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Quinoa as non–wheat flour source and its utilization in sponge cake production: cultivation, nutritional and technological assessment

Ayman A. Mohammad[1], Heba M. Amer[2], Fathy M. Mehaya[1] and Mohamed S. Hussein[2]

[1]Food Technology Department, National Research Center, 33 El-Buhouth St., (former El- Tahrir St.,) Dokki, Giza, Egypt. Postal Code: 12622
[2]Medicinal and Aromatic Plants Research Department, National Research Centre, 33 El-Buhouth St., (former El- Tahrir St.,) Dokki, Giza, Egypt. Postal Code: 12622.

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ABSTRACT

Quinoa (*Chenopodium quinoa* Willd.) recently garnered increasing interest as a potential field crop with balanced nutrients for improvement of human's food. So, this study explored the possibility of an economical quinoa production under Egyptian environmental conditions. Quinoa was grown under four locations with different climatic and soil conditions: Sinai in the North (sandy-clay); El-Fayuom (clay) and El-Sharkia (loamy) in the central area and El-Minya (sandy) in the Upper Egypt. The stability of agronomic performance (vegetative growth, grain yield, thousand kernel weight) during two successive growing seasons (2016 and 2017) was evaluated. Also, the proximate composition, minerals content as well as the technological properties of quinoa flour as a wheat flour replacer in sponge cake production were investigated. Sinai location recorded the highest agronomic performance producing quinoa seeds with significant higher protein content (15.5 %). The highest content of fat (6.9%) and ash (3.7%) was found in the El-Fayoum location, while the highest value of dietary fiber (10.99%) occurred in El-Minya location. Potassium was the predominant mineral with a maximum value of 1198 mg/100 g in El-Minya location. Micro-element contents varied in narrow ranges between quinoa cultivars. Substitution of wheat flour with quinoa flour at 25% significantly increased cake volume gaining the highest score for sensory acceptance. Further addition of quinoa flour decreased the specific volume of cake and declined its color attributes. In general, the cakes manufactured using 100% quinoa flour had the lowest scores for all measured organoleptic properties, but this sample suitable for gluten- hyper- sensitive patients.

Keywords: quinoa, cultivation, proximate analysis, minerals, sponge cake

Introduction

Wheat represents the best grains used in baking industry due to the rheological and baking performances of gluten. But, there is a global unbalance between wheat production and consumption, especially in developing countries. The lack of suitable soil and environmental condition are the main causes of this gab (Rodriguez-Sandova *et al.*, 2012). However, wheat flour could be partially replaced by another flour sources. In some cases, wheat flour should be completely emitted such as gluten-free products. In this concern, maize, rice, tuber, root and legume flours are usually used in bakery products (Greene and Bovell-Benjamin, 2004). The lack of gluten in these sources is the major technological challenge because gluten is necessary for the elastic and extensible properties (Gallagher *et al.*, 2003). Also, these flours based products lack to vitamins, minerals and fibers (Thompson, 2000). Quinoa has been promoted as an alternative field crop for improvement of human's food due to its stress-tolerant characteristics and nutritious qualities even under the conditions of marginal lands (Präger *et al.*, 2018).

Quinoa (*Chenopodium quinoa* Willd.) is belonging to the Amaranthaceae, (Ruiz *et al.*, 2014). Cultivation of quinoa was originated in South America and currently it is widely planted in Chile, Bolivia, Ecuador, Peru and Argentina (Abugoch-James *et al.*, 2009). Nowadays, quinoa is attracting the attention in many countries all over the world as an alternative cereal crop (Wu, 2016). Quinoa could be adapted under stress conditions to give high grain yields as it resists the drought and frost and could be planted in poor soils (Nowak *et al.*, 2016). Consequently, it represents an extremely

Corresponding Author: Heba M. Amer, 2Medicinal and Aromatic Plants Research Department, National Research Centre, 33 El-Buhouth St., (former El- Tahrir St.,) Dokki, Giza, Egypt. Postal Code: 12622. E-mail: hs.amer@nrc.sci.eg

agronomical choice providing food security (FAO, 2013). Beside human nutrition, quinoa by-products considered good animal feeds as well as its pharmaceutical applications (Brady *et al*., 2007).

