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ARTICLE

The Comparative Effect of Carrot and Lemon Fiber as a Fat Replacer on Physico-chemical, Textural, and Organoleptic Quality of Low-fat Beef Hamburger

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Abstract

This study was designed to determine the usability of lemon fiber (LF-2%, 4%, 6%) and carrot fiber (CF-2%, 4%, 6%) to produce low-fat beef hamburgers. To that end, a certain amount of fat was replaced with each fiber. The proximate composition, pH value, cholesterol content, cooking characteristics, color, texture profile, and sensory properties of low-fat beef hamburgers were investigated. LF increased moisture content and cooking yield due to its better water binding properties, while CF caused higher fat and cholesterol contents owing to its higher fat absorption capacity ($p<0.05$). LF resulted in a lighter, redder, and more yellow color ($p<0.05$). Hardness, gumminess, springiness, and chewiness parameters decreased when the usage level of both fibers increased ($p<0.05$). However, more tender, gummy, springy, and smoother hamburgers were produced by the addition of CF in comparison with LF ($p<0.05$). Moreover, hamburgers including CF were rated with higher sensory scores ($p<0.05$). In conclusion, LF demonstrated better technological results in terms of cooking yield, shrinkage, moisture retention, and fat retention. However it is suggested that CF produces better low-fat hamburgers since up to 2% CF presented sensory and textural properties similar to those of regular hamburgers.

Keywords: dietary fiber, meat products, functional foods, nutrition, fast food products

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Introduction

The consumption rate of fast food products has been increasing rapidly in recent years. Most fast food products are rich in fats and sugar (Aleson-Carbonell *et al.*, 2005). In particular, the contents of beef hamburgers include high fat, saturated fatty acids, salt, and cholesterol. As a consequence of this composition, a high level of beef hamburger consumption causes adverse effects such as obesity, cardiovascular diseases, hypercholesterolemia, and cancers (Aleson-Carbonell *et al.*, 2005; Chizzolini *et al.*, 1999; García *et al.*, 2002; Jiménez-Colmenero and Cofrades, 2001). Therefore, the WHO has suggested that dietary fat should provide between 15% and 30% of the daily intake of calories and saturated fat should not exceed 10% of these calories. It is also advised that cholesterol intake should be limited to 300 mg per day (Cengiz and Gokoglu, 2005; Chizzolini *et al.*, 1999; Jiménez-Colmenero and Cofrades, 2001). In light of these recommendations, a great number of studies have been carried out on the production of low-fat and healthier meat products (Pinero *et al.*, 2008). However, fat reduction brings some problems regarding the acceptance of these products, since fat is a crucial ingredient that affects the texture, flavor, and sensory properties of meat products (García *et al.*, 2002; Hughes *et al.*, 1997; Jiménez-Colmenero, 1996). The replacement of fat by the addition of non-meat proteins, carbohydrate-based materials, or dietary fiber (DF) is suggested as a practical method for elim-

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inating these problems (Desmond *et al.*, 1998).

It has been well documented that DF improves texture and increases cooking yield due to its water and fat binding properties. This functional food is also known to be protective agent against cardiovascular diseases, colon cancer, and diabetes (Eim *et al.*, 2008; Fernández-Ginés *et al.*, 2005; Yılmaz, 2004). Pinero *et al.* (2008) reported that the soluble fiber of oats increased cooking yield and the moisture and fat content of low-fat beef patties, which were softer and juicier. In another study, tapioca starch increased cooking yield and improved the tenderness and juiciness of low-fat beef burgers, but oat fiber and whey protein were not found to be as effective as tapioca starch (Desmond *et al.*, 1998). Similar studies have also been conducted by other researchers (Cengiz and Gokoglu, 2005; El-Magoli *et al.*, 1996; García *et al.*, 2002; Gök *et al.*, 2011; Huang *et al.*, 2005; Hughes *et al.*, 1997; Kumar and Sharma, 2004; Mansour and Khalil, 1997; Mendoza *et al.*, 2001; Serdaroğlu and Değirmencioğlu, 2004; Serdaroğlu, 2006; Ulu, 2006; Yılmaz and Dağlıoğlu, 2003; Yılmaz 2004). In these studies, DF from cereals was more frequently used than fruit and vegetable fibers, although fruit and vegetable fibers have better water and oil holding capacities, better colonic fermentability, as well as lower phytic acid and energy contents. Moreover, they have bioactive compounds (Eim *et al.*, 2008). As an illustration, lemon fiber has flavonoids and vitamin C, which have antioxidant properties (Aleson-Carbonell *et al.*, 2005; Fernández-Ginés *et al.*, 2004; Schieber *et al.*, 2001). Carrot fiber also contains phenolic acids and anthocyanins, which have a strong antioxidant potential, as well as carotenoids (O'Shea *et al.*, 2012). Some processors have also investigated the effects of fruit and vegetable fibers in the following different types of meat products such as pea fiber (Anderson and Berry, 2001) and lemon albedo (Aleson-Carbonell *et al.*, 2005) in low-fat beef burgers such as peach fiber (Grigelmo-Miguel *et al.*, 1999), citrus fiber (Cengiz and Gokoglu, 2005; Fernández-Ginés *et al.*, 2003), lemon albedo (Aleson-Carbonell *et al.*, 2003; Fernández-Ginés *et al.*, 2004), and peach, apple and orange fibers (García *et al.*, 2007) in sausages; lemon albedo (Aleson-Carbonell *et al.*, 2003; Aleson-Carbonell *et al.*, 2004) in dry-cured non-fermented sausage; peach, apple, and orange fibers (García *et al.*, 2002) in low-fat fermented sausage; and carrot fiber (Eim *et al.*, 2008) in dry-fermented sausage and pork sausage (Grossi *et al.*, 2011, 2012). While there have been many studies of the use of DF in meat products (Chizzolini *et al.*, 1999), only a limited number of studies have investigated the use of fruit and vegetable fiber as a fat replacer, especially in hamburgers. Therefore, the main objective of the current study was to compare the effects of lemon or carrot fiber on the physicochemical quality and textural and sensory properties of low-fat beef hamburgers. We included lemon and carrot fiber within the scope of the study because these fibers can be used as functional ingredients to improve the quality and nutritive properties of meat products without changing flavor. In addition, lemon fiber, as a by-product of the citrus industry, constitutes 25% of the entire fruit mass. Therefore, lemon fiber is considered to be another source of income for the citrus industry while it is also a cheap, readily available, and natural supplement for the meat industry (Elleuch *et al.*, 2011). This study also aimed to evaluate these by-products in the production of low-fat beef hamburgers.

