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Assessment of the Possibility of Using Poppy Seed Cake for the Production of Oat Cookies

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Abstract: The aim of the study was to investigate the properties of oat cookies fortified with poppy seed cake. The modification of the recipe and the supplementation with the by-product improved the nutritional value and maintained the overall sensory acceptability of the analyzed material. An increase in the amount of the poppy seed cake formulation (up to 15%) was accompanied by significant increases in the contents of individual components: protein (from 12.43 to 14.09%), fat (from 6.34 to 6.98%), and crude fiber (from 2.32 to 3.62%) compared to the control sample. In turn, the moisture level (from 34.8 to 32.86%) and the content of soluble sugars (from 18.7 to 16.15%) decreased. The addition of the poppy seed cake changed the texture properties of the product. Oat cakes supplemented with poppy seed cake were characterized by higher hardness and chewiness values and lower cohesiveness. The aroma and palatability of the product achieved greater acceptability with increasing amounts of poppy seed cake, whereas an opposite tendency was observed for changes in the appearance and texture of the modified oat cookies. The highest sensory rates were achieved by the sample containing 10% poppy seed cake. Cookies produced according to this recipe are recommended for industrial production (their texture and sensory properties are appropriate, and they contain polyphenols, flavonoids, and significant amounts of protein and crude fiber).

Keywords: by-products; poppy seed cake; oat cookies; nutritional value; texture properties

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1. Introduction

The growing consumer awareness of the importance of a healthy diet in the prophylaxis of lifestyle diseases is associated with the increasing interest in minimally processed food. An increase in the demand for cold-pressed vegetable oils can be observed, as cold pressing is the simplest and most beneficial method for the maintenance of the health-promoting properties of oils. However, this method is inefficient [1]. The large-scale production and the relatively low pressing efficiency yield considerable amounts of the cake by-product. Hence, it is necessary to investigate the possibility of the use of oil industry by-products for the fortification of food. The use of oilseeds on an industrial scale is primarily related to their high fat content, which is essential in the production of oil. Additionally, oilseeds are rich in protein and health-promoting ingredients, e.g., tocopherols, essential fatty acids, vitamins, and phytochemicals. The press cake formed during oil production can also be an important source of protein, carbohydrates, and phenolic compounds. They contain some vitamins and fat that are left after the pressing process and substantial amounts of micro- and macroelements [2–4].

One of the raw materials used for oil production is seeds of the opium poppy (*Papaver somniferum* L.). Due to the presence of medicinally used morphine alkaloids and codeine, this plant has been cultivated since ancient times [5–7]. Legal poppy seed production is allowed in compliance with the regulations of the United Nations, mainly in countries such as the Czech Republic, Turkey, Spain, Hungary, France, India, Australia, and China. The seeds are commonly used in the food industry to decorate breads and baked goods (such as various rolls, plait, burekas, buns, and muffins). In turn. the valuable seed oil is widely utilized as an edible cooking oil and in the manufacture of high-quality artists' paints, varnishes, and cosmetics. Oil contents change considerably depending on the origins and colors of the seeds, which may be white, yellow, brown to gray, and blue. The reported values of the oil contents in the seeds are in the range of 44.0–57.0% in Turkey, 47.0–53.0% in Pakistan, and 41.4–49.1% in India [8–10]. Poppy seed oil is appreciated for its high nutritional and health-promoting value [11]. The health benefits related to the consumption of poppy seed oil include the enhancement of immunity, the prevention of gallstone disease, the acceleration of wound healing, a reduction in vascular embolism risk, and the prevention of skin dryness and diabetes. These properties are associated with the appropriate fatty acid profile, comprising mainly acids with 18-carbon chains: C 18:1, C 18:2, and C 18:3 [5]. Poppy seeds may therefore potentially be used as a raw material for the commercial production of specialty oil.

To meet the requirements of sustainable food production, there is a search for technologies that can properly manage generated wastes. This issue is one of the most dynamically developing areas of research. Currently, efforts are being made to properly minimize the amount of generated waste in order to protect the natural environment and reduce production costs [3].

