Egypt. J. Chem. **Vol. 67**, No. 1 pp. 181 - 192 (2024)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

Quinoa and Quinoa Food Products as Nutritious and Functional Foods for Protection from Dyslipidemia

Sahar Y. Al-Okbi[1*], Ayman A. Mohammad[2], Thanaa E Hamed[1], Tarek A Elewa[3], Marwa A Desoukey[1]

[1]Nutrition and Food Sciences Department, National Research Centre, Cairo, Egypt, [2]Food Technology Department, National Research Centre, Cairo, Egypt. [3]Field Crops Research Department, National Research Centre, Dokki, Cairo, Egypt.

Abstract

Quinoa is a highly nutritious pseudo-cereal with reported health promotion effect. The aim of the present research was to prepare functional foods from two quinoa varieties [*Chenopodium quinoa* Willd *cv.* Quinoa 1 (Q1) and *Chenopodium quinoa* Willd *cv.* Hualhuas (QH)] and to evaluate their protein efficiency ratio and the anti-dyslipidemic effect. Crackers and talbina were prepared from Q1 and QH and subjected to sensory, chemical and physical evaluations. Protein efficiency ratio of the functional foods and quinoa varieties were assessed in rats. The potential protection from dyslipidemia by the functional foods and quinoa varieties were evaluated in triton X-100 induced dyslipidemic rat model. The percentages of protein in quinoa varieties were in the range of 16.45 to 18.96, while it varied in food products from 14.76 to 22.89. Glutamic acid was the dominant amino acid in QH and food products while alanine was the dominant in Q1. Concerning sensory attributes, cracker and talbina made from Q1 were more acceptable than those prepared from QH. Protein efficiency ratios of Q1 and QH were 1.8 and 1.67, respectively while that of the food products ranged from 1.07 to 1.78 compared to casein (2.4). The two quinoa varieties and the food products produced significant protection from dyslipidemia. QH was superior in reducing cardiovascular disease risk. It could be concluded that protein efficiency ratios of quinoa varieties and their products showed appreciable levels compared to casein. The two quinoa varieties and their products produced significant protection from dyslipidemia, QH was superior.

Keywords: Quinoa; Crackers; Talbina; Amino acids; Protein efficiency ratio; Anti-dyslipidemia..

Introduction

Quinoa seed is called pseudo-cereal not only for botanical reason but also due to its unique composition and the exceptional equilibrium between fat, protein and carbohydrates. The protein content was estimated to be ≥15%. It is considered as an important nutritious food especially in developing countries. Quinoa contains a better balanced amino acids composition than the traditional cereals with high minerals contents like calcium, magnesium, copper, iron and zinc, in addition to vitamins represented by tocopherols, α-carotene and niacin [1-4]. Quinoa also is a good source of dietary fibers and unsaturated fatty acids [5].

The chemical composition of quinoa is valuable for preparation of food products with enhanced nutritional properties [6]. Quinoa is an excellent example of functional food and as a source of nutraceuticals for lowering the risk of chronic diseases due to its contents from phytochemicals such as polyphenols, phytosterols and carotenoids [3-5, 7]. Such phytochemicals especially phenolic compounds possess antioxidant and anti-inflammatory activities that are capable for chronic diseases prevention [7,8]. Quinoa is a strong tolerant to stressing abiotic condition and a promising salt tolerant plant [4,9], therefore it does not need restricted conditions for cultivation.

The reported unique amino acids balance, high percentage of protein and nutrients and the phytochemicals contents of quinoa motivated the research team to prepare food products from quinoa seed as functional foods (crackers and talbina). Therefore, the objective of the present study was to compare the proximate composition and amino acids′ profile of two quinoa varieties [*Chenopodium quinoa* Willd *cv.* Quinoa 1 (Q1) and *Chenopodium quinoa* Willd *cv.* Hualhuas (QH)] and their food products. The food products were evaluated for their color and sensory attributes. The main goal of the present research was to study the protein value of the two

*Corresponding author e-mail s_y_alokbi@hotmail.com
Receive Date: 18 April 2023, Revise Date: 06 June 2023, Accept Date: 25 June 2023
DOI: 10.21608/EJCHEM.2023.206437.7881

quinoa varieties and their functional food products along with their potential protection from dyslipidemia in rat model.

Materials and Methods

The grains of *Chenopodium quinoa* Willd *cv.* Quinoa 1 were supplemented from Agriculture Research Center, Giza, Egypt. The grains of *Chenopodium quinoa* Willd *cv.* Hualhuas were obtained from International Potato Center (CIP), Lima, Peru. Wheat flour, barley flour, roasted chickpea, shortening, milk powder, honey and salt were obtained from local market, Cairo, Egypt. Triton X-100, used for induction of dyslipidemia was purchased from LOBA CEMIE PVT. LTD, laboratory reagents and fine chemicals, India.

Preparation of crackers

Crackers were made according to a previously reported method [10] where three different formulas were prepared. A control formula was mainly composed of 100% wheat flour (72% extraction). Formula I composed of Q1 flour (74%), chickpea flour (20%), pectin (3%) and Arabic gum (3%). Formula II composed of QH flour (74%), chickpea flour (20%), pectin (3%) and Arabic gum (3%). One hundred grams from each formula were mixed with 7.5g of shortening and 2g of salt. Water was added accurately to form smooth dough, and the resulted dough was left to rest for 5 min. The dough was kneaded and rolled to a uniform thickness of 3 mm then some sesame and spices were added. The crackers were cut out. Then the crackers were baked at 200ºC for 15 minutes and cooled at room temperature for about 1 h before sensory evaluation.

Preparation of talbina

Talbina was prepared according to a previously reported method [11] with some modifications where milk powder (62.5 g) was dissolved in water (1L) then 100 g from whole barley or quinoa flour from either variety (Q1 and QH) was added to prepare control formula, talbina I and talbina II, respectively. The different mixtures were heated at 80°C with continuous stirring until reaching porridge like texture then sweetened with honey (100 ml). The produced talbina formulas were dried at 55°C.

