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THE EFFECTS OF DIFFERENT MODIFIED STARCHES ON SOME PHYSICAL AND TEXTURE PROPERTIES OF MEAT EMULSION

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ABSTRACT
The effect of modified starch addition on the functional properties of meat emulsions was studied by using a model system. In this research, the effects of modified potato starches (native, acid, dextrinized and pre-gelatinized) and starch level (1%, 2 and 4 w/w) on the emulsion capacity, stability, pH and texture properties were investigated in oil/water model emulsion systems. The highest emulsion capacity (181.42 ml oil/g protein) was determined for acid modified starch. As a result of texture analysis, hardness, gumminess and chewiness values of raw and cooked meat emulsions were significantly (P <0.01) affected by the type of starch and starch level. It was concluded in this study that 1% pre-gelatinized modified starch is good for ensuring emulsion stability and can be used as stabilizer for meat emulsions in order to improve the some texture properties of meat emulsions due to higher emulsion stability and capacity than the other starch levels.
Keywords: Meat emulsion, modified starch, emulsion stability, texture profile analysis (TPA)

ET EMÜLSİYONLARININ BAZI FİZİKSEL VE TEKSTÜREL ÖZELLİKLERİ ÜZERİNE FARKLI MODİFİYE NİŞASTALARIN ETKİLERİ

ÖZ
Modifiye nişastanın et emülsiyonlarının fonksiyonel özelliklerine etkisi bir model sistem kullanılarak incelenmiştir. Araştırmada, model emülsiyon sisteminde yağ/su emülsiyon sistemlerinin, emülsiyon kapasitesi, stabilitesi, pH ve dokusal özellikleri üzerine modifiye edilmiş patates nişastalarının (doğal, asit, dekstrinize ve pre-jelatinize) ve nişasta seviyesinin (% 1, 2 ve 4 w/w) etkileri araştırılmıştır. En yüksek emülsiyon kapasitesi (181.42 ml yağ/g protein) asit modifiye nişasta için belirlenmiştir. En uygun emülsiyon kapasitesi ve stabilitesi %1 nişasta seviyesinde belirlenmiştir. Tekstür analizi sonucunda, nişasta ve nişasta seviyesinin çiğ ve pişmiş et emülsiyonlarının sertliği, yapışkanlığı ve çiğneme değerleri üzerinde çok önemli (P <0.01) etkileri belirlenmiştir. Bu çalışmada, %1 pre-jelatinize modifiye nişastanın diğer nişasta seviyelerine göre daha yüksek emülsiyon stabilitesi ve kapasitesi değerlerinden dolayı et emülsiyonlarının bazı doku özelliklerini iyileştirmek için kullanılabileceği belirlenmiştir.
Anahtar kelimeler: Et emülsiyonları, modifiye nişasta, emülsiyon stabilitesi, tekstür profil analizi (TPA).

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INTRODUCTION

In emulsified meat products, the increasing demand for better quality and healthy products has stimulated the use of new non-meat components. These non-meat components of natural or synthetic origin, known as hydrocolloids or structuring additions, are introduced during the processing and preservation of meat products (Baranowska et al., 2004). Starches are popular not only for their functional properties but also for their low cost relative to alternatives. Starch, the food reserve polysaccharide of plants, is commonly used in emulsion-based products as a thickening agent due to the large increase in viscosity that occurs when native starch granules swell during heating. Few studies have considered the effects that varying amounts of starch have on characteristics of reduced-fat meat emulsions (Yang et al., 1995; Colmenero et al., 1996; Sikora et al., 2008; Resconi et al., 2016). They have many functional applications, including adhesion, texture, viscosity, binding, emulsion stabilization, gelling, product homogeneity and moisture retention (Pietrasik, 1999; Kaur et al., 2012; Zhang et al., 2013).

Unmodified starches have limited use in the food industries. They are uneconomical or have poor qualities. Modification can be used to improve functional properties of food products (Bemiller and Whistler, 2009). Modification allows starch to maintain its desirable appearance and texture despite stresses during food processing and distribution, and to expand its range of utility in foods (Bemiller and Whistler, 2009; Seo et al., 2015). By gel formation, oil-in-water emulsion may be converted from liquid-like to solid-like form (Dickinson and Casanova, 1999). It contributes to the desired texture and oil-water emulsion stabilization in emulsified meat products (Clark et al., 2001; Farouk et al., 2002). During the gel formation, oil and water are retained inside the protein matrix in the products (Smith, 1988). Texture is an important characteristic that is significantly influenced by the gel strength (Nowsad et al., 2000).

Model emulsion system studies are frequently preferred because they are convenient, economical compared with practical applications, reproducible and require minimum time (Karakaya and Gökalp, 1991; Gökalp et al., 1999). In this respect, in recent years, several studies have been conducted to investigate some flow properties of the model emulsion systems, such as emulsion viscosity (Sarıçoban et al., 2008, 2010, Karaman et al., 2015), apparent yield stress and density (Zorba et al., 2005; Tunçtürk and Zorba, 2006; Zorba and Kurt, 2006, Gençcelep et al., 2015; Ağar et al., 2016). However, no study has been conducted so far to investigate the texture properties of the model system meat emulsions using Texture Analyzer. Studying the texture properties of a real food system is important with respect to the engineering design of continuous processes, development of new products and quality control during the processing of emulsion type foods (Yılmaz, 2012).

