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Red kidney bean and rice flours: potential ingredients in the production of gluten-free bread with functional quality

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Abstract

In the present investigation, an effort has been made to prepare functionally enriched gluten-free bread. Legumes are important sources of food proteins and provide well-balanced essential amino acid profiles when consumed with cereals and other foods. Apart from their nutritional properties, legume proteins also possess functional properties that play an important role in food formulation and processing. The objective of this study was to obtain and to characterize some gluten-free flour mixtures with high nutritional value by partially replacing rice flour (RF) with red kidney bean flour (RKBF) and to evaluate the nutritional and sensory characteristics of gluten-free bread obtained from these mixtures. RF was replaced by 10%, 20%, 30% and 40% RKBF. The gluten-free bread samples studied were obtained by the direct method. The obtained results indicate that the incorporation of RKBF up to a level of 40% in the gluten-free bread formula resulted in products with improved sensory and functional properties compared to the control sample (control bread). These findings come as arguments for the use of RKBF in the development of innovative gluten-free bread formulas with added value.

Keywords: red kidney bean flour, gluten free bread, sensory characteristics, nutritional profile

1.Introduction

At present, both nationally and internationally, the food market is experiencing a permanent improvement and diversification, taking into account the satisfaction of preferences, needs and not least, the increasing demands of consumers. This has led to major changes in the quality, distribution and perhaps most important, in the technology of obtaining food products. Thus, the current food products reflect an increasing volume of the technical-scientific evolution. As a result, modern food technology is clearly different from the traditional one. The traditional purpose of food processing is to transform raw materials into edible, safe food products with desirable physical-chemical characteristics and long shelf life. For this purpose, new raw materials and modern procurement technologies are used [1, 2].

Bread is a staple food for a large part of the world's population. The global market for bakery products exceeded $ 310 billion in 2014, with an average growth of 2.3% per year [3, 4]. The possibilities of improving the quality of the bread assortments existing on the Romanian market through the nutritional intervention bring to the attention of the population, products with the addition of active biological compounds, which will contribute to their higher valorization, to the good functioning of the organism and its health. The attainment of these consumer desires is mainly achieved by foods that bring health benefits such as functional bakery products that have an undeniable nutritional value [5].

The flours used in this study to obtain gluten-free bread with functional potential were: rice flour (RF) and red kidney bean flour (RKBF).

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The use as an addition in different proportions of RKBF in the manufacture of gluten-free bread by partial substitution of RF is justified starting from their complex chemical composition, implicitly from their nutritional and biological value.

Red kidney beans (*Phaseolus vulgaris*) are the whole grain consumed in the greatest quantity in the world [6]. Kidney beans are good sources of important nutrients with 22.7% protein, 3.5% mineral matter, 1% fat, 5.1% crude fiber, and 57.7% total carbohydrates. Red kidney beans have low sodium content and saturated fatty acids but are rich in unsaturated fatty acids (linoleic acid) [7]. They are also a good source of soluble and insoluble dietary fiber and display health benefits, which include reduced risk of heart disease and colon cancer [8]. However, red kidney beans as a nutraceutical is yet to gain popularity in the prevention of chronic diseases [9].

According to the World Health Organization (WHO), in order to meet the nutritional needs of older adults, healthy legume-based dishes are highly recommended. Red kidney bean is considered to be a gluten-free grain with high nutritional value. Thus, red kidney bean could be an alternative food for the older adults as well as celiac patient's and healthy consumer [10]. Referring to these observations, the purpose of this paper was to optimize an assortment of gluten-free bread with high nutritional value, through the addition of RKBF.

2.Material and Methods

2.1. Materials

The flours analyzed in this study have been purchased from hypermarkets and specialized stores.

2.2. Methods

2.2.1. Steps in the preparation of flour mixtures: When determining the proportion of RKBF to form a mixture, its physical, chemical and technological characteristics were taken into account. The RKBF proportions used in forming the 4 mixtures were: 10%, 20,%, 30% and 40% compared to RF, as it is known that this flour has a high nutritional value, being rich in proteins, fibers, essential amino acids, minerals and vitamins [6-10]. The 4 flour mixtures that will be used to obtain gluten-free bread are:

Mixture (M1): 90%RF:10%RKBF;
Mixture (M2): 80%RF:20%RKBF;
Mixture (M3): 70%RF:30%RKBF;
Mixture (M4): 60%RF:40%RKBF..