To date, poppy seed cake has mainly been used for the production of fodder since it was observed that both poppy seeds and cake are a source of protein. As reported by Özcan and Atalay [9], poppy seeds contain from 20 to 25% of this component. In turn, the protein in poppy seed cake constitutes up to 35% of the dry matter [12,13]. Recently, however, there has been a need for more innovative ways to use by-products, e.g., functional food additives to fortify cereal/snack products. Research results show that poppy seeds can be regarded as an alternative source of vegetable protein and can be used as an additive to food intended for vegans, vegetarians, and athletes [14]. Furthermore, the low molecular weight of the protein may contribute to the stability of emulsions. Poppy seeds also contain dietary fiber, antioxidants, tocopherols, and micronutrients [6]. Poppy seed cake has been found to contain high levels of minerals such as potassium, sodium, calcium, magnesium, and zinc [13]. There are few scientific studies on the use of residues from pressing poppy seed oil.

The aim of this study is to determine the potential of poppy seed cake to be used as an additive in a food product that will be acceptable to consumers and exhibit high nutritional quality and desirable textural properties.

2. Materials and Methods

2.1. Material

To prepare the cake, blue poppy seeds were cold-pressed using a screw press (Sana, EUJ-702). The process temperature did not exceed 50 °C. The seeds were not subjected to enzyme treatment before pressing. The cake was ground using a laboratory grinder (Chemland, FW100) to pass through a 500 µm screen [15].

2.2. Preparation of Dough

The control formulation consisted of 200 g of oat flakes, 150 g of fresh apple, 100 g of fresh banana, 12 g of honey, and 1 g of cinnamon. The dry ingredients were mixed, the fruit and honey were added, and all ingredients were blended for 3 min (KENWOOD food processor). In some samples, the oat flakes were partially replaced with the poppy seed cake. The amount of the additive is shown in Table 1. The amount of the poppy seed cake addition to the recipe was determined based on the results of preliminary sensory tests (data not shown).

Table 1. Model of experiment parameters.

Probe Code	Amount of Ingredients			
	Oat Flakes g	Oat Flakes %	Poppy Seed Cake g	Poppy Seed Cake %
C	200	100	0	0
PC5	190	95	10	5
PC10	180	90	20	10
PC15	170	85	30	15

2.3. Baking Cookies

Round 8 mm-high cookies were formed from a 20 g portion of the dough, placed on baking trays, and heated for 20 min at 180 °C. A convection-steam oven (Houno, DK 8940 Ronders) was used to carry out the baking process. Baked cookies (Figure 1) were allowed to cool (by placing on a stainless-steel grid) for two hours at room temperature. Part of the material was dried and ground to be used for chemical analyses. The remaining cookies were transferred to hermetic plastic containers and stored at ambient temperature. The sensory and textural analyses and the determination of humidity were carried out after 24 h.

Figure 1. Exemplary pictures of the appearance of oatmeal cookies with poppy seed expeller added: C—control probe, PC5—oatmeal cookies with 5% poppy seed expeller added; PC10—oatmeal cookies with 10% poppy seed expeller added; PC15—oatmeal cookies with 15% poppy seed expeller added.

2.4. Determination of Moisture

The moisture content was determined with the standard method [16]. Approximately 2 g samples of the material were dried until no weight loss was recorded. The process was carried out at the temperature of 130 °C with the use of a laboratory dryer (POL-EKO, SLN 15 STD).

2.5. Analysis of Protein Content

The protein content was determined using a Kjeltec (TM8400, Foss, Mulgrave, Australia) apparatus and ASN 3100 software. The distillation was performed on an automated Kjeltec Auto analyzer (Tecator). In the Kjeldahl procedure [17], after digestion in concentrated sulfuric acid, the total organic nitrogen was converted to ammonium sulfate. Ammonia was formed and distilled into boric acid solution under alkaline conditions. The formed borate anions were titrated with standardized hydrochloric acid, by which the nitrogen content was calculated, representing the amount of crude protein in the sample. The nitrogen content was converted into the protein content using the $N \times 5.7$ conversion factor.

