Effect of Pre-Treatment Techniques on the Quality Characteristics of Quinoa Flour

Ali R. Gomaa[1]; Sahar T. Ibrahim[2]; Amera T. Mohammed[1]✉
[1]Crops Technology Department, Food Technology Research Institute, ARC, Egypt
[2]Crop Intensification Research Section, Field Crops Research, ARC, Egypt

Received: *8/11/2019*

Abstract: The present study was carried out to evaluate the effect of different pre-treatment (dehulling process and treated with water) on physical, chemical and quality characteristics of flour produced from quinoa seeds cultivated under Egyptian conditions. The obtained results revealed that, quinoa produced small circular-shaped seeds, 1.96 mm diameter, the 1000-seed weight was 2.81g, bulk density was 0.83 g/cm^3 and test weight was 75.94 kg100l^{-1}. The dehulling process using quinoa scaler gave two products: quinoa hulls and dehulling quinoa seeds. Milling process gave two milled fraction from flour: from sieve less than 0.45 mm and from sieve bigger than 0.45 mm. The saponin content reduced significantly in the treatments which dehulling using quinoa scaler (DQS) followed by which were treated with water. Protein content was slightly decreased after dehulling for 60s (11.56%). The flour which dehulling process using quinoa scaler for 90s gave the lowest fat and ash content, while the total carbohydrates content was high. Phenylalanine + tyrosine were the highest aromatic essential amino acids and leucine was the limiting amino acid. The highest macro and micro elements were potassium and iron, respectively. Results indicated that using of quinoa flour resultant from dehuling for 60 s (DQS_{60s}) as the best treatment in preparation of cake at levels 25, 50, 75 and 100% did not affected on color and odor of cake. The best acceptance was up to 50% of the cake substitution level, all texture profile analysis (TPA) parameters of the resultant cake decreased with increasing of quinoa flour levels of substitution except the hardness. It can be concluded that the treated with water was the best technique to obtain the highest milling yield on a small-scale, while on a large -scale the dehulling process using quinoa scaler for 60s (DQS_{60s}) was the best technique to saving water, reducing time and to give high yield of dehulling quinoa.

***Keywords*:** Quinoa, quinoa scaler, saponin content, phytic, antioxidant, minerals

INTRODUCTION

Quinoa (*Chenopodium quinoa* Willd.) is a pseudocereal seeds that has been cultivated in Andean region for thousands of years (Bhargava *et al*., 2006). Quinoa can be grown in a wide range of pH soil. Also, it can be tolerated different stresses such as salinity, cold air, high solar radiation and night sub-freezing temperatures, it can be grown in arid, semiarid regions, lowlands, brackish lands, salt-water marshes (González *et al*., 2009) and in high altitudes mountain areas (Mari Repo *et al.,* 2011).

Quinoa has been promoted as on alternative agricultural crop and marketed as a" Super food" for its nutrition's qualities (Shokry, 2016). Quinoa is a complete food with high-nutritional value due to its high content of good quality protein, lipids, starch, minerals and vitamins like B, C and E. Quinoa was catalogued by FAO as one of the most promising crops for the humanity (Nisar *et al.,* 2017). Quinoa contains higher amounts of protein and greater balance in the distribution of essential amino acids than cereals, resembling the biological value of milk protein. It exceeds cereals in the amount of lipids, proteins, dietary fiber, and minerals, mainly calcium, phosphorus, iron and zinc (Gajendra *et al.,* 2019). In addition to presenting high nutritional quality, it is considered an option to solve human nutrition problems (FAO, 2011). Quinoa contained protein (14-18%), starch (48-69%) and lipid was ranged 4.4-8.8% of the dry matter in quinoa (Li and Zhu, 2017). Quinoa is a good source of dietary fiber (7-10%), lysine (5.1-6.4%) and methionine (0.4-1.0%) (Abugoch, 2009), also have amino acids balanced (Abdellattif, 2018). Quinoa protein is gluten-free to be used for people with celiac disease (Mota *et al.,* 2015) Arneja *et al.* (2015) reported that lysine content of quinoa (5.6%) is double as compared to wheat (2.8%). In addition, the sulfur-containing amino acids cysteine and methionine (3.1%) are found in concentrations that are unusually high compared to the other plants. It is also rich in certain types of micronutrients such as potassium, vitamins (B_6 and folate) as well as heath-beneficial bioactive compounds such as polyphenols (Stikic *et al.,* 2012; Tang *et al.,* 2016). Therefore, quinoa showed relatively high antioxidant activity than amaranth. The antioxidant activity of quinoa might be of particular interest to medical researchers and needs further attention regarding its utilization as a natural potent antioxidant (Paśko *et al*., 2009).

Quinoa seeds are surrounded by an epicarp containing saponins, which have a characteristic bitter (Vega-Gálvez *et al*., 2010). The content of saponin varied in quinoa between 0.1 and 5% (Stuardo and San Martín, 2008). Saponin removal is the essential first step in any utilization of quinoa seeds as a food product. On a small-scale, saponin removal could be accomplished by washing the seeds with cold running water, and also can be used alkaline water, while mechanical removal of the pericarp will likely to be the most economical method of reducing saponin, although probably not effective as washing (Tang *et al.,* 2015). The washing process under running water increasing the total phenolic compounds, antioxidant capacity and reducing the content of saponin, thus decrease the bitter taste of quinoa seeds (Nickel *et al.,* 2016).

✉Corresponding author e-mail: amirataha99@yahoo.com

The methods of elimination of saponin in quinoa can be classified as moist and dry techniques. The moist techniques are effective for saponin elimination; however, the problems are a high cost of drying the product, disposing of wastewater containing saponin and the seeds may be started to germinate during the washing process, because quinoa has a very high germinate power. The dry techniques (dehulling) using machinery to polish the seeds to eliminate saponin is cheaper than washing but has the disadvantage that it does not eliminate all the saponin. If was increased efficiency of polishing seeds some nutrients are lost and proteins which are mainly present in the exterior layer of the seeds (Repo-Carrasco *et al.,* 2003)

The objectives of this research were to study the effect of dehulling using quinoa scaler, treated with water and milling processes on physical, chemical, and quality characteristics of resultant quinoa flour, also to investigate the possibility of using quinoa flour as a substitute of wheat flour in cake production.

MATERIALS AND METHODS

Materials:

One exotic quinoa accessions were used in the present study. These accessions were introduced from Food and Agriculture Organization (FAO) of the United Nations through technical cooperation program (TCP) under a project technical assistance for the introduction of quinoa and appropriation/institutionalization of its production in Egypt.

Experimental design:

Two-year experiment was conducted at Giza Research Station, ARC, during 2014/2015 and 2015/2016 seasons. Dates of planting were 25 November 2014 and 28 November 2015. The randomized complete block experimental design with four replications was used. Each experimental plot consisted of 7 rows 3-m long and 0.6- apart. Quinoa seeds were sown at a distance of 20 cm between plants, one plant/ hill. Fertilizers were used at rate of 15.5 kg P_2O_5 at land preparation, 24 kg K_2O and 50 kg N/feddan. Fertilization was applied in three equal doses at three dates; after 20, 50 and 70 days from planting (at 4 leaf stage, 8 leaf stage and prior flowering). All other agronomic practices were applied as recommended.

