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FORTIFICATION NUTRITIONAL VALUE OF SNACKS PRODUCED FOR CELIAC DISEASE

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Celiac disease imposes the need to develop gluten-free products. Therefore, the possibility of producing functional yellow corn flour (YCF) snacks fortified with quinoa flour (QF) and *Spirulina* powder (SP) was studied to evaluate the effect of fortification on its nutritional, chemical and sensory properties. The effect of using SP (2.5, 5, and 7.5%) in fortifying functional snacks produced from the most acceptable mixture of QF and YCF (20% QF to 80% YCF) on the chemical composition of snacks was studied. The results showed that, there were an increase in protein, fat, ash and total phenolic contents and a decrease in carbohydrates content by increasing *Spirulina* addition ratios compared to the control sample. For example, protein content increased from 6.56 to 8.53% and total phenolic content increased from 0.58 to 1.53% in the control sample, compared the sample fortified with 7.5% SP. In the same direction, the amount of minerals in samples fortified with 2.5, 5, and 7.5% SP was higher than that of control sample with significant differences ($P \leq 0.05$), this was due to the addition of mineral-rich SP. In addition, sensory evaluation of snack samples exposed that all samples have no significant differences in odour, taste and texture compared with the control sample. The obtained results indicated that, using a mixture of QF and YCF plus SP to formulate novel functional snacks with nutritional value is applicable and show a new aspect of health benefits, especially for celiac disease.

Keywords: quinoa flour, *Spirulina* algae, celiac disease, nutritional value, functional snacks

INTRODUCTION

Recently, consumers in take from 30 to 70% of their daily nutritional needs from cereal-based foods, which required the innovation of cereals or grains products such as functional foods to convert agricultural crops into consumables (Poutanen et al., 2014). In addition, cereals are a rich source of dietary fibre, especially the functional food component beta-glucan, which is known for its many health benefits. Hence, Consumers are becoming more likely to use grains as a food source (Sullivan et al., 2010).

Corn is one of the prime crops in Egypt and expanding production per annum. Corn is a crop of miracles because of its extremely high potential yield. For good reason, it has been dubbed the "queen of cereals" because it contains no gluten and can be used to make pasta, corn is advised as a safe food for those with celiac disease. It contains a lot of carbohydrates, very little protein, and low amounts of tryptophan and lysine (Sharma et al., 2018). Currently, corn grains are considered the main source of bread replacement in many countries. There are many products prepared from corn, i.e., snacks and prepared foods, such as tortillas, tostads, tomales, taco shells and tortilla chips. These products have spread quickly throughout most parts of the world (Shalaby et al., 2009). Yellow corn flour (YCF) is rich in minerals, especially Fe, Zn, K and Na, which are essential for human health. It was also rich in biologically active compounds such as beta-carotene, caffeine, gallic acid and coumaric acid (Yasmin et al., 2023).

Quinoa (*Chenopodium quinoa* subsp. *quinoa*) is one of the most popular pseudocereals that has recently gained importance due to the high nutritional value of its distinctive composition of protein, amino acids, minerals, dietary fiber and trace components (e.g. antioxidants and vitamins) (Pritham et al., 2021). Quinoa has been called the "cereal of the 21st century" because of its resistance to harsh environmental conditions as well as its nutritional and biological properties by the Food and Agriculture Organization (FAO). Quinoa is an excellent source of gluten-free protein that has a well-balanced amino acid profile when compared to other grains, rich in unsaturated fats and phytochemicals, in addition to a high content of starchy carbohydrates. This indicates that quinoa could be a gluten-free alternative to traditional grains. Quinoa is a natural food resource with excellent nutritional value and is developing into high-quality food for the health and food security of current and future generations (Sreejith, 2022). An economic study also confirmed that growing quinoa could solve the food security problem in Egypt and reduce the food gap (Hossam and Helmy, 2014).

