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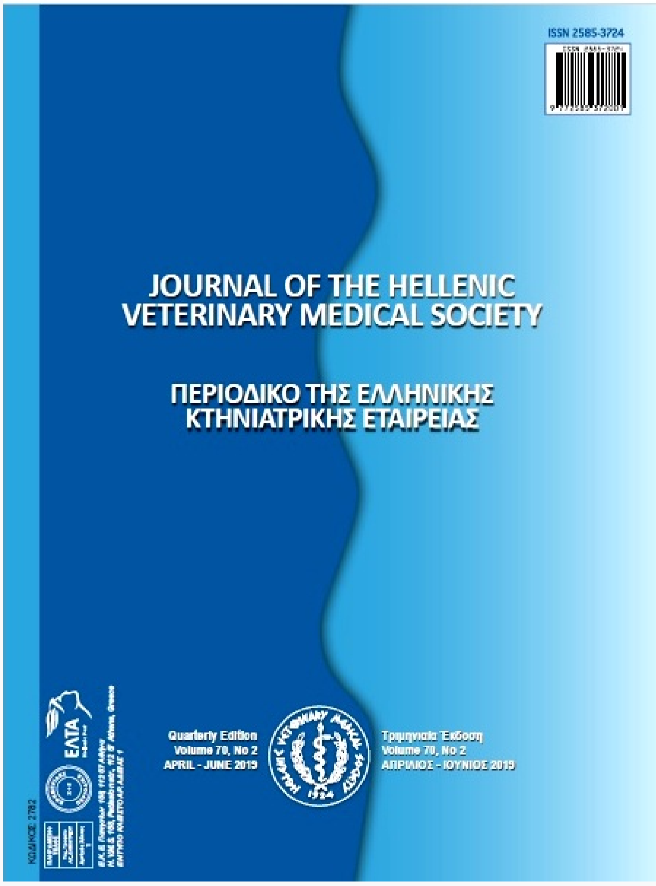

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Physicochemical, Technological and Sensory Properties of Chicken Meatballs Processed with Dietary Fibers

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ABSTRACT. In this study, raw chicken meatball samples were incorporated with apple, lemon and pea fibers at different concentrations (0, 4, 8 and 12%). Their physicochemical properties were evaluated at different refrigerated storage time spots (1st, 5th and 10th days) while the fried samples were investigated with respect to their color, technological and sensory properties. The results revealed that the physicochemical properties of raw samples were significantly (P <0.05) affected by fiber type and concentration within the storage periods while color, technological and sensory properties of the fried samples were also significantly changed (P <0.05) according to the fiber type and concentration. Thiobarbutiric acid reactive substance values of raw samples incorporated with the fibers were observed to be lower than those of the control samples at the end of the storage period, indicating that fiber addition could delay lipid oxidation increasing their storage stability. Fiber addition affected the brightness (L^* values), redness (a^* values) and yellowness (b^* values) of both the raw and fried samples. Regarding technological properties of the fried samples, fiber addition generally increased (P <0.05) frying yield, and moisture retention values up to 4%, followed by a decrease at further concentrations. Meatball diameter decreased by addition at level of 4% for all fiber types, but further increase in the fiber concentration did not decrease these values. The maximum fat retention was observed in the fried samples incorporated with the apple and lemon fibers at 12 % concentration. Sensory properties were affected by fiber concentration up to 8%, which constituted the highest tolerated concentration. As a result, fiber addition positively affected the physicochemical and technological properties of the meatballs, but this affect was strongly related to the fiber type and its concentration.

Keywords: chicken meatball, apple fiber, lemon fiber, pea fiber, physicochemical and technological properties

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INTRODUCTION

Recently, consumers in developed societies have been more interested in healthier diets. Food manufacturers have increased their efforts to contribute to limit health problems such as diabetes, obesity, and cardiovascular diseases by producing low-fat and low-calorie chicken products (Tabarestani and Tehrani, 2014). High-fat chicken products are also related to the enzymatic (proteolytic deterioration), oxidative, textural problems during storage period, leading to changes in essential fatty acid and vitamin composition, decreasing the nutritional values of such products as well as deteriorating their sensory properties. These problems cause financial losses for producers and increase consumers' health risks. Thus, many studies have been conducted to improve the quality and stability of these foods (Khalil, 2000; Mc-Carthy et al., 2001; Castro et al., 2011; Ibrahim et al., 2011).

