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ARTICLE

Effects of Partial Beef Fat Replacement with Gelled Emulsion on Functional and Quality Properties of Model System Meat Emulsions

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Abstract

The objective of this study was to investigate the effects of partial beef fat replacement (0, 30, 50, 100%) with gelled emulsion (GE) prepared with olive oil on functional and quality properties of model system meat emulsion (MSME). GE consisted of inulin and gelatin as gelling agent and characteristics of gelled and model system meat emulsions were investigated. GE showed good initial stability against centrifugation forces and thermal stability at different temperatures. GE addition decreased the pH with respect to increase in GE concentration. Addition of GE increased lightness and yellowness but reduced redness compared to control samples. The results of the study showed that partial replacement of beef fat with GE could be used for improving cooking yield without negative effects on water holding capacity and emulsion stability compared to C samples when replacement level is up to 50%. The presence of GE significantly affected textural behaviors of samples (p<0.05). In conclusion, our study showed that GE have promising impacts on developing healthier meat product formulations besides improving technological characteristics.

Keywords: fat replacement, gelled emulsion, olive oil, gelatin, inulin

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Introduction

In recent years, consumers believe the consumption of meat and meat products is unhealthy because of their high saturated fat and cholesterol content. Developing healthier lipid profileis one of the most important goals in meat industry and using GE prepared with healthy oils could be a good option to achieve nutritionally improved meat products (Pintado *et al.*, 2015b).

One of the main problems of fat replacement is maintaining the technological, rheological and sensory properties of meat products. GE could be defined as an emulsion with two characteristics: gel-like network structure and solid-like mechanical properties (Dickinson, 2013), for this reason GE could be a better option than simple oil-in water (O/W) emulsions to achieve better characteristics such as higher water holding capacity, better texture and lower cooking loss (Poyato *et al.*, 2014). The gelation process depends on the nature of the system, different polymers can be used to encourage hydrogel formation. Numerous proteins are obtained from milk, soy and egg have been used in protein-stabilized GE; heat treatment, acidification, and enzyme treatment are the main protein gelation methods (Dickinson, 2012).

Gelatin, a fibrous protein made from collagen, it contains a high amounts of amino acids which have great importance on the forming of thermoreversible gels (Hudson, 1994). In meat products, gelatin stabilizes shrinkage and promote cooking yield owing to its gelling and water binding properties (Jridi *et al.*, 2015).

Inulin is a prebiotic dietary fiber showing excellent properties as a carbohydrate-based fat substitute in relation to its ability to increase viscosity, form gels, provide mouthfeel and texture and increase water-holding capacity and thus presenting a good application potential in various food product formulations (Öztürk and Serdaroğlu, 2017). Inulin has been added to many products, including sausages, meatballs and restructured products, and has shown good performance as a fat substitute due to its ability to form a gel when mixed with water (Huang *et al.*, 2011).

Previous studies have shown the potential of GE containing a variety of bioactive compounds and healthy oils for use as healthier fat replacers. Poyato *et al.* (2015) used carragenan in burger patties without any negative influence on sensory properties while increasing unsaturated

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fatty acids. The incorporation of GE which was prepared with chia flour improved the fatty acid composition of frankfurters, exhibiting acceptable technological and quality properties (Pintado *et al.*, 2015a). Paradiso *et al.* (2015) evaluated the physical, chemical, sensorial and microbiological properties of emulsion filled gels (EFG) consisted of inulin and extra virgin olive oil and they concluded that characteristics of EFG depended on both the ingredients' proportions and homogenization technique. Sato *et al.* (2014) indicated that oxidation stability can be achieved during 30-d storage period where emulsion prepared with gelatin-alginate mixture and olive oil by using high pressure homogenization (0-60 MPa). In addition, oil-filled hydrogel emulsions were stated to be more effective in delaying lipid oxidation; samples which containing hydrogel were oxidatively more stable than conventional emulsions when added to meat systems (Salcedo-Sandoval *et al.*, 2015).