Measurements:

Growth, behavior, seeds yield, and its components: samples of ten plants were taken randomly from each inner rows of each experiment plot and were taken immediately to the laboratory for leaves and stems dissociation, manually. Then, the following traits were measured and recorded: Plants height (cm), number of branches/plant, seeds weight/plant (main head + seeds head of branches (g)), days to maturity, seeds yield kg/plot and seeds yield kg/fed.

Physical properties of the quinoa seeds:

Quinoa seeds were manually cleaned to remove foreign matter, broken and immature seeds. Then, seeds subjected to determine physical properties as follows:

- Spatial dimensions and size:

The weight of 1000-seeds (the weight in grams) was determined by weighing 100 seeds in triplicate and then extrapolating this weight to 1000 seeds. Diameter was measured using a micrometer at ten replications. The bulk density considered as the ratio weight of the seeds to its total volume was determined using 250 ml cylinder, then the volume and weight were recorded (Wongsa *et al.,* 2016). Test weight is a measure of the density of grain, measures how much a specific volume of grain weights was determined using Hectoliter (a Dickey-John GAC2100) and expressed in kilograms per hectoliter (*i.e.* the weight of a hundred liters) according to Diane Lee (2013).

Quinoa seeds preparation:

1- Removing the saponin:

Fresh quinoa seeds inspection to discard contaminant particles or impurities. Removing the saponin found in the seeds using scraping processes or treated with water prior to consumption. The control sample without any pre-treatment is using to comparing with different techniques. The different pre-treatment to remove the saponin of quinoa seeds as follow:

A. Water treatments:

Water treatments were washing with cold and hot water (60°C) 4-5 times or until there was no foam to remove saponin according to Margarita *et al.* (2010). Seeds soaked in water for 24 h according to Valencia *et al.* (1999). Then, all samples were dried at 40ºC/overnight.

B. Dehulling using quinoa scaler:

Dehulling for 30, 60 and 90 seconds using Quinoa scaler (MAQUINARIAS, INNOVA SRL., Peru).

2- Milling of quinoa seeds:

All the resultant samples from the different pre-treatments and control were milled with a laboratory grinder to obtain granules of quinoa flour about (60-80 mesh), then sieving and weighed the flour to produce two fractions: from sieve less than 0.45 mm (F1) and from sieve bigger than 0.45 mm (F2).

Analytical methods of resultant quinoa flour:

- Determination of color attributes:

The color of resultant quinoa flour from the different pre-treatments and control sample were measured after milling according to the method outlined by McGurie (1992) using a hand-held Chromameter (model CR-400, Konica Minolta, Japan). The results were expressed in terms of: L^* (lightness), a^* (redness-greenness) and b^* (yellowness-blueness).

- Determination of saponin content:

The saponin content was determined according to Lozano *et al*. (2012).

- Determination of phytic acid content:

The phytic acid content was determined according to Park *et al.* (2006).

- Determination of antioxidant activity (DPPH radical scavenging activity):

The free radical scavenging activity was determined using the 2.2-diphenyl-2-picryl-hydrazyl (DPPH) method and the absorbance at 517 nm with some modifications according to Fischer *et al*. (2013). The scavenging activity was calculated using the following equation:

DPPH radical-scavenging activity (%) =

[(A - B)/A] ×100.

Where, A is the absorbance of the control and B is the absorbance of the samples.

- Chemical composition of resultant quinoa flour:

Crude protein, fat, crude fiber and ash content were determined according to AOAC (2010). Total carbohydrates were calculated by difference.

- Determination of amino acids profile:

Amino acids profile for the control sample and the best treatment of quinoa flour were determined using an amino acid analyzer (Biochrom 30, USA) using the instruction manual according to AOAC (2010).

- Chemical score (CS):

Chemical score was calculated according to FAO/WHO (2007).

Chemical score (%) =

(EAA of crude protein / EAA of FAO/WHO) × 100.

- Biological value (B.V):

Biological value was positively correlated with the lysine concentration. It calculated according to Eggam *et al.* (1979) as follows:

Biological value (%) =

39.55 +8.89 × lysine (g /100g protein).

- Minerals content for the control sample and the best treatment of quinoa flour:

Magnesium, sodium, zinc, manganese, iron, calcium, potassium and copper for the control sample and the best treatment from quinoa flour were determined by using the flame photometer (Galienkamp, FGA 330, England) and Perkin Elmer Atomic Absorption Spectrophotometer. (Model 80, England) as described in AOAC (2010).

Cake preparation:

Cake was prepared from the best treatment of quinoa flour. The blends containing 0, 25, 50 and 75 and 100% of quinoa flour which substituted with wheat flour is shown in Table (1).

Table (1): Cake formulation

Ingredients (g)	Samples				
	1	2	3	4	5
Wheat flour	100	75	50	25	----
Quinoa flour	---	25	50	75	100
Butter	40	40	40	40	40
Sugar	75	75	75	75	75
Whole eggs	60	60	60	60	60
Vanilla	0.3	0.3	0.3	0.3	0.3
milk (ml)	50	50	50	50	50
Baking powder	3.0	3.0	3.0	3.0	3.0
Salt	0.2	0.2	0.2	0.2	0.2

Dry ingredients, butter and half milk were mixed at low speed for 30s by electric mixer (Moulinex, France) and was added a half remain milk, and then mixed for 30s on low speed. The cake immediately was poured into round cake pans (for each cake about 82 g batter) and baked at 180˚C for 40 min in preheated electric oven (Kumtel, Turkey). The cake was allowed to cool for 1 h then removed from the pans. The cooled cakes were sensory evaluated and packed in a polyethylene bags at room temperature before analysis according to Fondroy *et al.* (1989).

Sensory characteristics of resultant cake:

Sensory characteristics of cake were evaluated by ten panelists. The sensory characteristics were carried out using 9-point hedonic rating scale for five attributes (color, taste, odor, texture and overall acceptability). Attributes were rated on a 1-9 intensity scale, where 9 (like very much) and 1 (dislike very much). Cake were evaluated after cooling for 4 h. Cake were placed in plastic bags and stored at room temperature (25±2°C) until subjected to sensory evaluation (Itthivadhanapong and Sangnark, 2016).

Texture profile analysis (TPA) of resultant cake:

Cake texture was determined by texture profile universal testing machine (CT V1.6 Build Brookfield Engineering Labs. Inc. Middleboro, MA 02346-1031 USA). An aluminum cylindrical probe (TA-AACC36) 2.5 mm diameter was used in double compression test to penetrate to 50% depth at 2.5 mm/s speed test, return speed at 2.5mm/s and trigger load 5N. Hardness (N), cohesiveness, gumminess (N), springiness and chewiness (N) were calculated from TPA graphic according to (Bourne, 2003).

Statistical Analysis:

Data collected were statistically analyzed according to Gomes and Gomes (1984) using COSTAT Computer Program followed by Duncan multiple test. The LSD values at the 5% level were calculated according to the method of Snedecor and Cochran (1980). The multiple ranges of tests were applied to determine the significant differences between samples.

RESULTS AND DISCUSSION

Yield and physical properties of quinoa seeds:

Yield and physical properties of quinoa seeds are shown in Table (2). Results indicated that 2014/2015 seasons were higher in plant height and yield/plot seeds (152.3 cm and 12.5 kg/plot, respectively) compared to 2015/2016, while, the highest seeds yield (1360 kg/fed) was found in 2015/2016.

On the other hand, there were no significant differences between both seasons in number of branches/plant, seed weight of the main head (g), seed head weight (g) and days to maturity.