Addition of dietary fibers is one of the strategies to overcome the aforementioned problems Dietary fibers contribute healthier diet because a high-fiber diet normalizes bowel movements, maintain bowel health, lowers cholesterol levels and control blood sugar levels, and helps in achieving healthy body weight. Therefore, the trend for daily diets with high levels of dietary fiber is the incentive to produce such products (Sarıçoban et al., 2010). Dietary fibers are also more attractive than other materials such as thickeners and binders like starches, gums and whey protein concentrate, etc. since they have lower cost and are more available than the others. Fibers are known to remarkably develop technological properties of meat products due to their high water holding capacity, which reveals their possibility to be also used in the production of low-fat chicken meatballs. This appears to be good strategy to improve textural and sensory properties and to increase the shelf life of the chicken meatballs by reducing the metabolites resulting from spoilage. Accordingly, it was reported that the fibers could be used to prevent deterioration of meat and chicken products, increasing the quality of the final products (Talukder and Sharma, 2010; Elleuch et al., 2011; Pinero et al., 2008; Petracci et al., 2013).

In spite of the aforementioned beneficial health effects of the dietary fibers, their usage in meat formulations, is depending on their functionality and interaction with other ingredients in the formula. This limits their usage in some aspects. Therefore, the possible interactions of the dietary fibers with main components of meat products should be determined in order for them to play a key role on the functionality of final products. The present work was undertaken to determine the effect of fiber type (apple, lemon and pea) and concentration (0, 4, 8 and 12%) on physicochemical properties of raw chicken meatballs at different refrigeration storage periods (1st, 5th and 10th days) as well as on color, technological and sensory properties of fried chicken meatballs.

MATERIALS AND METHODS

Materials

Apple fiber (moisture–9.3%, total dietary fiber–70%, ash–1.40%, crude protein–6.8 %, crude fat–2.1 %, water holding capacity 4 mL/g) and lemon fiber (moisture–5.6%, total dietary fiber–90%, ash–1.60%, crude protein–2.2 %, crude fat–0.4 %, water holding capacity 6 mL/g) were purchased from Herbafood Co. (Herbafood Ingredients GmbH, Germany). Pea fiber (moisture–5.99%, total dietary fiber–70%, ash–4.30%, crude protein–7.2 %, crude fat–2.6 %, water holding capacity 3.7 mL/g) was obtained from Roquette Co. (France). Chicken breast meat used in meatball production was obtained from a local seller in Adiyaman, Turkey. Corn oil used as a frying medium was procured from Yudum Co. (Balıkesir, Turkey). A mini fryer (Arzum, 246, Turkey) was used for frying operations.

Methods

Preparation of chicken meatballs

Chicken breast meats were kept and transferred at -18 ^{o}C in plastic bags to laboratory. Before use in the meatball production, they were thawed at 4 ^{o}C and minced using a grinder machine (Tefal, Le Hachoir 1500, France). For preparation of the experimental batches, 4750 g ground meat was mixed with 100 g corn oil, 75 g salt, 50 g black pepper and 25 g curry and kneaded for 15 min to obtain a homogeneous raw meatball mixture. Then, the dough was allocated into three groups and each of them was separately added with dietary fibers (apple, lemon and pea) at four different concentrations (0% (Control), 4%, 8% and 12%, based on 100 g of the dough). Each sample was re-kneaded and shaped into meatballs by rounding with hand at equal diameters (approx. 20 g weight and 30 mm diameter for each sample, measured by a digital caliper). Then, all the meatball samples were separated into two groups as raw and cooked meatballs. Forty meatballs were produced for each treatment. The physicochemical analyses (pH, Thiobarbutiric Acid Reactive Substance, *L**, *a** and *b**) were conducted for the raw meatball samples placed in polystyrene foam dishes, wrapped with stretch film and stored at 4 °C and examined at certain storage days (1st, 5th and 10th days). The color (*L**, *a** and *b**), technological (frying yield, reduction in diameter, moisture retention and fat retention), and sensory (appearance, odor, taste and texture) analyses were performed for the chicken meatball samples fried in 1 L of corn oil at 180 °C for 5 min.

