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Nutritional and sensory evaluation of gluten-free cake obtained from mixtures of rice flour, almond flour and arrowroot flour

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Abstract

The main purpose of this study was the development and sensory and chemical evaluation of an assortment of gluten-free cake, specially designed for people with celiac disease or diabetes, made of rice flour, almond flour and arrowroot flour. Three cake samples from rice flour, almond flour and arrowroot flour were prepared, added in different proportions (80:10:10%, 60:20:20%, 40:30:30%), mixed with other ingredients and compared with control sample (100:0:0%). Standard procedures were used to estimate the proximate composition of flours and cake samples obtained in this study. The results obtained regarding the chemical composition of the studied cake samples show the superior nutritional profile of all three cake samples (CM1, CM2 and CM3) compared to CC. Following the sensory evaluation of this range of cakes, we can recommend the use of mixture: 60% rice flour: 20% almond flour: 20% arrowroot flour.

Keywords*:* gluten-free cake, almond flour, arrowroot flour, sensory evaluation, nutritional quality

1.Introduction

It is difficult for those who eat wheat to understand celiac disease, gluten intolerance or wheat allergy. One simple visit to the grocery store will demonstrate that our lives depends of wheat and other grains [1]. The incidence of celiac disease or other allergic reactions/intolerances to gluten is rising, the world average of people suffering from celiac disease increases by a factor of 10 in the coming years. The effects are already obvious – more people are asking for high-quality gluten-free products, which has led to a major challenge and increased research for the cereal technologists-bakers who are searching for alternatives to gluten in the manufacture of gluten-free products and for the cereal scientists, respectively [2].

Celiac disease is one of the most common food intolerances worldwide, affecting about 1% of the population and a gluten-free diet was successfully introduced as a treatment in 1950s. While celiac disease is characterized by a flat intestinal mucosa with villous atrophy that leads to malabsorption of nutrients, the clinical manifestations are very complex, which is why many cases remain undiagnosed and assume the risk of long-term complications, such as osteoporosis, anemia or malignancy, in addition to a substantial burden of the disease [3].

Improving textural and flavor attributes for gluten-free products is still a challenge for food technologists, but many products are already available in food stores, supermarkets and online. A variety of gluten-free symbols is used to compare these products, which have to comply with national and international legislation concerning foods for special dietary use for people intolerant to gluten [3].

Gluten-free diet is perceived to be healthier than gluten-containing one, but there has been very little research to evaluate this point of view. According to a study, two separate analyses using conceptually different approaches indicate that gluten-free eating patterns do not have healthier macronutrient or micronutrient profiles, with the exception of lower sodium. On the contrary, based on the results of this study, gluten-free patterns are less optimal for dietary fiber, total protein, vitamin E, magnesium, and potassium [4].

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Gluten-free products should not contain proteins found in all forms of wheat, rye and barley, but can undoubtedly contain proteins from vegetable oils, nuts, seeds as well as gluten-free cereals flours [5].

Almond flour has a high protein content and a special flavor in all dishes, is a beneficial alternative to traditional wheat flour, has a slightly sweet taste and has many benefits compared to wheat flour, such as lowering bad cholesterol and insulin resistance. Almond flour also has a higher caloric content than wheat flour [6].

Rice flour is a healthy replacement for wheat flour for those people who want to have a gluten-free diet. Rice flour is high in protein, contains a higher level of B vitamins, calcium, potassium, thiamin and niacin, iron, fiber, improves blood sugar levels, cholesterol level, help with weight loss, decreases the risk of diventricular disease, colon disease, type-2 diabetes and hypertension [7].

The benefits of arrowroot flour are multiple but the best known are those related to the digestive system, being often used to relieve stomach pain and treat diarrhea. The arrowroot flour is a good source of potassium, has a good content of minerals such as iron, manganese, phosphorus, mangesium, zync and has a low calorie intake. It is also an excellent source of protein, does not contain gluten, so it is perfect for people suffering from celiac disease. Is easily digestible, so it is often used in bread and biscuits for children [8].

Based on these observations, this study aimed to develop a gluten-free product: nutritionally optimized gluten-free cake, which would not have the allergenic factor, but would contain the nutrients needed to correct malabsorption deficiencies created by the disease, intended to be consumed by children and adults suffering from celiac disease.