*2.2.2. Proximate composition of flours, flour mixtures and bread samples:*For determining the average chemical composition of flours, flour mixtures and bread samples, the following were determined: moisture content, fat content, ash content, fiber content and carbohydrate content, according to standard method A.O.A.C. 1995 [11]; protein content by the Kjeldahl method, according to standard method A.A.C.C. 2000, No. 46-10 [12]. All determinations were performed in triplicate, calculating their arithmetic mean of three separate determinations. The data were statistically analyzed using the program Microsoft Excel.

*2.2.3. Technological process for obtaining gluten-free bread:*The technological process used to obtain gluten-free bread was the classic one (direct method). Four bread samples from the flour mixtures (**M1 ÷ M4**) and one control sample (**CB:** 100%RF:0%RKBF) were obtained, at each sample adding water - 56%, yeast - 2.5%, salt - 2%. Each flour mixture was added to the bowl of the Hauser DM601 mixer and homogenized at speed 1 for 5 minutes, then salt, yeast previously emulsified with warm water and the rest of water were added and the mixing was continued at speed 1 for 5 minutes and then at speed 2 for 10 minutes until a homogeneous dough was obtained. The dough thus obtained was divided into 500 g pieces, molded, placed in trays and then left to rest at 37°C for 60 minutes. After rest, the dough trays were placed in the oven and baked at 220°C for 55 minutes. After baking, the bread loafs were cooled at room temperature, then packed in cardboard boxes and stored at temperatures of 12ºC [13, 14, 15].

*2.2.4. Sensory evaluation of bread samples:*The bread samples obtained according to the method described in *paragraph 2.2.3.*, were submitted to sensory indices evaluation [16]. Tested groups and control toasts were served to 15 panelists to evaluate color, appearance, flavor, texture, taste, smell, appearance and overall acceptability scores. Panelists were instructed to evaluate each attribute using a scale from 1 (dislike extremely) to 9 (like extremely) using a 9 point hedonic scale.

Toasts coded with a three digits were supplied to them. Each data point from sensory analysis represents an average of twenty panelists. All five samples were served, one at a time, to each taster.

3. Results and discussion

3.1. Proximate composition of flours and flour mixtures

In *Table 1* are shown the results obtained from the proximate analysis of flours and flour mixtures. The results obtained regarding the chemical composition of RKBF compared to that of RF, show its nutritional potential, as a result of the higher content of proteins, raw fibers and minerals. The RKBF sample showed high levels of protein - 21.88% compared to 12.62% in RF, fiber – 4.24% compared to 2.78% in RF, ash - 3.28% compared to 2.72% in RF and lower fat levels - 1.18 % versus 1.52% in RF, carbohydrate - 49.68% compared to 57.99% in RF, results that are consistent with those obtained by Manonmani D. *et.al*. (2014), Mancebo C. M. *et. al*. (2015) and Chompoorat P. *et. al*. (2019) [10, 15, 17]. The carbohydrate content was lower in the case of RKBF compared to RF, which contributes to the decrease of the glycemic index of the products obtained from these flours [15, 17]. Regarding the moisture content of the flour samples analyzed, this was lower in the case of RKBF (9.76%) compared to that of RF (12.37%) [10, 17]. The flour mixtures were marked as: **M1, M2, M3, M4.**

Also, according to the results presented in Table 1, the studied mixtures (M1 ÷ M4) can be considered important "sources of proteins, fibers and minerals". Thus, an increase in protein content proportional to the incorporated RKBF dose can be observed, from 13.55% to M1 and 16.32% to M4. The same linear increase was recorded in the case of fiber content, from 2.93% in M1 to 3.36% in M4, and in that of ash content, from 2.77% in M1 to 2.95% in M4, results that are comparable to those in literature [17, 18, 19]. Dodevska *et al.*, in 2013 showed that the best food items for increasing total fiber, cellulose and resistant starch intake are cooked peas and kidney beans [19].