2.6. Determination of Fat Content

Total fat was determined with the method on a Soxtec apparatus (Foss Analytical Solutions Pty. Ltd., Victoria, Australia). The sample was placed in a porous thimble and extracted in petroleum ether for 60 min within individual extraction tins (AN 310 Soxtec^{TM} 8000 of Crude Fat using Extraction System). The sample was then placed in a laboratory drier for 30 min at 105 °C to further remove (vaporize) any residual solvent. The variation in sample weight before and after extraction was used to calculate the crude fat content, which was then expressed as a percentage of the dry weight.

2.7. Determination of Fiber Content

The crude fiber content was determined by sequential extraction with hot H_2SO_4 (conc. 1.25%) and hot NaOH (conc. 1.25%) [18]. After rinsing, filtration, and washing with acetone, the crucibles with the residue were dried, the precipitate was incinerated, and the weight was determined after cooling. The percentage of crude fiber was calculated as the difference between the sediment and the ash weight in the total weight of the sample.

2.8. Determination of Sugar Content

The contents of soluble sugars, i.e., glucose, fructose, and sucrose, were determined using HPLC in accordance with standard procedures [19].

2.9. Determination of Polyphenol Content

The analysis was performed using a Varian 100 Cary spectrophotometer. The determination by the Folin–Ciocalteu method consisted of the methanol extraction of the active substances contained in the material and the measurement of the absorbance of the solutions at a 765 nm wavelength (against the blind sample). The sum of polyphenols was expressed as caffeic acid.

2.10. Determination of Flavonoid Content

Flavonoids were determined spectrophotometrically at a wavelength of 425 nm. Prior to the measurement, acetone and hydrochloric acid extractions were performed. The total flavonoid content was expressed with reference to the quercetin standard curve.

2.11. Determination of Textural Properties

The textural properties were determined using a testing machine (Zwick/Roell, Z0.5) and testXpert II software. The TPA test was used in the analysis. The product was compressed twice to 50% of its original height. The travel speed of the measuring head was 0.83 $mm \cdot s^{-1}$. The compression was performed using a cylindrical compression punch with a diameter of 100 mm. The test was carried out 24 h after baking. To prepare the samples for the analysis, 3 cm diameter cylinders were cut from the centers of the cookies. The values of the following textural features were determined: hardness [N], elasticity [-], cohesiveness [-], and chewiness [N].

2.12. Determination of the Color

The color of the cookies was determined using an SF80 color spectrophotometer (Marcq-en-Barœul, France) with a standard light source (D65) and observer (10°). Before the analysis, white and black calibration references were applied. The following CIE parameters were recorded: L^*—lightness, 0 = black and 100 = white; a^*—greenness/redness; and b^*—yellowness/blueness (higher values of a and b mean more intensity of green and yellow, respectively). The measurements were performed five times per sample.

2.13. Sensory Analysis

The oat cookies supplemented with the poppy seed cake were assessed by a panel of seven partially trained panelists. They were trained in the descriptive aspects of the test [20]. The panelists rated the overall appearance, aroma, texture, and palatability using a five-point structural scale (1—"dislike very much" to 5—"like very much"). Additionally, the general acceptability of the material was assessed on a scale from 1 to 5. The panel consisted of a doctoral student and employees (three males and four females aged 19–48 years) from the faculty of Production Engineering, University of Life Sciences in Lublin. The following criteria were taken into account in the selection of the panelists: good health status, non-smoker, and consent to participate. The assessment was carried out in a laboratory with LED lighting at room temperature 24 h after baking. The panelists were provided mineral water as a neutralizing agent. A random order of serving the samples was adopted.

2.14. Statistical Analysis

The results of the research were statistically analyzed in the Statistica 12 software (v.13.3; StatSoft Inc., Tulsa, OK, USA). The significance level $\alpha = 0.05$ was adopted for inference. The significance of the differences was analyzed with the use of Anova extended by a post hoc analysis based on Tukey's test.

