

Rheological, Organoleptical and Quality Characteristics of Gluten-Free Rice Cakes Formulated with Sorghum and Germinated Chickpea Flours

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Abstract

Gluten-free bakery products are produced for people suffering from celiac disease due to sensitivity to gluten. So, the aim of this work was to study the effect of partial substitution of rice flour at 20%, 30% and 40% with sorghum and germinated chickpea flours on rheological, physical, sensory properties and staling rate of prepared gluten-free cake. Obtained results showed that germinated chickpea flour had the highest contents of crude protein (23.62%), lipids (4.89%) and crude fibers (5.76%) as compared to other grain flours. Gradual increase in gelatinization temperature and decrease in maximum viscosity and setback were found of cake batters with increasing the substituting levels of rice flour from 20% to 40% with sorghum or germinated chickpea flours in comparison to rice flour batter. No significant difference was observed in specific volume between rice cake and cake containing 20% of germinated chickpea and sorghum flours which given 2.71, 2.62 and 2.56 cm³/g, respectively. Data also revealed that gluten-free cake lightness (L*) and total intensity significantly increased with 40% of sorghum flour followed by 30 and 20% of sorghum flour. Substitution of 40% rice flour with germinated chickpea flour resulted in significant high in redness (a*), yellowness (b*) and chroma of gluten-free cake being 11.95, 33.72 and 35.77, respectively followed by substituted levels 30% and 20% which attributed to their natural yellow pigments compared with other investigated samples. Overall acceptability of gluten-free cakes was improved after adding 20, 30% of sorghum flour and 20% of germinated chickpea flour which being 90.7, 88.6 and 87.5, respectively compared to rice flour cake (88.4). Rice flour cake was more freshness than wheat flour cake and other treatments during storage duration. After 6 days, rice cake had significant high freshness (306.2%) followed by gluten-free cake samples with 20% of sorghum or germinated chickpea flours which given 294.5% and 289.4%, respectively. Generally, it could be concluded that the

quality and nutritional properties of gluten-free rice cakes could be improved when using 20%, 30% of sorghum flour and 20% of germinated chickpea flour as substitution levels of rice flour.

Keywords

Coeliac Disease, Gluten-Free Cake, Sorghum Flour, Germination Chickpea Flour

1. Introduction

The most common disease caused by cereal protein ingestion is celiac disease. The main agents responsible for celiac disease are gluten proteins from wheat and similar proteins in other related cereals such as barley, rye and oat. The only life-long treatment is strict gluten-free food which is difficult, since many foods contain gluten [1]. Celiac disease is characterized by a strong immune response to certain amino acid sequences found in the prolamin fractions of wheat, barley and rye. When people with celiac disease eat foods containing gluten, their immune system responds by destroying the intestinal villi leading to the malabsorption of nutrients, thus adversely affecting all systems of the body [2].

Gluten-free bakery products that are prepared with gluten-free flours often tend to have reduced quantities of fiber, proteins, iron and B vitamins compared with wheat products [3]. Therefore, a redesign of the gluten-free bakery goods is needed for obtaining products with similar nutritional composition to that of their gluten counterparts. Most of the gluten-free foods produced from starch with the addition of gum. However, the gluten-free formulations containing gums as the gluten replacements lack in fibers and nutrients [4]. Rice flour has been utilized to prepare gluten-free bakery products, such as bread and cake, which are traditionally made with wheat flour. Rice is naturally gluten-free and contains proteins that are known to be nutritious and hypoallergenic [5]. Sorghum (*Sorghum bicolor*) is a gluten-free grain with high potential in the gluten-free food processing. It is the 5th largest crop produced worldwide and has been shown to be safe for celiac disease people [6].

Chickpea (*Cicer arietinum* L.) is an annual grain legume that is cultivated in the Mediterranean basin, the Near East, Central and South Asia, East Africa, South and North America, and Australia for human consumption [7]. It is the second most important pulse crop in the world (after dry bean), covering 14% (7.9 million tons) of pulse production worldwide (FAOSTAT) [8]. Chickpea seed has a high protein digestibility, good balance of amino acid, contains high levels of complex carbohydrates (low glycemic index), is rich in vitamins and minerals and is relatively low levels of anti-nutritional factors [9] [10]. Germination can be improved legume digestibility and reducing flatulence properties, which are some of the factors that restrict consumption. Germinated legumes are a good source of highly bioavailable proteins, starch, lipids and minerals.

Additionally, germinated seeds contain significant amounts of polyphenols with well pro-health properties [11] [12]. Hydrocolloids (such as xanthan gum, guar gum and pectin) are added to naturally gluten-free flour to mimic the viscoelastic properties of gluten and to improve sensory properties, structure, and shelf-life of these products [13] [14].

The aim of the present study is to investigate the effect of partial substitution of rice flour by sorghum and germinated chickpea flours on pasting, physico-chemical, sensory and staling properties of gluten-free rice cakes.

