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THE EFFECTS OF CHIA (*Salvia hispanica* L.) AND QUINOA FLOURS ON THE QUALITY OF RICE FLOUR AND STARCH BASED-CAKES

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ABSTRACT
The rice flour and corn starch mixture used in the gluten-free cake formulation was replaced with chia flour (CF) and quinoa flour (QF) up to 25% CF and 25% QF level. The effects of CF and QF on the physical, chemical and sensory properties of gluten-free cakes were investigated. CF and QF replacement increased the ash, protein, fat, total phenolic content and antioxidant capacity of gluten-free cakes by 1.5, 1.8, 1.3, 3.5 and 2.9 times, respectively, when compared to the control samples. Statistically significant increases were found in Ca, P, K, Mg, Fe and Zn contents of cake samples (P <0.05). The cakes containing CF and QF, received higher texture and taste-odour scores than control. According to the sensory analyses results it can be concluded that QF and CF can be used in gluten-free cakes up to 20% and 20% levels, respectively.
Keywords: Chia, quinoa, gluten-free cake, cake quality.

CHIA (*Salvia hispanica* L.) VE KİNOA UNLARININ PİRİNÇ UNU VE NİŞASTA BAZLI KEKLERİN KALİTESİ ÜZERİNE ETKİLERİ

ÖZ
Glutensiz kek formülasyonunda kullanılan pirinç unu ve mısır nişastası karışımı, %25 chia unu (CF) ve %25 kinoa unu (QF) oranına kadar CF ve QF ile yer değiştirilmiştir. Glutensiz keklerin fiziksel, kimyasal ve duyusal özelliklerine CF ve QF'nin etkisi araştırılmıştır. CF ve QF'nin kullanımı, kontrol örnekleri ile karşılaştırıldığında glutensiz keklerin kül, protein, yağ, toplam fenolik içeriğini ve antioksidan kapasitesini sırasıyla 1.5, 1.8, 1.3, 3.5 ve 2.9 kat artırmıştır. Kek örneklerinin Ca, P, K, Mg, Fe ve Zn içeriklerinde istatistiksel olarak önemli artışlar belirlenmiştir (P <0.05). CF ve QF içeren kekler, kontrolden daha yüksek tekstür ve tat-koku puanı almıştır. Duyusal analiz sonuçlarına göre QF ve CF'nin sırasıyla %20 ve %20 oranına kadar glutensiz keklerde kullanılabileceği sonuçuna varılmıştır.
Anahtar kelimeler: Chia, kinoa, glutensiz kek, kek kalitesi

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INTRODUCTION

Celiac disease (CD) is a chronic inflammatory disorder of the small intestine caused by a permanent intolerance to gluten proteins found in cereal grains such as wheat, barley and rye in genetically susceptible individuals (Murray *et al.*, 2003; Saturni *et al.*, 2010). Clinical and histological improvement was achieved in celiac patients with gluten-free diet but lifelong adherence of CD patients to gluten-free diet is very difficult because products found in modern diets usually contain gluten (Green *et al.*, 2005; Caruso *et al.*, 2013). Moreover, many gluten-free products are poorer in nutrients than that of wheat-based foods intended to replace. CD affects approximately 1% of the population worldwide and there has been growing number of people diagnosed with CD by improved analytical methods. CD can occur at any age and it is necessary to produce high quality gluten-free products as an alternative to people who traditionally consume wheat-based products (Saturni *et al.*, 2010; Caruso *et al.*, 2013; Marti and Pagani, 2013; Steffolani *et al.*, 2014).

Quinoa, a pseudocereal that belongs to the *Chenopodiaceae* family (Jancurová *et al.*, 2009), has a higher nutritive value than traditional cereals (Vega-Gálvez *et al.*, 2010). It has high protein content (10-18%) with balanced amino acid composition, supplying high contents of lysine and methionine (Coulter and Lorenz, 1990; Nowak *et al.*, 2016). The fat content of raw quinoa seeds was 9.7% (dry-weight basis) and it has similar fatty acid composition with soybean oils with high amounts of essential fatty acids linoleic (52.3%) and linolenic acids (3.9%) (Coulter and Lorenz, 1990; Ruales and Nair, 1993; Jancurová *et al.*, 2009). These essential fatty acids required for good health, cannot be synthesized in human body and must be obtained from the diet (Costantini *et al.*, 2014). It contains a significant amount of fibre (2.1-4.9%), more calcium, magnesium, potassium, iron, copper, riboflavin (B2), α-Tocopherol (vitamin E), β-Carotene and ascorbic acid (vitamin C) than wheat, barley and rice (Coulter and Lorenz, 1990; Kozioł, 1992; Jancurová *et al.*, 2009). It is also a rich source of other bioactive compounds (polyphenols, phytosterols, etc.) (Alverez-Jubete *et al.*, 2010). Furthermore, quinoa does not contain gluten and can be used safely in the production of foods for CD patients (Pagano, 2006).