3. Results

3.1. Chemical Composition

The addition of poppy seed cake as an oat cookie ingredient had a significant effect ($p < 0.05$) on the chemical composition of the product (Tables 2 and 3). The control material exhibited the highest moisture content. The increase in the dose of the supplement was accompanied by a decline in the moisture content in the product. The contents of protein, fat, and fiber in the oat cookies increased with the increasing amounts of poppy seed cake. The statistical analysis revealed significant changes for each 5% increase in the additive dose. The addition of poppy seed cake reduced the contents of monosaccharides and sucrose in the oat cookies (Table 3).

Table 2. Chemical compositions of oatmeal cookies with poppy seed expeller added (n = 3).

	Moisture	Protein	Fat	Crude Fiber	Flavonoids	Polyphenols
	%	% d.b.	% d.b.	% d.b.	mg·100 $g_{d.b.}^{-1}$	% d.b.
C	34.80 ± 0.02 ^{a}	12.43 ± 0.15 ^{a}	6.34 ± 0.01 ^{a}	2.32 ± 0.02 ^{a}	-	0.136 ± 0.002 ^{a}
PC5	33.83 ± 0.01 ^{b}	13.14 ± 0.05 ^{b}	6.70 ± 0.01 ^{b}	3.18 ± 0.04 ^{b}	0.333 ± 0.015 ^{a}	0.119 ± 0.003 ^{b}
PC10	33.58 ± 0.13 ^{c}	13.64 ± 0.01 ^{c}	6.88 ± 0.01 ^{c}	3.34 ± 0.03 ^{c}	0.357 ± 0.006 ^{a}	0.117 ± 0.002 ^{b}
PC15	32.86 ± 0.07 ^{d}	14.09 ± 0.03 ^{d}	6.98 ± 0.01 ^{d}	3.62 ± 0.01 ^{d}	0.357 ± 0.012 ^{a}	0.104 ± 0.007 ^{c}

C—control probe, PC5—oatmeal cookies with 5% poppy seed expeller added; PC10—oatmeal cookies with 10% poppy seed expeller added; PC15—oatmeal cookies with 15% poppy seed expeller added. Data are presented as means ± standard deviations, values of each parameter with different superscript letters in rows are significantly different (Tukey's test, $p \leq 0.05$).

Table 3. The contents of soluble sugars of oatmeal cookies with poppy seed expeller added (n = 3).

	Saccharose	Glucose	Fructose
	% d.b.	% d.b.	% d.b.
C	7.03 ± 0.02 ^{a}	4.70 ± 0.02 ^{a}	6.97 ± 0.04 ^{a}
PC5	6.63 ± 0.06 ^{b}	4.67 ± 0.01 ^{a}	6.68 ± 0.02 ^{b}
PC10	6.46 ± 0.05 ^{c}	4.66 ± 0.02 ^{a}	6.57 ± 0.03 ^{b}
PC15	6.11 ± 0.03 ^{d}	4.24 ± 0.15 ^{b}	5.80 ± 0.09 ^{c}

C—control probe, PC5—oatmeal cookies with 5% poppy seed expeller added; PC10—oatmeal cookies with 10% poppy seed expeller added; PC15—oatmeal cookies with 15% poppy seed expeller added. Data are presented as means ± standard deviations, values of each parameter with different superscript letters in rows are significantly different (Tukey's test, $p \leq 0.05$).

No flavonoids were detected in the control oat cookies (Table 2). The poppy seed cake fortified products contained from 0.333 to 0.357 mg·100 g^{-1} of flavonoids in the dry matter. The statistical analysis did not confirm any significant changes in the contents of these components depending on the dose of the supplement. The contents of polyphenols in the oat cookies decreased after the poppy seed cake addition. No statistically significant changes were recorded in samples PC5 and PC10.