Determination of physicochemical analyses

The pH values of the samples were measured by using pH meter (WTW 315 i set model, Weilhem, Germany) after homogenization, as outlined (AOAC, 2002). The extent of oxidative rancidity (Thiobarbutiric Acid Reactive Substance, TBARS) was determined as described by Tarladgis et al. (1969). The absorbance was read at 538 nm (UV-160 A, UV-Visible Recording Spectrophotometer, Shimadzu, Tokyo, Japan) against a reagent blank. The TBARS numbers were expressed as mg of malon-dialdehyde (MDA/kg) equivalents. Color measurements were conducted using a Minolta Chroma Meter CR-400 (Konica Minolta, Inc., Osaka, Japan) with illuminant D65, 2° observer, Diffuse/O mode, 8-mm aperture of the instrument for illumination and 8mm for measurement. Prior to the measurements, a white reference tile (*L**= 97·10, *a**= –4·88, *b**=7·04) was employed to calibrate the instrument. The meatball samples were subjected to air for at least 20 min at 25 °C before the measurements. For each meatball sample, three locations were measured in terms of *L** (brightness), *a**(±red–green) and *b**(±yellow–blue) color values and the measurements were averaged and recorded (Hunt et al., 1991).

Determination of technological properties

Frying yield

Frying yield of the meatball samples were calculated using the equation (Eq. (1)) employed by Murphy et al (1975) and Tekin et al., 2010):

$$\text{Frying yield \%} = \frac{\text{fried meatball weight}}{\text{raw meatball weight}} \times 100 \tag{1}$$

Reduction in diameter

The reduction in meatball diameter before and after frying was estimated by a digital caliper (Mitutoyo, Japan) using the following equation (Eq. (2)):

$$\text{Reduction in diameter \%} = \frac{\text{raw meatball diameter-fried meatball diameter}}{\text{raw meatball diameter}} \times 100$$

$$\text{Reduction in diameter \%} = \frac{\text{raw meatball diameter-cooked meatball diameter}}{\text{raw meatball diameter}} \times 100 \tag{2}$$

Moisture retention

The amounts of moisture retained in the fried meatballs per 100 g sample can be indicated by moisture retention values. Moisture of raw and fried meatball samples was determined by oven air method, as outlined (AOAC, 2002). Moisture retention values were calculated according to the following equation (Eq. (3)) (Soltanizadeh and Ghiasi-Esfehani, 2015):

$$\text{Moisture retention \%} = \frac{\text{moisture in fried meatball \%}}{\text{moisture in raw meatball \%}} \times \text{frying yield} \tag{3}$$

Fat retention

Fat retention values were calculated according to the Eq. (4) (Tekin et al., 2010; Soltanizadeh and Ghiasi-Esfehani, 2015):

$$\text{Fat retention \%} = \frac{(\text{fried weight x fat in fried meatball \%})}{(\text{raw weight x fat in raw meatball \%})} \times 100 \tag{4}$$

Sensory analysis

The acceptability of sensory profile of the fried meatballs was evaluated by semi-trained 10 panellists of age between 20 and 40. Each panellist was served with 3 samples. Fried chicken meatballs were served in a random order to the ten panellists. The panellists were also served with water and cracker biscuits between the assessments to allow them to rinse properly and neutralize carryover flavours. Panellists were enabled to sit in the different locations separated from frying and preparation room. Panellists evaluated the coded samples to reduce bias. The sensory properties were evaluated using a hedonic scale for the appearance, odor, taste, and texture. The values in the scale indicated the following reactions: 1: dislike extremely to 9: like extremely (Gokalp et al., 1999).

Table 1. Effect of fiber type and concentration on physicochemical values of raw meatballs at different storage periods.