2. Materials and Methods

2.1. Materials

Commercial wheat flour (72% extraction), rice flour, sorghum (*Sorghum bicolour*) grains, chickpea (*Cicer arietinum* L.) seeds, Shortening, nonfat dry milk, sugar, eggs, salt and baking powder were purchased from the local market, Buraidah, Qassim, Saudi Arabia. Xanthan gum was obtained from Sigma chemical Co. (St. Louis, Mo), USA.

2.2. Methods

2.2.1. Preparation of Sorghum Flour

Sorghum grains were cleaned from foreign materials, tempered to 15% moisture content and milled using laboratory mill (3100, Perten Instruments, Sweden) to obtain whole sorghum flour. Sorghum flour was packed in polyethylene bags and stored at (-18°C) until used [15].

2.2.2. Preparation of Germinated Chickpea Flour

Germinated chickpea flour was prepared according to the method described by Fernandez-Orozco *et al.*, [16]. Chickpea seeds were cleaned from all impurities, washed and soaked in four volumes of tap water for 12 h under ambient laboratory conditions (22°C - 25°C). The seeds were allowed to germinate after drained the water under a wet muslin cloth in the dark at 22°C - 25°C for 48 h. The germinated seeds were collected and dried in an air dryer oven at 55°C for 16 h. Germinated seeds were dehulled and milled to flour using a laboratory mill (3100, Perten Instruments, Sweden) and sieved through a 50 mesh screen. The resultant flour was packed in polyethylene bags and stored under frozen condition until used.

2.2.3. Chemical Analysis

Wheat, rice, sorghum and germinated chickpea flours were chemically analyzed for their moisture content, ash, crude protein, lipids and crud fiber contents according to the methods described in AOAC [17]. The nitrogen free extract (NFE) was calculated by difference.

2.2.4. Determination of Tannins and Trypsin Inhibitors

Tannins according to the method of Hagerman [18], and trypsin inhibitors according to the method of Hamerstrand *et al.*, [19] were determined for chickpea

seeds flour before and after germination at 3 days.

2.2.5. Rheological Properties

Rheological properties of the various gluten-free blends consist of rice flour with sorghum or germinated chickpea flours were determined by Barbender Visco-Amylograph according to AACC [20].

2.2.6. Preparation of Gluten-Free Cake Samples

Gluten-free cakes were prepared according to the method of Levent and Bilgicili [21]. The control rice cake was prepared by whipping shortening (150 g) and sugar (150 g) to a white cream in a Hobart mixer (Hobart N50, Canada Inc., North York, Canada). Then egg (150 g) was added and whipped for 5 min, then the other ingredients, rice flour (200 g), nonfat dry milk (10 g), baking powder (9 g), salt (1 g) and xanthan gum (1 g) were added and the batter was mixed for additional 1 min. One hundred and fifty grams of cake batter were placed into baking pans with $7.5 \times 6.5 \times 12$ cm dimensions and baked at 180°C for 40 min in a baking oven (Bosch HBT 112, Athens, Greece). The treatments were carried out by substituted rice flour with sorghum or germinated chickpea flours at 20, 30% and 40%. Also, control wheat flour cake was prepared to compare with the treatments. After baking, gluten-free cakes were cooled for one hour to room temperature ($24^\circ\text{C} \pm 2^\circ\text{C}$), then packaging in polyethylene bags and stored at room temperature for six days.

2.2.7. Specific Gravity of Batter and Measurements of Cakes

Specific gravity of cake batter was calculated according to the method of Jyotsna *et al.*, [22]; weight (g), volume (cm^3) and specific volume (cm^3/g) of different cake samples were measured according to the method of Bennion and Bamford [23].

2.2.8. Color Measurement of Gluten-Free Cakes

Crumb color of gluten-free cakes was evaluated according to the method described by Francis [24] using a Hunter Lab Color QUEST II Minolta CR-400 (Minolta Camera, Co., Ltd., Osaka, Japan) by measuring the L (100 = white; 0 = black), a (+, red; -, green) and b (+, yellow; -, blue) values.

2.2.9. Sensory Evaluation of Gluten-Free Cakes

Gluten-free cake samples were assessed for their quality attributes after baking by ten members preference taste panels of food science and human nutrition department staff. They were asked to score the internal characteristics of cake samples *i.e.* cell uniformity, grain, texture, crumb color and flavor using the respect sheet according to AACC [20].

2.2.10. Determination of Gluten-free Cake Staling

The staling rate of different prepared gluten-free cakes was determined after baking within one hour and after 2, 4 and 6 days of storage at room temperature ($24^\circ\text{C} \pm 2^\circ\text{C}$) by alkaline water retention capacity (AWRC %) according to the AACC 56-10 method AACC [20].

2.2.11. Statistical Analysis

Data were expressed as the means \pm SE. Statistical analysis was carried out using the PROC ANOVA followed by Duncan's Multiple Range Test with $p \leq 0.05$ being considered statistically significant to compare between means according to Snedecor and Cochran [25]. All procedures were plicate using Statistical Analysis System program [26].

