PAPER

THE INFLUENCE OF QUINOA (*CHENOPODIUM QUINOA* WILLD.) FLOUR ON THE PHYSICOCHEMICAL, TEXTURAL AND SENSORIAL PROPERTIES OF BEEF MEATBALL

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ABSTRACT

In this study, beef meatballs were produced by using different percentages of quinoa flour as functional ingredient. The effects of quinoa flour levels on physicochemical, textural, sensorial properties of meatballs were examined. Quinoa level had significant effect on fat and moisture contents ($p<0.0001$). The protein content was improved by adding quinoa flour. Cohesiveness, springiness, gumminess, redness(a*), yellowness(b*) values were significantly affected by addition of quinoa flour. According to sensorial analysis, meatball samples had high acceptability and favorable scores. Consequently, quinoa flour has high potential as gluten-free ingredient for use in meatball production in addition to nutritional value and health benefits.

Keywords: beef, meatball, quinoa flour

1. INTRODUCTION

Celiac disease is one of the most common lifelong disorders worldwide with as estimated mean prevalence of 1% of the general population. The only acceptable treatment to date for celiac disease is the strict elimination of gluten from the diet. Gluten-containing wheat proteins and/or starches are often added to many commercial products such as ready meals, convenience food products (meatball etc.), some medicines for technological reasons, to act as fillers, thickeners, binders and stabilizers (ALVAREZ- JUBETE *et al.*, 2010).

The increasing consumer demand for foods that combine extra benefits in addition to common nutrients imposes on the food industry. Therefore, it is needed to advance the new ingredients and formulations, particularly for the production of functional foods. Quinoa (*Chenopodium quinoa* Willd) is a gluten-free pseudo-cereal that contains a high amount of fibre, high biological-value proteins and essential fatty acids (ω-3 and ω-6). It is consumed in the raw or processed as flakes and flour (BRITO *et al.*, 2015).

Quinoa, is a good source of minerals, vitamins and natural antioxidants like vitamin E. The most important characteristic of this pseudocereal is the high amount and quality of its protein. Studies have been carried out to investigate the use of quinoa as a food ingredient to increase the protein level and for taste improvement (SCHUMACHER *et al.*, 2010).

Currently, natural extracts, vegetable and fish oils can be used in order to develop the functional properties of meat products (BILEK and TURHAN, 2009). Non-meat ingredients such as bean flour, corn flour, oat flour have been used to binding and extending in comminuted meat products in previous studies. However, quinoa flour have not been used in meatballs before.

In this study, the effects of quinoa flour on the properties of beef meatballs were presented. The results of chemical composition, pH, cooking yield, Texture Profile Analysis, sensory analysis and Hunter (L*, a*, b*) were obtained.

2. MATERIALS AND METHODS

2.1. Preparation of meatballs

Meatballs were prepared in duplicate according to the following traditional recipe. Quinoa flour was provided from a local market in Manisa. Medium-fat (max. 15% fat) ground beef meat were purchased from a local butcher shop in Manisa 20 kg of ground beef were used in each batch. Ingredients were as follows; 2% salt, 3% ground onion, 2% red pepper, 0.3% black pepper, 3% cumin, 0.8% garlic powder. In the first batch (control) 5% bread crumbs was added; in the second batch 2.5% quinoa flour was added; in the third batch 5% quinoa flour was added, in the fourth batch 7.5% quinoa flour was added to the formulation. Therefore, four different quinoa flour levels (0%, 2.5%, 5% and 7.5%) were used in meatball preparation. All ingredients were mixed at Research Laboratories of Manisa Celal Bayar University-Food Engineering Department. Each batch was kneaded for 15 min by hand to obtain homogenous dough. The doughs were stored in a refrigerator (+4°C) for 12 hours and then shaped in to ball with a diameter of 3 cm and a weight of 20 g. The meatballs were cooked for 20 min in a preheated hot air oven at 180°C. For every treatment two replicates were maintained.