Materials and Methods

Formulation and production of low-fat beef hamburgers

Twenty-four hour post-mortem beef and the beef back fat were purchased from a local butcher in Ankara, Turkey. They were transferred in a cooler with ice to Ankara University, Meat Science and Technology Processing Facility. The beef and fat were separately ground through a 3 mm plate using a meat grinder machine (Arı Torna Et Makinaları Sanayii, Turkey). At first, the beef was analyzed in triplicate for fat content, which was approximately 6%. Based on this fat content, the required amounts of beef and fat were calculated to prepare three sets of hamburger dough including 10%, 15%, or 20% fat content of final mass based on the formulation shown in Table 1. The ingredients for each set of hamburger dough were mixed by using a Kitchen Aid mixer (Model: 5KSM 150, USA) for 3 min and each set was divided into seven equal portions. The first portion was separated as a control. For the following three portions, lemon fiber (LF; Herbacel AQPlus, Herbafood Ingredients GmbH, Werder [Havel], Germany) was added at the levels of 2%, 4%, or 6% to each portion after hydrating with tap water. The hydration of the fiber was done with 13 times water to used fiber amount according to the directions given by the producer. The composition of LF was 90% dietary fiber (20% soluble + 70% insoluble), 7.52% moisture, 0.25% fat, 1.53% ash, and 1.9% protein. For the remaining three portions, carrot fiber (CF; Hydrobind carrot fiber, Wm. Bolthouse Farm Inc, USA) was added in the same way. The composition of CF was 92% dietary fiber

Table 1. Formulation of beef hamburgers

Ingredients	Percent
Beef and back fat	71
Bread crumbs	10
Onion	7
Water	9
Salt	2
Sweet red pepper	0.25
Hot red pepper	0.25
Black pepper	0.40
Cumin	0.10

(14% soluble + 78% insoluble), 8.69% moisture, 0.5% fat, 4.94% ash, and 2.8% protein. Thus, the fat content of hamburgers was reduced by the addition of water and dietary fiber. On the addition of fiber, each hamburger dough was mixed again for 3 min. Then, it was placed in a stainless steel tray, covered with aluminum foil and stored in the cooler (4°C) for 3 h to form an intact structure by incorporating the hydrated fiber with the meat. For the next step, the dough from each treatment was divided into portions of 50 g weight and each portion was shaped into hamburger form using a template with a diameter of 9 cm. Each hamburger was wrapped with stretch film purchased from a local market, placed on a tray and frozen quickly using an individual quick freezer (IQF-Frigoscandia Equipment AB, Model: Mobile 0029 0015, Heisingborg, Sweden) to prevent the breakdown of the hamburger form. Then, the hamburgers were kept in the freezer (-18°C) until the following analyses were completed: proximate composition (moisture, fat, protein, ash) and cholesterol analysis, cooking measurements (cooking yield, shrinkage, moisture retention, fat retention), and sensory analysis. Texture profile analysis (TPA), color, and pH measurements were conducted on the same day as the hamburger production. Two replications were set up at different times and duplicate samples were analyzed from each replication.

Cooking procedure and measurements

After the hamburgers were thawed at 4°C, the diameter and thickness were measured by using a compass and the raw hamburger weight was determined for use in a further calculation related to cooking yield. The hamburgers were cooked in a pre-heated pan for 3 min on each side controlling the internal temperature, which should reach 72°C; then, they were allowed to cool for 30 min. The diameter, thickness, and cooked hamburger weight were measured again. Two hamburgers were used for each replication. The diameter and thickness of the hamburgers were measured at four different points on each hamburger. The cooking yield and shrinkage were calculated based on the equations given by Serdaroğlu and Değirmencioğlu (2004). The moisture and fat retention, the most important parameters in evaluating fiber quality, were calculated according to the equations reported by El-Magoli *et al.* (1996).

Physicochemical analysis

In the treatments, the following were determined according to the AOAC (2000) methods: moisture (950.46), crude fat based on the Soxhlet procedure (991.36), crude protein according to the Kjeldahl method for determining the percentage of nitrogen (955.04) and the ash content (920.153). The conversion factor of 6.25 was used to convert nitrogen to a percentage of protein. pH value was measured by dipping a pH electrode into homogenates of samples (10 g) in 100 mL of distilled water. The measurement was performed at room temperature by using a pH-meter (Hanna HI 221, Ann Arbor, USA). For cholesterol analysis, the total lipids of the hamburgers were extracted using the method suggested by Bligh and Dyer (1959). After saponification of the lipids, the cholesterol in the unsaponifiable fraction was detected using the spectrophotometric procedure described by Rudel and Morris (1973).

Color measurements

CIE L^*, a^*, and b^* color measurements were performed on both sides of the raw and cooked hamburgers using a Minolta (CR300, Japan) colorimeter (Diffuse illumination/0° viewing angle), which was standardized with a white calibration plate (reference number 1353123; Y = 92.7; x = 0.3133; and y = 0.3193). Measurements were obtained from six different points for each treatment per replication.

Texture Profile Analysis

The cooked hamburgers were subject to TPA using the Texture Analyzer (TA plus, LLOYD Instruments, a trademark of Ametek Inc.) as described by Ulu (2006). Two hamburgers for each treatment per replication were cooked as described in the subsection on the cooking procedure and allowed to cool for one hour before TPA. The hamburger was placed on the platform of the Texture Analyzer, a cylinder plunger of 6 mm diameter was attached to a 50 kg load cell and the sample was compressed (at three different locations) to 70% of its original height at a cross head speed of 100 mm/min, twice in two cycles. The following parameters were obtained:

Hard Hardness (N): the breaking force of the product at the first loading cycle of TPA

Cohe Cohesiveness: the ratio of storage work to total work in the second loading cycle of TPA

Sprin Springiness (mm): the ratio of storage deformation to total deformation in the second loading cycle of TPA

Gumm Gumminess (N): hardness × cohesiveness

Chew Chewiness (N mm): hardness × cohesiveness × springiness.

Sensory evaluation

An acceptance test was used to determine “acceptability” or “liking rate” for low-fat beef hamburgers in comparison with the control sample. Eight experienced panelists who were faculty members and graduate students in the Food Engineering Department at Ankara University with experience of the sensory analysis of various meat products evaluated the hamburgers with regard to parameters of appearance, color, odor, flavor, texture, and overall acceptability. Hamburgers were thawed at 4°C and cooked as described in the subsection on the cooking procedure. They were allowed to cool until the temperature reached 50°C. Then, they were divided into eight portions to serve to panelists. Hamburger pieces were placed on a plate and 3-digit random numbers were assigned to each piece. They were served warm to the panelists. Distilled water and unsalted, fat-free crackers were also provided for cleansing the mouth feel between each sample. Panelists were asked to indicate how much they liked or disliked low-fat beef hamburgers made with dietary fiber in comparison with the control on a nine-point hedonic scale (1=dislike extremely, 2=dislike very much, 3=dislike moderately, 4=dislike slightly, 5=neither like nor dislike, 6= like slightly, 7=like moderately, 8=like very much, 9=like extremely).