3. Results and Discussion

3.1. Chemical Composition of Wheat Flour and Gluten-Free Flours

The proximate chemical composition of gluten-free flours compared to wheat flour used in gluten-free cakes preparation was determined and the obtained data are listed in **Table 1**. It could be observed that wheat and sorghum flours had significant ($p \leq 0.05$) high in moisture content being 13.16% and 12.82%, respectively. On the other hand, used rice flour was containing lower moisture content 8.50%. Germinated chickpea flour showed significant ($p \leq 0.05$) increase in ash (3.10%) followed by 2.58% which given by sorghum flour, while wheat and rice flours were contained lower amounts of ash being 0.52 and 0.44%, respectively. Also, results in the same table revealed that the highest contents of crude protein (23.62%), lipids (4.89%) and crude fibers (5.76%) were given by germinated chickpea flour when compared to other used materials. These results are in agreement with Yousif and Faid [27] who found that germination caused increased of crude protein, amino acid contents, total dietary fiber, soluble and insoluble dietary fibers. In addition, rice flour has significant ($p \leq 0.05$) high of nitrogen free extract (88.22%) followed by wheat flour which recorded 85.75%, while the lowest nitrogen free extract (62.63%) was given by germinated chickpea flour. Similar findings are in accordance with Ranjbar *et al.*, [28] in chemical composition of rice flour. Leaching out of solid matter during soaking in water before germination resulted in significant reduction of nitrogen free extract content of germinated legume flour [29] [30].

3.2. Tannins and Trypsin Inhibitors of Chickpea Flour

The antinutritional factors of raw and germinated chickpea flours were determined and the data are illustrated by **Figure 1**. It could be found that germina-

Table 1. Proximate composition of wheat flour and gluten-free flours (% on dry weight basis).

Treatments	Moisture	Ash	Crude protein*	Lipids	Crude fiber	Nitrogen free extract (NFE)**
Wheat flour	13.16 \pm 0.07 ^a	0.52 \pm 0.04 ^c	10.73 \pm 0.11 ^b	1.85 \pm 0.06 ^b	1.15 \pm 0.09 ^c	85.75 \pm 0.23 ^b
Rice flour	8.50 \pm 0.12 ^c	0.44 \pm 0.06 ^c	9.56 \pm 0.23 ^c	1.28 \pm 0.11 ^c	0.50 \pm 0.08 ^d	88.22 \pm 0.13 ^a
Sorghum flour	12.82 \pm 0.17 ^a	2.58 \pm 0.09 ^b	8.38 \pm 0.06 ^d	2.25 \pm 0.14 ^b	3.51 \pm 0.12 ^b	83.28 \pm 0.11 ^c
Germinated chickpea flour	9.48 \pm 0.17 ^b	3.10 \pm 0.05 ^a	23.62 \pm 0.29 ^a	4.89 \pm 0.17 ^a	5.76 \pm 0.21 ^a	62.63 \pm 0.32 ^d

Data are the mean \pm SE; n = 3, Values followed by the same letters in the same column are not significantly different ($p \leq 0.05$). (NFE)**: calculated by difference. *Wheat, sorghum and rice flours ($N \times 5.70$) while, chickpea flour ($N \times 6.25$).

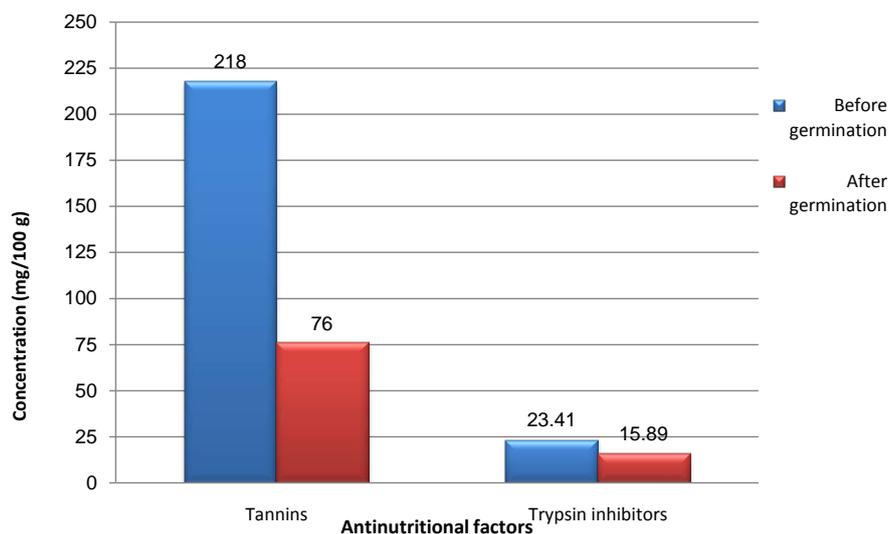


Figure 1. Tannins and trypsin inhibitors contents of raw and germinated chickpea flours.

tion has positive effect on reduction of tannins and trypsin inhibitors concentrations in germinated chickpea flour. Tannins level was decreased from 218 mg/100g in raw chickpea flour to 76 mg/100g in germinated chickpea flour. In addition, the raw chickpea flour was contained 23.41 mg of trypsin inhibitors activity/100g which reduced by germination procedure to 15.89 mg/100g in germinated chickpea flour. These results are going in parallel with those of Ghavidel and Prakash [31]; Yousif and Faid [27]. Cevallos-Casals, and Cisneros-Zevallos [11] reported that germinated legumes are a good source of highly bioavailable proteins, starch, lipids and minerals. Also, Legume digestibility was improved by germination and reducing the flatulence properties, which are the main factors that restrict of consumption.