3.2. Textural Properties

The changes in the textural properties of the oat cookies fortified with poppy seed cake are presented in Table 4. Hardness is the basic parameter of the mechanical properties of cereal products. The statistical analysis showed a significant increase in the hardness of the material along with the increase in the dose of poppy seed cake ($p < 0.05$). No statistically significant differences were observed between the hardness of samples PC5 and PC10. The elasticity and cohesiveness of the oat cookies generally decreased with the increasing doses of poppy seed cake. In turn, the statistical analysis did not reveal any significant changes in the elasticity of the material. The cohesiveness of sample PC15 differed significantly from the value of the parameter in the other samples. The mean values of the chewiness of the analyzed material were similar to the hardness parameter. It increased significantly with the increases in the dose of the additive in the oat cookie composition.

Table 4. Texture profile analysis of oatmeal cookies with poppy seed expeller added (n = 10).

	Hardness	**Elasticity**	**Chewiness**	**Cohesiveness**
	N	**-**	**N**	**-**
C	172.3 ± 7.4^{a}	0.843 ± 0.012^{a}	86.5 ± 3.2^{a}	0.595 ± 0.020^{a}
PC5	267.7 ± 5.0^{b}	0.847 ± 0.023^{a}	135.8 ± 9.2^{b}	0.599 ± 0.015^{a}
PC10	303.7 ± 26.3^{b}	0.817 ± 0.015^{a}	144.6 ± 11.0^{b}	0.583 ± 0.009^{a}
PC15	406.7 ± 12.9^{c}	0.813 ± 0.021^{a}	170.9 ± 3.7^{c}	0.517 ± 0.003^{b}

C—control probe, PC5—oatmeal cookies with 5% poppy seed expeller added; PC10—oatmeal cookies with 10% poppy seed expeller added; PC15—oatmeal cookies with 15% poppy seed expeller added. Data are presented as means ± standard deviations, values of each parameter with different superscript letters in rows are significantly different (Tukey's test, $p \leq 0.05$).

3.3. Color of Cookies

There were significant differences in the color between the control cookies and the cookies with poppy seed cake (Table 5). The lightness value (L^*) decreased with an increase in the amount of by-product. This was related to the influence of the darker color of the poppy seeds. The most noticeable change was observed in the lightness (L^*) of cookies with 10% poppy seed cake (PC10) compared to the 15% by-product amount (PC15). No statistically significant differences were observed between the L^* and b^* parameters of samples C and PC10. The highest a^* and b^* values were obtained in control probe samples. The red and yellow colors in the oat cookies decreased with the increasing amounts of poppy seed cake.

Table 5. Color parameters of oatmeal cookies with poppy seed expeller added (n = 3).

	L^*	a^*	b^*
C	51.92 ± 0.64^{a}	3.74 ± 0.11^{a}	12.67 ± 0.66^{a}
PC5	51.45 ± 0.28^{a}	3.52 ± 0.07^{b}	11.95 ± 0.31^{a}
PC10	49.85 ± 0.44^{b}	2.95 ± 0.18^{c}	9.77 ± 0.40^{b}
PC15	46.57 ± 0.51^{c}	2.73 ± 0.14^{d}	8.91 ± 0.22^{c}

C—control probe, PC5—oatmeal cookies with 5% poppy seed expeller added; PC10—oatmeal cookies with 10% poppy seed expeller added; PC15—oatmeal cookies with 15% poppy seed expeller added. Data are presented as means ± standard deviations, values of each parameter with different superscript letters in rows are significantly different (Tukey's test, $p \leq 0.05$).

3.4. Sensory Quality

The results of the sensory evaluation are presented in Figure 2. The highest scores for the overall appearance of the cookies were achieved by samples C and PC5. In turn, the aromas of the tested materials had different assessment scores. The data in Figure 1 show higher scores for the aroma of the oat cookies with the increasing amounts of poppy seed cake. The panelists found appropriate consistency of the material in samples C, PC5, and PC10. In contrast, cookies containing 15% of the supplement had low consistency scores, probably due to the increased hardness and chewiness of sample PC15. Generally positive scores were achieved for the palatability of the material. In the assessment, most panelists used the phrase "like" for samples C and PC5, whereas samples containing at least 10% poppy seed cake (PC10 and PC15) were mostly described with "like very much". In terms of the overall product acceptability, sample PC10 scored the highest number of points. It is noteworthy that the initial increase in the dose of the poppy seed cake (up to 10%) was associated with a greater acceptability of the oat cookies. In turn, the material supplemented with 15% poppy seed cake was regarded as the least acceptable. This may be related to the low scores in the assessment of the appearance and consistency of sample PC15.