From Table (2), it could be noticed that, the 1000-seed weight of quinoa seeds were 2.81 g, there was a similar trend by Bhargava *et al*. (2006) who found that the1000-seed weight for 17 cultivars of quinoa ranged from 1.99 to 5.08 g.

Table (2): Yield and physical properties of quinoa seeds

Season / Epidemiological parameters	Plant height (cm)	Number of branches / plant	Seeds weight of the main head (g).	Seeds head weight (g)	Days to maturity	Seeds yield kg/Plot	Seeds yield kg/fed
2014/ 2015	152.3[a] ±0.17	10.9[a] ±0.17	37.9[a] ±0.24	55.8[a] ±0.86	120	12.5[a] ±0.72	1250[b] ±2.10
2015/ 2016	150.7[b] ±0.46	10.8[a] ±0.17	37.7[a] ±0.13	56.5[a] ±1.73	120	15.5[b] ±1.15	1360[a] ±1.38
LSD	0.785	0.393	0.441	3.10		2.180	4.033

Physical Properties of quinoa seeds

1000-seed weight (g)	Diameter of seed (mm)	Bulk density (g/cm^3)	Test weight (Kg/100L)
2.81±0.89	1.96±0.77	0.83±0.08	75.94±0.89

Values are mean of three replicates ± SD, Means with different letters are significantly different at $P \leq 0.05$.

The quinoa produced small, circular-shaped seeds, about 1.96 mm diameter; the bulk density of quinoa seeds was 0.83g/cm^3 (Table 2). The obtained results were supported by (Vilche *et al.,* 2003). On the other hand, the test weight of quinoa seeds was 75.94 kg/100L.

Dehulling and milling processes of quinoa seeds and color attributes of resultant quinoa flour:

Dehulled quinoa seeds resultant from quinoa scaler (DQS) are presented in Table (3). The results showed that the dehulling using quinoa scaler process for 30s (DQS_{30s}) gave two products; 5.58% of quinoa hulls and 94.42% of dehulled quinoa seeds, dehulling for 60s (DQS_{60s}) gave 19.81% of quinoa hulls and 80.19% of dehulled quinoa seeds, meanwhile the dehulling for 90s (DQS_{90s}) gave 32.76% of quinoa hulls and 67.23% of dehulled quinoa seeds.

Milling fractions of quinoa flour are in Table (3). Milled fraction F1% was the highest in DOS_{90s} (85.94%). The lowest F1% was found QCW, DQS_{30s} and DQS_{60s} (78.21, 76.69 and 77.36, respectively) and there were no significant differences between them. The DQS_{90s} had the lowest of F2% milled fraction than the other samples. These results agreed with Hemalatha *et al*. (2016), who reported that the milled fraction of quinoa represented the remaining 75-77% of the kernel weight.

Table (3): Dehulling, milling processes of quinoa seeds and color characteristics of resultant quinoa flour

Treatment	Dehuuling process		Milling process		Color characteristic		
	Quinoa hulls %	Dehulled quinoa seeds %	Milled fraction (F1) %	Milled fraction (F2) %	L^*	a^*	b^*
Control	-	-	82.80[b] ±0.47	17.20[c] ±0.47	85.89[c] ±1.88	-0.52[b] ±0.09	13.90[ab] ±1.73
Water treatments							
QCW	-	-	78.21[d] ±0.89	21.79[a] ±0.92	87.42[bc] ±2.256	-0.12[c] ±0.08	14.62[ab] ±1.48
QHW	-	-	83.24[b] ±0.78	16.76[c] ±0.52	87.51[bc] ±3.60	-0.08[c] ±0.01	14.60[ab] ±1.34
QSW for 24h.	-	-	80.03[c] ±1.26	19.97[b] ± 1.1	88.32[abc] ±2.22	-0.97[a] ±0.14	15.57[a] ±1.28
Dehulling using quinoa scaler (DQS)							
DQS_{30s}	5.58	94.42	76.69[d] ±1.02	23.31[a] ±1.09	90.56[abc] ±3.02	-0.08[c] ±0.01	13.42[ab] ±0.87
DQS_{60s}	19.81	80.19	77.36[d] ±1.03	22.64[a] ±1.12	91.98[ab] ±2.86	-0.12[c] ±0.01	12.46[bc] ±1.05
DQS_{90s}	32.76	67.23	85.94[a] ±1.01	14.06[d] ±1.16	92.97[a] ±2.96	-0.10[c] ±0.03	10.83[c] ±0.75

Milled fraction (F1): resulted from sieve less than 0.45 mm, Milled fraction (F2): resulted from sieve bigger than 0.45 mm, Control: without any treatment, L^*: lightness; a^*: redness-greenness; b^*: yellowness-blueness, (QCW): quinoa seeds washing with cold water, (QHW): quinoa seeds washing with hot water, (QSW): quinoa seeds soaked with water for 24h, (DQS_{30s}): dehulling using Quinoa scaler for 30 second, (DQS_{60s}): dehulling using Quinoa scaler for 60 second, (DQS_{90s}): dehulling using Quinoa scaler for 90 second, Values are mean of three replicates ± SD, means with different letters are significantly different at $P \leq 0.05$.

Color is an important parameter for overall acceptance of the food product. Color attributes are presented in Table (3). The lightness value (L^*) was increased significantly in DQS treatments than treated with water. The lightness (L^*) increased with increasing of time of dehulling using quinoa scaler, where DQS_{90s} had the highest value L^* (92.97) and had the lowest yellowness-blueness values b^* (10.83) compared to the other samples. Also, the lowest redness-greenness (a^*) was found in QSW for 24h (-0.97).

Effect of the different pre-treatments on the saponin, phytic acid and antioxidant activity (%) of resultant quinoa flour:

The effect of different pre-treatments on saponin, phytic acid and antioxidant activity (%) of quinoa flour are shown in Table (4). The lowest saponin content was found (0.72%) in DQS_{90s} compared to the other treatments. There were no significant differences between DQS_{60s}, QHW and QSW for 24h. The reduction in saponin content after washing process probably due to the water solubility of some saponin compounds and the temperature used in this process may have optimized the excess of the saponin release, increasing their quantification. Vega-Gálvez *et al*. (2010) showed that a higher extraction of saponin compounds were with a temperature of 60°C. Filho *et al.* (2017) revealed that the pericarp of the quinoa grain contained saponin, which gave a bitter taste and must be eliminated so that the grain can be consumed.

Phytic acid content was presented in Table (4). The phytic acid content was decreased significantly in DQS treatments and QSW for 24 h compared to the other samples and control. The lowest phytic acid content was found in $DQS_{90\ s}$ (0.21%). There were no significant differences between DQS_{30s}, DQS_{60s} and QSW for 24 h (0.53, 0.43 and 0.53%, respectively). The obtained results were supported by Rosero *et al.* (2013), who found that, phytic acid content of different quinoa varieties cultivated in the Andean region were ranged from 0.979 up to 1.859 mg/g. During soaking, phytate content is reduced; this reduction may be due to enzymatic degradation by endogenous phytases (Duhan *et al.,* 2002). The content of phytic acid in the quinoa seeds was about 1%, scrubbing and washing reduced the phytic acid content of the seeds by about 30% (Ruales and Nair, 1993).