3.3. Visco-Amylograph Parameters of Gluten-Free Blends

Visco-amylograph properties are functions of the various parameters of flour like shape, size, hydrophilic and hydrophobic balance of the molecules, carbohydrates associated with proteins, solubility of starch and thermodynamic properties of the system [32]. Data in **Table 2** show the visco-amylogram results of rice flour and its blends with sorghum and germinated chickpea flours which used for gluten-free cake preparation. It could be found that increasing of substituting levels of rice flour with sorghum or germinated chickpea flours from 20 to 40% resulted in gradually increased in gelatinization temperature from 69.7 to 76.5°C in case of sorghum flour and from 73.2°C to 77.4°C in case of germinated chickpea flour. Also, the temperature at maximum viscosity was increased as a result to increasing the gelatinization temperature when compared to 91.5°C for rice flour. Pasting temperature provides an indication of the minimum temperature required to cook the flour [33]. The decrease in maximum viscosity of gluten-free blends was observed from 530 to 450 B.U for substituting rice flour with sorghum flour at 20% to 40%, respectively and from 420 to 350 B.U when subs-

Table 2. Visco-amylograph parameters of wheat flour and gluten-free flours blends.

Treatments	Gelatinization temp. °C	Maximum Viscosity		Viscosity at 95 °C (B.U)	Viscosity at 50 °C (B.U)	Setback (B.U)
		°C	B.U*			
Wheat flour	61.8	88.7	525	412	608	196
Rice flour (RF)	66.3	91.5	580	520	980	460
RF 80% with SF 20%	69.7	93.0	530	430	860	430
RF 70% with SF 30%	73.0	93.5	480	390	750	360
RF 60% with SF 40%	76.5	95.0	450	340	660	320
RF 80% with GCF 20%	73.2	93.0	420	390	790	400
RF 70% with GCF 30%	75.6	95.5	380	370	630	260
RF 60% with GCF 40%	77.4	97.0	350	320	540	220

SF: Sorghum flour; GCF: Germinated chickpea flour; *B.U: Brabender Unit, Setback = viscosity at 50 °C - viscosity at 95 °C.

tituting rice flour with germinated chickpea flour at 20% to 40%, respectively in comparison to 580 B.U for rice flour. These results may be attributed to the low content of carbohydrates (NFE) in each of sorghum and germinated chickpea flours which recorded 83.28 and 62.63%, respectively compared to rice flour 88.22 (Table 1). Incorporation of protein isolates with rice flour decreased paste peak viscosity and increased batter viscoelasticity [34].

The general trend of viscosity at 95 °C and at 50 °C is the reduction with increasing the replacement ratio or rice flour with sorghum and germinated chickpea flours. Whereas, viscosity at 95 °C ranged between 430 and 320 B.U for 20% of sorghum flour and 40% of germinated chickpea flour, respectively compared to 570 B.U for rice flour, as well as viscosity at 50 °C ranged from 860 to 540 B.U for 20% of sorghum flour and 40% of germinated chickpea flour, respectively compared to 980 B.U for rice flour. These findings are in harmony with those obtained by Yousif and Faid [27] as they found gradually decreased in maximum viscosity with increasing the replacement levels of corn and rice flour mixture at 10%, 20% and 30% with dehulling sweet lupine or chickpea flours. It could be also noticed that maximum viscosity, viscosity at 95 and 50 °C of wheat flour were lower than those for rice flour. Setback viscosity is the gelling of cooked starch that occurs as straight chain amylose molecules begin to realign and form a stable gel structure. Setback measure of retrogradation tendency of starch upon cooling of cooked starch pastes [35]. Rice flour had the highest setback value (460 B.U) and the substituting levels 20, 30 and 40% of rice flour with sorghum and germinated chickpea flours caused a reduction of setback of blends. Shevkani, *et al.*, [36] stated that with increasing levels of protein isolates in rice flour, breakdown viscosity was decreased indicated that more proteins gave the starch granules a greater stability at high temperature. Ouazib, *et al.*, [37] reported that pasting properties of the wheat-chickpea blends were significantly modified due to wheat flour replacement by 10% and 20%.

3.4. Cake Batters and Gluten-Free Cakes Measurements

The amount of air incorporated into a cake batter can be evaluated by measuring the batter's specific gravity; whereas low specific gravity is indicated good aeration of batter [38] [39]. Specific gravity of cake batters are illustrated by **Figure 2** and physical properties of prepared gluten-free cake are given in **Table 3**. Statistical analysis of results observed that addition sorghum and germinated chickpea flours with rice flour resulted in significant ($p \leq 0.05$) increase in specific gravity of batters when compared to rice flour batter. No significant ($p \leq 0.05$) difference was found between specific gravity of rice flour batter, 20 and 30% sorghum flour which recorded 0.87, 0.88 and 0.90, respectively. On the other hand, the highest specific gravity values 0.99 and 0.95 were given by incorporated 40% of germinated chickpea flour and 40% of sorghum flour, respectively.