Chemical analysis

Protein, fat, ash, crude fiber and moisture contents of raw materials, crackers and talbina were determined according to AOAC [12]. Carbohydrates were calculated by difference. Amino acids′ compositions of the experimental samples were assessed by applying Millipore Cooperative method [13] described in the AOAC [12] using HPLC-Pico-Tag method.

Color attributes of the processed crackers and talbina:

The color parameters of the food products 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). Total color difference (ΔE) between the control sample and the food products containing quinoa flour were calculated as follows: $\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{0.5}$

Sensory evaluation of the processed crackers and talbina:

Sensory properties of crackers and talbina samples (shown in Figure 1) were evaluated as recommended previously [14,15] by ten panelists. Crackers samples were served to the panelists and they were asked to rate the acceptability of the product in terms of shape, color, texture, taste, flavor and overall acceptability. Talbina samples were reconstituted in the respective water amount and presented to panel of sensory judges for analysis of color, appearance, sedimentation, flavor, consistency and overall acceptability using 9 point hedonic scale.

The biological experiment

Rats

Growing male albino rats of three weeks in age with body weight ranging from 40 to 50 g were obtained from the Animal House Unit, National Research Centre, Egypt. Rats were kept in stainless steel cages at ambient temperature, with 12h light/dark cycle. Food and water were supplied *ad-libitum*. Handling and care of animals were carried out according to the Medical Research Ethics Committee, National Research Centre, Cairo, Egypt, and followed the recommendations of the National Institutes of Health Guide for Care and Use of Laboratory Animals (Publication No. 85-23, revised 1985).

Diets

For evaluation of the protein value, represented by protein efficiency ratio (PER), of quinoa varieties and food products, different types of diets were prepared as shown in Table1. The casein balanced diet contained 10% protein supplemented from casein. The other diets were prepared so as to contain 10% protein from specific amounts from Q1, QH, crackers I, crackers II, talbina I and talbina II after being reduced into powder form. Fats, carbohydrates and fibers were calculated in such amounts and any nutrient that was less than that in the balanced diet was completed to resemble the balanced diet.

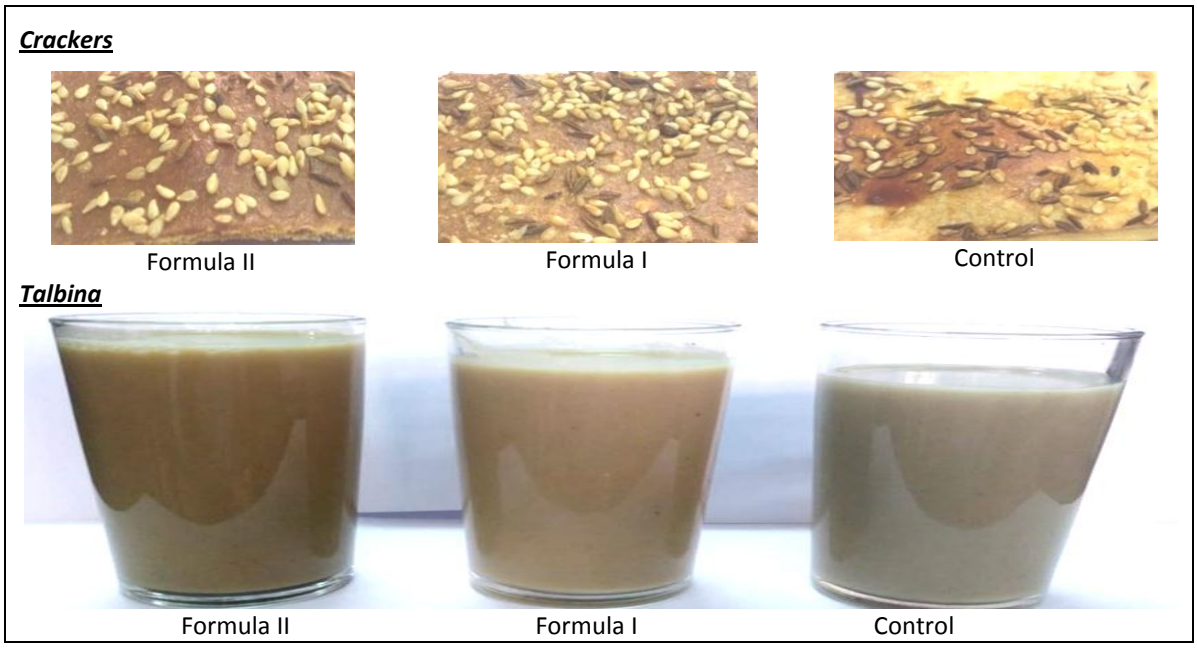

Figure 1. Photographs of crackers and talbina samples

Design of the animal experiment

Rats were divided into 8 groups each of eight rats; the first and second groups served as control fed on the same casein balanced diet while the other six groups were the test groups fed on diet containing Q1, QH, cracker I, cracker II, talbina I and talbina II, respectively for 4 weeks. Body weight and food intake were followed once weekly. At the end of this period, body weight gain (BWG), total food intake (TFI), food efficiency ratio (FER) which is body weight gain/total food intake and protein efficiency ratio (PER) (Body weight gain/ total protein intake) were calculated. Then the experiment was extended for extra two weeks during which the rats were continued feeding on the aforementioned diets. On the eleventh day after an overnight fast, the rats of all the groups except one of the control groups were treated with one intra-peritoneal dose of triton X-100 (100 mg/kg rat body weight, after being dissolved in saline) for induction of dyslipidemia [16]. The group that fed on balanced diet and treated by triton served as dyslipidemic control while the other six groups

Table 1. Diets′ composition (g/100g)

