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Effect of quinoa seed and tiger nut mixture on quality characteristics of low-fat beef patties

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Abstract

The present work aimed to investigate the effect of a newly proposed mixture of quinoa seeds and tiger nuts (QTM) (1:1) on low-fat beef patties. The chemical composition, vitamins, minerals, and antioxidant activity of QTM were determined. The chemical composition, water-holding capacity, cooking loss, and sensory evaluation of low-fat beef patties prepared with 10% QTM as a partial fat replacer were also studied. Microbiological quality of frozen minced meat semi-finished products (burger patties, at -18°C) for 126 days was also determined. Based on the results, QTM contained 14.35% lipid, 9.37% protein, and 11.38% dietary fibre. Moreover, QTM also contained good amount of minerals and vitamins. The antioxidant activity of QTM was 20.41 mg/g. Results also showed that the addition of QTM had a positive effect on the sensorial quality of beef patties. Chemical composition, water-holding capacity, cooking loss, and pH profiles of newly formulated burger patties significantly improved following the addition of 10% QTM as a partial fat replacer. During the storage of semi-finished products, thiobarbituric values showed that the newly formulated beef patties had a lower level of lipid oxidation as compared to control. With lower microbial loads and lipid oxidation, the shelf life of the newly formulated beef patties also significantly increased as compared to control. As the conclusion, QTM could be applied as a functional component in meat products.

Introduction

The alterations in eating habits following the shift in community's awareness in the past decades have motivated the population to search for affordable and healthy diets with pleasant taste and attractive appearance. To this end, food manufacturers are continually striving to modify and develop innovative formulations to extend the foods' shelf life by enhancing their safety and quality characteristics. Furthermore, various dietary supplements (functional foods) are currently being used to help in the therapy of various diseases. For these reasons, food manufacturers are also constantly developing novel additives especially those of plant origin (Hawkesworth *et al.,* 2010; Shao *et al.,* 2017; Abedelmaksoud *et al.,* 2018a; 2018b; 2019a; 2019b; Dial and Musher-Eizenman, 2019). At present, insufficient attention has been paid to biologically active ingredients / additives obtained from various plant species growing in Africa, South America, and other countries with hot climates. Given the insufficient amount of raw meat to meet the global dietary protein demand, the challenge is to replace and enrich the raw meat with ingredients from plant origin. For example, raw materials of plant sources with high protein content such as isolated soy protein (90% protein) and wheat gluten (80% protein) can be used (Wang *et al.,* 2016; Mykhailenko *et al.,* 2019).

The presence of large amount of animal fat in meat products accelerates lipid oxidation which leads to decreased shelf life. Lipid oxidation in meat products during processing and storage has a negative impact on important quality characteristics such as taste, colour, and nutritional value. Various types of plant additives that have antioxidant activity could be used to extend the shelf life of processed meat. In recent years, the application of natural antioxidants in food has increased (Verma *et al.,* 2019). Much attention has been paid to food additives derived from nuts, fruits, vegetables, herbs, and spices to fortify food products with dietary fibre and micro- and

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macroelements, increase shelf life, improve taste, and extend the range of meat products (Mariutti and Bragagnolo, 2017).

One of the non-traditional plant supplements is quinoa [*Chenopodium quinoa* C.L. Willdenow (Willd.)], which is a grain traditionally used for nutrition. It grows principally in Peru, Ecuador, Bolivia, Chile, Argentina, and Colombia. Lately, it has also been used in North America, Europe, and Africa. Quinoa is of ancient origin, and belongs to the Inca civilisation. Quinoa was one of the three main types of food, along with corns and potatoes, and the Inca regarded it as the "golden grain" (FAO, 2011; Bazile *et al.,* 2016; Zapata and Pava, 2018; Fernández-López *et al.,* 2020).