2. Material and Methods

2.1. Plant Materials

Rice flour (RF), almond flour (ALF), arrowroot flour (ARF) and the other ingredients used in this study were purchased from local market in Timisoara town, Romania.

Steps in the preparation of flour mixtures: In determining the proportion of each flour type to form a mixture, the physical, chemical and technological characteristics of each of these flours were taken into account. In the formation of the three mixtures RF, ALF and ARF were used in variable proportions: Mixture (M1): 80%RF:10%ALF:10%ARF; Mixture (M2): 60%RF:20%ALF:20%ARF; Mixture (M3): 40%RF:30%ALF:30%ARF.

2.2.Methods

Proximate composition of flours: For determining the average chemical composition of RF, ALF and ARF, the following chemical characteristics were determined: moisture, fat content, ash content, crude fiber content and carbohydrate content, according to standard method A.O.A.C. 1995 [9]; protein content by the Kjeldahl method according to standard method A.A.C.C. 2000, No. 46-10 [10]. The carbohydrate content was calculated from difference, using the equation: 100 – (moisture + fat + ash + protein + fibers). All determinations were performed in triplicate, calculating their arithmetic mean of three separate determinations. The data were statistically analyzed using the program Microsoft Excel.

Technological process for obtaining gluten-free cake: The gluten-free cake formulations are presented in *Table 1*. The cake was prepared according to the method described by Turabi *et al.*, (2010) [11] with some modifications. In this study we have obtained 4 types of gluten-free cake, as follows: a control cake (CC) – (100% RF:0%ALF:0%ARF), cake with 10% ALF and ARF addition (CM_1), cake with 20% ALF and ARF addition (CM_2) and cake with 30% ALF and ARF addition (CM_3). Butter and eggs were mixed together for 3 minutes at medium speed with an electric hand mixer. Dry ingredients (flour mixtures, stevia extract, xanthan gum, carob powder, baking powder and salt) were mixed together in a separate bowl, and then added over wet ingredients and mixed first for 2 min at medium speed, then for 1 min at high speed and finally for 2 min at medium speed. The four cake samples were baked in preheated electric oven (Kumatel, Turkey) at 30 minutes at 175°C. After baking, the gluten-free cake samples were cooled at room temperature, then packed in cardboard boxes and stored at temperatures of 12ºC [12, 13].

Table 1. Formulas for gluten- free cake with RF, ALF and ARF

Ingredients (g)	**Gluten-free cake samples**			
	CC	**CM1**	**CM2**	**CM3**
Rice flour (RF)	200	160	120	80
Almond flour (ALF)	0	20	40	60
Arrowroot flour (ARF)	0	20	40	60
Carob powder	50	50	50	50
Butter	100	100	100	100
Stevia extract sweetener	100	100	100	100
Xanthan gum	5	5	5	5
Salt	3	3	3	3
Baking powder	20	20	20	20
Egg	150	150	150	150

Table 2. Proximate composition of RF, ALF and ARF

Chemical composition (%)	**Flour samples**		
	RF	**ALF**	**ARF**
Moisture	10.32±0.09	11.28±0.22	8.92±0.33
Fat	1.68±0.11	36.44±0.14	0.84±0.09
Protein	12.94±0.06	26.74±0.44	8.86±0.12
Crude fiber	3.52±0.03	7.92±0.32	6.54±0.09
Carbohydrates	69.30±0.08	13.22±0.42	70.25±0.23
Ash	2.24±0.05	4.44±0.06	4.59±0.42

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

Table 3. Sensory evaluation of gluten-free cake by 9-point hedonic scales

Samples	**Appearance**	**Colour**	**Texture**	**Flavor**	**Overall acceptance**
CC	6.76 ± 0.04	7.25 ± 0.11	7.52 ± 0.14	7.77 ± 0.32	7.46 ± 0.24
CM1	6.42 ± 0.25	7.44 ± 0.41	7.48 ± 0.42	7.84 ± 0.44	7.66 ± 0.44
CM2	6.68 ± 0.21	7.65 ± 0.32	7.69 ± 0.09	8.14 ± 0.27	7.96 ± 0.62
CM3	6.24 ± 0.06	7.38 ± 0.09	7.38 ± 0.08	8.04 ± 0.08	7.56 ± 0.34

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

Sensory evaluation of gluten free cake with RF, ALF and ARF: A panel of 20 panelists have evaluated gluten-free cake using a 9-point hedonic scale (1=dislike extremely, 5=neither like nor dislike, 9=like extremely). Gluten-free cakes were sliced into half, labeled and offered to the panellists on a white plate at room temperature. All four cake samples were served, one at a time, to each taster. The general appearance, flavour, texture, taste and overall acceptability, were evaluated [12, 13].

