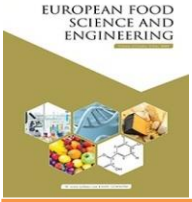

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The use of quinoa grain/flour instead of bulgur/wheat flour in traditional couscous production

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ABSTRACT

In this study, the possibility of quinoa flour-grains as a new alternative in couscous production was investigated. For this purpose, bulgur or quinoa grains (*Chenopodium quinoa Willd*) were coated with quinoa:wheat flour mixture at ratios of 0:100, 25:75, 50:50, 75:25 and 100:0 and couscous samples were produced. The chemical (crude ash, crude protein and protein digestibility, crude fat, total phenolic content (TFC), phytic acid, total dietary fiber (TDF), minerals and mineral digestibility), physical and cooking properties of couscous were determined. The use of quinoa grains as an alternative to bulgur in couscous production improved the cooking and chemical properties (higher crude protein, crude ash, crude fat, TFC, mineral matter and TDF) of the samples. In addition, couscous with a harder and brighter color was obtained. The use of quinoa flour instead of wheat flour in the coating material increased the cooking loss, although it gave chemically superior samples. As a result; it was determined that quinoa can be a new raw material alternative to bulgur in couscous production with its superior chemical properties. In terms of flour combinations, 50% wheat flour: 50% quinoa flour mixtures are suitable in terms of preserving structural properties.

1. Introduction

Couscous, a staple in many cultures, is a widely consumed grain product renowned for its nutritional richness (Demir et al., 2010; Carcea et al., 2017). Packed with complex carbohydrates and essential minerals, each half-cup serving of couscous offers a modest 100–120 calories (Çelik et al., 2004). Unlike industrially produced couscous, which is a pasta derivative created through extrusion technology, traditional variations found in the Middle East and certain African nations exhibit distinct ingredients and production methods. In these regions, couscous crafted through time-honored techniques diverges significantly from its mechanized counterpart, incorporating unique elements that contribute to its authentic character. As an illustration, Turkish couscous distinguishes itself by its preparation technique involving wheat bulgur granules enveloped in a dough mixture of wheat flour combined with either water or milk (Çelik et al., 2004; Yüksel et al., 2017). The traditional process of couscous preparation involves collaborative efforts, with groups of women gathering to meticulously create substantial batches over the course of several days. These handmade couscous varieties are subsequently sun-dried, ensuring longevity, and providing a supply that lasts for several months (Salem, 2017).

Due to its simplicity in preparation and nutritional richness, couscous enjoys widespread popularity across many nations. Similar products are part of diverse culinary traditions; for instance, Greece has "kouskousaki," Morocco embraces "couscous," and Lebanon boasts "maftoul" and "moghrabieh." In Berber culture, it is known as "seksu," while Libya uses the term "kusksi," and the Tuareg people refer to it as "keskesu." Literature also reveals a variety of grains employed in couscous production, including wheat, barley, pearl millet, sorghum, maize, rice, chickpea, soybean, oat, field bean, and proteinaceous pea (Çelik et al., 2004; Demir et al., 2010).

Nutrition is a fundamental aspect of human life, as it is essential for individuals to consume various food items in sufficient and balanced quantities in order to support their growth, development, and active continuation of life (Traş & Gökçen, 2021). However, in today's world, the disregard for proper dietary conditions has resulted in various eating disorders, primarily obesity and excessive eating (Traş & Gökçen, 2021) which in turn can lead to the emergence of several associated health conditions such as cancer, diabetes, lactose intolerance, digestive difficulties, cardiovascular diseases (Ertaş et al., 2019), and even certain neurological and psychological disorders (Çıkılı et al., 2019). In recent years, with the controversy surrounding the negative health effects of industrialized and refined foods (such as whole and white flour), there has been an increased interest in healthy and functional food products that aim to meet high nutritional

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demands with minimal consumption, leading to the use of functional and alternative ingredients in many food products (Demir & Kılınç, 2019; İlerigiden et al., 2020). Consumers' search for new and functional foods has also prompted the industry to produce couscous products in which durum wheat is partially or completely replaced with other raw materials (Carcea et al., 2017).

