



Effects of using quinoa flour in meatballs produced from turkey meat on mineral substances, cooking and sensory properties

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Abstract

In this study, quinoa flour (0-control, 2.5% and 5%) was used instead of breadcrumbs in meatballs produced from turkey meat. At the end of the production; pH, moisture, cooking properties (cooking loss, diameter reduction and cooking yield), phenolic compounds, mineral substances and sensory analyses were performed on the samples. As a result of the analyses, it was determined that sensory parameters were not statistically affected by the use of quinoa ($p>0.05$). Similarly, quinoa use had no statistical effect on pH and moisture ($p>0.05$). However, cooking loss, diameter reduction and cooking yield were affected by quinoa use at a rate of $p<0.01$. Cooking loss and diameter reduction, which decreased with the use of quinoa, showed the highest mean values in the control group. Furthermore, the lowest cooking yield value was also determined in the control group. Among the analyzed phenolic compounds (cinnamic acid, gallic acid, tannic acid, caffeic acid, 2-5 dihydroxy benzoic acid, trans ferulic acid, rutin trihydrate, myrcetin, naringenin, allagic acid, quercetin, luteolin, chrysin, apigenin, CAPE and triacetin), only gallic acid and catechin were detected in the meatballs. While gallic acid was not statistically affected by the quinoa usage rate ($p>0.05$), catechin was affected by this factor at $p<0.05$ level. Catechin showed the highest mean value in the group containing 5% quinoa. All mineral substances analyzed in the meatballs (Fe, Zn, Mg, Ca and P) were significantly affected by the quinoa usage ($p<0.01$). All of these mineral substances showed gradual increase with use of quinoa. It was concluded that quinoa could also be an alternative ingredient to breadcrumbs in meatballs produced from turkey meat.

Keywords: Turkey meat, Meatball, Quinoa, Mineral matter, Phenolic compounds

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1. Introduction

Quinoa contains the amino acid requirements of adults, according to the daily amino acid intake requirements specified by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO). Therefore, quinoa can be used in nutritious foods and beverages. The biological value of quinoa is 73%, which is close to beef, higher than white rice (56%), wheat (49%) and corn (36%) (Bastidas et al., 2016). Quinoa is rich food in terms of protein and has a high biological protein value as much as beef (Singh et al., 2016). Its seeds are remarkable not only for their high protein content but also their amino acid balance (Repo-Carrasco-Valencia et al., 2011; Carciochi et

al., 2014; Bastidas et al., 2016). In the report, published by FAO, WHO and United Nations University, it was stated that quinoa consumption has an amino acid profile that can meet the daily amino acid requirement of an adult such as 228% of tryptophan, 338% of lysine, 274% of isoleucine, 212% of methionine and cysteine, 320% of phenylalanine and tyrosine, 331% of threonine, 180% of histidine and 323% of valine. Quinoa plays a complementary role in the essential amino acids (especially lysine, methionine and cysteine) which are deficient in grains and legumes (Üçok et al., 2019).

Quinoa is a gluten-free grain type and a rich source of vitamins (E, C, B complex) and minerals (K, Ca, Mg, Fe,



P, Mn) (Miranda et al., 2012). On the other hand, carbohydrates constitute the majority of the dry weight of quinoa seeds. The most dominant components among these carbohydrates are starch and dietary fiber. Dietary fiber is resistant to enzymatic digestion and absorption in our digestive system; in addition to that, it usually undergoes complete or partial fermentation in the large intestine. Dietary fiber is essential for maintaining optimal digestive health and provides several functional advantages such as increasing satiety, reducing cholesterol and lipid absorption and improving the gut microbiota composition (Sharma et al., 2015). Moreover, this grain has a low glycemic index (Graf et al., 2015).