Regarding the carbohydrate content of the analyzed mixtures (M1 - M4), it can be observed that it decreases linearly from M1 (57.17%) to M4 (54.66%) as the percentage of RKBF added, increases [17, 18]. Regarding the moisture of the four mixtures, it can be observed that, this decreases linearly with the increase of the percentage of RKBF added, from 12.10% in M1 to 11.32% in M4, which makes the use of M1 ÷ M4 mixtures in the manufacturing technology of gluten-free bread to cause a slight prolongation of its freshness period [13, 14].

3.2. Proximate composition of gluten-free bread samples

In *Table 2* are shown the results obtained with regard to the nutritional profile of gluten-free bread samples. The bread samples obtained and analyzed in this study were:

CB: control bread with 100%RF:0%RKBF;
BM1: bread with 90%RF:10%RKBF;
BM2: bread with 80%RF:20%RKBF;
BM3: bread with 70%RF:30%RKBF;
BM4: bread with 60%RF:40%RKBF.

From the data presented in *Table 2* it can be observed that the moisture of all bread samples with the addition of RKBF was higher than that of the CB sample (27.74%), ranging between 28.44% in the BM1 sample and 31.49% in the BM4 sample. The results obtained regarding the chemical composition of the gluten-free bread samples analyzed in this study (*Table 2*), show that the addition of RKBF in the manufacturing recipe caused a significant increase of the nutrient content, thus, the products obtained can be considered products with a high functional potential, being important sources of protein, fiber and minerals [17,19, 20].

Thus, the protein content ranged between 13.79% in BM1 and 16.09% in BM4 compared to 12.28% in CB, fiber content between 6.15% and 8.04% compared to 5.69% in CB sample, and ash content varied between 2.26% in BM1 sample to 2.55% in BM4 sample compared to 2.15% in CB [17, 20]. Regarding the fat content of the analyzed samples, it can be seen from the data presented in *Table 2*, that it was lower for all samples with the addition of RKBF, ranging between 4.22% in BM1 and 4.06% in BM4 compared to 4.31% in CB. The carbohydrate content of the samples analyzed in this study decreased proportionally with the percentage of RKBF thus added, from 45.89% (BM1) to 39.67% (BM4), compared to the CB sample which had a carbohydrate content of 46.45 % [17, 19, 20].

Table 1. Proximate composition of flours and flour mixtures studied

Flours and flour mixtures	Moisture (%)	Fat (%)	Protein (%)	Fiber (%)	Carbohydrates (%)	Ash (%)
RF	12.37±0.24	1.52±0.22	12.62±0.42	2.78±0.15	57.99±0.18	2.72±0.21
RKBF	9.76±0.11	1.18±0.06	21.88±0.55	4.24±0.32	49.68±0.26	3.28±0.08
M1	12.10±0.12	1.48±0.42	13.55±0.09	2.93±0.44	57.17±0.16	2.77±0.04
M2	11.85±0.11	1.45±0.52	14.47±0.25	3.07±0.33	56.33±0.24	2.84±0.18
M3	11.58±0.03	1.41±0.44	15.40±0.29	3.22±0.09	55.53±0.55	2.88±0.33
M4	11.32±0.02	1.38±0.17	16.32±0.04	3.36±0.25	54.66±0.08	2.95±0.06

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

Table 2. Proximate composition of gluten-free bread samples

Proximate composition (%)	Bread samples				
	CB	BM1	BM2	BM3	BM4
Moisture	27.74±0.19	28.44±0.33	29.18±0.28	30.76±0.40	31.49±0.61
Fat	4.31±0.04	4.22±0.27	4.19±0.32	4.12±0.19	4.06±0.39
Protein	12.28±0.27	13.79±0.20	14.36±0.33	15.23±0.62	16.09±0.44
Crude fiber	5.69±0.42	6.15±0.45	6.68±0.26	7.88±0.09	8.04±0.02
Carbohydrates	46.45±0.08	45.89±0.46	43.15±0.23	41.53±0.11	39.67±0.01
Ash	2.15±0.05	2.26±0.35	2.32±0.53	2.48±0.88	2.55±0.09