		1st day				5th day				10th day			
		Fiber concentration				Fiber concentration				Fiber concentration			
	Fiber type	**Control (0%)**	**4%**	**8%**	**12%**	**Control (0%)**	**4%**	**8%**	**12%**	**Control (0%)**	**4%**	**8%**	**12%**
pH	Apple	6.07^{aAY}	5.82^{bBX}	5.55^{bCX}	5.25^{bDX}	5.91^{aAZ}	5.67^{aBY}	5.41^{bCZ}	5.14^{bDX}	6.51^{aAX}	5.92^{bBX}	5.49^{bCY}	5.17^{bDX}
	Lemon	6.07^{aAY}	5.76^{bBX}	5.38^{cCX}	5.13^{cDX}	5.91^{aAZ}	5.71^{aAX}	5.27^{cBX}	4.92^{cCY}	6.51^{aAX}	5.99^{bBX}	5.36^{bCX}	4.91^{cDY}
	Pea	6.07^{aBY}	6.09^{aBY}	6.14^{aABX}	6.19^{aAX}	5.91^{aBZ}	6.01^{aABY}	6.09^{aAX}	6.12^{aAXY}	6.51^{aAX}	6.58^{aAX}	6.09^{aBX}	6.02^{aBY}
TBARS (mg/kg)	Apple	0.085^{aBZ}	0.070^{cBZ}	0.095^{bBY}	0.195^{aAZ}	0.345^{aAY}	0.300^{aAY}	0.365^{aAY}	0.395^{aAY}	1.565^{aAX}	0.850^{abBX}	0.865^{aBX}	0.845^{aBX}
	Lemon	0.085^{aCZ}	0.120^{bBZ}	0.165^{aAY}	0.130^{aBY}	0.345^{aAY}	0.400^{aAY}	0.325^{aAXY}	0.285^{aAY}	1.565^{aAX}	0.765^{bBCX}	0.650^{aCX}	0.995^{aBX}
	Pea	0.085^{aCZ}	0.275^{aAY}	0.205^{aBZ}	0.185^{aBY}	0.345^{aAY}	0.325^{aAY}	0.315^{aAY}	0.350^{aAY}	1.565^{aAX}	1.020^{aBCX}	1.140^{aBX}	0.810^{aCX}
*L**	Apple	45.94^{aAX}	40.65^{bBX}	38.29^{bBCX}	36.62^{bCX}	44.93^{aAXY}	38.35^{cBY}	37.25^{bBCX}	35.90^{bCX}	42.33^{aAY}	37.56^{cBY}	34.81^{bCY}	34.66^{bCX}
	Lemon	45.94^{aBX}	45.47^{aBX}	46.16^{aABX}	48.59^{aAX}	44.93^{aAXY}	44.20^{bBY}	44.62^{aBXY}	48.52^{aAX}	42.33^{aBY}	40.01^{bCZ}	41.63^{aBCY}	47.29^{aAY}
	Pea	45.94^{aBX}	46.39^{aBX}	47.95^{aABX}	50.81^{aAX}	44.93^{aAXY}	45.41^{aBX}	45.57^{aBXY}	48.93^{aAXY}	42.33^{aBY}	42.46^{aBY}	44.43^{aBY}	47.01^{aAY}
*a**	Apple	1.50^{aCX}	4.26^{aBX}	5.25^{aABX}	5.78^{aAX}	0.23^{aDY}	2.60^{aCY}	4.11^{aBY}	4.56^{aAY}	1.32^{aCX}	2.43^{aBY}	3.99^{aAY}	4.30^{aAY}
	Lemon	1.50^{aAX}	1.17^{bABX}	1.05^{cABX}	0.77^{bBX}	0.23^{aAY}	0.01^{bABY}	-0.08^{bABY}	-0.60^{cBY}	1.32^{aAX}	0.13^{cBY}	-0.38^{cBCY}	-0.75^{cCY}
	Pea	1.50^{aAX}	1.32^{bAX}	1.53^{bAX}	0.73^{bBX}	0.23^{aAY}	-0.29^{bBY}	0.09^{bAZ}	0.18^{bAY}	1.32^{aAX}	1.07^{bABX}	0.74^{bBCY}	0.38^{bCXY}
*b**	Apple	16.74^{aAX}	15.18^{bBX}	13.96^{aCX}	13.55^{bCX}	15.24^{aAX}	14.04^{bABY}	13.83^{bABX}	13.08^{bBXY}	14.89^{aAX}	13.30^{cABZ}	12.42^{bBY}	12.50^{bBY}
	Lemon	16.74^{aAX}	17.85^{aAX}	16.81^{aAX}	17.33^{abAX}	15.24^{aCX}	17.54^{aBCX}	17.95^{aBX}	20.56^{aAX}	14.89^{aCX}	15.25^{bBCY}	16.85^{aBX}	20.06^{aAX}
	Pea	16.74^{aCX}	18.09^{aBCX}	19.23^{aABX}	20.52^{aAX}	15.24^{aCX}	17.67^{aBX}	18.31^{aBXY}	20.38^{aAX}	14.89^{aCX}	16.45^{aBCX}	17.46^{aABY}	18.94^{aAX}

