Enhancement of Functional Properties of Gluten-Free Bread

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ABSTRACT

The aim of the research to highlight the nutritional and sensory characteristics of gluten-free flat bread produced by using the different concentrations of quinoa flour. Methods: Gluten-free flatbread was prepared from different ratios of quinoa flour and rice flour. The following substitutions were used: replacing 0%, 25%, 50%, 75%, and 100% of rice flour with quinoa flour. The control group was 100% rice. A sensory evaluation was conducted with 200 participants. The chemical composition of quinoa flour, rice flour, and bread mixtures was assessed. Also, the amino acid profile, minerals, vitamin E, anti-nutritional factors, and antioxidant activities of quinoa flour and rice flour were analyzed. Results: A high score of overall acceptability was detected in bread samples supplemented with 50% rice and 50% quinoa. The data showed significant differences in the percentage of proximate analysis between quinoa and rice bread mixtures. Quinoa provides all essential amino acids. Furthermore, the lowest anti-nutritional factor in rice and quinoa was phytic acid. Also, rice and quinoa flour contains the most common minerals, vitamin E was recorded in quinoa around 1.20 mg/100 grams. The total antioxidant activity of quinoa was higher than rice flour. Conclusion: Bread fortified with quinoa, rice, and their mixtures has high nutritional value due to its high content of essential amino acids, minerals, vitamins and antioxidant activity. Therefore, gluten free flat bread prepared from quinoa and rice flour has the potential for celiac disease prevention and treatment.

Keywords: Amino acid, anti- nutritional factors, antioxidants and minerals.

INTRODUCTION

Functional food development that not only to meet individual needs for essential nutrients and energy but also provides therapeutic, preventive, and health benefits represents a major challenge facing the modern food industry. Traditional foods can gain functionality by adding bioactive ingredients. This turns food into medicine, and medicine eventually becomes food (Ivanov *et al.,* 2011). Quinoa, belonging to the amaranth family, under the subfamily Chenopodiaceae and genus Chenopodium, is scientifically known as *Chenopodium quinoa* Willd (Gomez-Pando and Aguilar-Castellanos, 2016). This crop originates from the Andean areas of Bolivia, Ecuador, Peru, and Chile, where it has been cultivated for many centuries. Quinoa is often categorized as a 'superfood' because of its substantial nutritional benefits. It is also promoted as a versatile crop, because of its resilience to environmental stress and its robust adaptability to various weather, soil, and climatic conditions (Sharma *et al.*, 2021). Both the leaves and seeds of quinoa are edible, with the seeds receiving more attention for their economic and scientific significance (Spehar, 2006 and Rocha, 2008). Quinoa is more nutrient-dense than traditional grains like rice, corn, barley, and wheat because it is enriched with higher concentrations of total protein, lysine, and methionine, complemented by a balanced profile of essential amino acids (Linnemann and Dijkstra, 2002). Quinoa contains a certain amount (52% to 69% decimeters (dm) of starch, which is the main carbohydrate component. The overall dietary fiber content approximates that of grains (7-9.7% dry matter). The content of soluble fiber varies from 1.3% to 6.1% in dry matter (James, 2009). Quinoa is richly supplied with α-carotene and niacin, and exhibits substantial amounts of thiamine (0.4 mg per 100 g) and folic acid (78.1 mg per 100 g) (Vega-Gálvez *et al.,* 2010). Quinoa grains contain anti-nutritional factors, these can be deactivated or reduced to levels considered safe for health through the application of suitable industrial processing methods or domestic preparation techniques (Filho *et al.,* 2017). Quinoa also has no gluten, making it suitable for persons with celiac disease or wheat allergies. The seed oil is highly nutritious and of excellent quality (Filho *et al.*, 2017). These advantages stem from the high levels of protein, fiber, fatty acids, minerals, vitamins, and a variety of phytochemicals in quinoa, which collectively provide superior nutritional and health benefits compared to other grains (Vilcacundo and Hernández-Ledesma, 2017). Quinoa, characterized as a starchy dicotyledonous seed rather than a true cereal, is classified as a pseudo-cereal (USDA, 2005). It lacks gluten, making it suitable for consumption by individuals with CD and those allergic to wheat. Quinoa seeds are highly nutritious, providing a source of high-quality protein (Abugoch *et al.,* 2008), lipids (Koziol, 1993), starch (Coulter and Lorenz, 1990), minerals (Oshodi *et al.,* 1999) and vitamins like

DOI: 10.21608/asejaiqjsae.2024.363443

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Received, May 15, 2024, Accepted, June 25, 2024.