Due to its tolerance towards extreme environmental conditions and its nutritional value and biological characteristics, quinoa is considered "one of the crops of the 21st century". Besides, it contains important proteins with a balanced content of essential and non-essential amino acids, lipids, dietary fibres, minerals, and vitamins (Sezgin and Sanlier, 2019). In addition, quinoa contains a large number of phytochemicals including saponins, phytosterols, phenolic compounds, and biologically active peptides. The presence of these compounds can have beneficial effect on the metabolic processes, and in the prevention and treatment of cardiovascular and gastrointestinal tract diseases (Repo-Carrasco-Valencia and Serna 2011; Navruz-Varli and Sanlier, 2016). Quinoa flour is used to make several toasted and baked products such as breads, cookies, noodles, macaroni, and pancakes. Also, in South America, quinoa seeds are used in the making of beer or a traditional ceremonial alcoholic drink called "chicha" (Baioumy *et al.,* 2014; Maradini-Filho, 2017).

Another non-traditional plant additives is the tiger nuts (*Cyperus esculentus* L.). Tiger nut grows in wet environment with different types ranging from 24 to 55 cm. It has triangular stems, and yellow and green leaves. The most valuable part of tiger nut is its tubers that have fibrous structure (Carvalho Barros *et al.,* 2020). Tiger nuts contain a significant amount of starch, sucrose, and lipid. Widely known in Egypt, it is consumed as a traditional snack after being soaked in water or blanched. It is also used as powder in drinks. In Spain, tiger nuts are traditionally used to produce oil for food processing. Further, not only the tubers of tiger nuts are used, but also the green parts as animal feeds; both fresh and as silage. Tiger nuts are one of the ancient plants found in Egyptian archaeological excavations. The ancient Egyptians used tiger nuts for medical purposes such as cleaning the mouth, enema, ophthalmology, ointment for dressing wounds, and as incense for fumigating houses and clothing, along with myrrh incense. From Egypt, Arab merchants brought the tiger nuts to Africa and Spain (Yeboah *et al.,* 2012; Bobreneva and Baioumy, 2018).

Thus far, there have been no studies carried out in the development of a mixture of quinoa seeds and tiger nuts as a fat replacer in low-fat beef patties. Therefore, the objective of the present work was to study the characteristics of this new mixture and its impact on the quality characteristics of low-fat beef patties when used as a fat replacer.

Materials and methods

Chemicals and raw materials

Chemicals and reagents used in the present work were purchased from Sigma-Aldrich Chemical Co. (Germany). Quinoa seeds were purchased from a regional market in Moscow, Russian. Tiger nuts were purchased from Egypt. The plant materials were washed, dried, and finely ground to obtain the powder which would be used in the formulation of beef patties.

Preparation of beef patties

The control beef patties were prepared without the addition of plant mixture following the Egyptian Organisation for Standardization (ES: 1688/2005 ICS: 67.120.10). In the newly formulated beef patties (treatment), animal fat was replaced with the plant mixture at 10% w/w (hydrated form 1:1 of quinoa seeds and tiger nuts). The 10% mixture was selected based on previous experiments (Bobreneva and Baioumy, 2018; Baioumy *et al.,* 2018) which yielded the highest sensory scores.

The ingredients (per kg) for control and treatment samples were the same except for the replacement of 10% animal fat with plant mixture: lean meat (650 g), animal fat (150 g) [animal fat (50 g), plant mixture (100 g) in treatment], soy flour (100 g), salt (17 g), onion (50 g), milk powder (20 g), and spice (13 g). Both control and treatment samples were formed with a mass of 100 g and a diameter of 10 cm, and then they were wrapped and stored frozen (-18°C) until further analyses.

Chemical composition

Moisture and ash contents were determined by the method described in AOAC (2010), crude protein content by the Kjeldahl method, and crude fat content by the Soxhlet fat extraction method (AOAC, 2010). Crude fibre content was determined after boiling 5 g defatted sample in refluxing sulphuric acid and sodium hydroxide. Carbohydrate content was determined by difference (subtraction of protein, fat, moisture, fibre, and ash from 100).