Antioxidants are play an important role in inhibiting free radicals and oxidative chain reactions within tissues and membranes and can delay or inhibit the oxidation of lipids, so the evaluation of antioxidant activities is considered an important step (Nsimba *et al*., 2008). The results in Table (4) showed that the antioxidant activity decreased significantly in DQS treatments and that treated with water. The lowest antioxidant activity was in DQS_{90s} (20.40%), while the highest value of antioxidant activity was in control sample (50.23%). These results are similar with Park *et al.* (2017), who mentioned that the antioxidant activity of quinoa cultivated from different countries ranged from 35.42% up to 72.1%. Soaked quinoa seeds had lower antioxidant activity compared to raw seeds (Kaur *et al.,* 2016). Reduction in antioxidant activity after industrial processing may be due to removal of hulls which are majorly responsible for antioxidant activity (Zielinski and Kozlowska, 2000), also may be due to leaching of phenols and flavonoids in water used for soaking the seeds, where phenols and flavonoids contributed significantly to antioxidant activity (Afiffy *et al.,* 2012).

Table (4): Effect of the different pre-treatments on saponin, phytic acid and antioxidant activity (%) of resultant quinoa flour

Treatment	Saponin (%)	Phytic acid (%)	Antioxidant activity (%)
Control	2.56^{a} ±0.44	0.97^{a} ±0.21	50.23^{a} ±0.99
Water treatments			
QCW	1.10^{c} ±0.03	0.85^{a} ±0.04	46.30^{b} ±1.40
QHW	0.92^{cd} ±0.08	0.84^{a} ±0.05	37.52^{c} ±0.44
QSW For 24h.	0.98^{cd} ±0.02	0.53^{b} ±0.03	32.59^{e} ±0.62
Dehulling using quinoa scaler (DQS)			
DQS_{30s}	1.90^{b} ±0.03	0.53^{b} ±0.04	35.99^{d} ±0.43
DQS_{60s}	0.87^{cd} ±0.02	0.43^{b} ±0.06	25.91^{f} ±0.35
DQS_{90s}	0.72^{d} ±0.03	0.21^{c} ±0.01	20.40^{g} ±0.53

Control: without any treatment, (QCW): quinoa seeds washing with cold water, (QHW): quinoa seeds washing with hot water, (QSW): quinoa seeds soaked with water for 24h., (DQS_{30s}): dehulling using Quinoa scaler for 30 second, (DQS_{60s}): dehulling using Quinoa scaler for 60 second, (DQS_{90s}): dehulling using Quinoa scaler for 90 second, Values are mean of three replicates ± SD, means with different letters are significantly different at $P \leq 0.05$.

Chemical composition of resultant quinoa flour:

Protein, fat, crude fiber, ash, and total carbohydrate of resulted quinoa flour from the different pre-treatments are presented in Table (5). The obtained data indicated that the protein content was reduced significantly in DQS_{90s} (10.15%) and was slightly decreased after DQS_{60s} (11.56%) compared to control sample (14.08%). The lowest fat content was found in DQS_{90s} (5.35 %), while the fat content slightly decreased in QHW, QSW for 24 h and DQS_{60s}. The obtained data were concurred with Ogungbenle *et al*. (2009) found that protein content of quinoa seed ranged from 13.5 to 13.96% and fat 5.0 to 6.3%. Vidueiros *et al*. (2015), who found that the protein content of 21 quinoa varieties ranged from 14.5 up to 18.2% and fat ranged from 4.7 up to 7.1%.

The crude fiber significantly decreased in the DQS treatments and there were no significant differences between them. The highest crude fiber contents were found in the control sample and in the samples that treated with water. The lowest ash content was found in DQS_{90s} (1.43%). These results agreed with Lamacchia *et al.* (2010), who observed that the content of ash of quinoa flour was 2.17%.

Table (5): Chemical composition (%) of resultant quinoa flour on dry weight basis (g/100 g)

Analytical / Treatment	Crude protein	Fat	Crude fiber	Ash	Total carbohydrate
Control	14.08 [a] ±1.79	8.46 [a] ±0.93	6.70 [a] ±0.72	3.79 [a] ±0.60	66.97 [e] ±0.43
			Water treatments		
QCW	13.43 [a] ±2.00	7.64 [a] ±1.44	6.48 [a] ±0.83	2.39 [b] ±0.58	70.06 [d] ±0.30
QHW	13.97 [a] ±1.65	7.26 [ab] ±1.29	6.61 [a] ±1.39	2.40 [b] ±0.40	69.76 [d] ±0.86
QSW For 24h.	13.75 [a] ±1.29	7.34 [ab] ±1.17	6.69 [a] ±0.62	2.51 [b] ±0.27	69.71 [d] ±0.86
			Dehulling with quinoa scaler (DQS)		
DQS_{30s}	13.53 [a] ±1.36	7.81 [a] ±0.94	4.81 [b] ±0.54	2.03 [bc] ±0.52	71.82 [c] ±0.78
DQS_{60s}	11.56 [ab] ±1.13	6.40 [ab] ±0.87	3.99 [b] ±0.46	1.98 [bc] ±0.31	76.07 [b] ±0.79
DQS_{90s}	10.15 [b] ±0.86	5.35 [b] ±0.79	3.53 [b] ±0.38	1.43 [c] ±0.12	79.54 [a] ±0.94

Control: without any treatment, (QCW): quinoa seeds washing with cold water, (QHW): quinoa seeds washing with hot water, (QSW): quinoa seeds soaked with water for 24h; (DQS_{30s}): dehulling using Quinoa scaler for 30 second, (DQS_{60s}): dehulling using Quinoa scaler for 60 second, (DQS_{90s}): dehulling using Quinoa scaler for 90 second, Values are mean of three replicates ± SD, means with different letters are significantly different at $P \leq 0.05$.

From the data, the total carbohydrate content increased significantly with increasing time of dehulling using quinoa scaler, where the highest total carbohydrate was found in DQS_{90s} (79.54%). The control sample had the lowest total carbohydrate content (66.97 %). Coda *et al*. (2010) found that similar high content of carbohydrates (68.9%). The reduction in chemical composition of quinoa seeds may be due to the milling process (McKevith, 2004). Ash and fiber content significantly decreased after the different processing as milling and dehulling, while total carbohydrate content was significantly increased (Eshraq *et al.,* 2016), also, soaking treatment reduced fat, ash and carbohydrate contents (Kajihausa *et al.,* 2014).

From the previous results was observed that DQS_{60s} gave adequate proportion of the flour during the milling process. Also, it had a low saponin content and phytic acid as well as a moderate percentage of protein and fat. It was contained a high carbohydrate compared to the control sample and the other treatments, therefore was selected it to complete the remainder of the study as the best treatment of quinoa flour.

Amino acid profile of the control sample and the best treatment (DQS_{60s}) of quinoa flour:

The essential amino acids are an important indicators of protein quality in food product. It is cannot be synthesized by the body and necessary for tissue maintenance and required for growth of children (Ola, 2017). The results presented in Table (6) indicated that the presence of 17 amino acids including 10 essential amino acids and 7 non-essential amino acids in control sample (C) and DQS_{60s} of quinoa flour. The results were supported by Stikic *et al.* (2012) and Escuredo *et al.* (2014), who reported that quinoa flour is characterized by quality of the protein, due to the essential amino acids are present as isoleucine, leucine, methionine, phenylalanine, threonine, tryptophan and valine, especially the lysine which is the limiting amino acid in most cereals. Ten essential amino acids are lysine, isoleucine, leucine, phenylalanine, tyrosine, threonine, tryptophan, valine, histidine and methionine are present in quinoa, in addition, the sulfur-containing amino acids cystine, and methionine are found in concentrations that are unusually high (Vega-Gálvez *et al.,* 2010).

