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THERMAL AND MICROSCOPIC PROPERTIES AND QUALITY CHARACTERISTICS OF LOW-FAT FRANKFURTERS AND EMULSIONS PRODUCED WITH CARBOXYMETHYL CELLULOSE, METHYL CELLULOSE AND PECTIN

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ABSTRACT

This study involves the effect of different concentrations of carboxymethyl cellulose (CMC), methyl cellulose (MC) and pectin (PEC) as fat replacers on thermal, microscopic and quality characteristics of low-fat frankfurters. Thermal analysis showed three peaks at 58.4, 66.6 and 81.9 for ground meat which were attributed to myosin, sarcoplasmic proteins and actin respectively. Addition of NaCl lowered the thermal denaturation temperature of myosin and actin. It was not possible to differentiate the second and third when phosphates and hydrocolloid were added to low-fat emulsion. The emulsion stability of the samples containing 0.5% MC, 0.5% and 1% PEC were significantly lower than control. The SEM result of the sample containing 1% PEC resembles most to that of the control. The sensory evaluations showed that addition of CMC decreased the acceptability of low-fat frankfurters, on the other hand MC and PEC at a concentration of 0.5% were acceptable.

1.Introduction

Meat and meat products are a valuable source of vitamins and minerals such as A, C, B_{12}, folic acid and Fe. Moreover meat is rich in proteins with high biological activity, amino acids and fat (Cierach et al. 2009; Schmiele et al. 2015). Fat in meat products like frankfurters is responsible for the stability of the batter, reduces cooking losses, and improves the texture, juiciness and mouthfeel. Also fat is an important source of energy, essential fatty acids and carrier of fat soluble vitamins in meat products (St.Clair Henning et al. 2016; Choi et al. 2009). On the other hand association of saturated fat consumption with many chronic diseases such as diabetes, obesity, cardiovascular diseases has led researchers to produced healthier meat products by reducing the fat content (Han and Bertram, 2017). Since fat has favourable effects on the quality of meat products, reducing the fat content causes undesirable effects such as increased cooking losses, undesired texture and flavour. In order to overcome these effects researchers have tried incorporation of different additives like carrageenan, pectin (PEC), guar gum, xhantan gum (Candogan and Kolsarici, 2003; Yilmaz et al., 2017; Méndez-Zamora et al., 2014), microcrystalline cellulose, carboxymethyl cellulose (CMC) (Schuh et al. 2013; Gibis et al. 2017). Addition of these additives and dietary fibers from different sources to low-fat meat products improved the water binding and water retention of the product. Therefore the shrinkage, cooking losses, drip losses during storage of meat products were

reduced (Almeida et al., 2014, St.Clair Henning et al., 2016).

Incorporation of dietary fibers like PEC, CMC and methyl cellulose (MC) to meat products as fa replacers may also enhance the nutritional attributes of the products since consumption of dietary fibers reduces the risk of obesity, colon cancer and cardiovascular diseases (Han and Bertram, 2017). Different studies have been carried out considering the effect of PEC, CMC and MC on the quality of low-fat frankfurters, however studies on the interactions between these additives and meat proteins were not fully investigated.

Meat proteins especially myofibrillar proteins (myosin and actin) are responsible for the three-dimensional gels during the production and these gels forms the desired structure in meat products. It was stated by Morin et al. (2004) that CMC may interact with meat proteins with its negatively charged carboxyl groups. And it is believed that the functional properties of proteins like gel formation, solubility and emulsifying capacity mat change due to the interactions between proteins and hydrocolloids (Ayadi et al. 2009). As a result, these interactions has an important part in the formation of desired product and its stability during storage. Differential scanning calorimetry (DSC) is an effective analytical method for the determination of interactions between meat proteins and hydrocolloids since it is accepted that changes in the denaturation temperature of proteins is an indication of these interactions (DeFreitas et al., 1997). In this study the quality characteristics of low-fat frankfurters formulated with different levels of CMC, MC and PEC and the interactions between meat proteins and CMC, MC and PEC were investigated by using DSC.

2. Materials and methods

2.1. Materials

The ground meat used in the DSC analysis and for preparation of emulsions were obtained from local butchers. The additives potato starch, pectin (PEC), carboxymethylcellulose (CMC) and methylcellulose (MC) were kindly provided by GMT-food (Istanbul, Turkey). The hermetic pans used for DSC analysis were supplied from Likrom Analytical Solutions (Ankara, Turkey). All the ingredients and additives except for hydrocolloids, used for production of frankfurters were obtained from Pınar Integrated Meat and Feed Industries (Izmir, Turkey).

2.2. Preparation of Low-fat emulsions, frankfurters and high fat frankfurter

Low-fat emulsions were prepared according to the established formulations of low-fat frankfurters which were formed by addition of 1.5% sodium chloride (NaCl), 0.3% sodium-phosphate, 3.2% potato starch and 0.5 or 1% of either one of PEC, CMC or MC, to the mixture of meat, fat and water.