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

Table 3. Quality attributes scored in sensory assessment of gluten-free bread samples

Parameters	Bread samples				
	CB	BM1	BM2	BM3	BM3
Crust color	6.86±0.14	6.69±0.27	6.51±0.16	6.42±0.13	6.26±0.24
Flavor	6.31±0.03	6.68±0.17	6.12±0.28	7.82±0.22	6.56±0.06
Texture	6.84±0.25	7.49±0.23	7.68±0.22	7.88±0.07	7.43±0.24
Crumb appearance	6.38±0.39	6.49±0.45	6.92±0.44	7.22±0.09	7.05±0.09
Overall acceptability	6.45±0.03	6.88±0.03	7.14±0.09	7.56±0.04	6.18±0.03

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

3.3. Sensory evaluation of gluten-free bread samples

In *Table 3* are shown the results obtained regarding the sensory evaluation of gluten-free bread samples.

The results of the sensory evaluation of the bread samples show significant differences (crust color, crumb appearance, texture, flavor, overall acceptability) between the control sample (CB) and the BM1 ÷ BM4 bread samples. The partial substitution of RF with 10%, 20%, 30% and 40% RKBF in the recipe for the manufacture of gluten-free bread, has led to obtaining bread assortments with optimal sensory attributes, thus highlighting a direct correlation between the dough composition, the technological working parameters and the qualitative properties of this bread assortments. The results obtained regarding the color of the crust and the appearance of the crumb of bread samples showed that the partial substitution of RF with RKBF directly influences these parameters, thus, the scores attributed to the color of the crust decrease from 6.86 in CB to 6.69 in BM1 and 6.26 in BM6, and those attributed to the appearance of the crumba, increase from 6.38 in CB to 7.22 in BM3. The scores attributed to the texture of the analyzed bread samples, increased compared to CB, from 6.84 in CB to 7.88 in MB3. However, comparing the four bread samples (BM1 ÷ BM4) among them, it can be seen that BM3 received the highest score of 7.88 for texture. The increase of the score attributed to the texture of samples BM1 ÷ BM4 compared to CB can be determined by a number of factors that contribute to the final texture of the bread, namely: baking conditions (variable temperature and time); the state of the components of the bread, such as fibers, starch, proteins, amount of water absorbed during dough formation [20, 21, 24].

The use of M1 ÷ M4 mixtures in gluten-free bread resulted in, the panelists attributing higher scores for the flavor compared to the score attributed to CB. The BM3 sample recorded the highest value, 7.82, and the lowest score was reached in CB, 6.31. The increase in the scores attributable to the flavor of BM1 ÷ BM4 samples compared to CB may be due to the reaction products of the Maillard reactions and the caramelization of the simple carbohydrates present in the doughs with increasing addition of RKBF [20, 22, 23].

The sensory evaluation also highlighted that the overall acceptability for all BM1 ÷ BM4 samples ranged from 6.18 to 7.56, compared to CB which received a score of only 6.45. Synthesizing all these data, it can be observed that the BM3 sample proved to be the optimum proportion to be added, in order to obtain the most appreciated sensory assortment of gluten-free bread.

4.Conclusions

The gluten-free bread obtained in this study has an increased content of nutrients such as: protein, fiber and minerals, and a low carbohydrate content. This bread assortment is a natural product, without the addition of preservatives, flavors and synthetic dyes, with nutrient controlled intake, intended for both people with gluten intolerance, as well as healthy people concerned with maintaining their health, people suffering from mild conditions of the digestive tract, diabetics, hypertensive and overweight people. The recommended recipe for this assortment of gluten-free bread, based on the observations from this study is: flour mixture (70% RF: 30% RKBF), 2.5% baking yeast, 2% NaCl, 56% water, kneading time of 15 minutes, the fermentation time of 60 minutes at 37°C, the baking time of the dough: 55 minutes, the baking temperature of the dough: 200-220°C. 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.

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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.

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