Demir et al. (2010) reported that chickpea flour can be used up to 50% in couscous formulation without any negative effect. In another study, used under size bulgur in couscous formulation and found that protein contents were higher than control sample (Yüksel et al. 2017). Moreover, recent research highlights a significant trend where raw products, such as pseudo-cereals, play a crucial role in enhancing and diversifying formulations of gluten-containing products (Demir et al., 2017).

Quinoa, a pseudo-cereal native to the Andean regions of South America, stands out as a nutritionally rich food source (Galway et al., 1990; Caperuto et al., 2001). Its proteins are particularly noteworthy for their high quality, boasting a well-balanced composition of essential amino acids akin to milk's casein protein (Repo-Carrasco et al., 2003). Quinoa serves as an excellent enrichment material for cereal products, providing proteins with high biological value, low glycemic index carbohydrates, phytosteroids, and omega-3 and 6 fatty acids (Farinazzi-Machado et al., 2012; Demir, 2014). In the past decade, the utilization of pseudocereals, not only in diets for individuals allergic to cereals but also in healthy diets, has seen a notable increase (Gorinstein et al., 2008, Hayıt & Gül, 2019). Quinoa, hailed as a food of the future, is positioned as a staple for the twenty-first century (Valencia-Chamorro, 2003; Demir, 2014). Contrary to gluten-free foods, which often lack nutritional value and are primarily starch-based, the incorporation of pseudo-cereal flours, like quinoa, in gluten-free products has shown promise in enhancing their chemical, nutritional, and sensory properties (Pasko et al., 2009).

The structure of quinoa grains is similar to bulgur. Therefore, quinoa is compared with bulgur and is considered an alternative. Indeed, when the chemical composition of quinoa grains is compared to wheat, their superior nutritional content makes a significant contribution to the higher nutritional value of grain products produced using refined wheat flour.

In the last decades there has been an increasing trend towards traditional products, especially organic-based food ingredients produced in natural environments. The processing of these natural products also requires changes in technological requirements. The aim of our study was to improve the nutritional, technological, and sensory properties of couscous produced using quinoa flour and grains. In couscous production, bulgur or quinoa grains were coated with a mixture of quinoa flour: wheat flour paste in ratios of 0:100, 25:75, 50:50, 75:25, and 100:0, and the physical, textural, chemical, nutritional, and sensory properties of the resulting couscous were examined.

2. Materials and methods

2.1. Materials

Wheat flour used in couscous production was obtained from a commercial flour mill (Selva Flour, Konya, Türkiye) and bulgur was obtained from a factory in Karaman (Duru Bulgur Company, Karaman, Türkiye). Quinoa grains were obtained from Bora Agricultural Products (Istanbul, Türkiye). UHT milk, another important raw material for couscous production, was obtained from a local market in Konya (Torku Milk Company, Konya, Türkiye).

Some of the quinoa grains were used as the material to be coated in couscous production (instead of bulgur). The remaining quinoa grains were processed into quinoa flour and used as the coating material. In the production of couscous, quinoa samples were reduced to a certain size using a hammer mill (Falling Number-3100) with a 500 micron sieving system to create a dough coating material. To ensure size control, all ground quinoa samples were sieved using a 500-micron sieve and used as quinoa flour in the experiments.

2.2. Production of couscous

Couscous production was carried out according to Demir (2008). The control **(a)** group, the couscous samples produced by coating quinoa grains **(b)** and the couscous samples produced by coating bulgur grains **(c)** were produced as described below.

a) In the control couscous formulation, 8.4 g of bulgur, 30.0 g of flour, and 12.9 g of milk were used.

b) In couscous with added quinoa flour, wheat flour was replaced with quinoa flour at substitution rates of 25, 50, 75, and 100% of its own weight, and the wet bulgur grains were coated with the resulting flour combinations. The formulation is the same as that of the control group.

c) In couscous where quinoa grains were used instead of bulgur grains, wheat flour was again replaced with quinoa flour at substitution rates of 25, 50, 75, and 100%, and the wet quinoa grains were coated with the resulting flour combinations. The formulation is the same as that of the control group.

Production continued after these processes were completed. In couscous production, bulgur/quinoa and milk were first mixed by hand in a large bowl (10 min), and during this mixing process, flour combinations were gradually added. Then, the resulting dough mass was rolled between the palms of the hands to form round couscous grains with a diameter of 3-5 mm. The rolled couscous grains of the desired diameter were dried on a flat surface at 25±1 °C (room temperature) with a humidity content below 10% for 3-4 days, and then stored in sealed polyethylene bags (Demir, 2008).