$^{a\text{-}c}$ Within each column, different superscript lowercase letters show differences between the fiber types within each concentration ($p< 0.05$). $^{A\text{-}D}$ Within each row, different superscript uppercase letters show differences between the fiber concentrations within each storage period ($p < 0.05$). $^{X\text{-}Z}$ Within each row, different superscript uppercase letters show differences between the storage periods with respect to same fiber type and concentration ($p < 0.05$).

Statistical analysis

The experimental procedure was repeated twice with three replications. Data were subjected to statistical analysis using JMP version 9.0.2 (SAS Institute, Inc., Cary, USA). Least Significant Differences (LSD) test was used to determine if the effects of factors on the studied parameters were significant ($p < 0.05$).

RESULTS AND DISCUSSIONS

Effect of fiber type and concentration on physicochemical properties of raw meatballs

Table 1 shows the effect of fiber type and concentration on physicochemical values of raw meatballs at different storage periods. As can be seen, pH values were significantly (P <0.05) influenced by fiber addition to raw meatball samples, decreasing by addition and apple and lemon fibers, but increasing by addition of pea fiber at the 1st and 5th storage day. These results could be expected due to malic and citric acid contents of apple and lemon, respectively. On the other hand, these effects were strongly fiber-concentration dependent, implying that pH values were more changed by further increase in the fiber concentration. At the end of the 10th storage day, pH values of the all raw samples were observed to decrease. In the literature different results were reported. Sanchez-Zapata et al. (2010) determined the pH value of burgers processed with tiger nut fiber in the range of 6.16-6.20 and observed that the fiber addition did not affect the pH values of pork burgers.

TBARS values, an indicator of oxidation stability of a food product, were observed to increase by storage time (Table 1). This can be expected because lipid oxidation increases by the storage time. At the 5th storage day, fiber addition did have any remarkable effect on the lipid oxidation of the raw samples, while apple, lemon or pea fiber addition significantly (P <0.05) limited the lipid oxidation of the raw samples at the 10th day of storage time, as revealed by the lower TBARS values observed in the raw meatball samples processed with the dietary fibers. When the dietary fibers were compared with each other in terms of their performance to limit lipid oxidation in the raw samples, it can be stated that all the fiber types had almost similar effects, but at 4% concentration, lemon and apple fibers retarded lipid oxidation more effective than did pie fiber. Similar results were reported in the literature. Cava et al. (2012) observed that tomato fiber and beef root fibers addition reduced the lipid oxidation in chicken products, reporting that oxidation was fiber concentration-dependent. On the other hand, they determined the TBARS values in the range of 2.03-3.82 mg/kg at 10th day of storage (4^{o}C). In addition, higher TBARS values were reported by Schormuller (1969) at the end of the storage period. In our study, lower TBARS values were determined, revealing that the studied fibers could successfully retard lipid oxidation. Also, the TBARS values of the raw meatballs in the end of the storage were determined at the levels of consumption that were given between 0.7 to 1 mg/kg by Gokalp et al (1999).