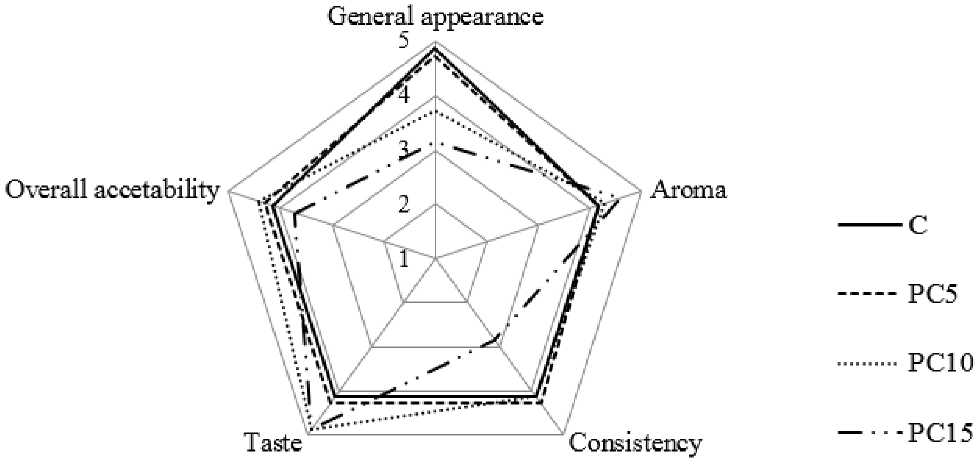

Figure 2. Sensory evaluation of oatmeal cookies with poppy seed expeller added: C—control probe, PC5—oatmeal cookies with 5% poppy seed expeller added; PC10—oatmeal cookies with 10% poppy seed expeller added; PC15—oatmeal cookies with 15% poppy seed expeller added.

4. Discussion

It can be assumed that reducing the moisture content of oat cookies with an increase in the poppy seed cake content is associated with the higher water absorption capacity of cereal flakes. As reported in the literature, water absorption determined with the centrifuge method (measuring the amount of liquid that can be centrifuged under set conditions from ground grain homogenate with added water) may be as high as 119% [21]. In the case of oilseed cake, the value of this parameter ranges from 10 to 25% [22]. In other studies [23,24] describing the quality of bread with the addition of oilseeds, lower crumb moisture was also found for the supplemented samples compared to the control sample. Changes in the protein, fat, and fiber contents were caused by the substantially higher contents of these components in poppy seed cake than in oats, which was partially confirmed by Grausgruber et al. [25] and Yılmaz and Emir [13]. In the research, the authors determined the contents of protein and fat in poppy seed pomace [13] and oat grain [24]. The analyses showed that the blue poppy pomace contained over 28% crude protein, while the hull-less oat grain contained less than 13%. However, the poppy seed cake analyzed by Yılmaz and Emir [13] contained a lower amount of fat (2.32–4.28%) than oat grain (4.82%), but it should be noted that the poppy seeds defatted by Yılmaz and Emir [13] were cold-pressed and then the cake was slurred in hexane three times (to remove the remaining oil). In our experiment, poppy seed cake was obtained only by cold-pressing, so it had a higher amount of fat. In is noteworthy that there were no significant changes in the contents of glucose and fructose along with the increase in the poppy seed cake dose from 5 to 10%. Oilseed cake is generally characterized by a lower carbohydrate content than that in cereal grains [6,12,26]. Hence, the use of oilseed or cake to fortify cereal products results in a reduced content of carbohydrates in their composition [4,27].