Minerals and vitamins

Mineral content was determined by atomic absorption spectrophotometric methods according to AOAC (2010). Sodium (Na), potassium (K), magnesium (Mg), phosphorus (P), iron (Fe), zinc (Zn), copper (Cu), and calcium (Ca) contents were determined for each sample. Vitamin C was determined by spectrometric method coupled with DNPH procedures. Vitamins B_1, B_2, B_6, and E were determined by method described by Granda *et al.* (2018).

pH

pH was determined by mixing 10 g of sample with 100 mL of distilled water for 30 s, and the solution was measured using a pH meter (Jenway 3510 pH meter) according to Fernández-López *et al.* (2006).

Cooking loss and thiobarbituric acid value

Samples were grilled using a pre-heated electric griller at 148°C for about 6 min, then turned, and grilled for another 4 min. To determine the cooking loss, the samples were weighed before and after cooking, and the percentage of loss was determined (Ali *et al.,* 2011). Thiobarbituric acid (TBA) was determined by the distillation method outlined by Tarladgis *et al.* (1960) and modified by Kirk and Sawyer (1991).

Water holding capacity

Water holding capacity (WHC) was determined as explained by Verbeken *et al.* (2005) with slight modifications. Briefly, each sample (1 g) was mixed with 10 mL of distilled water in a centrifuge tube, vortexed for 5 min, and then centrifuged for 30 min at 5,000 rpm. Next, supernatant was removed, and the weight of centrifuge tube (plus pellet) was measured. The WHC was determined using Eq. 1:

$$\% \text{ WHC} = [\text{weight of tube before centrifugation (g)} - \text{weight of tube after centrifugation (g)} - \text{weight of total sample (g)}] / \text{weight of total sample (g)} \times 100 \quad \text{(Eq. 1)}$$

Antioxidant activity

Antioxidant activity was determined by the device "Expert-006" coulometric titration using electrogenerated halogens. This method allows for estimating the total antioxidant activity. The method of coulometric titration is considered the most effective due to the ability of bromine to enter into reactions radical, redox, electrophilic substitution, and joining of multiple bonds, thereby encompassing all sorts of antioxidants in raw materials (Potoroko *et al.,* 2017).

Microbiological analysis

Total plate count (TPC), yeast and mould count (YMC), coliform count, and *Salmonella* count were determined as recommended by APHA (1976) and Difco manual (Difco Laboratories, 1984).

Sensorial analysis

Sensorial analysis of cooked samples was carried out as stated by Watts *et al.* (1989). Pieces from cooked samples were prepared and served warm for the analysis. Ten qualified and trained panellists were recruited among the staff of Department of Technology and Biotechnology of Food Products of Animal Origin, Moscow State University of Food Production to test the cooked samples.

Statistical analysis

One-way ANOVA was performed using XLSTAT software (Addinsoft, New York, USA). Duncan test was perform to evaluate the differences between means of all treatments at significant level of $p \leq 0.05$.

Results and discussion

Chemical composition of quinoa seeds, tiger nuts, and their mixture

The chemical compositions of quinoa seeds, tiger nuts, and their mixture are shown in Table 1, while the vitamin and mineral contents and antioxidant activity of quinoa seeds, tiger nuts, and their mixture are shown in Table 2. Quinoa seeds contained the highest amount of protein (14.12%) as compared to tiger nuts. Based on available data, quinoa seeds contain higher protein than barley, rice, rye, sorghum, and corn, and almost similar to wheat (USDA, 2015). Quinoa affords a protein content comparable to milk casein, and also contains essential amino acids. Quinoa is an example of rare plant that affords all of the amino acids required by human, and in contrast to grain protein deficient, mainly lysine, quinoa proteins are of high quality (Maradini-Filho, 2017).

Based on Table 1, the contents of lipid and

Table 1. Chemical composition of quinoa seeds, tiger nuts, and their mixture (g/100 g).