vitamin B (Koziol, 1993). As a hypoallergenic food, rice has a higher biological value and digestibility of protein than other main cereals. Thus, rice protein can be effectively used in diverse ways, such as in infant formula and as a component of sports nutrition (Amagliani *et al.*, 2017). Rice is a good source of zinc and iron, which are vital for enzymatic activities and hemoglobin synthesis in the human body, respectively. A deficiency in zinc may manifest as diarrhea, weight loss, and increased susceptibility to infections, and without intervention, can result in life-threatening conditions. Likewise, a lack of iron in the diet can severely impact health, resulting in anemia characterized by symptoms such as brittle hair, fragile fingernails, and general fatigue (Chaudhari *et al.*, 2018). A gluten-free diet (GFD) calls for the total avoidance of gluten, which is a protein complex found in foods made from hybridized strains of wheat, rye, barley, oats, and spelt. It consists only of naturally occurring gluten-free (GF) foods (like vegetables, fruits, legumes, fish, unprocessed meat, dairy products, and eggs) and/or wheat-based food substitutes that have been deliberately made with no gluten or with a gluten content lower than 20 ppm in accordance with European legislation (Melini and Melini, 2019). The aim of the research to highlight the nutritional and sensory characteristics of gluten-free flat bread produced by using the different concentrations of quinoa flour.

MATERIALS AND METHODS

Materials:

1- Source and preparation of raw materials:

Quinoa and rice flour brand name “Dobella”,– company in Alexandria – were purchased from local market Alexandria Governorate, Egypt.

2- Formulation and preparation of bread:

The formulation used for the bread preparation is shown Table (1) as outlined by Juarez-Garcia *et al*. (2006).

3- Bread-Making Procedure:

Quinoa flour or its blends were mixed with salt, yeast and an adequate amount of water was added. The ingredients were mixed for 7 min, left for 10 min, divided (100 g), kneaded, and then left again (15 min).

4- Baking Procedure:

Dough was manually rolled, proven (up to optimum volume increase at 28 ^{O}C, 85% relative humidity), and baked at 200 ^{O}C/29 min. Temperature and volume increase of dough was monitored at regular intervals during fermentation. After fermentation, dough was baked in an electric oven and cooled at room temperature for 60 min for subsequent analyses.

Analytical method:

1- Chemical composition of quinoa, rice flour and their mixture flat bread samples:

The analysis of ash, crude fiber, total protein, and total lipids was carried out as described in AOAC (2000). The total carbohydrate (TC) was calculated by the difference: 100- (proteins + lipids + moisture + ash) (AACC, 2000).

2- Determination of amino acid profile of quinoa and rice flour:

The amino acid composition of experimental samples was determined using the HPLC-Pico-Tag method according to Millipore Cooperative (1987).

3- Determination of anti-nutritional factor contents in quinoa and rice flour:

3.1- Determination of phytic acid:

Phytic acid content was quantified using the spectrophotometric method (Haug & Lantzsch, 1983 and Butt *et al*., 2004). The absorbance of the reaction mixture was measured at 519 nm against distilled water.

3.2- Determination of tannins:

Tannins were determined using the spectrophotometric method (Makkar *et al*., 1993 and European Community, 2000). The absorbance was read at 500 nm against distilled water.

Table 1. Ingredients used in preparation of rice and quinoa flour bread

Samples / Ingredients	Quinoa flour	Rice flour	Yeast	Salt	Sugar
Control bread (100%) rice flour	-	100	2.5	0.7	2
Bread (25% rice flour + 75% quinoa flour)	75	25	2.5	0.7	2
Bread (50% rice flour + 50% quinoa flour)	50	50	2.5	0.7	2
Bread (75% rice flour + 25% quinoa flour)	25	75	2.5	0.7	2
Bread (100% Quinoa)	100	-	2.5	0.7	2

3.3- Determination of trypsin inhibitor:

Trypsin inhibitors were measured using the spectrophotometric method (Kakade *et al.*, 1974). Absorbance was recorded at 410 nm against distilled water.

4- Determination of minerals content in quinoa and rice flour:

Dissolved ash was analyzed for calcium, magnesium, zinc and iron contents by using the AOAC methods (2000).

5- Determination of vitamin E content in quinoa and rice flour by HPLC:

The vitamin E of experimental samples were determined using HPLC using the AOAC methods (2000).

6- Determination of total antioxidant activity content in quinoa and rice flour:

DPPH (2,2-diphenyl-1-picrylhydrazyl) assay was performed as described (Brand-Williams *et al.*, 1995). A solution of 0.2 mm DPPH in methanol was added to aliquots of 5-1000 µg ascorbic/methanol solution or 1 ml of reconstituted extract sample, incubated for 30 min in the dark and absorbance was read at 517 nm by UV/VIS spectrophotometer (T80, PG Instrument Ltd., UK) versus the prepared blank (DPPH and methanol). Antioxidant activity was expressed as an inhibition % of DPPH radical and calculated from the equation:

$$\%Inhibition = \frac{Ac - As}{Ac} X100$$

Where:

Ac: Absorbance of control (methanol).