2.2. Cooking yield

Cooking yield was determined by measuring the difference in the sample weight before and after cooking and was calculated according to following equation (ULU, 2006).

$$Cooking\ yield\ (\%) = \frac{Cooked\ meatball\ weight\ (\%)}{Uncooked\ meatball\ weight\ (\%)}\ x\ 100$$

2.3. Proximate analysis

Ash, moisture, protein and fat contents were determined according to AOAC methods (AOAC, 2000). Protein content was measured by the Kjeldahl method (Nx6.25). Fat was determined extracting samples in a Soxhlet apparatus using diethyl ether as a solvent. Moisture content was measured by the weight difference before and after oven drying at 105°C. Ash was determined after incineration in a furnace at 500°C. Carbohydrate content was calculated by computing the difference.

2.4. pH

10 g meatball and 100 mL distilled water were blended for two minutes to obtain pH value by using pH meter (HANNA INSTRUMENTS MODEL HI 221, USA) (AOAC, 1984).

2.5. Color

The color of the surface of meatball samples was measured with a colorimeter (Minolta CR-300) on three different points using D-65 illuminant. The L*, a*, b* values were recorded.

2.6. TPA (Texture profile analysis)

Texture profile analyses (TPA) of cooked beef meatballs were determined by using TA.XT Plus Texture Analyzer (Godalming, England). Six cores (diameter 25 mm) were taken from random cooked beef meatballs per treatment. 50 kg of load cell was applied. P/25 cylindrical probe was used. The pretest speed was considered as 1mm/s with 2 mm/s of test and posttest speed. Double compression was applied with 50% of compression rate. The results of hardness, cohesiveness, springiness, chewiness and gumminess were achieved (BRUNA *et al.* 2000).

2.7. Sensory analysis

The sensory attributes (color, taste, odor, texture, appearance and overall acceptability) of cooked meatball samples were evaluated by 12 well trained panelists from the staff members of Manisa Celal Bayar University using a 9-point Hedonic scale. The analysis was performed in the Food Engineering Research Laboratory under white fluorescent lights. The samples were scored on scale of 1-9. The results between 1-3 are considered as unacceptable; 4-5 are acceptable; 6-7 are good; 8-9 are excellent.

2.8. Trial plan and statistical analysis

The data obtained from two replications were processed by analysis of variance (ANOVA) using Statistical Analysis System (SAS) (SAS Institute, 2001). PROC GLM procedure was done. The level of statistical significance is $p \leq 0.05$.

3. **RESULTS AND DISCUSSION**

Table 1 presents the results of moisture, ash, fat, protein and carbohydrate contents of quinoa flour and bread crumbs. The moisture content for quinoa flour and bread crumbs were found as 13.77 and 7.73, respectively. The results show that quinoa flour is good source of protein and carbohydrate. The similar results of quinoa flour composition were obtained in previous studies by OSHODI *et al*. (1999), ALVAREZ-JUBETE *et al*. (2009), OGUNBELLE (2003).

Table 1. Chemical composition of quinoa flour and bread crumbs (%).

Component	Quinoa flour	Bread crumbs
Moisture (%)	13.77±0.80	7.73±0.15
Ash (%)	2.46±0.06	1.28±0.04
Fat (%)	4.93±0.15	2.69±1.09
Protein (%)	13.60±0.22	10.75±0.71
Carbohydrate (by difference)	65.26±0.67	77.56±0.57

All the values indicate mean ± SD.

Mean percent of moisture, fat, protein, ash, cooking yield and pH values of raw meatballs with quinoa flour are given in Table 2. Meatballs had moisture contents ranging from 44.06% to 52.50%. The maximum content moisture content was determined in meatballs with the addition of 7.5% quinoa. The quinoa level used in meatball production had very significant effect on moisture content of meatball samples ($p<0.05$). The moisture contents increased by the percentage of quinoa flour was increased. In fact, the increase of the moisture content with the increase of quinoa flour percentage is related to the water holding capacity of quinoa flour. OSHODI *et al*. (1999) reported that the water absorption capacity for quinoa is 147%. According to OGUNGBENLE (2003), the water absorption capacity for quinoa seed is 14%. It is higher than soy flour, pumpkin seed and pigeon pea flour. The present findings of moisture contents are agreeing with the findings of BILEK and TURHAN (2009) and TURHAN *et al.* (2005).
Fat contents of meatballs having 0% (control), 2.5%, 5% and 7.5% quinoa flour were found as 12.66%, 12.09%, 9.86% and 9.80%, respectively. The amount of quinoa flour affected the fat content of meatball samples significantly ($p<0.05$). When the quinoa flour was increased, the fat content was decreased. The decrease of fat content with the increase of quinoa flour percentage is related to the composition of the flour. And also, OGUNGBENLE (2003) was determined that the oil absorption capacity of the quinoa flour (46.0%) was lower than wheat flour (84.2%). This is consistent with the findings of YıLMAZ (2005) who reported wheat bran addition at the level of 20% resulted in a significant ($p<0.05$) reduction in the fat content of meatballs. On the contrary, MODI *et al.*