From the nutritional point of view, quinoa has a unique nutritional profile as it contains numerous health-promoting and functional ingredients (Vega-Gálvez *et al.* 2010). Protein of quinoa is characterized with a better amino acid balance due to the presence of methionine, lysine and cysteine in relatively higher amounts than that of wheat or corn (Becker and Hanners, 1990). Also, its fat is rich in phytosteroids, and omega-3 and 6 fatty acids (Farinazzi-Machado *et al*., 2012). Furthermore, it is a good source of dietary fiber (Alvarez-Jubete *et al.*, 2010). Moreover, quinoa contains adequate levels of vitamins (C, E and B complex) (Jancurova *et al.*, 2009), minerals (calcium, potassium, zinc, iron, magnesium, manganese, phosphorus) (Prado *et al.*, 2014; Diaz-Valencia *et al.* (2018). Bioactive compounds (phenolics, flavonoids and saponins) were also identified in quinoa seeds (Gómez-Caravaca *et al.*, 2011).

Functional ingredients of quinoa offer a good choice for a variety of food applications, especially gluten-free products (Berti *et al.*, 2004). Thus, it is rational that quinoa seeds are easily ground to flour, which could be used to produce toasted and baked products with unique nutritional and textural properties. In this concern, several studies investigated the suitability of quinoa flours for preparation of many baked products such as breads, cookies, biscuits, noodles, flakes, tortillas and pancakes (Alvarez-Jubete *et al*., 2010; Zevallos *et al*. 2014; Wang *et al.*, 2015).

This study aims to maximize the productivity of quinoa crop under the Egyptian condition and evaluate its nutritional value. Also, quinoa seeds were undertaken to produce sponge cake with high nutritional characteristics by using quinoa flour. The influence of quinoa flour on cake properties was assessed by measuring physical, chemical, nutritional and sensory properties.

Materials and Methods

Materials

Quinoa seeds were obtained from Field Crops Research Institute (FCRI), Agricultural Research Center, Ministry of Agriculture and Land Reclamation of Egypt. Wheat flour and other materials used in cake making like eggs, whole milk powder, sugar powder, shortening, baking powder and salt were obtained from local market.

Methods:

Cultivation of quinoa

Quinoa seeds were cultivated under different environmental locations during two consecutive seasons 2016 and 2017. Field plot experiment was established using a completely randomize design within; El-Sharkia, El-Fayoum, Sinai and El-Minya locations. The physical and chemical properties of studied soil were determined according to IUSS (2015) and presented in Table (1).

Table 1: Physical and chemical properties of the soil of different locations

	El-Sharkia	El-Fayoum	Sinai	El-Minya
Physical properties				
Sand %	76.2	55	75	86
Silt %	7.3	20	16.75	4.8
Clay %	16.5	25	8.25	9.2
Texture	Loamy	Clay	Sandy clay	Sandy
Chemical properties				
pH	8.3	8.2	8.1	8.4
EC (ds/m)	0.85	0.83	1.09	0.17
Ca^{++}	364	755	222	220
Mg^{++}	104	309	105	86
Na+	133	67	42	35
P	1.79	2.11	1.45	2.85
K	24	25	18	20
Mn	14.5	2.3	3.5	0.8
Zn	2.4	1.6	2.1	1.3
Cu	0.6	1.7	0.8	0.5

Planting was carried out in rows 50 cm apart and the distance between plants was 30 cm (one plant/hill). All plants treated with recommended dose for quinoa production according to the estimated recommendations (ammonium nitrate150 Kg/fed., calcium super phosphate 150 Kg/fed. and potassium sulfate 50 Kg/fed.) according to Gomaa (2013). After 150 days, the vegetative parameters were recorded for each sample; plant height (cm), branches number, seed yield (g/plant), seed yield (kg/ha) and weight of 1000 seeds (g) for each location.

