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Evaluation of physicochemical, textural, and sensory properties of reduced-fat chicken patties produced with chia flour and κ-carrageenan

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ORIGINAL ARTICLE

Abstract

The effects of chia flour and κ-carrageenan on the physicochemical, textural, and sensory properties of reduced-fat chicken patties were investigated. Usage of chia flour decreased pH, while addition of κ-carrageenan increased it. Chicken patties with chia flour had higher thiobarbituric acid reactive substances (TBARS) and lower L*, a*, and b* values. Production stages significantly affected pH, TBARS, and color of the samples ($p < 0.01$); while pH, TBARS, a*, and b* values increased and L* value decreased after cooking. Adding chia flour and *Kappa-carrageenan* (κ-carrageenan) to reduced-fat chicken patties increased cooking yield and moisture retention while decreasing the shrinkage. Chia flour and κ-carrageenan increased hardness of samples and the highest mean value was found to be 68.70 ± 1.40 N in the group containing 8% beef fat + 4% chia flour + 5% breadcrumbs + 1% κ-carrageenan. However, adhesiveness and cohesiveness decreased by addition of chia flour and κ-carrageenan. Among the sensory properties, flavor, texture, and general acceptability were significantly affected by the addition of chia flour and κ-carrageenan ($p < 0.01$). Sensory properties were studied by panelist, and it was found that usage of 2% chia flour and 1% κ-carrageenan in reduced-fat chicken patties could be effective regarding product quality, health benefits, and consumer acceptance.

Keywords: chia flour; chicken patty; fat reduction; hardness; κ-carrageenan; pH

Introduction

Chicken meat products are widely produced and consumed because of their affordability, lack of religious/cultural restrictions, and favorable taste (Ferreira *et al.*, 2017). The chicken patty, one of such products, is prepared by kneading minced chicken meat and animal fat by adding spices and additives and then shaping patty dough in certain portions. However, as with many other processed meat products, chicken patties also contain high levels of animal fat, which brings some health risks. In fact, animal fat, which contains high levels of saturated fatty acids and cholesterol, is reported to cause obesity, hypertension, cardiovascular diseases, and coronary heart disease, and consumers are advised to reduce intake of animal fat (Choi *et al.*, 2016; Ding *et al.*, 2018). Thus, interest in reduced-fat meat products is increasing day by day. On the other hand, fat is an important source of energy and a carrier of fat-soluble vitamins. In addition, animal fat in meat products is effective due to its sensory and structural properties. Hence, minimizing animal fat used in meat products while maintaining its positive effects is an important issue (Choi *et al.*, 2016; Ulu, 2006).

In recent years, research into functional foods has been widely pursued by food companies. Consumers demand foods that provide necessary nutrients not only to meet nutritional requirements but also to prevent diet-related diseases and improve physical/mental health. Thus, a close relationship between nutrition and health has been established through functional foods, which are considered to be healthier and being developed technologically (Niva, 2007).

Chia seeds, considered as a functional food because of their composition, offer an important possibility for reformulated meat products. Chia seeds contain 25–41% carbohydrate, 20–22% proteins, 30–35% oil, and 4–6% ash (European Union [EU], 2013). On the other hand, chia seeds do not contain gluten and have biologically active components with antioxidant properties (Munoz *et al.,* 2013). Also, chia seeds contain high levels of unsaturated fatty acids. Chia seeds are a natural source of omega-3 fatty acids and are also rich in α-linolenic acid, an essential fatty acid (Munoz *et al.,* 2013; Yurt and Gezer, 2018). Furthermore, another important feature of chia seeds is their high dietary fiber content (Ullah *et al.,* 2016). Fiber consumption improves functioning of the digestive system and also contributes to the prevention of colon cancer and constipation. In addition to these health beneficial effects, dietary fiber used in meat products also affects functional and technological properties of the product. Dietary fiber has various technological properties, such as water retention, gelling, and structure formation in meat products, and can also be used as a fat replacer (Choi *et al.,* 2015; Yadav *et al.,* 2018).

Hydrocolloids are long-chain polymers that have a thickening effect by dispersing or spreading in water. This class of ingredients is generally used for their texturizing ability. One of these polymers, carrageenan, is a natural carbohydrate derived from edible red algae. There are three different varieties of carrageenan, kappa (κ), iota (ι), and lambda (λ), and the main difference affecting their properties is the number and positioning of ester sulfate groups in repeating galactose units (Hsu and Chung, 2001). However, κ-carrageenan is the most widely used type of carrageenan in the food industry. Carrageenan is used in meat products to improve texture and prevent loss during cooking. In addition, carrageenan is also used to accomplish some properties of fat in reduced-fat meat products (Yasin *et al.,* 2016).

Consumers' interest in nutrition and health issues has led the chicken meat industry toward producing functional products as in other branches of the food industry. Hence, in the present study, the effects of chia flour and κ-carrageenan were investigated on some physicochemical, textural, and sensory properties of reduced-fat chicken patties.