Very limited research has been conducted to determine texture properties of meat emulsion dependence of starch to characterize the protein network formations of meat emulsions. Therefore, the aims of this study were (a) to determine the texture properties of native potato starch and modified potato starches (acid modified starch; dextrinized modified starch; pre-gelatinized modified starch) in emulsion; (b) to determine the effect of starch modification and starch concentration (1%, 2 and 4w/w) on emulsion capacity and stability properties of meat emulsions.

MATERIALS AND METHODS

Materials and starch modification

Meat source used in this study was beef from a 3 to 4-year old animal. Meat, refined corn oil and native potato starch were obtained from local markets, and minced meat, ground through a 3-mm plate, was stored at -18±1 ^{o}C until it was used. Corn oil was stored at room temperature in a dark environment. Native potato starch was stored at 4±1 ^{o}C until it was used. Analytical grade chemicals were used.

Acid modified starch (AMS): 375 ml of 0.1 M HCl solution was added to a mixture of 750 g starch and 375 ml deionized water and mixed for 30 min. Then, pH (2.26) was adjusted to 7.0 with 1 M NaOH. Neutralized starch was dried at 40 ^{o}C and then sieved at 212 μ. Starches were stored at 4±1 ^{o}C until they were used (Çağlarırmak and Çakmaklı, 1993; Aktaş and Gençcelep, 2006).

Dextrinized modified starch (DMS): 750 g of starch was mixed thoroughly with 600 ml of 0.1 M HCl. Then the mixture was dried at 50 ^{o}C for 32 hr. until the moisture content dropped to 5%. The dried starch was dissolved in 750 mL deionized water and then pH was adjusted to 7.0 by adding 1 M NaOH. Dextrinized starch was dried at 40 ^{o}C to moisture of 14-15% and then sieved at 212 μ. Starches were stored at 4±1 ^{o}C until they were used (Çağlarırmak and Çakmaklı,1993; Aktaş and Gençcelep, 2006).

Pre-gelatinized modified starch (PGMS): The Micro Visco Brabender Amylograph (model 8101, Brabender, Duisburg, Germany) was used to prepare modified starch samples with some modifications according to the method of (Aktaş and Gençcelep, 2006; Yglesias and Jackson, 2005). Slurries of native potato starches (15 g of potato starch and 100 mL of water) were poured into the amylograph bowl and loaded into amylograph. The starch suspensions were uniformly heated from 30 to 95 ^{o}C, held at 95 ^{o}C for 3 min, and then uniformly cooled to 40 ^{o}C. Pre-gelatinized starch was dried at 40 ^{o}C and then sieved at 212 μ. Starches were stored at 4±1 ^{o}C until they were used (Çağlarırmak and Çakmaklı, 1993; Aktaş and Gençcelep, 2006).

Homogenate and Emulsion Preparation

About 0.4 M NaCl solution was prepared and standardized to pH 6.60. 100 mL of NaCl solution (2–4 ^{o}C) and 25 g ground meat mixture and starch (on total weight) in were placed in a blender (Waring-80011 S, USA) jar and blended for 2 min at 3550 rpm. Emulsion was prepared using a model system, as described by (Ockerman, 1985). 37.5 mL of NaCl solution and 12.5 g homogenate were placed into the blender (Homend table blender S3 series 4901, İstanbul, Turkey) jar and homogenized at 2250 rpm for 10 s. and 100 mL corn oil was added. During emulsification 92 mL of corn oil was added at a rate of 0.9–1.0 mL/min. After all the oil was added, the emulsion was mixed for extra 5 sec.

Methods

Emulsion capacity (EC)

EC was expressed as the maximum amount (mL) of emulsified oil held per unit of protein. It was determined as described by Ockerman, (1985) and the end point was determined as described Zorba et al. (1993). About 12.5 g homogenate and 37.5 mL NaCl solution were placed in the blender (Homend table blender S3 series 4901, İstanbul, Turkey) jar and homogenized at 3500 rpm for 5 s and then 50 mL corn oil was placed into this homogenate. During emulsification at 3500 rpm, oil was added at the rate of 0.9–1.0 mL/min until the emulsion broke. The burette was cooled with circulating water to maintain the oil at a constant temperature (11 ^{o}C). The electrical conductivity of the emulsion was monitored by Ohm-meter. At the breaking point, the conductivity rapidly dropped and oil addition was stopped. The amount of oil added, including the first 50 mL, was recorded as EC.

