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Effects of quinoa flour on lipid and protein oxidation in raw and cooked beef burger during long term frozen storage

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Abstract

The objective of this work was to assess the effects of quinoa flour in the improving the quality characteristics and oxidation and storage stability (-18 °C for 3 months) of cooked and raw beef burger. The effects of quinoa flour addition (3, 5, 7 and 10%) on physicochemical composition, pH, cooking parameters and dimensional changes, color and texture characteristics of raw and cooked burgers were evaluated. Furthermore, lipid and protein oxidation stability for raw and cooked burgers were determined during long-term frozen storage. The cooking yield and reduction in diameter and thickness of burgers were improved and ash and protein contents of burger increased by the addition of quinoa. The control samples had the highest pH. Texture analysis showed that with the addition of quinoa, hardness values of burger increased and adhesiveness values decreased. All groups showed similar L*, a* and b* values. The results indicated that addition of quinoa significantly decreased TBARS values for raw and cooked burger compared to control group during storage. However, the addition of quinoa flour did not affect protein oxidation level of raw and cooked burger.

Keywords: beef burger; quinoa; lipid oxidation; protein oxidation; quality parameters.

Practical Application: The use of quinoa flour in burger production may provide to improve quality characteristics.

1 Introduction

Consumers often avoid consuming meat and meat products due to health concerns caused by animal fat, saturated fatty acids, cholesterol, sodium nitrite and sodium chloride in meat products (Decker & Park, 2010). However, food and nutritional scientists and some leading health organizations have also suggested that decreasing harmful components in meat products to human health and food and nutritional scientists and some leading health organizations have also suggested that decreasing harmful components in meat products to human health and improved meat products compositions with incorporated health enhancing ingredients (Lachance & Fisher, 2005). Enrichment of meat products with some vegetable source compounds such as some cereals and fruits have been considered as a good strategy to development of functional meat products and studied extensively in recent years. The quinoa, which is shown as one of the most valuable of these vegetable sources, has also begun to be tried in the formulations of different products in many studies and their results have shown that quinoa can be very important ingredient for improving food quality and nutritional value (Arihara, 2006; Wang & Zhu, 2016; Zhang et al., 2010).

Quinoa (*Chenopodium quinoa* Willd.) is a seed crop, which has some healthy properties such as easy to digest and a good sources of protein, dietary fiber, minerals and essential amino acids e.g. lysine, methionine and histidine (Ramos Diaz et al., 2015; Ibrahium, 2015). Additionally, the quinoa seed contains antioxidant compounds such as carotenoids and flavonoids (Dini et al., 2010; Maradini et al., 2017). Because of these important features, the enrichment of food products with quinoa became the interest of food industry to development of functional foods. Some studies have indicated that quinoa may be used as a diet supplement and binder because of its carbohydrate, fiber and protein content (Ramos Diaz et al., 2015, 2016). Although there are many studies about using quinoa and quinoa flour in different food manufacturing technologies such as bread, baby foods, flakes and beer, studies about using quinoa and quinoa flour in meat and meat products technology are limited in the literature(James, 2009; Maradini et al., 2017; Wang & Zhu, 2016).

The main objective of this research was to evaluate the efficiency of added quinoa flour for inhibiting the development of lipid and protein oxidation further during freeze storage in cooked and raw beef hamburger. Furthermore, it was investigated the effect of quinoa flour on the quality parameters such as cooking parameters, pH, color, moisture, protein, fat, ash, texture and in hamburger patties.