Preparation of quinoa flour:

Quinoa seeds were cleaned and washed several times with running tap water (with constant stirring for about 1-2 min). The water was drained off and the wet seeds were dried in an air oven at 55°C. The dried quinoa seeds were milled using Quadrumat Junior flour mill. Quinoa flour (whole meal) was packaged into polyethylene bags and stored in deep freezer (-18°C) until using.

Chemical composition and dietary fiber:

Protein, fat, ash and moisture contents of quinoa flour were determined according to the methods described by AOAC (2005). Carbohydrates were determined by difference. Soluble and insoluble dietary fibers were determined using a Total Dietary Fiber Assay Kit (TDF100A, Sigma-Aldrich, St. Louis, Missouri, USA) according to the gravimetric enzymatic method (AOAC, 2005). Total dietary fiber was calculated as the sum of soluble and insoluble dietary fiber.

Determination of Mineral

Samples were digested using nitric acid, where it is an acceptable matrix for consistent recovery of metals which are compatible with the analytical method (Rice *et al.*, 2017). All minerals analyses were performed on *Agilent 5100 Inductively Coupled* Plasma – Optical Emission Spectrometer (*ICP-OES*) with *Synchronous Vertical Dual View (SVDV)*. For each series of measurements intensity calibration curve was constructed composed of a blank and three or more standards from Merck Company (Germany). Accuracy and precision of the metals measurements were confirmed using external reference standards from Merck, and standard reference material for trace elements from National Institute of Standards and Technology (NIST), were used to confirm the instrument reading.

Sponge cake preparation

Sponge cakes batter formulations were prepared according to Lee *et al.* (2015) with some modifications as follows: Flour (27%) and baking powder (0.8%), whole fresh eggs (34%), sugar (20.2%), whole milk powder (2%), shortening (4%) , water (11.5%) and vanilla (0.5%). the liquid whole eggs, water and sugar were whipped in a Kitchen-Aid mixer at speed 3 for 1 min and further mixed at speed 6 for 9 min. Then, dry ingredients (the flour blend, whole milk powder, baking powder and vanilla) were added simultaneously to the mixture and beaten using the mixer at speed 1 for 1 min and further mixed at speed 3 for 2 min. The melted shortening was added finally and mixed at speed 1 for 20 s. Sponge cakes containing quinoa flour were prepared by replacing wheat flour with quinoa flour at 25, 50, 75 and 100% levels. Each batter formulation (100 g) was placed in an aluminum pan (8.5 × 16 × 5 cm) and baked in a preheated oven at 180ºC for 35 min. Cakes were allowed to cool for 30 min. The cooled cakes were packed in polypropylene bags at room temperature.

Baking quality of cakes:

Baking quality of cakes was determined according to AACC (2000). Volume (Cm^3) of produced samples was determined by the displacement of rape seeds, specific volume was calculated as the ratio between the volume of the cooled baked cakes and their weight.

Color attributes of cakes

The color parameter were evaluated using Hunter, Lab Scan XE, Reston VA., calibrated with a white standard tile of Hunter Lab color standard (LX No. 16379) x = 77.26, y = 81.94 and z = 88.14 (L*= 92.43, a*= -0.88, b*= 0.21). The results were expressed in accordance with the CIELAB system where: L (L = 0 [black], L = 100 [white]), a (-a = greenness, +a = redness), b* (-b = blueness, +b = yellowness).

Sensory evaluation of cakes

Consumer preference for sponge cakes samples was determined using the hedonic test according to Lee *et al.* (2015) by ten untrained panelists from the staff of Food Technology Department. Samples (3×3×3 cm) were served to the panelists in random order and they were asked to rate the acceptability of the product in terms of color, flavor, taste, softness, and overall acceptability. The nine point hedonic scale (9=like extremely, 5=neither like nor dislike, and 1=dislike extremely) was used.

