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Utilization of quinoa flour in cookie production

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Abstract

Quinoa -one of three pseudocereals- are an exceptionally nutritious food source, owing to their high level of protein, omega-3 and 6 fatty acid, fiber, vitamin, mineral and micro constituents, phytosteroids, carbohydrates of low glycemic index. In this study, the use of quinoa flour (QF) instead of wheat flour (WF) in cookies was investigated. QF was used in cookie formulation at different levels (0%, 10%, 20%, 30%, 40% and 50%). Afterwards, in order to determine the effects of QF on physical, chemical, nutritional and sensory properties of cookies were analyzed. The use of QF led to a slight increase in the product thickness values of the cookie samples. Also, diameter values decreased as levels of QF increased in cookie formulation but significant decrease was not noted with 10% QF addition. Moreover, addition of QF to the formulations containing decreased the spread ratio of the samples. Also, QF affected the colour (L^*, a^* and b^*) of cookie. The cookie samples containing 50% QF had the highest a^* and b^* values, while cookie samples containing 0% QF had the highest L^* values. The highest ratios of QF adversely affected hardness values of the cookie samples. The use of QF increased ash, crude protein, crude fat, total phenolic content (TPC) content of cookie samples ($p<0.05$). As expected a substantial increase in the levels of phytic acid was found in all cookie samples containing QF. Generally potassium (K), magnesium (Mg), calcium (Ca), iron (Fe) and zinc (Zn) contents of the cookies increased with increasing levels of QF. Moreover, QF affected the scores of sensory properties of cookie samples. QF addition had statistically significant effect at $p<0.05$ on colour, taste, crispness and overall acceptability except odour scores. As a result of this study, cookies were satisfactorily improved in terms of chemical, nutritional and sensory properties nutritional properties by quinoa flour.

Introduction

Quinoa (*Chenopodium quinoa* Willd.) is a seed-producing crop, which has been cultivated in the Andes for thousands of years. It was important food in some ancient (Aztec, Mayan and Incan) civilizations of the past (Galway *et al*., 1990; Caperuto *et al*., 2001; Ng *et al*., 2007; Alvarez-Jubete *et al*., 2010). Quinoa, a facultative halophyte (Adolf *et al*., 2012) belonging to the Amaranthaceae, is a dicotyledonous herbaceous plant comprising wild relatives and domesticated populations (Ruiz *et al.*, 2014). Cultivated quinoa was originated some seven thousand years ago from South America and in today's it is receiving considerable attention as an alternative crop in the World (Caperuto *et al*., 2001; Comai *et al*., 2007; Gely and Santalla, 2007).This crop constitutes a great potential for agronomic demands because it can adapt to produce high grain yields under adverse or stressing conditions (Comai *et al*., 2007; Gely and Santalla, 2007). Quinoa is an extremely healthy food (gluten-free) of the twenty-first century (Valencia-Chamorro, 2003). By the FAO, quinoa has been declared to be a good alternative crop to provide food security and to prevent poverty in next century (FAO, 2013; Miranda *et al.*, 2014; Ruiz *et al.*, 2014). Also, the United Nations General Assembly has therefore declared 2013 as the International Year of Quinoa (FAO, 2013).

Quinoa is considered a pseudo-cereal with proteins of high biological value, carbohydrates of low glycemic index, phytosteroids, and omega-3 and 6 fatty acids that bring benefits to the human health (Farinazzi-Machado *et al*., 2012). The edible seed of the quinoa plant has been called both a pseudo-cereal and a pseudo-oil seed because of its unique nutritional profile (Goundan, 1992). The nutrient composition is very good compared with common cereals (Demir, 2014a). Oil content in quinoa ranges from 1.8% to 9.5% (Vega-Gálvez *et al*., 2010). It has been reported unsaturated fatty acid level of about 70%, having linoleic (38.9%) and oleic acids (27.7%) (Dini *et al*., 1992). Also, quinoa protein is exceptionally high in methionine, lysine and cysteine amino acids (Becker