(2009) reported that the fat content of uncooked kofta did not affected by different levels of carrageenan and out flour (p>0.05).

Protein contents of meatballs with 0% (control), 2.5%, 5% and 7.5% quinoa flour were found as 33.38%, 33.81%, 34.36% and 38.49%, respectively. Analysis of variance showed that the differences of protein amounts of the meatballs were non significant (p>0.05). Similarly, SERDAROĞLU and DEĞIRMENCIOĞLU (2004) determined that the protein content of uncooked meatballs did not affected by corn flour addition (p>0.05). Also, AUKKANIT *et al.* (2015) found that protein contents in corn silk added low fat meatballs have not significant difference(p>0.05).

Table 2. Moisture, fat, protein, ash contents and pH, cooking yield (%) and Lab values of beef meatballs formulated with different percentages of quinoa flour.

Parameters	Control (0)	Quinoa flour level (%)		
		2.5	5	7.5
Moisture (%)	44.06 [d]	46.45 [c]	48.93 [b]	52.50 [a]
Fat (%)	12.66 [a]	12.09 [b]	9.86 [c]	9.80 [c]
Protein (%)	33.38 [b]	33.81 [ab]	34.36 [ab]	38.49 [a]
Ash (%)	2.60 [d]	3.23 [c]	3.89 [b]	4.39 [a]
pH	5.57 [a]	5.59 [a]	5.59 [a]	5.59 [a]
Cooking yield (%)	70.49 [a]	68.44 [b]	66.39 [c]	66.32 [c]
L*	44.32 [a]	43.06 [a]	43.87 [a]	45.38 [a]
a*	9.91 [c]	14.00 [a]	10.94 [b]	11.50 [b]
b*	11.03 [a]	10.20 [b]	9.94 [b]	10.44 [ab]

[a-d]Mean in the same row with different letters are significantly different (p<0.05).

The ash contents of meatball samples formulated with quinoa flour were presented in Table 2. The highest ash content was observed in 7.5% quinoa flour added meatballs as 4.39%. The percentage of quinoa affected the ash content of meatball samples significantly (p<0.05). Similar results of ash contents were obtained by several researchers (BILEK and TURHAN, 2009; AUKKANIT *et al.*, 2015; YILMAZ, 2005). Utilization of quinoa flour affected the pH values of the samples non-significantly (p>0.05). The pH values ranging from 5.57 to 5.59. This is similar with the data of BAUGREET *et al.* (2016) who reported that there was no treatment effect or interaction between treatments among pH values. Also, BILEK and TURHAN (2009) found that the pH values of raw and cooked beef patties enhanced with flaxseed flour at different levels (3%, 6%, 9%, 12% and 15%) were not significantly different between treatments.

From the perspective of meatball production process, cooking yield is the most important factor to guess the characteristic of final products during cooking considering non-meat ingredients (AUKKANIT *et al.*, 2015). It was determined that cooking yield values did not affected by the quinoa flour percentage significantly (p<0.05). Cooking yield value decreased with the increase of quinoa flour percentage. The maximum value was obtained in control samples and the minimum value was found in 7.5% quinoa flour added samples. Similarly, AUKKANIT *et al.* (2015) found that cooking yields of low fat meatballs decreased with the addition of corn silk powder (1-4%). Also, SERDAROĞLU *et al.* (2005) observed that cooking yields ranged between 85.2% and 93.2% for meatballs having