Materials and Methods

Production of chicken patties

Five different groups of patties were produced in the study. In the control group, 70% chicken breast meat, 12% beef fat, 6% onion, 0.3% garlic, 1.4% salt, 0.85% paprika, 0.3% ascorbic acid, 0.05% thyme, 0.2% black pepper, 0.4% cumin, 2.5% egg, and 6% breadcrumbs were used. In other groups, the proportion of beef fat and breadcrumbs was reduced and replaced with different proportions of chia flour (Wefood, Türkiye) and κ-carrageenan (Merck, Germany) (Table 1). The basic composition of chia flour was 37.6% fat, 16.5% proteins, 3.8% moisture, and 34.4% fiber. In general, breadcrumbs are used to enhance texture and juiciness in patty production. Also, carrageenan improves texture, prevents cooking losses, and fulfills some properties of fat in reduced-fat meat products. In the study, since chia flour was used in reduced-fat chicken patties, breadcrumbs were partially replaced with κ-carrageenan to obtain advanced texture and juiciness. All ingredients for each treatment were placed simultaneously in a mixer (AR1129, Arzum, Türkiye) and kneaded for 2 min to obtain a homogeneous dough. Chicken patties were shaped using a ready-made mold (7-cm diameter × 1-cm thickness), rested overnight in a refrigerator, and then frozen at –18°C. The frozen patties were thawed at +4°C for 18 h and then cooked on a hot plate (Elektro-Mag, M4060, Turkey) at 200°C for 8 min (4 min per surface).

Table 1. Beef fat, chia flour, κ-carrageenan, and breadcrumbs levels used in chicken patties.

Group	Beef fat (%)	Chia flour (%)	κ-carrageenan (%)	Breadcrumbs (%)
A1 (control)	12	0	0	6
A2	10	2	0	6
A3	10	2	1	5
A4	8	4	0	6
A5	8	4	1	5

Physicochemical analysis

The pH values of the samples were determined according to guidelines of the Association of Official Analytical Chemists (AOAC; Horwitz and Latimer, 2005). The color intensities were determined according to the criteria established by the International Commission on Illumination (CIE, Austria) based on three-dimensional color measurements. Color values (L*, a* and b*) of the samples were measured using a colorimeter (CR-200, Minolta Co., Osaka, Japan) having a 2° standard observer, 8-mm aperture and diffused illumination. L* defines color lightness (ranging from 0 for white to 100 for black), a* indicates the degree of color between red and green (negative values indicate green color and positive values indicate red color), and b* indicates degree of color between yellow and blue (negative values indicate blue color and positive values indicate yellow color). Analysis of thiobarbituric acid reactive substances (TBARS) was performed according to Lemon (1975). The absorbance values were measured by a spectrophotometer (Thermo Electron Corporation, Aquamate, UK) at 532-nm wavelength, and TBARS was expressed as µmol malondialdehyde (MDA)/kg using the standard curve for 1,1,3,3 tetraethoxypropane (TEP). Moisture retention represents the amount of moisture retained in the cooked product per 100 g of raw sample; cooking yield shows yield per 100 g of raw sample; and shrinkage describes dimensional reduction because of cooking; all these properties are calculated as follows:

$$\%\text{Moisture Retention} = \frac{\text{cooked weight} \times \%\text{moisture in cooked sample}}{\text{raw weight} \times \%\text{moisture in raw sample}} \times 100$$

$$\%\text{Cooking yield} = \frac{\text{cooked weight}}{\text{raw weight}} \times 100$$

$$\%\text{Shrinkage} = \frac{(\text{uncooked thickness} - \text{cooked thickness}) + (\text{uncooked diameter} - \text{cooked diameter})}{\text{uncooked thickness} \times \text{uncooked diameter}} \times 100$$

Texture profile analysis (TPA)

Texture profile analysis was performed using a texture analyzer (CT3 Texture Analyser, Brookfield Engineering, Middleboro, MA, USA). Cylindrical cooked samples (2-cm diameter × 1-cm thickness) extracted from chicken patties were analyzed at room temperature with two consecutive compression cycles using a 50.8-mm diameter cylindrical probe (TA 25/1000, Brookfield). In the analysis, 1-mm/s pre-test speed, 2-mm/s test and post-test speed, 5-s recovery time, and 50% target strain were used. Hardness (force required for a deformation, maximum peak force during the first compression cycle; expressed as N), adhesiveness (work required to overcome sticky forces between sample and probe, negative force area for the first cycle; expressed as mJ), resilience (how well a product fights to regain its original height, ratio of the area under the up-stroke curve to that under the downstroke curve in the first cycle), cohesiveness (strength of internal bonds in the sample, ratio of tpositive force area during second compression to that during the first compression), springiness (rate at which a deformed sample returns to its original size and shape, the ratio of the time difference between the start and maximum peak force in the second cycle to the same in the first cycle; expressed as mm), and chewiness (energy needed to chew a solid food until it is ready for swallowing, product of gumminess × springiness; expressed as mJ) were determined from the typical force–time curve.

Sensory analysis

Chicken patties in each treatment group, taking the size of a quarter per sample, were subjected to sensory analysis after cooking. The sensory evaluation was carried out by 10 panelists, comprising 5 females and 5 males, aged 25–35 years, from the food engineering department in two separate sessions using a 5-point Hedonic scale (1 = very bad, 2 = bad, 3 = medium, 4 = good, 5 = very good) for appearance, color, flavor, texture, and general acceptability. The tests were conducted by the panelists in a room with fluorescent lighting after they were briefed about the scale. The panelists were instructed to cleanse their mouths between samples using water and bread.