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and Hanners, 1990). Thus, it is a good complement for legumes, which are often low in methionine and cysteine. Some types of wheat come close to matching quinoa's protein content, but grain such as barley, corn and rice generally have less than half the protein content of quinoa. Quinoa grains also have vitamins (C, E and B complex), important minerals (calcium, potassium, iron, magnesium, manganese, phosphorus) and high quality lipids (Jancurová *et al*., 2009; Vega-Gálvez *et al*., 2010; Miranda *et al*., 2012). The Aztecs and Incas credited quinoa with medicinal properties including lowering blood cholesterol, improving glucose tolerance and reducing insulin requirements (Guzman-Maldonado and Paredes-Lopez, 1998). Furthermore, it is a good source of dietary fiber (Alvarez-Jubete *et al.*, 2010). In recent years, scientific information supporting the health benefits of quinoa has accumulated and functional properties of quinoa have been investigated (Guzman-Maldonado and Paredes-Lopez, 1998; Watanabe *et al.*, 2014). Phenolics, flavonoids and saponins have been identified as bioactive components from quinoa seeds (Ridout *et al*., 1991; Gee *et al*., 1993; Masterbroek *et al*., 2000). Due to its high nutritional quality, interest in quinoa is growing in other parts of the world (Yael *et al*., 2012).

Cookies have become one of the most desirable snacks for all ages due to their low manufacturing cost, convenience, long shelf life, good eating quality and ability to serve as a vehicle for important nutrients (Akubor, 2003; Hooda and Jood, 2005). Cookies represent the largest category of snack items among baked foods all over the world (Awasthi and Yadav, 2000; Rababah *et al*., 2006). Cookies hold an important position among the bakery products and in snack foods due to variety in taste, crispiness, digestibility and longer shelf life (Hussain *et al*., 2006; Demir, 2014b). Also cookie products can easily be enriched and fortified (Demir, 2014b).

This investigation was undertaken to produce a food product with high nutritional characteristics by using quinoa flour (QF). The purpose of this research was to determine the effect of the addition of QF to cookie samples by measuring some physical, chemical, nutritional and sensory properties.

Materials and Methods

Materials

Quinoa groats were obtained from Bora Tarım Ürünleri, İstanbul, Turkey. Quinoa groats were ground in a hammer mill (Falling Number-3100 Laboratory Mill, Perten Instruments AB, Huddinge, Sweden) equipped with 0.5 mm opening screen. Whole QF was used in cookie production. Wheat flour, sodium bicarbonate and ammonium bicarbonate were obtained from Saray Biscuit and Food Industry A.Ş. (Karaman, Turkey). All-purpose shortening, skimmed milk powder, salt and fine granulating sucrose were procured from local market in Konya, Turkey. High-fructose corn syrup (HFCS-F55) was purchased from Cargill (Turkey). The samples were kept at +4 °C till the analysis.

Production of cookies

AACC Standard No:10-54.01 method (baking quality of cookie flour-micro wire-cut formulation) was used for cookie preparation. All ingredients used for cookie preparation were kept at room temperature. The formulation of control cookies (100% WF) were sucrose (fine granulating) (84 g), skimmed milk powder (2 g), NaCl (2.5 g), sodium bicarbonate (2.0 g), shortening (80 g), high-fructose corn syrup-42% (3.0 g), ammonium bicarbonate (1.0 g), WF (200 g) and water as required (AACC, 2000). For preparation of cookie samples with QF; the WF was replaced with QF at the levels of 10%, 20%, 30%, 40% and 50%. Cookie dough was mixed in laboratory type mixer (Kenwood KMX-50, Kenwood Ltd., United Kingdom). The dough was sheeted to a thickness of 5 mm and cut into round shapes using a 55 mm diameter dough cutter. The dough was transferred to aluminum trays and placed in a baking oven (Arçelik ARMD-580, İstanbul, Turkey). These were baked at 205^{o}C for 11 min. Afterwards the cookie samples were allowed to cool at room temperature (22^{o}C) and these samples were packaged in polyethylene bags, until used.

Chemical analysis

The AACC International methods were used for the determination of ash (method 08-01.01), crude protein (method 46-12.01) and crude fat (30-10.01) contents of WF, QF and cookie samples (AACC, 2000).