Ingredients	*Types of diets*						
	Casein diet	Quinoa 1	Hualhuas quinoa	Cracker I	Cracker II	Talbina I	Talbina II
Casein	10.5	-	-	-	-	-	-
Methionine	0.3	-	-	-	-	-	-
Corn oil	10	7.276	7.258	3.266	3.593	5.409	5.531
Starch	46.47	0.337	8.77	-	3.312	15.435	18.844
Sucrose	23.23	23.23	23.23	20.43	23.23	23.23	23.23
Cellulose	5	3.857	3.502	4.052	3.755	4.436	4.205
Mineral mixture	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Vitamin mixture	1	1	1	1	1	1	1
Quinoa 1	-	60.8	-	-	-	-	-
Hualhuas quinoa	-	-	52.74	-	-	-	-
Cracker I	-	-	-	67.75	-	-	-
Cracker II	-	-	-	-	61.61	-	-

Talbina I	-	-	-	-	-	46.99	-
Talbina II	-	-	-	-	-	-	43.69
Total	100	100	100	100	100	100	100

represented the test groups that fed on the tested diets along with the induction of dyslipidemia. The other control group served as normal control was given only intra-peritoneal saline as the vehicle. Body weights of all rats were measured once weekly along with the food intake. At the end of the experiment, BWG and TFI were calculated after elapsing of the whole experimental period (six weeks). Blood samples were taken from fasted anesthetized rats, and received on heparinized test tubes. Plasma was obtained by blood centrifugation. Plasma triglycerides (TGs), total cholesterol (TC), high density lipoprotein-cholesterol (HDL-C) and low density lipoprotein-cholesterol (LDL-C) that constitute plasma lipid profile were determined using colorimetric methods [17-20]. The TC/HDL-C ratio was calculated as indicator of cardiovascular disease risk.

Statistical analysis

Data of the biological experiment were analyzed by standard procedures for analysis of variance and least significant difference test (LSD) to compare the means and determine the effect of treatments using the Statistical Analysis Software (SAS). The probability value of $p<0.05$ was used as the criteria for significant differences. All data were expressed as means ± SE.

Chemical composition of the raw materials and the processed products

Chemical composition was determined in wheat, quinoa, barely, chickpea flours and milk powder as well as the produced talbina and crackers. The results are assembled in Table 2. From the results concerning raw materials it could be noticed that milk powder was the highest in protein, fat and ash (31.63, 20.30 and 5.63 %, respectively) whereas, barely flour had the highest fiber content (3.54%). Also, quinoa flour had reasonable protein content (18.96% for QH and 16.45 for Q1) compared to wheat flour (9.6%). Meanwhile, wheat flour was the highest in total carbohydrates (75.19%). The protein content of Q1 and QH varieties fall within the range reported previously (10–22%) depending on the genotype [21-23]. Fat contents were 4.48% and 5.20% in Q1 and QH, respectively which agreed with the previous work of Nowak et al. [24] that showed percentage ranged from 4.0 to 7.6.

Table 2 also shows the proximate compositions of the produced crackers and talbina. The moisture contents of the crackers and talbina were generally of low values ranged between 5.48 and 7.01% for crackers, whereas it ranged between 7.55 and 8.26% for talbina. The higher values of moisture content were recorded to crackers and talbina manufactured using

Results and Discussion

Table 2. Chemical composition of raw materials, crackers and talbina (%)

Sample	Moisture	Protein	Fat	Ash	Fibers	CHO
Raw materials						
Wheat flour	12.85±0.39	9.60±0.29	1.10±0.11	0.66±0.08	0.60±0.14	75.19±2.26
Barley flour	11.27±0.34	12.60±0.28	1.56±0.18	2.11±0.13	3.54±0.25	68.92±2.07
Quinoa 1	10.19±0.31	16.45±0.49	4.48±0.22	1.64±0.10	1.88±0.19	65.36±1.95
Hualhuas quinoa	6.25±0.19	18.96±0.57	5.20±0.26	2.06±0.12	2.84±0.20	64.68±1.94
Chickpea	3.59±0.11	25.40±0.76	4.04±0.20	2.82±0.17	1.12±0.11	63.03±1.89
Milk powder	5.10±0.15	31.63±0.95	20.30±0.61	5.63±0.34	ND	37.34±1.12
Crackers						
Control	5.48±0.16	8.32±0.25	7.46±0.37	1.52±0.09	0.52±0.08	77.22±2.32
Formula I	6.88±0.21	14.76±0.44	9.94±0.50	2.45±0.15	1.40±0.11	64.57±1.94
Formula II	7.01±0.21	16.23±0.49	10.40±0.52	2.72±0.16	2.02±0.17	61.62±1.85
Talbina						

Control	7.55±0.23	18.82±0.56	7.90±0.39	3.26±0.20	2.27±0.16	62.47±1.87
Formula I	8.26±0.25	21.28±0.64	9.77±0.45	2.96±0.22	1.20±0.10	56.52±1.70
Formula II	7.89±0.24	22.89±0.69	10.23±0.51	3.23±0.19	1.82±0.13	53.94±1.62

CHO = total carbohydrates

quinoa flour. This could be due to the higher water binding affinity of quinoa and chickpea flours compared to wheat and barley flours. Formula I and II of crackers and talbina had higher protein content (14.76 and 21.28% for formula I and 16.23 and 22.89% for formula II, respectively) compared to the control samples (8.32 and 18.82%, respectively). The changes in fat content of crackers and talbina showed the same trend. On contrary, crackers and talbina made from wheat and barley flour, respectively, had higher carbohydrates content than those made from the composites flour which is certainly due to the high content of carbohydrates in wheat and barley compared to that in quinoa, chick pea and milk powder.

Quinoa is currently considered by FAO as being the food of the future due to its contribution to global food security of the 21st century [25]. The protein isolates of quinoa can be used in foods intended for children and infants [23] and for celiac disease patients due to the absence of gluten [26]. Therefore the present work offered food products represented by crackers and talbina containing two varieties of quinoa and the crackers were supplemented by chick pea while talbina was fortified with milk to elevate the protein percentage and the protein value.