Another nutritional importance of quinoa is that it does not contain gluten. Despite the fact that consumption habits have changed worldwide, grain products still maintain their importance in nutrition. However, for some people, grains such as wheat, rye, oat and their products can cause intestinal malabsorption that can lead to celiac disease. Therefore, the only long-term solution for celiac patients is to follow a gluten-free diet (Al Shehry, 2016). It is stated that quinoa is a suitable ingredient for gluten-free diet followers who do not want to give up the foods such as bread or pasta (Singh et al., 2016). According to a study, 22 students between the ages of 18-45 were given quinoa in the form of a cereal bar once a day for 30 days. At the end of the study, it was revealed that quinoa-supported nutrition caused a decrease in triglyceride and LDL-cholesterol levels (Farinazzi-Machado et al., 2012).

Quinoa is usually mixed with wheat flour and can be used in bakery products (Enriquez et al., 2003). Many studies have been conducted on the use of quinoa in bread production (Lorenz & Coulter, 1991; Morita et al., 2001; Enriquez et al., 2003). However, studies on the use of this grain in meat products are quite limited. Ince (2019) added quinoa flour and κ -carrageenan to chicken meatballs at different rates and analyzed the product in terms of pH, moisture, aw, TBARS, L*, a*, b*, cooking efficiency, moisture retention, textural properties and sensory parameters. In another study, quinoa flour was included in the production of beef meatballs; the product was examined in terms of physicochemical, sensory and textural aspects (Bağdatlı, 2018). In the study conducted by Kuru (2021), quinoa flour was added to beef patties at different rates and the product was analyzed in terms of acrylamide and some other quality criteria. On the other hand, no study was found in the literature examining the effects of quinoa flour on the properties of patties produced from turkey meat. In addition, no study was also found examining the effects of quinoa flour on the mineral substances and phenolic compounds of turkey meatballs.

In this research, quinoa flour instead of breadcrumbs was used in meatball production from turkey meat at different rates (0-control, 2.5% and 5%). At the end of production; pH, moisture, cooking properties (cooking loss, diameter reduction and cooking yield), phenolic compound and

mineral substance analyses were applied to the meatballs. Furthermore, the products were also tested in terms of sensory properties.

2. Material and Method

2.1. Material

Ground turkey meat, ground beef fat, quinoa flour, salt and breadcrumbs used in meatball production were purchased from the Kastamonu market.

2.2. Method

Meatball production

In all groups, 84% turkey meat, 10% beef fat and 1% salt were used. In addition, 5% breadcrumbs, 2.5% breadcrumbs + 2.5% quinoa flour and 5% quinoa flour were used in the other groups, respectively. 40 g of meatballs were taken and shaped using a metal mold (6.5 cm diameter and 1 cm thickness). Sensory, mineral matter, phenolic compound, cooking properties, pH and moisture analyses were performed on the produced meatball samples.

Sensory analysis

Meatball samples were cooked and subjected to sensory analysis by 10 semi-trained panelists using a hedonic type scale (1-9). Meatballs were tested for sensory analysis in terms of color, appearance, odor, texture, taste, degree of cooking and general acceptability. 1 point was evaluated as the lowest (undesirable) score and 9 point as the highest (desirable) one.

pH

10 g of meatball sample was weighed and 100 ml of pure water was added on. Measurements were performed using a previously calibrated pH meter (Isolab, Germany) with appropriate calibration fluids. Analyses were performed in two replicates.

Moisture

10 g of meatball samples were weighed, then taken into pre-dried and tared nickel containers. After that they kept drying at 105 °C up to a constant weighing weight. As a result, the results were expressed as moisture %. Analyses were performed in two replicates.

Cooking loss, diameter reduction and cooking yield

Meatball samples were weighed both before and after cooking. In addition, the diameters of the meatballs were measured using a ruler both before and after cooking. Cooking loss (CL), diameter reduction (DR) and cooking yield (CY) were determined using the appropriate formulas. Analyses were performed in five replicates.

$$CY = \frac{A}{B} \times 100 \quad (1)$$

$$CL = \frac{A - B}{B} \times 100 \quad (2)$$

$$DR = \frac{C - D}{C} \times 100 \quad (3)$$

Where;

A: Cooked meatball weight (g),

B: Raw meatball weight (g),

C: Raw meatball diameter (cm),

D: Cooked meatball diameter (cm).