Spirulina is a genus of Cyanobacteria that grows primarily in tropical and subtropical lakes and has nutritional features including high concentrations of protein, fat, vitamins (B_1, B_2, B_3, B_6, B_9, B_{12}, C, D and E), minerals (mainly, K and Fe) and other compounds such as immune stimulating compounds, carotenoids, polysaccharides, and antioxidants. So, it is also used for its therapeutic properties in the treatment of many diseases including, detoxes heavy metals (especially arsenic), a powerful antioxidant, anti-infammatory, anti-cancer, immune system enhancement and controlling diabetes. It has been utilized as a dietary supplement (capsules or flakes, powder) and has been exercised in many food products such as pasta, biscuits, sauces, snacks and ice cream (Bortolini et al., 2022).

Celiac disease is a chronic disorder of the immune system that occurs in genetically susceptible people due to ingestion of gluten, a water-insoluble protein that is a component of wheat, barley, and rye. Celiac disease is described by inflammatory damage to the small intestine with gastrointestinal or systemic symptoms, or both. It can also occur with mild or no symptoms. About 1% of the general population is affected by this disease; most people with the disease remain undiagnosed (Nasser et al., 2023). Ferropenia, vitamin B12, folic acid, and fat-soluble vitamin deficiencies are among the several nutritional, vitamin, and dietary mineral deficiencies brought on by the intestinal lesion induced by celiac disease. When combined with dairy intolerance, the deficits result in reduced bone density and a higher risk of fractures. Because gluten is included in up to 70% of produced food products and manufacturing regulations are not uniform, following a gluten-free diet can present some challenges (García-Manzanares and Lucendo, 2011). Therefore, there is an urgent need to provide gluten-free food products for people with celiac disease, which is a challenge that requires the use of novel food materials. Snack foods considered vastly used, predominately by young people. According to consumer trends studies, most consumers prefer to substitute one of their daily meals with snacks due to their fast-paced lifestyle **(**Beswa et al., 2016).

This research aims to produce new functional gluten-free snacks with nutritional value fortified with quinoa flour (QF) and *Spirulina* algae to suit celiac patients and provide their nutritional needs. This research also aims to determine the effect of adding QF and *Spirulina* algae on the quality of functional gluten-free snacks by measuring several nutritional, chemical and sensory properties and determining the best addition ratios for them. It is necessary to constantly strive to provide functional food products for some special groups, such as celiac patients, in the markets, especially the Egyptian market.

MATERIALS AND METHODS

Materials

Quinoa (*Chenopodium quinoa* Willd.) seeds were obtained from Desert Research Center, Egypt. *Spirulina (Spirulina platensis*) biomass was obtained from the Algae Biotechnology Unit, National Research Center, Egypt. Yellow corn flour (YCF), starch, baking powder, garlic powder, onion powder, guar gum, cheese flavor, salt and sunflower oil for snacks preparation were purchased from the local market in Cairo.

Methods

1. Technological Preparation

1.1. Preparation of quinoa flour

Quinoa seeds were cleaned, washed and soaked in water for 24 hours then washed several times with running tap water. The water was filtered well and then dried in the oven at 60°C. The dried quinoa seeds were milled, sieved and packed into polyethylene bags and stored at -18°C until using.

1.2. Preparation of snacks

1.2.1. Preparing control snacks

Control snacks were prepared by mixing 70.5 g YCF, 10 g starch, 5 g garlic powder, 5 g onion powder, 3 g guar gum, 3 g cheese flavour, 1.5 g salt, 1.5 g citric acid and 0.5 g baking powder then water was added. Then, the blend was mixed for 5 min and allowed to rest in a polyethylene bag and equilibrated for 10 min. The dough was rolled out into slices of 1 mm thickness using the laboratory machine (Titania, 1932, 10024 Moncalieri), then cut into triangles and deep fried in sunflower oil at 200°C for 30 seconds. Snacks were drained, cooled, and stored in polyethylene bags for later analysis.

1.2.2. Preparing various treatments of snacks

Snacks were prepared by replacing YCF with 0, 10, 20 and 30% QF, which were expressed by Q_1, Q_2, Q_3 and Q_4, respectively. As an initial experiment to choose the best sample by sensory evaluation, which showed that 20% QF is the best ratio. Then, *Spirulina* algae was added to the best sample at rates of 0, 2.5, 5 and 7.5%, which were expressed by A, B, C and D, respectively (Table 1).

Table (1). Formula of the studied snacks.

