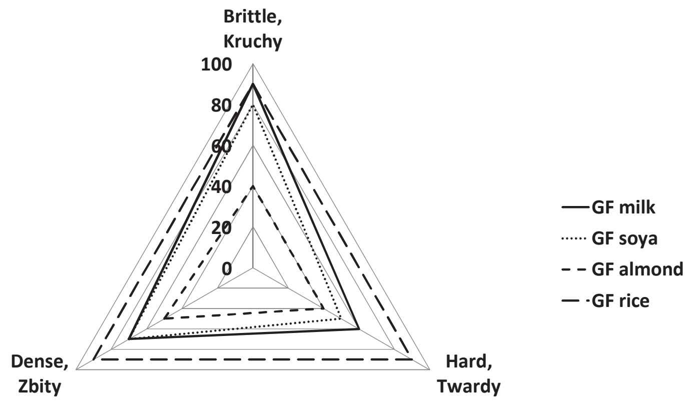

Figure 4. The structure features of the gluten-free breads with the addition of cow's milk (GF milk), and plant-based drinks: soy (GF soy), almond (GF almond) and rice (GF rice) drinks.
Rysunek 4. Struktura miękiszu pieczywa bezglutenowego z dodatkiem mleka krowiego (GF milk), oraz napojów roślinnych: sojowego (GF soy), migdałowego (GF almond) i ryżowego (GF rice).

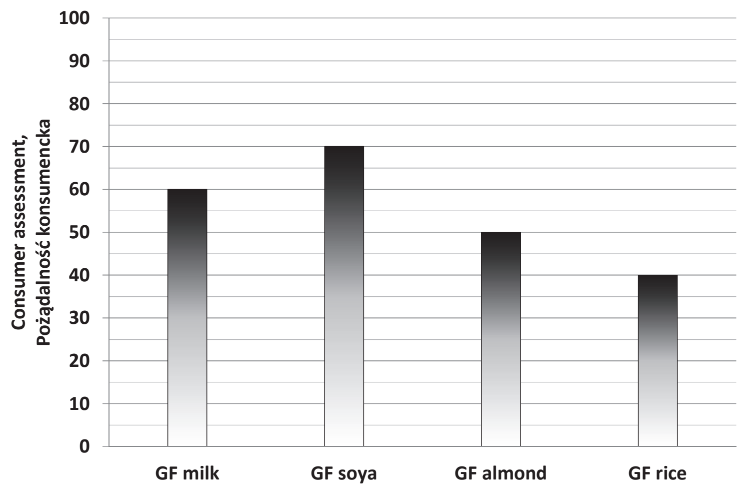

Figure 5. The consumer assessment of the gluten-free breads with the addition of cow's milk (GF milk), and plant-based drinks: soy (GF soy), almond (GF almond) and rice (GF rice) drinks.
Rysunek 5. Pożądalność konsumencka pieczywa bezglutenowego z dodatkiem mleka krowiego (GF milk), oraz napojów roślinnych: sojowego (GF soy), migdałowego (GF almond) i ryżowego (GF rice).

A Principal Component Analysis (Figure 6) of the results of the evaluated bread samples showed that sample variation corresponded to the first main component (Factor 1), which accounted for 54.88 % of the total variability and was related mainly to taste features (bread, salt, yeast), yeast smell, specific weight and texture features (chewiness, springness, cohesiveness, hardness and gumminess) and moisture. The second component (Factor 2) constituted 33.60 % of the general variable and was related mainly to the structure (hard, dense, brittle), tastes (sour, foreign) and bread smell. Based on the eigenvalues obtained, the analysis can be limited to two factors explaining 88.48 % of the total variability.

The PCA results showed that the analyzed samples can be clustered into four distinctive groups. Each cluster corresponds to a different sample, as well as some of them can be clustered in groups as having similar influence in the phenomena explanation.

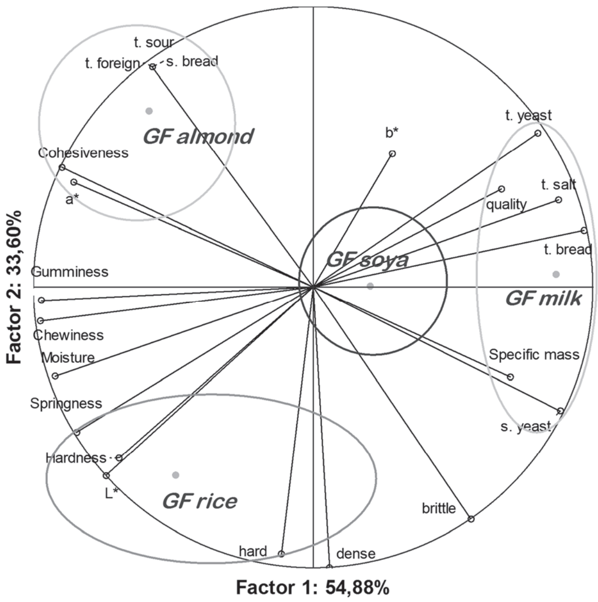

Figure 6. A Principal Component Analysis (PCA) of the gluten-free breads with the addition of cow's milk (GF milk), and plant-based drinks: soy (GF soy), almond (GF almond) and rice (GF rice) drinks.

Rysunek 6. Analiza składników głównych (PCA) pieczywa bezglutenowego z dodatkiem mleka krowiego (GF milk), oraz napojów roślinnych: sojowego (GF soy), migdałowego (GF almond) i ryżowego (GF rice).