Phenolic compounds

The method proposed by Escarpa and González (2001) was applied for the extraction of phenolic compounds. 25 ml of 1% BHT solution prepared using 80% methanol was added on 5 g of sample. The samples homogenized using Ultra-turrax device (Velp Scientica, Italy) were processed for 2 hours in an ultrasonic water bath (ISOLAB Ultrasonic Water Bath, Germany) at room temperature. The samples were transferred to vials by passing through a 0.45 micron membrane filter. Phenolic compounds were determined by liquid chromatography-mass spectrometry (LC-MS/MS). While the injection volume of the device was 10 µL, the device column was Inertsil ODS4 analytical column (GL Sciences, Japan), the column diameter was 3 µM, the column size was 2.1 x 50 mm; the mobile phases in the analysis were Mobile Phase A: Water that contains 1% Formic Acid, Mobile Phase B: Methanol that contains 1% Formic Acid. The flow rate in the column was 0.4 mL/min and the column temperature was 40 °C. The calibration points were determined as 10, 50, 100, 200 and 500 ppb. Analyses were performed in two replicates.

Mineral matters

The samples dried at 105 °C and weighed as 0.25 g were transferred into teflon beakers. Then, 10 ml of HNO₃ (67% v/v) was added to the meatball samples and organic burning process was performed in the microwave at 210 °C for 30 min using the Run-Food method. After that, ultrapure water was added on the samples that were left cooling at room temperature in order to complete the volume up to 25 ml. The samples filtered through the microfilter were processed so that no particles remained in them. Concentrations of the metals were measured in the ICP-OES (Spectro Blue, Germany) device. Multielement standard stock solution (Merck, Germany) was used in the preparation of calibration standards for the ICP-OES device. Measurements against the blank for each element were performed. Analyses were performed in three replicates.

Statistical analysis

In the study, quinoa flour ratio was selected as the factor and the trial was carried out as 2 replications depending on complete randomization. The data found to be significant ($p < 0.01$ or $p < 0.05$) in the variance analysis

applied to the results that were obtained from the analyzes were compared using Duncan's Multiple Comparison test.

3. Results and Discussion

As seen in Table 1, the use of quinoa flour had no statistically significant effect on any sensory parameter ($p > 0.05$). In other words, according to the panelists, the use of quinoa showed no change in the sensory properties of the meatballs such as traditional taste, appearance, texture, color, odor and general acceptability (Figure 1). This result shows that quinoa flour can be used instead of breadcrumbs in meatball production from a sensory perspective. In a study investigating the effects of quinoa flour on some properties of chicken meatballs, the use of quinoa flour increased the texture scores of sensory parameters, while decreasing the scores of appearance, odor, taste and color. Researchers have also emphasized that moisture and fat content can change the sensory characteristics of cooked products, especially affecting texture and taste parameters (Meral et al., 2022). In fat-reduced chicken meatballs produced with quinoa flour and κ-carrageenan, sensory analysis was not statistically affected by these factors (İnce, 2019).

Table 1. The effect of using quinoa in turkey meatball on sensory properties

Sensory parameters	Quinoa Flour Ratio (%)			Sig.
	0-Control	2.5	5	
Color	6.85±1.53 ^a	6.95±1.23 ^a	6.60±1.35 ^a	NS
Appearance	7.20±1.32 ^a	7.25±1.12 ^a	6.80±1.32 ^a	NS
Odor	7.05±1.39 ^a	7.10±1.29 ^a	6.85±1.27 ^a	NS
Texture	7.15±1.66 ^a	7.00±1.75 ^a	6.80±1.47 ^a	NS
Taste	7.10±1.52 ^a	6.90±1.77 ^a	6.40±1.23 ^a	NS
Cooking level	7.10±1.68 ^a	7.00±1.86 ^a	6.50±1.67 ^a	NS
General acceptability	7.10±1.59 ^a	7.15±1.46 ^a	6.45±1.61 ^a	NS

^a: Same letters indicate no statistical difference ($p > 0.05$) in each line, NS: not significant.