Parameter	Chemical composition (%)		
	Quinoa seed	Tiger nut	Mixture (1:1)
Moisture	13.28 ± 0.12^{a}	7.82 ± 0.09^{c}	10.35 ± 0.17^{b}
Ash	2.37 ± 0.06^{b}	2.43 ± 0.1^{a}	2.47 ± 0.14^{a}
Protein	14.12 ± 0.05^{a}	4.73 ± 0.08^{c}	9.37 ± 0.13^{b}
Fat	6.27 ± 0.08^{c}	22.64 ± 0.12^{a}	14.35 ± 0.11^{b}
Carbohydrate	56.80 ± 0.15^{a}	46.61 ± 0.18^{c}	52.08 ± 0.11^{b}
Dietary fibre	7.16 ± 0.04^{c}	15.77 ± 0.08^{a}	11.38 ± 0.14^{b}

Means within the same parameter followed by different lowercase superscripts indicate significant differences between treatments ($p \leq 0.05$).

Table 2. Vitamins, minerals, and antioxidant activity in quinoa seeds, tiger nuts, and their mixture.

Parameter	Quinoa seed	Tiger nut	Mixture (1:1)
Vitamin (mg/100 g)			
Vitamin C	12.01 ± 0.01^{a}	10.13 ± 0.02^{c}	11.0 ± 0.02^{b}
α-tocopherol (E)	2.44 ± 0.02^{c}	5.26 ± 0.03^{a}	3.82 ± 0.02^{b}
Thiamine (B_1)	0.36 ± 0.01^{a}	0.13 ± 0.01^{c}	0.23 ± 0.01^{b}
Riboflavin (B_2)	0.31 ± 0.02^{a}	0.23 ± 0.01^{b}	0.25 ± 0.02^{b}
Pyridoxine (B_6)	0.48 ± 0.01^{c}	0.55 ± 0.01^{a}	0.53 ± 0.01^{a}
Mineral (mg/100 g)			
Na	5.04 ± 0.01^{c}	12.34 ± 0.02^{a}	8.52 ± 0.07^{b}
K	563.23 ± 0.02^{c}	710.51 ± 0.05^{a}	636.61 ± 0.03^{b}
Mg	197.45 ± 0.01^{a}	90.13 ± 0.03^{c}	143.72 ± 0.08^{b}
P	457.34 ± 0.04^{a}	34.16 ± 0.02^{c}	245.67 ± 0.02^{b}
Fe	4.57 ± 0.01^{a}	0.83 ± 0.01^{c}	2.68 ± 0.01^{b}
Zn	3.10 ± 0.02^{a}	0.01 ± 0.00^{c}	1.55 ± 0.02^{b}
Cu	0.94 ± 0.03^{a}	0.01 ± 0.00^{c}	0.47 ± 0.01^{b}
Ca	47.08 ± 0.01^{c}	90.35 ± 0.04^{a}	68.54 ± 0.04^{b}
Antioxidant activity (mg/g)	29.79 ± 0.24^{a}	10.46 ± 0.13^{c}	20.41 ± 0.14^{b}

Means within the same parameter followed by different lowercase superscripts indicate significant differences between treatments ($p \leq 0.05$).

carbohydrate in tiger nuts were higher than those in quinoa. Sánchez-Zapata *et al.* (2010) stated that free fatty acids in tiger nut oil were 14:0 (0.2%), 20:0 (0.4%), 18:0 (3.2%), 16:1 *n*-7 (0.3%), 18:1 *n*-9 (72.6%), 18:2 *n*-6 (8.9%), and 18:3 *n*-3 (0.4%). In a study conducted on some vegetable oils by Dubois *et al.* (2007), they verified that the oil of tiger nut has a monounsaturated profile (> 60%). In terms of carbohydrates, Manek *et al.* (2012) reported that starch in tiger nuts was bright white, odour-free, with a warm mild taste and soft texture. Tiger nut starch shows elliptical to spherical granules with a moderately smooth surface. Scanning electron microscopy showed that starch in tiger nuts has uniform granular volume, shape, and morphology. It was also found in the present work that tiger nuts contained the highest dietary fibre (15%) as compared to that of quinoa seeds.