Statistical analysis

The study was conducted according to the randomized complete block design with different formulations and production stages as factors. Chicken patties were produced at two different times using two different raw material blocks for each treatment. For physicochemical analyses, three measurements were taken for each replicate, while six measurements were performed for TPA. The same statistical evaluation was also used for sensory analysis. Treatments and replications were accepted as fixed effects and random effects, respectively, while panellists were identified as a repeated factor. Analysis of variance (two-way ANOVA) was applied to the obtained data to determine significant effects of factors and interactions, and the mean values of significant sources of variation were compared by Duncan multiple comparison test (IBM, 2011). All data were presented as mean values ± standard error (SE) in tables and figures.

Results and Discussion

Physicochemical properties

The physicochemical properties of chicken patties with different formulations are presented in Table 2. pH has a direct effect on quality characteristics and shelf life of meat products, such as chicken patties. The ingredients and production stages of these products affect pH; therefore, determining pH is essential for product quality and safety. It was observed that different formulations used in producing chicken patties had a significant effect on pH ($p < 0.01$). The lowest mean pH was obtained in A4 group, and the highest value was determined in A3 group ($p < 0.05$). It was observed that using chia flour in reduced-fat chicken patties decreased pH, compared to the control where adding κ-carrageenan increased pH. Pires *et al.* (2020) reported that sausages containing chia flour had a lower pH than control samples, possibly because of the lower pH of chia flour than meat. In the present study, the decreasing effect of chia flour on pH in reduced-fat chicken patties is explained by this approach. In addition, Antonini *et al.* (2020) indicated that beef burgers prepared with chia seeds had lower pH. Similar results were also obtained in other studies conducted with chicken patties containing different fat replacers (Choi *et al.,* 2016; Guedes-Oliveira *et al.,* 2016).

Ready-made foods, such as chicken patties, are generally preserved in cold chain after preparation until consumption and served after thawed and cooked. Therefore, determining changes in physicochemical properties during production stages is very important in terms of product safety and quality. Changes in the physicochemical properties of samples depending on production stages are presented in Table 3. The production stage significantly affected pH of samples ($p < 0.01$). While mean pH determined in patty dough and before cooking did not differ statistically ($p > 0.05$), higher mean pH was determined after cooking ($p < 0.05$). Increase in pH was probably due to protein denaturation during cooking, resulting in imidazolium, the basic R group of amino acid histidine (Choi *et al.,* 2015). Higher pH after cooking was also reported in chicken patties with dietary fiber by Choi *et al.* (2015), and in mutton kofta including κ-carrageenan by Modi *et al.* (2009).

In addition, the effect of formulation and production stage interaction on the pH of chicken patties was significant ($p < 0.01$). While higher pH was observed in A3 and A5 groups in patty dough and before cooking, the highest pH was determined for the control (A1) group after cooking (Figure 1). This was probably due to the higher water-holding capacity of patties with κ-carrageenan and the higher fat content of the control (A1) group, compared to other groups. On the other hand, pH increased before cooking in A3 and A5 groups, and after cooking in all groups.

The degree of oxidation in the samples was measured by TBARS, which evaluated MDA formed during oxidation. TBARS values were significantly affected by different formulations used in producing chicken patties ($p < 0.01$). The mean values determined for all groups were statistically different from each other; the lowest mean value was discovered in the control (A1) group, while the highest mean value was determined in A4 group (Table 2). These results show that the addition of chia flour to chicken patties caused an increase in TBARS, while the addition of κ-carrageenan decreased the same. Pintado *et al.* (2016) determined higher TBARS in frankfurters with chia flour and suggested that it was due to presence of polyunsaturated fatty acids in chia seeds. Similarly, Heck *et al.* (2017) determined higher TBARS in burgers produced with chia

Table 2. Physicochemical properties of chicken patties produced in different formulations.

		A1	A2	A3	A4	A5	Significance
pH		5.53 ± 0.04^{c}	5.51 ± 0.04^{b}	5.54 ± 0.03^{d}	5.50 ± 0.03^{a}	5.53 ± 0.03^{c}	**
TBARS (μmol MDA/kg)		20.36 ± 1.07^{a}	26.30 ± 1.08^{d}	23.28 ± 1.12^{b}	30.39 ± 1.48^{e}	24.84 ± 0.87^{c}	**
Cooking yield (%)		85.60 ± 0.25^{a}	87.90 ± 0.39^{b}	89.44 ± 0.26^{c}	89.50 ± 0.37^{c}	90.51 ± 0.19^{d}	**
Moisture retention (%)		79.83 ± 0.59^{a}	82.09 ± 0.55^{b}	84.58 ± 0.46^{c}	84.41 ± 0.14^{c}	85.99 ± 0.43^{d}	**
Shrinkage values (%)		7.28 ± 0.46^{b}	6.09 ± 0.54^{b}	4.69 ± 0.50^{a}	4.46 ± 0.73^{a}	3.74 ± 0.45^{a}	**
Color	L*	53.28 ± 0.46^{d}	51.18 ± 0.52^{b}	52.06 ± 0.45^{c}	49.75 ± 0.36^{a}	49.79 ± 0.31^{a}	**
	a*	9.01 ± 0.25^{d}	7.77 ± 0.33^{c}	7.30 ± 0.19^{b}	6.39 ± 0.11^{a}	6.66 ± 0.15^{a}	**
	b*	29.90 ± 0.23^{d}	26.48 ± 0.30^{c}	26.28 ± 0.24^{c}	23.67 ± 0.21^{a}	24.16 ± 0.36^{b}	**

Presented values are mean values ± standard error; TBARS: thiobarbituric acid reactive substances; MDA: malondialdehyde; A1: 12% beef fat + 6% breadcrumbs; A2: 10% beef fat + 2% chia flour + 6% breadcrumbs; A3: 10% beef fat + 2% chia flour + 1% κ-carrageenan + 5% breadcrumbs; A4: 8% beef fat + 4% chia flour + 6% breadcrumbs; A5: 8% beef fat + 4% chia flour + 1% κ-carrageenan + 5% breadcrumbs; $^{a–e}$Different superscript letters in the same row are statistically different from one another ($p < 0.05$); $^{**}p < 0.01$.