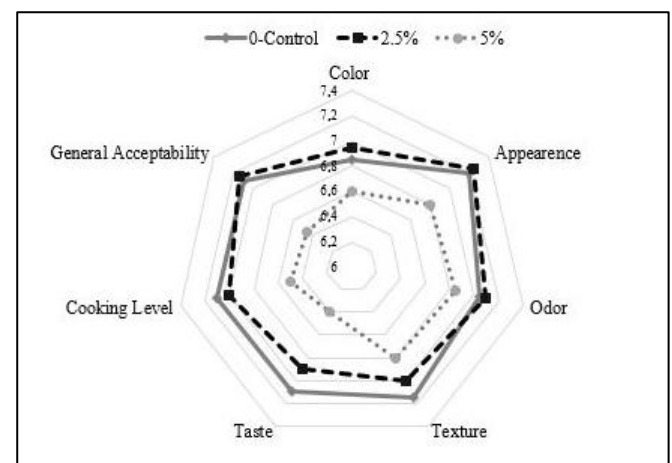


Figure 1. Sensory analysis of meatball with quinoa flour

The use of quinoa flour in meatball production did not cause a statistical change in pH and moisture values (Table 2). Kuru (2021) found that the pH value in meatballs produced from beef increased with the increase in the amount of quinoa flour and there were statistical changes in moisture value. In the fat-reduced chicken meatballs produced with quinoa flour and κ -carrageenan, the highest pH value was determined in the control group and the moisture value was not affected by the quinoa usage rate (İnce, 2019). The use of quinoa flour in chicken meatballs caused statistical changes in pH value during storage (Meral et al., 2022). Bağdatlı (2018) determined that the moisture value increased with the use of quinoa flour in meatballs produced from beef, but there was no change in pH value. Cooking loss, diameter reduction and cooking yield values were affected by the use of quinoa flour at the $p<0.01$ level. The use of quinoa flour had a positive effect on these values. The cooking loss value showed the highest average value of 12.06 in the control group. In addition, the highest average diameter reduction value was determined in the control group meatballs. There was a decrease in cooking loss and diameter reduction values with the use of quinoa flour. On the other hand, the lowest average cooking yield value was determined in the control group. Cooking yield increased with the use of 2.5% and 5% quinoa flour in the samples (Table 2). Cooking yield is one of the most important factors affecting the water retention capacity of myofibrillar proteins during cooking (Jiang et al., 2024). Thus, yield is closely related to the shrinkage of the product. This also affects consumer preference (Meral et al., 2022). In the study conducted by Jiang et al. (2024), it was determined that quinoa protein increased the cooking yield of meatballs produced from pork. Meral et al. (2022) determined that quinoa flour increased the cooking yield in chicken meatballs produced using quinoa. In the reduced-fat chicken meatballs produced

with quinoa flour and κ -carrageenan, the lowest average cooking yield was determined in the control group. These results show that the use of quinoa flour in meatball production improves cooking properties and contributes to the reduction of economic losses. In a study conducted on beef meatballs, it was determined that the highest cooking loss value was in the 2% quinoa group and the lowest value was in the 6% quinoa group (Kuru, 2021).

Phenolic compounds, which are secondary metabolites of plants, have at least one hydroxyl group containing an aromatic hydrocarbon ring (Agarwal et al., 2023). Xanthonenes, flavonoids, quinines, phenolic acids, phenols, cumarines, phenylpropanoids and lignans are phenolic compounds found in plants. On the other hand, quinoa also contains some important phenolic compounds such as quercetin and kaempferol. Quinoa seeds show antioxidant properties due to the phenolic compounds they contain (Balakrishnan & Schneider, 2022; Agarwal et al., 2023). Meatballs produced using quinoa were analyzed for phenolic compounds (cinnamic acid, gallic acid, tannic acid, caffeic acid, 2-5 dihydroxy benzoic acid, trans ferulic acid, rutin trihydrate, myricetin, naringenin, allagic acid, quercetin, luteolin, chrysin, apigenin, CAPE and triacetin). Of the analyzed phenolic compounds, only gallic acid and catechin was within the detectable limits. The failure to detect other phenolic compounds is probably due to their amounts being below the calibration value. Gallic acid was not affected by the quinoa usage rate ($p>0.05$). On the other hand, catechin, another phenolic compound determined in meatballs, was statistically affected by the use of quinoa and showed the highest average value in the group with 5% quinoa (Table 2). This situation proves that the use of quinoa resulted in increase of phenolic compounds in meatballs.