Concerning to gluten-free cake properties in **Table 3**, No significant ($p \leq 0.05$)

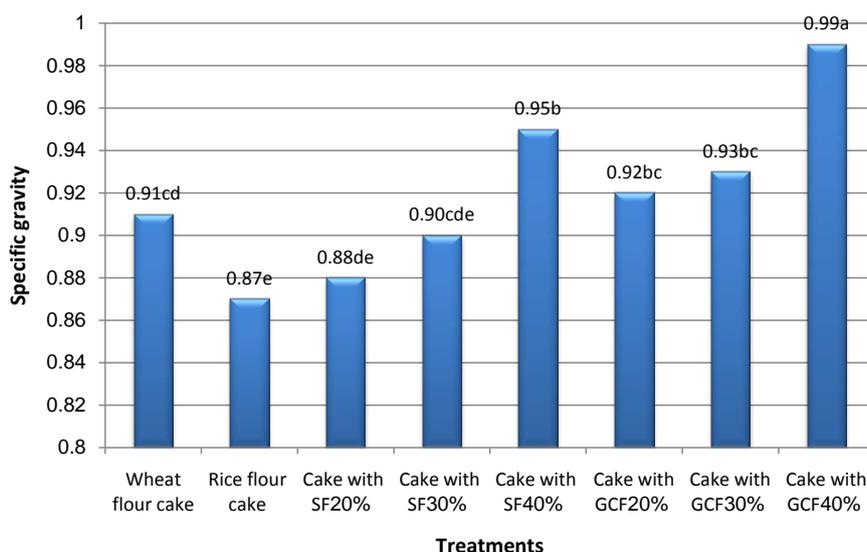


Figure 2. Specific gravity of gluten-free batters with sorghum and germinated chickpea flours.

Table 3. Physical measurements of prepared gluten-free rice cakes.

Treatments	Cake weight (g)	Cake volume (cm ³)	Specific volume (cm ³ /g)
Wheat flour cake	133.8 ± 0.81 ^{ab}	375 ± 3.48 ^a	2.80 ± 0.02 ^a
Rice flour cake	128.5 ± 0.86 ^b	348 ± 7.32 ^{bc}	2.71 ± 0.11 ^{ab}
Cake with 20% SF	135.3 ± 0.77 ^{ab}	345 ± 2.88 ^{bc}	2.56 ± 0.13 ^{bc}
Cake with 30% SF	137.6 ± 0.46 ^a	337 ± 1.73 ^{bc}	2.44 ± 0.01 ^c
Cake with 40% SF	138.6 ± 0.58 ^a	290 ± 5.77 ^d	2.09 ± 0.03 ^d
Cake with 20% GCF	135.4 ± 1.31 ^{ab}	355 ± 2.88 ^{ab}	2.62 ± 0.02 ^{abc}
Cake with 30% GCF	138.1 ± 3.53 ^{ab}	327 ± 7.50 ^c	2.37 ± 0.03 ^{bc}
Cake with 40% GCF	141.2 ± 0.58 ^a	275 ± 8.66 ^d	1.95 ± 0.07 ^d

SF: Sorghum flour; GCF: Germinated chickpea flour; Data are the mean ± SE, n = 3, Mean values in the same column bearing the same superscript do not differ significantly ($p \leq 0.05$).

difference was appeared in cake weights between all of treatments except cake prepared from only rice flour which recorded the lowest value (128.5 g). Gradually increase was found in cake weight from 135.3 to 138.6 g and from 135.4 to 141.2 g when increasing levels from 20% to 40% of sorghum flour and from 20% to 40% of germinated chickpea flour, respectively. These results may be due to the high crude fiber content in sorghum and germinated chickpea flours which characterized by high water holding capacity (**Table 1**).

As expected, wheat flour cake had the highest volume 375 cm³ followed by gluten-free cake with 20% germinated chickpea flour which given 355 cm³ and without significant difference. Contrarily, using 40% of sorghum flour or germinated chickpea flour lead to significant ($p \leq 0.05$) decrease in cake volume being 290 and 275 cm³, respectively as compared to rice flour cake 348 cm³. These results are in agreement with Gomez *et al.*, [40] and Herranz, *et al.*, [12] as they reported that supplemented of cakes with chickpea flour resulted in lower gas retention and lower expansion of cake and the volume was decreased with increasing levels of chickpea flour.

Specific volume of cakes is depending on cake volume so; a similar trend was observed. It could be easily to say that, no significant ($p \leq 0.05$) difference was observed in specific volume between wheat cake, rice cake and cake containing 20% germinated chickpea flour which given 2.80, 2.71 and 2.62 cm³/g, respectively. Moreover, with increasing of sorghum or germinated chickpea flours levels in gluten-free cake, the specific volume was slightly decreased. Levent and Bilgicli [21] reported that cakes volume index improved with buckwheat flour at 5% or lupine flour up to 20% levels compared to control. Ouazib, *et al.*, [37] stated that germinated chickpea flour was the most appropriate flour for wheat replacement up to 20% pertaining bread specific volume, crumb hardness and nutritional composition (higher protein content).