Statistical Analysis

Statistical analysis was assessed using the Statistical Analysis Software System for Windows (SAS, 2008). The significant difference between the mean values were determined by using the analysis of variance (ANOVA) and Duncan's multiple range test was conducted at a significance level of $p<0.05$. All samples were analyzed in triplicates and the results were expressed as means ± standard error.

Results and Discussion

Table (2) shows that there were significant differences in growth and yield characteristics between quinoa cultivated under different locations. Plant height, branches No., seed yield and thousand grain weights (seed index) were recorded the highest value under Sinai locations during both seasons. Under Sinai and El-Fayoum locations plants gave the maximum mean values of plant height which recorded 170.3 and 165.3 cm, respectively, while El-Minya gave the shortest quinoa plants (149.0cm,). Sinai location recorded the highest value for branches No. (40.7), seed yield (1244.5 Kg/ha) and thousand kernel weight (3.7 g). There were no significant differences between El-Fayoum and El-Sharkia locations when these characters were considered. The lowest values were recorded under El-Minya location. The variation in growth characters at different locations could be due to the variation of growing conditions like soil texture and its chemical properties, air temperature, humidity, radiation, precipitation, altitude, length of exposure to sun and wind patterns (Prado *et al.*, 2014; Ruiz *et al.*, 2014; Präger *et al.*, 2018). All these factors affected some physiological parameters of plants (germination, sprouting …..etc.), resulting in varying grain yields between locations (Geren *et al.,* 2015).

Table 2: Growth and yield characters of quinoa plants under different locations

Location	Vegetative characters		Seed Yield (g/plant)	Seed Yield (Kg/ha)	Thousand kernel weight (g)
	Plant height (cm)	Branches No. /plant			
El-Sharkia	153.0^{B}	36.3^{B}	15.4^{BC}	1028.9^{BC}	3.5^{BC}
El-Fayoum	165.3^{A}	37.3^{B}	16.6^{B}	1111.2^{B}	3.5^{B}
Sinai	170.3^{A}	40.6^{A}	18.6^{A}	1244.5^{A}	3.7^{A}
El-Minya	149.0^{B}	34.6^{C}	15.1^{C}	1006.7^{C}	3.4^{C}
LSD at 5%	5.040	1.438	1.351	90.084	0.133

*Data are the average of two successive cultivation periods
Means having the same letter within the same column are not significantly different

Nutritional assessment of quinoa seeds

Proximate composition

The proximate composition and dietary content of quinoa seeds planted in different locations are presented in Table (3). Quinoa seeds showed no significant differences in moisture content (10.23-10.33%), being thus suitable for storing. Quinoa seeds planted in El-Sharkia and Sinai showed the highest protein content (15.37 and 15.51%, respectively), which can be due to high N bioavailability in the soils (Huygens *et al*., 2008). The lowest protein content (13.58%) was presented by those planted in El-Minya. Protein content of quinoa seeds is in agreement with the values reported by Diaz-Valencia *et al.* (2018). Crude fat content (6.15 - 6.91%) is comparable with previous values reported by Wang *et al.* (2015) and Vega-Gálvez *et al.* (2018). The ash content of quinoa seeds (3.3 -

3.7%) falls within the range (2.2–3.7%) reported previously by Zevallos *et al.* (2014) and Vega-Gálvez *et al.* (2018). The variation in the protein, fat and ash contents of quinoa may be due to the regional production (climate, soil, temperature, management) (Diaz-Valencia *et al.*, 2018). Generally, Literature knowledge confirmed that quinoa flour had richer chemical and nutritional composition compared with cereal flours, such as wheat, rice, maize, and rye (Alvarez-Jubete *et al.*, 2010; Watanabe *et al.*, 2014; Demir and Kılınc, 2017).