Ingredients (g)	Samples							
	Q_1	**Q_2**	**Q_3**	**Q_4**	**A**	**B**	**C**	**D**
YCF	70.5	60.5	50.5	40.5	50.5	48.0	45.5	43.0
QF	=	10.0	20.0	30.0	20.0	20.0	20.0	20.0
SP	-	-	-	-	-	2.5	5.0	7.5
Starch	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Garlic powder	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Onion powder	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Guar gum	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Cheese flavour	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Citric acid	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Baking powder	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Salt	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Water	According to water absorption							

YCF =Yellow corn flour, QF= Quinoa flour and SP= *Spirulina* powder.

2. Methods of Analysis

2.1. Proximate composition

Moisture, ash, crude protein (total nitrogen X 6.25) and total lipids contents were determined according to A.O.A.C. (2005), while total sugar content was determined according to Chaplin and Kennedy (1994). Total carbohydrates were calculated by differences as follow:

Total carbohydrates (on dry basis) = 100 – (protein + fat + ash)

2.2. Determination of the phenolic content

Total phenolic compounds were determined by the method of Kaur and Kapoor (2002).

2.3. Hardness

Hardness (mg/cm^3) was determined using a penetrometer tester (modal pillion Advanced, Force Gauge, AFG-500), as recommended by Bourne and Comstock (1986).

2.4. Sensory evaluation of produced snacks

Sensory assessments of prepared snack samples were evaluated by 20 panellists of the staff Agriculture Industrialization Unit, Desert Research Center, Cairo, Egypt. Panellists were asked to evaluate color, odor, taste, crispness, and overall acceptability, of all samples according to the method described by ISO 8589 (1988).

3. Statistical Analysis

All data were expressed as mean values. Statistical analysis was performed using the SPSS (Statistical Program for Sociology Scientists) Statistics Version 20 for computing one way analysis of variance (ANOVA) followed by Duncan's Multiple Range Test with $P \leq 0.05$ being considered statistically significant (Armonk, 2011).

RESULTS AND DISCUSSION

1. Proximate Composition of Different Raw Materials

Chemical composition of YCF, QF and *Spirulina* powder (SP) as raw materials was analyzed and the obtained data are shown in Table (2). Moisture content was the lowest in QF (6.28%) followed by YCF (7.88%) then SP (8.01%). Significant differences ($P \leq 0.05$) were noticed for the different raw materials in the major constituents. The result of SP was significant higher of protein and ash content compared to QF and YCF. Where, protein content was recorded 37.08, 11.38 and 8.09%, respectively, while ash content recorded 11.81, 1.58 and 1.83%, respectively.

On the other hand, QF was significantly higher in fat content (7.20%) compared to YCF (4.51%) and SP (2.81%). Also, QF was significantly higher in total phenolic content (2.21%) compared to SP (1.40%) and YCF (0.54%). However, YCF was exposed higher content of total sugar and total carbohydrate (10.17 and 85.82%) than QF (8.26 and 79.59%) and SP (8.00 and 48.30%), respectively. These results are consistent with the results of Morsy et al. (2014) and Ama Moor et al. (2016). From the above results, it is clear that SP is a rich source of protein and minerals, while QF is a rich source of phenols and fats. These results are consistent with Ama Moor et al. (2016), who showed that *Spirulina* contains a high concentration of nutritional elements. Also, Ragaee et al. (2006) noted that quinoa may be a premium source of phenolic component in the nutritional meal. Therefore, adding them to YCF leads to enriching the nutritional value of the flour.

Table (2). Chemical composition of raw materials.

Components (%)	Yellow Corn flour (YCF)	Quinoa flour (QF)	*Spirulina* powder (SP)
Moisture content	7.88[b]±0.01	6.28[c]±0.01	8.01[a]±0.01
Total fat	4.51[b]±0.03	7.20[a]±0.02	2.81[c]±0.02
Proteins	8.09 [c] ±0.03	11.38 [b] ±0.01	37.08[a]±0.03
Ash	1.58[b]±0.02	1.83[c]±0.02	11.81[a]±0.01
Total sugar	10.17[a]±0.03	8.26[b]±0.03	8.00[c]±0.02
Total	85.82[a]±0.03	79.59[b]±0.02	48.30[c]±0.03
Total phenols	0.54[c]±0.02	2.21[a]±0.01	1.40[b]±0.01

Means followed by different small letters in the same raw (effect of treatments) are significantly different by Duncan´s multiple test ($P \leq 0.05$), *determined by difference.