2 Materials and methods

2.1 Beef burger preparation

24 h post-mortem boneless beef cuts (*M. longissimus dorsi*), beef back fat and other ingredients were purchased from a butcher shop (Nevşehir, Turkey). All subcutaneous fat and intermuscular fat was removed from the muscles and were ground through a 4 mm plate grinder. Whole grain quinoa were purchased from local food stores (Nevşehir, Turkey) and quinoa was milled to fine flour using

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a grinding device (Yücebaş Machinery, Izmir, Turkey). The burger contained 70% lean meat and 15% fat. Other ingredients added were as follows: 2% NaCl, 4% grated onion, 1% grated garlic, 7% breadcrumbs, 0.5% black pepper and 0.5% cumin. Control groups were produced as in the above-described formulation, and other treatments were produced without breadcrumbs and with 3, 5, 7 and 10% quinoa flour, respectively. Hamburger dough was randomly divided into five treatment groups (2 kg each) and processed into burger that has 1 cm thickness, 90 mm diameter and 50 g weight by using a metal shaper. 1 kg of each batch burger was stored -18 °C for 90 days in vacuum-packages and other 1 kg of each batch burger was cooked using an electric plate. Cooking time was 3 min per side of the burgers and the core temperature was 70 ± 2 °C at the end of the cooking time. The cooked burger was also stored -18 °C for 90 days in vacuum-packages. The entire experiment was replicated three times on separate processing days.

2.2 Physicochemical composition

Fat, protein, ash, moisture content and pH of all burgers were measured using Association of Official Analytical Chemists (2000) procedure. The pH was determined using pH meter (HI 9024, Hanna Instruments, Germany). pH meter was calibrated against 4 and 7 pH buffer standards.

2.3 Cooking measurements

Cooking measurements were done on three replicates per treatment. Cooking yield, fat and moisture retention, reduction in diameter and thickness and shrinkage in diameter of burger was determined in cooked burgers (El-Magoli et al., 1996; Modi et al., 2004; Murphy et al., 1975).

2.4 Lipid oxidation measurement

The formations of thiobarbituric acid reactive substances (TBARS) were determined for evaluation of lipid oxidation stability. TBARS values of samples were determined as described by Kilic & Richards (2003) at the manufacturing day and during storage period (7, 15, 30, 60, 90 d) for raw and cooked burgers. This method requires addition of EDTA and propyl gallate to the trichloroacetic acid (TCA) extraction solution to prevent the development of TBARS during the analytical procedure. Briefly, 1 g burger sample was weighted and blended into 6 mL of extraction solution (EDTA, propyl gallate and trichloroacetic acid). The sample was homogenized for 15 s. The homogenate was filtered through filter paper (Whatman No: 1). Then, 1 mL filtrate was mixed with 1 mL of thiobarbituric acid (TBA) and vortexed. The mixture was heated at 100 °C for 40 min. After cooling, the sample was centrifuged at 2000 x g for 5 min. Absorbance was determined at 532 nm against a blank containing 1 mL TCA extraction solution and 1 mL TBA solution. The TBARS values were expressed as μmol TBARS per kg meat.

2.5 Protein oxidation measurement

The total carbonyl content were determined for evaluation of protein oxidation stability and as described by Laudadio & Tufarelli (2011) at the manufacturing day and during storage period (7, 15, 30, 60, 90 d) for raw and cooked burgers. Briefly, 1 g burger sample was homogenized in 20 mM sodium phosphate buffer containing 6 M NaCl (pH 6.5) for 1 min. Then, 0.2 mL were taken from the homogenates and proteins were precipitated by cold 1 mL TCA (10%) with centrifugation process for 5 min at 4200 *g*. One pellet was treated with 1 mL 2 M HCl for measurement of protein concentration and the other with an equal volume of 0.2% (w/v) dinitrophenylhydrazine in 2 M HCl for measurement of carbonyl concentration. Samples were incubated for 1 h at room temperature (22-24 °C). Then, samples were precipitated by 1 mL TCA (10%) and washed three times with 1 mL ethanol: ethyl acetate (1:1, v/v) to remove excess dinitrophenylhydrazine. The pellets were dissolved in 1.5 mL of 20 mM sodium phosphate buffer containing 6 M guanidine HCl (pH 6.5), stirred and centrifuged for 2 min at 4,200*g*. Protein concentration was calculated from the absorption at 280 nm using bovine serum albumin as the standard. The amount of carbonyls was expressed as nmol of carbonyl per mg of protein using an absorption coefficient of 21.0 nM^{-1} cm^{-1} at 370 nm for protein hydrazones.