To the best of our knowledge, no research has been performed regarding utilization of GE containing gelatin and inulin as beef fat replacers. Moreover, the studies on GE mainly aimed to investigate its effects on lipid oxidation and structural properties. Therefore, the objective of this study was to investigate the effect of using GE as fat replacer on functional and technological quality characteristics of model system meat emulsions.

Material and Methods

Raw material

Fresh boneless post-rigor lean beef and beef fat were purchased from local meat market. Extra virgin olive oil was supplied from Taris Co. (according to the specifications of the supplier, it was consisted of 70.98% oleic acid (C18:1), 12.46% palmitic acid (C16:0), 11.4% linoleic acid (C18:2), 2.66% stearic acid (C18:0), 0.5% linolenic acid (C18:3) and 2243 ppm total sterol), oil phase emulsifier polyglyserol polyricinoleate (PGPR) was obtained from Çağdaş Chemicals Co. (Turkey). Gelatin was purchased from Sigma-Aldrich. Inulin powder (Ash Content: 0.05-0.15% Glucose: 0-1.6% Sacarose: 1.05-3.05% Dry Matter Content: 93-97% Carbohydrates: 94.90% Inulin: 88-92% Fructose: 1.2-3.2%) was obtained from BENEO-Orafti.

Gelled emulsion preparation

The gelled emulsion (GE) was prepared according to the method described by Poyato *et al.* (2014) with modifications. The oil phase (50 g/100 g emulsion) containing the PGPR as surfactant (6.4 g/100 g oil), was added to the aqueous phase containing 3 g gelatin/100 g emulsion and 9 g inulin/100 g emulsion and homogenized. Both phases were previously heated separately to 55°C on a hot plate stirrer. After the homogenization process (6000 rpm, Ultra-Turrax® T25basic, UK), the emulsion was cooled to room temperature. The GE was kept for 12 h at 4°C until being used in meat emulsions.

Table 1. Formulation of MSME

Samples[a]	Meat (g)	Beef fat (g)	GE (g)	Water (Ice) (g)
C	227.5	35	-	87.5
GE30	227.5	24.5	22.4	75.6
GE50	227.5	17.5	37.4	67.6
GE100	227.5	-	74.8	47.7

All of our samples also contains: 7 g NaCl, 1.75 g STTP, 0.05 g $NaNO_2$

[a]Sample denomination: C: Control 100% beef fat; GE30: 70% beef fat + 30% GE; GE50: 50% beef fat + 50% GE; GE100: 100% GE.

Design and preparation of model system meat emulsions

Four different model system meat emulsions (MSME) were formulated (Table 1), and prepared following the procedure reported by Cofrades *et al.* (2008) with modifications. Control sample was prepared 100% beef fat (C). Three of MSME groups were prepared by replacing beef fat with a level of 30%, 50%, 100% GE (GE30, GE50, GE100). All MSME samples had 10% added fat content (beef fat, GE or both).

Samples of MSME prepared in dublicate for each formulation. Lean and beef fat were minced through a grinder with a 3 mm plate. The meat was homogenized for 1 min in Tchibo Compact Food Processor (Germany) placed in cooling bath (2°C). Fat or GE, half of the ice, curing ingredients were added and mixed again for 1 min. The other half of the ice was then added and mixed for 2 min. The final temperature was below 12°C in all cases. Portions of each samples (approximately 25g) were placed in Falcon tubes (50 mL, which were hermetically sealed. The tubes were heated for 30 min in 70°C water bath. Samples were cooled to room temperature and analyzed.

Methods

pH

pH value of GE and MSME were measured three times by using a pH-meter (WTW pH 3110 set 2, Germany) equipped with a penetration probe.

Color

Color parameters of model system meat emulsions and GE were measured using a digital colorimeter (Chromameter CR400, Minolta, Japan) to obtain the color coordinates lightness (CIE L*), redness (CIE a*) and yellowness (CIE b*).