Table 1. Amount of hydrocolloids used for each sample and abbreviations of the samples

Sample	Hydrocolloid	Hydrocolloid Percentage (%)	Abbreviations
1	-	-	Control
2	Carboxymethylcellulose	0.5	0.5CMC
3	carboxymethylcellulose	1	1CMC
4	Methylcellulose	0.5	0.5MC
5	Methylcellulose	1	1MC
6	Pectin	0.5	0.5PEC
7	Pectin	1	1PEC

The high fat frankfurter (control group) and low-fat frankfurters were produced by Pınar Integrated Meat and Food Industries (Izmir, Turkey). The high fat frankfurter (control group) was produced with 35% beef meat (with 15% fat), 25% beef meat (with 30% fat), 15% beef fat and 25% ice. The fat content of the low-fat frankfurters were reduced to 5% and different

levels of PEC, CMC and MC were used so as to obtain the targeted texture. Seven kilograms of batter (meat, fat and ice) was prepared for each group, in each group the ingredients used per kilograms of batter were as follows, 15g of sodium chloride, 3 g of sodium phosphate, 0.5 g of ascorbic acid, 0.5 g of ascorbate, 0.125 g of sodium nitrate, 2 g of black pepper, 2 g of red pepper, 0.5 g of coriander, 0.4 g of ginger, 8 g of sodium caseinate and 32 g of starch. Six different low-fat frankfurter formulations were produced and the different hydrocolloids and their quantities were given in Table 1.

For the production of frankfurters meat, fat, half of the ice and the ingredients other than potato starch and caseinate were mixed in a cutter (Kilia, vacuum cutter, Neumünster Germany) at low speed (1000 rpm). After incorporation of the hydrocolloid additives the mixture was blended at 3500 rpm for 1-2 min. the cutter speed was then raised to 5500 rpm. Until the mixture temperature reached 6°C. At this point potato starch, caseinate and the remaining of the ice were added and mixed at 5500 rpm until the temperature of the mixture reached 12°C. The mixture was stuffed into 18 Ø synthetic casings and hand-linked at 19 cm intervals. Stuffed mixtures were heat-processed and smoked in the smokehouse according to the following conditions, drying for 50 min at 60°C and 60 % relative humidity (RH), smoking for 50 min at 60°C 60 % RH and then steam cooking until the internal temperature reached 72°C. The frankfurters were then showered with cold water for 5 min. After cooling the frankfurters were peeled, vacuum packed and pasteurized for 30 min. at 78°C. Lastly, the frankfurters were transported to Hacettepe University, Department of Food Engineering under cold storage (4°C).

2.3 Determination of emulsion stability of the low-fat frankfurters

The emulsion stability of low-fat emulsions were determined according to the method of Zhou et al. (2010) and Hughes et al. (1997). 10 g of each sample were weighed into a 30 mL centrifuge tube and the samples were centrifuged at 3600 ×g, for 1 min (Sigma 3-30K, Germany) in order to remove the unbound water. Following the centrifugation the samples were placed in a water bath at 85°C for 35 min, the samples were then cooled to room temperature and then they were centrifuged once more at 3600 × g for 3 min. Analysis were performed in triplicate. After removal of the supernatant the samples were weight anew and the total expressible fluid (TEF) were measured by calculating the difference between the initial and the last weights. The percent TEF was determined according to the formula given below,

$$\% \text{ TEF} = (\text{TEF} / \text{Sample weight}) \times 100 \quad (1)$$

2.4. Determination of Thermal Properties of Potato Starch, Pectin, Hydroxymethylcellulose, Methylcellulose, ground meat, low-fat emulsion and frankfurters.

The thermal properties like denaturation and gelatinization temperature and glass transition temperature of ground meat, starch, hydrocolloids and low-fat emulsion and frankfurters were determined by using Q20 differential scanning calorimeter (TA instruments, Delaware, USA). DSC was calibrated with indium (melting point, 156.6°C and melting enthalpy, 28.5 J/g) before usage. DSC runs were performed under nitrogen atmosphere at a flow rate of 50 mL/min and all the analysis were performed in triplicate. Thermograms obtained from the DSC analysis were examined with TA universal analysis 2000. The solutions of potato starch (5%) and hydrocolloids (1%) were pr**e**pared in beakers and stored in refrigerator overnight before thermal analysis. Samples (composed of potato starch, hydrocolloids, ground meat, low-fat emulsions and frankfurters) were weighed (6.5 ± 0.5 mg) in an aluminium hermetic pan which were hermetically sealed. Samples were analysed between 20 and 100°C at a scanning rate of 5°C/min. The thermograms were evaluated to identify the denaturation and gelatinization peak temperatures, to this end an empty pan was used as a reference.

In order to determine the glass transition temperature of frankfurters the samples were

weighed (6.5 ± 0.5 mg) into an aluminium pan and hermetically sealed. The samples and the reference were equilibrated at 20°C, after equilibration the pans were cooled to -80°C and kept at that temperature for 15 min. then the pans were brought up to annealing temperature and were kept at that temperature for 60 min. At the end of this time the pans were cooled to -80°C and held again for 15 min. the samples were then scanned to 20°C at a scanning rate of 5°C/min against an empty reference. Annealing temperature was determined in line with preliminary studies. For the identification of glass transition temperature first derivative of the DSC thermograms were used. Glass transition was analysed for onset, mid- and conclusion- points and midpoint temperature was reported as glass transition temperature.

2.5. Determination of quality characteristics of the frankfurters

Moisture, fat, protein and pH values of the low-fat frankfurters and the control group were determined following the methods in Oztan and Vural (1996); and each analysis was performed in triplicate, at the beginning of the storage.

2.6. Water Holding Capacity (WHC) determination of samples

The WHC of the samples was determined according to the methods of Zayas and Lin (1988, 1989); which was modified by Oztan and Vural (1993), each analysis was performed in triplicate, at the beginning of the storage.

2.7. Colour Measurements

The colour measurements of the samples were performed at the inner cuts of the samples using a benchtop Spectrophotometer CM-3600 (Minolta, Osaka, Japan) using a Hunter colour scale. The lightness (L*), redness (a*) and yellowness (b*) of the samples were evaluated. Each analysis was performed in triplicate at the beginning of the storage.