Emulsion stability (ES)

ES was determined using model systems, as described by Ockerman, (1985) and Zorba et al. (1993). 10 g of emulsion was weighed into a centrifuge tube and capped and immediately heated at 80 ^{o}C in a water bath for 30 min. The tubes were centrifuged at 900 g for 15 min and the amounts of water and oil separated were measured, and ES was calculated using the following equations:

ES% = 100- (SW)

SW= g of water separated x10

Physicochemical analyses

pH, protein and fat

The pH of the raw batters was measured using a pH meter (Schott Lab Star pH Meter, Germany) on a homogenate of 10 g sample in 90 mL of distilled water. Protein concentrations of homogenates were measured using the Kjeldahl method. Fat content was measured petroleum ether extractable lipid according to standard (Ockerman, 1985) procedures.

Texture profile analysis (TPA)
Texture profile analysis (TPA) of the raw and cooked emulsions was performed using a Texture Analyzer (TA.XT. plus, Texture Technologies Corp., UK) with a 30 kg load cell with a two-cycle compression. A two-cycle compression force was used versus time to compress the samples till 90% of the original cooked thickness, returned to the original position and compressed again. A 6-mm diameter ebonite probe was used to compress, with pre-test speed of 1.0 mm/s, test speed and post-test speed of 0.5 mm/s. The emulsions were heated at 80 ^{o}C in a water bath for 30 min in glass jar (50 mL volume). After cooled to room temperature texture analysis was performed. Parameters recorded from the test curves were hardness, springiness, adhesiveness, cohesiveness, gumminess, chewiness and resilience. All texture analyses were replicated six times per sample, and results were presented as mean values.

Statistical analysis
All levels (1, 2, 4%) of starch varieties were studied and analyzed. All data were subjected to variance analyses, and differences between means were evaluated by Duncan's multiple range test (significance P <0.05 and P <0.01) with the help of SPSS statistic program (SPSS, version 20.0.0 software, 2010). The results of statistical analysis were shown as mean values ± Standard Deviation in tables.

RESULTS AND DISCUSSION
The proximate composition of meat, native potato starch and modified starch are summarized in Table 1. The suspension of pH values of meat, starch and modified starches were summarized in Table 2.

Table 1. Properties of meat, starch and modified starch.

	Moisture (%)	Protein (%)	Fat (%)	pH
Meat	73.65	20.63	5.32	5.89
Native potato starch	17.06	-	-	6.38
Acid modified potato starch	14.32	-	-	7.28
Dextrinized modified potato starch	12.62	-	-	6.01
Pre-gelatinized modified potato starch	10.83	-	-	5.74

Table 2. pH values of suspensions.

	pH	Starch level		
		1 %	2 %	4 %
Meat	6.60	-	-	-
Native potato starch	-	6.79	6.84	7.09
Acid modified potato starch	-	6.93	6.92	7.01
Dextrinized modified potato starch	-	6.87	6.93	6.95
Pre-gelatinized modified potato starch	-	6.85	6.88	6.92

The pH value of the starches changed with modification technique. Low pH value (5.74) was observed, mainly in the treatments containing pre-gelatinized potato starch. The highest pH value was found (7.28) for acid modified starch. pH values of suspensions were found with increasing adding starches. The highest pH values were determined in 4% starch level. Honikel (1987) reported that pH had a profound effect on physical properties such as the water-holding capacity, tenderness and color of meat. Usually, a high pH (~ 6.80) is closely related to high shear force or gel strength in meat products. Therefore, pH was found to have effect on the texture properties in any replacing beef with potato starch, which increased the hardness, adhesiveness, cohesiveness, gumminess and chewiness of raw and cooked meat emulsions in the present study.

Emulsion capacity (EC)

The overall effect of the starch type and starch level on the emulsion capacity, emulsion stability and pH values of meat emulsions were presented in Table 3. Starch types and level had very significant effects on the emulsion capacity ($P<0.01$) of raw meat emulsions (Table 3). Among the starch types, acid and pre-gelatinized modified starches had the most pronounced ($P<0.05$) effect on the emulsion capacity values. The highest emulsion capacity value was determined in acid modified groups and this was statistically different from that of the native potato starch and dextrinized modified groups ($P<0.05$). Also, the emulsion capacity of acid modified groups was found higher than the other meat emulsions (Table 3). The emulsion capacity of the native starch and dextrinized modified starches was approximately 170 mL oil/g protein.

Table 3. Overall effect of starch type and starch level on the emulsion capacity, emulsion stability and pH values of meat emulsions (mean±SD)

	Emulsion capacity (ml oil/g protein)	Emulsion stability (%)	pH
Starch type (S)			
Native potato starch	170.25±4.45[b]	78.75±1.36[b]	7.02±0.20[a]
Acid modified potato starch	181.42±5.16[a]	83.75±0.52[a]	6.91±0.07[ab]
Dextrinized modified potato starch	169.58±4.42[b]	84.35±1.87[a]	6.83±0.15[b]
Gelatinize modified potato starch	177.62±6.53[a]	84.02±2.35[a]	6.87±0.08[b]
Significance	**	**	NS
Starch level (%) (L)			
1	178.79±8.16[a]	83.92±2.85[a]	6.93±0.13[a]
2	172.92±5.80[b]	81.45±2.71[b]	6.91±0.21[a]
4	172.44±5.81[b]	82.79±2.65[a]	6.87±0.07[a]
Significance	**	**	**
S x L	NS	NS	NS

[a–b]: Any two means in the same column having the same letters in the same section are not significantly different at $P > 0.05$.
**$P < 0.01$. NS: not significant; SD: standard deviation.