2. Mineral Contents of Different Raw Materials

Mineral contents of different raw materials are presented in Table (3) and the results showed that, the highest studied minerals contents (Fe, Ca, Mg, Zn and Cu) were found in SP followed by QF, then YCF. There were significant differences ($P \leq 0.05$) found in mineral content for the different raw materials.

Table (3). Mineral contents of different raw materials.

Sample	Concentration (ppm)				
	Fe	Ca	Mg	Zn	Cu
YCF	46.92±0.01[b]	900 ±0.02[c]	673.50 ±0.03[c]	28.50±0.01[a]	3.15±0.001[c]
QF	343 ±0.20[c]	1448.25±0.02[b]	1488.25±0.02[b]	40±0.01[b]	12.13±0.001[b]
SP	529±0.01[a]	1850 ±0.04[a]	1886±0.01[a]	45±0.00[c]	215.10±0.010[a]

YCF =Yellow Corn flour; QF= Quinoa flour and SP= *Spirulina* powder. Means followed by different small letters in the same raw (effect of treatments) are significantly different by Duncan´s multiple test ($P \leq 0.05$).

Whereas, Fe content recorded 46.92 ppm in YCF sample, while recorded 343 and 529 ppm for QF and SP, respectively. Ca was 1448.25 and 1850 ppm in QF and SP, respectively compared to YCF (900 ppm). Also, SP and QF had higher contents of Mg, Zn and Cu compared to YCF, which were 1886, 1488.25, 673.50 ppm for Mg, 45, 40, 28.5 ppm for Zn and 215.13, 12.13, 3.15 ppm for Cu, respectively. The rise in the amount of minerals in SP and QF may be due to the greater ash content compared to YCF. These data agree with Alvarez-Jubete et al. (2010), Milovanović et al. (2014) and El Sohaimy et al. (2018), who mentioned that quinoa is considered a good source of minerals such as Fe, Ca, K, Mn, and Mg. These data are in line with Diaa et al. (2014), who showed that all main minerals are discovered in *Spirulina* with the range of 2.7 and 3.0% of dry weight. It was also said to be a good source of K. These data are also consistent with the findings of Hussein et al. (2021), who showed that one of the top trends in the food sector globally is *Spirulina*. It is a superfood ingredient that can be used to make functional foods. Many food products containing *Spirulina* are being manufactured daily.

3. Initial Sensory Evaluation of Snacks

An initial sensory evaluation of snacks from YCF and different ratios of QF was conducted to determine the best percentage of replacing YCF by QF in snacks, which presented in Table (4). Initial sensory evaluation showed that, there were no significant differences by replacing QF compared to control sample (Q_1) in odor, taste and texture. On the other hand, there were significant differences between sample Q_4 and the other samples in color and overall acceptability. As the results showed increasing in the percentage of replacing QF by 30% (Q_4) leading to a negative effect on color of snacks, which affected overall acceptability for the sample. Therefore, QF replacing rate of 20% (Q_3) was chosen as the best replacing rate for the production of snacks to which percentages of *Spirulina* are added.

Table (4). Initial sensory evaluation of snacks from yellow corn and quinoa flour.

Samples	Odor (10)	Taste (10)	Color (10)	Texture (10)	Overall acceptability (10)
Q_1	9.33±0.21^a	9.00±0.26^a	9.17±0.17^a	9.42±0.20^a	9.33±0.21^a
Q_2	9.17±0.31^a	8.83±0.31^a	8.92±0.20^{ab}	9.25±0.31^a	9.08±0.33^a
Q_3	9.42±0.20^a	9.33±0.21^a	8.75±0.31^{ab}	9.42±0.20^a	9.25±0.17^a
Q_4	9.25±.048^a	9.17±0.40^a	8.17±0.31^b	9.25±0.48^a	8.22±0.35^b

Q_1= 100% YCF, Q_2= 90% YCF+ 10% QF, Q_3= 80% YCF+20% QF, Q_4=70% YCF+ 30% QF
Means followed by different small letters in the same raw (effect of treatments) are significantly different by Duncan´s multiple test ($P \leq 0.05$).