2.8. Instrumental Texture Profile analysis

The texture profile analysis of the samples was performed with a texture analyser (Amatek Lloyd Instrument Ltd., United Kingdom) using Warner Bratzier shear blade. The test speed was 200mm/min, trigger was 0.05 N, the compression rate was 50% and the samples length was 15 mm. Changes in hardness (Ncm^{-1}), springiness (cm), gumminess (Ncm^{-1}) and chewiness between the samples were evaluated at the beginning of the storage and each analysis was performed quadruplicate for each sample.

2.9. Determination of cooking loss in the frankfurters

The cooking loss of the frankfurters was measured by weighing the linked frankfurters before and after cooking in the smokehouse using the following equation,

% Cooking loss = (Weight before cooking – Weight after cooking) / Weight before cooking ×100 (2)

2.10. Scanning Electron Microscope analysis

The microscopic properties of the samples were determined by means of SEM (Zeis EVO50, Germany). The frankfurters, ground meat and fat were directly placed on the samples holder for analysis. Hydrocolloid gels were coated with gold and were placed on an aluminum holder, analyses were performed at 15 kW at three different locations on each sample.

2.11. Sensory Evaluation

The frankfurters were evaluated in one session with two replicates. Ten untrained panellists, who were members of the faculty aged between 25 and 30 years old, evaluated both the control group and the low-fat frankfurters for their appearance, colour, texture and flavour on a 9-point hedonic scale; 9 representing strongly like and 1 representing strongly dislike on the hedonic scale. The samples were prepared by keeping the frankfurters in boiling water for 2 min and they were randomly served to the panellists. In order to evaluate the total acceptability of the samples the appearance, colour, texture and flavour scores were multiplied by specific weighing factors which are 1, 3, 3 and 3 respectively. To reach the final score, the sum of the multiplied criteria was divided by the sum of weighing factors which is 10.

2.12. Statistical analysis

The statistical analysis of the results was conducted using IBM statistics 21 and the statistical significance of the differences between means were determined by Duncan multiple range test.

3.Results and discussions

3.1. Thermal Properties of Potato Starch, carboxymethyl cellulose, methyl cellulose, pectin, ground meat and meat emulsions.

Table 2. Thermal denaturation temperatures and enthalpies of meat batters.
Values represents means (n=3)

Sample	T_{p1} (°C)	ΔH_1 (j/g)	T_{p2}(°C)	ΔH_2 (J/g)	T_{p3}(°C)	ΔH_3 (J/g)	ΔH_T (J/g)
M	57.50^{e}	0.0145^{a}	64.74^{a}	0.3296^{a}	78.72^{a}	0.1628^{a}	0.5069^{a}
M+S	56.58^{bcd}	0.0410^{b}	68.21^{bc}	0.3272^{a}	74.00^{b}	0.0176^{b}	0.3858^{a}
Control	56.86^{cde}	0.0899^{c}	67.58^{b}	0.4572^{a}			0.5472^{ab}
0.5CMC	57.26^{de}	0.0967^{c}	68.49^{cd}	1.0274^{c}			1.1240^{e}
1CMC	56.48^{bc}	0.0747^{c}	69.45^{e}	0.7532^{b}			0.8279^{cd}
0.5MC	54.55^{a}	0.0229^{ab}	69.10^{de}	0.6691^{b}			0.6987^{bc}
1MC	54.40^{a}	0.0416^{b}	69.05^{de}	0.7017^{b}			0.7433^{cd}
0.5PEC	56.33^{bc}	0.0843^{c}	68.44^{cd}	0.7930^{b}			0.8773^{d}
1PEC	56.05^{b}	0.0251^{ab}	68.83^{cde}	0.4782^{a}			0.5034^{a}

M, Meat, M+S, Meat containing 1.5 g/100 g of NaCl, Control, High fat meat emulsion. CMC, Carboxymethyl cellulose, MC, Methyl Cellulose, PEC, Pectin, T_{p1}, Denaturation peak temperature for myosin, ΔH_1, Denaturation enthalpy of myosin. T_{p2}, Denaturation peak temperature for sarcoplasmic proteins. ΔH_2, Denaturation enthalpy of sarcoplasmic proteins. T_{p3}, Denaturation peak temperature for actin, ΔH_3, Denaturation enthalpy of actin.
$^{a-e}$, Means with the same superscript at the same column do not differ significantly ($p>0.05$).

The thermal properties of the samples were examined by using TA Universal analysis 2000. According to the thermograms obtained from DSC the gelatinization temperature of potato starch was 64.41°C. This outcome was slightly lower than those reported in the literature, this could be due to the differences in sample preparation techniques and differences in the DSC analysis parameter like scanning rate (Li and Yeh 2003, Yassaroh et al. 2019). There were no transition peaks observed for CMC, MC and PEC between the temperature ranges of this study, which was 20-100°C. Akhtar et al. (2018) reported that CMC shows a glass transition peak (T_g) at 78.21°C and El-Sayed et al. (2011) reported a glass transition for CMC at 75°C. It could be argued that the reason for the absence of glass transition in our DSC results stemmed from the differences in the sample preparation. Several studies have been conducted on thermal properties of pectin and it was stated that the thermal behaviour of the pectin depends on its chemical composition as well as the source it was obtained from. In a study conducted by Iijima et al. (2000), phase transitions of pectins were analysed with DSC in a temperature range of -150 to 180°C and an endothermic peak was observed at 150°C for highly methoxylated pectin. Since the temperatures in our analyses did not exceed 100°C, thermal degradation temperatures for pectin were not observed.