Based on Table 2, quinoa seeds contained potassium (563.23 mg/100 g), phosphorus (457.34 mg/100 g), and magnesium (197.45 mg/100 g), while tiger nuts contained potassium (710 mg/100 g). Magnesium and calcium were in the same amount of 90 mg/100 g. Tiger nuts were rich in vitamins C (10 mg/100 g) and E (5.2 mg/100 g). Similarly, quinoa seeds were also rich in vitamins C (12.01 mg/100 g) and E (2.44 mg/100 g). These vitamins have a positive effect on antioxidant activity.

Natural antioxidants are often found in tea extracts, spice extracts, fruit juices, and seed extracts. Plants, including spices and herbs, have various phytochemicals that can be considered potential sources of natural antioxidants, especially phenolic compounds. These compounds have antioxidant, anti-inflammatory, and antitumor activities. Based on Table 2, quinoa seeds contained antioxidant up to 29.79 mg/g, and in tiger nuts up to 10.46 mg/g. These results indicated the possibility of using quinoa seeds and tiger nuts as biologically active food additives aimed to increase the shelf life and nutritional value of various types of meat products by lowering the oxidative damage.

Chemical composition, water-holding capacity, and cooking loss of burger patties

The quality characteristics of burger patties are presented in Table 3. It was found that when the plant mixture was added to the recipe, the moisture content increased by 3.74%, WHC by 10.38%, protein by 2.3%, carbohydrate by 1.03%, dietary fibre by 1.64%, and pH by 0.28. Moreover, there was a decrease by 9.39% in fat content, and 30.03% in caloric value, with 5.72% weight loss recorded. The decrease in fat content was due to the replacement of animal fat with the newly formulated plant mixture. These results suggested that the mixture enabled a development of a low-calorie food product. According to Verma *et al.* (2015), the replacement of animal fat with plant substitute positively affected the quality properties of low-fat meat patties.

Microbiological quality

The effect of storage (-18 ± 1°C) on the microbiological analysis of burger patties samples for 126 days was presented in Table 4. The results showed that after 4 months of storage, there was an increase in the total number of microorganisms in both samples. During further storage, there was a slight increase in mesophilic aerobic and facultative anaerobic counts in the samples of cutlets for the control burger. The mesophilic aerobic and facultative anaerobic counts in the sample prepared with the plant mixture increased to 2.02 log CFU/g during the 108 days of storage. In the control sample, the increase was up to 6.69 log CFU/g occurred after only 90 days. Pathogenic organisms including

Table 3. Chemical composition, water-holding capacity, cooking loss of burger patties. Control: without addition; and treatment: with the addition of quinoa seeds and tiger nuts mixture.

Parameter	Control	Treatment
Moisture (%)	59.73 ± 0.14^{b}	63.47 ± 0.09^{a}
Ash (%)	2.21 ± 0.03^{b}	2.89 ± 0.04^{a}
Protein (%)	16.53 ± 0.08^{b}	18.83 ± 0.09^{a}
Fat (%)	18.26 ± 0.07^{a}	8.87 ± 0.04^{b}
Carbohydrate (%)	1.64 ± 0.04^{b}	2.67 ± 0.11^{a}
Dietary fibre (%)	1.63 ± 0.05^{b}	3.27 ± 0.08^{a}
Caloric value (kcal/100 g)	237.02 ± 0.11^{a}	165.83 ± 0.09^{b}
pH	5.86 ± 0.10^{b}	6.14 ± 0.12^{a}
Water holding capacity (WHC) (%)	67.45 ± 0.03^{b}	77.83 ± 0.04^{a}
Cooking loss during heat treatment (%)	21.04 ± 0.23^{a}	15.32 ± 0.23^{b}

Means within the same parameter followed by different lowercase superscripts indicate significant differences between treatments ($p \leq 0.05$).