The color properties of the raw meatballs were expressed as $L*$ (brightness), $a*$ (redness) and $b*$ (yellowness) in this study. The results are also presented in Table 1 where it can be seen that apple fiber addition decreased (P <0.05) the brightness of the raw meatball samples while lemon and pea fiber addition generally increased the brightness (P <0.05) at all the storage periods. These effects were concentration-dependent. Accordingly, lemon and pea fiber addition resulted in brighter raw product in almost all concentrations at all test time spots. An inverse trend was observed in the redness values. In other words, apple fiber addition increased (P <0.05) the redness of the raw meatball samples while lemon and pea fiber addition decreased (P <0.05) at all the test time spots. Similarly, these effects were also concentration-dependent. Accordingly, apple fiber addition resulted in redder raw product during storage. Regarding yellowness of the raw meatball samples, the same phenomenon observed in the $L*$ values; namely, apple fiber addition decreased (P <0.05) the yellowness of the raw meatball samples, while lemon and pea fiber addition generally increased (P <0.05) during storage. These effects were also concentration-dependent. Accordingly, lemon and pea fiber addition resulted in yellower raw product in almost all concentrations at all tst time spots during storage. Similar results were observed by Aleson-Carbonel et al. (2005) who determined that the inclusion of fiber from citrus changed color values of beef burgers.

Effect of fiber type and concentration on color and technological properties of fried meatballs

Table 2 shows the effect of fiber type and concentration on color properties of fried meatball samples. As can be seen, a different phenomenon was observed in the fried meatball samples in terms of the color values. Apple fiber addition resulted in darker, greener and more bluish (P <0.05) product than did lemon and pea fibers and this effect was prominent at increasing concentration levels. In other words, lemon and pea fiber addition resulted in brighter, redder and yellower product than did apple fiber addition; however, this effect was more prominent when the meatballs were processed with pea fiber. Similar results were reported by Allesson- Carbonell et al. (2005) and Sanchez-Zapata et al. (2010) for beef and pork burgers, respectively.

Table 2. Effect of fiber type and concentration on color properties of fried meatballs.

		Fiber concentration			
	Fiber type	**Control (0%)**	**4%**	**8%**	**12%**
L^*	Apple	41.21^{aA}	29.70^{bB}	25.58^{cC}	22.54^{cC}
	Lemon	41.21^{aAB}	45.27^{aA}	42.52^{bAB}	39.97^{bB}
	Pea	41.21^{aC}	43.95^{aB}	46.10^{aB}	49.87^{aA}
a^*	Apple	7.21^{aB}	11.38^{aA}	8.26^{cB}	5.66^{cC}
	Lemon	7.21^{aC}	8.61^{bB}	9.66^{aA}	9.32^{bA}
	Pea	7.21^{aC}	9.47^{bB}	11.45^{aA}	11.85^{aA}
b^*	Apple	19.10^{aA}	11.73^{bB}	7.37^{cC}	5.17^{cD}
	Lemon	19.10^{aAB}	20.96^{aA}	19.87^{bAB}	18.65^{bB}
	Pea	19.10^{aC}	20.75^{aB}	22.23^{aB}	24.03^{aA}

$^{a-c}$ Within each column, different superscript lowercase letters show differences between the fiber types within each concentration (p < 0.05). $^{A-D}$ Within each row, different superscript uppercase letters show differences between the concentrations within each fiber (p < 0.05).

Table 3. Effect of fiber type and concentration on technological properties of fried meatballs.