As the Absorbance of the sample.

The measurements were performed in triplicates.

7- Sensory evaluation of quinoa, rice and their mixtures of flatbread:

The baked bread quality characteristics were carried out following cooling to room temperature. Sensory evaluation was performed by 200 panelists who were staff members and students of the High Institute of Public Health, Alexandria University. The bread was randomly assigned to each panelist. The panelists were asked to evaluate each bread for bread shape, flavor, texture, color, and aftertaste.

The two hundred Panelists evaluated bread samples on a 9 points hedonic scale quality analysis with 9= liked extremely, 8=liked very much, 7= liked moderately, 6= liked slightly, 5= neither liked nor disliked, 4=disliked slightly, 3= disliked moderately, 2 = disliked very much and 1 = disliked extremely (El-Sohaimy *et al*., 2019).

The testing area was in a quiet, temperature-controlled room with good ventilation, controlled lighting and free of food preparation or foreign odors to allow panelists to perform tasks free from distractions (De Kock and Magano, 2020).

RESULTS AND DISCUSSION

Table 2. Chemical composition of rice, quinoa and bread mixtures

Variables / Treatment groups	Moisture %	Ash %	Protein %	Fat %	Carbohydrate %	Crude fiber %
100% Quinoa	61.23^{a}±0.98	2.49^{a} ±0.08	7.34^{a} ±0.28	0.90^{a}±0.01	17.55^{d} ±0.58	10.49^{a}±0.91
100% Rice	48.74^{c}±0.85	1.51^{b} ±0.05	4.46^{c} ±0.15	0.25^{d} ±0.02	41.49^{b} ±0.61	3.55^{e} ±0.26
25% Quinoa and 75% Rice	50.63^{b}±1.06	1.09^{c} ±0.04	4.10^{c} ±0.11	0.66^{b} ±0.01	38.11^{c} ±0.93	5.41^{d}±0.11
50% Quinoa and 50% Rice	50.72^{b}±1.07	1.09^{c} ±0.03	4.43^{c} ±0.21	0.46^{c} ±0.03	36.41^{c} ±0.58	6.89^{c} ±0.24
75% Quinoa and 25% Rice	50.99^{d}±0.98	1.24^{c} ±0.06	5.49^{b} ±0.40	0.53^{c}±0.03	35.61^{a} ±0.70	8.12^{b} ±0.74
F	91.310*	100.294*	27.609*	116.300*	252.472*	68.950*
P	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
LSD 5%	3.120	0.185	0.794	0.071	2.190	1.001

F: F for ANOVA test, Pairwise comparison bet. Each 2 groups was done using a Post Hoc Test (LSD).
Means in the same column with common letters are not significant (i.e. Means with Different letters are significant).
P: p-value for comparing between the studied groups.
*: Statistically significant at $P \leq 0.05$.