Table 3. Physicochemical properties of chicken patties at production stages.

		Patty dough	Before cooking	After cooking	Significance
pH		5.42 ± 0.01^{a}	5.42 ± 0.01^{a}	5.72 ± 0.01^{b}	**
TBARS (μmol MDA/kg)		19.10 ± 0.57^{a}	26.80 ± 0.80^{b}	29.20 ± 0.75^{c}	**
Color	L*	52.71 ± 0.30^{c}	51.70 ± 0.38^{b}	49.23 ± 0.24^{a}	**
	a*	7.05 ± 0.12^{b}	6.79 ± 0.17^{a}	8.43 ± 0.28^{c}	**
	b*	26.03 ± 0.42^{b}	25.10 ± 0.43^{a}	27.16 ± 0.44^{c}	**

Presented values are mean values ± standard error. TBARS: thiobarbituric acid reactive substances; MDA: malondialdehyde. $^{a–c}$Different superscript letters in the same row are statistically different from one another ($p < 0.05$); $^{**}p < 0.01$.

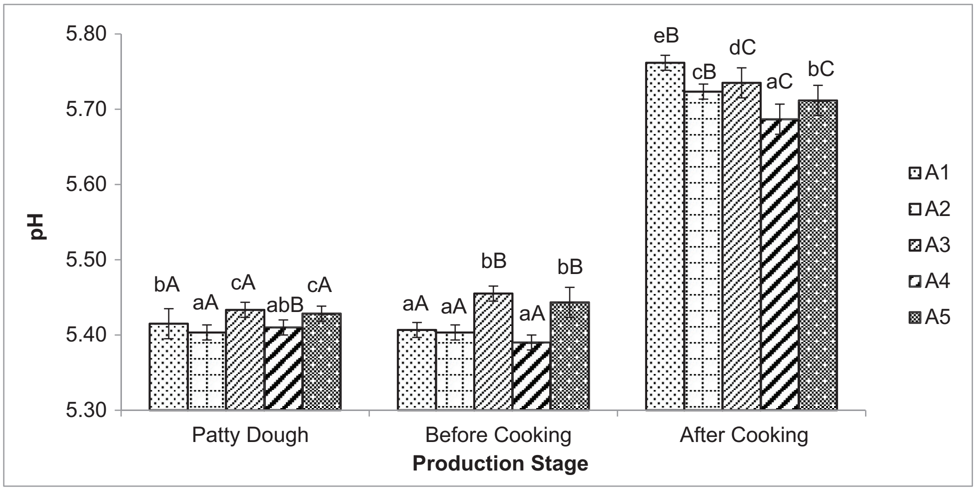

Figure 1. Changes in pH during the production stages of chicken patties with different formulations. A1: 12% beef fat + 6% breadcrumbs; A2: 10% beef fat + 2% chia flour + 6% breadcrumbs; A3: 10% beef fat + 2% chia flour + 1% κ-carrageenan + 5% breadcrumbs; A4: 8% beef fat + 4% chia flour + 6% breadcrumbs; A5: 8% beef fat + 4% chia flour + 1% κ-carrageenan + 5% breadcrumbs. $^{a–e}$Different superscript small letters in different formulations at the same production stage are statistically different from each other ($p < 0.05$). $^{A–C}$Different superscript capital letters at different production stages for the same formulation are statistically different from one another ($p < 0.05$).

oil and reported that polyunsaturated fatty acids in chia oil were effective for this situation. A similar result was also reported by Botella-Martinez *et al.* (2023) for beef burgers produced with chia oil as a pork backfat replacer. Indeed, it was reported that chia seeds contain high levels of polyunsaturated fatty acids, especially omega-3 fatty acids (Munoz *et al.,* 2013; Yurt and Gezer, 2018).

The present study suggests that the use of chia flour in reduced fat chicken patties increases the amount of polyunsaturated fatty acids, and therefore higher TBARS was observed in patties containing chia flour. On the other hand, TBARS was lower in groups A3 and A5, in which κ-carrageenan was used with chia flour, compared to the groups in which only chia flour was used. This was probably due to the stabilizing effect of κ-carrageenan on the structure. The mean TBARS values of chicken patties increased throughout the production stages and the highest TRARS was determined after cooking (Table 2). Heck *et al.* (2017) and Botella-Martinez *et al.* (2023) also reported higher TBARS in beef burgers after cooking produced with chia oil. It was reported that cooking affects the lipid oxidation of meat products and accelerates oxidative reactions (Jo *et al.,* 2003; Paula *et al.,* 2019) because of release of iron in meat proteins and deterioration of the cellular structure of meat during the cooking process (Ramirez *et al.,* 2004; Rojas and Brewer, 2007). In addition, the treatment and production stage interaction had a significant effect on TBARS ($p < 0.01$). As observed in Figure 2, the lowest TBARS was determined in the control (A1) group during all stages of production. While the highest values were determined for A2 and A4 groups containing only chia flour after cooking, the use of κ-carrageenan (in A3 and A5) caused lower TBARS in production stage. Moreover, TBARS values increased after cooking in all groups except A5.