2.3. Color and cooking quality properties

The samples' color values were assessed using a colorimeter (Minolta CR 400, Konica Minolta Inc., Tokyo, Japan) for $L*$ (lightness/darkness), $a*$ (redness/greenness), and $b*$ (yellowness/blueness) parameters (Francis, 1998).

Firmness values of the couscous was measured by Approved Method 16-50 (AACC 1999) for pasta with modifications. A stainless steel cylindrical probe (5 cm diameter) was used to compress cooked samples. Peak force as firmness (N), adhesion as a negative force, area under the negative peak force curve, and final force after 10 sec of compression was recorded using a texture analyzer (TA-XT plus, Stable Micro systems, UK). The firmness value for each sample was determined as F, N (load cell: 5 kg, pretest speed: N/A, test speed: 0.17 mm/s, post-test speed: 10.0 mm/s, distance: 4.5 mm, trigger force: 50 g)

To determine weight increase values (WI); 10g of couscous sample was cooked in 250 mL of distilled water for 18 min. After draining the water, the cooked samples were allowed to rest for 2 min and then weighed to determine the weight of the cooked sample. The weight increase (%) resulting from the cooking process was determined by subtracting the weight of the uncooked sample from the weight of the cooked sample and expressing it as a percentage (%). The volume increase of couscous samples was determined according to Bilgiçli (2009) (Eq. 1). Cooking loss (CL) was determined according to Bilgiçli (2009) with dried cooking water to constant weight. (Eq. 2).

$$Volume\ Increase\ (\%) = \frac{Volume\ of\ cooked\ couscous(mL) - Volume\ of\ dry\ couscous(mL)}{Volume\ of\ dry\ couscous\ (mL)} X100 \quad (1)$$

$$Cooking\ Loss\ (\%) = \frac{Weight\ of\ couscous\ and\ flask\ (g) - Weight\ of\ flask\ (g)}{Weight\ of\ coussous\ (g)}\ X\ 100 \quad (2)$$

2.4. Chemical analysis

Quinoa grains, bulgur, wheat flour, and couscous samples underwent comprehensive analysis to determine their moisture (method 44-19), ash (method 08-01), crude protein (method 46-12) (with factors of 5.70 for wheat flour and bulgur, and 6.25 for quinoa and couscous), and fat content. The analysis followed the AACC (1999) standard methods. Additionally, the total dietary fiber (TDF) content was assessed using the Velp GDE/CSF6 dietary fiber assay device from Italy, in accordance with AACC method 32-07 (AACC, 1999).

The analytical procedure involved the treatment of 1.000 ± 0.005 g of the analyzed sample with sequential α-amylase, protease and amyl-glucosidase enzymes. The sample was then washed with 95% and 78% ethyl alcohol and acetone, respectively. The remaining material was then dried in a dielectric oven and weighed at 105 °C until a constant weight was obtained. In a parallel experiment, ash (k) and protein (p) analyses were performed on one of the weighed samples. TDF content was calculated using the given formula.

$$Total\ Dietary\ fiber\ \ (\%) = \frac{M2\ (g) - M1\ (g) - (k+p)}{M\ (g)}\ X\ 100 \quad (3)$$

M1 = weight of crucible (g); M2 = weight of crucible + weight of TDF residue; M = Sample weight (g)

For mineral analysis, approximately 0.5 g of dried sample was subjected to wet digestion in a microwave oven using 10 mL HNO_3 + H_2SO_4 (Mars 5, CEM Corporation, USA) in an ICP-AES instrument (Vista Series, Varian International, AG, Switzerland) as described by Skujins (1998). Results are reported in mg/100 g on a dry matter basis.

In vitro protein digestibility (IVPD) and HCl-extractable mineral content were determined by Bookwalter et al. (1987) and Saharan et al. (2001) with minor modifications. Specifically, 25 mL of pepsin solution (1 L HCl 0.03 N + 2 g pepsin) was added to 1 g of ground couscous sample and incubated at 40 °C for 3 h in a shaking water bath. After filtration through standard ashless filter paper, 20 mL of these filters were subjected to wet digestion supplemented with 100 mL of distilled water. Protein analysis (AACC, 1999) and mineral matter analysis were then performed on the solutions obtained. The digestible protein and digestible mineral matter percentages were determined by proportioning the results obtained to the total protein and mineral matter amounts.