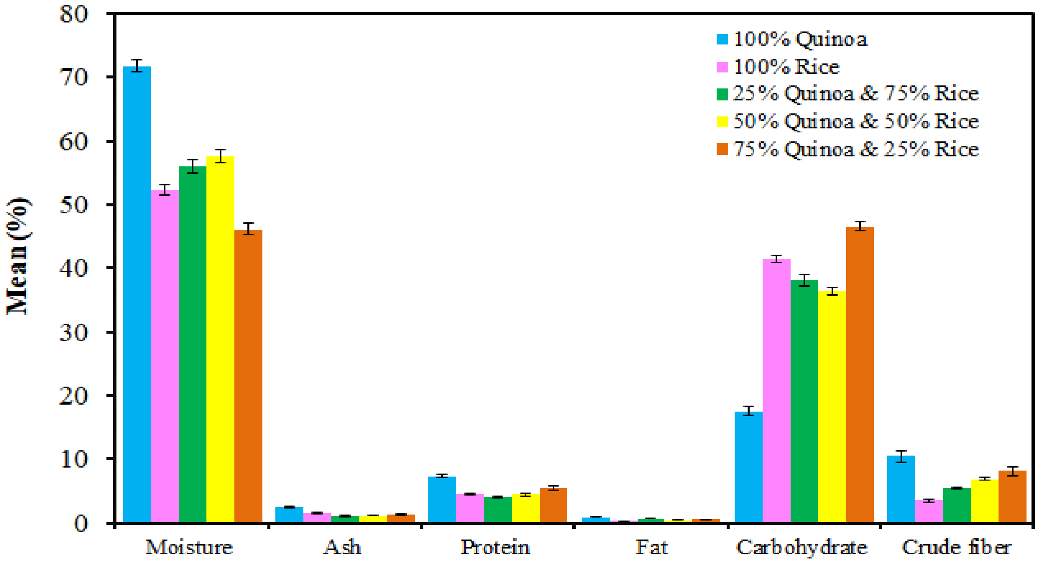

Figure 1. Chemical composition of quinoa, rice and their flatbread mixtures

The chemical composition of the rice, quinoa, and bread mixtures was analyzed, and the obtained results shown in Table (2) and Figure (1) showed the chemical composition of rice bread (control), bread of 25, 50, 75, and 100% quinoa flour, and 75, 50, 25 and 100 % rice. The mean values of moisture, ash, protein, fat, carbohydrate and fiber in rice bread (control) were 48.74%±0.85, 1.51%±0.05, 4.46%±0.15 ,0.25%±0.02, 41.49%±0.61 and 3.55%±0.26, respectively.

Table 3. Amino acids profile of quinoa and rice flour

Amino Acids (Treatment groups)	Quinoa (mg/ gram Protein)	White rice (mg/ gram Protein)	t	p
Aspartic acid	58.23 [a] ±0.14	46.51 [b] ±0.37	29.544*	<0.001*
Glutamic acid	64.35 [a] ±0.54	62.56 [a] ±0.61	2.200	0.093
Serine	45.98 [a] ±1.82	36.70 [b]±0.91	4.550*	0.010*
Glycine	32.84 [a] ±1.14	22.76 [b] ±0.55	7.934*	0.001*
Histidine	67.89 [a] ±1.52	40.07 [b] ±1.07	14.947*	<0.001*
Arginine	76.21 [a] ±2.04	43.49 [b] ±1.42	13.147*	<0.001*
Threonine	52.10 [a] ±0.97	40.06 [b] ±1.18	7.882*	0.001*
Alanine	38.97 [a] ±0.54	38.07 [a] ±0.32	1.434	0.225
Proline	50.35 [a] ±0.64	48.52 [a] ±1.03	1.509	0.206
Tyrosine	79.27 [a] ±1.51	78.82 [a] ±1.76	0.194	0.856
Valine	51.24 [b] ±0.95	83.93 [a] ±0.92	24.710*	<0.001*
Methionine	65.27 [b] ±1.18	91.35 [a] ±2.37	9.835*	0.001*
Cysteine	15.33 [b] ±0.37	20.56 [a] ±0.54	8.020*	0.001*
Isoleucine	57.40 [b] ±1.70	89.53 [a] ±2.80	9.803*	0.001*
Leucine	57.40 [a] ±1.81	60.22 [a] ±1.72	1.128	0.322
Phenylalanine	72.27 [a] ±2.84	64.08 [a] ±1.23	2.646	0.057
Lysine	63.96 [b] ±0.90	80.72 [a] ±1.56	9.287*	0.001*

t: Student t-test.
*: Statistically significant at $p \leq 0.05$.
Data was expressed as mean ±SEM.