Physical properties

A digital micrometer (0.001 mm, Mitutoyo, Minoto-Ku, Tokyo, Japan) was used to measure the dimensions (diameter and thickness) of the cookie samples. The spread ratio was found using the following formula;

$$\text{Spread ratio} = \text{Diameter (D)} / \text{Thickness (T)}$$

The hardness of cookie samples after baking was measured in Newtons by a texture analyzer using the procedure of Aydın and Öğüt (1991).

Color measurement was performed using Hunter Lab Color Quest II Minolta CR 400 (Konica Minolta Sensing, Inc., Osaka, Japan). The color measurements were determined according to the CIELab color space system (Francis, 1998). Color was expressed as L^* (100 = white ; 0 = black), a^* (+,redness ; -, greenness), and b^* (+, yellowness ; -, blueness).

Nutritional properties

Phytic acid was measured by a colourimetric method according to Haugh and Lantzsch (1983). Phytic acid in the sample was extracted with a solution of hydrochloric acid (0.2 N) and precipitated with solution of ammonium iron (III) sulphate.12H2O. The mineral (potassium (K), magnesium (Mg), calcium (Ca), iron (Fe) and zinc (Zn)) contents of the cookie samples were determined by inductively coupled plasma atomic emission spectrometry (ICP-AES) (Vista series, Varian International AG, Switzerland) with an automatic sampler system. Approximately 0.5 g of the couscous sample was put into a burning cup, and 5 mL of nitric acid (HNO_3) +5 mL sulfuric acid (H_2SO_4) was added. The samples were incinerated in a microwave oven (Mars 5, CEM Corporation, USA). The solution was diluted to 100 mL with water. Concentrations were determined by ICP-AES (Bubert and Hagenah, 1987). Total phenolic content (TPC) was determined using the Folin-Ciocalteau method (Singleton and Rossi, 1965). The TPC was used a Hitachi-U1800 spectrophotometer (Hitachi High-Technologies, Tokyo, Japan). The results were expressed as µg gallic acid equivalents per g sample.

Sensorial properties

Cookie samples were evaluated by ten panellists, who are familiar with the characteristics of cookies and studied in Food Engineering Department of Necmettin Erbakan University, Konya, Turkey. Ages ranged from 21 to 45. Seven of them were females. All panellists were non-smokers. Instructions were given in full to panellists beforehand. The samples were brought to room temperature before testing. The samples were coded with letters and the order of sample presentation was completely randomized for serving to the panelists to guard against any bias. The panellists cleansed their palates with water before rating each sample. The panelists were asked to score the cookie in terms of colour, taste, odour, appearance, crispness and overall acceptability using a 5-point scale where 1 represented “dislike extremely”, 3 represented “acceptable” and 5 represented “like extremely” in a particular attribute.

Statistical analysis

A commercial software program (Tarist, version 4.0; Izmir, Turkey) was used to perform statistical analyses. Data were assessed by analysis of variance. Means that were statistically different from each other were compared using Duncan’s multiple range tests at 5% confidence interval. Standard deviations were calculated using the same software.

Results and Discussion

Analytical results

The results for the analysis of the raw materials (WF and QF) used in the production of cookie samples are presented in Table 1. In colour values, QF had lower lightness *(L^*)* and higher yellowness *(b^*)* than WF because of the natural dark colour and pigmentation. Also, QF had higher crude protein, ash, crude fat, phytic acid, TPC and mineral contents (K, Mg, Ca, Fe and Zn) when compared with WF. QF had richer chemical and nutritional composition since it was produced from whole QF seed. Literature knowledge on chemical composition and nutritional properties of WF and QF confirmed our results (Alvarez-Jubete *et al.,* 2009; Jancurová *et al*., 2009; Alvarez-Jubete *et al*., 2010; Repo-Carrasco-Valencia *et al*., 2010; Watanabe *et al*., 2014).

