JAP&T
TPA-Timisoara

Available online at http://journal-of-agroalimentary.ro

Journal of Agroalimentary Processes and Technologies 2020, *26*(4), 397-405

Journal of Agroalimentary Processes and Technologies

Sensorial and nutritional quality of gluten-free cookies developed from rice and coconut flour mixtures

Daniela Stoin, Călin Jianu*, Ariana – Bianca Velciov, Ileana Cocan

Faculty of Food Engineering, Banat`s University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania" from Timisoara, Calea Aradului 119, Timisoara 300645, Romania

Abstract

The aim of this study was to capitalize on the nutritional potential of coconut flour in the development of a product with added nutritional value for both people with gluten intolerance and consumers who want a healthy diet. This study asses the proximate composition and sensory analysis of cookies made from rice and coconut flour mixtures. Five mixtures were prepared by homogenously mixing rice flour with coconut flour in the percentage proportion ratios of 85:15, 70:30, 55:45, 40:60 and 100:0 respectively. The 100% rice flour serve as the control. Standard procedures were used to estimate the proximate composition of flours and cookie samples obtained in this study. The results obtained regarding the physico-chemical composition of the two analyzed flours highlight their superior nutritional profile. The obtained results indicate that the incorporation of up to a level of 45% coconut flour in the gluten-free cookies formula resulted in products with improved sensory and functional properties compared to the control sample (control cookie). The sensory quality is based on the taste, aroma, crispiness, appearance and overall acceptability. The overall acceptability shows sample C45CF was preferred among the cookies. The results obtained could be very valuable for local industries to partially or completely substitute wheat in production of snacks.

Keywords: coconut flour, rice flour, *Aronia Melanocarpa L.*, gluten-free cookies quality

2.Introduction

Food is one of the most important factors in protecting and promoting human health. Therefore, the food consumed must be varied and complex, with nutritional and biologically active value appropriate to the physiological needs [1, 2].

Currently, both nationally and internationally, the population is facing a rising epidemic of disorders related to the consumption of gluten-containing foods such as celiac disease, allergies and gluten sensitivity [3, 4].

Celiac disease is an autoimmune disease caused by ingestion of gluten, a protein found in wheat, rye and barley [5]. Gluten consumption by a person diagnosed with celiac disease triggers an autoimmune response that is responsible for damaging intestinal villi by preventing the proper absorption of vitamins and minerals by exposing people to nutritional deficiencies, gastrointestinal cancer and other autoimmune diseases [6].

The treatment of this condition involves a strict gluten-free diet (complete elimination of cereals containing gluten or their derivatives from the diet). Products labeled as "gluten-free" must not contain more than 20 mg / kg of gluten, according to European Commission Regulation (EU) no. 828/2014.

In 2013, Regulation 609 of the European Union established norms on the requirements, composition and labeling of gluten-free products, providing people with gluten intolerance with clear and reliable information on the difference between naturally occurring gluten-free products and those processed, to reduce gluten content [7].

Gluten-free diet involves not only the elimination of gluten-containing raw materials but also all products that contain them, which requires constant vigilance, and there is a feeling of isolation and social pressure that accompanies a gluten-free diet.

Corresponding authors: calin.jianu@gmail.com

Since most breads, biscuits, pastas, cakes, cookies, cereals, baguettes, soups are made from wheat, avoiding all of these things indicates a complete lifestyle change that would not be feasible for everyone. For all these reasons, the demand for gluten-free products is now increasing [8, 9]. Studies that have investigated the nutritional composition of gluten-free products have shown that these have high levels of lipids, sugars and salt [10]. Other studies [11] have shown that gluten-free products have a higher content of calories, salt and cholesterol and lower content of macronutrients, fiber, sodium, compared to conventional products.

The segment of gluten-free products on the international market is constantly growing, and in recent years in Romania also, the interest in this category of products has increased, an interest attributed to meeting preferences, needs and last but not least, the growing demands of consumers. This is causing major changes in quality, distribution and perhaps most importantly, in food production technology [8, 9]. Optimizing recipes and the technological process for obtaining gluten-free products is a great challenge, especially for improving the sensory characteristics of the product. Many ingredients are commonly used to replace the functionality of gluten [12].