2.6 Color measurement

Color measurement was conducted by a Hunterlab model Precise Color Reader TCR 200 (BAMR Ltd., Claremont, South Africa) colorimeter using D65 as a standard daylight illuminant and a standard observer position of 10°. 8-mm-diameter circle and the specular component included (SCI) mode was used to measure. The colorimeter was standardized against a white calibration plate (D65, L*=97.79, a*=−0.11, b*=2.69). Three readings were taken and averaged for each of the three replications. Color values were determined at the manufacturing day and during storage period (7, 15, 30, 60, 90 d) for raw and cooked burgers.

2.7 Texture profile analysis

Texture profile analysis (TPA) tests were performed on cooked samples at 4 ± 1 °C using a texture analyzer (Brookfield, CT3, Middleboro, MA, United States) to determine hardness (N), adhesiveness (Ns), springiness, cohesiveness, and resilience. Samples were cut into (1 × 1 × 1 cm) from cooked burger and then held for equilibration to room temperature (20 °C), wrapped with plastic film for TPA. Test conditions were: probe (aluminum rectangular probe; 5 cm × 4 cm); test speed 5 mm/s; pre-test speed 2 mm/s, post-test speed 2 mm/s; compression 70% and 50 kg load cell. Three replicate measurements were taken for each sample per treatment and TPA parameters were determined as described by Bourne (1978).

2.8 Statistical analysis

The results were expressed as mean values with standard errors from the three replications. The statistical evaluation of the results was performed using the SPSS 22.0.0 (SPSS Inc., Chicago, USA). Data collected for chemical composition and physicochemical properties of burgers were analyzed by one-way analysis of variance (ANOVA). A completely randomized design was used with 5 treatment groups and 3 replications. The treatments were one control group and four groups, which were assigned, and the data were analyzed using general linear model (GLM)

procedure, in which treatment groups and storage time were assigned as fixed effects and replications as a random effect. Duncan multiple comparison test was used to compare mean values and differences among mean values were considered significant when $P<0.05$.

3 Results and discussion

3.1 Physicochemical composition analysis

Physicochemical properties of used quinoa flour were determined and results showed that it contained 57.23% ± 0.4 carbohydrates, 14.94% ± 0.2 protein, 8.32% ± 0.2 fat, 3.12% ± 0.1 ash and 10.29% ± 0.1 dietary fiber. Additionally, pH of an aqueous dispersion of quinoa flour was 5.72 ± 0.1. The determined mean proximate compositions for quinoa are consistent with the literature (James, 2009; Kozioł, 1992; Ruales & Nair, 1993).

The physicochemical compositions of raw and cooked beef burger formulated with different levels of quinoa flour are given in Table 1.

The use of quinoa flour had shown significant differences in protein and ash content for raw burger and protein and fat content for cooked burger ($P<0.05$). The protein content for both raw and cooked burger was lower in control groups than other treatment groups ($P<0.05$). Also, the highest fat content for cooked burger and lowest ash content for raw burger was determined in burger with 7% and 10% quinoa flour ($P<0.05$). The effects of added quinoa flour on fat content may be related with the oil holding function of quinoa flour that leading to more oil retention in meat products during cooking process. Previous studies also support this idea and have reported that an increase in protein and ash content in produced meat products with vegetable ingredients was observed as the level of replacement with vegetable ingredients increased (Hu & Yu, 2015; Liu et al., 2015; Talukder, 2015).