Phytic acid analysis employed the colorimetric method by Haug & Lantzsch (1983). The obtained results were expressed in mg/100g of dry matter.

For the determination of Total Phenolic Content (TPC), the Folin-Ciocalteu method was employed. All samples (200 mg) were extracted in acidified methanol (HCl/methanol/water, 1:80:10, v/v) (4 mL) through shaking for 2 h in a shaking water bath (24±1 °C). After centrifugation at 3000 rpm for 10 min, the supernatant was utilized for TPC determination (Gao et al., 2002; Beta et al., 2005). In the analysis, 0.1 mL of the supernatant was mixed with 0.5 mL of Folin-Ciocalteu reagent (10% in water, v/v) and 1.5 mL of sodium carbonate solution (20% in water, w/v) in a test tube. This mixture was then incubated at room temperature (24±1 °C) for 2 h. Post-incubation, absorbance values were read at 760 nm using a spectrophotometer (Hitachi-U1800, Japan), and the total phenol content was calculated in milligrams of gallic acid equivalents per gram of extract (mg GAE/g) (Slinkard & Singelton, 1977; Gamez-Meza et al., 1999).

2.5. Statistical analysis

The data obtained from the study were subjected to analysis of variance and the mean values for significantly different variance sources were compared using Duncan test. Statistical comparisons were performed at $P<0.05$ significance level. The research was conducted in two replications.

3. Results and Discussion

3.1. Analytical analysis

The analytical analysis results of wheat flour, bulgur, and quinoa grain samples used in the experiments are given in Table 1. Quinoa samples are characterized by high ash, crude protein, crude fat, total dietary fiber, and mineral content compared to wheat flour. Moreover, it has been determined that bulgur and quinoa samples are darker, redder, and more yellowish in color than wheat flour. The physical, chemical, and nutritional analysis results of wheat flour, bulgur, and quinoa samples are also in line with the literature information (Ranhotra et al., 1993; Repo-Carrasco et al., 2003; Valencia-Chamorro, 2003; Alvarez-Jubete et al., 2010a; Alvarez-Jubete et al., 2010b). Especially, quinoa and quinoa flour, which are used as a substitute, are clearly suitable for improving the nutritional quality of the final product due to their rich chemical composition. The only negative aspect of quinoa in terms of its composition is that it has approximately 2.7 times more phytic acid content than wheat flours. Phytic acid reduces the bioavailability of minerals and proteins by binding to them (Rickard & Thompson, 1997) but it is also an important compound in functional nutrition due to its antioxidant properties (Graf et al., 1987).

3.2. Cooking properties of couscous

Some cooking properties of couscous samples are given in Table 2. When Table 2 was examined, it was determined that the weight increase (WI), volume increase (VI) and cooking loss (CL) changed as the covered materials (bulgur or quinoa grain) were changed. In other words, it was observed that the use of different covered materials in couscous production affected the cooking properties. Couscous samples in which quinoa grain was the covered material gave higher WI and VI values. In addition, the use of quinoa grain instead of bulgur caused a decrease in CL. Also, the use of quinoa flour as a coating material on the outer surface and its substitution in couscous samples with an increase from 0% to 100% is investigated in Table 2. It is determined that as the substitution amount of quinoa flour used as a coating material in couscous production increases, WI values (from 109.95 to 83.78%) and VI values (from 98.28 to 58.60%) decreased, CL values (from

5.98 to 8.29%) increased. High cooking loss indicates that starch is highly soluble and has low cooking tolerance (Yalçın, 2005). In addition, the starch content decreases in such products, resulting in unacceptable products in terms of cooking quality (Sabanis et al., 2006). The amount of gluten diluted by quinoa flour replacing wheat flour in the couscous formulation resulted in soft textured products during cooking, which increased the CL of the couscous. The dilution of gluten content in the couscous formulation might caused weakened the structure of samples which results in the leaching of more solids into the cooking water. Demir (2008) reported that as chickpea flour increased in couscous samples, WI and VI values decreased due to the decrease in starch content, while CL values increased.