Technological properties	Fiber type	Fiber concentration			
		Control (0%)	4%	8%	12%
Frying yield (%)	Apple	86.04[aB]	90.59[aA]	83.49[bC]	79.09[bD]
	Lemon	86.04[aA]	83.45[bA]	77.15[cB]	78.81[bB]
	Pea	86.04[aC]	90.03[aA]	87.69[aB]	86.27[aBC]
Reduction in diameter (%)	Apple	6.30[aA]	-1.90[aB]	-0.25[abB]	1.57[aAB]
	Lemon	6.30[aA]	-1.68[aB]	3.20[aAB]	1.61[aAB]
	Pea	6.30[aA]	-2.52[aB]	-2.30[bB]	-2.87[aB]
Moisture retention (%)	Apple	74.00[aB]	81.21[aA]	71.11[bB]	62.86[bC]
	Lemon	74.00[aA]	72.63[bA]	61.34[cB]	56.29[cC]
	Pea	74.00[aB]	80.59[aA]	78.44[aA]	74.20[aB]
Fat retention (%)	Apple	3.58[aAB]	3.37[aB]	3.31[bB]	4.74[bA]
	Lemon	3.58[aB]	3.05[aB]	4.18[aB]	8.26[aA]
	Pea	3.58[aA]	3.28[aAB]	2.59[bBC]	2.36[cC]

[a-c] Within each column, different superscript lowercase letters show differences between the fiber types within each concentration ($p < 0.05$). [A-C] Within each row, different superscript uppercase letters show differences between the concentrations within each fiber ($p < 0.05$).

Effect of fiber type and concentration on technological properties of fried meatballs can be seen in Table 3. As seen, frying yield of the meatball samples increased ($P < 0.05$) with the addition of apple and pea fibers at 4%. This was attributed to the ability of apple and pea fibers to keep the moisture and fat in the matrix. The mechanism responsible for moisture and fat retention was suggested to be affiliated with the swelling of the fibers, which would enable them to absorb some fat and interact with the protein in ground chicken to form a matrix. This phenomenon finally was hypothesized to hinder the coalescence and migration of fat out of the fried meatballs (Anderson and Berry, 2001). As a result, the apple and pea fibers could be said to have high fat retention ability, reducing the cooking loss and so increasing the frying yield. However, further increase resulted in a decrease in the frying yield of the meatball samples. This could be ascribed to hard and friable structure caused by the fact that the fiber addition in higher concentrations gave rise to softer structure, finally leading to loss of fat and moisture. It should be also pointed out here that lemon fiber addition did not increase the frying yield in spite of its high total fiber content (90 %). This could have been due to the lowest pH values of the raw meatball samples processed with lemon fiber (Table 1). As can be seen from the table, the raw meatball samples processed with lemon fiber had generally the lowest pH values, which caused pH of the samples to approach the isoelectric point of proteins where moisture retention ability of the chicken proteins is almost close to zero.

The effect of fiber type and concentration on reduction in diameter of the meatball samples can be seen from Table 3. As can be clearly seen, the fiber addition significantly ($P < 0.05$) decreased the reduction in diameter values. This result could also be expected due to the fact that fibers have capability to entrap fat and water, which led to a decrement in the reduction in diameter of the meatball samples in this study (Tekin et al., 2010). However, this effect was prominent at 4 % concentration and further increase in the fiber concentration did not change these values. This implicated that the fiber addition decreased reduction in meatball diameter but further increase in fiber concentration (8 and 12 %) did not significantly change the diameters of meatballs. It is interesting to report here that pea fiber addition even increased the diameter of meatballs (Table 3). Similar results have been previously reported for wheat, cellulose, oat, inulin and carrot fibers (Kılıncceker, 2017; Kılınççeker and Kurt, 2018).

Moisture retention values were observed to be significantly ($P < 0.05$) affected by fiber type and concentration (Table 3). Apple and pea fibers increased the moisture retention values. This could be similarly affiliated with the effect of these fibers to increase water retention ability of meatballs; namely, this result could be due the capability of the fibers to keep the moisture in the matrix (Tekin et al., 2010). On the other hand, an inverse trend was also observed at their further concentrations. Namely, after 8 % concentration, these fibers could not hold moisture; furthermore at 12 % concentration, these fibers started to release the moisture that they could hold at 4 % concentration. Same phenomenon could was not observed in the meatball samples processed with lemon fiber. Increase in the level of lemon fiber resulted in decrease of the moisture retention values. This could also be attributed to the aforementioned explanation that the raw meatball samples processed with lemon fiber had generally the lowest pH values, leading pH of the meatball samples to approach the isoelectric point of proteins at which moisture retention ability of the chicken proteins is almost close to zero.