The *Salvia hispanica L.*, an oilseed plant, is commonly known as chia and is native from southern Mexico and northern Guetamala. It is a traditional food in Central and South America (Coates and Ayerza, 1996; Ixtania *et al.*, 2008; Norlaily *et al.*, 2012). Chia seed contains 25 to 40% oil with high essential fatty acids (omega) ω-3 alpha-linolenic acid (60%) and (omega) ω-6 linoleic acid (20%). It is also high in protein (19-23%), dietary fibre (18-30%), vitamins, minerals and antioxidants (Taga *et al.*, 1984; Ixtania *et al.*, 2008; Norlaily *et al.*, 2012). Due to its unique nutritional composition, especially its high unsaturated fatty acid composition, dietary fibre and antioxidant activities its consumption helps to increase satiety index and decreases the risk of various types of diseases such as cardiovascular diseases, cancer, diabetes, inflammatory and autoimmune diseases (Simopoulos, 2002; Muñoz *et al.*, 2013).

The aim of this study was to formulate gluten-free cake prepared from quinoa and chia flour to increase the nutritional value of gluten-free cakes and to ensure that CD patients have adequate amounts of nutrients.

MATERIALS AND METHODS

Materials

Chia seeds, whole quinoa flour, rice flour, corn starch, fine granulating sucrose, all purpose shortening, skimmed milk powder, whole egg, salt, baking powder and ethyl vanillin were obtained from local markets in Konya. Chia flour (CF) was obtained by milling of chia seeds with coffee grinder (Tefal, Istanbul, Turkey). Xanthan gum (Vatan Gıda, Istanbul, Turkey) and diacetyl tartaric acid esters of mono and diglycerides (DATEM; Rikevita, Malaysia) were used in cake formulations.

Methods

Cake preparation

Control gluten-free cake sample was prepared using the following recipe: Gluten free flour mixture (50 g rice flour: 50 g corn starch), fine granulating sucrose (75 g), shortening (75 g), whole egg (75 g), skimmed milk powder (5 g), salt (0.5 g), baking powder (4.5 g), xanthan gum (1 g), DATEM (0.5 g), ethyl vanillin (0.1 g). In CF and quinoa flour (QF) enriched cake samples, gluten-free flour mixture was replaced with 5% CF:5% QF, 10% CF:10% QF, 15% CF:15% QF, 20% CF:20% QF and 25% CF: 25% QF (w/w), respectively. All purpose shortening and fine granulating sucrose were whipped to a white cream in a Hobart mixer (Hobart N50, Canada Inc., North York, Ontario, Canada). Then eggs were added and whipped for 5 minutes then the other ingredients were added and the batter was mixed for additional 1 minute. One hundred and thirty grams of cake batter was placed into baking pans with 7.5 × 6.6 × 12 cm dimensions and baked at 175 ℃ for 35 min in the oven (Bosch HBT 112, Athens, Greece). After baking, cakes were removed from the pan and left for 30 minutes to cool. Cooled cakes were packed in polyethylene bags and sealed at room temperature (22 ℃) until their test and analyses.

Chemical properties

The cake samples were analysed for moisture (AACC Method 44-01), ash (AACC Method 08-01), protein (AACC Method 46-12) and fat (AACC Method 30-25) content according to AACC (1990). Mineral element contents of the samples were determined by inductively-coupled plasma spectroscopy, ICP-AES (Vista series, Varian International AG, Switzerland). Dry samples were digested using closed vessel microwave digestion oven (MARS 5, CEM Corporation, USA) with concentrated nitric acid and sulphuric acid. Mineral concentrations were determined by ICP-AES (Bubert and Hagenah, 1987).