3.3. Physical properties (color and firmness) of couscous

Food products can be tested for their resistance to impacts during transportation and cooking using fracture force/firmness tests (Aktaş, 2012). In addition, color characteristics of products such as noodles and couscous are important parameters for end product quality and consumer preferences (Demir, 2008). According to the multiple comparison results given in Table 3, it was determined that firmness and color values (L* and b*) changed as the coated materials (bulgur or quinoa grain) changed, except for a* (redness) values. It was found that the couscous samples in which bulgur was used had a softer texture and a darker and yellowish color than those in which quinoa grains were used. On the other hand, couscous samples produced by covered quinoa grains were found brighter, but have less yellowness.

The substitution of bulgur/quinoa did not have an effect on the redness values. Additionally, it was determined that the firmness values of couscous samples produced using different ratios of quinoa flour substitution decreased from 66.16 to 42.01 N, and the L* color values decreased from 87.17 to 82.24, while the b* color values increased from 12.73 to 16.36. However, the redness (a*) values did not show any change. Therefore, the increase in the addition of quinoa flour instead of wheat flour decreased the brightness of the final product couscous and caused yellowing of the color.

Table 1. Analytical analysis results of wheat flour, bulgur and quinoa samples[1]

Properties		Wheat flour	Bulgur	Quinoa
Color	***L****	92.74 ± 0.25	80.99 ± 0.81	89.11 ± 0.31
	a*	-0.50 ± 0.08	1.74 ± 0.11	-0.20 ± 0.01
	b*	9.34 ± 0.16	23.49 ± 0.64	12.02 ± 0.38
Moisture (%)		8.77 ± 0.33	11.64 ± 0.12	10.97 ± 0.32
Ash (%)[2]		0.57 ± 0.01	0.99 ± 0.06	2.91 ± 0.08
Crude protein (%)[2,3]		10.99 ± 0.18	12.53 ± 0.11	14.92 ± 0.17
Crude fat (%)[2]		0.81 ± 0.04	0.91 ± 0.08	4.91 ± 0.15
Total Dietary fiber (TDF) (%)[2]		3.16 ± 0.08	7.11 ± 0.13	12.76±0.09
Phytic acid (mg/100g)[2]		368 ± 17.68	694 ± 18.38	995 ± 10.61
Mineral contents (mg/100g)[2]	**Ca**	21.35 ± 0.41	41.22 ± 1.27	38.97 ± 0.72
	Mg	52.39 ± 0.78	110.24 ± 2.53	192.56 ± 4.11
	Zn	1.34 ± 0.05	1.79 ± 0.05	3.29 ± 0.06
	Fe	2.09 ± 0.05	2.78 ± 0.16	4.12 ± 0.13
	P	265.73 ± 3.42	323.07 ± 3.37	458.01 ± 10.40
	K	211.56 ± 4.40	372.75 ± 5.88	778.49 ± 4.07

[1]Results are the mean of two replicates and are given with standard deviations; [2]Presented as dry matter; [3]Bulgur and Wheat flour: N x 5.70, Quinoa: N x 6.25.

Table 2. Duncan's multiple comparison test results of cooking properties of couscous samples[1]

	n	Weight increase (%)	Volume increase (%)	CL[2] (%)
Coated raw material				
Bulgur	10	88.76^b	74.46^b	7.49^a
Quinoa	10	101.09^a	81.75^a	6.87^b
Quinoa substitution rate (%)				
0	4	109.95^a	98.28^a	5.98^e
25	4	97.05^b	86.50^b	6.79^d
50	4	93.55^c	80.00^c	7.15^c
75	4	90.30^d	67.15^d	7.69^b
100	4	83.78^e	58.60^e	8.29^a

[1]Means followed by the different letters within a column are significantly (P<0.05) different. Duncan's multiple comparison test results are according to two ways analysis of variance. n: number of samples analyzed according to (2 × 5) × 2 factorial design. [2] CL: Cooking Loss.