Amino acids contents of the products

The amino acids content of the different food products and quinoa varieties are shown in Table 3. Glutamic acid was the highest amino acids in both QH and the food products while alanine was the most prominent in Q1. Essential amino acids represented by histidine, isoleucine, leucine, lysine, methionine, phenylalanine, valine and threonine are present in the two quinoa varieties and their products in a variable amounts. The percentage essential amino acids in Q1 and QH in the present study were 6.73 and 5.88, respectively. Leucine and methionine were the highest essential amino acids in QH and Q1, respectively. The percentage essential amino acids ranges in food products in the present study were 4.7%-5.12% in crackers and 5.93-6.31 in talbina. Comparable essential amino acids were noticed in talbina and quinoa. This might be due to the added milk in talbina which has good essential amino acids as an animal protein compared to crackers. The obtained results are in accordance with a previous study that showed leucine as the most abundant essential amino acid in quinoa [27]. Quinoa demonstrated a high lysine content and amino acid score in comparison to other cereals [21,28]. Lysine was the second predominant essential amino acid in Q1 in the present study. Quinoa was also reported to have high concentration of essential amino acids and better-balanced amino acid composition than the traditional cereals [5].

Table 3. The amino acids content of the two quinoa varieties and the processed food products (g/100 g sample)

Amino Acids	Quinoa1	Hualhuas quinoa	Crackers I	Crackers II	Talbina I	Talbina II
Aspartic acid	0.49	0.36	0.55	1.08	0.63	0.90
Glutamic acid	2.22	4.17	1.25	3.60	3.23	4.42
Serine	0.71	1.24	0.95	0.42	1.22	1.77
Glycine	1.27	1.47	1.25	0.31	1.19	1.88
Arginine	0.48	1.17	0.52	0.12	0.99	1.48
Alanine	2.32	2.22	0.73	0.24	2.61	2.43
Proline	0.12	0.16	0.72	0.21	0.45	0.82
Tyrosine	0.97	0.81	0.48	0.36	0.92	0.99
Cysteine	0.11	0.06	0.22	0.19	0.30	0.27
Histidine	0.66	0.49	0.39	0.36	0.65	0.64
Methionine	1.75	0.93	0.88	0.85	0.45	0.51
Lysine	1.26	0.77	0.46	0.32	1.15	0.57
Leucine	0.63	1.02	0.72	1.06	1.04	0.91

Isoleucine	0.63	0.58	0.50	1.45	0.70	0.50
Valine	0.67	0.93	0.46	0.64	0.46	1.13
Phenylalanine	0.79	0.74	0.70	0.32	1.25	0.66
Threonine	0.34	0.42	0.59	0.12	0.61	1.01
Total essential amino acids	6.73	5.88	4.7	5.12	6.31	5.93

Hydroxyproline and Tryptophan were not determined

Color attributes of the processed crackers and talbina:

Color is the first perceived characteristic by the consumer and affects the acceptability of the product. Therefore, the Hunter color parameters (L*, a*, b* values) of crackers and talbina made from different formulas were determined and the obtained results are shown in Table 4. Differences in crackers and talbina colors were noticed and had a wide range. The surface color for crackers made from wheat flour was lighter than those containing quinoa and chickpea flours. Lightness "L* values" ranged from 55.48 to 43.65. Likewise, the control samples had higher b* values compared to crackers containing quinoa and chickpea flours, while the changes in redness of crackers (a* values) were not pronounced. In terms of the total color difference (Δ**E**), the data showed pronounced differences between cracker samples made from formula I and II (9.60 and 16.90). Similar results were obtained by Isabelle et al. and Thejasri et al. [29,30].

Talbina products showed higher L* values (58.62 – 65.79) and lower a* values (2.94 – 3.22) compared to crackers. Baked products developed brown color as could be seen in Fig. 1. This might be due to the presence of milk in talbina in addition to lower heat exposure compared to cracker samples. The development of brown color in crackers might be due to the high protein, sugars and phenolic content along with the high proportions of quinoa and chickpea flours. These compounds stimulate the Maillard reaction, with a consequent increase of melanoidin formation, resulting in a darkening of the product [31-33].

Sensory evaluation of the processed crackers and talbina:

The sensory attributes of crackers and talbina processed from formula I and the control varied in narrow range from 9 to 6.6 (Figure 2). Crackers made from wheat flour (control) scored high scores for all sensory attributes when compared with that containing quinoa and chickpea flours. Also, except for the color, barley talbina recorded the highest scores for all sensory characters compared to those prepared using quinoa flours. Quinoa crackers received high scores for shape and flavor. While,

Table 4. Color attributes of the processed crackers and talbina

Sample	Lightness (L*)	Redness (a*)	Yellowness (b*)	Total color differences (ΔE)
Crackers				
Control	55.48±1.66	11.43±0.57	33.17±1.00	0.00
Formula I	49.33±1.12	9.69±0.42	26.01±0.78	9.60±0.48
Formula II	43.65±1.31	10.00±0.50	21.18±0.64	16.90±0.80
Talbina				
Control	62.41±1.87	1.07±0.19	15.13±0.45	0.00
Formula I	65.79±1.95	3.22±0.26	23.56±0.71	9.34±0.47
Formula II	58.62±1.52	2.94±0.24	23.06±0.66	8.98±0.54