The main component found in quinoa seeds was carbohydrates (64.07 – 65.94%). The observed results are close to the ranges already reported in previous studies. Total carbohydrates of quinoa seeds with different colors (red, yellow and white) was early evaluated by Bruin (1964), reporting its contents ranged from 58.1 to 64.2% and the white samples showed the highest levels. Recently Vega-Gálvez *et al.* (2018) found similar range (61.42–69.22%) in six quinoa ecotypes. On the other hand, quinoa seeds showed 7.36 – 7.90, 2.27 – 3.08 and 9.36 – 10.99% Insoluble, soluble and total dietary fibers, respectively Table (3). the obtained results agrees with the values reported by Vega-Gálvez *et al.* (2018), as they stated that total dietary fiber varied between 10.95 and 14.99%. According to USDA (2017), the dietary fiber content of quinoa seeds is comparable to that of hulled barley and superior to that of raw white rice (17.3 % and 1.3%, respectively). Moreover, Lamothe *et al.* (2015) indicated that quinoa dietary fiber contains fiber fractions, such as xyloglucans and pectic polysaccharides, which closely resemble those of fruits and vegetables, providing favorable functions in the colon.

Tale 3: Proximate analysis of quinoa seeds planted in different locations

Parameter (%)	El-Sharkia	El-Fayoum	Sinai	El-Minya	LSD 0.05
Moisture	10.28±0.01	10.33±0.05	10.23±0.04	10.32±0.04	NS
Protein	15.37^{A}±0.06	13.83^{B}±0.07	15.51^{A}±0.01	13.58^{C}±0.07	0.2333
Crude fat	6.15^{C}±0.03	6.91^{A}±0.05	6.57^{B}±0.01	6.54^{B}±0.01	0.1166
Ash	3.30^{B}±0.03	3.70^{A}±0.01	3.60^{A}±0.07	3.60^{A}±0.09	0.2476
Carbohydrate	64.89^{C}±0.04	65.22^{B}±0.08	64.07^{D}±0.05	65.94^{A}±0.10	0.2943
ISDF	7.36±0.18	7.75±0.19	7.45±0.18	7.90±0.19	NS
SDF	2.27^{C}±0.05	2.85^{A}±0.07	2.57^{B}±0.06	3.08^{A} ±0.07	0.2617
TDF	9.63^{B}±0.23	10.60^{AB}±0.26	10.02^{AB}±0.24	10.99^{A}±0.27	0.9928

NS = not significant, ISDF = Insoluble dietary fiber, SDF = Soluble dietary fiber, TD = Total dietary fiber, Means with the same letter in the same raw are not significantly different.

Minerals content

Data in table (4) showed that quinoa seeds are a good source of both macro-elements (potassium, phosphor, magnesium and calcium) and micro-elements (iron, manganese, zinc, and copper). Potassium recorded the highest content (1058 -1198 mg/100g), confirming that this element represents about the half of minerals in quinoa grains. Comparable value (1200 mg/100g) was reported by Ruales and Nair (1993), while higher potassium values (1672 – 2325 mg/100g) were reported by Miranda *et al.* (2012). On contrary, Diaz-Valencia *et al.* (2018) found lower potassium content of quinoa grains ranges from 593 to 815 mg/100g. Moreover, quinoa grains present comparable phosphor content (462 - 598 mg/100g) to those reported by the same authors (490-588 mg/100g). Magnesium and calcium contents (226 - 296 and 82 - 136 mg/100g, respectively) were close to the values reported by Diaz-Valencia *et al.* (2018) for white quinoa samples. Miranda *et al.* (2012) reported broader ranges for the concentration of calcium (25.15-116.60 mg/100g), whereas Prado *et al.* (2014) reported a range from 77.10-211.29 mg/100g). Quinoa seeds obtained from El-Minya had the highest potassium, phosphorus and calcium contents, while those obtained from Sinai had the highest magnesium content.