Statistical analysis

The Kolmogorov-Smirnov and Levene’s tests were applied to test normality and homogeneity of variance, respectively. Then, the data sets were analyzed with a three-way fixed effects ANOVA model with fat level (10%, 15%, 20%), fiber level (0%, 2%, 4%, 6%), and fiber type (LF or CF) and means were compared with Duncan’s multiple range test. The Duncan’s test results were displayed in the form of letters. Variables were displayed as mean±standard error of the mean (SEM). The alpha level was set at 5%. The statistical analysis was performed using Minitab 17 statistical programs.

Results and Discussion

Proximate composition and cooking quality of hamburgers

The composition of the beef used in the production of hamburgers was 73.86% moisture, 19.54% protein, 6.02% fat, and 1.10% ash; the composition of fibers has already been covered in the materials and methods section. The proximate composition, cholesterol contents, and pH value for raw and cooked low-fat beef hamburgers are summarized in Fig. 1, while Table 2 presents the results of the “fiber level×fiber type” interaction regarding these analyses. In Fig. 1, the histogram and the left vertical axis presents the results of raw hamburgers. The line chart and the right vertical axis shows the results of the cooked hamburgers. A two-way interaction effect of the “fiber level×fiber type” was determined as significant for the moisture ($p<0.01$) and ash ($p<0.05$) content of raw hamburgers. In general, the differences between treatments originated from additional water that came with the fiber and different technological properties of fiber types. With reference to raw hamburgers, the moisture content gradually increased while the ash, fat, protein, and cholesterol contents decreased as a consequence of additional water coming with increasing levels of both fiber LF and CF ($p<0.05$). A similar increase in moisture content caused by the use of peach fiber in sausages was also observed by Grigelmo-Miguel *et al.* (1999). As shown in Table 2, the two-way interaction of “fiber level×fiber type” was determined to be significant for the moisture, fat, protein ($p<0.01$), and cholesterol ($p<0.05$) contents of cooked hamburgers. A significantly higher moisture content was determined in cooked hamburgers that included LF than in the control, while they had significantly lower fat and cholesterol contents ($p<0.05$). On the other hand, the fat content of cooked hamburgers produced with CF increased and the protein content decreased when compared to the control ($p<0.05$). Based on these results, it is clear that hamburgers with CF presented a higher fat and cholesterol content than those of with LF since CF has a higher fat absorption capacity (Eim *et al.*, 2008). Significantly higher moisture and protein contents were observed in hamburgers that included LF than those with CF since LF has a better water absorption capacity owing to its high level of soluble components, mainly pectin (Aleson-Carbonell *et al.*, 2004, 2005). In addition, the ash content of cooked hamburgers decreased with an increasing

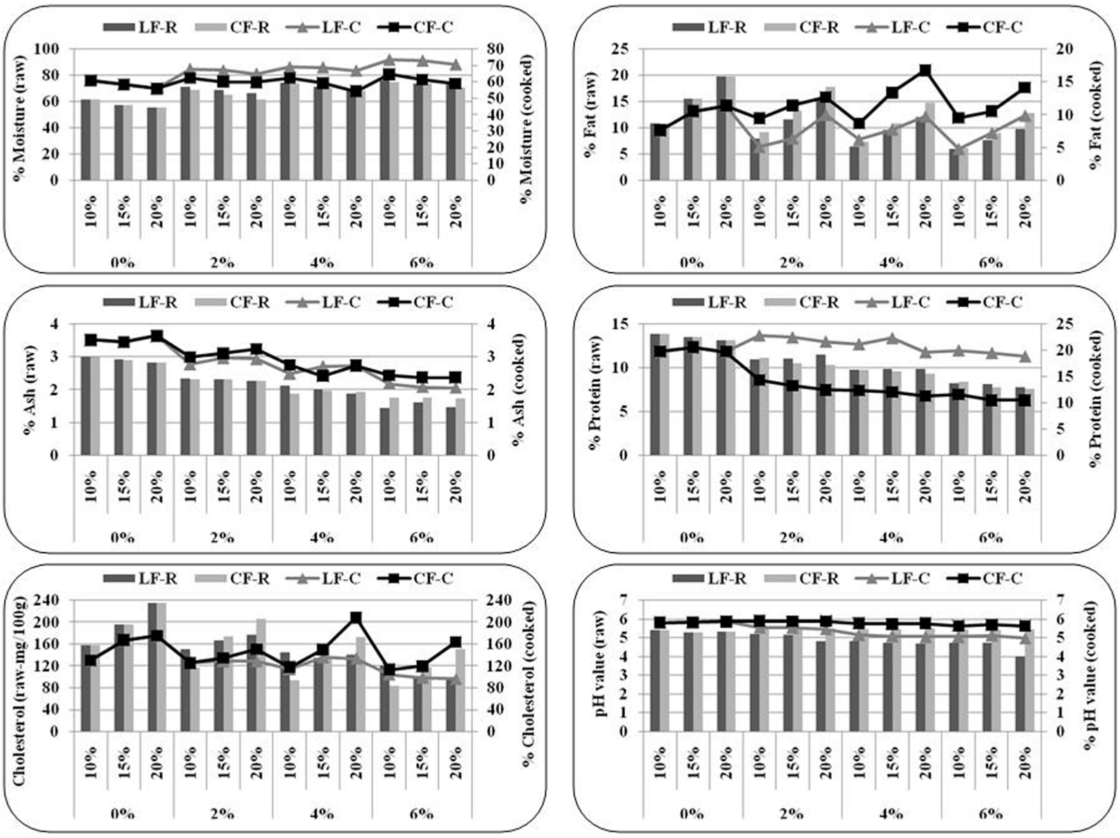


Fig. 1. Proximate composition, pH value, and cholesterol content of raw and cooked low-fat beef hamburgers (n=2).