Table 2. The effect of using quinoa in turkey meatball on pH, moisture, cooking properties, gallic acid and catechin

Analyses	Quinoa Flour Ratio (%)			Sig.
	0-Control	2.5	5	
pH	6.55±0.05 ^a	6.61±0.02 ^a	6.62±0.04 ^a	NS
Moisture (%)	58.23±0.59 ^a	57.55±0.34 ^a	58.05±0.83 ^a	NS
Cooking loss (%)	12.06±1.82 ^a	10.01±1.05 ^b	9.35±0.98 ^b	**
Diameter reduction (%)	6.07±3.62 ^a	3.09±2.76 ^b	1.67±2.61 ^b	**
Cooking yield (%)	87.94±1.82 ^b	89.99±1.05 ^a	90.65±0.98 ^a	**
Gallic acid (ppb)	8.75±0.20 ^a	8.55±0.71 ^a	9.12±0.16 ^a	NS
Catechin (ppb)	5.03±4.37 ^b	5.15±3.51 ^b	12.35±3.29 ^a	*

^{a-b}: Different letters indicate statistical difference ($p<0.05$) in each line, *: $p<0.05$, **: $p<0.01$, NS: not significant.

Quinoa has a higher mineral content than many other grains. While minerals such as P, K and magnesium are found in the embryo of quinoa, calcium and phosphorus in the pericarp (outer shell) are associated with the pectic compounds of the cell wall. Sulfur is distributed homogeneously in the quinoa embryo. Quinoa can be an

alternative food source for anemia caused by iron deficiency due to its high soluble iron content (Arneja et al., 2015). In addition, it has been stated that it contains higher amounts of calcium, phosphorus, magnesium, iron, zinc, potassium and copper compared to other grains (Ruales & Nair, 1993). The mineral

substances of meatballs produced using quinoa flour are given in Table 3. Quinoa flour usage had a very significant ($p<0.01$) effect on all analyzed mineral substances. Fe, Zn, Mg, Ca and P showed the lowest

mean values in the control group with 588.740, 300.843, 4.170, 2.019 and 34.751, respectively. The highest mean values were found in the groups produced using 5% quinoa flour.

Table 3. The effect of using quinoa in turkey meatball on mineral matters

Mineral matter	Quinoa Flour Ratio (%)			Sig.
	0-Control	2.5	5	
Fe (ppb)	588.740±69.554 ^c	647.106±62.350 ^b	703.914±108.030 ^a	**
Zn (ppb)	300.843±20.403 ^c	376.707±29.406 ^b	311.293±24.134 ^a	**
Mg (ppm)	4.170±0.257 ^c	5.028±0.124 ^b	5.146±0.030 ^a	**
Ca (ppm)	2.019±0.028 ^c	2.272±0.044 ^b	2.840±0.634 ^a	**
P (ppm)	34.751±1.202 ^c	36.349±1.805 ^b	39.121±0.228 ^a	**

^{a-c}: Different letters indicate statistical difference ($p<0.05$) in each line, **: $p<0.01$.

4. Conclusion

The use of quinoa flour in meatballs did not affect the sensory parameters. This shows that the use of quinoa does not affect the desired taste of the meatball and can be used in terms of sensory aspects. On the other hand, quinoa flour reduces cooking loss and diameter reduction values and increases cooking yield, improving the cooking properties of the product and providing economic gain. In addition, the mineral substances of the groups where quinoa flour is used show higher values than the other groups and this contributes to the nutritional value of the meatball. It was also concluded that quinoa is a good alternative to bread crumbs, especially for the production of gluten-free meatballs.

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Conflict of interest

The authors declare no conflict of interest.

Ethical Approval

This article does not require ethics committee approval.

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