In this regard, in recent years, on a national level were studied different experimental gluten-free systems in order to develop gluten-free products, studies which involved a diverse approach and included the use of various types of alternative flours (amaranth, buckwheat, millet, rice, sorghum, quinoa, chestnuts, almonds) as alternatives to gluten, to improve the structure, taste, acceptability and shelf life of gluten-free products [13, 14]. In the category of alternative flours goes the coconut flour which does not contain gluten and which represents an important source of nutrients, in particular fibers and proteins, no *trans* fatty acids and has a low glycemic index [14]. This study provides the development of gluten-free producing technology using rice flour and coconut flour as raw material and also fruit (*Aronia Melanocarpa L.*) peanuts and almond. As a sweetener was used Demerara sugar.

Coconut flour is a good source of dietary fiber, having the highest percentage of dietary fiber found in any flour [15, 16] and can play an important role in controlling cholesterol and blood sugar levels, and prevent colon cancer. Coconut flour from coconut residue, a by-product of the coconut-milk industry, contained 600 g total dietary fiber/kg (560 g insoluble and 40 g soluble fiber/kg) [17]. This gluten-free flour has become increasingly important in the bakery industry, with many studies showing that coconut flour can be used to make food, such as bakery, pastry and confectionery, especially biscuits, noodles and snacks. There is also the possibility of combining this type of flour with other flours to obtain gluten-free foods, important for patients with gluten intolerance [17, 18].

Of particular interest are the fruits of *Aronia*, being rich in vitamins (A, B2, B6, B9, C, E, K), minerals (Ca, Zn, Fe, Mg, K, Mn), fiber [19] and have the highest antioxidant content compared to acai berries, blueberries, raspberries, cranberries and Goji berries [20]. Consumption of *Aronia* fruits contributes to the improvement of the immune system, helps to support cognitive function, maintain heart and blood vessel health, prevents eye degeneration, has antibacterial effect [21].

Rice flour is rich in fiber, vitamins, minerals and antioxidants. The content of insoluble fiber stimulates metabolism, speeds up digestion and helps contributes to lowering cholesterol, the content of antioxidants prevents premature aging, and the content of complex carbohydrates helps to stabilize blood sugar [22].

Almonds and peanuts are excellent sources of monounsaturated fats, fiber, protein, contain antioxidants, flavonoids, minerals (Mn, Mg, Cu, P, Ca, Fe, K, Zn, Se). Eating almonds and peanuts helps protect the cardiovascular system, improves the immune system and vision, prevents anemia, improves memory, lowers cholesterol, regulates blood sugar levels, weight control, helps prevent various cancers, helps reduce fatigue [23, 24].

Based on these observations, this study aimed at developing gluten-free cookies optimized nutritionally, because the cookies are one of the most consumed cereals food apart from bread, are readily available in local shops as food products containing digestive and dietary principles of vital importance

2. Materials and methods

2.1. Plant Materials

Rice flour (RF), coconut flour (CF), *Aronia* fruits, almond, peanuts and the other ingredients used in this study were purchased from local market in Timisoara town, Romania.

Steps in the preparation of flour mixtures: RF was mixed with CF in different proportions to obtain four mixtures: Mixture 1 (M1): 85%RF:15%CF; Mixture 2 (M2): 70%RF:30%CF; Mixture 3 (M3): 55%RF:45%CF and Mixture 4 (M4): 40%RF:60%CF.

2.2. Methods

2.2.1. Proximate composition of rice flour and coconut flour

The proximate composition of flour and cookie samples were determined using standard procedures: moisture determined according to standard method AOAC 1995 [25]; fat content by extraction with Soxhlet apparatus according to standard method AOAC 1995 [25]; protein content by the Kjeldahl method according to standard method AACC 2000, No. 46-10 [26]; fiber content according to standard method AOAC 1995, No. 32-10 [25]; Carbohydrate content was determined by difference using the equation: 100 – (moisture + fat + ash + protein + fibers), by standard method AOAC 1995 [25]. All analyses were carried out in triplicate.

2.2.2. Gluten-free cookies preparation

Cookies were produced from the mixtures using the method described by Onabanjo (2014) [27]. All the ingredients were weighed accurately. Cookie dough was prepared from RF (control – 100%) and CF combinations (15%, 30%, 45%, 60%) using flour (100%), *Aronia* fruits (50%), Demerara sugar (75%), butter (75%), egg (65%), peanuts (50%), almond (50%) and baking powder (5%). *Aronia* fruits, peanuts and almonds were chopped. After homogenisation, rice flour, coconut flour, baking powder, Aronia fruits, almonds, peanuts and Demerara sugar were added. The resulting mixture was subjected to kneading operation until a firm and homogeneous dough was obtained and then allowed to rest for 30 minutes at 4°C. The dough thus obtained was rolled (thickness of 1 cm) and cut into circular portions by using a round shaped cutter (6 cm). After baking at 170°C for 15 minutes, the cookies were allowed to cool and packed in high density polyethylene film and stored at room temperature for subsequent analyses. The cookie samples produced from 100% rice flour served as control.