4. Effect of *Spirulina* Powder Fortification on Chemical Composition of Snacks

Effect of fortifying the best snacks formula with SP (2.5, 5 and 7.5%) on the chemical composition of snacks was studied and data are defined in Table (5). The data showed that, there were significant noticed observations ($P \leq 0.05$) in the different snack samples for main components. The established data in Table (5) show an increase in moisture, protein, fat, ash and total phenolic content in the samples with increasing *Spirulina* addition ratios, compared to sample A (control). However, total sugar content was decreased by increasing *Spirulina* addition ratios compared to sample A. Protein content ranged from 6.56 to 8.53%. Fat content ranged from 10.28 to 15.82%, due to deep frying of snacks in oil and the high fibre content (31.32%) of *Spirulina*, which increases the absorption of oil by the snacks (Ama Moor et al., 2016).

Moisture content increased from 4.53 to 5.82% and ash content increased from 4.09 to 5.09%. Total phenolic content increased from 0.53 to 1.53%. Total sugar content decreased from 9.35 to 6.82% and total carbohydrate decreased from 79.07 to 70.74%. The trend of these results is consistent with the results of Gautam et al. (2021), who showed that, using *Spirulina* as a protein source for tortilla chips resulted in a 44% increase in protein content and a 4.6% decrease in carbohydrate content compared to sample without *Spirulina*. From the above, it is clear that increasing the percentage of *Spirulina* added to snacks led to improving the nutritional value.

Table (5). Effect of *Spirulina* powder fortification on chemical composition of snacks.

Components (%)	**A**	**B**	**C**	**D**
Moisture content	4.53^{d}±0.03	5.15^{c}±0.02	5.78^{b}±0.04	5.82^{a}±0.03
Total fat	10.28^{d}±0.02	11.42^{c}±0.04	15.28^{b}±0.02	15.82^{a}±0.03
Proteins	6.56^{d}±0.02	8.09^{c}±0.03	8.31^{b}±0.02	8.53^{a}±0.01
Ash	4.09^{d}±0.02	4.35^{c}±0.02	4.86^{b}±0.01	5.09^{a}±0.03
Total sugar	9.35^{a}±0.07	7.43^{b}±0.06	7.10^{c}±0.04	6.82^{d}±0.04
Total carbohydrates*	79.07^{a}±0.03	76.14^{b}±0.02	71.55^{c}±0.04	70.74^{d}±0.03
Total phenols	0.53^{d}±0.02	0.58^{c}±0.03	1.00^{b}±0.01	1.53^{a}±0.02

A= 80%YCF+ 20%QF (control); B= 80%YCF+ 20%QF +2.5%SP; C= 80%YCF+ 20%QF+ 5% SP and D= 80%YCF+ 20%QF+ 7.5% SP. Means followed by different small letters in the same raw (effect of treatments) are significantly different by Duncan´s multiple test ($P \leq 0.05$)* determined by difference.

5. Effect of *Spirulina* Powder Fortification on Mineral Contents of Snacks

The effect of fortifying snacks with SP (2.5, 5 and 7.5%) produced by replacing 20% QF to 80% YCF on mineral contents of snacks was assessed and data are detected in Table (6). The amount of minerals in fortified samples B, C, D was significantly higher than that of control sample A ($P \leq 0.05$). This is due to the increased addition of mineral-rich SP. Fe content increased from 54.47 to 175 ppm, Ca content ranged from 1100.25 to 1239.75 ppm, Mg content ranged from 883.4 to 1025 ppm, Zn content ranged from 32.25 to 35.38 ppm and Cu content ranged from 4.90 to 21.03 ppm in sample A compered to sample D.