3.5. Color Attributes of Gluten-Free Cakes

Color is one of the most important sensory attribute that affect directly the consumer preference of any product. Crumb color of gluten-free cakes prepared from rice flour with 20%, 30% and 40% of sorghum or germinated chickpea flour was determined and obtained results are tabulated in **Table 4**. Gluten-free cake containing 40% sorghum flour had significant ($p \leq 0.05$) high in lightness (L*) being 73.88 followed by 68.57 and 65.45 which given by incorporated 30 and 20% of sorghum flour in gluten-free cake. On the other hand, germinated chickpea flour at 40% in cake caused significant ($p \leq 0.05$) low in lightness (darker) being 56.87 followed by 59.60 which recorded by 30% of germinated chickpea flour when compared to wheat and rice cakes. Such findings are in agreement with Hussein *et al.*, [41] as they found that gluten-free cake prepared from germinated rice flour was darker than cake with sorghum, rice and wheat flours.

Millard reaction fails to take place in cake crumb because it does not reach above 100°C, therefore crumb color reflects of used raw materials colors and

Table 4. Crumb color parameters of prepared gluten-free rice cake samples.

Treatments	L*	a*	b*	Total Intensity (I)	Chroma (C)
Wheat flour cake	62.70 ± 0.55 ^d	8.83 ± 0.08 ^c	21.57 ± 0.43 ^g	63.31 ± 0.56 ^d	23.31 ± 0.38 ^f
Rice flour cake	64.04 ± 0.14 ^c	5.13 ± 0.07 ^e	19.47 ± 0.11 ^h	65.24 ± 0.13 ^c	20.14 ± 0.12 ^g
Cake with 20% SF	65.45 ± 0.25 ^c	4.55 ± 0.02 ^f	24.34 ± 0.47 ^f	65.62 ± 0.25 ^c	24.77 ± 0.48 ^e
Cake with 30% SF	68.57 ± 0.07 ^b	3.86 ± 0.34 ^g	27.23 ± 0.09 ^e	68.67 ± 0.08 ^b	27.53 ± 0.14 ^d
Cake with 40% SF	73.88 ± 0.38 ^a	3.15 ± 0.09 ^h	31.45 ± 0.10 ^b	73.95 ± 0.38 ^a	31.60 ± 0.09 ^b
Cake with 20% GCF	62.74 ± 0.28 ^d	7.55 ± 0.06 ^d	28.82 ± 0.28 ^d	63.19 ± 0.27 ^d	29.79 ± 0.29 ^c
Cake with 30% GCF	59.60 ± 0.29 ^e	10.34 ± 0.05 ^b	30.59 ± 0.02 ^c	60.49 ± 0.30 ^e	32.29 ± 0.04 ^b
Cake with 40% GCF	56.87 ± 0.37 ^f	11.95 ± 0.19 ^a	33.72 ± 0.12 ^a	58.12 ± 0.32 ^f	35.77 ± 0.05 ^a

SF: Sorghum flour; GCF: Germinated chickpea flour; Data are the mean ± SE, n = 3, Mean values in the same column bearing the same superscript do not differ significantly ($P \leq 0.05$). L*: lightness; a*: redness; b*: yellowness.

their interactions [40]. It could be noticed that substituted rice flour at 40% with germinated chickpea flour in gluten-free cake resulted in significant ($p \leq 0.05$) increase in redness (a*), yellowness (b*) and chroma being 11.95, 33.72 and 35.77, respectively followed by substituted levels 30 and 20% compared with other treatments, wheat and rice cake samples. These results may be due to the natural pigments in germinated chickpea flour which had a positive effect on yellowness of prepared gluten-free cakes. Shevkani *et al.*, [34] Mentioned that white cowpea protein isolate influenced crumb color of gluten-free rice muffin (L*, a* and b*) marginally whereas red cowpea protein isolate increased a* while decreased L* and b* significantly.

The same trend of lightness was found in case of cake total intensity, whereas cake sample containing 40% sorghum flour exhibited significant ($p \leq 0.05$) increase in total intensity value 73.95 followed by incorporated levels 30 and 20% which recorded 68.67 and 65.62, respectively compared to other selected treatments. Xu and Diosady, [42] reported that the differences in protein sources color might be due to the presence of different coloring constituents in the flours, like polyphenols, that might have interacted with the proteins.

3.6. Sensory Characteristics of Gluten-Free Cakes

The influence of substitution different levels of rice flour with sorghum or germinated chickpea flours on sensory quality of gluten-free cake was evaluation and data are found in Table 5. It was clear that wheat flour cake had the highest values with significant high in all sensory scores except crumb color in comparison with rice cake and other substituted treatments. Incorporated of sorghum flour at 20% in prepared cake caused significant ($p \leq 0.05$) increase in cake cell uniformity, grain and texture being 27.4, 18.5 and 27.5, respectively when compared to 26.4 which given by rice flour cake. Also, no significant ($p \leq 0.05$) difference was observed in gluten-free cake texture prepared with 30% of sorghum flour and 20% of germinated chickpea flour with rice flour cake. On the other

Table 5. Mean scores of sensory characteristics of prepared gluten-free cakes.