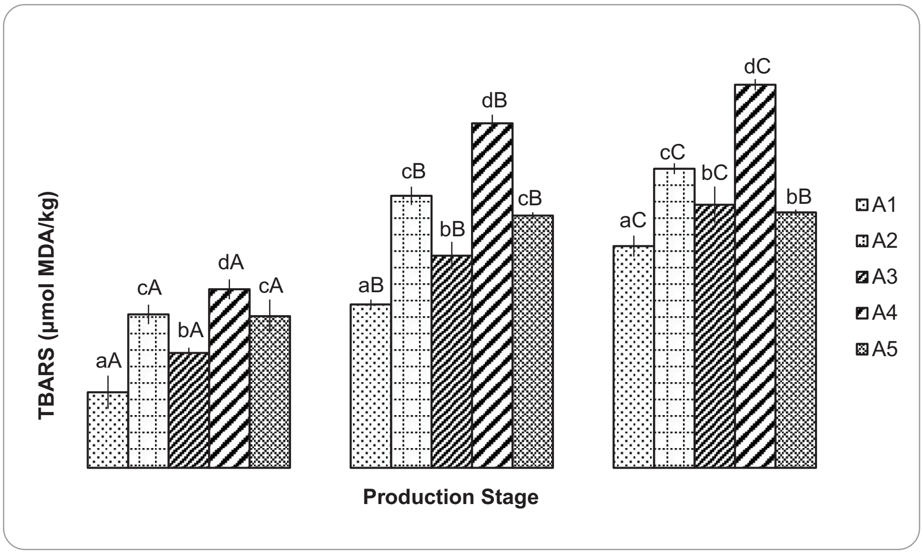

Figure 2. Changes in TBARS values during the production stages of chicken patties with different formulations. A1: 12% beef fat + 6% breadcrumbs; A2: 10% beef fat + 2% chia flour + 6% breadcrumbs; A3: 10% beef fat + 2% chia flour + 1% κ-carrageenan + 5% breadcrumbs; A4: 8% beef fat + 4% chia flour + 6% breadcrumbs; A5: 8% beef fat + 4% chia flour + 1% κ-carrageenan + 5% breadcrumbs. a–dDifferent superscript small letters in different formulations at the same production stage are statistically different from each other ($p < 0.05$). A–CDifferent capital letters at different production stages for the same formulation are statistically different from one another ($p < 0.05$).

Color is an important quality parameter that affects consumer preferences. In this study, different formulations used in production had a significant effect on the color characteristics (L*, a* and b*) of chicken patties ($p < 0.01$). The highest mean L*, a* and b* values were determined in the control (A1) group. However, the lowest mean L* and a* values were discovered in A4 and A5 groups, and the lowest mean b* value was found in A4 group (Table 2). These results showed that the addition of chia flour to reduced-fat chicken patties decreased L*, a*, and b* values in general. The decrease in color parameters was probably due to the dark color of chia flour. Indeed, Pintado *et al.* (2016) reported that adding chia flour to reduced-fat frankfurters decreased L* and a* values and suggested that this was due to the relatively dark color of chia flour. In addition, Barros *et al.* (2018) found that using chia flour decreased L* and b* values in chicken nuggets and reported that adding 5% chia flour to chicken nuggets did not affect the a* value.

As observed in Table 3, production stages also significantly affected L*, a* and b* values ($p < 0.01$). It was observed that L* value decreased throughout the production, while a* and b* values decreased before cooking and increased after cooking. The thermal denaturation of proteins as a result of cooking and the loss of moisture and fat in patties are effective in this situation. Modi *et al.* (2009) detected that L*, a* and b* values decreased during cooking of meat kofta by adding κ-carrageenan and oat flour.

On the other hand, Heck *et al.* (2017) reported that the a* value decreased due to cooking of burgers using chia oil, while L* and b* values showed no change. As shown in Figures 3 and 4, the treatment and production stage interaction had a significant effect on the L* and a* values of chicken patties ($p < 0.01$). While the highest L* value was determined for the control (A1) group during all production stages, the lowest value was observed in A4 and A5 groups containing 4% chia flour.

The use of 2% chia flour and 1% κ-carrageenan (A3) had an increasing effect on L* value during all stages of production. In addition, at the end of cooking, the closest L* values to the control were obtained for A3 group. However, the L* value for A2 group decreased at a higher rate than others as a result of cooking. It was observed that L* values decreased in A1, A4 and A5 groups before cooking, and in all groups, except A4, after cooking. The highest mean a* value was observed in the control (A1) group during all stages. A4 and A5 groups had the lowest a* values before and after cooking. While A4 and A5 groups showed a higher decrease in a* value before cooking, compared to other groups, A1, A2 and A3 groups showed a higher increase after cooking. Thus, as a result of cooking, closest results were obtained for a* value in A2 and A3 groups, compared to the control.