The pH values of raw and cooked burger samples were observed during 90d storage (data is not presented). pH values ranged from 5.72 to 5.68 for raw burger and ranged from 5.83 to 5.98 for cooked burger on the manufacturing day. Results of pH analysis showed that quinoa flour had a non-significant effect on pH of the raw burger during manufacturing and storage period. However, significant differences in pH for cooked burgers were determined at the manufacturing and storage periods ($P<0.05$). The pH values of cooked burger samples decreased depending on the amount of added quinoa flour in the burger formulation and control group had highest pH level among the other treatment groups at the manufacturing day ($P<0.05$). The reason of decrease in pH of cooked burger may be related to fat and moisture retention ability of quinoa and pH of quinoa (pH 5.72). Some researchers have reported that the change in pH on addition of vegetable source largely depends upon the pH of the added source and generally, plant-derived components, which had acidic pH, when incorporated in meat products reduced pH of products as the level of incorporation increased. (Aleson-Carbonell et al., 2004; Dzudie et al., 2002; Grigelmo-Miguel et al., 1999). During the storage period, pH of beef burger samples insignificantly decreased and were shown a similar trend in both raw and cooked samples.

3.2 Cooking measurements analysis

Cooking characteristics of burgers are given in Table 2. The use of quinoa flour in burger showed a significant effect on all cooking properties values ($P<0.05$). Cooking yield varied between 58.65% and 84.27% and the highest yield was found in samples with 10% quinoa flour. Similarly, highest fat and moisture retention value also were found in burger with 10% quinoa flour ($P<0.05$). When increasing the amount of quinoa flour from 3% to 10%, cooking yield, moisture and fat retention of burger significantly increased ($P<0.05$). Generally, it can be said that the use of 3 and 5% quinoa flour and control group that contain 7% breadcrumbs in burger, had similar cooking characteristics. Additionally, quinoa flour significantly improved the reduction in diameter and thickness and shrinkage of burger ($P<0.05$).

The lowest shrinkage values and reduction in diameter and thickness were determined in burger with 10% quinoa flour ($P<0.05$). This improvement on cooking parameters could be related with functional properties of quinoa flour.

Table 1. Physicochemical composition* of raw and cooked beef burger.

	Quinoa level (%)	Protein (%)	Fat (%)	Moisture (%)	Ash (%)
Raw Beef Burger	0	23.34^{c}	15.79^{a}	56.98^{a}	3.89^{b}
	3	24.06^{b}	15.92^{a}	56.03^{a}	4.02^{b}
	5	24.34^{ab}	15.82^{a}	55.75^{ab}	4.10^{b}
	7	24.42^{ab}	15.81^{a}	55.32^{ab}	4.45^{a}
	10	24.89^{a}	15.78^{a}	54.76^{b}	4.58^{a}
	SEM	0.05	0.09	0.11	0.04
Cooked Beef Burger	0	27.25^{c}	20.83^{b}	47.12^{a}	4.71^{a}
	3	27.72^{b}	20.57^{c}	47.19^{a}	4.62^{ab}
	5	27.88^{ab}	20.81^{bc}	46.86^{ab}	4.53^{ab}
	7	28.01^{a}	21.63^{a}	46.06^{b}	4.34^{ab}
	10	28.08^{a}	22.06^{a}	45.61^{b}	4.25^{b}
	SEM	0.05	0.05	0.06	0.03

SEM = standard error of the mean; (n = 45); ^{a,b} (↓) Different letters within a column are significantly different (P<0.05); *All values are the mean of three replicates.

Many studies reported that quinoa flour has high water and oil holding capacity, emulsifying and foaming capacity, gelation properties (Abugoch et al., 2008; James, 2009; Lindeboom, 2005; Ogungbenle et al., 2009). Dietary fiber, starch and protein in quinoa flour increased cooking yield and decreased shrinkage of burger samples. These results agree with studies about meat products containing dietary fiber and some vegetable protein and bakery products containing quinoa flour (Ergezer et al., 2014; Park & Morita, 2005; Rizzello et al., 2009).