Table 2. Descriptive statistics and Duncan test results regarding "fiber level×fiber type" interaction for proximate composition, pH value, and cholesterol content of raw and cooked low-fat beef hamburgers (n=2)

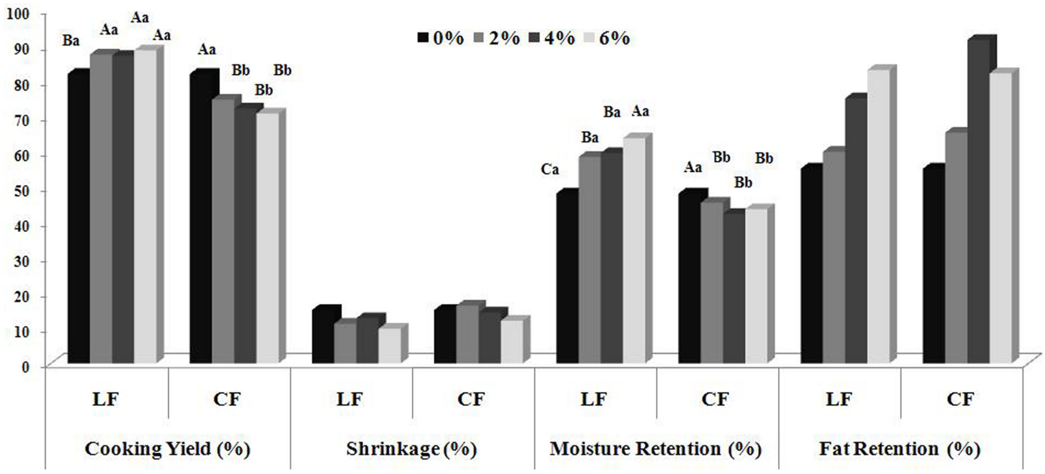
			Moisture (%)	Fat (%)	Ash (%)	Protein (%)	Cholesterol (mg/100g)	pH
Raw hamburgers	0%	LF	58.13±1.50^{Da}	15.91±1.86	2.91±0.04^{Aa}	13.55±0.15	199.00±16.90	5.46±0.04^{Aa}
		CF	58.13±1.50^{Da}	15.91±1.86	2.91±0.04^{Aa}	13.55±0.15	199.00±16.90	5.46±0.04^{Aa}
	2%	LF	68.92±1.09^{Ca}	10.30±2.10	2.31±0.03^{Ba}	11.19±0.15	165.15±4.93	5.07±0.10^{Bb}
		CF	65.32±1.44^{Cb}	13.39±1.61	2.38±0.08^{Ba}	10.69±0.26	166.00±18.50	5.50±0.08^{Aa}
	4%	LF	71.67±1.06^{Ba}	9.34±1.34	1.99±0.08^{Ca}	9.84±0.12	140.53±5.19	4.75±0.07^{Cb}
		CF	70.97±1.29^{Ba}	10.40±1.44	1.91±0.06^{Ca}	9.55±0.14	132.60±18.80	5.47±0.09^{Aa}
	6%	LF	74.29±0.97^{Aa}	7.78±1.12	1.50±0.06^{Db}	8.06±0.12	104.46±5.38	4.49±0.20^{Cb}
		CF	73.16±0.78^{Aa}	9.93±0.97	1.75±0.02^{Ca}	7.92±0.25	120.50±11.60	5.45±0.09^{Aa}
Cooked hamburgers	0%	LF	58.52±0.93^{Ca}	10.02±0.90^{Aa}	3.54±0.05	20.07±0.47^{Ba}	157.72±9.15^{Aa}	5.84±0.02^{Aa}
		CF	58.52±0.93^{Ba}	10.02±0.90^{Ba}	3.54±0.05	20.07±0.47^{Aa}	157.72±9.15^{Aa}	5.84±0.02^{Aa}
	2%	LF	66.81±0.73^{Ba}	6.58±1.16^{Bb}	2.86±0.17	22.37±0.82^{Aa}	127.55±1.64^{Ba}	5.52±0.03^{Bb}
		CF	60.87±0.62^{Ab}	11.17±0.63^{ABa}	3.11±0.07	13.37±0.57^{Bb}	136.84±7.10^{Ba}	5.89±0.02^{Aa}
	4%	LF	68.43±0.59^{Ba}	7.88±1.10^{Bb}	2.65±0.24	21.09±0.71^{ABa}	127.7±10.4^{Bb}	5.10±0.10^{Cb}
		CF	58.72±1.70^{Bb}	12.95±1.54^{Aa}	2.64±0.16	11.93±0.41^{BCb}	158.8±17.3^{Aa}	5.77±0.02^{ABa}
	6%	LF	72.66±0.73^{Aa}	7.27±1.25^{Bb}	2.15±0.12	19.53±0.34^{Ba}	99.88±1.95^{Cb}	5.06±0.07^{Cb}
		CF	61.76±1.35^{Ab}	11.39±0.93^{ABa}	2.40±0.07	10.87±0.33^{Cb}	132.3±11.2^{Ba}	5.66±0.03^{Ba}

$^{A-D}$Means that do not share a letter in the same column are significantly different between different levels of LF or CF (p<0.05).
^{a,b}Means that do not share a letter in the same column are significantly different between LF and CF at the same level of fiber (p<0.05).

level of fiber (p<0.05). These expressions were proven by the cooking measurement results (Table 3). Concerning the "fiber level×fiber type" interaction (Fig. 2), hamburgers produced with LF had a significantly higher yield and

Table 3. Cooking yield, shrinkage, moisture retention, and fat retention results of low-fat beef hamburgers (n=2)

	Fat level	0% LF	0% CF	2% LF	2% CF	4% LF	4% CF	6% LF	6% CF
Cooking yield (%)	10%	84.63±1.33	84.63±1.33	86.78±3.76	77.67±2.78	84.21±1.41	73.22±3.90	87.66±0.29	72.37±1.64
	15%	81.48±0.28	81.48±0.28	86.92±2.58	74.06±3.35	89.17±0.31	72.96±4.06	90.34±1.34	69.85±4.15
	20%	79.90±1.40	79.90±1.40	88.69±2.66	72.32±3.58	87.99±3.10	70.33±3.69	88.00±1.49	70.10±3.74
Shrinkage (%)	10%	12.26±0.80	12.26±0.80	10.38±5.04	13.98±1.14	13.52±0.53	13.70±0.60	7.61±0.26	12.15±1.79
	15%	15.68±0.84	15.68±0.84	9.88±0.20	16.94±2.38	12.62±0.14	14.48±1.82	10.23±1.23	11.70±0.15
	20%	17.40±0.07	17.40±0.07	13.31±0.01	18.18±3.18	12.28±2.27	14.97±1.37	11.57±0.55	12.31±0.66
Moisture retemtion (%)	10%	53.19±0.57	53.19±0.57	59.08±3.10	48.59±2.60	58.22±1.19	45.64±1.43	64.75±0.25	46.89±0.06
	15%	49.33±0.36	49.33±0.36	58.45±2.31	44.62±2.25	61.58±1.54	43.30±1.49	64.15±4.35	42.79±0.60
	20%	46.45±1.61	46.45±1.61	57.80±3.12	43.29±2.48	58.98±2.21	38.12±0.18	62.42±1.93	41.37±1.86
Fat retention (%)	10%	60.90±24.50	60.90±24.50	66.90±16.70	80.40±10.30	80.93±5.46	95.37±0.04	72.08±9.32	87.81±6.77
	15%	56.90±20.80	56.90±20.80	53.60±10.30	64.06±1.75	75.10±9.49	92.88±7.07	88.69±2.36	81.50±1.04
	20%	47.74±1.94	47.74±1.94	59.35±3.92	51.52±0.46	69.30±13.40	86.63±2.27	88.53±2.12	77.14±1.67



[A-C]Means that do not share a letter are significantly different between different levels of LF or CF ($p<0.01$).
[a,b]Means that do not share a letter are significantly different between LF and CF at the same level of fiber ($p<0.01$).