Table 3. Duncan's multiple comparison test results of color and firmness values of couscous samples[1]

	n	Firmness (N)	Color		
			L*	***a****	***b****
Coated raw material					
Bulgur	10	34.96^b	83.68^b	0.12^a	15.68^a
Quinoa	10	73.87^a	85.27^a	0.14^a	14.37^b
Quinoa substitution rate (%)					
0	4	66.16^a	87.17^a	0.15^a	12.73^d
25	4	59.20^{ab}	85.37^b	0.15^a	14.37^c
50	4	55.86^b	84.47^c	0.13^a	15.57^b
75	4	48.82^c	83.12^d	0.12^a	16.09^a
100	4	42.01^d	82.24^e	0.12^a	16.36^a

[1]Means followed by the different letters within a column are significantly (P<0.05) different. Duncan's multiple comparison test results are according to two ways analysis of variance. n: number of samples analyzed according to (2 × 5) × 2 factorial design

In couscous, the bright yellow-cream color is preferred by consumers. In this study, quinoa, with its specific color, had different effects on the final product properties depending on the addition rate and usage type. Lee et al. (1998) found that *L** values decreased and *b** values increased as the addition of chickpea flour substitute increased in noodles produced by using chickpea flour at different ratios (10, 20 and 30%) instead of wheat flour.

3.4. Chemical composition of couscous

According to the results of multiple comparison test (Table 4), the substitution and increase of quinoa grain and/or flour added to the composition of couscous samples increased the crude ash, crude protein and crude fat content of the samples. As can be seen from Table 1, the fact that quinoa has richer ash, crude protein and crude fat content than wheat flour and bulgur affected the chemical composition of the final product and caused an increase in these values (Demir, 2008). In addition, the production of a new couscous product using quinoa grains instead of bulgur increased the phytic acid content significantly. The average phytic acid content of the samples produced by coating bulgur grains in couscous sample was 440.71 mg/100g, while the average phytic acid content of the samples produced by using quinoa grains was 517.09 mg/100g. Also, increasing quinoa flour substitution rates instead of wheat flour increased the average phytic acid content of couscous from 247.75 mg/100g to 726.56 mg/100g. The bran fractions and germ layers of cereal grains are rich in phytate phosphorus, which is present in the phytic acid structure, and phytic acid is usually located in the embryo (Hoseney, 1994). In quinoa grain, it is present in the outer layers as well as the embryo (Valencia-Chamorro, 2003). Therefore, phytic acid values are expected to increase with quinoa substitution, which has a higher phytic acid content than wheat flour and bulgur.

When the IVPD results were analyzed, the average IVPD values of the couscous samples produced with bulgur were 82.38% and those produced with quinoa grains were 79.88% (Table 4). In addition, in couscous samples produced by using different wheat-quinoa flour combinations, increasing quinoa flour ratios significantly decreased the digestible protein ratios. While the average protein digestibility rate of couscous samples coated with 100% wheat flour was 83.49%, this rate decreased to 78.70% in samples coated with 100% quinoa flour. In other words, the use of quinoa grains or flours decreased the protein digestibility rates of all couscous samples. The probable reason for this is the quinoa raw material. Phytic acid is thought to play a major role in this. Because phytic acid can react with proteins and reduce their digestibility (Rickard & Thompson, 1997).

Phenolic substances are compounds with antioxidant activity that are found in significant amounts in many plants, cereals and other cereal products. These phenolic are particularly concentrated in the kernel layers of grains (Beta et al., 2005). Quinoa is rich in phenolic substances. According to Table 4, the average TFC was 0.80 mg GAE/g in couscous samples produced with bulgur and 0.91 mg GAE/g in those produced with quinoa grains. This shows that quinoa grain has higher Phenolic substance content than bulgur. Also, it was determined that the average total phenolic matter content increased from 0.70 mg GAE/g to 1.03 mg GAE/g with increasing quinoa flour substitution. These results clearly show that quinoa has a higher phenolic content than wheat products (wheat flour and bulgur).

According to the literature, pseudo cereals are a good source of fiber (Alvarez-Jubete et al., 2009) and have similar or higher dietary fiber content (12.88%) compared to other cereals (Hirano & Konishi, 2003). In this study, the average TDF content of couscous samples produced with bulgur was found to be 6.73% and 8.06% for couscous produced with quinoa flour. In couscous with quinoa flour substitution, TDF content increased with the increase in the substitution rate. The average total dietary fiber (TDF) amounts of couscous samples produced with different proportions of quinoa flour were determined as follows in Table 4: TDF was found to be 3.85% in samples using 0% quinoa flour (i.e. 100% wheat flour). For samples using 25% quinoa flour, TDF was 5.62%, while it was 7.40% for samples using 50% quinoa flour. In samples using 75% quinoa flour, TDF was 9.23%, and for those using 100% quinoa flour, it was determined to be 10.89%. It is known that quinoa has a high dietary fiber content as a raw material (Repo-Carrasco et al., 2003). The fact that the wheat flour used in our study has a total dietary fiber content of 3.16%, bulgur has 7.11%, and quinoa has 12.76% (Table 1) is an indication of this. Increasing the dietary fiber content of the final products by using quinoa, which has a high dietary fiber content, as a grain and/or flour is a natural consequence.