The increase in starch concentration from 1.0 to 4.0% caused to changes in the emulsion capacity, ranging from 178.79 to 172.44 mL oil/g protein in oil/water (O/W) model emulsion systems. The EC values of samples with 1% starch level were higher ($P<0.01$) than that of the 2 and 4% starch level samples. When the starch level increased, emulsion capacity decreased. This decrease, dependent on starch concentration, could be attributed the relationship between pH and EC. Cheftel et al., (1985) reported that pH was one of the most important parameters affecting emulsion characteristics. pH influences the emulsification properties of the proteins, in other words, EC values of the meat species. At the isoelectric point (pI) of proteins, hydrophobic interactions between lipids and proteins are enhanced. Myofibrillar proteins have better emulsifying properties at pH values further away from the pI (Cheftel et al. 1985). In this study, the increase in starch concentration was decreased pH values (Table 3) and consequently, EC values; therefore, decreasing pH values caused proteins to approach the isoelectric point where they had the least EC (Cheftel et al. 1985), in spite of the effect of starch addition to decrease EC until 4% of the concentration. Starch addition did not increase the EC values of model emulsions (O/W) which was in accordance with the information given by Nilsson and Bergenståhl (2007) who reported that such modification enhances the water holding capacity of the starch matrix and the development of more organized structures, leading to a higher resistance to deformation and thus a higher peak viscosity can be achieved. The driving force for adsorption at the oil droplets is, in the case of hydrophobically modified polysaccharides, mainly hydrophobic interaction. These functional properties of starch are consequences of a hydrocarbon chain entering the hydrophobic cavity of amylose, which may constitute up to 20% of the tissue. In addition, given the fact that the emulsion capacity of the starch increases due to the absorption of the water and swelling of the granules and hydrophobic interaction of oil droplets, it is suggested that the emulsion capacity of the starch can be increased when the acid modified starch is used.

Emulsion stability (ES)

Stability is the most important factor to be considered in emulsion technology. Emulsion stability is an indicator of unseparated fat and moisture retained by meat proteins. When oil content is reduced, and droplet concentration decreases, creaming velocity increases. Thus, polysaccharides are added to food emulsions to stabilize emulsion droplets against creaming and to modify their texture properties (Parker, 1995; McClement, 2000; Tahmasebi et al., 2016).

While the emulsion stability of native potato starch was found 78.75%, the values of the acid, pre-gelatinized and dextrinized modified starches were found 83.75%, 84.35% and 84.02% respectively. Starch types and starch level had very significant effects on the emulsion stability ($P < 0.01$) of raw meat emulsions (Table 3). The highest average emulsion stability values were determined in modified groups, and these were statistically different from that of native potato starch groups ($P < 0.01$). Modified starches decreased the amount of oil separated out (Table 3). The native potato starch gave the highest water separation. The result reached in this model system study, demonstrated that starch addition decreased ($P < 0.01$) the emulsion stability (ES) values of the samples. Also, the increase in starch concentration influenced the ES values (Table 3). The results for ES in the samples with starch were similar to those for EC, in other words, samples with 1% of starch showed higher ($P < 0.01$) ES values than did samples with 2 and 4%. The reason for this could be explained by the fact that water and oil holding capacity was affected by starch and processing method. The possible reason could be attributed to the same phenomena seen in EC values in which the linear pH decrease (Table 3) might cause a decrease in ES values at the starch concentrations. The relationship between pH and the water retaining capacity of protein has been well established by Sarıçoban et al., (2008) and Warriss et al., (1999).

The stabilizing effect of modified starches in emulsions is related to their high electrical charge and having more hydrophilic–lipophilic groups within their structure, which increase the lipid and water interactions (Alamanou et al., 1996). These groups form a charged layer a round oil droplets, causing mutual repulsion, reducing interfacial tension and preventing coalescence. Incorporation of modified starches into a meat batter improved the emulsion stability and reduced the jelly and oil separation, probably due to the formation of a more stable complex. Starch type and starch level interactions was statistically insignificant ($P > 0.05$) on the emulsion capacity and stability. Determining emulsion stability of various meat and meat products and their emulsification properties with different oil and polysaccharide sources is important for successful production using current production technologies (Gökalp et al., 1999). Lots of modified starches have been used as fat replacers or substitutes in the food industry. Starch-based fat substitutes have been used to achieve fat mimetic properties by retaining substantial quantities of water into weak gel structures (Luo and Xu, 2011).

pH

The pH value is one of the most important factors during the manufacture of food products, which significantly affects the stability of meat emulsions (Song et al., 2015). The results of variance analysis for the parameters were shown in Table 3. As it can be seen, starch types had very significant effects on the emulsion pH values ($P < 0.01$) of raw meat emulsions (Table 3). Starch level and starch type x starch level interactions were statistically insignificant ($P > 0.05$) on the pH values of emulsions. The pH values of emulsions with native potato starches were higher than those of emulsions with modified starches, which could be due to the lower pH value of dextrinized modified potato starches (Table 3). Furthermore, an increase in the concentration of starches decreased the pH values of the emulsions (Table 3). The lowest pH value was obtained for samples with 4% starch (Table 3) which could be due to the presence of some modification properties in the starch.