2.2.3. Sensory evaluation of gluten-free cookies

The sensory evaluation of the cookie samples was carried out for consumer acceptability and preference using 20 semi-trained panelist comprised of students and staff of Faculty of Food Engineering, Banat's University. They were to evaluate the sensory properties based on Taste, Aroma, Crispiness, Appearance and Overall acceptability using a 9-point Hedonic scale (*9: Like extremely; 8: Like very much; 7: Like moderately; 6: Like slightly; 5: Neither like nor dislike; 4: Dislike slightly; 3: Dislike moderately; 2: Dislike very much; 1: Dislike extremely*) [28].

2.2.4. Physical parameters of gluten-free cookies

Physical properties of the cookie samples were determined according to AACC (2000) methods [29]. The weight of three cookies from each sample was determined on an electronic weighing balance (Mettler, Germany) and average recorded in grams (g). The diameters of cookies was determined by placing six cookies edge to edge and by measuring it with ruler of mm and by rotating at an angle of 90°. This was repeated once more and average diameter was reported in millimeters. The thickness of the cookie samples was measured using a micrometer screw gauge (zero error). Thickness was measured by stacking three well-formed cookies on top of one another, then restacking in a different order and measuring them to get the average in millimeters. The spread ratio of the cookie samples was determined by dividing the average value of the diameter by average value of thickness of same cookie samples [30]. All analyzes were performed in triplicate.

2.2.5. Chemical evaluation of gluten-free cookies

The gluten-free cookies samples obtained according to the method described in *paragraph 2.2.2.*, were submitted to chemical evaluation aiming: moisture, fat, protein, fiber, carbohydrate, ash according to A.O.A.C. and A.A.C.C. standard method (*paragraph 2.2.1.*) [25, 26].

3. Results and Discussion

3.1. Proximate composition of flours

The chemical composition of the flours are presented in *Table 1*.

The proximate compositions of RF and CF are presented in *Table 1*. The results obtained in terms of the chemical composition of CF compared to RF highlight its nutritional potential, due to the higher content of protein, fat, crude fiber and ash. But CF contains no gluten and consequently cannot be used exclusively in baked goods that require leavening. When used, however, a limit of the substitution level with RF was necessarily imposed on the extent to which the flour could be used as a substitute for RF [31]. The moisture of CF was significantly lower (3.76%) than that of RF (10.54%), which determines the extension of shelf life of the products obtained from this flour assortment [32]. Considering the lower moisture content in CF, this can be used for the development of bakery and pastry products [33]. CF showed high levels of protein - 19.56% compared to 12.78% in RF, fiber - 10.89% compared to 3.76% in RF, fat - 12.82% compared to 1.64% in RF, ash - 4.59% compared to 2.14% in RF and lower carbohydrate levels - 48.35% compared to 69.11% in RF which contributes to the decrease of the glycemic index of the products obtained from this flour, results that are comparable to those obtained by Castillo J.C. *et. al.* (2003), Poonam D. (2013), Makinde F.L. *et. al*. (2019) and Afoakwah N.A. *et. al*. (2019) [31, 33-35].

It is also known that the addition of RF contributes to increasing the caloric value of products, therefore substituting it in cookies with CF, will reduce their caloric value and increase the nutritional value, providing benefits for consumer health [18, 36].

Table 1. Chemical composition of flour samples

Chemical composition (%)	Flour samples	
	RF	CF
Moisture	10.54±0.25	3.76±0.12
Fat	1.64±0.17	12.82±0.17
Protein	12.78±0.12	19.56±0.22
Fiber	3.76±0.14	10.89±0.21
Carbohydrates	69.11±0.09	48.35±0.26
Ash	2.14±0.18	4.59±0.15

All determinations were done in triplicate and the results were reported as average value ± standard deviation (SD).