Chemical evaluation of gluten free cake with RF, ALF and ARF: In order to evaluate the average nutritional value of gluten-free cake with RF, ALF and ARF, the following parameters were determined: moisture, fat content, protein content, ash content, crude fiber content, carbohydrate content according to A.O.A.C. and A.A.C.C. standard method [9, 10]. The carbohydrate content was calculated from difference, using the equation: 100 – (moisture + fat + ash + protein + fibers).

All determinations were performed in triplicate, calculating their arithmetic mean of three separate determinations. The data were statistically analyzed using the program Microsoft Excel [13, 14, 15].

3. Results and discussion

Proximate composition of RF, ALF and ARF: The results obtained from the proximate analysis of flours are shown in *Table 2*. The results obtained regarding the chemical composition of RF, ALF and ARF, highlight their functional potential. According to these results, ALF and ARF can be considered important "fiber sources" and "mineral sources", as the fiber content ranges between 6.54% in ARF and 7.92% in ALF versus 3.52% in RF, the ash content between 4.44% in ALF and 4.59% in ARF versus 2.24% in RF, results that are consistent with those obtained by Akpakpan A.E. et.al. (2012), Blase, M.E.M *et. al.* (2017), Nugraheni, M. *et. al.* (2017), Raman R. (2017), Wahjuningsih S.B. *et. al.* (2017) [16 - 20].

ALF also had a higher protein content of 26.74% compared to 12.94% in RF and fat of 36.44% compared to 1.68% in RF and a lower carbohydrate content of 13.22% compared to 69.30% in RF, results which are in accordance with those obtained by Moodley R. *et. al.* (2007), Akpakpan A.E. *et.al.* (2012) and Raman R. (2017) [16, 17, 21]. The use of ALF to obtain the gluten-free cake determines the obtaining of a product with low glycemic index due to the low carbohydrate content [22]. In contrast, ARF had a lower protein content of 8.86% compared to 12.94% in RF and fat of 0.84% compared to 1.68% in RF, and a higher carbohydrate content of 70.25% compared to 69.30% in RF, results which are comparable to those obtained by Wahjuningsih S.B. *et. al.* (2017), Blase, M.E.M. *et. al.* (2017) and Nugraheni, M. *et. al.* (2017) [18 - 20]. Analyzing the moisture values (*Table 2*) corresponding to the three flours analyzed, it can be seen that it was lower in the case of ARF (8.92%) and RF (10.32%) compared to that of ALF (11.28%) [16, 19].

Sensory evaluation of gluten free cake with RF, ALF and ARF: Sensory characteristics of gluten-free cake obtained in this study, were influenced mainly by the raw materials (RF, MF and PN) and proportions used in the formulation, the results being presented in the *Table 3*. Experiments showed a direct correlation between the dough composition, working technological parameters and qualitative properties of these cake assortments.

The four assortments of gluten-free cake obtained were sensory evaluated using 9-point hedonic scale by a number of 20 panelists. The analysis of the data presented in *Table 3* showed that the best scores were obtained by the CM2 sample with 20% ALF and 20% ARF, from all points of view for all sensory attributes. The gluten-free cake samples showed changes in flavor depending on the proportion of ALF or ARM added, therefore the lowest score was obtained by the CC sample (flavor - 7.77 ± 0.32) and the highest score by CM2 sample (flavor - 8.14 ± 0.27). The results obtained regarding the appearance, color and texture of the gluten-free cake samples showed that the partial substitution of RF with variable proportions of ALF and ARF directly influences these characteristics, thus, the scores assigned to the aspect decrease from 6.76 in CC to 6.24. in CM3, those attributed to color increase from 7.25 in CC to 7.65 in CM2, and those attributed to texture increase from 7.38 in CM3 to 7.69 in CM2. Previous product attributes influenced the overall acceptability of the gluten free cake, the rate increasing in CM1- 7.66 and CM2 - 7.96 samples compared with CC (7.46) but to CM3 sample, the hedonic rate decreased to 7.56. Summarizing all these data, it can be seen that the CM2 sample was the most appreciated by the panelists, so it can be considered that the addition of 20% ALF and 20% ARF is the optimal proportion that must be used in order to obtain the most appreciated variety of gluten-free cake from the sensory point of view (overall acceptance -7.96) [23, 24].