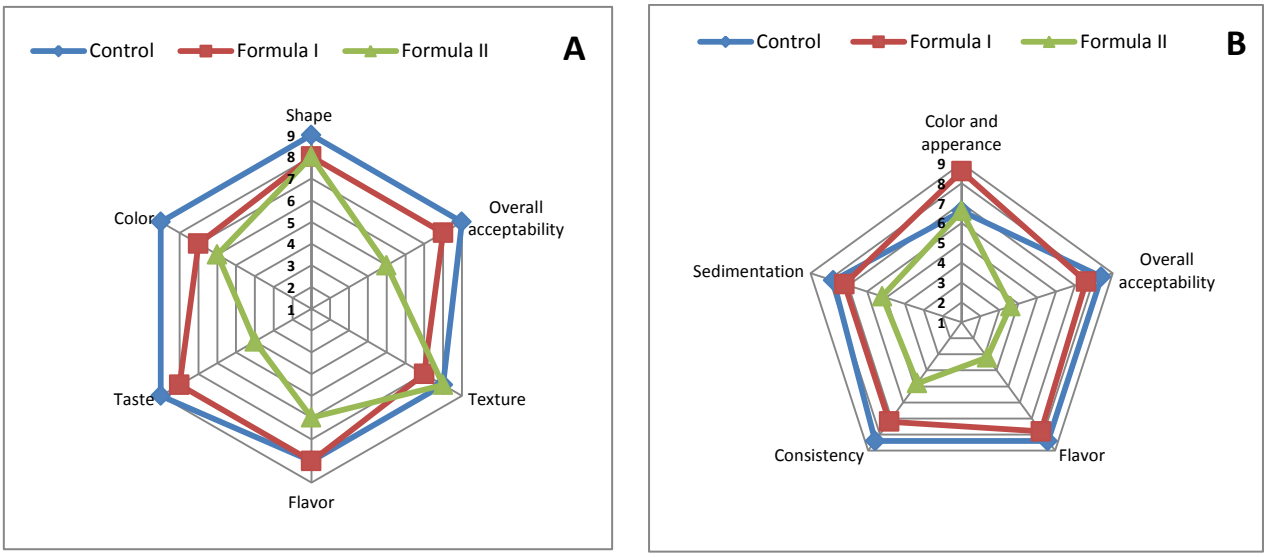

Figure 2. Sensory attributes of the processed crackers (A) and talbina (B).

panelists reported that crackers made from quinoa and chickpea flours were darker in color and harder in texture when compared with crackers made from wheat flour. Also, formula I talbina had high scores for sedimentation, consistency, flavor and overall acceptance however the panelists preferred its color and appearance compared to barley talbina.

Regarding taste character, the panelists stated that formula II of crackers and talbina had a bitter taste. From the results of the overall acceptability of the samples, there was no pronounced difference between formula I crackers and control sample (9 and 8, respectively) and the respective talbina samples (8.4 and 7.6), whereas the panelists dislike the formula II of crackers and talbina. These results showed that the panelists accepted crackers and talbina products processed from quinoa 1. Since all the parameters used in this sensory evaluation had good sensory scores, it could be recommended that Q1 flour could be used in substitution of wheat or barley flour in the production of crackers or talbina, respectively.

Biological results

Table 5. Nutritional parameters of different experimental groups after 4 weeks

Groups	Initial body weight (g)	Final body weight (g)	Body weight gain (g)	Total food intake (g)	Food efficiency ratio	Protein efficiency ratio
Casein diet*	44.13±0.91	94.13^{A}±5.63	50.00^{A}±2.90	208.38^{A}±2.31	0.240^{A}±0.012	2.40^{A}±0.12
Casein diet#	44.13±0.89	94.00^{A}±5.13	50.00^{A}±4.74	204.20^{A}±2.21	0.244^{A}±0.021	2.44^{A}±0.21
Quinoa 1	43.25±0.94	80.63^{B}±3.20	36.63^{B}±3.33	202.14^{AB}±5.65	0.179^{B}±0.013	1.80^{B}±0.14
Hualhuas quinoa	44.00±0.60	74.13^{BC}±5.3	30.13^{BCD}±5.19	178.42^{D}±4.36	0.166^{B}±0.025	1.67^{B}±0.25
Cracker I	44.00±1.00	75.00^{BC}±4.4	31.00^{BCD}±4.24	175.15^{D}±7.16	0.178^{B}±0.025	1.78^{B}±0.25
Cracker II	44.13±0.83	77.25^{B}±3.35	32.89^{BC}±3.17	190.50^{BC}±2.19	0.175^{B}±0.015	1.75^{B}±0.15
Talbina I	43.88±0.40	63.88^{C}±3.44	20.12^{D}±3.42	187.04^{CD}±0.99	0.107^{C}±0.018	1.07^{C}±0.18
Talbina II	43.88±1.01	68.63^{C}±4.31	24.25^{D}±4.16	183.95^{CD}±4.79	0.131^{BC}±0.02	1.31^{BC}±0.20
LSD	NS	12.54	11.243	11.895	0.0545	0.5449

Different superscript letters in the same column means significant difference at $p< 0.05$.
*and #Casein diets: Two groups fed on balanced control diets having the same ingredients (repeated groups),
LSD: The least significant difference, NS: Insignificant

Nutritional parameters after 4 weeks are outlined in Table 5. It could be noticed that FBW and BWG of rats fed on different formulas and quinoa diets were significantly lower than the casein diets. No significant changes in FBW and BWG were noticed between the groups fed on cracker I, cracker II, Q1 and QH diets; which also showed higher values than those fed on talbina diets. There was insignificant change in TFI between the group fed on the casein diet and that maintained on Q1 diet, while all other groups showed significant reduction. Similar results were reported for rats fed diet containing quinoa as major protein source compared to casein diet [34].

All test groups showed significant reductions in PER and FER compared to casein balanced diets. The PER of quinoa varieties and their food products ranged from 1.07 to 1.8 while that of casein was 2.4 reflecting the appreciable protein quality of quinoa varieties and their products. It is worthy to mention that crackers (I and II) containing chickpea showed higher PER (1.78±0.25 & 1.75±0.15) compared to talbina (I & II) (1.07±0.18 & 1.31±0.20). This result denoted that mixing pseudocereals with legumes represented by chickpea could elevate the protein quality. The PER of Q1 (1.8) was higher than QH (1.67), which is parallel to the percentage of the essential amino acids that showed higher percentage in Q1 compared to QH.