Physical properties

The effect of QF on physical properties of cookies including diameter, thickness, spread ratio, hardness and colour (L^*, a^* and b^*) were given in Table 2. According to the Table 2, the addition of QF to the cookie samples resulted in a slight increase in the product thickness values. However, the cookie samples containing 40% and 50% QF did not show significant ($p<0.05$) thickness values. Also, diameter values decreased as levels of QF increased in cookie formulation but not significant decrease was noted with 10% QF addition. The changes in diameter and thickness were reflected in spread ratio of cookie samples. Generally, addition of QF to the formulations decreased the spread ratio of the samples. In previous published studies, researchers also reported reduction in spread ratio when soy flour, buckwheat and fenugreek flour were incorporated in substitution to wheat flour (Singh *et al*., 1996; Hooda and Jood, 2005; Baljeet *et al*., 2010). Reduced spread ratios of QF fortified cookie samples were attributed to the fact that composite flours apparently form aggregates with increased numbers of hydrophilic sites available that compete for the limited free water in cookie dough (McWatters, 1978; Baljeet *et al*., 2010). Also, previous results for high protein

Table 1. Chemical composition and colour values of raw materials (mean values ± standard deviation)[1].

		Wheat flour (WF)	Quinoa flour (QF)
Colour values	L^*	91.74±0.19	89.74±0.12
	a^*	-0.77±0.16	-0.27±0.11
	b^*	8.85±0.06	12.43±0.27
Crude protein (%)[2,3]		9.62±0.08	14.45±0.33
Ash (%)[3]		0.63±0.01	2.82±0.08
Crude fat (%)[3]		0.51±0.03	5.01±0.15
Phytic acid (mg/100g)[3]		195.49±8.25	1192.41±8.43
Total phenolic content (µg GAE/g)[3]		791.36±15.56	1219.26±22.62
Minerals[3] (mg/100g)	K	340.63±5.75	801.39±4.16
	Mg	34.05±0.23	210.01±1.44
	Ca	22.81±0.04	36.38±0.24
	Fe	2.11±0.01	4.45±0.03
	Zn	1.13 ±0.01	3.57±0.02

[1]Results are the average of two trials ± standard deviation.
[2]Conversion factors; N x 5.7for wheat flour; N x 6.25 for quinoa flour.
[3]Values are dry weight basis.

cookies also showed a decrease in the spread factor (Singh *et al*., 1993; McWatters *et al*., 2003; Singh and Mohamed, 2007; Yamsaengsung *et al.*, 2012). These results show that replacement of WF with QF influenced characteristics of cookie dough and caused more compact cookies. Thus, the use of QF with replacement to WF has more advantages particularly in the production of cookies from weak wheat in order to improve texture of cookies and the cookies which are desired to spread lower.

The hardness values of cookies increased by the replacement of WF with QF. The cookies containing the highest QF (50%) had the hardness values above the values of other formulation. The lowest hardness values were determined for cookies made with 100% WF (control group). According to these results, the use of QF led to more compact cookie dough and cookies with harder characteristics. Bilgiçli and İbanoğlu (2015) reported that QF increased hardness of bread samples. According to the Table 2, brightness *(L^*)* values of cookie samples declined after the quinoa flour addition. As expected from the colour of the flour samples (Table 1) the L^* values of the cookie samples show a significant darkening of colour on addition of QF. Lorenz and Coulter (1991) reported that the colour of bread samples became darker when higher levels of QF. A significant increase in a^* and b^* values was noted as QF was added to the control cookie. The cookie samples containing 50% QF had the highest a^* and ^{b*} values. The samples in control group had the lowest a^* and $b*$ values.

Chemical and nutritional properties

Some chemical and nutritional properties of cookie samples were given in Table 3 and 4. According to Table 3, the ash, crude protein and crude fat content of cookie samples increased significantly ($p<0.05$) with QF addition. The highest ash, crude protein and crude fat contents were determined in the cookies made with 50% QF addition, while cookies of control group had the lowest ash, crude protein and crude fat content. This was an expected result, because QF is a very nutrient rich product (Table 1). Crude protein, ash and crude fat contents in quinoa are generally higher than in common cereals such as wheat (Koziol, 1992; Alvarez-Jubete *et al.*, 2010). In a study of Alvarez-Jubete *et al*. (2009) quinoa seeds was reported to contain 14.5% protein, 5.2% fat, 64.2% total starch, 14.2% dietary fiber and 2.7% ash. Also, compared to control group higher levels of TPC were measured in cookie samples containing QF 50% usage levels. The TPC of quinoa flour was high compared to wheat flour (Table 1). The TPC value of the control cookie was 720.02 µg GAE/g. In contrast,

Table 2. Effect of quinoa flour on the physical properties of cookies (mean values ± standard deviation)[1].