Table (6): Amino acid profile of the control sample and the best treatment (DQS_{60s}) of quinoa flour (g/100g protein)

Essential amino acid	Protein (g/100g)		FAO/WHO * (g/100g)	(CS) %		Non Essential amino acid	Protein (g/100g)	
	C	DQS_{60s}		C	DQS_{60s}		C	DQS_{60s}
Isoleucine	3.11	2.89	3.0	103.67	96.33	**Glutamic acid**	14.37	13.22
Leucine	5.14	4.97	5.9	87.12	84.24	**Aspartic acid**	7.12	6.81
Lysine	4.98	4.70	4.5	110.67	104.44	**Proline**	4.78	4.39
Methionine + Cystine	2.87	2.70	2.2	130.45	122.73	**Alanine**	3.34	3.10
Valine	4.33	4.16	3.9	111.03	106.67	**Serine**	3.55	3.21
Phenylalanine + Tyrosine	7.16	6.05	3	238.67	201.67	**Glycine**	4.79	4.39
Threonine	2.97	2.80	2.3	129.13	121.73	**Arginine**	10.11	9.33
Histidine	2.48	2.31	1.5	165.33	154.00	**-**	-	-
Total essential amino acids	33.04	30.58				**Total non-essential amino acid**	48.06	44.45
Biological value (%)	83.82	81.33						

C = control quinoa flour sample (without any treatment), (DQS_{60s}): dehulling using Quinoa scaler for 60 second as a best treatment,*FAO/WHO (2007), CS = Chemical score

The treatment DQS_{60s} caused a reduction in all amino acids content compared to control sample (C). From the data are presented in Table (6), it observed that the highest percentage of aromatic essential amino acids were phenylalanine + tyrosine (7.16%) in (C) sample compared to (6.05%) in DQS_{60s}, this may be due to remove the outer layers of the quinoa seeds. These results agreed with Oghbaei and Prakash (2016), who mentioned that the nutritional quality of grains is influenced by pre-processing treatments and processes as dehulling and milling, where abstraction any part of the grain led to reduce nutrients. Also, leucine was the limiting amino acid in (C) sample and DQS_{60s}, may be due to contain the lowest chemical score (87.12 and 84.24 %) in both samples, respectively. The limiting amino acid is defined as the acid that having the least concentration in protein mg/g (WHO/FAO/UNU, 2007).

The biological value (B.V) described how well the body absorbed protein. More precisely, it is a measure of the percentage of the protein that is actually incorporated into the proteins of the human body (WHO, 2007). Results in Table (6) showed that the biological values (BV) were (83.82%) for (C) sample may be due to contain high lysine content (4.98 g/100g protein). Higher lysine content was associated with increasing of biological value (Kohajdova *et al*., 2011). However, the obtained results declared that quinoa could serve as an excellent protein supplement, where the other amino acids histidine, methionine + cystine, threonine, valine and lysine gave higher scores, indicating that degree of excellence amino acids compositions. The acquired results were confirmed by Ogungbenle *et al.* (2009), who reported that quinoa contained balanced essential amino acids.

In generally, it could be noticed that, the total EAA and total non-EAA were highest in (C) sample compared to DQS_{60s}.

Minerals content of the control sample and DQS_{60s} of quinoa flour:

Minerals are essential chemical elements that play a role in regulating electrolyte balance, glucose homeostasis, the transmission of nerve impulses and enzyme cofactors in the body, quinoa is considered as a good source of minerals, where contains a large amounts of calcium, magnesium and potassium in sufficient quantities and bioavailable necessary for maintaining a balanced human diet (Gordillo-Bastidas *et al.,* 2016). Table (7) showed that the macro and micro elements significantly decreased in DQS_{60s} compared to control sample (C).

Table (7): Minerals content of the control sample and DQS_{60s} of quinoa flour (mg/100)

Treatments	Macro elements					Micro elements			
	K	P	Mg	Ca	Na	Fe	Zn	Cu	Mn
C	879.29^{a} ± 0.21	412.13^{a} ± 0.24	198.93^{a} ± 0.37	93.45^{a} ± 0.27	15.73^{a} ± 0.38	15.04^{a} ± 0.21	6.20^{a} ± 0.30	5.61^{a} ± 0.50	1.79^{a} ± 0.28
DQS_{60s}	658.24^{b} ± 0.38	381.12^{b} ±0.15	138.75^{b} ± 0.42	74.41^{b} ± 0.40	12.17^{b} ± 0.39	12.39^{b} ± 0.45	4.47^{b} ± 0.45	3.17^{b} ± 0.31	1.23^{b} ± 0.40

C = control quinoa flour sample (without any treatment), (DQS_{60s}) = dehulling using Quinoa scaler for 60 second as a best pre-treatment, Values are mean of three replicates ± SD, means with different letters are significantly different at $P \leq 0.05$.

On the other hand, the potassium (K) was high in macro elements followed by (P) 879.29 and 412.13 mg/100g, respectively in control sample (C), while decreased up to (658.24 and 381.12 mg/100g, respectively) in DQS_{60s}. Moreover, iron (Fe) was high in micro elements followed by Zn (15.04 and 6.20 mg/100g, respectively) in (C) sample, while decreased up to (12.39 and 4.47 mg/100g, respectively) in DQS_{60s}. These results concurred with Palombini *et al*. (2013), who mentioned that the major mineral in quinoa was potassium. Hulling procedures to remove saponin caused losses minerals like P, K, M, Ca and P (Konishi *et al.,* 2004). Separating bran and milling process led to loss of elements content in flour and concentrates them in the milling residues (Oghbaei and Prakash, 2016).

Sensory characteristics of resultant cake from the best treatment of quinoa flour (DQS_{60s}) with different levels of substitutions:

Sensory evaluation is considered a valuable tool in solving problems including food acceptability. It is useful in product improvement, quality maintenance and more important in a new products development (Mona and Hinar, 2015). The sensory characteristics of different cake samples are presented in Table (8). The results showed that there were no significant differences in color and odor between control and the substituted samples.

Table (8): Sensory characteristics of resultant cake from the DQS_{60s} flour with different level of substitutions

Attributes / Samples	Color	Taste	Odor	Texture	Overall acceptability
Control	$8.40^{a} \pm 0.69$	$8.50^{a} \pm 0.52$	$8.0^{a} \pm 0.81$	$7.65^{b} \pm 1.27$	$8.50^{a} \pm 0.74$
T_1	$7.95^{a} \pm 1.21$	$8.40^{a} \pm 0.69$	$8.05^{a} \pm 0.83$	$7.75^{b} \pm 1.23$	$8.45^{a} \pm 0.49$
T_2	$8.0^{a} \pm 1.17$	$8.41^{a} \pm 0.81$	$7.75^{a} \pm 0.97$	$8.20^{ab} \pm 0.91$	$8.50^{a} \pm 0.85$
T_3	$7.40^{a} \pm 1.26$	$7.40^{b} \pm 0.51$	$7.60^{a} \pm 0.96$	$8.45^{ab} \pm 0.83$	$7.50^{b} \pm 0.97$
T_4	$7.30^{a} \pm 1.25$	$6.50^{c} \pm 0.74$	$7.25^{a} \pm 1.18$	$8.75^{a} \pm 0.26$	$7.45^{b} \pm 1.16$

Control = 100 wheat flour,T_1= 75% wheat flour + 25% quinoa flour,T_2 = 50% wheat flour +50% quinoa flour, T_3= 25% wheat flour + 75% quinoa flour, T_4= 100 % quinoa flour, Values are mean of ten replicates ± SD, means with different letters are significantly different at $P \leq 0.05$.