After treating rats with triton X-100, all groups showed significant reductions in FBW compared to normal control group except for the control dyslipidemic group and the rats fed on cracker I diet that only showed insignificant reduction (Table 6). Rats fed on talbina II diet showed significant reduction in FBW and BWG compared to all other groups. The dyslipidemic control group showed insignificant reduction in BWG compared to normal control while all test groups showed significant reductions. It was noticed that all test groups except that fed on Q 1 showed significant reduction in TFI compared to normal control.

All Lipid profiles of the different experimental groups after 6 weeks are shown in table 7. It could be noticed that TG, TC, LDL-C and TC/HDL-C were significantly high along with significant reduction of HDL-C in dyslipidemic control compared to normal control and to all test groups. TG, TC, LDL-C and TC/HDL-C of all test groups were still significantly higher than that of normal control except for those fed on QH that matched the control level concerning TC, LDL-C and TC/HDL-C. Similar health benefits of quinoa were reported in celiac patients [35] and overweight healthy men [36].

The anti-dyslipidemic effect of two quinoa varieties and their products in the present study might be attributed to its phenolic acids, flavonoids, betacyanins, betalains, tocopherols, phytosterols, unsaturated fatty acids and dietary fibers contents reported previously [26,37-39]. In addition, several studies have shown the functional attributes of protein isolates from quinoa that include antioxidant, antihypertensive and anticholesterolemic activities [40]. Al-Okbi et al. [37] showed the total phenolic content in alcohol extract of Q1 (6.761±0.42 mg GAE/g) to be higher than that in QH (5.435±0.31 mg GAE/g). The same study showed antioxidant activity of both quinoa varieties with Q1 to be superior. The study of Al-Okbi et al. [37]

Table 6. Nutritional parameters of different experimental groups after 6weeks including triton X-100 injection

Diet	Initial body weight (g)	Final body weight (g)	Body weight gain (g)	Total food intake (g)
Balanced diet	44.13±0.91	104.17^{A}±7.51	60.50^{A}±6.48	301.03^{A}±3.63
Dyslipidemic	44.13±0.89	99.27^{AB}±7.40	55.50^{AB}±7.46	280.50^{AB}±5.15
Quinoa 1	43.25±0.94	82.57^{C}±5.94	38.73^{C}±5.61	300.75^{A}±20.50
Hualhuas quinoa	44.00±0.60	86.30^{BC}±1.56	42.35^{BC}±0.95	239.33^{D}±6.10
Cracker I	44.00±1.00	89.30^{ABC}±5.91	45.27^{BC}±3.30	249.97^{CD}±4.71
Cracker II	44.13±0.83	85.23^{BC}±6.60	40.67^{C}±4.7O	261.03^{BCD}±0.60
Talbina I	43.88±0.40	81.82^{C}±3.64	38.00^{C}±3.31	256.52^{CD}±4.07
Talbina II	43.88±1.01	71.10^{D}±1.18	27.28^{D}±1.19	263.58^{BC}±2.56
LSD	NS	15.72	13.561	23.542

Different superscript letters in the same column means significant difference at $p< 0.05$.

Table 7. Plasma lipid profile of different experimental groups after triton X-100 injection

Groups	Triglycerides (mg/dL)	TC (mg/dL)	HDL-C (mg/dL)	LDL-C (mg/dL)	TC/HDL-C
Balanced diet	50.00^{F}±1.90	74.17^{E}±1.18	48.03^{AB}±0.57	15.55^{D}±0.61	1.54^{E}±0.028
Dyslipidemic control	80.08^{A}±0.77	114.35^{A}±1.79	29.87^{E}±0.96	68.00^{A}±1.18	3.85^{A}±0.135
Quinoa 1	59.87^{D}±0.70	93.10^{BC}±1.64	41.05^{C}±0.59	40.15^{B}±0.57	2.27^{B}±0.067
Hualhuas quinoa	61.53^{CD}±1.07	76.00^{E}±1.57	50.17^{A}±0.58	13.57^{D}±0.55	1.52^{E}±0.032
Cracker I	63.25^{C}±0.88	85.48^{D}±0.59	46.25^{B}±0.59	26.98^{C}±0.58	1.85^{D}±0.034
Cracker II	56.13^{E}±0.93	85.63^{D}±1.31	47.37^{B}±0.56	27.12^{C}±0.97	1.81^{D}±0.029
Talbina I	61.27^{CD}±1.14	95.58^{B}±0.74	46.08^{B}±1.19	38.13^{B}±1.12	2.08^{C}±0.039
Talbina II	70.18^{B}±1.31	91.23^{C}±1.40	38.23^{D}±0.92	39.25^{B}±0.56	2.39^{B}±0.069
LSD	3.272	3.866	2.2264	2.319	0.183

TC: Total cholesterol, HDL-C: High density lipoprotein-cholesterol, LDL-C: Low density lipoprotein-cholesterol, Different superscript letters in the same column means significant difference at $p< 0.05$.

demonstrated twelve phenolic compounds identified in both Q1 and QH. The major phenolic compound in both quinoa varieties was protocatechuic, other phenolic compounds in the two varieties were p-hydroxybenzoic, ferulic, cinnamic, rutin, lutiolin, sinapic, chlorogenic acid, p-coumaric, syringic, kaempferol and chrysin.

On the other hand, it was reported that quinoa is rich in essential fatty acids exemplified by linoleic acid and linolenic acid [41]. Dyslipidemia that induced by triton X-100 in the present study agreed with a previous work [16]. Hypercholesterolemia was reported to produce reduction in the body antioxidants (glutathione and catalase) causing damage to the antioxidative defense system of the cell. Such changes lead to reactive oxygen species that lead to high oxidative stress [42] therefore the hypocholesterolemic effect seen in the present study together with the reported antioxidant effect of quinoa could have the potential of protection from CVDs. However the lipid profile of rats did not return to normal levels on different treatments except in case of rats treated with QH that showed insignificant changes from control normal concerning TC, HDL-C, LDL-C and TC/HDL-C.