Texture profile analysis (TPA)

TPA results of raw and cooked meat emulsions produced with different modified starches at various starch levels were shown in Table 4 and 5, respectively. Comparing the TPA results of this study directly with those in the literature was difficult because no study appeared to investigate the effect of the starch level on the TPA parameters and very limited number of studies has been conducted to determine the TPA profile of the model system emulsions. The starch type and starch level had very significant (*P* <0.01) effects on hardness, cohesiveness, gumminess, chewiness and resilience in raw meat emulsions (Table 4). In cooked meat emulsions, all texture parameters were affected very significantly (*P* <0.01) by the starch type and starch level (Table 5).

Table 4. Overall effect of starch and starch level on the texture properties of raw meat emulsions (mean±SD)

	Hardness (N)	Springiness (cm)	Adhesiveness (N.sec)	Cohesiveness	Gumminess (N)	Chewiness (N.cm)	Resilience
Starch type (S)							
Native starch	0.429±0.018[c]	0.934±0.007[a]	-0.282±0.064[a]	0.680±0.021[a]	0.288±0.002[c]	0.269±0.002[a]	0.153±0.013[a]
AMS	0.529±0.085[a]	0.917±0.110[a]	-0.372±0.102[a]	0.614±0.027[b]	0.323±0.040[ab]	0.296±0.040[b]	0.106±0.017[c]
DMS	0.509±0.103[ab]	0.914±0.039[a]	-0.341±0.113[a]	0.670±0.088[a]	0.333±0.030[a]	0.300±0.030[b]	0.123±0.031[bc]
PGMS	0.470±0.028[b]	0.905±0.034[a]	-0.286±0.051[a]	0.661±0.032[a]	0.309±0.018[b]	0.287±0.018[ab]	0.131±0.018[b]
Significance	**	NS	NS	**	**	**	**
Starch level (%)							
1	0.523±0.075[a]	0.913±0.037[a]	0.373±0.075[b]	0.637±0.041[b]	0.330±0.032[a]	0.300±0.024[b]	0.113±0.027[a]
2	0.460±0.077[b]	0.927±0.015[a]	-0.262±0.077[a]	0.687±0.066[a]	0.310±0.024[b]	0.287±0.029[b]	0.145±0.024[b]
4	0.470±0.066[b]	0.912±0.025[a]	0.325±0.066[ab]	0.644±0.039[b]	0.301±0.030[b]	0.275±0.021[a]	0.124±0.017[a]
Significance	**	NS	**	**	**	**	**
SxL	**	NS	NS	**	**	**	NS

[a–c]: Any two means in the same column having the same letters in the same section are not significantly different at $P > 0.05$.

** $P < 0.01$. NS: not significant; SD: standard deviation; **L:** Starch level

Table 5. Overall effect of starch and starch level on the texture properties of cooked meat emulsions (mean±SD)

	Hardness (N)	Springiness (cm)	Adhesiveness (N.sec)	Cohesiveness	Gumminess (N)	Chewiness (N.cm)	Resilience
Starch type (S)							
Native starch	1.403±0.258[b]	0.948±0.022[a]	-0.592±0.133[b]	0.480±0.016[b]	0.948±0.022[a]	0.653±0.076[b]	0.061±0.012[b]
AMS	1.561±0.312[a]	0.942±0.016[a]	-0.573±0.140[b]	0.475±0.017[b]	0.942±0.016[a]	0.723±0.104[a]	0.052±0.007[c]
DMS	1.200±0.120[c]	0.903±0.047[b]	-0.518±0.191[b]	0.520±0.036[a]	0.903±0.047[b]	0.582±0.051[c]	0.068±0.010[a]
PGMS	1.411±0.321[b]	0.955±0.006[a]	-0.348±0.198[a]	0.504±0.010[a]	0.955±0.006[a]	0.668±0.145[b]	0.059±0.004[b]
Significance	**	**	**	**	**	**	**
Starch level (%)							
1	1.556±0.318[a]	0.950±0.017[a]	-0.610±0.073[b]	0.487±0.011[b]	0.950±0.017[a]	0.732±0.125[a]	0.061±0.010[a]
2	1.180±0.084[b]	0.937±0.037[ab]	-0.332±0.146[a]	0.505±0.023[a]	0.937±0.037[ab]	0.583±0.037c	0.061±0.010[a]
4	1.445±0.253[a]	0.925±0.038[c]	-0.582±0.178[b]	0.493±0.041[ab]	0.925±0.038[c]	0.654±0.088[b]	0.057±0.011[a]
Significance	**	**	**	**	**	**	**
SxL	**	**	**	**	**	**	**

[a–c]: Any two means in the same column having the same letters in the same section are not significantly different at P >0.05.