The taste score decreased significantly in T_3 and T_4 samples (7.40 and 6.50, respectively) compared to the other samples. On the other hand, the texture score increased significantly with increasing of substitution level, the highest texture score was found in T_4 sample (8.75), while the texture score was slightly decreased in T_2 and T_3 compared to the other samples. These results are similar with Bhaduri (2013), who mentioned that the texture decreased with the increase of quinoa flour substitution. Overall acceptability scores provide a general acceptability of the product based on all of the sensory parameters. Overall acceptability scores decreased significantly in T_3 and T_4 samples and there were no significant differences between them. These results clearly indicated that using quinoa flour in cake at levels 25, 50, 75 and 100% did not effect on some characteristics of cake as color and odor compared to control sample. The results showed that the best acceptance was up to 50% of substituted levels.

Texture profile analysis (TPA) of resultant cake:

Texture measurements can be very valuable for the quality control and process optimization as well as for the development of new products with desirable properties and characteristics (Mona and Hinar, 2015). Data in Table (9) presented the textural parameters assessed from texture profile analysis (TPA) test curves results for the cake samples. A marked increase in hardness from 13.99 N to 16.08 N was observed.

Table (9): Texture profile analysis (TPA) of resultant cake

Analysis / Samples	Hardness (N)	Cohesiveness	Gumminess (N)	Springiness	Chewiness (N)
Control	$13.34^{e} \pm 0.02$	$0.69^{a} \pm 0.03$	$10.16^{a} \pm 0.01$	$6.29^{a} \pm 0.01$	$63.94^{a} \pm 0.06$
T_1	$13.99^{d} \pm 0.04$	$0.60^{b} \pm 0.04$	$9.69^{b} \pm 0.03$	$6.06^{b} \pm 0.04$	$58.30^{b} \pm 0.02$
T_2	$15.14^{c} \pm 0.03$	$0.57^{bc} \pm 0.03$	$9.63^{b} \pm 0.04$	$5.58^{c} \pm 0.02$	$54.0^{c} \pm 0.03$
T_3	$15.54^{b} \pm 0.04$	$0.56^{bc} \pm 0.05$	$9.53^{c} \pm 0.09$	$5.00^{d} \pm 0.03$	$47.60^{d} \pm 0.02$
T_4	$16.08^{a} \pm 0.07$	$0.51^{c} \pm 0.05$	$7.66^{d} \pm 0.02$	$4.10^{e} \pm 0.04$	$31.40^{e} \pm 0.04$

Control = 100 wheat flour, T_1= 75% wheat flour + 25% quinoa flour, T_2 = 50% wheat flour +50% quinoa flour, T_3= 25% wheat flour + 75% quinoa flour, T_4 = 100 % quinoa flour, Values are mean of three replicates ± SD, Means with different letters are significantly different at $P \leq 0.05$.

On the other hand, the cake became more hardness with increasing the level of quinoa flour substitution. Data showed that T_4 sample had the highest hardness value (16.08 N). Also, the results showed a decrease of cakes cohesiveness, gumminess, springiness and chewiness with increasing the level of quinoa flour substitution. All the TPA parameters decreased with increasing of the quinoa flour levels of substituted except hardness. The hardness increases with the increasing of quinoa flour substitution (Bhaduri, 2013).

CONCLUSION

From the results it could be concluded that the saponin content was decreased significantly when quinoa seeds treated with water and dehulling processes using quinoa scaler. On the other hand, the results revealed that the treated with water was the best technique to obtain the highest milling yield on a small-scale, while on a large -scale showed that the dehulling processes with quinoa scaler for 60 s was the best technique to saving water, reducing time and to give high yield of milled. It is possible to use quinoa flour resultant from dehulling for 60 s (DQS_{60s}) to produce cake up to 50% level substitution with high sensory characteristics similar to cake sample from wheat flour 100%.

REFERENCES

Abdellatif, A. S. A. (2018). Chemical and technological evaluation of quinoa (*Chenopodium quinoa* Wild) cultivated in Egypt. Acta Scientific Nutritional Health, 2(7): 42-53.

Abugoch, L. E. (2009). Quinoa (*Chenopodium quinoa* Willd.): Composition, chemistry, nutritional, and functional properties. Adv. Food Nutri. Res., 58: 1-31.

Afify, A. E. M., H. S. El-Beltagi, S. M. Abd El-Salam and A. Omran (2012). Biochemical changes in phenols, flavonoids, tannins, vitamin E, beta-carotene and antioxidant activity during soaking of three white sorghum varieties. Asian Pacific Journal of Tropical Biomedicine, 2: 203-209.

AOAC (2010).Official Methods of Analysis of the Association of Official Analytical Chemists, 19th ed., (Ed. Horwitz, W.), Washington.

Arneja, I., B. Tanwar and A. Chauhan (2015). Nutritional composition and health benefits of golden grain of 21st century, quinoa (*Chenopodium quinoa* Willd.): A review. Pakistan J. Nutri., 14(12): 1034-1040.

Bhaduri, S. (2013). A comprehensive study on physical properties of two gluten-free flour fortified muffins.J Food Process Technol., 4: 7.

Bhargava, A., S. Shukla and D. Ohri (2006). *Chenopodium quinoa* an Indian perspective. Industrial Crops and Products, 23(1): 73-87.

Bourne, M. C. (2003). Food texture and viscosity: Concept and measurement. Elsevier Press, New York/London. Pp. 416.

Coda, R., C. G. Rizzello and M. Gobbetti (2010). Use of sourdough fermentation and pseudo-cereals and leguminous flours for the making of a functional bread enriched of γ-aminobutyric acid (GABA). Int. J. Food Micro., 137: 236–245.

Diane Lee, G. (2013). Determining reference test weight per bushel value of grains. Weights and Measures Connection, 4(6): 1-4.

Duhan, A., N. Khetarpaul and S. Bishnoi (2002).Content of phytic acid and HCl-extractability of calcium, phosphorus and iron as affected by various domestic processing and cooking methods. Food Chem., 78: 9-14.

Eggam, B. O., E. M. Villegas and S. K. Vasal (1979).Progress in protein quality of maize. J. Sci. Food Agri., 30: 1148-1153.

Escuredo, O., M. I. G. Martín, G. W. Moncada, S. Fischer and J. M. H. Hierro (2014). Amino acid profile of the quinoa (*Chenopodium quinoa* Willd.) using near infrared spectroscopy and chemometric techniques. J. Cereal Sci., 60(1): 67-74.

Eshraq, B. K., A. M. Mona, A. F. Sayed and A. A. Emam (2016). Effect of soaking, cooking and germination on chemical constituents and bioactive compounds as well as their cytotoxic activities of black bean extracts. Nat. Prod. Chem. Res., 4(6): 1-7.

FAO (2011). Quinoa: An ancient crop to contribute to world food security. Technical report of the 37th FAO Conference. Rome, Italy.

FAO/WHO (2007). Energy and protein requirement. In Geneva, Nutrition Report Series, No. 935.