The changes in the thermal denaturation temperatures of ground meat with and without other ingredients are presented in Table 2. The thermograms obtained from DSC for ground meat showed three peaks which were ascribed to the denaturation of myosin, sarcoplasmic proteins and actin and Tp values, for these proteins were 58.50, 64.74 and 78.72°C respectively (Table 2). Similar results were reported in the literature. Chen et al. (2007) found that transition temperatures for myosin, sarcoplasmic proteins and actin were 58.4°C, 66.6°C and 81.9°C respectively. Vasquez Mejia et al. (2018) reported that denaturation peak temperature for myosin, sarcoplasmic proteins

and actin were 54.84, 65.18 and 77.18°C. Slight differences in the denaturation temperature could be due to the variation in muscle type of the meat samples and analysis parameters studied. The enthalpy (ΔH J/g) gives information about the energy needed for denaturation of proteins. According to the results obtained the highest energy was needed for the denaturation of sarcoplasmic proteins which was 0.3296 J/g (Table 2) and the lowest enthalpy value was of myosin for ground meat.

Addition of NaCl to ground meat significantly lowered the denaturation peak temperatures (T_p) of myosin and actin. On the other hand, the Tp value of sarcoplasmic proteins were increased from 64.74 to 68.21°C. Graiver et al. (2006) reported that only two peaks can be observed in DSC when brining applied to meat samples with concentrations over 20g/L and that the peak temperatures for sarcoplasmic proteins and actin could not be differentiated. Furthermore T_p values of actin and myosin were decreased. Similar results were obtained by Pighin et al. (2008) and by Aktaş et al. (2005) proving that addition of NaCl destabilizes myofibrillar proteins which results in a decrease in the Tp values of those proteins. According to the DSC results of low-fat emulsions only two denaturation peak temperatures were observed (Table 2). The first peak was attributed to myosin and the second one was attributed to sarcoplasmic proteins and actin. While the Tp value of sarcoplasmic proteins were increased the T_p of actin was decreased. As a result the peaks could not be differentiated from each other and were observed as one peak in the thermograms. These results were in agreement with the results of Marchetti et al. (2013) and Graiver et al. (2006). The T_p value of control samples which contains phosphate aside from NaCl was not significantly different from the sample containing only NaCl. It was reported by Pighin et al. (2008) and by Findlay and Barbut (1992) that when phosphates were used with more than 1% of NaCl their effects were minimized. The results revealed that the T_p values of myosin for the samples containing 0.5% and 1% MC and 1% PEC was significantly lower than that of the control group. The T_p values of the second peak for all the samples were significantly higher when compared to the T_{p2} values of control group. Increasing the level of added CMC from 0.5% to 1% increased the T_{p2} values significantly, whereas increase in the T_{p2} values of samples containing MC and PEC were not significant. When the level of CMC increased from 0.5% to 1% the T_p value for myosin were significantly decreased, yet increasing the level of MC and PEC had no significant effect of T_p value of myosin. Morin et al. (2004) stated that CMC is an anionic water-soluble polymer and likely to interact with meat proteins via cross-linking its negatively charged carboxyl groups with the positively charged groups of amino acids in the myofibrillar proteins. In light of this, it can be argued that the changes in the denaturation temperatures of the low-fat frankfurters produced with CMC could be due to the interactions between CMC and meat proteins.

ΔH_T value gives information about the total amount of energy needed for the denaturation of all the proteins. Addition of NaCl to ground meat decreased the ΔH_T value, which was expected since myosin and actin are salt soluble proteins and destabilizes with NaCl. Even though, the total energy needed for the denaturation of proteins for control group was increased, it did not differ significantly from that of the ground meat and ground meat with NaCl. However, the increase in the ΔH_T value for low-fat emulsions was significantly different than that of the control except for the samples containing 0.5% MC and 1% PEC.

3.2. Quality Characteristics, Water Holding Capacity and pH results of Low-fat Frankfurters.

The moisture, fat, protein, WHC and pH result of low-fat frankfurters were given in Table 3. These results show that the moisture content of the samples varied between 70.59 and 62.02%. The highest moisture content was found for the sample produced with 1% MC and the lowest was for the sample produced with 0.5% PEC. The moisture content of the samples containing 1% MC and PEC were significantly higher than that of the control group (p<0.05).

On the other hand, the moisture content of the low-fat frankfurters produced with 0.5 and 1% CMC and 0.5% MC were found to be lower than that of the control but this difference lacked significance (p>0.05). The low-fat frankfurters had significantly lower fat content than that of the control. Among the low-fat frankfurters, the sample produced with 0.5% PEC had the highest fat content. The results show that increasing the level of hydrocolloids from 0.5% to 1% causes a decrease in the fat content of the samples. The protein content of the control group was 15.42% which was significantly higher than that of the low-fat frankfurters (p<0.05). The protein contents of the low-fat frankfurters varied between 12.54 – 13.75%. It was stated in the meat and meat products communique (Anonymous 2012) that for emulsifies meat products, the ratio of moisture content to protein content (M,P) and of fat content to total protein content (F,P) should be less than 6.5 and 3.2 respectively. The obtained results for M,P and F,P did not exceed this limit. It was also stated in the communique that the protein content of the emulsified meat products should not be less than 10% and the obtained results are higher than their threshold value.

Table 3. Moisture%, Fat%, Protein%, WHC and pH of the frankfurters. Values represent mean ± standard deviation (n=3).