Explanatory notes / Objaśnienia:
's.' stands for smell, 't.' stands for taste, features 'hard', 'dense' and 'brittle' correspond to the structure / 's.' oznacza zapach, 't.' oznacza smak, cechy 'hard', 'dense' i 'brittle' odpowiadają strukturze miękiszu.

The clusters obtained distinguish the samples with a different type of the addition of plant-based drinks. The gluten-free bread with the addition of cow's milk can be characterized by the high level of specific weight. Additionally, bread, salt and yeast taste was recognized. One can notice that those breads were accompanied by yeast smell and could be almost fully explained by Factor 1. The gluten-free breads with the addition of almond drink shows better texture features than the samples with soy drink and cow's milk. The bread smell and foreign and sour taste was more intense in such samples. The rice drink addition creates a less harder, dense and brittle structure. The texture features are similar as in the case of the almond drink addition. As for the addition of almond drink, the case of rice drink addition were characterized by the similar texture features and moisture level. The addition of soy drink can be explained by the features corresponding to Factor 1. A brittle structure, bread taste and high mass index distinguish this sample. Based on the analysis provided, one can conclude that the bread samples with different types of drinks addition were characterized by different factors. Lower values of texture features can distinguish the samples with the almond and rice drinks addition form other samples. The addition of the soy milk and cow's milk increases the bread taste and specific weight index. For both samples, the structure was more brittle, and together with the features mentioned previously, both samples obtained the highest consumer assessment score. One can conclude that the results obtained suggest that the addition of soy drink or cow's milk has the promising organoleptic and sensory features of gluten-free breads. As a result, both samples were recognized as the most demanding breads among the analyzed ones.

Conclusions

1. The use of plant-based drinks does not affect the weight after baking, specific weight and volume of the bread.
2. The moisture of the bread analyzed in the work was in the range of 47.53 ÷ 48.65 % after 24 hours and 45.98 ÷ 48.62 % after 48 hours. There were also no significant differences in the moisture content of the bread after 24 and 48 hours of storage. The most noticeable decrease in moisture after 48 hours was observed for the gluten-free bread with the addition of rice drink.
3. The parameters of the color components of the bread crumb measured in the CIELAB system (L*, a*, b*) did not differ significantly. The values of the L* parameter ranged from 72.43 ÷ 75.02, and the lowest value was observed for the gluten-free bread with the addition of milk.
4. The analysis of the texture parameters showed that the bread with the addition of milk had the lowest value of the hardness parameter and it did not change during the 48-hour storage. The gluten-free bread with the addition of rice drink was characterized by the highest value of the hardness parameter after 24 hours.

5. The type of plant drink / milk used affects the sensory characteristics of a gluten-free bread. The type of drink affects both the taste and aroma, as well as the structure and texture. Breads with milk substitutes have a less noticeable taste of bread and added yeast. However, in the assessment of sensory desirability, the best results were obtained in the case of the gluten-free bread with the addition of soy drink.
6. The results obtained justify the continuation of research in this direction. It is planned to expand the research to include unconventional plant drinks such as oat, coconut or mixtures of plant drinks. It is worth mentioning that the use of plant-based drinks to make gluten-free breads can be an alternative for people on a vegan diet.

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OCENA MOŻLIWOŚCI ZASTOSOWANIA NAPOJÓW ROŚLINNYCH W RECEPTURZE CHLEBA BEZGLUTENOWEGO

S u m m a r y

Wprowadzenie. Dieta bezglutenowa jest jedynym sposobem leczenia schorzeń związanych z nietolerancją glutenu. Pieczywo jest podstawowym składnikiem każdej diety. Na przestrzeni ostatnich lat na rynku polskim możemy zaobserwować wzrost dostępności produktów bezglutenowych, jednak ich jakość wciąż odbiega od jakości produktów tradycyjnych. Produkcja żywności bezglutenowej wiąże się z wieloma trudnościami technologicznymi związanymi z nadaniem produktom odpowiedniej konsystencji i tekstury. Stosunkowo często u osób ze świeżo zdiagnozowaną celiakią występuje również nietolerancja laktozy. Dlatego też celowym wydaje się podjęcie badań w kierunku zastąpienia mleka w recepturze chlebów bezglutenowych napojami roślinnymi. Celem niniejszej pracy było określenie wpływu dodatku napojów roślinnych na jakość pieczywa bezglutenowego. Do wypieku użyto mleka, napoju sojowego, migdałowego oraz ryżowego. Chleby bezglutenowe poddano ocenie sensorycznej. Badano również masę, masę właściwą, objętość, wilgotność, teksturę oraz barwę chlebów.

Wyniki i wnioski. Zauważono, iż rodzaj zastosowanego napoju wpływa zarówno na smak, zapach jak i na strukturę i teksturę. Chleby, w których zastosowano zamienniki mleka posiadają mniej wyczuwalny smak chlebowy oraz dodanych drożdży. Natomiast w ocenie pożądalności sensorycznej najlepsze rezultaty uzyskano w przypadku chleba bezglutenowego z dodatkiem napoju sojowego. Stwierdzono, że zastosowanie napojów roślinnych nie wpływa istotnie na masę po wypieku, masę właściwą oraz wilgotność. Zastosowanie napojów roślinnych do otrzymywania chlebów bezglutenowych może być alternatywą dla osób stosujących dietę wegańską.

Słowa kluczowe: pieczywo bezglutenowe, napoje roślinne, tekstura, analiza sensoryczna