blackeye bean flour and lentil flour resulted in the maximum cooking yield values ($p<0.05$).
The color (L*, a*, b*) values were given in Table 2. The redness and yellowness values were significantly ($p<0.05$) affected by quinoa flour percentage. The lightness of meatballs was measured by Hunter-L. Amount of quinoa had no significant effect on lightness (L*) values ($p>0.05$). The maximum L* values were displayed for 7.5% addition of quinoa flour, which means that the addition of quinoa flour resulted in a lighter-colored product. YıLMAZ and DAĞLıOĞLU (2003) found similar results with oat bran added meatballs. a* (redness) values were also different ($p<0.05$) for different amount of quinoa flour. Therefore, a* values were higher in the samples with quinoa flour than in the control. The highest a* value was for the samples with 2.5% quinoa. Also, the lowest redness value was determined in control group samples. Similarly, BILEK and TURHAN (2009) reported that redness values were the lowest in the uncooked control beef patties (20% fat) when compared with different amounts of flaxseed flour added samples ($p<0.05$).
All values for yellowness were higher in control samples than in the samples formulated with quinoa flour. Quinoa addition appears to decrease product yellowness. TURHAN *et al.* (2005) obtained similar results of yellowness values in low-fat beef burgers produced with hazelnut pellicle.

Table 3. Texture Profile Analysis (TPA) of cooked beef meatballs formulated with different levels of quinoa flour.

Parameters	Control (0)	Quinoa flour level (%)		
		2.5	5	7.5
Hardness (N)	46.382 [a]	46.460 [a]	51.356 [a]	56.359 [a]
Cohesiveness	0.466 [c]	0.494 [bc]	0.499 [b]	0.638 [a]
Springiness	75.143 [b]	78.512 [a]	72.795 [c]	68.016 [d]
Chewiness (N)	15.853 [a]	20.130 [a]	23.632 [a]	20.768 [a]
Gumminess (N)	21.614 [b]	22.951 [b]	25.627 [b]	35.957 [a]

[a-d]Mean in the same row with different letters are significantly different ($p<0.05$).

TPA parameters of meatball samples were given in Table 3. The maximum hardness value was detected in samples of 7.5% quinoa flour and the minimum value was obtained in control samples. The differences of hardness values of the meatballs were nonsignificant ($p>0.05$). Table 3 indicates that increasing quinoa flour level increased hardness. Similar results of hardness values were found by SARıÇOBAN *et al.* (2009) and ULU (2006). Also, AUKKANIT *et al.* (2015) observed that corn silk powder did not affect the hardness values significantly.
Cohesiveness is defined as the degree to which the sample can be deformed before it breaks. Results of statistical analysis demonstrated that the amount of quinoa flour affected the cohesiveness values significantly ($p<0.05$). When the quinoa flour was increased, the cohesiveness values were increased.
Springiness can be defined as the rate at which the deformed beef meatball springs back after the compression (BAUGREET *et al.*, 2016) Quinoa level had a very significant ($p<0.05$) effect on springiness of meatballs. The minimum springiness value was determined in the samples with 7.5% quinoa flour. On the other hand, the maximum springiness value was found in the samples with 2.5% quinoa flour. Similarly, ULU (2006)

determined that guar gum significantly affected the springiness of cooked meatballs produced with 15% and 10% fat levels.

In this study, chewiness values of meatball samples varied between 15.853 N to 23.632 N. Quinoa flour level did not affect the chewiness values significantly (p>0.05). Meatballs with 5% quinoa flour had the maximum chewiness value and the control meatballs had the lowest chewiness value. AL-JUAHIMI *et al.* (2016) reported that the chewiness of uncooked meatballs increased with increment of moringa seed flour.

The amount of quinoa flour displayed a significant (p<0.05) effect on the gumminess values of meatball samples. When the amount of quinoa flour in meatball formulation increased, the gumminess values were increased. All gumminess values were higher in the samples with quinoa flour than in the control groups. The highest gumminess value was found in the samples with 7.5% quinoa flour. Consistent results of gumminess values were determined by AUKKANIT *et al.* (2015). They observed that gumminess increased as the increment of corn silk powder amount.

Duncan's multiple range test results for sensory scores of meatball samples were given in Table 4. All values for color (sensorial) were lower (p<0.05) in the samples with quinoa flour than the control samples.

Table 4. Sensorial Characteristics of cooked beef meatballs formulated with different levels of quinoa flour.