3.3 Lipid oxidation analysis

The oxidative rancidity measured by TBARS values is presented in Table 3. The TBARS values for both raw and cooked burger gradually increased during storage period (P<0.05). The use of quinoa flour in burger had shown no significant effect on TBARS values at the manufacturing day for both raw and cooked burger. However, TBARS values of raw burger with 5, 7, 10% quinoa flour had lower than other treatment groups during the first month of storage (P<0.05) and control group had highest TBARS values at 60 and 90 days of storage (P<0.05).

The antioxidant effect of quinoa flour has been identified in raw beef burger at all usage rates (3, 5, 7, 10%) during -18 °C storage for 90 days. Previous studies reported that quinoa has remarkable and higher antioxidant activity than some cereals because of its phenolic and flavonoid content and it can be used as a source of free radical scavenging agents (Gorinstein et al., 2008; James, 2009; Zhu et al., 2001). The use of quinoa flour in cooked burger had shown no significant effect on TBARS values during the first week of storage, unlike the raw burger. After the 7d of storage, group with 5% quinoa flour had lowest TBARS values in the rest of storage period (P<0.05). TBARS values during the storage period were found to be at the same level for control, 7% and 10% quinoa flour group. This situation may be associated with moisture and oil retention function of quinoa flour. Both 7% and 10% quinoa flour groups had higher fat and moisture binding than other treatments during the cooking process, and so fat and moisture content that are important components for oxidative stability are higher than other groups. Therefore, degrees of oxidative rancidity for 7% and 10% quinoa flour group were at the same level for control.

Table 2. Cooking parameters* of beef burger formulated with different levels of quinoa flour.

Quinoa level (%)	Cooking yield (%)	Fat retention (%)	Moisture retention (%)	Reduction in diameter (%)	Reduction in thickness (%)	Shrinkage (%)
0	58.65^{e}	16.36^{d}	21.35^{b}	16.45^{ab}	26.60^{b}	-30.67^{a}
3	63.49^{d}	12.15^{e}	17.73^{d}	17.52^{a}	33.28^{a}	-44.67^{b}
5	75.17^{c}	18.51^{c}	19.22^{c}	15.42^{b}	25.01^{b}	-47.33^{b}
7	80.78^{b}	23.28^{b}	24.83^{a}	7.17^{c}	21.99^{c}	-58.67^{c}
10	84.27^{a}	28.66^{a}	26.51^{a}	4.10^{d}	20.10^{c}	-63.33^{c}
SEM	0.05	0.04	0.05	0.03	0.06	0.09

SEM = standard error of the mean; (n = 45); $^{a-e}$ (↓) Different letters within a column are significantly different (P<0.05); *All values are the mean of three replicates.

Table 3. TBARS levels* of raw and cooked beef burger formulated with different levels of quinoa flour at manufacturing and storage period (µmol TBARS / kg meat).

	Quinoa level (%)	Manufacturing day	-18 °C Storage (days)						SEM
			1 d	7 d	15 d	30 d	60 d	90 d	
Raw beef burger	0	1.80^{aG}	2.33^{aF}	2.67^{aE}	3.30^{aD}	5.07^{aC}	8.51^{aB}	11.49^{aA}	0.05
	3	1.90^{aG}	2.29^{aF}	2.64^{aE}	3.27^{aD}	4.91^{aC}	7.92^{bB}	11.02^{bA}	0.08
	5	1.86^{aG}	2.14^{bF}	2.48^{bE}	3.09^{bD}	4.71^{bC}	7.68^{cB}	10.01^{cA}	0.05
	7	1.90^{aG}	2.10^{bF}	2.43^{bE}	3.03^{bD}	4.56^{cC}	7.47^{dB}	9.76^{dA}	0.06
	10	1.80^{aG}	2.03^{cF}	2.42^{bE}	3.00^{bD}	4.17^{dC}	6.82^{eB}	9.35^{eA}	0.08
	SEM	0.09	0.06	0.07	0.04	0.07	0.08	0.11	
Cooked beef burger	0	2.29^{aG}	2.74^{aF}	3.29^{aE}	4.17^{aD}	6.18^{aC}	9.98^{abB}	13.97^{abA}	0.02
	3	2.35^{aG}	2.70^{bF}	3.21^{bE}	4.02^{bD}	6.06^{bC}	9.81^{bB}	13.00^{bA}	0.06
	5	2.30^{aG}	2.51^{cF}	3.09^{cE}	3.60^{cD}	5.35^{dC}	8.59^{dB}	10.64^{dA}	0.05
	7	2.31^{aG}	2.64^{bcF}	3.17^{bcE}	3.95^{bD}	5.79^{cC}	9.41^{cB}	12.29^{cA}	0.08
	10	2.26^{aG}	2.76^{abF}	3.27^{abE}	4.12^{abD}	6.28^{aC}	10.23^{aB}	14.48^{aA}	0.05
	SEM	0.03	0.02	0.06	0.03	0.05	0.13	0.05	