Phytic acid (PA) was measured by a colorimetric method according to Haug and Lantzsch (1983). PA in the sample was extracted using a solution of HCl (0.2 mol/L) and precipitated by solution of ammonium iron (III) sulphate dodecahydrate. For determining PA, phytate phosphorus value was multiplied by a factor 3.546.

The extracts for the measurement of total phenolic content (TPC) and antioxidant capacity were prepared according to modified methods of Wronkowska *et al.* (2010). The 1 g of freshly ground samples were extracted with 10 mL of 80% aqueous methanol by shaking for 2 hours at 37 ^{o}C. Then samples centrifuged at 2600 g for 15 minutes. The fresh methanolic extracts were used to determine the TPC and their ability to scavenge DPPH (2,2- diphenyl-1-picrylhydrazyl) radicals.

The TPC of the methanolic extracts was determined by using Folin-Ciocalteu reagent as described by Wronkowska *et al.* (2010) with some modifications. Briefly, 0.1 mL aliquot extract was mixed with 0.9 mL of de-ionized water, 2 mL of sodium carbonate (10% w/v) and 1 mL of Folin–Ciocalteu reagent (90% v/v). The mixture was incubated in the dark for 1 hour at room temperature. The absorbance was then measured at 765 nm by using a spectrophotometer (Mecasys Optizen Pop UV-Vis Single Beams Spectrophotometer, 10F, 640-3, Banseok-dong, Yuseong-gu, Daejeon, Korea). The results are expressed in µg of gallic acid equivalent (GAE) per g dry weight basis.

The free radical scavenging capacity of the sample extracts was measured using a stable 2,2 diphenyl-1-picrylhydrazyl (DPPH) radical according to the method given also by Wronkowska *et al.*, (2010) with some modifications. The extract (100 µL) was mixed with freshly made methanolic DPPH solution (250 µl, 10 mg DPPH/25 mL 80% methanol) and 80% methanol (2 mL). The mixture was left in the dark for 20 minutes at room temperature. The absorbance was then measured at 517 nm against the blank. The blank consisted of 80% methanol and the reagent solution without 80% methanolic extract added and the procedure was performed as described above. Antioxidant capacity was calculated as percentage of discolouration defined as in "Eq. 1".

$$\textit{Antioxidant capacity} = [1-(\textit{Abs sample}_{t=20}/\textit{Abs control}_{t=0})] \times 100 \qquad \text{Eq. 1}$$

Physical measurements

Volume index, symmetry index and uniformity index of the cakes were measured by using AACC template method 10-91 (AACC, 1990). Color measurements were made on the cake's crust and crumb by measuring L^* (light /dark), a^* (red/green), and b^* (yellow/blue) parameters with a chromo meter (Model CR 400, Minolta Camera, Co. Ltd., Osaka, Japan). The chroma (C*) ($\sqrt{(a^{*2}+b^{*2})}$) describes the brightness or vividness of color. Hue angle (H), which indicates the tone (0: reddish tones; ~ 90=yellowish tones), was calculated as arctan [b^*/a^*] (if $a>0$ and $b>0$) or arctan [b^*/a^*] +180° (if $a<0$ and $b>0$) (Francis, 1998; Gómez *et al*., 2008).

Specific gravity of the cake batter was calculated by dividing of the weight of a certain volume of cake batter to the weight of the same volume of distilled water (Gómez *et al*., 2008).

Sensory properties

Cakes were evaluated by untrained panellists (n=26) on the basis of acceptance of appearance, texture, taste-odour, mouthfeel and overall acceptability on a nine-point hedonic scale where 1- dislike extremely, 2- dislike very much, 3- dislike moderately, 4- dislike slightly, 5- neither like nor dislike, 6- like slightly, 7- like moderately, 8- like very much, 9- like extremely.

Statistical analysis

The data were analysed by using statistical software JMP 8.0 (SAS Institute, Cary, NC, USA). The values are average of triplicate determinations on two replicate cake preparations. Tukey HSD was used to determine significant differences between the treatments. Significant differences were based on a $P<0.05$.