Table 4. Microbial loads of frozen (-18°C) burger patties (semi-finished products) during storage for 126 days (18 weeks). Control: without addition; and treatment: with the addition of quinoa seeds and tiger nuts mixture.

Microbial indicator (day)	Control	Treatment
Total plate count (TPC; log CFU/g)		
0	3.43 ± 0.04[a]	2.93 ± 0.05[b]
18	4.43 ± 0.02[a]	4.08 ± 0.09[b]
36	5.73 ± 0.07[a]	5.16 ± 0.08[b]
72	6.59 ± 0.04[a]	6.06 ± 0.04[b]
90	6.69 ± 0.08[a]	6.19 ± 0.07[b]
108	6.73 ± 0.03[a]	6.20 ± 0.01[b]
126	6.82 ± 0.04[a]	6.26 ± 0.02[b]
Yeast and mould count (YMC; log CFU/g)		
0	1.92 ± 0.01[a]	1.41 ± 0.07[b]
18	2.09 ± 0.08[a]	1.58 ± 0.08[b]
36	2.23 ± 0.06[a]	1.63 ± 0.03[b]
72	2.29 ± 0.05[a]	1.85 ± 0.06[b]
90	2.35 ± 0.09[a]	1.90 ± 0.03[b]
108	2.46 ± 0.05[a]	2.02 ± 0.08[b]
126	2.47 ± 0.04[a]	2.04 ± 0.06[b]
Coliform count (log CFU/g)		
0	n.d.	n.d.
18	n.d.	n.d.
36	n.d.	n.d.
72	n.d.	n.d.
90	n.d.	n.d.
108	n.d.	n.d.
126	n.d.	n.d.
***Salmonella* count (log CFU/25 g)**		
0	n.d.	n.d.
18	n.d.	n.d.
36	n.d.	n.d.
72	n.d.	n.d.
90	n.d.	n.d.
108	n.d.	n.d.
126	n.d.	n.d.

Means within the same parameter followed by different lowercase superscripts indicate significant differences between treatments ($p \leq 0.05$). n.d.: not detected.

Salmonella bacteria and enteropathogenic *Escherichia* in the samples of burger and control after storage were not detected. According to the obtained data, it can be concluded that the use of a plant mixture instead of animal fat increased the shelf life of the frozen product by 18 days, compared to the control sample. This refers to the increase in the shelf life by 20%. This decrease in microbial counts was mainly attributed to quinoa seeds that are rich in not only macronutrients for example fats, polysaccharides, and protein, but also in micronutrients mainly phenolic compounds (which have antimicrobial effect in addition to antioxidant effect), minerals, and vitamins (Benavente-Garcia and Castillo, 2008; Repo-Carrasco-Valencia *et al.,* 2010; Vega-Gálvez *et al.,* 2010; Mohsen *et al.,* 2013; Abedelmaksoud *et al.,* 2021).

TBA values

Thiobarbituric values (TBA) values (mg malonaldehyde/kg of beef patties) for control and treatment were affected by using the plant mixture as a partial fat replacer, as presented in Figure 1. The