Fischer, S., R. Wilckensa, J. Jara and M. Arandac (2013). Variation in antioxidant capacity of quinoa (*Chenopodium quinoa* Will) subjected to drought stress. Indust. Crops Products, 46: 341– 349.

Filho, A. M. M., M. R. Pirozi, J. T. D. S. Borges, H. M. P. Sant' Ana, J. B. P. Chaves and J. S. D. R. Coimbra (2017). Quinoa: Nutritional, Functional and Antinutritional Aspects, Critical Reviews in Food Science and Nutrition, 57(8): 1618-1630.

Fondroy, E. B., P. J. White and K. J. Prusa (1989). Physical and sensory evaluation of lean white cakes containing substituted fluffy cellulose. Cereal Chem., 66(5): 402-404.

Gajendra, K., N. K. Singh, K. K. Deshmukh and S. P. Mishra (2019). Quinoa: New Light on An Old Super food: A Review. Agricultural Reviews, 40(4): 319-323.

Gomes, K. A. and A. A. Gomes (1984).Statistical procedures for agricultural (2nd edn.). John Wiley and Sons Inc., New York, P 680.

González, J. A., M. Gallardo, M. Hilal, M. Rosa and F. E. Prado (2009). Physiological responses of quinoa (*Chenopodium quinoa* Willd.) to drought and waterlogging stresses: dry matter partitioning. Botanical Studies, 50: 35-42.

Gordillo-Bastidas, E., D. A. Díaz-Rizzolo, E. Roura, T. Massanés and R. Gomis (2016). Quinoa (*Chenopodium quinoa* Willd), from nutritional value to potential health benefits: An integrative review. J. Nutr. Food Sci., 6(3): 1-10.

Hemalatha, P., B. B. V. Dikki Pedenla, R. Sathyendra and N. S. Yadahally (2016). Distribution of phenolic antioxidants in whole and milled fractions of quinoa and their inhibitory effects on α-amylase and α-glucosidase activities. Food Chem., 199: 330-338.

Itthivadhanapong, P. and A. Sangnark (2016). Effects of substitution of black glutinous rice flour for wheat flour on batter and cake properties. International Food Research Journal, 23(3): 1190-1198.

Kajihausa, O. E., R. A. Fasasi and Y. M. Atolagbe (2014). Effect of different soaking time and boiling on the proximate composition and functional properties of sprouted sesame seed flour. Nigerian Food Journal, 32(2): 8-15.

Kaur, I., B. Tanwar, M. Reddy and A. Chauhan (2016). Vitamin C, total polyphenols and antioxidant activity in raw, domestically processed and industrially processed Indian *Chenopodium quinoa* seeds. Journal of Applied Pharmaceutical Science, 6(04): 139-145.

Kohajdova, Z., J. Karovičova and Š Schmidt (2011). Lupin composition and possible use in bakery: A Review. Czech Journal Food Science, 29(3): 203- 211.

Konishi, Y., S. Hirano, H. Tsuboi and M. Wada (2004).Distribution of minerals in quinoa (*Chenopodium quinoa* Willd.) seeds. Biosci. Biotechnol. Biochem., 68: 231-234.

Lamacchia, C., S. Chillo, S. Lamparelli, N. Suriano, E. La Notte and M. A. Del Nobile (2010). Amaranth, quinoa and oat dough: Mechanical and rheological behavior, polymeric protein size distribution and extractability. J. Food Eng., 96: 97-106.

Li, G. and F. Zhu (2017). Physicochemical properties of quinoa flour as affected by starch interactions. Food Chem, 221: 1560-1568.

Lozano, M., E. Tícona, C. Carrasco, Y. Flores and G. R. Almanza (2012). Cuantificación de saponinas en residuos de quinua real *Chenopodium quinoa* Willd. Revista Boliviana de Química, 29(2): 131-138.

Margarita, M., A. Vega-Gálvez, J. López, G. Paradac, M. Sanders, M. Aranda, E. Uribea and K. Di Scala (2010). Impact of air- drying temperature on nutritional properties, total phenolic content and antioxidant capacity of quinoa seeds (*Chenopodium quinoa* Willd). Industrial Crops Products, 32: 258-263.

Mari Repo, R. A., C. Valencia and L. A. Serna (2011). Quinoa (*Chenopodium quinoa* Willd.) as a source of dietary fiber and other functional components. Cienc. Tecnol. Aliment., 31(1): 225-230.

McGurie, R. G. (1992). Reporting of objective color measurements. Hort Science, 27: 1254-1255.

McKevith, B. (2004). Nutritional aspects of cereals. British Nutrition Foundation Nutrition Bulletin, 29: 111-142. http://dx.doi.org/10.1111/nbu.29.

Mona, M. A.A. and A. S. Hinar (2015). Gluten-free flat bread and biscuits production by cassava, extruded soy protein and pumpkin powder. Food and Nutrition Sciences, 6: 660-674.

Mota, C., M. Santos, R. Mauro, N. Samman, A. S. Matos, D. Torres and I. Castanheira (2015). Protein content and amino acids profile of pseudocereals. Food Chem., 193: 55-61.

Nickel, J., L. P. Spanier, F. T. Botelho, M. A. Gularte and E. Helbig (2016). Effect of different types of processing on the total phenolic compound content, antioxidant capacity, and saponin content of *Chenopodium quinoa* Willd grains. Food Chem., 209: 139-143.

Nisar, M., D. R. More, S. Zubair and S. I. Hashmi (2017). Physico-chemical and nutritional properties of quinoa seed: A review. Journal of Pharmacognosy and Photochemistry, 6(5): 2067-2069.

Nsimba, R. Y., H. Kikuzaki and Y. Konishi (2008). Antioxidant activity of various extracts fractions of *Chenopodium quinoa* and *Amaranthus* spp. seeds. Food Chem., 106:760-766.

Oghbaei, M. and J. Prakash (2016). Effect of primary processing of cereals and legumes on its nutritional quality: A comprehensive review. Cogent Food and Agriculture, 2(1):1-14.

Ogungbenle, H. N., A. A. Oshodi and M. O. Oladimeji (2009). The proximate and effect of salt applications on some functional properties of quinoa (*Chenopodium quinoa*) flour. Pakistan J. Nutr., 8: 49-52.

Ola, S. Ibrahim (2017). Utilization of sorghum, broken rice and white beans flours for producing high nutritional value and high quality gluten-free biscuits. Curr. Sci. Int., 6(3): 670-683.

Palombini, S. V., T. Claus, S. A. Maruyama, A. K. Gohara, A. H. P. Souza, N. E. Souza, J. V. Visentainer, S. T. M. Gomes and M. Matsushita (2013). Evaluation of nutritional compounds in new amaranth and quinoa cultivars. Food Sci. Technol., 33(2): 339-344.

Park, H. R., H. J. Ahn, S. H. Kim, C. H. Lee, M. W. Byun and G. W. Lee (2006). Determination of the phytic acid level in infant foods using different analytical methods. Food Control, 17: 727-732.

Park, J. H., Y. J. Lee, Y. H. Kim and K. S. Yoon (2017). Antioxidant and antimicrobial activities of quinoa (*Chenopodium quinoa* Willd.) seeds cultivated in Korea. Prev. Nutr. Food Sci., 22(3): 195-202.