RESULTS AND DISCUSSION

Analytical results

CF and QF used to prepare gluten-free cakes contain 4.21% and 3.47% ash, 19.56% and 12.36% protein, 31.87% and 5.65% fat, 2165.48 mg/100g and 1640.89 mg/100g PA, 610.68 mg/100g and 462.74 mg/100 g phytate phosphorus, 1628.45 μg/g and 1260.14 μg/g TPC and 88.45% and 59.95% antioxidant capacity in dry weight basis, respectively. The Ca, P, K, Mg, Fe and Zn contents of CF and QF were 612.31 mg/100g, 987.52 mg/100g, 748.65 mg/100g, 332.14 mg/100g, 7.21 mg/100g, 4.38 mg/100g (CF) and 42.10 mg/100g, 369.94 mg/100g, 803.77 mg/100g, 182.99 mg/100g, 7.51 mg/100g and 2.25 mg/100g (QF), respectively. L*, a*, b*, C* and hue values were 42.14, 2.39, 8.42, 8.75 and 74.15 for CF; 87.08, -0.29, 11.61, 11.61 and 91.43 for QF, respectively. Similar results have been reported in previous works (Bilgiçli and Ibanoğlu, 2015; Muñoz *et al*., 2013; Pizarro *et al*., 2013; Ranhotra *et al*., 1993).

Chemical properties

Proximate composition, phytic acid, phytate phosphorus, total phenolic contents and antioxidant capacity of gluten-free cakes are given in Table 1 and Table 2. The moisture contents of gluten-free cakes containing CF and QF were found higher than that of control prepared with rice flour and corn starch. This may be caused by the mucilage which is known to have excellent water holding properties found in chia fibre. It was reported that chia has possible applications in bakery products requiring hydration and conservation of freshness (Vázquez- Ovando *et al*., 2009). Increasing amount of CF and QF increased the ash, protein, fat, TPC and antioxidant capacity of the cake samples significantly ($P<0.05$). These increases were 1.5 times in ash, 1.8 times in protein, 1.3 times in fat, 3.5 times in TPC and 2.9 times in antioxidant capacity. The rich composition of CF and QF affected the chemical composition of the final product. Similarly, Barrientos *et al.* (2012) prepared sugar-snap cookies by replacing wheat flour with CF at 10% and 20% (flour basis) and reported that cookies supplemented with CF contained more ash, protein, fat, crude fibre, calcium and zinc than control cookies. Alencar *et al.* (2015) studied the effects of whole quinoa and amaranth flour (20%, flour and starch basis) with sweeteners on gluten-free bread quality and reported that the bread containing amaranth, quinoa and sweeteners showed higher protein, lipid and ash content than that of control bread.

Table 1. Proximate composition of gluten-free cakes

	Moisture (%)	Ash (%)*	Protein (%)*	Fat (%)*
Control	25.77±0.08[e]	1.58±0.03[f]	5.46±0.08[f]	25.42±0.10[f]
5% CF-5% QF	27.37±0.06[b]	1.72±0.04[e]	6.40±0.14[e]	26.93±0.07[e]
10% CF-10% QF	26.01±0.04[d]	1.83±0.01[d]	7.11±0.16[d]	28.23±0.16[d]
15% CF-15% QF	27.17±0.07[c]	2.01±0.03[c]	7.92±0.17[c]	29.87±0.14[c]
20% CF-20% QF	28.33±0.03[a]	2.16±0.04[b]	8.83±0.10[b]	31.42±0.06[b]
25% CF-25% QF	28.40±0.07[a]	2.35±0.01[a]	9.61±0.16[a]	32.82±0.10[a]

Values are the average of triplicate measurements on the duplicate sample ±standard deviation;
* Results are dry-weight basis; CF, Chia flour; QF, Quinoa flour; Data in the same column sharing a lowercase common letter are not significantly (P <0.05) different.