Regarding the evaluated micro-elements (Table 4), the iron content (30 - 36 mg/100g) is in agreement with the value previously reported by Ruales and Nair (1993). Our result was higher than those reported by Prado *et al.* (2014) and Diaz-Valencia *et al.* (2018) (4.76 to 24.04 mg/100g). Zinc contents of quinoa seeds (4.8 – 6.8 mg/100g) are comparable to those reported by Miranda *et al.* (2012) and Diaz-Valencia *et al.* (2018) (2.73-5.12 m/100g). Manganese content of quinoa cultivars varied in narrow range from 3.4 to 3.8 mg/100g. Similar values were reported by Diaz-Valencia *et al.* (2018), but surpassed levels were reported by Miranda *et al*. (2012) and Prado *et al.* (2014). Copper represents higher values (3.2 – 5.0 mg/100g) compared to the values reported by Miranda *et al.* (2012) and Diaz-Valencia *et al.* (2018) for quinoa harvested in Chile and Peru, respectively. The variations in elemental composition could be due to the soil type and mineral composition, climate condition as well as fertilizer application (Miranda *et al.*, 2012). In general, Quinoa contains more minerals than common cereals *i.e.* corn, wheat, rice and barley (USDA 2017), which are enough to satisfy the nutritional recommendations. But, calcium needs to be supplemented through other sources; however, iron availability may be affected by saponins and phytic in the seeds (Ruales and Nair, 1993).

Tale 4: Element contents of quinoa seeds planted in different locations (mg / 100g)

Element	El-Sharkia	El-Fayoum	Sinai	El-Minya
Potassium	1118.0	1158.0	1058.0	1198.0
Phosphorus	518.0	538.0	462.0	598.0
Magnesium	226.0	286.0	296.0	276.0
Calcium	82.0	102.0	106.0	136.0
Iron	30.0	35.2	36.0	34.0
Zinc	6.6	6.8	4.8	5.6
Manganese	3.4	3.8	3.6	3.8
Copper	3.4	4.4	3.2	5.0

Quality characteristics of cake samples

Baking quality

Table (5) represents the technological characteristics of cake samples supplemented with different levels of quinoa flour. The specific volume of baked cakes provides a quantitative measurement of baking performance since it indicates the amount of retained gas in the final product. Moreover, this parameter determines the consumer's preference as they desire light cakes than the dense ones. Wheat flour substitution with quinoa flour at 25% significantly increased cake specific volume. This could be due to that addition of quinoa flour at this level exhibited cake batter that allowed higher gas expansion and retention resulting in a higher specific volume. But, further addition of quinoa flour decreased the specific volume of cakes in a concentration-dependent fashion. Specific volume of cake was decreased by 15.5% when wheat flour completely replaced with quinoa flour. In accordance with previous investigators, wheat flour substitution with quinoa flour up to 10% increased bread loaf volume but further substitution decreased the volume (Morita *et al*., 2001). While, Wang *et al.* (2015) revealed that the significant decrease in specific volume of cookie occurred when the addition of quinoa flour was greater than 60%. The reduction of specific volume could be related to the lack of gluten in quinoa flour. Furthermore, quinoa fibers and polyphenols modify the molecular conformation and polymer structure of gluten network (Sivam *et al*. 2013). These factors decreased dough strength consequently, lower gas retention capacity and smaller pores, thus reducing the volume of the finished product (Jaldani *et al*., 2018).

Table 5: Quality characteristics of cake samples

Parameters	Control	Cakes containing quinoa flour (%)				LSD 0.05
		25	50	75	100	
Baking quality						
Weight (g)	80.09	79.87	78.88	78.27	77.65	NS
Volume (cm^3)	156.44^{AB}	162.13^{A}	148.48^{BC}	143.64^{C}	128.00^{D}	12.625
Specific volume	1.99^{AB}	2.08^{A}	1.92^{AB}	1.88^{B}	1.69^{C}	0.164
Crust color						
L*	63.76^{A}	63.09^{A}	60.75^{AB}	57.73^{BC}	53.41^{C}	5.103
a*	16.62^{C}	16.74^{C}	17.44^{BC}	18.60^{AB}	19.99^{A}	1.527
b*	48.57^{A}	44.53^{B}	41.51^{BC}	40.49^{C}	39.29^{C}	3.668
Crumb color						
L*	68.09^{A}	64.16^{AB}	60.72^{BC}	60.32^{BC}	57.91^{C}	5.312
a*	5.19^{D}	6.78^{C}	7.87^{B}	8.34^{AB}	8.77^{A}	0.638
b*	36.91^{A}	34.52^{AB}	33.81^{B}	35.29^{AB}	34.83^{AB}	2.986