**P <0.01. NS: not significant; SD: standard deviation; L: Starch leve

Hardness was defined as the peak force during the first compression cycle. Hardness is a main parameter that influences the overall acceptability of emulsion products. Hardness obtained from the TPA was significantly different among different samples (Table 4 and 5). Hardness of raw meat emulsions was increased markedly by the addition of native and acid, dextrinized and pre-gelatinized modified starches ($P < 0.05$), from 0.429 N to 0.529, 0.509 and 0.470 N, respectively. Modified starches were found harder than the native potato starch in raw meat emulsions (Table 4). Hardness of cooked meat emulsions was increased markedly by the native starch and acid modified starches ($P < 0.05$), from 1.403 N and 1.561 N, respectively. Nevertheless, dextrinized starches could not increase the hardness of cooked meat emulsions ($P > 0.05$) (Table 5). Higher hardness was observed in the acid modified potato starch in both raw and cooked meat emulsions (Table 4 and 5). Acid modification also increased solubility and gel strength and decreased viscosity of starches (Wang et al., 2003). Therefore, hardness values of emulsions obtained with acid modified starch were found the greatest in this study. Hoseney (1994) indicated that short chains of acid modified starch formed by hydrolysis swells less and the viscosity is lower. Also, short chains during the gelation due to the interaction of acid modified starches form a gel harder than the normal starch. Acid modified starch also decreases viscosity, increases the solubility of the granules and minimizes syneresis (Sandhu et al., 2007; Sarıçoban et al., 2010). This effect could be partly due to the effect of the starch to increase EC values, an indicator of the amount of emulsified oil (Table 3). As the oil was emulsified, the protein matrix extended in the emulsion, which resulted in an increase in the viscosity (Nowsad et al., 2000). Increase in emulsion viscosity (EV) is desired in the high fat emulsion type products, because higher EV gives an increased elasticity to emulsion type meat products (Yapar et al., 2006). Modified starches increased hardness of the emulsion according to the non-modified starch which was in accordance with the information by Tharanathan (2005) who reported that the resulting modified starch shows greater paste viscosity, paste clarity, and reduced syneresis. As it can be seen, increasing starch level tended to decrease the hardness, chewiness and gumminess values. Yılmaz et al., (2012) found that increasing the oil level tended to increase the hardness, chewiness and gumminess values in model system meat emulsion. When starch level was increased, hardness decreased in both raw and cooked meat emulsions (Table 4 and 5). Cooking led to an increase in the hardness values of emulsions. Sikora et al., (2008) reported that the starch increases viscosity in emulsion-based products as a thickening agent that occurs when starch granules swell during heating.

The addition of native starch resulted in a decrease in the hardness values of raw meat emulsions compared to the modified starch meat emulsions (Table 5). Starch type x starch level interactions was statistically significant ($P < 0.05$) on the hardness in raw and cooked meat emulsions. Particularly, after cooking, the hardness of the cooked meat emulsion with the addition of 1% starch decreased significantly ($P < 0.05$). Pietrasik (1999) suggested that starch addition favorably increased the hardness of sausages. Modified food starches have been used as binders to maintain juiciness and tenderness in meat products. Results of the study by Claus and Hunt (1991) indicated that modified food starches improve texture and reduce purge accumulation in low-fat bologna. It has also been reported that potato starch was very beneficial in improving the texture of low-fat frankfurters (Yang et al., 1995). Friction and/or binding among meat particles may be increased by adding starch. Liu et al., (2014) found that modified corn starch had higher values of hardness than normal corn starch in surimi-starch gel. As a result, acid modified starch was the most effective starch to increase hardness of both raw and cooked meat emulsions.

Springiness values were related to the elastic properties of the emulsion samples, so a decrease in the springiness value indicates that elasticity of the sample is lost (Yılmaz et al., 2012). Starches did not have a significant influence on the springiness and adhesiveness of raw meat emulsions ($P > 0.05$) (Table 4). Similar results were also determined by Liu et al., (2014) and Fan et al.,

(2017) for surimi-starch gel. However, in cooked meat emulsions, springiness and adhesiveness was statistically significant (P <0.05). Improved springiness suggested that low-fat frankfurters were less brittle or more elastic. Starch type x starch level interactions was statistically significant (P >0.01) on the springiness of cooked meat emulsions, but, had no effect on raw meat emulsions (Table 4 and 5).

Adhesiveness is defined as the negative force area under the curve obtained between cycles. Starch type was statistically insignificant (P >0.05) on the adhesiveness of raw meat emulsions. Starch level caused a decrease in the adhesiveness of cooked meat emulsions. Also, cooking led to a decrease in the adhesiveness of cooked meat emulsions (Table 4 and 5). The addition of starch resulted in small changes in the adhesiveness values in contrast with the meat emulsion (Table 5). Yılmaz et al., (2012) found that oil level had a decreasing effect on the adhesiveness of the meat emulsion samples.