Table 3 also presents the effect of fiber type and concentration on the fat retention values of fried meatball samples. The fat retention of meatballs increased (P <0.05) with apple and lemon fiber addition. It was reported that fat retention is a complex phenomenon which is probably the result of several chemical and physical mechanisms. In these mechanisms, proteins are thought to be perfect fat binders since they have double-functions in regards of fat interactions in which non-polar side chains of proteins furnish sites for lipid–protein interactions and interfacial film formation. Moreover, myofibrillar proteins gelation, which forms three-dimensional matrix, hold fat (Zayas, 1997; Anderson and Berry, 2001). In addition, fibers possess some fat-holding properties (Sosulski and Cadden, 1982). Accordingly, in our study, further increase in the apple and lemon fibers also increased the fat retention of the patty samples (Table 3). This was due to the dominant impact of these fibers to entrap fat. The maximum fat retention could be achieved by addition of lemon fiber at 12 % concentration. Briefly, it could be concluded that the effects of apple and especially lemon fibers were strongly dependent on the fiber level. Regarding the effect of pea fiber, the fat retention values were observed to decrease by increase in the pea fiber concentration, which reveals that pea fiber was not an affective fiber source in increasing the fat retention in the chicken meatballs.

The sensory properties of fried chicken meatballs

Sensory scores allocated for each sensory characteristic are shown in Table 4. The sensory results from the present study revealed that fiber addition did not significantly influence the sensory scores for appearance, color, odor, taste and texture. However, further increase in fiber concentration caused a decrease in these scores. In general, the panelists gave a lower score to the chicken meatballs processed with the fibers in the higher concentration (at 12%). Therefore, addition of these fibers into the chicken meatballs should be kept under 12 %.

Table 4. Effect of fiber type and concentration on sensory properties of fried meatballs.

		Fiber concentration			
Sensory properties	Fiber type	Control (0%)	4%	8%	12%
Appearance	Apple	4.95^{aA}	4.65^{aAB}	5.20^{bA}	2.60^{bB}
	Lemon	4.95^{aB}	5.70^{aAB}	6.40^{aA}	4.60^{bB}
	Pea	4.95^{aA}	5.90^{aA}	6.45^{aA}	7.35^{aA}
Odor	Apple	5.70^{aA}	5.50^{aA}	5.50^{bA}	4.00^{bB}
	Lemon	5.70^{aA}	6.00^{aA}	5.70^{bA}	5.45^{aA}
	Pea	5.70^{aA}	6.30^{aA}	6.05^{aA}	6.35^{aA}
Taste	Apple	6.25^{aA}	6.00^{aA}	5.70^{bA}	2.85^{bB}
	Lemon	6.25^{aA}	6.10^{aA}	6.05^{abA}	4.75^{abB}
	Pea	6.25^{aA}	6.70^{aA}	6.55^{aA}	6.20^{aA}
Texture	Apple	6.45^{aA}	6.15^{aA}	6.25^{aA}	3.15^{bB}
	Lemon	6.45^{aA}	6.05^{aAB}	5.85^{aAB}	4.65^{abB}
	Pea	6.45^{aA}	7.00^{aA}	6.45^{aA}	6.15^{aA}

$^{a\text{-}c}$ Within each column, different superscript lowercase letters show differences between the fiber types within each concentration (p < 0.05). $^{A\text{-}C}$ Within each row, different superscript uppercase letters show differences between the concentrations within each fiber (p < 0.05).

CONCLUSION

Apple and pea fibers exhibited good performance increasing the frying yield, reducing the diameter, moisture and fat of chicken meatballs, while lemon fiber had the best performance for increasing the fat retention. In addition, these fibers did not negatively affect the sensory properties of the fried chicken meatballs at the concentrations 4 and 8%. Therefore, these fibers might be a promising ingredient for the development of low-fat meat products with improved cooking properties at high-temperature processing as well as for production of healthier products with high fiber content. However, effect of fiber was concentration dependent and this should be taken into consideration in applications in the meat industry. Therefore, the results of this study may be useful for meat industry which aims to augment the product yield for meatballs.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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