Sample	Moisture (M%)	Fat (F%)	Protein (P%)	WHC	M/P	F/P	pH
Control	68.31 ± 1.40^{b}	24.53 ± 1.70^{d}	15.42 ± 1.20^{b}	0.42 ± 0.14^{a}	4.43	1.59	6.09 ± 0.03^{b}
0.5CMC	67.43 ± 0.73^{b}	14.36 ± 2.19^{b}	13.75 ± 0.29^{a}	0.31 ± 0.09^{a}	4.90	1.04	6.17 ± 0.01^{d}
1CMC	67.15 ± 0.33^{b}	14.08 ± 0.32^{b}	12.54 ± 0.31^{a}	0.47 ± 0.24^{a}	5.35	1.12	6.27 ± 0.05^{e}
0.5MC	67.28 ± 1.56^{b}	11.96 ± 1.04^{a}	13.12 ± 0.51^{a}	0.27 ± 0.10^{a}	5.13	0.91	6.12 ± 0.02^{bc}
1MC	70.59 ± 0.81^{c}	10.82 ± 0.62^{a}	12.73 ± 0.30^{a}	0.34 ± 0.07^{a}	5.54	0.85	6.05 ± 0.02^{a}
0.5PEC	62.06 ± 0.48^{a}	18.67 ± 0.14^{c}	13.49 ± 0.46^{a}	0.39 ± 0.11^{a}	4.60	1.38	6.03 ± 0.15^{a}
1PEC	70.33 ± 0.16^{c}	11.62 ± 1.88^{a}	13.25 ± 0.40^{a}	0.48 ± 0.68^{a}	5.31	0.88	6.14 ± 0.01^{cd}

WHC, Water Holding Capacity. M,P , Moisture%,Protein% F,P , Fat%,Protein%, Control, High-fat Frankfurter. κCGN, kappa carrageenan, λCGN, Lambda carrageenan, GG, Guar gum, XTH, Xanthan Gum, CHI, Chitosan.
a-e, Means with the same superscript at the same column do not differ significantly (p <0.05).

Gupta and Sharma (2018) concluded in their studies that addition of different dietary fibers for production of hen meat slices, the moisture and protein contents and M,P ratio were decreased when compared to the control, which is in agreement with our study. Albeit; Gibis, Schuh and Weiss (2015) showed that addition of carboxymethyl methyl cellulose and microcrystalline cellulose for production of low-fat fried beef patties increased the moisture content, yet the fat levels were significantly lower. The differences in quality characteristics among the studies could stem from the differences in the applied processes during production. The moisture content of the control group in our study was as expected, the divergences in the moisture content of the low-fat frankfurters may result from the differences in the water binding capacities of the hydrocolloids used.

Table 3 presents the water holding capacity (WHC) of the samples. Although, the addition of hydrocolloids effected the WHC of the samples differently, these differences did not produce significant outcomes when compared with the control group. The results show that increasing the level of hydrocolloid used in the production of frankfurters increased the water holding capacity of the samples. Han and Bertram (2017) stated that addition of CMC and PEC increased the water binding of the fat reduced model systems when compared to the control. Méndez-Zamora et al. (2014) reported that the low-fat frankfurters produced with inulin and pectin showed lower WHC values than that of the control, and when the amount of pectin used was increased the WHC values were

increased as well. These findings were in agreement with our findings.

The pH values of the samples varied between 6.03 – 6.27. The lowest value was for the sample containing 0.5% PEC and the highest value was for the sample containing 1% CMC. The pH values of samples produced with 0.5 and 1% CMC, 0.5% MC and 1%PEC differed significantly from that of the control. On the other hand, the pH values of samples containing 1 % MC and 0.5% PEC were significantly lower when compared to the control. Méndez-Zamora et al (2014) reported that addition of pectin together with inulin lowered the pH of low-fat frankfurters. On the other hand, when pectin was used with carrageenan in the production of low-fat frankfurters the pH levels of samples were not significantly affected

3.3. Emulsion Stability and Cooking Loss

The lowest cook loss result was found to be that of the control group and the highest cook loss was for the sample produced with 0.5% MC (Table 4). The results show that addition of different additives for the production of low-fat frankfurters did not improve the cooking loss of the samples. When the quantity of hydrocolloids used were increased the cooking loss of the low-fat frankfurters were decreased because of the increased water holding capacity of hydrocolloids. Lin et al. (1988) stated that lowering the ratio of F,P would result in increased water loss and the process yield depends on the mobilization of fat and water by the proteins. However, for low-fat frankfurters the WHC and gelling properties of hydrocolloids are the main factors affecting the emulsion stability. Morin et al. (2004) also proposed that the ability of a meat system to keep water within the matrix depends on the protein network strength and the capacity of hydrocolloids the entrap water within that system. The divergence in the results in our study might have caused by the differences in the gelling properties occurred in the emulsions and the different origins of the hydrocolloids. Gibis et al. (2015) showed that when CMC was used at a level of 2 to 3% a significant decrease in the weight loss occurred when compared the control group. In our study, the amount of the hydrocolloids was not as high as in their study which could also explain the high cooking loss values. The cooking loss values of samples produced with 1% pectin were lower than other samples containing CMC and MC (Table 4), and also the moisture values were higher than other samples (Table 3). Han and Bertam (2017) pointed out that pectin fibers may cover and surround the myofibrillar proteins and lipid droplets like Chitosan, and this structure may prevent the water and fat expulsion during cooking.