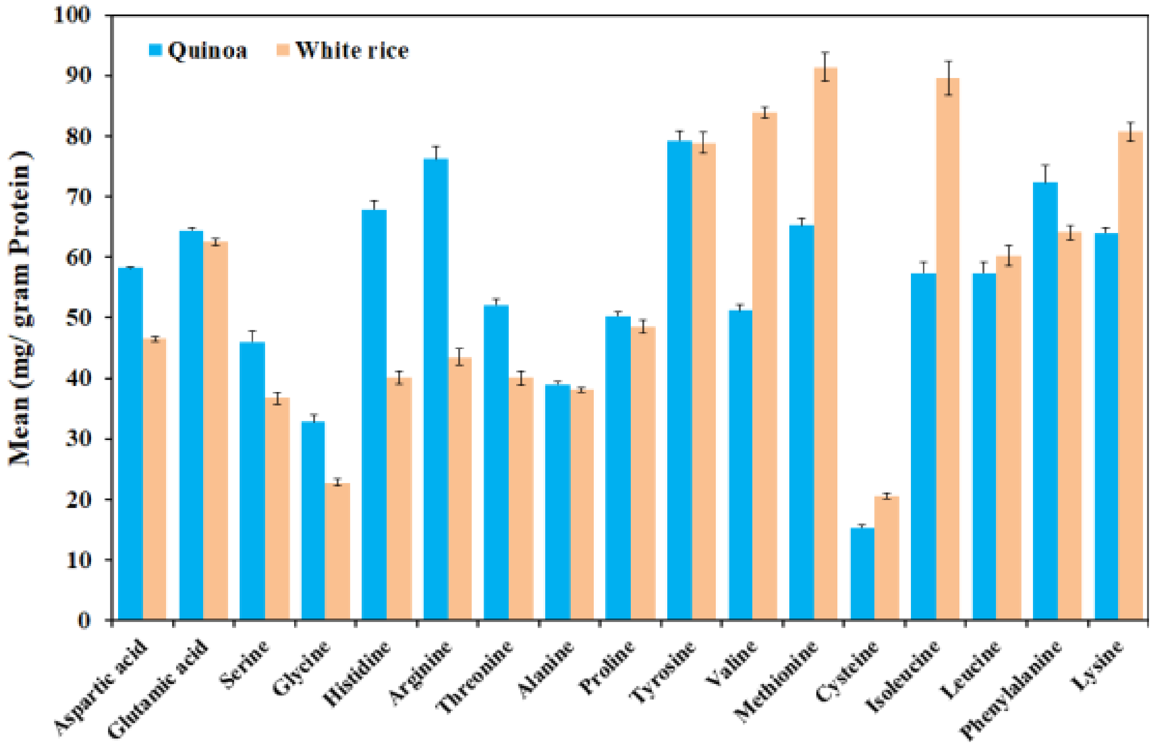

Figure 2. Amino acids profile of quinoa and rice flour.

The obtained data was in line with those reported by Levent (2018), who found that quinoa flour used to prepare gluten-free cakes contains 3.47% ash, 12.36% protein, and 5.65% fat, respectively. Gambus *et al*. (2002) revealed that gluten-free bread enhanced with quinoa flour increased the protein level of the bread and represented a promising source for gluten-free bread production.

Furthermore, Alvarez-Jubete *et al.* (2009) agreed with our study that revealed bread made from amaranth, quinoa, and buckwheat flour demonstrated significant improvements in gluten-free bread production, achieving increased protein levels of 11.60%, 10.60%, and 8.4% respectively, compared to 4.2% in unfortified gluten-free bread.

Chiang and Yeh (2002) reported that the proximate composition of rice flour can vary depending on the processing method used, such as dry or wet milling. Specifically, wet-milled rice flour typically has a higher carbohydrate content but lower levels of other components. This variation is attributed to the soaking and grinding steps in wet milling, which cause soluble proteins, sugars, and non-starch components to bind with lipids and subsequently be removed.

Table (3) and Figure (2) showed the amino acids profile in quinoa flour were aspartic acid, glutamic acid, serine, glycine, histidine, arginine, threonine, alanine, proline, tyrosine, valine, methionine, cysteine, isoleucine, leucine, phenylalanine and lysine by 58.23 a ±0.14, 64.35 a ±0.54, 45.98 a ±1.82, 32.84 a ±1.14, 67.89 a ±1.52,76.21 a ±2.04, 52.10 a ±0.97, 38.97 a ±0.54, 50.35 a ±0.64, 79.27 a ±1.51, 51.24 b ±0.95, 65.27 b ±1.18, 15.33 b ±0.37, 57.40 b ±1.70, 57.40 a ±1.81, 72.27 a ±2.84 and 63.96 b ±0.90 %, respectively.

Table (3) showed the amino acids profile of rice flour were aspartic acid, glutamic acid, serine, glycine, histidine, arginine, threonine, alanine, proline, tyrosine, valine, methionine, cysteine, isoleucine, leucine, phenylalanine and lysine by 46.51 B ±0.37, 62.56 a ±0.61, 36.70 b±0.91, 22.76 b ±0.55, 40.07 b ±1.07, 43.49 b ±1.42, 40.06 b ±1.18, 38.07 a ±0.32, 48.52 a ±1.03, 78.82 a ±1.76, 83.93 a ±0.92, 91.35 a ±2.37, 20.56 a ±0.54, 89.53 a ±2.80, 60.22 a ±1.72, 64.08 a ±1.23 and 80.72 a ±1.56 %, respectively.

Methionine 91.35 mg/g, isoleucine 89.53 mg/g, and valine 83.93 mg/g recorded higher values of essential amino acids in rice flour, while tyrosine 78.82 mg/g, glutamic acid 62.56 mg/g and proline 48.52 mg/g had higher values of non-essential amino acids in rice flour.

Quinoa contains sufficient amounts of aromatic amino acids, including tyrosine and phenylalanine, as well as other essential amino acids like valine, threonine, and isoleucine, histidine (Abugoch James, 2009). These findings were in line with those noted by Bhathal *et al*. (2017). The amino acid profile of raw quinoa (lysine 6.5 g/100 g protein and methionine 5.37 g/100 g protein) was found to be better than the processed forms and it can serve as a valuable addition to legumes, which may lack these amino acids.

In quinoa, leucine was recorded at 63.7 mg/g by Mota *et al*. (2016), which nearby our results of 57.40 mg/ml. Also, lysine recorded 49.6 mg/g, while its concentration was 63.96 mg/ml in our results. Phenylalanine recorded 33.5 mg/g, which was lower than our results of 72.27 mg/ml; the same was true for histidine, threonine, valine, isoléucine, and methionine, which recorded lower concentrations than ours.