Sensory scores	Control (0)	Quinoa flour level (%)		
		2.5	5	7.5
Color	7.85 [a]	7.13 [b]	7.07 [b]	6.83 [c]
Taste	7.78 [b]	8.28 [a]	8.40 [a]	7.07 [c]
Odor	8.00 [a]	8.34 [a]	8.00 [a]	5.36 [b]
Appearance	8.58 [a]	7.46 [c]	7.83[b]	6.69 [d]
Texture	7.61 [a]	7.57 [a]	7.93 [a]	6.75 [b]
Overall acceptability	8.00 [a]	8.00 [a]	7.93 [a]	6.75 [b]

[a-d]Mean in the same row with different letters are significantly different (p<0.05).

Quinoa flour level had a significant effect on scores of taste (p<0.05). The highest score of taste was determined in meatball samples with 5% quinoa flour. A significant correlation *(r =+ 0.88, p<0.05)* was found between taste and odor scores.

The quinoa flour amount affected the odor significantly (p<0.05). The lowest odor score was found in meatball samples with 7.5% quinoa flour. On the contrary, SERDAROĞLU *et al.* (2005) reported that no differences in flavor scores were observed among treatments containing legume flours (p>0.05). A significant correlation *(r =+ 0.74, p<0.05)* was found between odor and appearance scores.

The mean values of appearance scores were shown in Table 4. The amount of quinoa flour affected the appearance scores significantly (p<0.05). The highest score was determined in the control samples and the lowest appearance score was found in samples with 7.5% quinoa flour. The present findings are agreeing with the findings of TURHAN *et al.* (2005) who reported that increasing the pellicle level resulted in beef burgers with decreased appearance scores. Also, SERDAROĞLU and DEĞIRMENCIOĞLU (2004) determined that adding corn flour (4%), affected the appearance scores (p<0.05) significantly; meatballs with 4% corn flour had lower appearance scores. In this study, a significant correlation *(r =+ 0.91, p<0.05)* was found between appearance and color scores.

Quinoa flour level had significant effect on the texture scores ($p<0.05$). The meatball samples with 5% quinoa flour had the highest texture score and the lowest score was determined in the samples with 7.5% quinoa flour. Similarly, AUKKANIT *et al.* (2015) concluded that meatballs with 4% corn silk powder had the lowest texture scores compared with control and the meatballs with 1%, 2%, 3% of corn silk powder. Also, a significant correlation *($r =+ 0.90$, $p<0.05$)* was determined between texture and taste scores. On the other hand, a significant correlation *($r =+ 0.81$, $p<0.05$)* was found between texture and odor scores.

The overall acceptability score was shown in Table 4. The quinoa level affected the overall acceptance scores significantly ($p<0.05$). The maximum score was observed in the control and samples with 2.5% quinoa flour (8.00). On the other hand, the lowest score was found in the samples with 7.5% quinoa flour (6.75). The scores of overall ACCEPTABILITY decreased as the quinoa flour was increased. Similar results were found by TURHAN *et al.* (2005). A significant correlation *($r =+ 0.92$, $p<0.05$)* was found between acceptability and odor scores. Also, a significant correlation *($r =+ 0.86$, $p<0.05$)* was obtained between acceptability and taste scores.

In this study, 2.5% and 5% of quinoa flour is considered optimum for use an enhancer to the functional properties in beef meatballs. Similarly, SARıÇOBAN *et al.* (2009) concluded that patties enriched with <7.55% wheat bran were determined as more suitable with respect to sensorial overall quality.

4. CONCLUSIONS

In conclusion, the addition of quinoa flour had significant and variable effects on moisture, fat, ash, cooking yield, cohesiveness, springiness, gumminess values and all sensorial characteristics (color, taste, odor, appearance, texture and overall acceptability) of beef meatballs. The addition of quinoa flour improve the protein content compared to control. Considering sensorial analysis, all meatball samples had high acceptability and favorable scores (5.36 and above). In this study, it is found that when the functional properties of beef meatballs are considered, the samples with 2.5% and 5% of quinoa flour give the best results. It is concluded that, in addition to its nutritional value and health benefits of quinoa flour, it has high potential as gluten-free ingredient to use in meatball production instead of bread crumbs.

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