Total expressible fluid results give information about the emulsion stability of the systems, showing that the higher the TEF value the greater the water and fat release from the emulsion. It was observed from the results that the emulsion stability of the low-fat emulsions were lower than that of the control. The lowest one being the sample produced with 1% PEC. Increasing the level on hydrocolloids MC and CMC increased the emulsion stability of the samples. The emulsion stability of samples containing PEC and 0.5% MC were significantly lower than that of the control. Samples containing pectin has the lowest emulsion stability among other samples. Candoğan and Kolsarici (2003) reported that pectin was not effective on improving the emulsion stability. Lurueña-Martinez et al. (2004) pointed out that differences between cooking loss and emulsion stability (TEF) could be caused by different cooking procedures applied. Although the final temperatures reached similar values for both processes', it took longer to reach the targeted temperature during the determination of cooking loss in the smokehouse. On the contrary, during the determination of emulsion stability a small amount of sample was used and brought to the desired temperature quickly which probably improved the formation and strength of the gel.

Table 4. Cook loss and Total Expressible Fluid results.
Values represents mean ± standard deviation (n=3).

Sample	Cook Loss (%)	TEF (%)	F,P
Control	6.38	1.00 ± 0.01^{a}	1.59
0.5CMC	8.49	1.93 ± 0.28^{a}	1.04
1CMC	8.12	1.83 ± 0.73^{a}	1.12
0.5MC	9.42	3.34 ± 0.26^{b}	0.91
1MC	7.31	1.51 ± 0.06^{a}	0.85
0.5PEC	8.46	12.96 ± 0.63^{c}	1.38
1PEC	6.62	13.60 ± 0.52^{c}	0.88

a-c, Means with the same superscript at the same column do not differ significantly ($p > 0.05$). TEF, Total Expressible Fluids, Control, High-fat frankfurter/emulsion,CMC, Carboxymetyl cellulose, MC, Methyl Cellulose, PEC, Pectin. F,P, Fat%,protein%

3.4. Texture Profile Analysis

The results reveal that the hardness values of the low-fat frankfurters were significantly lower ($p<0.05$) than that of the control (Table 5) except for the sample containing 0.5% PEC which was not significantly different ($p>0.05$).

Table 5. Texture Profile analysis.
Values represents mean ± standard deviation (n=3).

Sample	Hardness	Springiness	Gumminess	Chewiness
Control	13.23 ± 0.34^{d}	9.06 ± 0.04^{a}	5.92 ± 0.31^{d}	53.62 ± 2.64^{e}
0.5CMC	10.39 ± 0.51^{c}	7.72 ± 0.50^{a}	4.38 ± 0.18^{c}	33.68 ± 1.99^{cd}
1CMC	7.20 ± 0.35^{a}	8.18 ± 0.85^{a}	3.27 ± 0.14^{b}	27.12 ± 3.64^{bc}
0.5MC	10.49 ± 0.26^{c}	9.07 ± 0.01^{a}	4.21 ± 0.01^{c}	38.28 ± 0.17^{d}
1MC	8.58 ± 0.37^{b}	8.70 ± 0.38^{a}	2.84 ± 0.22^{b}	24.64 ± 1.79^{b}
0.5PEC	12.62 ± 0.57^{d}	8.77 ± 0.25^{a}	4.31 ± 0.52^{c}	37.84 ± 4.69^{d}
1PEC	6.10 ± 0.07^{a}	8.71 ± 0.34^{a}	1.72 ± 0.05^{a}	15.01 ± 0.79^{a}

a-c, Means with the same superscript at the same column do not differ significantly ($p > 0.05$). Control, High-fat frankfurter, CMC, Carboxymetyl cellulose, MC, Methyl Cellulose, PEC, Pectin.

Increasing the level of hydrocolloid used lowered the hardness values. The addition of hydrocolloids did not have a significant effect in the springiness of the low-fat frankfurters. The gumminess and the chewiness values of the low-fat frankfurters were significantly lower than that of the control ($p<0.05$). Like hardness values, increasing the quantity of hydrocolloids used decreased the gumminess and chewiness values. TPA results of our study were in agreement with the findings of Han & Bertram (2017), Méndez-Zamora et al. (2014) who showed that addition of hydrocolloids lowered the hardness, gumminess and chewiness values. Schuh et al. (2013) suggested that the decrease in the firmness of the low-fat frankfurters may be due to the destabilization of batter with the addition of CMC and PEC. As a result of this no coherent protein network was formed upon heating. The same effect could also be the reason for the lower hardness value of MC added samples.

3.5. Scanning Electron Microscopy Results

SEM results of the control group and the low-fat frankfurters were presented in Figure 1. It was observed from the results that a three-dimensional structure was formed with large or small holes in the control group (Figure 1a). Similar structures were observed by Li and Yeh (2002) who stated that these holes were formed due to the disruption of starch molecules during heat treatment. Results of samples containing CMC and MC showed clusters which probably belongs to those hydrocolloids indication of no-gel like structure formation. Samples produced

with MC showed cavities in the results. When the concentration of hydrocolloids CMC and MC was increased from 0.5% to 1% the number of those clusters like structures were increased. The SEM results of sample produced with 0.5% PEC resembled to the SEM results of the control group.