Hussein et al. (2023) found that, addition of SP to QF by 5, 10 and 15%, increased the minerals content in all samples. Moreover, *Spirulina* is said to contain significant levels of Ca, P, Se, Na, Fe, Mg, Mn, Cu, and Zn. The above results suggested that, prepared snacks can avail as a functional food substantial in protein and minerals, forming them appropriate for individuals with celiac disease. Several previous studies have shown that adding SP from 1.5 to 6% increases the levels of protein and minerals in food products (Hussein et al., 2023).

Table (6). Effect of *Spirulina* powder fortification on mineral contents of snacks.

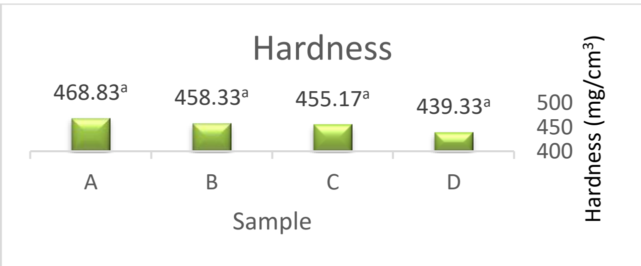
Treatment	Concentration (ppm)				
	Fe	**Ca**	**Mg**	**Zn**	**Cu**
A	54.47±0.01[c]	1100.25±0.01[c]	883.4±0.01[d]	32.25±0.001[d]	4.90±0.001[c]
B	162.75±0.01[bc]	1147±0.02[b]	930±0.01[c]	33.75±0.001[c]	10.25±0.001[b]
C	168±0.02[b]	1193±0.02[ab]	977±0.01[b]	34.25±0.001[b]	15.65±0.002[ab]
D	175±0.01[a]	1239.75±0.03[a]	1025±0.02[a]	35.38±0.001[a]	21.03±0.020a

A= 80% YCF+ 20% QF (control); B= 80% YCF+ 20% QF +2.5% SP; C= 80% YCF+ 20% QF+ 5% SP and D= 80% YCF+ 20% QF+ 7.5% SP. Means followed by different small letters in the same raw (effect of treatments) are significantly different by Duncan´s multiple test ($P \leq 0.05$).

6. Physical Properties of Produced Snacks

6.1. Effect of *Spirulina* powder fortification on hardness of snacks

Texture (hardness) is an essential parameter that impacts consumers' perception, which affected by the interaction between fibre and protein materials (Hussein et al., 2023). Fig. (1) presents hardness of snacks fortified with SP (2.5, 5 and 7.5%) produced by replacing 20% QF to 80% YCF. It was observed that, no significant differences between samples B and C in hardness by increasing SP compared with sample A (458.33±9.400, 455.17±13.43 and 468.83±16.14, respectively) but the only decrease in snacks hardness in comparison with control sample was observed for sample D. These results are in line with Jaworska et al. (2020) and Hussein et al. (2023), who demonstrated that pasta made from QF and SP at levels of 5, 10, 15% had lower hardness compared to pasta without SP, which can be attributed to lower moisture content and fibre presence which weak hardness of sample.



A= 80% YCF+ 20% QF (control); B= 80% YCF+ 20% QF +2.5% SP; C= 80%YCF+ 20% QF+ 5% SP and D= 80% YCF+ 20% QF+ 7.5% SP. Means followed by different small letters in the same raw (effect of treatments) are significantly different by Duncan´s multiple test ($P \leq 0.05$).

Fig. (1). Effect of *Spirulina* powder fortification on the hardness of snacks.

6.2. Sensory evaluation of snacks fortified with *Spirulina* powder

The impact of fortifying snacks with SP (2.5, 5 and 7.5%) produced by replacing 20% QF to 80% YCF on sensory evaluation of snack samples were evaluated and showed in Table (7).

Table (7). Sensory evaluation of snacks fortified with *Spirulina* powder.

Sample	Odor (10)	Taste (10)	Color (10)	Texture (10)	Overall acceptability (10)
A	9.00±0.26[a]	8.75±0.48[a]	9.08±0.45[a]	9.55±0.22[a]	9.17±0.31[a]
B	8.83±0.40[a]	8.92±0.45[a]	8.67±0.17[a]	9.55±0.22[a]	9.33±0.31[a]
C	8.58±0.33[a]	8.08±0.58[a]	7.33±0.33[b]	9.25±0.36[a]	8.17±0.21[b]
D	8.17±0.48[a]	8.00±0.45[a]	6.50±0.43[b]	8.00±0.26[b]	7.08±0.20[c]

A= 80% YCF+ 20% QF (control); B= 80% YCF+ 20% QF +2.5% SP; C= 80% YCF+ 20% QF+ 5% SP and D= 80% YCF+ 20% QF+ 7.5% SP. Means followed by different small letters in the same raw (effect of treatments) are significantly different by Duncan´s multiple test ($P \leq 0.05$).