Table 2. Phytic acid, phytate phosphorus, total phenolic contents and antioxidant capacity of gluten-free cakes

	Phytic acid (mg/100g) *	Phytate phosphorus (mg/100g) *	Total phenolic content (µg/g)*	Antioxidant capacity (%)*
Control	133.59±2.40[f]	37.67±2.88[f]	151.11±4.23[f]	16.43±0.35[f]
5% CF-5% QF	272.99±2.29[e]	76.99±2.61[e]	218.74±2.83[e]	27.03±0.23[e]
10% CF-10% QF	435.70±2.12[d]	122.87±1.22[d]	301.33±3.49[d]	34.92±0.52[d]
15% CF-15% QF	583.61±2.62[c]	164.58±2.32[c]	345.56±5.60[c]	40.98±0.47[c]
20% CF-20% QF	736.58±2.14[b]	207.72±2.79[b]	433.21±2.74[b]	43.99±0.38[b]
25% CF-25% QF	878.75±2.18[a]	247.81±1.84[a]	525.19±5.84[a]	48.14±0.17[a]

Values are the average of triplicate measurements on the duplicate sample ±standard deviation;
* Results are dry-weight basis; CF, Chia flour; QF, Quinoa flour; Data in the same column sharing a lowercase common letter are not significantly (P <0.05) different.

Repo-Carrasco-Valencia and Serna (2011) reported that quinoa can be considered as a good source of polyphenol and other antioxidant compounds. Costantini *et al.* (2014) reported that the use of chia flour (at 10% level) led to a significant increase in the TPC and antioxidant capacity of bread samples. The PA and phytate phosphorus content of cake samples were ranged from 133.59 mg/100 g to 878.75 mg/100g and 37.67 mg/100g to 247.81 mg/100g, respectively. As expected, the use of CF and QF caused substantial increase in the levels of PA and phytate phosphorus content of gluten-free cakes. Phytic acid is considered to be an antinutrient due to its ability to bind minerals, proteins and starch either indirectly or directly. This binding alters the bioavailability or digestibility of these nutrients (Zhou and Erdman, 1995; Rickard and Thompson, 1997; Oatway et al. 2001; Kumar et al. 2010). However, some healhtful effects of phytic acid including antioxidant and anticarcinogenic effects have been reported by many researchers (Graf and Eaton, 1993; Thompson 1993; Zhou and Erdman, 1995; Febles et al. 2002). But, dosage information is limited for humans to elicit beneficial effects (Kumar et al. 2010).

Mineral contents

Mineral contents of gluten-free cakes are given in Table 3. In general, all the mineral content of gluten-free cakes increased significantly (P <0.05) by the addition of CF and QF, and the richest mineral composition was obtained at highest enrichment ratio. The Ca, P, K, Mg, Fe and Zn contents of gluten-free cakes containing 25% CF and 25% QF were found to be 7.2, 2.4, 3.1, 10.3, 4.4 and 3.0 times higher than the control. The Recommended Dietary Allowances (RDAs) for adults are 900 mg of calcium, 1.4-1.5 g phosphorus, 2 g of potassium, 350 mg of magnesium, 10 mg of iron and 13 mg of zinc (Demirci, 2011).

Table 3. Mineral contents of gluten-free cakes (mg/100g)*

	Ca	P	K	Mg	Fe	Zn
Control	21.06±0.25^{f}	178.51±0.57^{f}	127.75±0.42^{f}	6.91±0.14^{f}	0.56±0.03^{f}	0.49±0.03^{f}
5% CF-5% QF	48.33±0.17^{e}	224.67±0.85^{e}	185.93±0.68^{e}	18.23±0.31^{e}	0.93±0.01^{e}	0.66±0.01^{e}
10% CF-10% QF	69.42±0.20^{d}	277.38±0.37^{d}	236.32±0.35^{d}	33.09±0.45^{d}	1.22±0.06^{d}	0.87±0.04^{d}
15% CF-15% QF	94.76±0.28^{c}	326.60±0.61^{c}	280.61±0.71^{c}	42.10±0.27^{c}	1.65±0.01^{c}	1.06±0.03^{c}
20% CF-20% QF	125.18±0.14^{b}	381.36±0.44^{b}	343.18±0.54^{b}	55.86±0.18^{b}	2.11±0.03^{b}	1.22±0.01^{b}
25% CF-25% QF	151.40±0.21^{a}	422.18±0.71^{a}	394.72±0.28^{a}	71.40±0.59^{a}	2.46±0.04^{a}	1.45±0.04^{a}

*Results are dry-weight basis; Values are the average of triplicate measurements on the duplicate sample ±standard deviation; CF, Chia flour; QF, Quinoa flour; Data in the same column sharing a lowercase common letter are not significantly (*P* <0.05) different.