Fig. 2. Descriptive statistics and Duncan test results regarding fiber levelxfiber type interaction for cooking yield, shrinkage, moisture retention, and fat retention results of low-fat beef hamburgers (n=2).

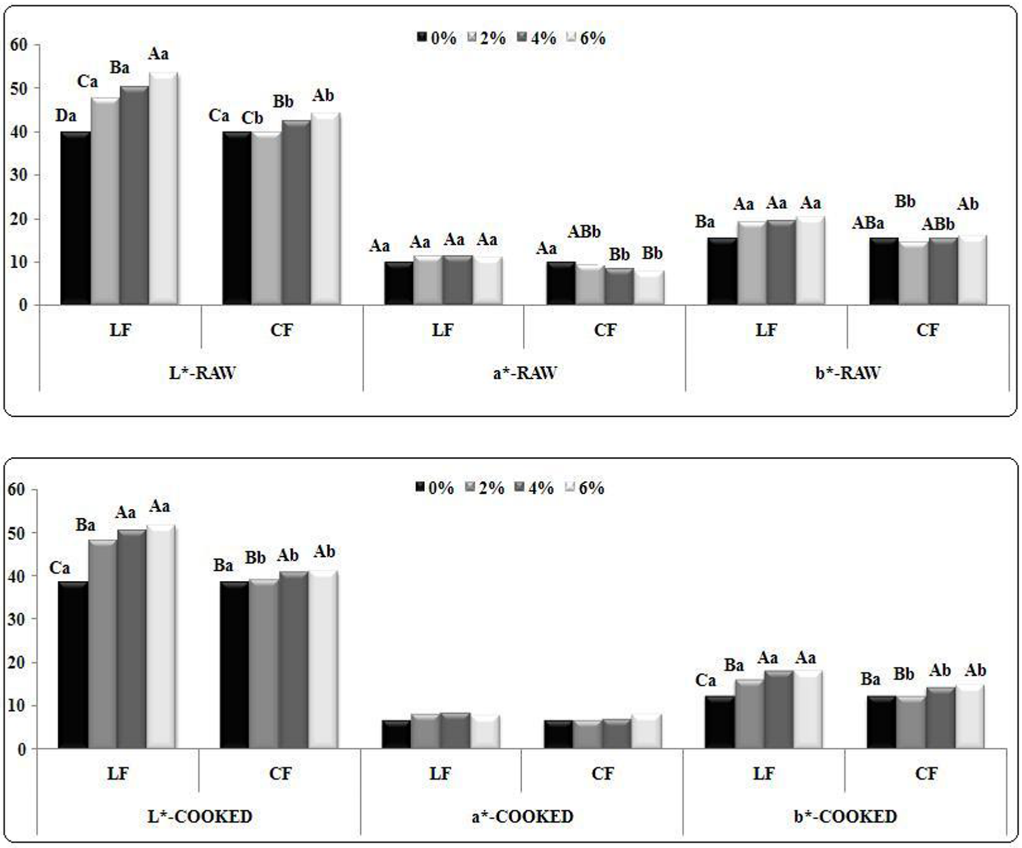
moisture retention value than those of with CF at each level of fiber ($p<0.05$). In addition, these parameters increased with the use of LF, whereas they decreased for CF when compared to the control ($p<0.05$). Aleson-Carbonell *et al.* (2005) observed that the cooking yield of beef burgers including lemon albedo was higher than the control, and Fernández-Ginés *et al.* (2004) also determined a higher moisture content in sausages produced with raw or cooked lemon albedo. Although, cooked hamburgers with CF demonstrated a higher fat content, no significant differences were determined between CF and LF regarding fat retention values ($p>0.05$). Without considering fiber type and fat level, the main effect of fiber level was found to be significant regarding fat retention results. The average value was 55.17%, 62.64%, 83.36%, and 82.63% for hamburgers including 0%, 2%, 4%, and 6% fiber (data not shown), respectively, which means that a 4% or 6% fiber level increased the fat retention ($p<0.05$). With reference to shrinkage levels, a main effect of fat level, fiber level, and fiber type was each determined as significant ($p<0.01$). The average shrinkage value was 11.98%, 13.40%, and 14.68% for hamburgers including 10%, 15%, and 20% fat, respectively (data not shown). As might be expected, shrinkage increased with an increased level of initial fat, since a higher amount of fat was removed during cooking ($p<0.05$). In addition, hamburgers with CF presented a higher shrinkage value (14.48%) compared to those with LF (12.23%) due to the lower water holding capacity of CF (data not shown). Regarding fiber levels, a significant lower shrinkage value was measured for hamburgers with 6% fiber ($p<0.05$). For the pH value presented in Table 2, a significant two-way interaction of "fiber level×fiber type" was observed ($p<0.01$). The usage of LF significantly decreased the pH value of both raw and cooked hamburgers when compared to the control ($p<0.05$). However, while CF did not affect the pH value of raw hamburgers, it lowered the pH value at the 6% level in cooked hamburgers ($p<0.05$). In addition, both raw and cooked hamburgers with CF had significantly higher pH values than those of with LF ($p<0.05$). Possibly, the presence of some organic acids in LF could be a reason for lower pH values in hamburgers (Braddock, 1995). Aleson-Carbonell *et al.* (2005) also reported lower pH values in beef hamburgers produced using different types and concentrations of lemon albedo.

*L**, *a**, and *b** color measurements in hamburgers

Color is a critical food quality attribute because it affects the consumer's initial selection of a raw meat product in the market place (Fletcher, 1999). It also has an effect on a consumer's preferences for the consumption of cooked products. Hamburgers sell out the market place as either raw or cooked, and it is possible to identify at first glance that color is a determinant parameter for sales. The L^*, a^*, b^* color values of raw and cooked low-fat beef hamburgers are shown in Table 4. In addition, the two-way interaction effect of "fiber level×fiber type" was determined to be significant for L^*, a^*, and b^* ($p<0.01$) color values which are presented in Fig. 3, where the value L^* indicates lightness, a^* indicates redness, and b^* indicates yellowness of color coordinates. As can be seen in Fig. 3, lighter color was measured in both raw and cooked hamburgers with increasing levels of LF or CF ($p<0.05$) according to the increase in water and fat contents (Aleson-Carbonell *et al.*, 2005), since water distribution in the meat matrix has the dominant effect upon the evolution of lightness (Aleson-Carbonell *et al.*, 2004). a^* value did not differ for any of the cooked hamburgers, but the usage of CF decreased the redness value in raw hamburgers when compared to the control ($p<0.05$). On the other hand, LF was found to be effective in both raw and cooked hamburgers in increasing the yellowness value in comparison to the control ($p<0.05$), a similar increase to that observed by Aleson-Carbonell *et al.* (2004). This increase is related to the incorporation of yellow components present in the LF (Aleson-Carbonell *et al.*, 2005). When LF is compared to CF for each level of fiber, it is clear that the LF resulted in a lighter, more reddish, and more yellowish color in raw low-fat beef hamburgers ($p<0.05$). Moreover, LF caused a lighter and yellower color in cooked low-fat beef hamburgers, although there were no differences regarding the a^* value ($p<0.05$). Similarly, previous researchers have also examined the effect of fruit dietary fibers on the color of different meat products. Aleson-Carbonell *et al.* (2005) measured a lighter and more yellow color in burgers made with lemon albedo. Fernández-Ginés *et al.* (2003, 2004) reported that citrus fiber presented higher lightness