Syneresis

Syneresis (S) was measured in triplicate according to Bot *et al.* (2014). Sample was cut in half in the tube, and one of both halves was removed. The weight of the half-filled 100 mL tube [W_1] was determined and the tube is sealed again. The tube was stored for 4 h at 25 °C. Subsequently, the lid was removed and the sample was weighed again [W_2]. Then all fluid was removed from the tube by decanting of dabbing the sample using a tissue, and afterwards the weight of the tube was determined again [W_3]. Finally, the sample was removed from the tube, and the empty tube was weighed [T]. Syneresis calculated from the equations as follows:

$$\text{Syneresis} = (W_1 - W_3) / (W_1 - T)$$

Gelled emulsion stability

Centrifugation and thermal stability were determined in GE. Centrifugation stability was measured after the preparation of GE to observe any phase separation after centrifugation at 1400 rpm for 3 min. Creaming stability was measured according to Gu *et al.* (2005) in samples stored at 4°C. Serum layer separation was observed and measured to express creaming stability as a percentage of initial sample height.

Thermal stability, in terms of water and fat binding properties,was measured in GE according to Surh *et al.* (2007). For thermal stability testing, the tubes containing each of the GE was heated (70ºC/30 min) in a water bath. The stability of the emulsions after heating (thermal stability) or storage (creaming stability) were recorded in terms of phase separation and expressed as a percentage of initial sample height. These parameters were determined in triplicate.

Chemical composition

Moisture and ash contents of the raw and cooked model system meat emulsions were determined according to AOAC (2012). Protein content of the samples was determined using an automatic nitrogen analyzer (FP 528 LECO, USA) based on the Dumas method. Fat content was evaluated according to Flynn and Bramblet (1975).

MSME emulsion stability

Emulsion stability (ES) was measured in triplicate according to Hughes *et al.* (1997). Twenty Five g of raw emulsion was centrifuged for 1 min at 4000 rpm. The samples were heated in a water bath for 30 min at 70°C and tubes were centrifuged again for 3 min at 4000 rpm. The pellets were removed and weighed and the supernatants were seperated into pre-weighed crucibles and dried overnight at 100°C. The volumes of total expressible fluid (TEF) and the expressible fat (EFAT) were calculated from the equations as follows:

TEF = (Weight of centrifuge tube + Weight of sample) − (Weight of centrifuge tube + Weight of pellet)

%TEF = TEF/Weight of sample × 100

%EFAT = [(Weight of crucible + Weight of dried supernatant) − (Weight of empty crucible)] / TEF × 100

Water holding capacity

The ability of the uncooked product to retain moisture was determined in triplicate according to Hughes *et al.* (1997) with modifications. Ten g batter was weighed (W_1), placed into glass jars and heated in 90°C water bath for 10 min. After cooling to room temperature, the samples were wrapped in cotton cheese cloth and centrifuged at 1400 rpm for 15 min and weighed again (W_2). Water-holding capacity (WHC) was calculated from the equation below:

$$\%WHC = 1 - T/M \times 100 = 1 - (W_1 - W_2)/M \times 100$$

Where T is water loss after heating and centrifugation and M indicate total moisture content of the sample.

Jelly and fat seperation

Jelly and fat seperation (JFS) of MSME was measured in triplicate according to Bloukas and Honikel (1992). Two hundred g of raw emulsion sample was placed in glass jars, sieved and heated in boiling water bath for 35 min (with core temperature about 90°C). After that, the jars were cooled to room temperature (25±2°C) and stored at 4°C for 24 h. Jars were then re-heated (45°C for 1 h). The fluid jelly and fat were drained in a volumetric cylinder and measured in mL. JFS was calculated as % of the original weight of batter.

Cooking yield

The weights of MSME before and after cooking were recorded and the cooking yield calculated for three replicates.

Texture profile analysis

Texture profile analysis (TPA) was performed five times for each treatment using a texture analyzer (TA-XT2, Stable Micro Systems, UK). Samples (2.5 cm × 2 cm × 2 cm) were taken and compressed to 50% of their original height with a crosshead speed of 5 mm/s and 50 kg load cell. The parameters calculated from the force and time curves were hardness (maximum force required for the initial compression as N), cohesiveness (ratio of active work done under the second compression curveto that done under the first compression curve as dimensionless), springiness (distance of the sample recovers after the first compression asmm), gumminess (the strength of internal bonds making up the body of the sample as N) and chewiness (the required work tomasticate the sample as N×mm).