Treatments	Cell uniformity (30)	Grain (20)	Texture (30)	Crumb color (10)	Flavor (10)	Overall acceptability (100)
Wheat flour cake	28.6 ± 0.12 ^a	19.3 ± 0.09 ^a	29.4 ± 0.11 ^a	8.7 ± 0.06 ^c	9.5 ± 0.12 ^a	95.6 ± 0.28 ^a
Rice flour cake	26.4 ± 0.16 ^c	17.7 ± 0.17 ^{cd}	26.6 ± 0.32 ^c	9.1 ± 0.10 ^b	8.5 ± 0.11 ^b	88.4 ± 0.22 ^c
Cake with 20% SF	27.4 ± 0.15 ^b	18.5 ± 0.10 ^b	27.5 ± 0.33 ^b	9.3 ± 0.20 ^{ab}	8.4 ± 0.10 ^b	90.7 ± 0.34 ^b
Cake with 30% SF	26.2 ± 0.13 ^c	18.0 ± 0.21 ^{bc}	26.6 ± 0.12 ^c	9.2 ± 0.05 ^{ab}	8.6 ± 0.16 ^b	88.6 ± 0.41 ^c
Cake with 40% SF	23.5 ± 0.15 ^e	17.4 ± 0.15 ^{de}	22.7 ± 0.12 ^e	9.5 ± 0.09 ^a	8.0 ± 0.21 ^c	81.2 ± 0.33 ^e
Cake with 20% GCF	25.4 ± 0.14 ^d	17.0 ± 0.21 ^{ef}	27.0 ± 0.22 ^{bc}	8.6 ± 0.11 ^c	9.3 ± 0.10 ^a	87.5 ± 0.50 ^c
Cake with 30% GCF	24.9 ± 0.21 ^d	16.7 ± 0.25 ^f	25.7 ± 0.24 ^d	7.6 ± 0.16 ^d	8.5 ± 0.15 ^b	83.6 ± 0.62 ^d
Cake with 40% GCF	21.5 ± 0.33 ^f	13.7 ± 0.24 ^g	22.4 ± 0.15 ^e	6.4 ± 0.15 ^e	7.4 ± 0.13 ^d	71.5 ± 0.76 ^f

SF: Sorghum flour; GCF: Germinated chickpea flour; Data are the mean ± SE, n = 10, Mean values in the same column bearing the same superscript do not differ significantly (p ≤ 0.05).

hand, adding 40% of germinated chickpea flour in gluten-free cake preparation resulted in significant (p ≤ 0.05) decreased in all organoleptic parameters as compared to wheat, rice flours cake and investigated samples. These obtained results may be related with results of specific volume of prepared gluten-free cake which found in **Table 3**. Whereas, the cake samples prepared with 20 and 30% of sorghum flour and 20% of germinated chickpea flour which recorded high values in specific volumes were accepted by panelists in cake cell uniformity, grain and texture when compared with other replacement concentrations of sorghum flour and germinated chickpea flour. These results are in agreement with Hussein *et al.*, [41] as they indicated that grain, texture, and flavor properties of gluten-free cake samples were not affected significantly when using sorghum, gelatinized corn, germinated rice, rice flours, and their mixture when compared with control wheat flour cake.

It was clearly noticed that using sorghum flour at substitution levels 20%, 30% and 40% in gluten-free cake preparation caused significant (p ≤ 0.05) high in crumb color which recorded 9.3, 9.2 and 9.5, respectively as compared to wheat and rice flours cakes. These results may be attributed to the high lightness (L*) color of sorghum flour used in this study (**Table 4**) and with increasing substitution levels from 20% to 40% of sorghum flour, the crumb color of prepared gluten-free cake was improved as indicated by the panelists. Man *et al.*, [43] stated that the bread slices color became visually darker as the chickpea flour level increased. Also, a darker color of the crumbs was reported by Fărcaș *et al.*, [44] and linked directly to increased fiber content and to the high content in carotenoids.

As can be expected, wheat flour cake had the highest score of flavor (9.5) followed by cake prepared with 20% of germinated chickpea flour which given 9.3 and without significant difference between them when compared with other gluten-free cake samples. In addition, no significant (p ≤ 0.05) difference was found in cake flavor between rice flour cake being 8.5 with 20, 30% of sorghum

flour and 30% of germinated chickpea flour which recorded 8.4, 8.6 and 8.5, respectively. The same trend was found for overall acceptability which improved when adding 20%, 30% of sorghum flour and 20% of germinated chickpea flour in gluten-free cake which being 90.7, 88.6 and 87.5, respectively as compared to rice flour cake (88.4). Moreover, substituting of rice flour at 40% with sorghum or germinated chickpea flour in cake preparation resulted in significant ($p \leq 0.05$) decrease and were rejected by panelists in overall acceptability which given 81.2 and 71.5, respectively. Preichardt *et al.*, [45] reported that 0.3% and 0.4% of xanthan gum produced desirable sensory gluten-free cakes with high acceptance by the consumers. The cakes resembled physically and sensorial to the control cake made with only wheat flour. From the previous results, it could be concluded that gluten-free cake quality could be enhanced when using sorghum flour at 20, 30% and germinated chickpea flour at 20% as a substitution levels of rice flour in gluten-free cake processing.