Table 4. ***L**, *a** and *b** color values of raw and cooked low-fat beef hamburgers (n=2)**

	Fat level	0% Fiber		2% Fiber		4% Fiber		6% Fiber	
		LF	CF	LF	CF	LF	CF	LF	CF
Raw L^*	10%	38.14±0.10	38.14±0.10	46.45±0.22	38.08±0.04	49.46±0.92	42.02±1.88	53.86±1.53	43.19±0.29
	15%	40.02±0.04	40.02±0.04	46.81±0.36	40.29±0.34	50.64±0.23	42.07±1.80	52.75±1.17	43.95±1.65
	20%	41.59±0.28	41.59±0.28	49.55±0.98	41.28±0.06	51.25±0.22	43.33±0.34	53.97±0.32	45.25±0.05
Raw a^*	10%	10.05±0.04	10.05±0.04	11.97±0.14	9.70±0.40	10.39±0.13	8.15±0.96	11.03±0.68	7.81±1.26
	15%	9.84±0.18	9.84±0.18	10.68±0.01	9.20±1.01	12.09±0.37	7.84±0.34	11.02±1.40	7.71±0.28
	20%	9.82±0.46	9.82±0.46	11.39±0.28	8.38±0.65	11.01±1.79	8.86±0.38	10.81±2.97	7.97±0.55
Raw b^*	10%	14.42±0.12	14.42±0.12	18.99±0.06	13.52±0.25	18.67±1.34	15.08±1.10	19.56±3.19	15.44±0.26
	15%	15.61±0.10	15.61±0.10	18.59±0.33	14.76±0.02	18.81±2.08	15.32±1.16	20.40±1.43	16.09±1.14
	20%	16.45±0.08	16.45±0.08	19.50±0.56	15.32±0.27	20.46±0.93	15.92±0.05	20.55±0.75	16.63±0.48
Cooked L^*	10%	39.34±0.26	39.34±0.26	48.99±0.53	38.45±2.28	50.49±1.69	40.78±1.09	52.96±2.88	40.23±1.49
	15%	37.16±1.71	37.16±1.71	47.75±0.47	39.95±0.86	50.36±1.03	41.44±1.57	50.67±1.39	41.53±0.36
	20%	39.10±0.35	39.10±0.35	48.12±0.46	39.47±0.11	50.96±0.42	40.84±0.59	51.80±2.06	42.07±0.27
Cooked a^*	10%	7.05±0.84	7.05±0.84	8.00±0.61	6.39±0.25	7.73±0.40	7.57±0.23	7.63±0.73	8.57±1.26
	15%	7.04±0.35	7.04±0.35	8.13±1.24	6.87±0.79	9.15±1.30	6.85±0.32	7.78±0.99	8.06±0.44
	20%	6.76±0.30	6.76±0.30	8.43±1.13	6.94±0.12	9.21±2.18	7.05±0.38	8.39±1.66	7.75±0.26
Cooked b^*	10%	12.41±0.08	12.41±0.08	16.31±1.40	11.89±0.56	18.19±1.75	14.49±0.47	18.47±1.74	14.12±0.14
	15%	11.72±0.34	11.72±0.34	15.69±0.57	12.71±0.31	17.95±1.67	13.44±1.45	17.95±0.87	15.36±0.28
	20%	12.73±0.34	12.73±0.34	16.42±0.54	12.13±0.44	18.26±2.21	15.37±0.09	18.63±1.36	15.23±0.73



A-D Means that do not share a letter are significantly different between different levels of LF or CF ($p<0.01$).
a,b Means that do not share a letter are significantly different between LF and CF at the same level of fiber ($p<0.01$).

Fig. 3. Descriptive statistics and Duncan test results regarding fiber levelxfiber type interaction for *L*, a*, b color values of raw and cooked low-fat beef hamburgers (n=2).**

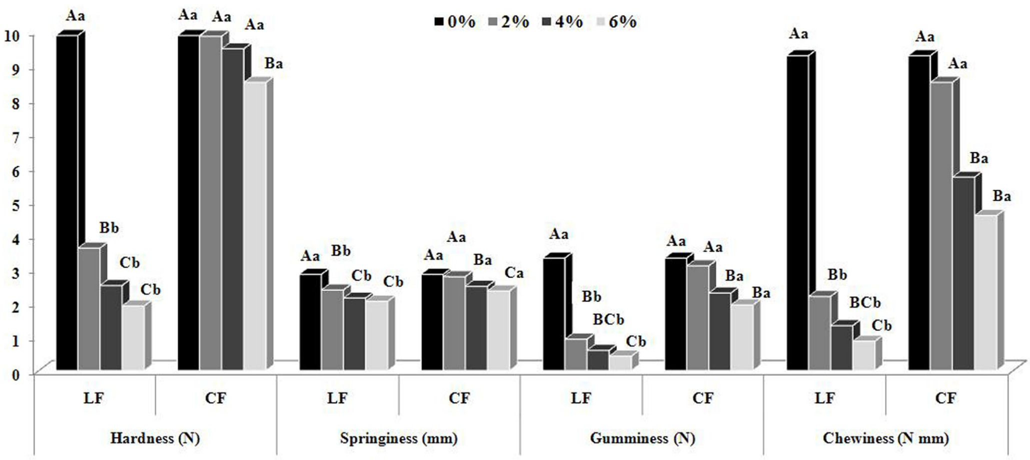
and yellowness values (2003) and lemon albedo resulted in a lighter color and lower redness (2004) in sausages. In another study, Grigelmo-Miguel *et al.* (1999) observed redder and yellower colors in sausages made with increasing levels of peach fiber at low fat content. In the current study, the main effect of fat level was also significant for the L^* and b^* values of raw hamburgers ($p<0.01$). It is possible to report that the L^* and b^* values significantly increased with an increasing level of fat (data not shown).