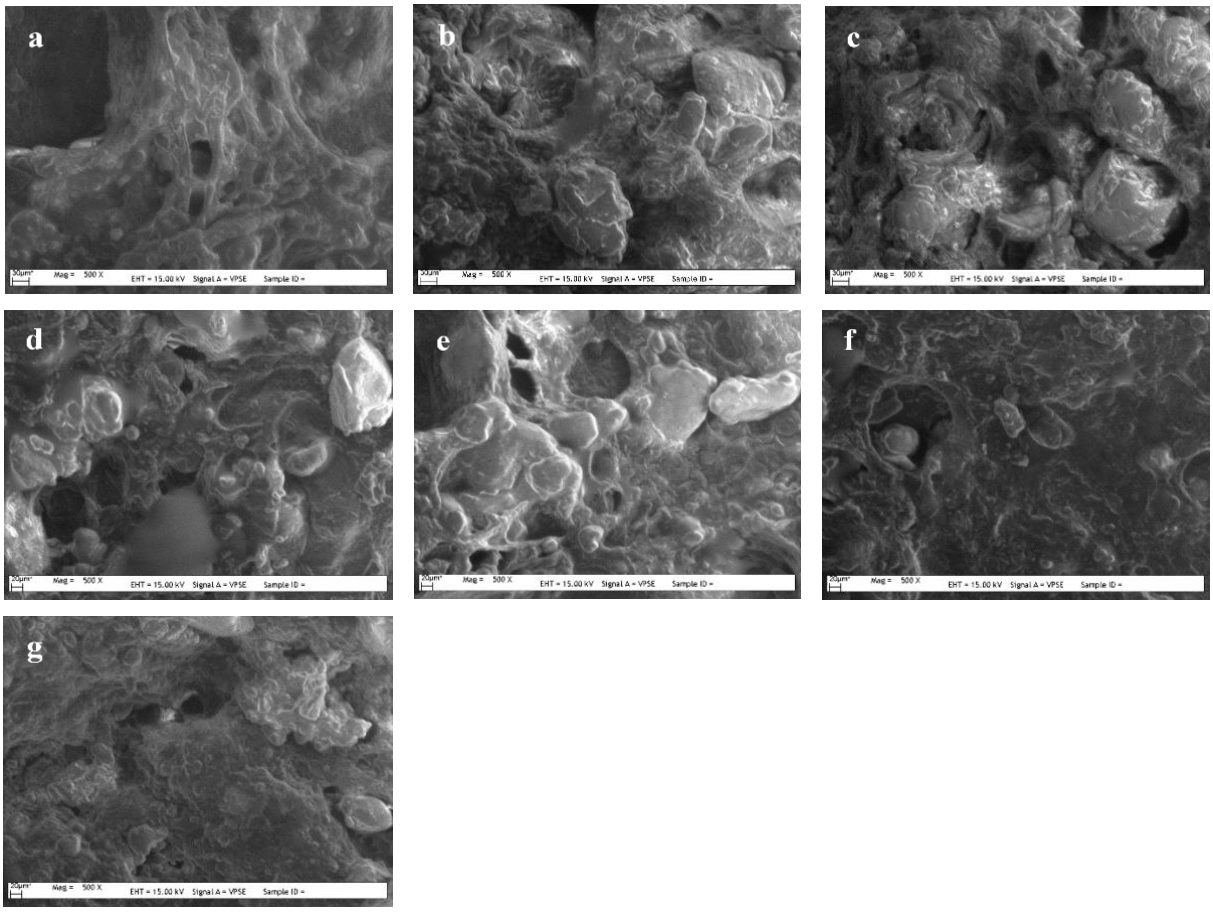

Figure 1. SEM images of the frankfurters.
a,Control, b, 0.5% CMC, c, 1% CMC, d, 0.5%MC, e, 1% MC, f, 0.5%PEC, g, 1% PEC containing samples

On the other hand, when the concentration of PEC was increased to 1% the structure formed was very different from all the low-fat frankfurters and the control. The hardness value of the sample 1PEC was the lowest and the samples were least acceptable among others, which indicate that the structure was not as requested.

Taking the hardness values into consideration together with SEM results, it was remarked that the sample with the hardness value closest to the control group (0.5% PEC) showed SEM results similar to that of the control. Moreover, total acceptability of these samples was also close to that of the control group. The protein networks in emulsified meat products are mainly formed by myofibrillar proteins (actin and myosin) which are soluble in the presence of NaCl (ionic strength). This network is formed during the heat treatment applied during production, which enhances the binding and consistency of the system (Li-Chan et al. 1984, Tornberg 2005). This system is affected by ionic strength, pH, formulation and temperature (Gibis et al. 2015). Gibis et al. (2017) stated that CMC at low concentration (0.5%) did not suffice to form a coherent protein network, and when the concentration was increased the fibers were able to retain the added water. On the other hand, Chattong et al. (2007) reported that no changes were observed when CMC was used at a level of 1%.

3.6. Colour Measurement Results

The lightness and redness values of the low-fat frankfurters were not significantly affected by the addition of hydrocolloids (Table 6, $p>0.05$). On the other hand, yellowness (b*) of the samples containing 0.5 and 1% CMC and 1% MC were significantly higher than that of the control ($p<0.05$). Increasing the level of hydrocolloids decreased the redness (a*) values of low-fat frankfurters, on the contrary increased the yellowness (b*) values, yet without a significance ($p>0.05$). Kim et al. (2016) found in their study that addition of pectin obtained by different methods decreased L* while increasing the b* value of low-fat meat emulsions. On the other hand, a* values were affected differently by the addition of pectin obtained by different methods.

Consumers demand the frankfurters to have pink-red colour which is a major factor influencing the purchase rates of the meat products. Although the colour measurement results showed no significant change in the redness of the samples, the sensory evaluation scores (Table 7) showed that the colour results of samples containing 0.5% CMC, 1% CMC, 1% MC and 1% PEC were significantly lower than that of the control which was not acceptable by the consumers.

Table 6.Color measurement results of frankfurters. Values represents mean ± standard deviation (n=3).