Adding chia flour and κ-carrageenan to the chicken patty samples significantly affected the cooking yield

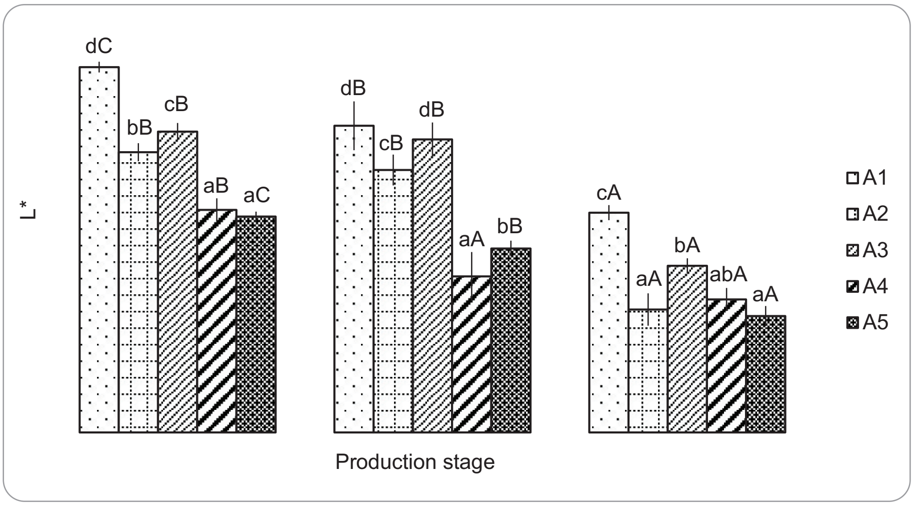

Figure 3. Changes in L* values during the production stages of chicken patties with different formulations. A1: 12% beef fat + 6% breadcrumbs; A2: 10% beef fat + 2% chia flour + 6% breadcrumbs; A3: 10% beef fat + 2% chia flour + 1% κ-carrageenan + 5% breadcrumbs; A4: 8% beef fat + 4% chia flour + 6% breadcrumbs; A5: 8% beef fat + 4% chia flour + 1% κ-carrageenan + 5% breadcrumbs. [a–d]Different small superscript letters in different formulations at the same production stage are statistically different from each other ($p < 0.05$). [A-C]Different capital superscript letters at different production stages for the same formulation are statistically different from one another ($p < 0.05$).

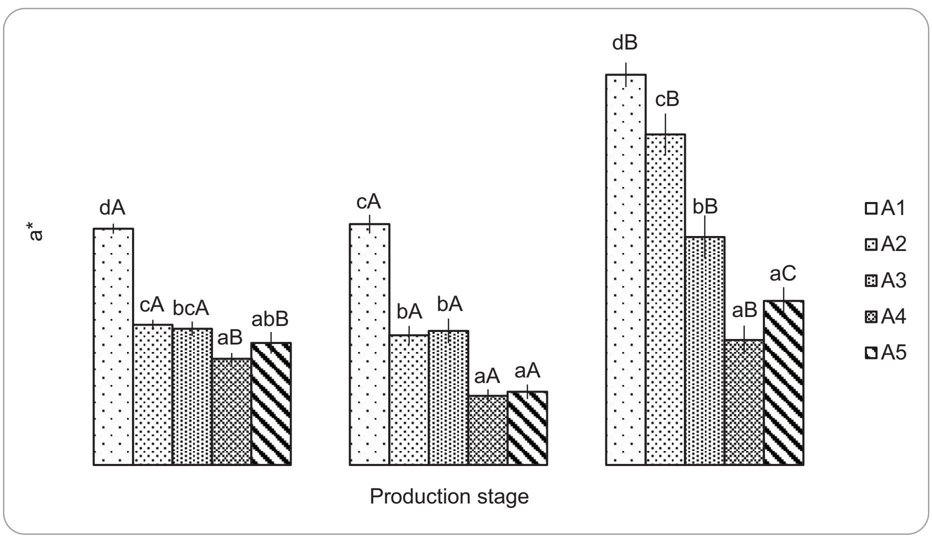

Figure 4. Changes in a* values during the production stages of chicken patties with different formulations. A1: 12% beef fat + 6% breadcrumbs; A2: 10% beef fat + 2% chia flour + 6% breadcrumbs; A3: 10% beef fat + 2% chia flour + 1% κ-carrageenan + 5% breadcrumbs; A4: 8% beef fat + 4% chia flour + 6% breadcrumbs; A5: 8% beef fat + 4% chia flour + 1% κ-carrageenan + 5% breadcrumbs. [a–d]Different superscript small letters in different formulations at the same production stage are statistically different from each other ($p < 0.05$). [A–C]Different superscript capital letters at different production stages for the same formulation are statistically different from one another ($p < 0.05$).

($p < 0.01$). The lowest mean cooking yield was determined in the control (A1) group. On the other hand, using a higher proportion of chia flour as a fat replacer and adding κ-carrageenan in the composition of chicken patties increased the cooking yield so that the highest mean value was determined in A5 group containing 4% chia flour and 1% κ-carrageenan (Table 2). This is because, in addition to reducing fat content, adding chia flour and κ-carrageenan increased the water-holding capacity of samples. It was reported that chia flour has excellent water retention and water-absorption capacities because of its high fiber content and could have improved the cooking yield (Barros *et al.,* 2019). Barros *et al.* (2018) reported that the use of chia flour in producing chicken nuggets increased the cooking yield, and this was due to the improvement of water-holding capacity as a result of the higher fiber content of chia flour. Also, different formulations of chicken patties significantly affected the moisture retention values of samples ($p < 0.01$). The lowest mean value was obtained in the control (A1) group, while the highest was determined in A5 group containing 4% chia flour and 1% κ-carrageenan (Table 2). Therefore, adding chia flour and κ-carrageenan to reduced-fat chicken patties increased moisture retention values. These findings supported the cooking yield results.