Samples[2]	Diameter (D) (mm)	Thickness (T) (mm)	Spread ratio (D/T)	Hardness (N)	Colour values[3]		
					L^*	a^*	b^*
Control	63.77±0.16[A]	8.06±0.05[D]	7.92±0.03[A]	36.37±0.38[F]	67.83±0.53[A]	3.23±0.04[E]	23.51±0.37[E]
10% QF	63.35±0.13[A]	8.18±0.06[D]	7.74±0.04[A]	39.46±0.98[E]	65.99±0.15[B]	3.74±0.08[D]	24.12±0.16[D]
20% QF	63.24±0.15[AB]	8.47±0.09[C]	7.47±0.10[B]	43.34±1.39[D]	64.76±0.37[C]	4.13±0.03[C]	24.98±0.17[C]
30% QF	62.76±0.34[B]	8.72±0.09[B]	7.20±0.11[C]	48.79±1.59[C]	63.59±0.12[D]	4.32±0.11[BC]	25.65±0.04[B]
40% QF	61.00±0.14[C]	9.03±0.04[A]	6.76±0.05[D]	52.87±0.86[B]	62.27±0.16[E]	4.51±0.10[AB]	26.08±0.09[AB]
50% QF	60.53±0.18[C]	9.15±0.15[A]	6.62±0.09[D]	58.01±0.65[A]	61.43±0.15[F]	4.68±0.17[A]	26.79±0.04[A]

[1] Duncan's multiple range test. The means with the same letter in column are not significantly different ($p<0.05$).
[2] QF= Quinoa flour.
[3] L^* = light/dark; a^* = green (negative values) / red (positive values); b^* = blue (negative values) / yellow (positive values).

Table 3. Effect of quinoa flour on the chemical and nutritional properties of cookies (mean values ± standard deviation)[1,2].

Samples[3]	Ash (%)	Crude Protein (%)	Crude fat (%)	Phytic acid (mg/100 g)	Total phenolic content (µg GAE/g)
Control	1.13±0.02[F]	7.23±0.04[F]	18.81±0.16[F]	122.82±3.77[F]	720.02±7.69[F]
10% QF	1.27±0.02[E]	7.59±0.05[E]	19.17±0.07[E]	162.51±2.79[E]	815.63±6.19[E]
20% QF	1.47±0.04[D]	8.20±0.02[D]	19.54±0.05[D]	204.17±6.06[D]	937.71±17.39[D]
30% QF	1.68±0.04[C]	8.49±0.04[C]	20.06±0.06[C]	221.57±5.49[C]	1042.60±17.82[C]
40% QF	1.86±0.01[B]	8.84±0.04[B]	20.45±0.07[B]	256.74±2.47[B]	1142.85±10.11[B]
50% QF	2.00±0.03[A]	9.28±0.03[A]	21.09±0.08[A]	297.54±4.53[A]	1285.00±21.21[A]

[1] Duncan's multiple range test. The means with the same letter in column are not significantly different ($p<0.05$).
[2] Values are dry weight basis.
[3] QF= Quinoa flour.

the TPC values of 40% QF and 50% QF cookies were 1142.85 and 1285.00 µg GAE/g, respectively (Table 3). The value was increased significantly by the substitution of QF. It was suggested that the addition of QF increased the antioxidant capacity of the cookies. Quinoa has stronger antioxidant activity in comparison with wheat (Watanabe *et al.*, 2003; Asao and Watanabe, 2010).

Phytic acid is found in cereals, legumes and seeds as a natural component. Phytic acid makes complex with necessary minerals important for human nutrition by hindering absorption (Demir and Elgün, 2014). It is an important anti-nutrient due to reducing effect on some minerals and also protein bioavailability (Rickard and Thompson, 1997). Most phytic acid -mineral complexes are insoluble at physiological pH level, which is the main cause of the poor bio -availability of the mineral complexes (Harland and Harland, 1980). In our study, mean phytic acid contents of cookie samples changed between 122.82 mg/100 g and 297.54 mg/100 g. As the QF addition ratio increased in cookie formulae, phytic acid content increased and the highest phytic acid content was obtained with 50 % QF addition levels. As expected a substantial increase in the levels of phytic acid was found in all cookie samples containing QF. Valencia-Chamorro (2003) reported that phytic acid is located in the external layers as well as in the endosperm and the average phytic acid concentration was 1.18 g/100 g in varieties of quinoa.