3.2. Sensory evaluation of gluten-free cookies

For the sensory analysis, the hedonic scale was chosen, the method that is generally used when it is desired to place new foods on the market or to verify the consumer's behavior towards the products already on the market. The mean scores of the sensory attributes of the various cookie samples are presented in *Table 2.* The cookie samples studied in this study were: **CC:** Control cookies with 100% RF:0% CF; **C15CF**: Cookies with 85% RF:15% CF; **C30CF**: Cookies with 70% RF:30% CF; **C45CF**: Cookies with 55% RF:45% CF; **C60CF**: Cookies with 40% RF:60% CF.

Partial substitution of wheat flour with other flours causes significant changes in terms of taste, aroma, crispiness, appearance and overall acceptability of the obtained products [36]. The five assortments of gluten-free cookies obtained were sensory evaluated using 9-point Hedonic scale by a number of 20 panelists. Experiments conducted showed a direct correlation between the dough composition, working technological parameters and qualitative properties of these cookies assortments. The results of the sensory evaluation highlight significant differences (taste, aroma, crispiness, appearance and overall acceptability) between CC and cookie samples with the addition of 15%, 30%, 45% and 60% CF. The variation in the samples is due to the addition of CF which was not commonly eaten by the people before.

a.CC

b. C15CF

c. C30CF

d. C45CF

e. C60CF

Figure 1. The assortments of gluten-free cookies:
a. Control cookies **(CC)**; **b.** Cookies with 85% RF:15% CF **(C15CF)**; **c.** Cookies with 70% RF:30% CF **(C30CF)**; **d.** Cookies with 55% RF:45% CF **(C45CF)**; **e.** Cookies with 40% RF:60% CF **(C60CF)**.

Table 2. Quality attributes scored in sensory assessment of gluten-free cookies

Parameter	**Cookies samples evaluated**				
	CC	**C15CF**	**C30CF**	**C45CF**	**C60CF**
Taste	6.52±0.13	6.87±0.04	7.15±0.03	7.86±0.08	7.58±0.05
Aroma	6.88±0.02	7.22±0.06	7.49±0.11	8.13±0.05	7.87±0.12
Crispiness	7.23±0.12	7.19±0.04	7.07±0.05	6.92±0.03	6.86±0.06
Appearance	6.42±0.03	6.28±0.12	6.04±0.24	5.82±0.13	5.56±0.09
Overall acceptability	6.35±0.13	6.89±0.14	7.29±0.13	7.59±0.04	7.38±0.03

All determinations were done in triplicate and the results were reported as average value ± standard deviation (SD).

Fortification of cookies by adding CF and *Aronia* fruits is an accessible technique that allows both increasing the nutritional profile and improving the sensory attributes of the formulas developed. The attributes that had the greatest influence on the evaluators' perception were taste, aroma and general acceptability. The analysis of the data presented in *Table 2*, showed that the best scores were obtained by the C45CF test with 55% RF and 45% CF in all respects for all sensory attributes. Sensory rating of cookies for taste shows that sample C45CF was highest rated (7.86±0.08), followed by sample C60CF (7.58±0.05) and sample C30CF (7.15±0.03) while control sample CC was rated lowest (6.52±0.13). The sensation of taste is function of aroma which is a complex of sensations [37]. The cookie samples showed changes in the flavor depending on the proportion of CF added, thus, the lowest score was obtained by the CC sample (aroma - 6.88 ± 0.02), and the highest score by the C45CF sample (aroma –8.13 ± 0.05), followed by samples C60CF (aroma –7.87 ± 0.12), C30CF (aroma –7.49 ± 0.11) and C15CF (aroma –7.22 ± 0.06). Aroma is the main criteria that makes the product to be liked and disliked [38]. The taste and aroma of the cookie samples with the addition of CF, were appreciated by evaluators with higher scores than the control sample due to the characteristic aroma given by CF, aroma determined by volatile compounds (series of saturated methyl ketones and a series of saturated delta-lactones) which this flour contains [39]. The crispiness of the products was well accepted by the panelists, as sample CC had a mean value of 7.23±0.12 closely followed by sample C15CF (7.19±0.04), C30CF (7.07±0.05), C45CF (6.92±0.03) and C60CF (6.86±0.06) respectively. However, the observed decrease in crispiness, depending on substitution with non RF levels may be due to moisture uptake by CF [40]. Significant differences were also registered in the case of appearance, thus, sample CC had the highest attributes 6.42±0.03 while samples C45CF had 5.82±0.13 and C60CF had the lowest attributes of 5.56±0.09. For the overall acceptability, sample C45CF was rated highest (7.59±0.04) while sample CC was lowest (6.35±0.13). Similar results regarding the sensory evaluation of cookies with the addition of CF were also obtained by Poonam D. *et.al.* (2013), Makinde F.L. *et. al*. (2019) and Afoakwah N.A. *et. al*. (2019) [31, 33, 35]. Following the sensory analysis of the five assortments of cookies it resulted that gluten-free cookies assortment with 45% CF was the most appreciated in sensory terms.