Cohesiveness is defined as the ratio of the positive force area during the second compression to that during the first compression. Cohesiveness includes both the adhesive and cohesive forces as well as viscosity and elasticity. In practice, it shows how good the sample retains its structure after compression. Addition of the modified starch type also led to a decrease in cohesiveness and resilience, an increase in gumminess and chewiness for raw meat emulsions (P >0.05) (Table 4). Cooking had a small effect on the springiness values of meat emulsions (Table 5). Yılmaz et al., (2012) found that oil tended to increase the resilience of the emulsion samples. In the same study, cohesiveness, which is how good the sample retains its structure after compression, was also increased with the increase in the oil level in the model emulsion system.

Gumminess and chewiness are calculated using hardness as a factor which suggests resistance to compression force. Gumminess and chewiness values of emulsions produced with modified starches were found much higher than native starch in raw meat emulsions. Similar results were obtained in surimi-starch gel with native and modified corn starch (Liu et al., 2014; Seo et al., 2015). In the same study, chewiness of gels produced with modified starches was found different from native starch. Gumminess and chewiness values were not changed by the starch level except for dextrinized groups. The results of the interaction between starch type and starch level on gumminess and chewiness values were significantly decreased at 2% of starch level and increased in 4% starch level of dextrinized groups (Fig. 1 and 2). Gumminess and chewiness of raw meat emulsions were also decreased by the increase in the starch level, which followed a similar trend to that of hardness (Table 4). Starch type x starch level interactions was statistically significant (P <0.01) on the gumminess and chewiness of the emulsion (Fig. 1 and 2). When starch level was increased, gumminess and chewiness decreased in raw meat emulsions. Cooking had a high effect on gumminess and chewiness of meat emulsions (Table 5).

Resilience is a measurement of how the sample recovers from deformation both in terms of speed and force derived. All of the resilience values were close to 0.150 in raw emulsions and 0.06 in cooked emulsions (Table 4 and 5). Similar results were also determined by Liu et al., (2014). In the same study, resilience values were not found to have great differences between the modified corn starch and normal corn starch in surimi-starch gel. In meat products, starch is added primarily to bind water. Increased levels of starch decrease the firmness of sausages and bologna, probably because of increased water retention. The gelatinization temperature of starch is also important in determining the final product properties of comminuted sausages containing wheat, corn, tapioca or modified potato starches (Pietrasik, 1999). The starch motification presents a higher influence on the physicochemical and functional properties of meat emulsion. As starch granules absorb water from the surroundings during heating, the expanded starch granules exert pressure to the gel matrix, resulting in increased gel strength. The internal structure of the granule probably influenced the texture of meat emulsion (Hirsch and Kokini, 2002; Yılmaz et al., 2012; Sun et al., 2014).

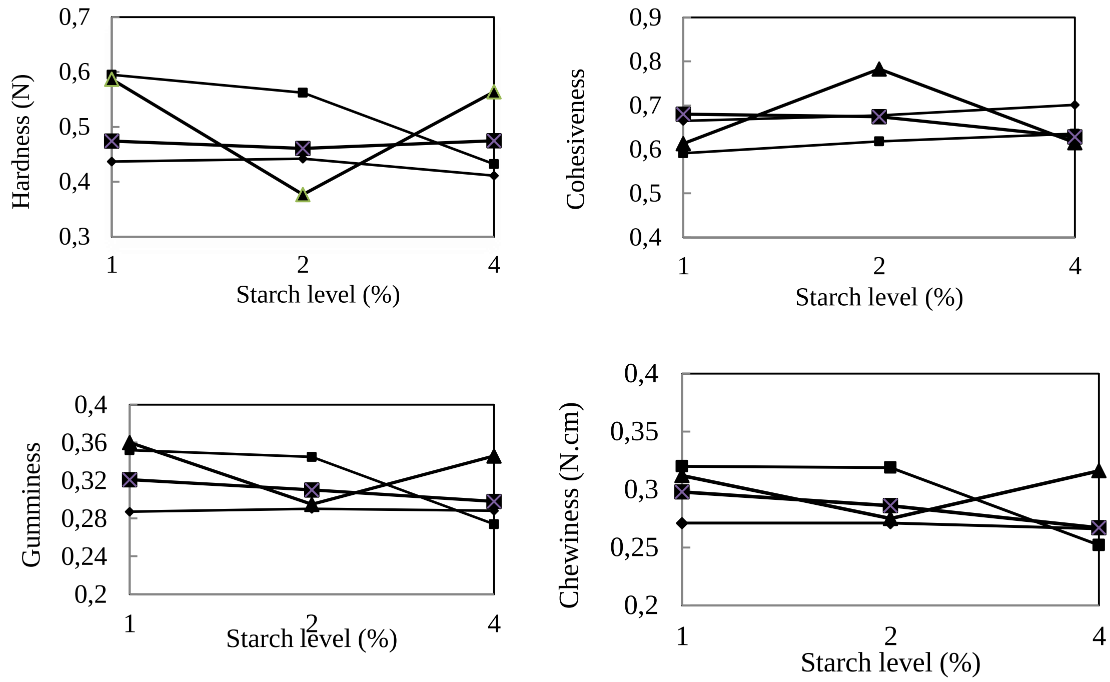

Figure 1. The effect of interaction of starch type × starch level on texture properties in raw meat emulsion.
NPS(——♦——); AMS(——■——); DMS (——▲——); PGS (—— ⊠——).