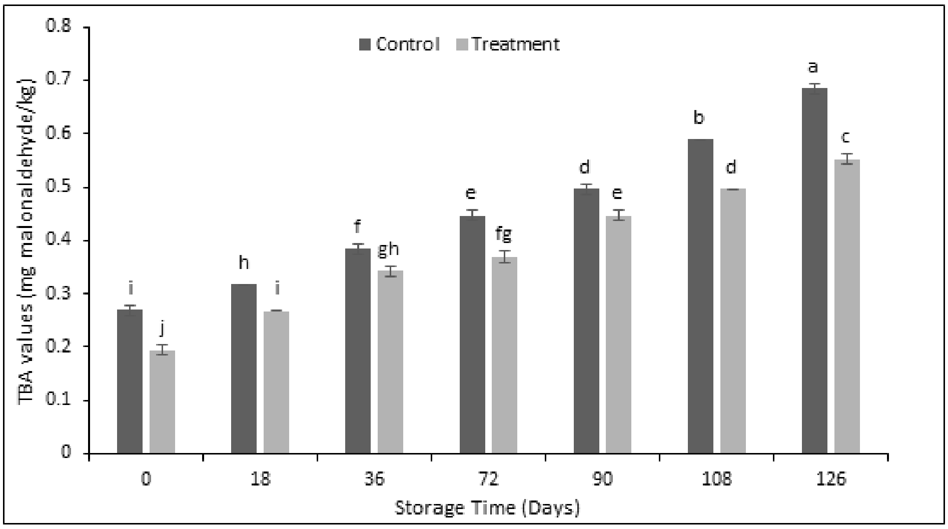

Figure 1. Thiobarbituric acid (TBA) values (mg malonaldehyde/kg) which indicate the degree of lipid oxidation of frozen (-18°C) burger patties (semi-finished products) during storage for 126 days (18 weeks). Control: without addition; and treatment: with the addition of quinoa seeds and tiger nuts mixture.

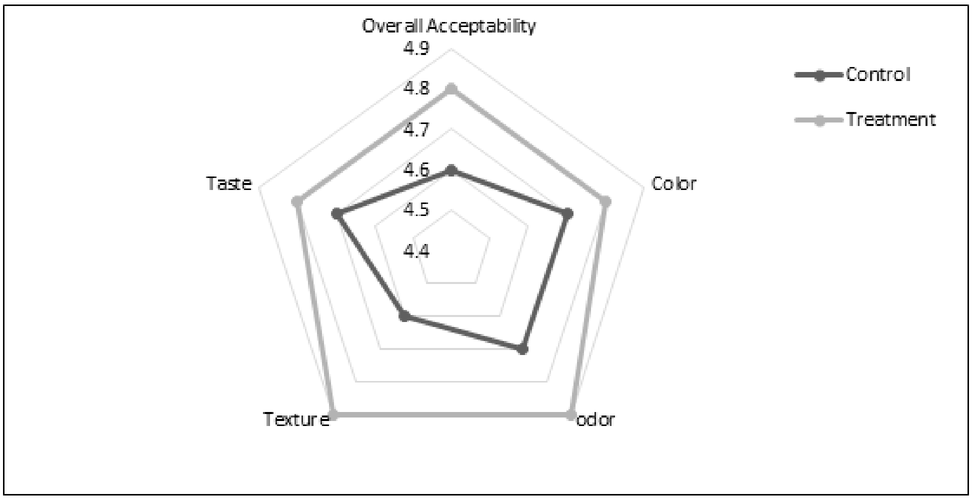

Figure 2. Sensorial of grilled burger patties. Control: without addition; and treatment: with the addition of quinoa seeds and tiger nuts mixture.

TBA during storage of semi-finished products showed that the treatment samples had a lower level of lipid oxidation as compared to control. This indicated that the partial replacement of animal fat with the plant mixture had a positive effect on the quality characteristics and shelf life of the products.

Sensorial quality

From the point of view of consumers, sensorial / organoleptic quality is the ultimate indicator in assessing the quality of the products, and influencing their purchasing / consuming preference. Therefore, the sensorial analysis of the newly formulated beef patties (grilled) was conducted to assess the colour, odour, taste, texture, and overall acceptability as compared to control. The data presented in Figure 2 reveal that the use of plant mixture had a positive effect on all organoleptic indicators. Improvement of sensorial quality such as texture, colour, aroma, and taste varied in the range of 0.1 to 0.2 points. The improvement in overall acceptability was 0.3 points between control and treatment.

Conclusion

The newly proposed plant mixture containing quinoa seeds and tiger nuts could improve the quality attributes and storage stability of beef patties; the use of this mixture will enhance the protein and fibre contents of the beef patties. Quinoa seeds and tiger nuts may be desirable to meat producers as inexpensive substitutes for traditional additives in meat products.

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