Abugoch James (2009) Reported that the essential amino acid profile of quinoa is superior due to its broader range of amino acids compared to cereals and legumes that agreed with our study.

The location and environmental conditions can influence the growth and nutrient composition of quinoa. Environmental and climatic conditions, for instance, have been linked to differences in seed production, total protein content, and amino acid composition across cultivars growing in the Argentinean Northwest and the Andean Highlands (Gonzalez *et al*., 2012).

The data in Table (4) shows the anti-nutritional factor content of rice and quinoa flour. The results showed significant differences in the anti-nutritional factors between rice and quinoa flour. The lowest anti-nutritional factor in rice was phytic acid, recorded at 1.75% ±0.1 and the highest percentage in rice was tannins at 185% ±10.9. The lowest percentage of anti-nutritional factor in quinoa flour was phytic acid 1.55±0.0 %. On the other hand, the highest anti-nutritional factor was tannins 45% ±0.1.

Vega-Gálvez *et al.* (2010) Observed that quinoa had modest quantities of trypsin inhibitor, far lower than those found in regularly consumed grains, and so they do not constitute serious issues, which was consistent with our investigation.

Furthermore, MacKown *et al.* (2008) revealed that tannins content in plants varies between species and genotypes, and can be influenced by biotic stressors and environmental changes.

Minerals are necessary for biological processes and metabolic functions are abundant in quinoa and rice flour (Demirbas, 2005). Zn, Fe, Mg, and Ca were found in quinoa flour at 40.48 ±1.26, 52.09±2.25, 2203.27 ±12.66, and 780.47 ±9.65 ppm, respectively.

Table 4. Anti-nutritional factors content of quinoa and rice flour

Variables / Treatment groups	Phytic acid (%)	Tannins (mg/100g)	Trypsin inhibitor (mg/ 100g)
Quinoa	1.55 [b] ±0.0	45.0 [b] ±0.1	20.05 [b] ±0.05
White rice	1.75[a]±0.1	185 [a] ±10.9	23.52 [a] ±0.48
t	3.464*	22.246*	12.454*
p	0.026*	<0.001*	<0.001*

t: Student t-test.
*: Statistically significant at $p \leq 0.05$.
Data was expressed as mean ± SEM.
Means in the same column with common letters are not significant (i.e. Means with Different letters are significant.

Table 5. Minerals content of quinoa and rice flour.

Variables / Treatment groups	Zn (ppm)	Fe (ppm)	Mg (ppm)	Ca (ppm)
Quinoa	40.48[a]±1.26	52.09 [a] ±2.25	2203.27[a]±12.66	780.47 [a] ±9.65
White rice	11.46 [b] ±0.14	16.60 [b] ±0.85	313.67 [b] ±5.30	74.13 [b] ±5.28
t	22.910*	14.771*	137.668*	64.218*
p	<0.001*	<0.001*	<0.001*	<0.001*

t: Student t-test.
*: Statistically significant at $p \leq 0.05$.
Data was expressed as mean ± SEM.
Means in the same column with common letters are not significant (i.e. Means with Different letters are significant).

In rice flour, the same minerals were found at 11.46 ±0.14, 16.60±0.85, 313.67 ±5.30 and 74.13±5.28 ppm, respectively (Table 5). In every one of the aforementioned categories, quinoa and rice flour differed significantly.

Okumuş and Temiz (2021) reported that quinoa was rich in Mg, Cu, Fe, Mn, and Mo, which are elements that are incomplete in almost all gluten-free cereals. That was in line with our study.

According to Ogungbenle's research (2003), magnesium was the most prevalent mineral in quinoa grains, followed by calcium; zinc had the lowest concentration,which is comparable to our research that is useful for the growth of the child's bones and teeth.

These results indicated that vitamin E in quinoa flour was recorded at 1.20, while in rice flour it was not found (Table 6). Ng *et al*. (2007); Ryan *et al*. (2007); Abugoch James *et al*. (2009) and Mohamed Ahmed *et al*. (2021) reported that the presence of α-tocopherol, like vitamin E, is crucial as it serves as a natural antioxidant within cell membranes, safeguarding fatty acids from damage caused by free radicals.

Islam *et al*. (2023) documented that quinoa contains different phenolic and antioxidant substances that may play a protective role for polyunsaturated fatty acids and stability against oxidation. This observation was previously reported in several studies. Quinoa flour presented a concentration of 48.15±0.21%, while rice flour presented a concentration of antioxidants of 19.12%±0.12 (Table 7).

The current results are in line with Repo-Carrasco *et al.* (2003) who identified quinoa as a valuable source of polyphenols and additional antioxidant compounds.