Texture profile of hamburgers

Texture profile analysis is an important objective test for estimating the eating quality of meat products, and it also provides an idea for the selection of the best treatment (Eim *et al.*, 2008). The texture profile results of cooked low-fat beef hamburgers are seen in Table 5. In addition, significant "fiber level×fiber type" interaction results regarding hardness, springiness, gumminess, and chewiness parameters are presented in Fig. 4 ($p<0.01$). Of these parameters, hardness is the most crucial since the lower the hardness value, the softer the meat product. As shown by Fig. 4, the increased use of LF gradually decreased hardness, but this value did not differ (except for the 6% level) for CF ($p<0.05$). A reduction in hardness is an inevitable result since it is well documented that the dilution effect of fibers on the meat protein system is because its water and fat binding properties cause a softer texture (Tsai *et al.*, 1998). In addition, a significant decrease was reported for the springiness, gumminess, and chewiness parameters in hamburgers including 2%, 4%, and 6% LF compared to the control ($p<0.05$). However, the same trend for these three parameters was also seen for CF at the level of 4% and 6% fiber, but the 2% level of CF presented comparable results to the control as the differences between control and hamburgers with 2% CF was insignificant for the parameters of springiness, gumminess, and chewiness. On the other hand, hamburgers that included CF indicated higher hardness, springiness, gumminess, and chewiness values at each level of fiber when compared to those of with LF ($p<0.05$). These results

Table 5. Texture profile results of cooked low-fat beef hamburgers (n=2)

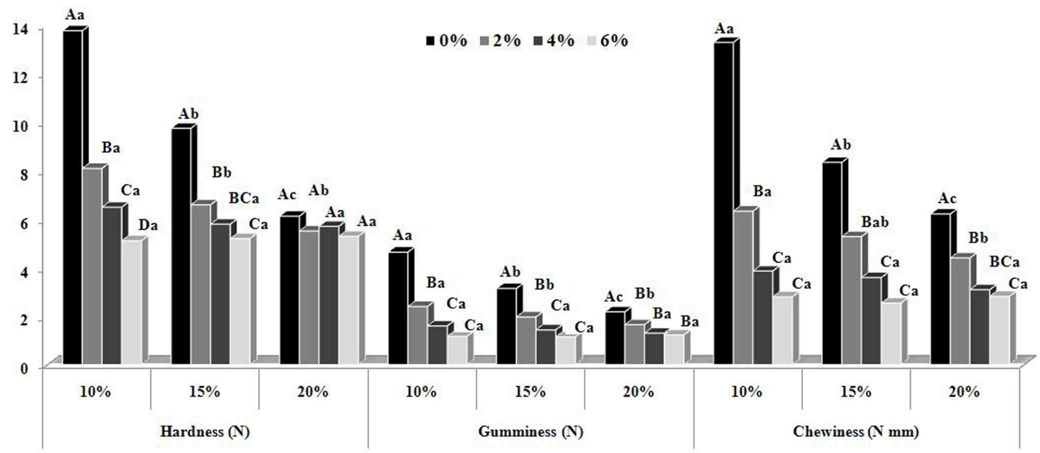
	Fat level	0% Fiber		2% Fiber		4% Fiber		6% Fiber	
		LF	CF	LF	CF	LF	CF	LF	CF
Hardness (N)	10%	13.75±1.78	13.75±1.78	5.39±0.86	10.77±.41	3.15±0.39	9.81±0.01	2.32±0.32	7.87±0.64
	15%	9.73±0.82	9.73±0.82	3.17±0.84	9.99±0.02	2.45±0.41	9.11±0.71	1.59±0.08	8.80±1.12
	20%	6.11±0.01	6.11±0.01	2.24±0.51	8.76±0.50	1.90±0.09	9.48±0.80	1.79±0.35	8.77±1.10
Cohesiveness	10%	0.33±0.01	0.33±0.01	0.25±0.01	0.32±0.01	0.25±0.01	0.25±0.02	0.22±0.04	0.23±0.04
	15%	0.31±0.01	0.31±0.01	0.28±0.03	0.31±0.01	0.25±0.01	0.25±0.02	0.23±0.02	0.22±0.01
	20%	0.38±0.03	0.38±0.03	0.27±0.01	0.31±0.01	0.21±0.01	0.23±0.02	0.23±0.05	0.23±0.02
Springness (mm)	10%	2.85±0.03	2.85±0.03	2.40±0.04	2.73±0.03	2.19±0.04	2.49±0.04	2.28±0.3	2.40±0.13
	15%	2.76±0.02	2.76±0.02	2.35±0.09	2.79±0.02	2.21±0.09	2.51±0.06	1.96±0.05	2.23±0.08
	20%	2.87±0.02	2.87±0.02	2.36±0.01	2.75±0.04	1.99±0.02	2.43±0.05	1.89±0.13	2.40±0.08
Gumminess (N)	10%	4.63±0.72	4.63±0.72	1.34±0.28	3.44±0.25	0.79±0.08	2.39±0.15	0.47±0.06	1.85±0.41
	15%	3.13±0.18	3.13±0.18	0.84±0.13	3.08±0.13	0.58±0.13	2.27±0.39	0.37±0.05	1.92±0.20
	20%	2.17±0.17	2.17±0.17	0.57±0.15	2.72±0.11	0.41±0.04	2.18±0.31	0.43±0.20	2.01±0.39
Chewiness (N mm)	10%	13.27±2.15	13.27±2.15	3.23±0.69	9.41±0.76	1.72±0.15	6.00±0.45	1.11±0.29	4.48±1.22
	15%	8.33±0.76	8.33±0.76	1.96±0.22	8.58±0.32	1.43±0.21	5.73±1.14	0.73±0.08	4.32±0.55
	20%	6.20±0.52	6.20±0.52	1.34±0.35	7.45±0.40	0.81±0.08	5.35±0.81	0.75±0.23	4.87±1.08



[A-C]Means that do not share a letter are significantly different between different levels of LF or CF ($p<0.01$).
[a,b]Means that do not share a letter are significantly different between LF and CF at the same level of fiber ($p<0.01$).