Statistical analysis

One-way analysis of variance (ANOVA) was used to evaluate the statistical significance ($p<0.05$) of the effect of MSME formulations, using the SPSS for Windows statistical package program (IBM, version 21.0, USA). The data was analyzed by using general linear model procedure (GLM). Least square differences (LSD) were used to compare mean values of formulations and significant differences ($p<0.05$) between MSME formulations were identified by Duncan multiple test.

Results and Discussion

Characteristics of gelled emulsion

Better understanding of the behaviour of pre-emulsions in meat systems is important to guarantee the quality of the end product which contains them (Serdaroğlu *et al.*, 2016). The characteristics of GE are shown in Table 2. The pH of GE was 5.35. CIE L*, CIE a* and CIE b* parameters of GE were recorded as 81.43, 3.71 and 15.98, respectively. Keeping syneresis (release of exudate) at minimum levels is an important parameter for pre-emulsions since higher syneresis level can affect yield, stability and also consumer's attitude of the product.In our study syneresis value is 10.37% which is similar to Bot *et al.* (2014) who found that an increase in the gelling agent concentration reduced syneresis at 25°C. They also underlined that rearrangements of protein network, density difference of phases and drainage of thickener phases could promote syneresis.

The interaction of gelatin with the gel matrix and its water binding properties helped GE to show good initial stability against centrifugation forces, no phase separation was observed after centrifugation. GE protected its stability at different temperatures (4°C for 48 h, 25°C for 24 h). High thermal stability was recorded in GE (96%), also creaming stability results showed that GE protected its stability without any turbidity and separation of the layer up to 7 d at 4°C.

Characteristics of model system meat emulsions

Chemical composition and pH

Chemical composition and pH values of raw and cooked treatments are presented in Table 3 and 4, respectively. GE addition showed significant differences among samples' moisture and protein content ($p<0.05$) while no effect was recorded on ash and lipid content ($p>0.05$). Replacing beef fat with GE showed lowering effect on moisture content of raw MSME since the addition of water in formulations was reduced with respect to GE addition. pH values of raw MSME were found between 5.95 and 6.06, increasing the GE concentration ($p<0.05$) resulted slight decreament in pH since olive oil has lower pH than beef fat.

Cooking process increased pH, fat, protein and ash content while decreased moisture content due to the loss of fluids during cooking. In cooked samples significant differences were found in moisture and fat content ($p<0.05$). Moisture content of C and GE30 were found similar and showed significant differences with GE50 and GE100 ($p<0.05$). Fat content of cooked MSME was found higher in GE100 with respect to decreament on moisture content. pH values of cooked MSME were found between 6.15 and 6.18, C and GE30 showed significant differences with GE50 and GE100 ($p<0.05$).

Water holding capacity

WHC results of MSME are shown in Table 5. Effect of pH on WHC is well-known phenomena where meat has the lowest WHC at isoelectric pH. The lowest WHC was found in GE100 treatment ($p<0.05$) may attributed pH value, in these samples pH values were close to the isoelec-

Table 2. Gelled emulsion characteristics

Sample	pH	CIE L*	CIE a*	CIE b*	Syneresis (%)	Thermal stability (%)
GE	5.35±0.01	81.43±0.27	3.71±0.13	15.98±0.22	10.37±0.18	96.00±0.11

Data are presented as the mean values of 3 replications ± SD.

Table 3. Chemical composition of raw MSME treatments

Sample	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	pH
C	67.75^{a} ±0.21	15.33^{ab} ±0.36	11.31±0.69	3.05±0.18	6.06^{a} ±0.02
GE30	67.31^{a} ±0.46	15.03^{b} ±0.35	11.54±0.48	3.07±0.02	5.97^{b} ±0.01
GE50	65.92^{b} ±0.47	14.00^{c} ±0.17	11.03±0.61	2.98±0.06	5.96^{b} ±0.01
GE100	65.66^{b} ±0.69	15.78^{a} ±0.05	12.12±0.41	2.99±0.02	5.95^{b} ±0.01

Data are presented as the mean values of 3 replications ± SD.
$^{a-c}$Means with the different letter in the same column are significantly different (p<0.05).