The overall acceptability revealed that bread supplemented with rice and quinoa flour was acceptable for the panelists. The mean values of color showed that the control bread had the highest score value of color acceptance (6.38±0.13) followed by the bread supplemented with 25% quinoa and 75% rice (6.28 ±0.14) while bread supplemented with 25% quinoa had the lowest values of the color acceptance (Table 8 and Figure 3). Moreover, all the prepared bread might considered useful for children with celiac disease, adults, and people who are safer from celiac disease and gluten sensitivities.

In general, the overall acceptability revealed that bread supplemented with rice and quinoa flour was acceptable for the panelists mostly bread supplemented with 50% rice and 50% quinoa. Moreover, all the prepared bread might be considered useful for people suffering from gluten sensitivity and celiac disease (Figure 4).

Table 6. Vitamin E content of quinoa and rice flour

Variables / Treatment groups	Quinoa (Mg/100g)	White rice (Mg/100g)	t	p
Vitamin E	1.20 ^{a} ±0.05	0.0 ^{b} ±0.0	23.094*	<0.001*

t: Student t-test.
*: Statistically significant at p ≤ 0.05.
Data was expressed as mean ± SEM.
Means in the same column with common letters are not significant (i.e. Means with Different letters are significant).

Table 7. Antioxidant activity of quinoa and rice flour

Treatment groups / Variables	DPPH radical scavenging activity (%)	IC_{50} (mg/ ml)
Quinoa	48.15 ^{a} ±0.21	8.65 ^{b} ±0.06
White rice	19.12 ^{b} ±0.12	21.79 ^{a} ±0.49
t	120.645*	26.554*
p	<0.001*	<0.001*

t: Student t-test.
*: Statistically significant at p ≤ 0.05.
Data was expressed as mean ± SEM.
Means in the same column with common letters are not significant (i.e. Means with Different letters are significant).

Table 8. Sensory evaluation of flat bread of rice, quinoa flour and their mixtures.

Variables / Treatment groups	Color	Taste	Smell	Texture	Acceptance	After taste
100% Quinoa (Q1)	5.60 [b] ±0.17	3.88 [cd] ±0.17	5.45 [b] ±0.17	5.51 [ab] ±0.17	4.43 [b] ±0.17	4.41 [cd] ±0.18
100% Rice (control group)	6.38[a]±0.13	5.16 [a] ±0.17	5.91 [a] ±0.13	5.09 [b] ±0.16	5.31 [a] ±0.14	4.98 [ab] ±0.16
75% Quinoa and 25% Rice (Q2)	5.62 [b] ±0.16	4.12[bc] ±0.17	4.91 [c] ±0.17	5.44 [ab] ±0.16	4.76 [bc] ±0.16	4.58 [bd] ±0.19
50% Quinoa and 50% Rice(Q3)	6.22 [a] ±0.15	4.44 [b] ±0.17	5.65 [a] ±0.16	5.87 [a] ±0.14	5.51 [a] ±0.14	4.99 [ab] ±0.17
25% Quinoa and 75% Rice(Q4)	6.28 [a] ±0.14	4.89 [ab] ±0.18	5.77 [a] ±0.16	5.55 [a] ±0.17	5.17 [ac] ±0.16	5.11 [a] ±0.17
F	6.329*	9.381*	5.966*	2.994*	7.765*	3.065*
P	<0.001*	<0.001*	<0.001*	0.018*	<0.001*	0.016*
LSD 5%	1.443	1.653	1.522	1.543	1.495	1.655

Data was expressed as mean ± SEM.
F: F for ANOVA test, Pairwise comparison bet. Each 2 groups was done using a Post Hoc Test (LSD).
Means in the same column with common letters are not significant (i.e. Means with Different letters are significant).
p: p-value for comparing between the studied groups.
*: Statistically significant at $P \leq 0.05$.