Gluten-free cake (100 g, dry weight) containing 25% CF and 25% QF meets the daily requirements of Ca, P, K, Mg, Fe and Zn for adults by 16.8%, 29.1%, 19.7 %, 20.4%, 24.6% and 11.2% respectively. These RDA ratios were 2.3% of Ca, 12.3% of P, 6.4 % of K, 2.0% of Mg, 5.6% of Fe and 3.8% of Zn in the control gluten-free cake.

The rich mineral contents of CF and QF affected the mineral content of the final product. It is reported that quinoa is also an excellent source of Fe, Ca, Mg, B vitamins and fibre (Pagano, 2006). Gohara *et al.* (2013) used chia and azuki flour in gluten-free chocolate cakes and conclude that the addition of 20% of both flours introduced higher mineral contents in chocolate cakes. (Levent, 2017) reported that chia seed flour usage in gluten-free noodles caused significant increase in Ca, P, K, Mg, Fe and Zn contents (*P* <0.05). In the study conducted by Giménez *et al.* (2016), gluten-free spaghetti-type pasta made with corn flour enriched with 30% broad bean flour and 20% quinoa flour and it is reported that the substitution of broad bean and quinoa flour separately increased remarkably the contents of dietary fibre, unsaturated fatty acids, iron and zinc. The mineral enrichment of gluten-free foods is important for celiac patients because iron, folate, vitamin B12, vitamin D, zinc, and magnesium deficiencies are common in untreated celiac disease and nutrient deficiencies may be responsible for extra intestinal signs/symptoms of celiac disease (Caruso *et al.*, 2013).

Physical properties of cake samples

Some physical properties of cake batters and cake samples are given in Table 4. The specific gravity values of the gluten-free cake batters were found to be higher than the control samples except for the 5% CF and 5% QF replacement level. The volume index is an indicator of cake volume which is strongly influences consumer preference (Gómez *et al.*, 2008). 10% CF-10% QF and 15% CF-15% QF gave the highest volume index value. All gluten-free cakes containing CF and QF had higher volume index values than control (*P* <0.05). Borneo *et al.*, (2010) studied the effect of replacing 25g/100g, 50g/100 and 75g/100g of the eggs or the oil in cake formulation by chia gel and reported that substituting egg or oil with chia gel up to 25% level maintained the functional properties of cake samples. The symmetry index values varied between -1 mm and 13 mm and the lowest symmetry index value was obtained at 20% CF and 20% QF level. The high symmetry index value showed that cakes mainly rise in the central part (Borneo *et al.*, 2010). The uniformity index values of gluten-free cakes ranged from -2 mm to 3 mm which are near zero. Uniformity index is desired to be close to zero for good cake quality (Bath *et al.*, 1992).

In the study conducted by Lorenz *et al.* (1995), quinoa flour was used in bread, cake and cookie formulations at 5, 10, 20 and 30% levels and it was reported that cake pore structure became more open and the texture less silky as the level of quinoa substitution increased. In the same study, cake quality was found acceptable at 5% and 10% quinoa flour usage levels.

Table 4. Physical properties of gluten-free cake batter and cake samples

	Specific gravity (g/cm^3)	Volume Index (mm)	Symmetry Index (mm)	Uniformity Index (mm)
Control	1.01±0.03^b	133±0.57^d	5±0.28^b	1±0.14^b
5% CF-5% QF	1.05±0.01^{ab}	137±0.71^c	4±0.14^c	-2±0.00^e
10% CF-10% QF	1.09±0.04^a	146±0.48^a	4±0.14^c	0±0.14^c
15% CF-15% QF	1.08±0.01^a	146±0.85^a	13±0.00^a	3±0.42^a
20% CF-20% QF	1.10±0.04^a	142±0.57^b	-1±0.14^d	3±0.00^a
25% CF-%25 QF	1.09±0.02^a	136±0.71^c	5±0.28^b	-1±0.14^d

Values are the average of triplicate measurements on the duplicate sample ±standard deviation. CF, Chia flour; QF, Quinoa flour; Data in the same column sharing a lowercase common letter are not significantly (*P* <0.05) different.