3.3. Physical parameters of gluten-free cookies

The experimental results obtained in this study, are given in *Table 3:*

Table 3. Physical properties of gluten-free cookie samples

Parameter	Cookies samples evaluated				
	CC	**C15CF**	**C30CF**	**C45CF**	**C60CF**
Weight (g)	9.44±0.03	10.02±0.12	10.54±0.09	11.12±0.13	11.63±0.08
Diameter (mm)	50.41±0.04	50.53±0.03	50.62±0.06	50.74±0.22	50.86±0.12
Thickness (mm)	7.35±0.02	6.96±0.12	6.72±0.23	6.61±0.12	6.54±0.08
Spread ratio	6.21±0.11	6.13±0.09	5.98±0.22	5.82±0.14	5.76±0.12
Water absorption capacity (g)	30.22±0.14	28.29±0.09	26.42±0.22	24.61±0.08	22.23±0.14

All determinations were done in triplicate and the results were reported as average value ± standard deviation (SD).

Baking quality of cookies, such as weight, diameter, thickness, spread ratio and water impregnation capacity were affected by the level of CF in the products. According to the results presented in *Table 3*, the average weight of the cookie samples with the addition of CF varied from 10.02 ± 0.12 g in the case of C15CF to 11.63 ± 0.08 g in the case of C60CF, compared to CC which had an average weight of only 9.44 ± 0.03 g, thus finding that the weight of cookies analyzed in this study, increased in proportion to the ratio of CF incorporated in the dough. Regarding the diameter and average thickness of the analyzed cookie samples, the following were found: the average diameter of the cookie samples increased from 50.53 ± 0.03 mm in sample C15CF to 50.86 ± 0.12 mm in C60CF, compared to CC which presented an average diameter of 50.41 ± 0.04 mm, and the average thickness of the cookie samples decreased from 6.96 ± 0.12 mm in C15CF to 6.54 ± 0.08 mm in C60CF, compared to the CC which showed an average thickness of 7.35 ± 0.02 mm. The results obtained in this case also show that the addition of CF in the dough causes an increase in the diameter and a decrease in the thickness of the cookies compared to the control sample, variations proportional to the ratio of CF added. It has been reported that substitution of wheat flour resulted in lower protein gluten and subsequent decrease in viscosity of cookies dough [41].

According to studies carried out by Abou-Zaid *et. al.* (2012) and Poonam *et.al.* (2013) [35, 42], cookies spread ratio is an important quality parameter, the higher the spread ratio, the higher the product yield will be. According to the data obtained in this study (*Table 3*) the spread ratio in the case of CC was 6.21 ± 0.11 and decreased to 5.76 ± 0.12 in the case of the C60CF sample, thus finding a decrease in this ratio, proportional to the increase in the percentage of added CF.

The results are comparable with other studies, according to which, the cookies thickness has increased, while the diameter and spread ratio decreased proportionally with the ratio of rice, bran-fenugreek blends, fenugreek flour and different bran mixtures [31, 43, 44]. The water absorption capacity of the cookie samples analyzed in this study, decreases from 28.29 ± 0.09 g (C15CF) to 22.23 ± 0.14 g (C60CF) compared to CC which showed a water absorption capacity value of 30.22 ± 0.14 g, which demonstrates that the addition of CF favors the absorption of a smaller amount of water in the product. By analyzing the data obtained in this study, we concluded that mixing RF and CF in different percentages a significant effect on weight, diameter, thickness, spread ratio and water absorption capacity of cookies was recorded.