NS = not significant, Means with the same letter in the same raw are not significantly different

Color attributes

The color parameters (*L*, a** and *b**) of cake samples manufactured from wheat-quinoa flour blends are presented in Table 5. Crust lightness (L*) and yellowness (b*) declined as the addition level of quinoa flour increased in the blends. On contrary, Redness of cake crust (a* values) increased as the substitution level increased. Nevertheless, levels of quinoa flour higher than 25% in the blends were necessary to produce significant reduced lightness. Regarding the crumb color, L* and a* values showed similar tendency to the crust, yielding darker crumbs. While, b* values showed no clear tendency with increasing the substitution level. Cake manufacture using 100 % quinoa flour displayed the darkest value, which was visually evident in the crust and crumb parameters. The darker color of quinoa flour is probably due to its higher ash content and phenolic pigments (Tang *et al*. 2015). Also, the higher protein content of quinoa flour, with lysine residues, that react with reducing sugars during baking producing Maillard browning (Repo-Carrasco *et al.,* 2003).

Organoleptic characteristics

The mean values for organoleptic characteristics of cake samples are shown in Table (6). Panellists were asked to evaluate taste, color, flavor, softness and overall acceptability during sensory analysis. Wheat flour substitution with quinoa flour resulted in diverse effects on the sensory properties of cake. Cake sample containing 25% quinoa flour gained the highest score for overall acceptance, being preferred over the control sample. Moreover, sensory acceptable cakes with no significant differences were obtained in the presence of up to 50% quinoa flour. In general, the cakes manufactured using 100% quinoa flour had the lowest scores for all measured properties, but this sample suitable for gluten- hyper- sensitive patients. Rothschild *et al.* (2015) investigated the effect of roasted and non-roasted quinoa flour on consumer acceptance of an allergen-free, gluten-free cake formulation. There were no significant differences between commercial chocolate cake and those made from non-roasted quinoa flour, which had the highest sensory scores. Moreover, Demir and Kılınc, (2017) found that addition of quinoa flour improved all sensorial properties of cookies samples. They stated that more satisfying cookies can be manufactured using quinoa flour up to levels at least 20%.

Table 6: Organoleptic characteristics of cake samples

Parameters	**Control**	**Cakes containing quinoa flour (%)**				**LSD**
		25	**50**	**75**	**100**	**0.05**
Taste	7.42^{A}	7.57^{A}	7.42^{A}	6.28^{AB}	5.7^{B}	1.667
Color	8.14^{A}	7.71^{A}	7.00^{AB}	7.00^{AB}	5.57^{B}	1.464
Flavor	7.00^{AB}	7.71^{A}	6.57^{AB}	6.00^{B}	5.7^{B}	1.674
Softness	8.00^{AB}	8.42^{A}	7.14^{BC}	6.14^{C}	6.14^{C}	1.021
Overall preference	8.14^{A}	8.28^{A}	7.71^{AB}	6.71^{BC}	5.85^{C}	1.351

Conclusion

It could be concluded that the economic production of quinoa, with high grain yield and quality, is possible under the soil and climatic conditions in Egypt. Sinai location seems to be suitable for quinoa production showing the greatest yield potential with the highest thousand kernel weight, protein and iron contents. On the other hand, successful sponge cake formulations were developed based on wheat flour substitution by quinoa flour. Regarding the physicochemical and sensory characteristics of sponge cakes, partial replacement of wheat flour with 25% quinoa flour received the most acceptable sensory scores. Furthermore, gluten-free cake could be successfully produced with satisfactory consumer acceptance using quinoa flour. However, further studies are needed to investigate the micro-nutrients of quinoa flour such as vitamins, amino acids, fatty acids and phenolic compounds.

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