Color values of cake crumb and crust

The color of the cakes is one of the most important characteristics which affect the acceptability of product by consumers. Color values of gluten-free cake samples prepared with CF and QF are given in Table 5. In general, as the levels of CF and QF increased in the formulation, lightness (L*), yellowness (b*) and hue values of gluten-free cakes decreased and redness (a*) values increased. At the 25% CF and 25% QF level, the highest redness (a*) and the lowest chroma (C*) values were obtained in cake crumb. High chroma values indicate vivid colors whilst low values near 0 indicate subdued colors (Gómez *et al.*, 2008). Similarly, Pizarro *et al.* (2013) reported that whole chia powder usage (15 g /100 g flour mixture) in pound cake formulation contributed to a decrease in L* (making the crumb darker), C* (with a less saturated color) and h values (tending more red) of samples. Demir (2014) studied the effect of quinoa flour on the quality of gluten-free tarhana and observed a decrease in L*, b* and an increase in a* values of tarhana samples with the addition of quinoa at 40-60 % levels.

Color values of CF and QF had a significant effect (*P* <0.05) on color parameters of the final product. In addition, the rich composition of CF and QF may accelerate the Maillard reaction which may increase darkness and redness of gluten-free cakes. But the cake crumb does not reach temperatures above 100 °C and Maillard or caramelization reactions occur on the cake crust rather than cake crumb. Therefore, the color of raw materials and their interactions are effective on cake crumb color (Gómez *et al.*, 2008).

Table 5. Crust and crumb color values of gluten-free cakes

CAKE CRUST	L*	a*	b*	C*	hue
Control	48.91±0.27^a	3.27±0.07^f	20.82±0.12^a	21.08±0.14^a	81.08±0.12^a
5% CF-5% QF	41.16±0.30^b	7.99±0.10^e	15.98±0.07^b	17.87±0.11^c	63.43±0.18^b
10% CF-10% QF	37.81±0.18^c	9.34±0.04^d	14.98±0.05^c	17.65±0.06^c	58.07±0.03^c
15% CF-15% QF	36.88±0.25^d	10.02±0.06^c	13.22±0.04^e	16.58±0.02^d	52.88±0.30^d
20% CF-20% QF	36.44±0.23^d	12.84±0.05^a	14.72±0.09^d	19.53±0.10^b	48.89±0.08^f
25% CF-%25 QF	31.86±0.17^e	10.84±0.13^b	12.87±0.07^f	16.83±0.14^d	49.88±0.19^e
CAKE CRUMB					
Control	62.10±0.21^a	-2.10±0.04^e	17.78±0.08^a	17.90±0.09^a	96.74±0.11^a
5% CF-5% QF	61.20±0.14^b	-0.62±0.03^d	15.19±0.06^b	15.20±0.06^b	92.34±0.11^b
10% CF-10% QF	56.16±0.28^c	0.53±0.05^c	13.87±0.03^c	13.88±0.04^c	87.82±0.21^c
15% CF-15% QF	54.61±0.16^d	0.77±0.08^b	13.21±0.04^d	13.23±0.06^d	86.65±0.31^d
20% CF-20% QF	49.03±0.11^e	1.88±0.01^a	12.04±0.08^e	12.18±0.07^e	81.12±0.11^e
25% CF-%25 QF	49.45±0.09^e	1.89±0.05^a	11.88±0.06^f	12.03±0.04^f	80.98±0.27^e

Values are the average of triplicate measurements on the duplicate sample ±standard deviation. CF, Chia flour; QF, Quinoa flour; Data in the same column sharing a lowercase common letter are not significantly (*P* <0.05) different.

Sensory properties

Sensory properties of gluten-free cake samples are presented in Figure 1. CF and QF usage improved the taste-odour score of gluten-free cakes compared to control. Cakes with 10% CF and 10% QF received the highest appearance, texture, mouthfeel and overall acceptability score in all cake samples. Usage of 25% CF and 25% QF decreased especially appearance, mouthfeel and overall acceptability scores of gluten-free cakes. Pizarro *et al.* (2013) reported that pound cake produced with whole chia powder (15 g/ 100 g flour mixture) showed good sensory acceptance. In a study by Steffolani *et al.* (2014), it was found that the use of chia flour at 15% (rice flour basis) in gluten-free bread formulation did not reduced sensorial acceptability of these products. In the study conducted by Turkut *et al.* (2016) it was reported that quinoa flour can be successfully used in gluten-free bread formulation and 25% quinoa bread gained higher sensory scores with its softer texture.