Literature data confirm that oilseeds are a valuable source of antioxidants. For instance, the total phenolic content in raw poppy seeds is approximately 332 mg·100 g^{-1} [15]. However, it can be assumed that these compounds were lost during the pressing process and were part of the extracted oil [28]. Hence, the contents of flavonoids and polyphenols in the products we studied were quite low.

The textural research results are consistent with the findings shown in other reports [29,30] on the properties of other cereal products fortified with seed cake. Analogous changes in the textural properties were observed in the experiment conducted by Pojić et al. [29] in which bread was supplemented with hemp seed cake. The authors reported significant increases in hardness and chewiness and decreases in elasticity and cohesiveness caused by the addition of hemp seed cake. The hardness could be greatly influenced by the composition of the flour. There were positive correlations between fiber and protein and the hardness values of cookies [30]. It is also possible that there is an influence of the particle size of the poppy expeller, and hence its hardness, on the texture of the final product. Previous studies have shown the effect of particle size on the texture properties of cereal products [31]. As shown in the study conducted by Pojić et al. [29], elasticity changed significantly only in the 20% supplementation variant. The same trend in the changes in mechanical properties was also found in a study on the supplementation of buns with coconut residue [32].

The significant changes in the color parameters of the different oat cookie probes were mainly caused by the characteristic dark color of the poppy seeds. However, it should be mentioned that the literature data show that the use of enriching or functional additives, which may be subject to browning reactions to different degrees during baking, has an effect, in particular, on the brightness of baking [33–35].

The use of a higher poppy seed cake dose in the composition of the oat cookies exerted a negative effect on their appearance. This is probably associated with the color of the poppy seeds. In their research, Martínez et al. [26] reported that the color of bread supplemented with poppy seed cake achieved lower scores than bread with sesame and flax cake. In turn, the positive effect of the poppy seed cake supplementation on the palatability and aroma of oat cookies may be related not only to the sensory value of poppy seeds but also to the method of defatting the seeds. As shown by Tate et al. [36] in experiments where nut pomace was added to cookies, the modification of the recipe exerted a negative effect on all sensory parameters. However, the pomace used in the study was defatted with the n-hexane and ethanol extraction method.

5. Conclusions

Currently, it has become essential to ensure sustainable food production, including the generation of as little waste as possible. The results of the conducted experiment confirm the possibility of using by-products of the oil industry as a material for the production of oat cookies. It should be noted that the cakes obtained from poppy seed residues were characterized by a high nutritional value and sensory acceptability.

The addition of poppy seed cake increased the nutritional value of the oat cookies. The modification of the recipe contributed to higher protein, crude fiber, and fat contents. Concurrently, the contents of glucose, fructose, and sucrose in the modified oat cookies decreased. The fortification had a slight effect on the contents of antioxidant components. Moreover, there were significant changes in the textural properties of the analyzed material. The oat cakes fortified with poppy seed cake had higher hardness and chewiness and lower cohesiveness values. The sensory properties of the material were maintained at an acceptable level. The oat cakes containing 15% poppy seed cake were regarded by the panelists as much less attractive in terms of appearance and texture, but their flavor and aroma achieved high scores. The results of the general acceptability of the products indicate the best sensory values of sample PC10, i.e., cookies fortified with 10% supplement. Cookies produced according to this recipe are recommended for industrial production. Their texture and sensory properties are not significantly different from the sample without poppy seeds. In addition, cookies fortified with 10% supplement contain polyphenols, flavonoids, and significant amounts of protein and crude fiber.

The conducted research has shown that, thanks to the appropriately selected ingredients of the recipe, it is possible to obtain a highly nutritious product with adequate structural properties. In further analyses, it is advisable to modify the composition of oatmeal cookies enriched with poppy seed cake in order to improve the visual aspects. Dark spices, such as cocoa or carob, should be included in the recipe to improve the acceptability of the appearance of the oatmeal cake. It is also worth introducing cakes with various fineness values into the biscuits, thus improving their mechanical properties.

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Data Availability Statement: Datasets from the time of this study are available from the respective authors upon reasonable request.

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