SEM = standard error of the mean; (n = 45); $^{a-e}$ (↓) Different letters within a column are significantly different (P<0.05); $^{A-G}$ (→) Different letters within a raw are significantly different (P<0.05); *All values are the mean of three replicates.

3.4 Protein oxidation analysis

No significant effect on protein oxidation was observed related to using quinoa flour in raw and cooked burger during frozen storage (Table 4).

Protein oxidation levels for both raw and cooked burger gradually increased during storage period ($P<0.05$). Some researchers have reported that lipid and protein oxidation may be related in certain oxidizing systems and the timely interaction in several meat systems (Lund et al., 2011; Mercier et al., 1998). However, our results are different from this opinion. While the lipid oxidation level in using quinoa flour group had lower than control, there are no significant differences were determined for protein oxidation levels among all groups. These results may be related may be related to increasing protein and some essential amino acids content such as lysine, methionine and histidine which are abundant in quinoa and play important role in protein oxidation. Laudadio & Tufarelli (2011) reported that the oxidative degradation occurs on side chains of lysine and histidine amino acids and forms carbonyl compounds. Therefore, the reason to obtained unlike results with lipid oxidation in protein oxidation results may be related with increasing the protein and some essential amino acids content such as lysine, methionine and histidine due to the quinoa addition.

3.5 Color analysis

Quinoa flour was shown a similar effect on color values (L*, a*, b*) in raw and cooked burger (data is not presented). The use of quinoa flour in raw and cooked beef burger resulted in increased L* and b* values at a level of 7 and 10% ($P<0.05$) and decreased a* values at a level of 10% ($P<0.05$). During the storage period, pigment oxidation has taken place and redness values decreased (Jouki & Khazaei, 2012). Our results were similar to some previous studies about the use of some flour in meat products and researchers have indicated that responsible of color differences in meat products used different flour has the dilution of meat pigments rather than the color of the flour additives (Alakali et al., 2010; Ergezer et al., 2014; Tabarestani & Tehrani, 2014).

3.6 Texture profile analysis

The use of quinoa flour in cooked burger had shown a significant effect on all textural properties except resilience, cohesiveness and springiness index (Table 5).

Table 4. Carbonyl protein levels* of raw and cooked beef burger formulated with different levels of quinoa flour at manufacturing and storage period (nmol DNPH / mg protein)