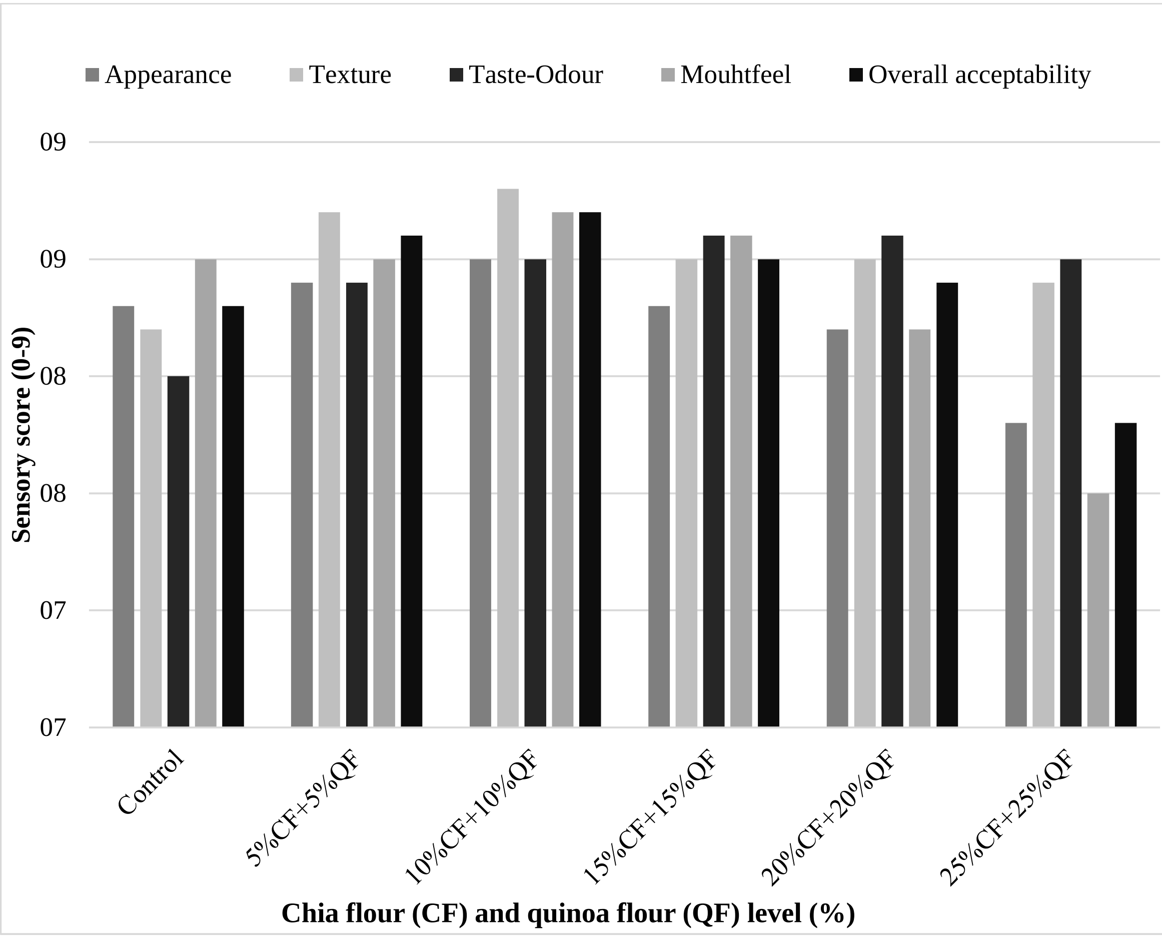

Figure 1. Sensory properties of gluten-free cake samples

CONCLUSION

CF and QF were successfully incorporated in gluten-free cake formulation. The usage of CF and QF increased the ash, protein, fat, TPC, antioxidant capacity, Ca, P, K, Mg, Fe and Zn contents of gluten free cakes. As the CF and QF levels increased, the PA content of gluten-free cakes increased significantly (P <0.05). All the gluten-free cakes containing CF and QF had higher volume index values than control. Gluten-free cakes containing CF and QF up to 20% and 20% level were appreciated by the panellists in terms of texture, taste-odour and overall acceptability.

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