There was also a significant effect of different formulations on the shrinkage values of chicken patty samples ($p < 0.01$). As observed in Table 2, the lowest mean value was determined in A5 group, while the highest mean value was in the control (A1) group. Thus, adding chia flour and κ-carrageenan to reduced-fat chicken patties decreased shrinkage value in general. During cooking, moisture and fat loss and thermal denaturation of proteins affect shrinkage (Alakali *et al.,* 2010). It was also reported that dietary fibers reduce shrinkage in meat products by keeping moisture and fat in meat matrix (Lopez-Vargas *et al.,* 2014; Selani *et al*., 2016). In this context, decrease in shrinkage is explained by the high fiber content of chia flour and the water-retention capacity of κ-carrageenan.

Texture

Texture is one of the most important parameters for determining the quality of meat products (Bekhit *et al.,* 2014; Chen and Opara, 2013). The mean values of textural properties determined in chicken patties with different formulations are shown in Table 4. Different formulations used in producing chicken patties had a significant effect on hardness value ($p < 0.01$). Accordingly, the mean values determined for all groups were statistically different from one another, and the lowest mean hardness value was observed in the control (A1) group, while the highest mean value was determined in A5 group ($p < 0.05$). The addition of chia flour and κ-carrageenan to reduced-fat chicken patties increased the hardness value. Increase in hardness was probably due to low moisture and high fiber contents of chia flour and the presence of carrageenan, which improves structural properties. Barros *et al.* (2018) reported that the use of high levels of chia flour in producing chicken nuggets increased hardness due to low moisture and high dietary fiber content. Similarly, Herrero *et al.* (2017) and Pintado *et al.* (2016) found that the addition of chia flour to reduced-fat frankfurters increased hardness. Also, in some other studies, it was reported that κ-carrageenan, which is used to improve the structural properties of meat products, increased hardness of meatballs (Hsu and Chung, 2001; Yasin *et al.,* 2016). Similarly, Ulu (2006) determined that hardness of beef meatballs decreased with decrease of fat content, while the addition of 1% carrageenan to meatballs increased their hardness.

The production of chicken patties with different formulations significantly affected the adhesiveness values ($p < 0.05$). The highest mean adhesiveness value was 0.16 ± 0.19 mJ in the control (A1) group, while the lowest mean value was 0.04 ± 0.06 mJ in A5 group (Table 4). The addition of chia flour or κ-carrageenan to reduced-fat chicken patties reduced the adhesiveness value. However, adding κ-carrageenan to chicken patties decreased the adhesiveness value at a higher rate.

Different formulations also affected cohesiveness significantly ($p < 0.01$). The highest mean cohesiveness was determined in the control (A1) group, while lower cohesiveness was found in A2 and A3 groups and minimum cohesiveness was established in A4 and A5 groups (Table 4). Thus, the cohesiveness values of samples decreased with increase in the proportion of chia flour used in reduced-fat chicken patties, and these samples disintegrated easily, but using κ-carrageenan did not affect cohesiveness.

In the present study, usage of chia flour in low-fat chicken patties caused variations in texture parameters because of chia flour having high protein and fiber contents and low moisture content, resulting in a meat product with a relatively crumbling texture. Barros *et al.* (2018) found that cohesiveness decreased with increase in the proportion of chia flour used in production of chicken nugget. Lower cohesiveness was also reported by Ding *et al.* (2018) in lean ham-like products with 1% chia flour or 0.5% κ-carrageenan as well as in reduced-fat frankfurters by adding chia flour, as reported by Pintado *et al.* (2016).

The use of chia flour and/or κ-carrageenan in producing reduced-fat chicken patties did not affect resilience ($p > 0.05$), but had a significant effect on springiness and chewiness values. The highest mean springiness value was obtained in group A3 containing 2% chia flour and 1% κ-carrageenan, while lower mean values were determined in other groups. The use of chia flour in producing reduced-fat chicken patties slightly decreased their springiness, but the addition of κ-carrageenan relatively increased the same. In addition, the highest mean chewiness value was determined in A3 group containing 2% chia flour and 1% κ-carrageenan and in A5 group containing 4% chia flour and 1% κ-carrageenan. These results show that the addition of κ-carrageenan to reduced-fat chicken patties significantly ($p < 0.05$) increased their chewiness, a measure of the energy required to chew a

Table 4. Texture profile properties of chicken patties produced in different formulations.

	A1 (control)	A2	A3	A4	A5	Significance
Hardness (N)	54.58 ± 1.34^{a}	57.55 ± 0.48^{b}	62.26 ± 1.40^{c}	66.11 ± 1.70^{d}	68.70 ± 1.40^{e}	**
Adhesiveness (mJ)	0.16 ± 0.04^{c}	0.15 ± 0.03^{b,c}	0.07 ± 0.03^{a,b}	0.09 ± 0.02$^{a–c}$	0.04 ± 0.01^{a}	*
Resilience	0.07 ± 0.00^{a}	0.07 ± 0.00^{a}	0.07 ± 0.04^{a}	0.09 ± 0.03^{a}	0.06 ± 0.00^{a}	NS
Cohesiveness	0.30 ± 0.01^{c}	0.27 ± 0.01^{b}	0.27 ± 0.01^{b}	0.26 ± 0.00^{a}	0.25 ± 0.01^{a}	**
Springiness (mm)	4.37 ± 0.05^{a}	4.34 ± 0.04^{a}	4.54 ± 0.06^{b}	4.24 ± 0.04^{a}	4.39 ± 0.10^{a}	**
Chewiness (mJ)	70.98 ± 1.88^{a,b}	67.59 ± 1.55^{a}	75.76 ± 1.10^{b}	71.99 ± 2.09^{a,b}	73.62 ± 1.71^{b}	**