The data on the mineral content (Zn, Fe, Ca, K, Mg and P) of the couscous samples produced are summarized in Table 5, HCl-extractable mineral substance ratio (%) are summarized in Table 6. According to the results given in Table 5, it was determined that all the determined mineral contents of different couscous samples, except Ca content, increased with the use of quinoa grain. In addition, the mineral content of couscous samples obtained by using different wheat/quinoa flour combinations increased with quinoa substitution. Demir (2008), reported that chickpea flour added to the couscous produced by traditional methods increased the mineral content and the amount of Ca, Mg, K, P, Fe and Zn increased 2.27, 2.47, 2.88, 1.37, 1.88 and 1.79 times, respectively, in couscous samples prepared using 100% chickpea flour compared to control samples. Although wheat is a grain with mineral substances, the minerals decrease during the reduction process to flour (Elgün & Ertugay, 1995). Table 5 clearly shows that quinoa has a much higher mineral content than bulgur and wheat flour. Therefore, the use of quinoa, which is rich in mineral matter, increased the mineral matter content of couscous samples. According to the HCl-extractable mineral substance ratio (%) (Table 6), it was determined that couscous produced with quinoa grain decreased all other digestible mineral content ratios except Fe. HCl-extractable mineral substance rates have decreased as the ratio of quinoa substitute has increased in couscous produced with different quinoa/wheat flour combinations. For example, in couscous samples coated with 100% wheat flour, the ratios of HCl extractable (%) Zn, Fe, Ca, K, Mg, and P were determined as 67.97, 66.12, 71.92, 87.51, 79.02, and 71.02%, respectively. However, in those produced with 100% quinoa flour, these ratios were found to be 64.04, 64.71, 67.79, 81.91, 74.85, and 65.09%, respectively, indicating a decrease in mineral digestibility rates compared to those produced with wheat flour. This is probably due to the raw material as in IVPD. Because the high phytic acid content of quinoa may affect the digestibility of minerals such as zinc, iron, calcium, magnesium and copper.

Table 4. Duncan's multiple comparison test results of chemical composition of couscous samples[1]

	n	Ash (%)	Crude protein (%)	Crude fat (%)	Phytic acid (mg/100g)	In-vitro Protein digestibility (%)	TFC[2] (mg GAE/g)	TDF[3] (%)
Coated raw material								
Bulgur	10	1.383^{b}	12.43^{b}	2.73^{b}	440.71^{b}	82.38^{a}	0.80^{b}	6.73^{b}
Quinoa	10	1.499^{a}	13.33^{a}	3.28^{a}	517.09^{a}	79.88^{b}	0.91^{a}	8.06^{a}
Quinoa substitution rate (%)								
0	4	0.908^{e}	11.44^{e}	1.74^{e}	247.75^{e}	83.49^{a}	0.70^{e}	3.85^{e}
25	4	1.163^{d}	12.18^{d}	2.32^{d}	362.43^{d}	82.38^{b}	0.77^{d}	5.62^{d}
50	4	1.512^{c}	12.87^{c}	2.91^{c}	466.53^{c}	81.14^{c}	0.86^{c}	7.40^{c}
75	4	1.655^{b}	13.57^{b}	3.47^{b}	591.23^{b}	79.94^{d}	0.93^{b}	9.23^{b}
100	4	1.967^{a}	14.35^{a}	4.58^{a}	726.56^{a}	78.70^{e}	1.03^{a}	10.89^{a}

[1]Means followed by the different letters within a column are significantly ($P<0.05$) different. Duncan's multiple comparison test results are according to two ways analysis of variance. n: number of samples analyzed according to $(2 \times 5) \times 2$ factorial design.[2] TFC: Total Phenolic Content. [3] TDF: Total Dietary Fiber.