Chemical evaluation of gluten free cake with RF, ALF and ARF: Results showed in *Figure 1*÷ 6 are the chemical composition of gluten-free cake substituted with different levels of ALF and ARF. The results obtained regarding the chemical composition of the gluten-free cake samples analised in this study, show that the addition of ALF and ARF in the manufacturing recipe, caused a significant increase in nutrient content, so the products obtained can be considered products with a high functional potential, being important sources of minerals and fibers.

From the data presented in *Figure 1* it can be seen that the moisture of the gluten-free cake samples with the addition of ALF and ARF in different proportions, were without exception higher than that of the CC sample (26.86%), ranging from 27.74% in the CM1 sample to 29.66% in the CM3 sample. The moisture values recorded for the studied gluten-free cake fall within the range of values indicated in the literature for semi-finished products cake-type (22 - 32%) [22, 23].

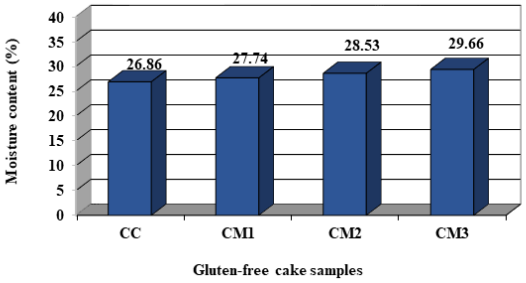

Figure 1. Moisture content of gluten-free cake samples

In *Figure 2*, the variations of the fat content of the studied gluten-free cake samples are presented, observing an increase in the fat content as the proportions of ALF and ARF added increase. It can be observed that in the case of the CC sample, the lipid content is 10.47% followed by an ascending curve from 16.22% in the CM1 sample to 20.28% in

the case of the CM3 sample. ALF being much richer in fat (36.44%) than RF (1.68%) influences the amount of fat registered in the finished product. The fat content of the analyzed cake samples falls within the values provided in the literature data [22, 23].

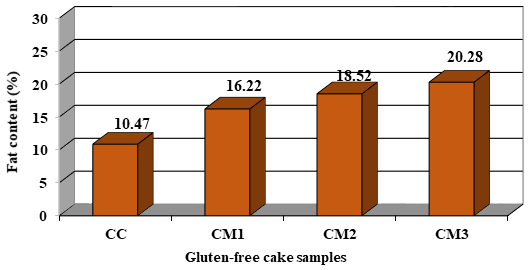

Figure 2. Fat content of gluten-free cake samples

Observing *Figure 3* in which the protein content is represented, there is an increase in protein content as the percentage of added ALF increases, because ALF is richer in protein (26.74%) than RF (12.94%). The CC sample in which ALF and ARF is missing, has a protein content of 12.33% compared to the CM3 sample which contains 22.48% protein. The protein content of the analyzed samples falls within the limits of permissible values provided in the standard as well as those existing in the literature data [22, 24, 25].

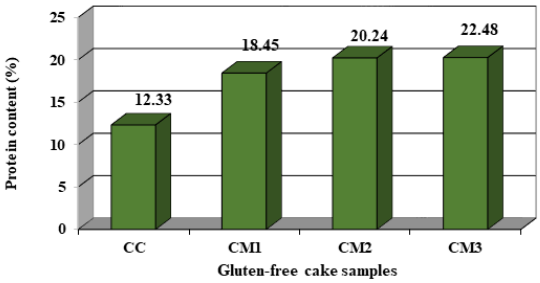

Figure 3. Protein content of gluten-free cake samples

According to the results presented in *Figure 4*, it can be appreciated that the cake samples obtained at a laboratory level have a high fiber content, up to 5.98% in the CM3 sample compared to 3.14% in the CC sample. Among the three gluten-free cake samples with added ALF and ARF, the highest value of fiber content was recorded in the CM3 sample (5.98%), followed by the CM2 sample (5.26%) and the CM1 sample (4.88%) respectively. Given the high fiber content of the studied gluten-free cake samples, due to the raw materials used to obtain them, it is possible to label the product with the statement "Rich in fiber" [22 - 25].