Paśko, P., H. Bartoń, P. Zagrodzki, S. Gorinstein, M. Fołta and Z. Zachwieja (2009). Anthocyanins, total polyphenols and antioxidant activity in amaranth and quinoa seeds and sprouts during their growth. Food Chem., 115(3): 994-998.

Repo-Carrasco, R., C. Espinoza and S. E. Jacobsen (2003). Nutritional value and use of the sndean crops quinoa (*Chenopodium quinoa*) and kañiwa (*Chenopodium pallidicaule*). Food Reviews International, 19(1-2): 179-189.

Rosero, O., M. Marounek, N. Břeňová and D. Lukešova (2013). Phytase activity and comparison of

chemical composition, phytic acid P content of four varieties of quinoa grain (*Chenopodium quinoa* Willd.). Acta Agronómica, 62(1): 13-20.

Ruales, J. and B. M. Nair (1993). Saponins, phytic acid, tannins and protease inhibitors in qulnoa (*Chenopodium quinoa*, Willd.) seeds. Food Chemistry, 48: 137-143.

Shokry, A. M. (2016). The uses of quinoa as a potently ingredient in production of meat burger with functional properties. Middle East J. Applied Sciences, 6(4): 1128-1137.

Snedecor, G. W. and W. G. Cochran (1980). Statistical Methods. Oxford and J.B.H Publishing Com, (7th ed.), pp. 71-99.

Stikic, R., D. Glamoclija, M. Demin, B. Vucelic-Radovic, Z. Jovanovic, S. Jacobsen and M. Milovanovic (2012). Agronomical and nutritional evaluation of quinoa seeds (*Chenopodium quinoa* Willd.) as an ingredient in bread formulations. J. Cereal Sci., 55: 132-138.

Stuardo, M. and R. San Martín (2008). Antifungal properties of quinoa (*Chenopodium quinoa* Willd.) alkali treated saponins against *Botrytis cinerea*. Industrial Crops Product, 27: 296-302.

Tang, Y., X. Li, B. Zhang, P. X. Chen, R. Liu and R. Tsao (2015). Characterisation of phenolics, betanins and antioxidant activities in seeds of three *Chenopodium quinoa* Willd. genotypes. Food Chem., 166: 380-388.

Tang, Y., B. Zhang, X. Li, P. X. Chen, H. Zhang, R. Liu and R. Tsao (2016). Bound phenolic of quinoa seeds released by acid, alkaline, and enzymatic treatments and their antioxidant and α-glucosidase and pancreatic lipase inhibitory effects. J. Agric. Food Chem., 64: 1712-1719.

Valencia, S., U. Svanberg, S. Ann-Sofie and J. Ruales (1999). Processing of quinoa (*Chenopodium quinoa* Willd): effects on *in vitro* iron availability and phytate hydrolysis. International Journal of Food Sciences and Nutrition, 50: 203-211.

Vega-Gálvez, A., M. Miranda, J. Vergara, E. Uribe, L. Puenteb and E. A. Martınez (2010). Nutrition facts and functional potential of quinoa (*Chenopodium quinoa* willd.) an ancient Andean grain. J. Sci. Food Agric., 90: 2541-2547.

Vidueiros, S. M., R. N. Curti, L. M. Dyner, M. J. Binaghi, G. Peterson, H. D. Bertero and A. N. Pallaro (2015). Diversity and interrelationships in nutritional traits in cultivated quinoa (*Chenopodium quinoa* Willd.) from Northwest Argentina. J. Cereal Sci., 62: 87-93.

Vilche, C., M. Gely and E. Santalla (2003). Physical properties of quinoa seeds. Biosystems Eng., 86(1): 59-65.

WHO (2007). Protein and amino acid requirements in human nutrition. WHO Technical Report Series No. 935. Geneva: World Health Organization.

WHO/FAO/UNU (2007). Expert consultation.Proteins and amino acids in human nutrition.World Health Org Tech Rep Ser.

Wongsa, J., D. Uttapap, P. L. Buddhi and V. Rungsardthong (2016). Effect of puffing conditions on physical properties and rehydration characteristic of instant rice product.International Journal of Food Science and Technology, 51: 672-680.

Zielinski, H. and H. Kozlowska (2000). Antioxidant activity and total phenolics in selected cereal grains and their different morphological fractions. J. Agric. Food Chem., 48: 2008-2016.

تأثير المعاملات التكنولوجية الأولية على خصائص الجودة لدقيق الكينوا

رفاعي جمعه على[١]، سحر عزمى[٢]، أميرة طه محمد[١]

[١]قسم بحوث تكنولوجيا المحاصيل الحقلية - معهد بحوث تكنولوجيا الأغذية - مركز البحوث الزراعية- مصر

[٢]قسم التكثيف المحصولي- معهد المحاصيل الحقلية - مركز البحوث الزراعية- مصر

أجريت هذه الدراسة لتقييم تأثير المعاملات الأولية المختلفة (عملية التقشير والغسيل بالماء) على الخصائص الفيزيائية والكيميائية والجودة للدقيق المنتج من بذور الكينوا المنزرعة تحت الظروف المصرية. أظهرت النتائج التي تم الحصول عليها أن نبات الكينوا تنتج بذور دائرية صغيرة، قطرها حوالي ١.٩٦ مم، وزن ١٠٠٠ حبة من الكينوا ٢.٨١ جم، والكثافة الظاهرية ٠.٨٣ جم/سم^{٣}، اختبار الوزن لبذور الكينوا ٧٥.٩٤ كجم/١٠٠ لتر. أعطت عملية التقشير باستخدام قشارة الكينوا منتجين من الكينوا: قشر الكينوا وبذور الكينوا المقشورة . أعطت عملية الطحن جزئين مطحونين من الدقيق: الأول من غربال أقل من ٠.٤٥ ملم والثاني من غربال أكبر من ٠.٤٥ ملم. انخفض محتوى السابونين بشكل كبير في المعاملات التي تم تقشيرها باستخدام قشارة الكينوا يليها التي تمت معالجتها بالماء. انخفض محتوى البروتين بشكل طفيف بعد التقشير لمدة ٦٠ ثانية (١١.٥٦٪). أعطت عملية التقشير باستخدام قشارة الكينوا لمدة ٩٠ ثانية اقل محتوى للدهون والرماد، بينما كان إجمالي محتوى الكربوهيدرات مرتفعًا. كان الفينيلألانين + التيروزين أعلى الأحماض الأمينية الحلقية وكان الليوسين هو الحامض الأمينى المحدد. أعلى العناصر الكبرى والصغرى كان البوتاسيوم والحديد على التوالي. أشارت النتائج إلى أن استخدام دقيق الكينوا الناتج من التقشير لمدة ٦٠ ثانية كأفضل معاملة في تحضير الكيك بمستويات ٢٥ و ٥٠ و ٧٥ و ١٠٠٪، لم يؤثر على لون ورائحة الكيك، وكان أفضل قبول حتى ٥٠٪ من مستوى الاستبدال في الكيك، انخفضت جميع خصائص تحليل القوام بزيادة مستويات دقيق الكينوا باستثناء الصلابة. يمكن نستنتج أن المعالجة بالماء هي أفضل تقنية للحصول على أعلى إنتاجية لدقيق الكينوا على نطاق صغير، بينما على نطاق واسع كانت عملية التقشير باستخدام قشارة الكينوا لمدة ٦٠ ثانية هي أفضل تقنية لتوفير المياه وتقليل الوقت ولإعطاء محصول مرتفع من الكينوا المقشورة.