Table 5. Duncan's multiple comparison test results of mineral contents (mg/100g) of couscous samples[1]

	n	Zn (mg/100g)	Fe (mg/100g)	Ca (mg/100g)	K (mg/100g)	Mg (mg/100g)	P (mg/100g)
Coated raw material							
Bulgur	10	1.97^{b}	2.60^{b}	63.20^{a}	417.50^{b}	107.92^{b}	357.61^{b}
Quinoa	10	2.43^{a}	3.22^{a}	62.89^{a}	576.50^{a}	140.52^{a}	411.16^{a}
Quinoa substitution rate (%)							
0	4	1.41^{e}	2.32^{e}	55.38^{e}	378.07^{e}	89.84^{e}	324.87^{e}
25	4	1.91^{d}	2.55^{d}	59.28^{d}	432.89^{d}	106.89^{d}	355.36^{d}
50	4	2.23^{c}	2.90^{c}	63.09^{c}	489.87^{c}	123.43^{c}	383.05^{c}
75	4	2.52^{b}	3.25^{b}	66.63^{b}	555.41^{b}	140.82^{b}	409.68^{b}
100	4	2.93^{a}	3.55^{a}	70.84^{a}	623.75^{a}	160.14^{a}	448.98^{a}

[1]Means followed by the different letters within a column are significantly ($P<0.05$) different. Duncan's multiple comparison test results are according to two ways analysis of variance. n: number of samples analyzed according to $(2 \times 5) \times 2$ factorial design

Table 6. Duncan's multiple comparison test results of HCl-extractability (%) of minerals of couscous samples[1]

	n	Zn (%)	Fe (%)	Ca (%)	K (%)	Mg (%)	P (%)
Coated raw material							
Bulgur	10	66.60a	65.59a	70.26a	85.44a	77.47a	69.13a
Quinoa	10	65.53b	65.29a	69.77b	84.21b	76.37b	67.20b
Quinoa substitution rate (%)							
0	4	67.97a	66.12a	71.92a	87.51a	79.02a	71.02a
25	4	67.07b	65.86a	71.20b	86.19a	77.98b	69.91b
50	4	66.09c	65.52ab	70.28c	85.01b	76.96c	68.30c
75	4	65.18d	64.99bc	68.89d	83.51c	75.78d	66.51d
100	4	64.04e	64.71c	67.79e	81.91d	74.85e	65.09e

[1]Means followed by the different letters within a column are significantly ($P<0.05$) different. Duncan's multiple comparison test results are according to two ways analysis of variance. n: number of samples analyzed according to $(2 \times 5) \times 2$ factorial design

4. Conclusions

In this study, cereal-based traditional couscous product was targeted and it was aimed to produce a new product with better quality and high nutritional value with quinoa, which is thought to have an important place in the world nutrition cultures in the coming centuries. For this purpose, firstly, quinoa grains were ground and 5 different substitution ratios (0, 25, 50, 75 and 100%) were added to wheat flour to form flour blends. These flour blends were used on two different raw materials (Bulgur and Quinoa grains) and couscous samples were produced. The following results were obtained from this research:

A) When an evaluation is made considering different coated raw materials (bulgur/quinoa grain) in couscous production;
- In terms of cooking properties; couscous using quinoa grains instead of bulgur gave more positive results.
- As a result of using quinoa grain instead of bulgur in couscous production; higher crude protein, ash, crude fat, TFC, mineral matter and TDF were obtained, which had a harder and brighter color.

B) Couscous samples produced with different wheat/quinoa flour combinations were analyzed;
- It was determined that more negative results were obtained with increasing quinoa flour substitution, especially CL values increased. On the other hand, couscous with improved

nutritional and chemical properties were obtained with quinoa substitution.

In general, it was determined that quinoa has a significant effect in terms of improving chemical and nutritional properties in couscous production. In particular, the use of quinoa grains instead of bulgur was determined as a new alternative. In terms of different flour combinations; 50% wheat flour: 50% quinoa flour mixtures were found to be suitable for the preservation of structural properties.

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CRediT Authorship Contribution Statement

Mehmet Kılınç: Investigation, Formal analysis, Data curation, Writing – original draft
Mustafa Kürşat Demir: Supervision, Funding acquisition, Project administration, Resources, Writing – review & editing, Formal analysis, Data curation.

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