Mineral contents of the cookie samples are given in Table 4. Generally, all of the investigated minerals of cookie samples were increased by the addition of quinoa flour. QF addition levels showed a significant effect ($p<0.05$) on total K, Mg, Ca, Fe and Zn contents. Cookie samples containing 0% QF (control group) had the lowest values of K, Mg, Ca, Fe and Zn minerals. The Recommended Dietary Allowances (RDAs) for children (4-8 years) are 800 mg of calcium, 10 mg of iron, 3.8 g of potassium, 130 mg

Table 4. Effect of quinoa flour on the mineral content of cookies (mg/100 g) (mean values ± standard deviation)[1,2.]

Samples[3]	K	Mg	Ca	Fe	Zn
Control	123.02±3.30[f]	15.10±1.10[f]	41.99±0.18[f]	1.74±0.06[f]	0.83±0.04[f]
10% QF	174.41±5.72[e]	29.75±0.91[e]	43.13±0.02[e]	1.95±0.06[e]	1.15±0.08[e]
20% QF	232.18±4.56[d]	47.30±1.62[d]	44.34±0.03[d]	2.22±0.05[d]	1.37±0.05[d]
30% QF	282.95±6.63[c]	61.27±1.24[c]	45.57±0.07[c]	2.44±0.03[c]	1.62±0.04[c]
40% QF	322.80±5.81[b]	74.01±0.78[b]	46.74±0.21[b]	2.65±0.06[b]	1.88±0.04[b]
50% QF	361.31±8.65[a]	89.82±0.94[a]	48.28±0.23[a]	2.90±0.03[a]	2.10±0.02[a]

[1] Duncan's multiple range test. The means with the same letter in column are not significantly different ($p<0.05$).
[2] Values are dry weight basis.
[3] QF= Quinoa flour.

of magnesium, and 5 mg of zinc. When 100-g (dry matter) cookie containing 50% QF were consumed 6.1% of RDA for Ca, 29.0% of RDA for Fe, 9.5% of RDA for K, 69.1% RDA for Mg and 42.0% of RDA for Zn were taken by the children body.

These ratios are very important to overcome mineral deficiency, especially in terms of Fe, Mg and Zn. Thus, the use of QF instead of WF which contain high levels of minerals led to an increase in mineral content of the final product cookie. This was an expected result. Because, quinoa contains more calcium, magnesium, iron, and zinc than common cereals, and the iron content is particularly high (Jancurová *et al*., 2009; Demir, 2014a). It was previously reported that QF addition increased the mineral contents of foods such as tarhana and bread (Demir, 2014a; Bilgiçli and İbanoğlu, 2015).

Sensory properties

The scores of sensory properties of cookies are shown in Figure 1. Panellists were asked to evaluate colour, taste, odour, appearance, crispness and overall acceptability during sensory analysis. It can be seen in Figure 1, QF affected the scores of sensory properties of cookie samples. QF addition had statistically significant effect ($p< 0.05$) on colour, taste, crispness and overall acceptability except odour scores. Cookie samples made of 100% WF (control group) had lower scores for all the tested sensorial parameters. Statistically, 10% QF containing samples had the same sensory scores compared to control cookie. Also, addition of QF improved all sensorial properties. These results show that more satisfying cookies can be manufactured using QF up to levels at least 20% (Figure 1).

Conclusion

Several recent studies have showed the successful formulation of pseudo-cereal containing cereal based products. In this study, possible use of QF as a pseudo-cereal was investigated in cookie production. QF was successfully incorporated into cookie formulation. As conclusion, chemical and nutritional properties of cookie improved with QF addition. QF additions increased the ash, crude protein, crude fat, TPC and mineral contents. Also, sensory properties of the cookie samples were enhanced by the addition of QF. In conclusion, it is suggested that quinoa is a nutritious and functional substitute for wheat. However, it should be noted that high levels of the antinutrients, such as phytic acid were found in quinoa. The effect of use of higher levels of QF addition (i.e. 100% QF, gluten free) on the properties of cookie samples requires further research.

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