The significant reduction of TC/HDL-C on consuming the two crackers formulas compared to talbina might be related to the presence of chickpeas. Chickpea was reported to contain genistein and daidzein which are the 2 major forms of isoflavones in addition to dietary fibers with lipid lowering effect [43,44]. The dyslipidemic rats of 9 weeks of age used in the present study have been reported to be parallel to adolescent in human [45] when translated to human subjects speculating that quinoa and food products used in the present study could be beneficial in combating dyslipidemia in such age stage.

Conclusion

The percentage of protein in QH was higher than in Q1 while it was higher in talbina compared to crackers. Alanine and glutamic acids were the highest amino acids in both quinoa varieties. Crackers and talbina made from Q1 were more acceptable than those prepared from QH concerning sensory attributes. Protein efficiency ratios of Q1 and QH were 1.8 and 1.67, respectively while that of the food products ranged from 1.07 to 1.78 compared to casein that was 2.4. The two quinoa varieties and the food products produced significant protection from dyslipidemia with variable degrees. QH was superior in reducing TC, LDL-C and cardiovascular disease risk (TC/HDL-C). The anti-dyslipidemic effect of quinoa and its products in the present study might be capable in combating dyslipidemia in adolescent in terms of human subjects.

Acknowledgments

The authors would like to thank National Research Centre for partially funding the present research.

The work was completely carried out in the National Research Centre.

References

1. Ogungbenle H.N., Nutritional evaluation and functional properties of quinoa (*Chenopodium quinoa*) flour. *International Journal of Food Sciences and Nutrition* **54**(2), 153-158 (2003).
2. Konishi Y., Hirano S., Tsuboi H. and Wada M., Distribution of minerals in quinoa (*Chenopodium quinoa* Willd.) seeds. *Bioscience, Biotechnology, and Biochemistry* **68**(1), 231-234 (2004).
3. James L.E. Quinoa (*Chenopodium quinoa* Willd.): composition, chemistry, nutritional, and functional properties. *Advances in Food and Nutrition Research* **58**,1-31(2009).
4. Vega-Gálvez A., Miranda M., Vergara J., Uribe E., Puente L. and Martínez E. A., Nutrition facts and functional potential of quinoa (Chenopodium quinoa willd.), an ancient Andean grain: a review. *Journal of the Science of Food and Agriculture* **90**(15), 2541-2547 (2010).
5. Alvarez-Jubete L., Wijngaard H., Arendt E.K. and Gallagher E., Polyphenol composition and in vitro antioxidant activity of amaranth, quinoa buckwheat and wheat as affected by sprouting and baking. *Food Chemistry* **119**(2), 770-778(2010).
6. Stikic R., Glamoclija D., Demin M., Vucelic-Radovic B., Jovanovic Z., Milojkovic-Opsenica D., Jacobsen S. and Milovanovic M., Agronomical and nutritional evaluation of quinoa seeds (*Chenopodium quinoa* Willd.) as an ingredient in bread formulations. *Journal of Cereal Science* **55**(2), 132-138 (2012).
7. Hirose Y., Fujita T., Ishii T. and Ueno N., Antioxidative properties and flavonoid composition of *Chenopodium quinoa* seeds cultivated in Japan. *Food Chemistry* **119**(4), 1300-1306 (2010).
8. Rice-Evans C., Miller N. and Paganga G. Antioxidant properties of phenolic compounds. *Trends in Plant Science* **2**(4), 152-159 (1997).
9. Eisa S., Hussin S., Geissler N., Koyro H.W., Effect of NaCl salinity on water relations, photosynthesis and chemical composition of Quinoa (*Chenopodium quinoa* Willd.) as a potential cash crop halophyte. *Australian Journal of Crop Science* **6**(2), 357-368 (2012).
10. Hafez D.A. Utilization of amaranth and quinoa flour to produce some bakery products to autism children. *Advances in Environmental Biology* **11**(6), 1-11 (2017).
11. Youssef M.K.E., El-Fishawy F.A., Ramadan E.A. and Abd El-Rahman A.M., Nutritional assessment of barley, talbina and their germinated products. *Frontiers in Science* **3**(2), 56-65 (2013).
12. AOAC , Official Methods of Analysis. Association of Official Analytical Chemists.18th Edition. Arlington VA 2209, Washington, DC, USA (2005).
13. Millipore Cooperative, Liquid chromatographic analysis of amino acids in foods using a modification of the PICO-TAG method. New York, USA (1987).
14. Meilgaard M.C., Carr B.T. and Civille G.V., Sensory evaluation techniques. 3rd eition, CRC press (1999).
15. Ahuja K.K., Development of barley-milk based fermented probiotic drink. Doctoral dissertation, Dairy Tehnology Division, Icar-National Dairy Research Institute, India (2015)
16. Al-Okbi S.Y. and Al-Siedy E.S.K., Potential anti-dyslipidemia and hepatoprotection of functional food components represented by tetracosanol and mixture of policosanol in Triton X-100 induced dyslipidemic rats. *Egyptian Journal of Chemistry*, **65**(11), 313-321(2022).
17. Watson D. A simple method for the determination of serum cholesterol. *Clinica Chimica Acta*, **5**(5), 637-643(1960).
18. Burstein M.S., Scholnick H.R. and Morfin R., Rapid method for the isolation of lipoproteins from human serum by precipitation with polyanions. *Journal of Lipid Research*, **11**(6), 583-595(1970).
19. Friedewald W.T., Levy R.I. and Fredrickson D.S., Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clinical Chemistry*, **18**(6), 499-502 (1972).
20. Megraw R.E., Dunn D.E. and Biggs H.G., Manual and continuous-flow colorimetry of triacylglycerols by a fully enzymic method. *Clinical Chemistry*, **25**(2), 273-278 (1979).
21. Ranhotra G.S., Gelroth J.A., Glaser B.K., Lorenz J. and Johnson L., Composition and protein nutritional quality of quinoa. *Cereal Chemistry*, **70** (3), 303-305 (1993).
22. Jacobsen S.E., Mujica A. and Ortiz R. The global potential for quinoa and other Andean crops. *Food Reviews International* **19**(1-2), 139-148 (2003).