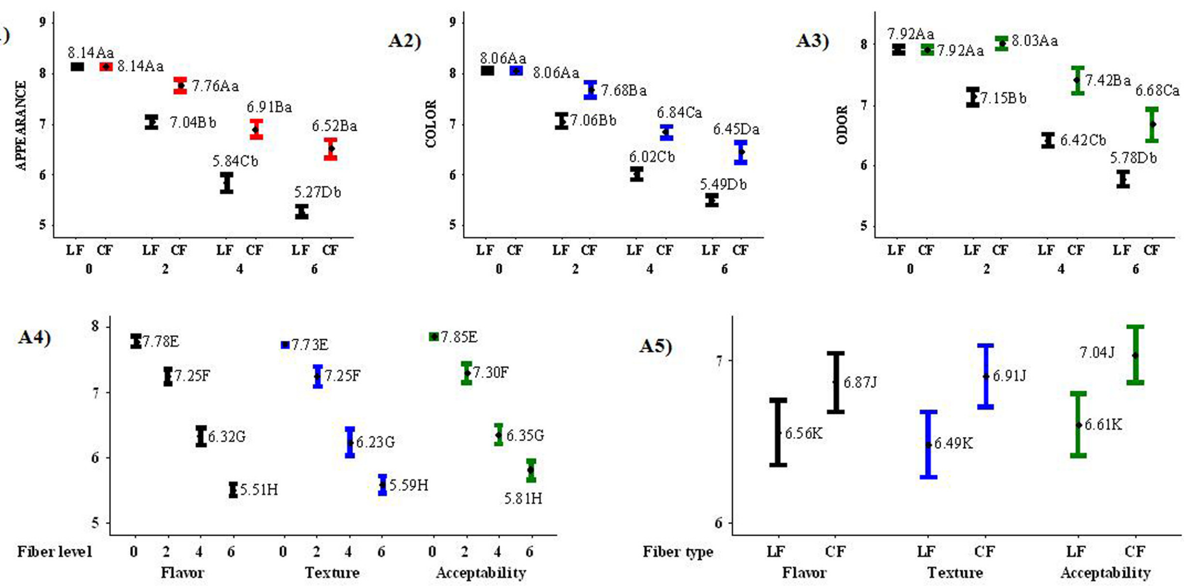
Fig. 4. Descriptive statistics and Duncan test results regarding fiber levelxfiber type interaction for texture profile of cooked low-fat beef hamburgers (n=2).

demonstrate that more tender, springy, and smoother low-fat beef hamburgers were produced by using up to 2% CF without changing texture profiles. In agreement with our results, Aleson-Carbonell *et al.* (2004, 2005) reported that lemon albedo lowered the hardness value of sausages (2004) and also caused a gummier and softer structure in low-fat beef burgers (2005). García *et al.* (2002) produced less hard and more elastic low-fat dry fermented sausages using fruit fibers. In another study, the use of over 3% carrot fiber negatively affected the hardness and compression parameters in dry fermented sausages (Eim *et al.*, 2008). In the current study, as seen in Fig. 5, the two-way interaction effect of “fat level×fiber level” was also found to be significant for the hardness, gumminess, and chewiness parameters ($p<0.01$). Hardness (except 20% fat level), gumminess, and chewiness values gradually decreased with an increasing level of fiber in comparison with control for each fat level ($p<0.05$). Moreover, when the fat level was increased in initial hamburger dough, a significant decrease was observed in hamburgers with 0% and 2% fiber regarding the hardness, gumminess, and chewiness parameters ($p<0.05$). However, no significant effect of initial fat level was determined in hamburgers with 4% and 6% fiber ($p>0.05$). This result showed that increasing the level of initial fat resulted in a softer structure in hamburgers with 0% or 2% fiber.



A-D Means that do not share a letter are significantly different between fiber levels at the same level of fat ($p<0.01$).
a-c Means that do not share a letter are significantly different between fat levels at the same level of fiber ($p<0.01$).

Fig. 5. Descriptive statistics and Duncan test results regarding fat levelxfiber level interaction for texture profile of cooked low-fat beef hamburgers (n=2).



*All results are presented as the mean±standard error.
A-D Means that do not share a letter in the graph A, A2, and A3 are significantly different between different levels of LF or CF ($p<0.01$).
a,b Means that do not share a letter in the graph A1, A2, and A3 are significantly different between LF and CF at the same level of fiber ($p<0.01$).
E-H Means that do not share a letter in the graph A4 are significantly different between different levels of fiber ($p<0.01$).
J,K Means that do not share a letter in the graph A5 are significantly different between LF and CF ($p<0.01$).

Fig. 6. Descriptive statistics and Duncan test results for sensory parameters of low-fat beef hamburgers (n=2).

Sensory evaluation of hamburgers

Fat makes a great contribution to the mouth feel and flavor of meat products by influencing the balance, intensity, realization, distribution and migration of flavor compounds (Hughes *et al.*, 1997). It also affects the texture of meat products by improving the rheological, structural and binding properties of meat (García *et al.*, 2002). Thus, previous studies have reported that fat reduction in meat products has adverse effects on flavor and texture, a determinant attributes for the acceptability of the products. In addition, appearance and color, which are important attributes that affect consumer choice, are also affected by fat reduction (Aleson-Carbonell *et al.*, 2005; Jiménez-Colmenero, 1996; Ulu, 2006). Based on these explanations, it is possible to identify that sensory analysis is a crucial for judging whether use of dietary fiber is acceptable or not in low-fat hamburgers. In the sensory evaluation of hamburgers, the interaction effect of "fiber level× fiber type" was found to be significant for appearance, color, and odor ($p<0.01$) properties (Fig. 6-A1, A2, A3). Appearance, color, and odor scores gradually decreased with an increasing level of both LF and CF fiber in hamburgers when compared to the control ($p<0.05$). However, hamburgers with CF had higher scores than those with LF ($p<0.05$), possibly due to the effect of the better fat binding ability of CF, since keeping fat within the meat matrix ensures sensory quality and acceptability (Anderson and Berry, 2001). Concerning flavor, texture, and the overall acceptability properties, the main effect of "fiber level" or "fiber type" was significant ($p<0.01$). As can be seen from graph A4 (Fig. 6), the flavor, texture, and overall acceptability scores decreased with increasing levels of fiber ($p<0.05$). In graph A5 (Fig. 6), the average scores of hamburgers with LF or CF (regardless main effect of fat and fiber levels) were 6.56 and 6.87 for flavor, 6.49 and 6.91 for texture, and 6.61 and 7.04 for overall acceptability, respectively, which means that hamburgers produced with CF were preferred to those with LF ($p<0.05$). Overall, of the CF treatments, the utilization of 2% CF presented comparable results to the control, but the sensory scores were deficient when the CF added was greater than 2%. In agreement with our results, Aleson-Carbonell *et al.* (2003) reported that the use of 2.5% lemon fiber demonstrated sensory properties similar to traditional sausage. In another study, carrot fiber up to 3% improved the sensory properties of dry fermented sausage (Eim *et al.*, 2008).

Conclusion

When considering sensory scores and texture profile results, it is suggested that up to 2% CF could be used to produce low-fat hamburgers that have comparable properties to regular hamburgers. However, the higher fat binding ability of CF may restrict its use in low-fat meat products. On the other hand, LF should not be ruled out since it has advantages of increased yield and moisture retention due to its better water binding capacity and decreased fat and cholesterol content. Moreover, LF and CF contribute to the nutritional and health qualities of the products. Therefore, further studies are recommended to determine the appropriate usage level for the production of acceptable low-fat meat products.

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