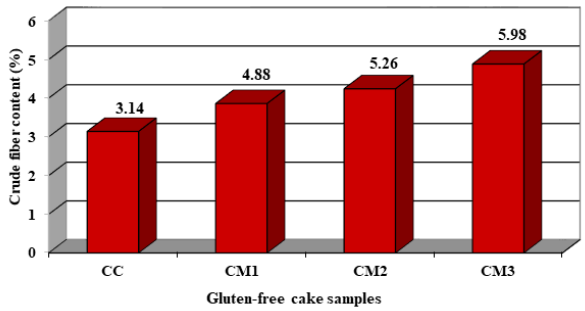

Figure 4. Crude fiber content of gluten free cake samples

The carbohydrate content of the analyzed gluten-free cake samples (*Figure 5*) decreases with increasing percentage of ALF, so the highest value of carbohydrate content was recorded in the CC sample - 45.24%, followed by CM1 sample with 42.33%, CM2 sample with 39.68% and CM3 sample (36.74%). The decrease in carbohydrate content in the studied gluten-free cake samples is due to the low carbohydrate content of ALF (13.22%) compared to RF (69.30%) or ARF (70.25%) [24, 25, 26].

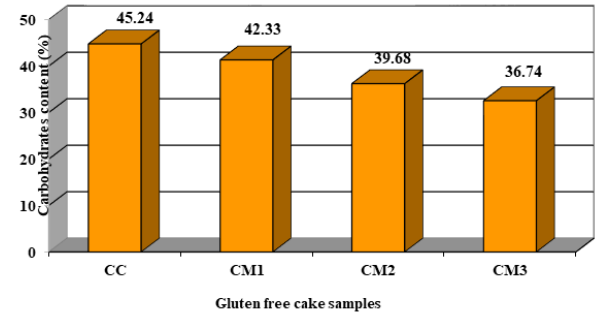

Figure 5. Carbohydrates content of gluten free cake samples

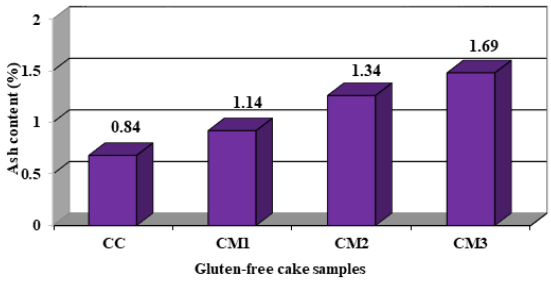

Figure 6. Ash content of gluten free cake samples

The ash content of the analyzed cake samples (*Figure 6*) reflects the level of mineral substances of the cake with the addition of ALF and ARF, and falls within the limits of permissible values provided in the standards, as well as in the existing values in the literature data [22, 23, 26].

The ash content of the three gluten-free cake samples increases in direct proportion to the percentage of ALF and ARF added, thus from 1.14% in the CM1 sample to 1.69% in the CM3 sample, compared to 0.84% in the CC sample.

4. Conclusion

ALF and ARF investigated in this study can be considered as suitable ingredients for gluten-free cake supplementation, due to their high nutritional value. The gluten-free cake obtained from RF, ALF and ARF has a high content of nutrients such as: protein, fiber, fat and ash, and a low content of carbohydrates. The scores for sensory attributes such as flavor, texture and appearance were generally higher. Therefore, the cake with ALF and ARF had better overall acceptability scores than the CC. Correlating the results obtained in terms of sensory and chemical analysis of cake samples, we can appreciate that the recipe established for obtaining the cake with the addition of 20% ALF: 20% ARF can be successfully applied on an industrial scale, thus obtaining both nutritionally and qualitative rich products.

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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