3.7. Staling Rate of Gluten-Free Cake Samples

Results in **Table 6** showed staling rate (freshness) of gluten-free cake samples prepared with substituting of rice flour at 20%, 30% and 40% by sorghum or germinated chickpea flours during six days of storage at room temperature ($24^\circ\text{C} \pm 2^\circ\text{C}$). Data indicated that rice flour cake was more freshness than wheat flour cake and other treatments during all storage duration. Similar results were obtained by Hussein *et al.* [41], they found that rice cake sample producing from rice flour had the highest values of freshness. Also, there was gradually increase in staling (low AWRC %) of gluten-free cake with all partial replacement levels and with storage periods up to 6 days. At zero time, no significant ($p \leq 0.05$) difference was observed in staling between cake samples containing 20% of sorghum or germinated chickpea flours which recorded 357.2% and 352.3%, respectively. After 2 and 4 days of storage, it could be seen that with increasing of

Table 6. Staling rate (AWRC %) of gluten-free cakes during storage periods at room temperature ($24^\circ\text{C} \pm 2^\circ\text{C}$).

Treatments	Storage periods (days)			
	0	2	4	6
Wheat flour cake	365.8 \pm 1.07 ^{Ab}	352.6 \pm 1.33 ^{Bb}	327.2 \pm 1.58 ^{Cb}	304.8 \pm 2.09 ^{Da}
Rice flour cake	381.4 \pm 3.49 ^{Aa}	367.8 \pm 1.76 ^{Ba}	335.7 \pm 1.06 ^{Ca}	306.2 \pm 2.95 ^{Da}
Cake with 20% SF	357.2 \pm 2.03 ^{Ac}	343.7 \pm 0.98 ^{Bc}	328.8 \pm 3.58 ^{Cb}	294.5 \pm 2.31 ^{Db}
Cake with 30% SF	336.8 \pm 2.33 ^{Ad}	321.8 \pm 1.46 ^{Be}	304.9 \pm 2.60 ^{Cd}	283.1 \pm 1.73 ^{Dc}
Cake with 40% SF	327.5 \pm 1.74 ^{Ae}	314.3 \pm 1.81 ^{Bf}	275.6 \pm 2.89 ^{Cf}	261.5 \pm 0.86 ^{De}
Cake with 20% GCF	352.3 \pm 1.65 ^{Ac}	337.4 \pm 2.61 ^{Bd}	316.5 \pm 1.90 ^{Cc}	289.4 \pm 0.92 ^{Db}
Cake with 30% GCF	339.2 \pm 1.44 ^{Ad}	319.7 \pm 2.65 ^{Bef}	297.3 \pm 1.15 ^{Ce}	272.6 \pm 0.94 ^{Dd}
Cake with 40% GCF	312.6 \pm 2.02 ^{Af}	294.3 \pm 1.64 ^{Bg}	268.4 \pm 3.58 ^{Cg}	248.3 \pm 1.73 ^{Df}

SF: Sorghum flour; GCF: Germinated chickpea flour; Data are the mean \pm SE, $n = 3$, Values followed by the same capital letters in the same row; and values followed by the same small letters in the same column are not significantly different ($p \leq 0.05$).

substituting levels from 20% to 40% with sorghum or germinated chickpea flours, the freshness of resulted cake samples was significantly ($p \leq 0.05$) decreased as compared with wheat or rice flour cakes. Moreover, gluten-free cake samples containing 40% of sorghum or germinated chickpea flours had the highest firmness values beginning of storage time and until 6 days of storage. The same trend was observed after 6 days whereas, rice cake had significant ($p \leq 0.05$) high in freshness being 306.2% followed by gluten-free cake samples with 20% of sorghum or germinated chickpea flours which given 294.5% and 289.4%, respectively. Generally, it could be concluded that the results of staling rate of gluten-free cakes were compatible with those of sensory evaluation in **Table 5** where the best substituting levels in gluten-free cake were 20, 30% of sorghum flour and 20% of germinated chickpea flour. Preichardt *et al.*, [45] reported that the gluten-free cakes firmness increased with the length of storage, but the xanthan postponed the hardening of the cakes.

4. Conclusion

It could be concluded that gluten-free cakes enriched in crude protein, fibers and minerals can be prepared by substituting of rice flour with sorghum and germinated chickpea flours. With increasing the substituting levels of rice flour from 20% to 40% with sorghum or germinated chickpea flours, maximum viscosity and setback of cake batters were decreased compared with rice flour batter. No significant difference was found in specific volume between wheat cake, rice cake and cake with 20% germinated chickpea flour. Previous results suggested that using sorghum flour at 20, 30% and germinated chickpea flour at 20% as substitution levels of rice flour produced the healthy gluten-free cakes with acceptable freshness and sensory properties for coeliac patients. Future studies will be needed for evaluating the effect of other grains and legumes on quality and consumer acceptable of enriched gluten-free cakes.

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