Sample	Lightness (L*)	Redness (a*)	Yellowness (b*)
Control	59.41 ± 0.17^{ab}	14.35 ± 0.22^{a}	15.44 ± 0.53^{a}
0.5CMC	59.85 ± 0.49^{b}	14.63 ± 0.32^{a}	17.18 ± 0.32^{cd}
1CMC	60.17 ± 0.72^{b}	14.05 ± 0.52^{a}	17.51 ± 0.49^{d}
0.5MC	59.30 ± 0.18^{ab}	14.71 ± 0.08^{a}	16.02 ± 0.53^{ab}
1MC	57.91 ± 0.62^{ab}	14.04 ± 0.40^{a}	16.53 ± 0.90^{bc}
0.5PEC	59.76 ± 0.27^{b}	14.13 ± 0.14^{a}	15.35 ± 0.28^{ab}
1PEC	59.53 ± 0.69^{b}	14.35 ± 0.10^{a}	16.00 ± 0.49^{a}

a-d, Means with the same superscript at the same column do not differ significantly ($p > 0.05$). Control, High-fat frankfurter, CMC, Carboxymetyl cellulose, MC, Methyl Cellulose, PEC, Pectin.

3.7. Sensory Evaluation Results

According to the sensory evaluation of the samples the outer appearance of the samples produced with 1% PEC was significantly lower than that of the control (Table 7, $p<0.05$). The TPA and SEM results of this sample also showed a poor formation of structure being the least acceptable sample by the consumers. Outer appearances of other samples were not significantly different from than that of the control ($p>0.05$). Contrarily, the colour and texture results were significantly lower when compared to the control except for the samples containing 0.5% MC and 0.5% PEC.

Table 7. Sensory Evaluation Results. Values represents mean ± standard deviation.

Sample	Outer appearance	Color	Texture	Flavor	Total Acceptability
Control	7.1 ± 0.40^{bc}	7.3 ± 0.30^{b}	7.0 ± 0.36^{bc}	6.6 ± 0.54^{ab}	6.9 ± 0.30^{b}
0.5CMC	6.3 ± 0.39^{ab}	5.9 ± 0.43^{a}	5.8 ± 0.44^{ab}	6.1 ± 0.37^{ab}	5.9 ± 0.34^{a}
1CMC	6.0 ± 0.29^{a}	5.4 ± 0.22^{a}	5.5 ± 0.42^{a}	6.2 ± 0.29^{ab}	5.7 ± 0.14^{a}
0.5MC	7.7 ± 0.30^{c}	7.7 ± 0.30^{b}	6.3 ± 0.66^{abc}	6.9 ± 0.50^{b}	7.0 ± 0.42^{b}
1MC	6.2 ± 0.32^{ab}	5.8 ± 0.38^{a}	5.6 ± 0.42^{a}	5.7 ± 0.21^{ab}	5.8 ± 0.28^{a}
0.5PEC	7.3 ± 0.15^{c}	7.1 ± 0.34^{b}	7.2 ± 0.41^{c}	6.6 ± 0.26^{ab}	7.0 ± 0.26^{b}
1PEC	5.6 ± 0.22^{a}	5.3 ± 0.33^{a}	5.1 ± 0.17^{a}	5.6 ± 0.37^{a}	5.4 ± 0.22^{a}

a-c, Means with the same superscript at the same column do not differ significantly ($p > 0.05$). Control, High-fat frankfurter, CMC, Carboxymetyl cellulose, MC, Methyl Cellulose, PEC, Pectin

The flavour scores of the low-fat frankfurters were not significantly affected from addition of different hydrocolloids. Total acceptability of the samples 0.5CMC, 1CMC, 1MC and 1PEC were significantly lower than the controls. In contrast, containing 0.5% PEC and 0.5% MC were the most acceptable ones which also had the highest hardness values. Furthermore, SEM results showed that the sample containing 0.5% PEC resembles the most to the SEM results of the control. The colour scores of the samples 0.5PEC and 0.5MC were also significantly different than other low-fat frankfurters. It was observed from the panellists preferences that low-fat frankfurters produced with PEC and MC at a level of 0.5% was more acceptable than the other low-fat frankfurters providing a close score to the total acceptability of the control.

4. Conclusions

Addition of different hydrocolloids at varying levels to low-fat frankfurters effected the quality properties differently. This effect was arguably caused mainly by the different sources of fibers and different behaviours of additives under certain pH, ionic strength and temperature. Increasing the level of hydrocolloids used in this study enhanced neither the acceptance of the final product in general nor the quality characteristics, yet it enhanced the moisture and cook loss. Low-fat frankfurters produced with methyl cellulose and pectin at a concentration of 0.5% were the most acceptable among the frankfurters. However, the cook loss of these samples was higher in comparison to others. Considering these effects, the level of the hydrocolloid should be determined carefully. The DSC results showed three distinct peaks for meat which were myosin, sarcoplasmic proteins and actin. While the addition of NaCl to the meat increased the denaturation temperature of sarcoplasmic proteins; destabilized the myofibrillar proteins and as a result their denaturation temperatures were decreased. Addition of phosphates and starch along with NaCl caused the peaks of sarcoplasmic proteins and actin to merge. Addition of different hydrocolloids increased the denaturation peak temperature of the second peak, on the other hand the denaturation peak temperature of myosin was either increased or decreased depending on the additive used. The changes in the denaturation temperatures of the meat proteins occurred due to the addition of hydrocolloids are accepted as a sign of interactions between proteins and the hydrocolloid. DSC is a promising method for the determination of interactions between hydrocolloids and proteins. For a detailed analysis the meat proteins could be extracted and their interactions with different hydrocolloids from different sources could be examined. It should also be considered to study different ionic strength, pH values and concentrations since hydrocolloids may behave differently under different conditions.

5.References

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