23. Abugoch L.E., Romero N., Tapia C.A., Silva J. and Rivera M., Study of some physicochemical and functional properties of quinoa (*Chenopodium quinoa* Willd) protein isolates. *Journal of Agricultural and Food chemistry*, **56**(12), 4745-50 (2008).
24. Nowak V., Du J. and Charrondière U.R., Assessment of the nutritional composition of quinoa (*Chenopodium quinoa* Willd.). *Food Chemistry*, **193**, 47-54 (2016).
25. FAO, Food and Agricultural Organization., Año internacional de la Quinua. Recuperado de http://www.fao.org/quinoa-2013/es/. Accessed 1 December (2013).
26. Asao M. and Watanabe K., Functional and bioactive properties of quinoa and amaranth. *Food Science and Technology Research* **16**(2), 163-168 (2010).
27. Mota C., Santos M., Mauro R., Samman N., Matos A.S., Torres D. and Castanheira I., Protein content and amino acids profile of pseudocereals. *Food Chemistry*, **193**, 55-61(2016).
28. Watanabe K., Ibuki A., Chen Y.C., Kawamura Y. and Mitsunaga T., Composition of quinoa protein fractions. *Journal of the Japanese Society for Food Science and Technology* (Japan) 50 (11), 546–549 (2003).
29. Isabelle L.B., Souza E.L., Felexs S.S., Madruga M.S., Yamashita F. and Magnani M., Nutritional and sensory characteristics of gluten free quinoa (*Chenopodium quinoa* wild) based cookies development using an experimental mixture design. *Journal of Food Science and Technology* **52**(9), 5866-5873 (2015).
30. Thejasri V., Hymavathi T.V., Roberts T.P., Anusha B. and Devi S.S., Sensory, physico-chemical and nutritional properties of gluten free biscuits formulated with Quinoa (*Chenopodium quinoa* Willd.), Foxtail Millet (*Setaria italica*) and hydrocolloids. *International Journal of Current Microbiology and Applied Sciences*, **6**(8), 1710-12721(2017).
31. Singh M. and Mohamed A. Influence of gluten–soy protein blends on the quality of reduced carbohydrates cookies. *LWT-Food Science and Technology*, **40**(2), 353-360 (2007).
32. Secchi N., Stara G., Anedda R., Campus M., Piga A., Roggio T. and Catzeddu P., Effectiveness of sweet ovine whey powder in increasing the shelf life of Amaretti cookies. *LWT-Food Science and Technology* **44**(4), 1073-1078 (2011).
33. Zucco F., Borsuk Y. and Arntfield S.D., Physical and nutritional evaluation of wheat cookies supplemented with pulse flours of different particle sizes. *LWT-Food Science and Technology* **44**(10), 2070-2076 (2011).
34. Mithila M.V. and Khanum F. Effectual comparison of quinoa and amaranth supplemented diets in controlling appetite; a biochemical study in rats. *Journal of Food Science and Technology*, 52(10): 6735-6741(2015).
35. Zevallos V.F., Herencia I.L., Chang F., Donnelly S., Ellis H.J. and Ciclitira P.J., Gastrointestinal effects of eating quinoa (*Chenopodium quinoa* Willd) in celiac patients. *American Journal of Gastroenterology* **109**(2), 270-278 (2014).
36. Li L., Lietz G., Bal W., Watson A., Morfey B. and Seal C., Effects of quinoa (*Chenopodium quinoa* Willd.) consumption on markers of CVD risk. *Nutrients* **10**(6), 777 (2018).
37. Al-Okbi S.Y., Hamed T.E., Elewa T.A., Ramadan A.A., El-Karamany M.F. and Bakry B.A. Role of polar extracts from two quinoa varieties in prevention of steatohepatitis and cardiovascular diseases and improving glucose tolerance in rats. *Journal of Herbmed Pharmacology* 10(1), 93-101(2021).
38. Martínez-Villaluenga C., Peñas E. and Hernández-Ledesma B. Pseudocereal grains: Nutritional value, health benefits and current applications for the development of gluten-free foods. *Food and Chemical Toxicology* **137**: 111178 (2020).
39. Shen Y., Zheng L., Peng Y., Zhu X., Liu F., Yang X., and Li H., Physicochemical, antioxidant and anticancer characteristics of seed oil from three Chenopodium quinoa Genotypes. *Molecules*, **27**(8), 2453(2022).
40. Takao T., Watanabe N., Yuhara K. and Itoh S., Hypocholesterolemic effect of protein isolated from quinoa (*Chenopodium quinoa* Willd.) seeds. *Food Science and Technology Research* **11**(2), 161-167 (2005).
41. Hafid R.E., Imaalem H.A., Driedger D., Bandara M. and Stevenson J., Quinoa… The next Cinderella crop for Alberta. *Alberta Agriculture, Food, and Rural Development Ag. Entrepreneurship* 1-28 (2005).
42. Nwichi S.O., Adewole E.K., Dada A.O., Ogidiama O., Mokobia O.E., Farombi E.O., Cocoa powder extracts exhibits hypolipidemic potential in cholesterol-fed rats. *African Journal of Medicine and Medical Sciences*, **41**, 39-49 (2012).
43. Park D., Huang T., Frishman W.H., Phytoestrogens as cardioprotective agents. *Cardiology in Review*, **13**(1), 13-17(2005).

44. Silva V., Jayasinghe M.A., Senadheera S.A. and Ranaweera KKDS. Determination of macronutrient compositions in selected, frequently consumed cereals, cereal based foods, legumes and pulses prepared according to common culinary methods in Sri Lanka. *Journal of Food Science and Technology*, **57**(3), 816-820 (2020).
45. Ghasemi A., Jeddi S. and Kashfi K. The laboratory rat: Age and body weight matter. *EXCLI Journal*, **20**, 1431-1445 (2021).