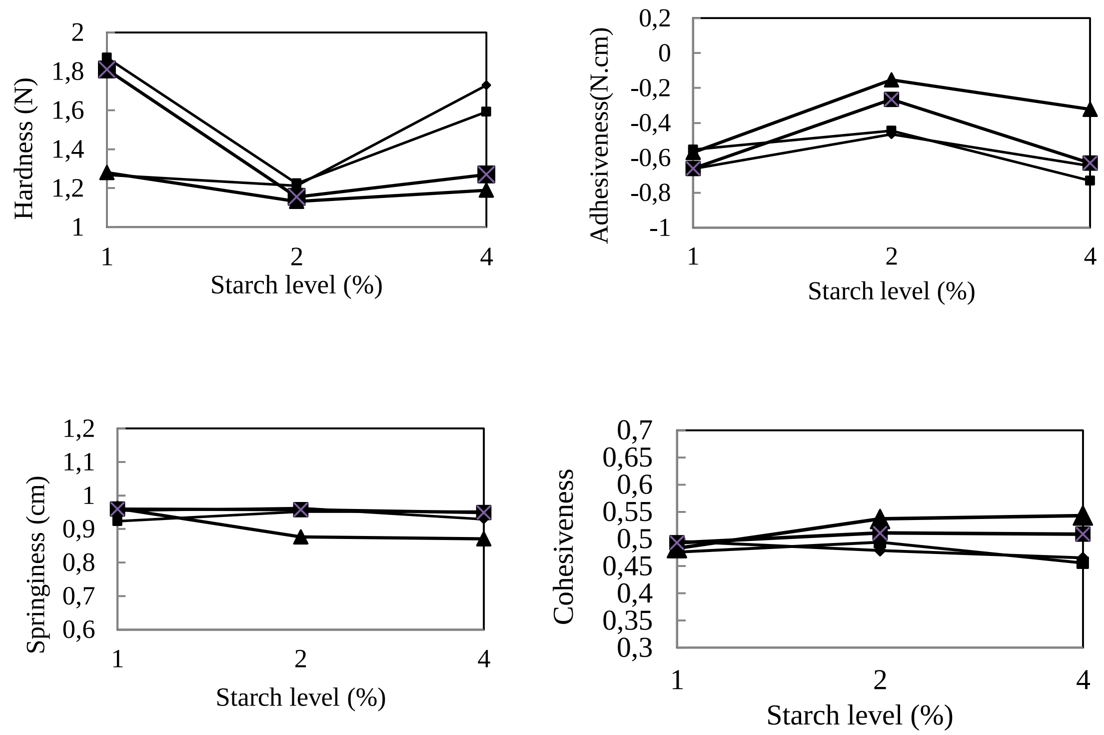

Figure 2. The effect of interaction of starch type × starch level on texture properties in cooked meat emulsion.
NPS(——♦——); AMS(——■——); DMS (——▲——); PGS (—— ⊠——).

Aleson-Carbonell et al. (2005) suggested that the textural properties of a meat product are determined by the ability of its protein matrix to retain water and bind fat. From the results obtained in the present study and previous studies it can be said that the addition of modified potato starch can increase the hardness, adhesiveness, gumminess and chewiness and decrease springiness, cohesiveness and resilience of the raw emulsion. The results suggest that modified potato starch can improve texture properties in sausages.

CONCLUSIONS

It was noted that the level of modified starch and starch type used in the study were very significant on the value of the emulsion capacity and emulsion stability. From the results of emulsion stability, we concluded that modified potato starch was better than native potato starch for meat emulsion. Especially, emulsion stability increases the shelf life, and considerably, determining the shelf life values is a very important aspect in production. As a result, modified starch is a potentially good source to control binding properties for frankfurter-type meat products and to enhance these emulsion properties. The TPA results indicated that the type and additive amount of modified starch had a strong impact on the textural properties of meat emulsion. In cooked emulsions, the type of starch, starch level, starch level x starch type interaction on values of springiness and adhesiveness was determined as highly significant. Therefore, for meat processors who aim to control the stability and texture properties of their products, these results could be important especially in the formulation of frankfurter-type products, because, the meat industries could determine the possible structural changes in different batter formulations during the heat treatment. Furthermore, based on these results, meat processors will be able to envisage in advance how the product structure and/or texture would be before a large scale of production is made. This will enable them to save time and cost when manufacturing a product with acceptable texture characteristics. As a result, the use of pre-gelatinized modified starch (1%) in frankfurter type meat products can be evaluated to enhance the shelf life, functional and technological properties of the product.

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