All samples have no significant differences ($P \leq 0.05$) in odor, taste and texture (with one exception related to the texture of sample D, which decreased) compared with sample A. These results are in agreement with Zen et al. (2020), who suggested that snacks can be enhanced with SP at level of 2.5 or 5% without negatively affecting the odor and taste. Also, there were no significant differences ($P \leq 0.05$) in color and over acceptability between sample A and B. However, there were significant decrease ($P \leq 0.05$) in color and overall acceptability in sample C and D compared with samples A and B, which still have good sensory parameters compared with sample A. These outcomes are in line with Bastidas et al. (2016) and Hussein et al. (2023), who reported a decrease in the color of produced samples by increasing SP percentage, this can be ascribed to the dark color of SP because of its pigments. These results indicate that adding SP to snacks does not significantly affect their most sensory properties.

CONCLUSION

It is important to care for celiac patients and provide food products rich in nutrients to enhance the health of the body, as they eat limited types of cereals. Therefore, there was a need to search for new sources of gluten-free cereals such as quinoa, which is considered a cereal rich in protein and minerals compared to yellow corn. Also, the use of *Spirulina* in food products leads to supporting them with high nutritional value, as it is a rich source of protein and minerals.

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تدعيم القيمة الغذائية للمقرمشات المنتجة لمرضى السيلياك

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يفرض مرض السيلياك (مرض الإضطرابات الهضمية) الضرورة لتطوير منتجات خالية من الجلوتين، لذلك تمت دراسة إمكانية إنتاج مقرمشات وظيفية مدعمة بدقيق الكينوا (QF) ومسحوق الأسبيرولينا (SP) إلى دقيق الذرة الصفراء (YCF) لتحسين قيمتها الغذائية ومعرفة تأثير التدعيم على خواصها الغذائية والكيميائية والحسية. تمت دراسة تأثير استخدام SP (٢,٥ و٥ و٧,٥٪) في تدعيم المقرمشات الوظيفية المنتجة بإضافة ٢٠٪ QF إلى ٨٠٪ YCF على التركيب الكيميائي للمقرمشات، وأظهرت النتائج أنه كان هناك زيادة في محتوى البروتين والدهون والرماد والفينولات الكلية وإنخفاض في محتوى الكربوهيدرات بزيادة نسب إضافة الأسبيرولينا مقارنة بالعينة المرجعية. على سبيل المثال، قد زاد محتوى البروتين من ٦,٥٦ إلى ٨,٥٣٪ وزاد محتوى الفينولات الكلية من ٠,٥٨ إلى ١,٥٣٪ في العينة المرجعية مقارنة المدعمة بـ ٧,٥٪ SP. وفي نفس الإتجاه، كان المحتوى من العناصر المعدنية في العينات المدعمة بـ ٢,٥ و٥ و٧,٥٪ SP أعلى من تلك الموجودة في العينة A مع اختلافات كبيرة ($P \leq ٠.٠٥$)، وهذا بسبب إضافة SP الغنية بالعناصر المعدنية. بالإضافة إلى ذلك، أظهر التقييم الحسي لعينات المقرمشات أن جميع العينات لا توجد بها فروق معنوية في الرائحة والطعم والقوام مقارنة بالعينة A. أوضحت النتائج التي تم الحصول عليها إلى أن استخدام خليط من دقيق الكينوا ودقيق الذرة بالإضافة إلى طحالب الأسبيرولينا لإنتاج مقرمشات وظيفية مبتكرة جديدة ذات قيمة غذائية أصبح أمر قابل للتطبيق ويظهر جانبًا جديدًا من الفوائد الصحية، وخاصة لمرضى السيلياك.