3.4. Chemical evaluation of gluten-free cookies

Chemical evaluation of gluten-free cookies RF and CF-based are shown in *Table 4:*

Table 4. Chemical evaluation of gluten-free cookies

Chemical composition (%)	Cookies samples evaluated				
	CB	**C15CF**	**C30CF**	**C45CF**	**C60CF**
Moisture	3.22±0.12	3.63±0.22	4.06±0.09	4.54±0.06	4.96±0.09
Fat	11.56±0.06	14.55±0.09	16.34±0.05	18.21±0.14	21.24±0.26
Protein	12.06±0.15	14.94±0.08	16.36±0.22	18.58±0.23	20.18±0.09
Fiber	2.44±0.02	6.65±0.14	7.74±0.06	8.35±0.09	9.74±0.14
Carbohydrates	69.36±0.04	58.52±0.22	53.66±0.09	48.4±0.13	41.74±0.09
Ash	1.28±0.05	1.62±0.12	1.76±0.22	1.84±0.24	2.02±0.33

All determinations were done in triplicate and the results were reported as average value ± standard deviation (SD).

According to the data presented in *Table 4* it can be seen that the moisture of the cookie samples was without exception, higher than that of the CC sample (3.22 ± 0.12%), ranging from 3.63 ± 0.22% in the C15CF sample to 4.96 ± 0.09% in the sample C60CF, but all the values obtained fall within the limits provided by the specialized literature (max. 9%). An explanation for these higher values of cookie samples with the addition of CF than of CC, is the ability of the fibers in CF to absorb a larger amount of water than those in RF, values also mentioned by Singthong *et.al.* (2011), of 4.48 - 8.31% [45], by Poonam *et.al.* (2013), of 5.02% [35] and Afoakwah N.A. *et. al.* (2019), of 6.48-8.26% [33]. The high moisture content is an indication that the product cannot be kept for a long period of time before microbiological degradation sets in [46]. Regarding the fat content of the studied cookie samples, this was higher than in the case of CC (11.56 ± 0.06%), ranging from 14.55 ± 0.09% in the C15CF sample to 21.24 ± 0.26% in the C60CF sample, values attributed to the high fat content found in CF, in almonds and peanuts [14, 23, 24]. The protein content of the cookie samples with added CF, was higher than in the CC sample (12.06 ± 0.15%), ranging from 14.94 ± 0.08% in C15CF to 20.18 ± 0.09 in the case of the C60CF sample, proportional to the ratio of CF added. This is expected, because CF have appreciable quantity of protein (19.56±0.22%) compared to RF (12.78±0.12%) as shown in *Table 1*. *Table 4* shows an increase in the fiber content of cookies, in proportion to the percentage of CF added, ranging from 6.65 ± 0.14% in C15CF to 9.74 ± 0.14 in C60CF, compared to the CC sample which had a fiber content of 2.44 ± 0.02%, results that were consistent with the results presented by Poonam, (2013) [35]. The crude fiber contained by this cookies were within the recommended range for diets of not more than 5g dietary fiber per 100g dry matter (FAO/WHO, 1994) and would enhance gastrointestinal tract and cardiovascular health [47]. The carbohydrate content of the samples analyzed in this study decreased proportionally with the percentage of CF added, thus from 58.52 ± 0.22% (C15CF) to 41.74 ± 0.09% (C60CF), compared to the CC sample that had a carbohydrate content of 69.36 ± 0.04%, thus obtaining an assortment of cookies with low glycemic index. The same trend was observed by Iwe (2007) [37] and wheat flour supplemented with cowpea flour (Okaka and Isieh, 1990) [48].

4. Conclusions

The data obtained from this study have applicative importance but also scientific value, contributing to the expansion of the directions of capitalization of CF in food applications in order to design and develop food formulas with improved functionality. Quantification of all data resulted from this study could lead to new variants of fortified foods with health benefits, integrated into the current diet. The scores for sensorial attributes like taste, aroma and overall acceptability were superior. The nutritional analysis of the gluten-free cookie samples showed that the use of the mixture of 55% RF and 45% CF, together with the other ingredients presented, led to an assortment of cookies with a higher nutritional profile, being rich in fiber, minerals, fats and proteins. The results in this research confirm this mixture is a good source of many important nutrients that appear to have very positive effect on human health and could be used for obtaining potential functional foods. The cookies will be ideal for people of different age groups and most importantly can be consumed by people with gluten intolerance.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human or animal subjects (if exist) respect the specific regulation and standards.

Acknowledgement. The present paper was funded by the Research Project "Research on the use of biologically active substances in order to obtain high-nutrition foods", No 1545/28.02.2019.

This work was performed with the help of the equipment from the "***Food Science***" Research Center, Faculty of Food Engineering, Banat's University of Agricultural Sciences and Veterinary Medicine "*King Michael I of Romania*" from Timişoara

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