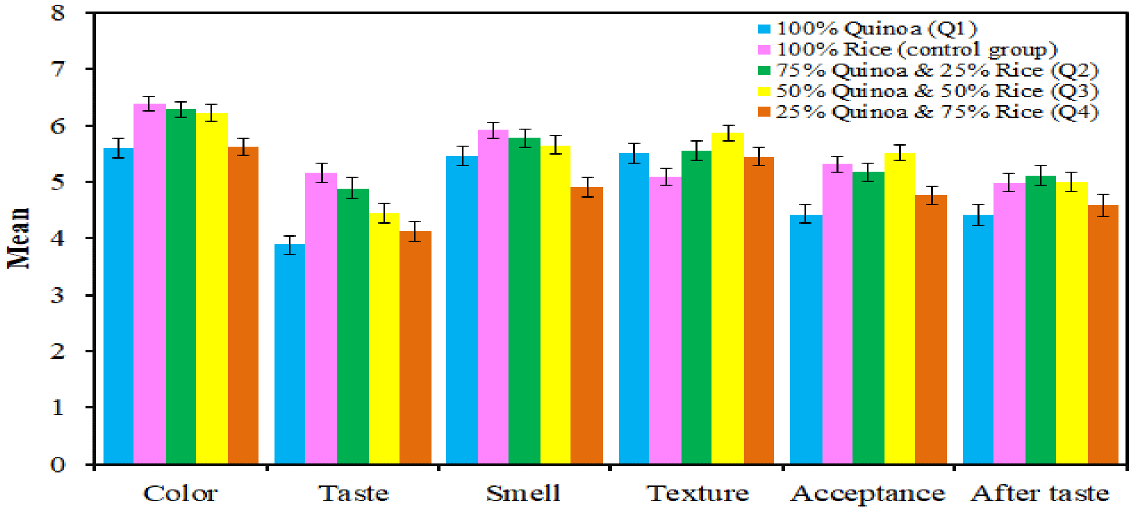

Figure 3. Sensory Evaluation of flat bread of rice, quinoa flour and their mixtures.

Figure 4. Quinoa, rice flour and their mixtures of bread.

Gluten-free bread containing 50% quinoa flour earned the highest average score for flavor and overall liking, in contrast to the control sample, which scored lowest on these quality properties. The difference in sensory hardness of bread was not as evident as the measurements, but the panelists reported a similarity in hardness between Q2 and Q3 bread. Sensory analysis of newly produced gluten-free bread may be undertaken with celiac disease patients in future research to improve these formulations, as their sensory perception may differ from others.

Turkut *et al*. (2016) found that quinoa flour may be effectively employed in gluten-free bread formulations, and 25% of quinoa bread received superior sensory evaluations due to its softer texture. That's near our study.

CONCLUSION

A high score of overall acceptability was detected in bread samples supplemented with 50% rice and 50% quinoa, additionally, quinoa has all essential amino acids. Also, the lowest anti-nutritional component in rice and quinoa was phytic acid. In this investigation, quinoa flour contains more minerals (calcium, magnesium, zinc, and iron) than rice flour, and vitamin E was also detected.

CONFLICT OF INTEREST

The authors confirm that this article's content has no conflict of interest.

ACKNOWLEDGEMENT

My thanks are directed to Prof. Dr. Neveen Fahmy Mohamed Agamy, Professor of Food Analysis, High Institute of Public Health, Alexandria University, for her unlimited help. I would like to express my deepest gratitude and appreciation to Dr. Nashwa Mahmoud Younes, Lecturer of Nutrition, Faculty of Specific Education, Alexandria University for her laborious effort, and indispensable help.

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الملخص العربي

تعزيز الخصائص الوظيفية للخبز الخالي من الجلوتين

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هدفت الدراسة إلى تعزيز الخصائص الغذائية للخبز الخالي من الجلوتين المنتج باستخدام تركيزات مختلفة من دقيق الكينوا عن طريق تحضير الخبز المسطح الخالي من الجلوتين من نسب مختلفة من الكينوا ودقيق الأرز. ثم استخدام البدائل التالية، ٠%، ٢٥%، ٥٠%، ٧٥% و١٠٠% من دقيق الأرز تم استبداله بدقيق الكينوا. وكانت المجموعة الكنترول هى ١٠٠٪ الأرز.

تم تقييم الخصائص الحسية للخبز من خلال ٢٠٠ شخص كما تم إجراء التحاليل الكيمائيه لعينات دقيق الكينوا ودقيق الأرز وخليطهما مع تحليل الأحماض الأمينية ومحتوى المعادن وفيتامين E والعوامل المضادة للتغذية ومضادات الأكسدة في الكينوا ودقيق الأرز. أظهرت النتائج أن الخبز المضاف إليه دقيق الأرز والكينوا بنسبه ٥٠% أرز و٥٠% كينوا هو الأكثر قبولا فى التقييم الحسى. وأظهرت التحاليل وجود فروق معنوية في نسبة التحليل الكيمائى بين خبز الكينوا وخبز الأرز.

توفر الكينوا جميع الأحماض الأمينية الأساسية. كما يوجد فيتامين E في دقيق الكينوا بنسبة ١,٢٠ ملجم/ ١٠٠ جرام. ومحتوى المواد المضادة للأكسدة الكلية للكينوا أعلى من دقيق الأرز. كما أن أقل عامل مضاد للتغذية في الأرز والكينوا هو حمض الفيتيك. نستنتج من ذلك أن الخبز المدعم بالكينوا والأرز وخليطهما له قيمة غذائية عالية بسبب احتوائه على نسبة عالية من الأحماض الأمينية الأساسية والمواد المضادة للأكسدة. ولذلك فهو مهم لعلاج أمراض الاضطرابات الهضمية وحساسية الجلوتين.