Presented values are mean values ± standard error. A1: 12% beef fat + 6% breadcrumbs; A2: 10% beef fat + 2% chia flour + 6% breadcrumbs; A3: 10% beef fat + 2% chia flour + 1% κ-carrageenan + 5% breadcrumbs; A4: 8% beef fat + 4% chia flour + 6% breadcrumbs; A5: 8% beef fat + 4% chia flour + 1% κ-carrageenan + 5% breadcrumbs. $^{a–e}$Different superscript letters in the same row are statistically different from one another ($p < 0.05$); $^{*}p < 0.05$; $^{**}p < 0.01$; NS: not significant.

solid food item to the point that it is adequate for swallowing. Similarly, Yasin *et al.* (2016) reported that using κ-carrageenan in chicken patties increased chewiness. In addition, Pintado *et al.* (2016) and Herrero *et al.* (2017) determined that adding chia flour to reduced-fat frankfurters increased their chewiness, compared to the control. Barros *et al.* (2018) reported that chewiness decreased with increase in the amount of chia flour used in producing chicken nuggets, and this was due to the presence of high protein and dietary fiber content in chia flour.

Sensory evaluation

The results of sensory analysis of chicken patties with different formulations are presented in Table 5. No significant differences were observed in groups for appearance and color parameters ($p > 0.05$); however, statistically significant differences were found for flavor, texture and general acceptability ($p < 0.01$). The closest values for flavor to the control were obtained in A2 group, for texture in A3 group, and for general acceptability in A2 and A3 groups. However, the highest mean flavor value was determined in the control (A1) group, the mean texture value in A2 group, and the general acceptability value in A1, A2 and A3 groups. On the other hand, the lowest mean values for sensory characteristics were observed in A4 and A5 groups. This indicates that it is more appropriate to use 2% chia flour or 2% chia flour and 1% κ-carrageenan for the sensory preference of reduced-fat chicken patties.

In a study conducted by Barros *et al.* (2018) on chicken nuggets, it was found that using 5% chia flour for production provided similar results to the control in terms of sensory parameters. However, Pintado *et al.* (2016) reported that adding chia flour to frankfurters reduced the flavor, color, texture and overall acceptability scores. In another study, it was determined that general acceptability values similar to the high-fat control sample were obtained for lean ham prepared by adding 1% chia flour and 0.5% carrageenan (Ding *et al.,* 2018).

Conclusions

Using chia flour and κ-carrageenan in reduced-fat chicken patties caused significant changes in physicochemical, textural, and sensory properties. These

Table 5. Sensory properties of chicken patties produced in different formulations.

	A1	A2	A3	A4	A5	Significance
Appearance	3.95 ± 0.15^{a}	4.15 ± 0.15^{a}	3.85 ± 0.15^{a}	3.60 ± 0.15^{a}	3.65 ± 0.15^{a}	NS
Color	4.00 ± 0.22^{a}	3.85 ± 0.15^{a}	4.00 ± 0.16^{a}	3.70 ± 0.16^{a}	3.65 ± 0.15^{a}	NS
Flavor	3.95 ± 0.20^{c}	3.85 ± 0.15^{b,c}	3.40 ± 0.15^{b}	2.70 ± 0.13^{a}	2.50 ± 0.17^{a}	**
Texture	3.85 ± 0.20^{b,c}	3.90 ± 0.12^{c}	3.65 ± 0.15^{b,c}	3.35 ± 0.20^{a,b}	3.05 ± 0.20^{a}	**
General acceptability	4.00 ± 0.21^{b}	4.05 ± 0.14^{b}	3.75 ± 0.12^{b}	3.15 ± 0.15^{a}	2.95 ± 0.18^{a}	**

Presented values are means ± standard error. A1: 12% beef fat + 6% breadcrumbs; A2: 10% beef fat + 2% chia flour + 6% breadcrumbs; A3: 10% beef fat + 2% chia flour + 1% κ-carrageenan+ 5% breadcrumbs; A4: 8% beef fat + 4% chia flour + 6% breadcrumbs; A5: 8% beef fat + 4% chia flour + 1% κ-carrageenan + 5% breadcrumbs. $^{a–c}$Different superscript letters in the same row are statistically different from one another ($p < 0.05$). $^{**}p < 0.01$; NS: not significant.

findings should be considered in producing healthier processed chicken meat products containing chia flour and κ-carrageenan. In the study, using 2% chia flour and 1% κ-carrageenan for producing reduced-fat chicken patties provided the most convenient results for determined properties. Results demonstrated that it is possible to obtain low-fat chicken patties with improved health benefits and positive consumer acceptance by using chia flour and κ-carrageenan. However, future studies are required to determine changes in the physicochemical, textural, and sensory properties of chicken patties containing chia flour under certain storage conditions.

Author Contributions

Ali Murat Kesemen: Conceptualization, Methodology, Investigation, Writing. Ahmet Akköse: Conceptualization, Supervision, Review and Editing. Both authors read and approved the final manuscript.

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