	Quinoa level (%)	Manufacturing day	-18 °C Storage (days)						SEM
			1 d	7 d	15 d	30 d	60 d	90 d	
Raw beef burger	0	0.43^{aF}	0.43^{aF}	0.53^{aE}	0.67^{aD}	1.09^{aC}	1.25^{aB}	1.43^{aA}	0.04
	3	0.41^{aF}	0.44^{aF}	0.54^{aE}	0.67^{aD}	1.11^{aC}	1.23^{aB}	1.46^{aA}	0.06
	5	0.42^{aF}	0.44^{aF}	0.58^{aE}	0.69^{aD}	1.11^{aC}	1.21^{aB}	1.37^{bA}	0.04
	7	0.44^{aF}	0.46^{aF}	0.53^{aE}	0.63^{abD}	1.14^{aC}	1.29^{aB}	1.44^{aA}	0.05
	10	0.42^{aF}	0.46^{aF}	0.59^{aE}	0.61^{bD}	1.13^{aC}	1.24^{aB}	1.39^{abA}	0.03
	SEM	0.09	0.07	0.12	0.04	0.05	0.14	0.06	
Cooked beef burger	0	0.62^{aF}	0.61^{aF}	0.71^{aE}	0.82^{bD}	1.18^{aC}	1.56^{bB}	1.86^{abA}	0.06
	3	0.60^{aF}	0.62^{aF}	0.71^{aE}	0.84^{abD}	1.20^{aC}	1.56^{bB}	1.91^{aA}	0.11
	5	0.58^{aF}	0.61^{aF}	0.72^{aE}	0.83^{bD}	1.24^{aC}	1.60^{abB}	1.93^{aA}	0.08
	7	0.61^{aF}	0.62^{aF}	0.75^{aE}	0.85^{abD}	1.23^{aC}	1.64^{aB}	1.87^{abA}	0.04
	10	0.59^{aF}	0.61^{aF}	0.77^{aE}	0.88^{aD}	1.24^{aC}	1.69^{aB}	1.84^{bA}	0.07
	SEM	0.11	0.08	0.07	0.16	0.10	0.09	0.08	

SEM = standard error of the mean; (n = 45); $^{a-b}$ (↓) Different letters within a column are significantly different (P<0.05); $^{A-F}$ (→) Different letters within a row are significantly different (P<0.05); *All values are the mean of three replicates.

Table 5. Texture profile analysis* of cooked beef burger.

Quinoa level (%)	Hardness (N)	Adhesiveness (mj)	Resilience	Cohesiveness	Springiness Index	Gumminess (N)	Chewiness Index
0	92.20^{c}	-6.12^{b}	0.16^{bc}	0.38^{a}	0.61^{a}	88.12^{b}	905.45^{b}
3	97.61^{a}	-5.64^{c}	0.13^{c}	0.36^{a}	0.56^{a}	109.60^{a}	1006.12^{a}
5	88.72^{b}	-6.04^{b}	0.21^{a}	0.35^{a}	0.64^{a}	94.65^{b}	864.24^{c}
7	80.67^{c}	-6.65^{b}	0.27^{ab}	0.31^{a}	0.63^{a}	90.12^{b}	760.68^{d}
10	72.11^{d}	-10.06^{a}	0.20^{b}	0.34^{a}	0.61^{a}	71.25^{c}	641.27^{e}
	0.12	0.21	0.06	0.65	0.11	0.15	0.18

$^{a-e}$ (↓) Different letters within a column are significantly different (p<0.05); *All values are the mean ± standard error of three replicates.

Burger with 10% quinoa flour had the lowest hardness, adhesiveness, gumminess and chewiness index values and however, burgers with the 3% quinoa flour had the highest values for these properties ($P<0.05$). Responsible for these results may be hydrochemical and physical properties of components in quinoa flour. Some researchers reported that carbohydrates such as starch and dietary fiber component in the added vegetable sources may interact with water and fat of meat products to form a softer texture thus leading to a change in textural properties (Ergezer et al., 2014; Kurt & Kilincceker, 2012). Similar results have been reported the use of some ingredients such as oatmeal, Nata, rice bran (Choi et al., 2011; Lin & Lin, 2004; Yang et al., 2007).

4 Conclusıon

Production of beef burger with the quinoa flour can be improved nutritional quality of burger without adversely affecting the quality characteristics. Ash and dietary fiber content of burger can be increased and protein and essential amino acids content can be enhanced by vegetable protein by using quinoa flour. Additionally, use of quinoa flour inhibited lipid oxidation during frozen storage for both raw and cooked burger.

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