Table 4. Chemical composition of cooked MSME treatments

Sample	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	pH
C	66.50^{a} ±0,33	19.83±0.38	11.47^{c} ±0.65	3.01±0.03	6.18^{a}±0.01
GE30	66.21^{a} ±0,05	20.52±0.68	11.69^{bc} ±0.89	3.07±0.06	6.18^{a}±0.01
GE50	64.63^{b} ±0.14	20.01±0.69	13.33^{ab} ±0.95	3.06±0.03	6.15^{b}±0.01
GE100	63.64^{b} ±1.01	20.09±0.17	14.34^{a} ±1.05	3.05±0.03	6.15^{b}±0.01

Data are presented as the mean values of 3 replications ± SD.
$^{a-c}$Means with the different letter in the same column are significantly different (p<0.05).

Table 5. MSME Characteristics

Sample	WHC (%)	JFS (%)	ES		Cooking yield (%)
			TEF (%)	EFAT (%)	
C	95.91^{a} ±0.16	13.61^{b} ±0.93	9.14^{b} ±0.28	4.47^{b} ±0.67	90.29^{b} ±0.61
GE30	96.17^{a} ±0.25	12.35^{b} ±0.71	8.35^{b} ±0.68	3.99^{b} ±0.55	92.46^{a} ±0.56
GE50	96.19^{a} ±0.17	11.08^{b} ±1.86	7.51^{b} ±1.66	3.87^{b} ±0.59	91.90^{a} ±0.67
GE100	93.49^{b} ±0.09	18.61^{a} ±2.25	13.34^{a} ±1.35	5.27^{a} ±0.72	83.28^{c} ±0.61

Data are presented as the mean values of 3 replications ± SD.
$^{a-c}$Means with the different letter in the same column are significantly different (p<0.05).

tric point of meat. WHC of GE30 and GE50 samples showed similar results with C samples (p>0.05) although lower WHC was expected when olive oil and water were added to systems. That could be due to formation of covalent crosslinks in the presence of aqueous solution while using gelatin, also total dietary fiber content in inulin may also played role on WHC in MSME. WHC of some fibers is related to the type and amount of their polysaccharides; large particles are associated with open structures that improve the properties of hydration and fat absorption capacity (Lopez-Lopez *et al.*, 2010). This could explain the fact that the addition of inulin which is in the GE increased WHC due to its ability to bind water molecules and retain fat in the system.Gelatin which is derived from collagen, could be another factor improving WHC since collagen works synergistically with the myofibrillar structure in meat proteins to bind water. Doerscher *et al*. (2003) reported that pork collagen addition to pork myofibrillar gel showed higher WHC and better textural properties compared to sample which was produced without pork collagen.It has been reported that increasing gelatin concentration from 0% to 1.5% increased WHC in turkey meat sausages (Jridi *et al.*, 2015).

Jelly and fat seperation

JFS refers to the amount of total liquid released from emulsions at a certain temperature, and it is an important indicator for emulsion stability (Serdaroğlu *et al.*, 2016). The aim of producing GE which includes dietary fiber such as inulin and gelling agent such as gelatin is having better gel and oil retention characteristics in meat products. JFS results are shown in Table 5. It was found that the addition of GE to the system significantly affected JFS of samples (p<0.05). JFS results of C, GE30 and GE50 showed no significant differences (p>0.05) while the highest JFS was found in GE100 samples (p<0.05) as a result of low WHC and emulsion stability. Also, having high amount of olive oil in system although it was pre-emulsified could cause higher JFS since olive oil could not be retained within the sausage matrix.

Emulsion stability

ES could be explained as resistance of emulsion characteristics to changes over time. A stable emulsion should retain fluids in the system and also shows stable structure at maximum levels. Emulsion stability results of MSME are shown as total expressible fluid (TEF%) and express-

ible fat (EFAT%) in Table 5. The highest TEF% and EFAT% values were found in GE100 treatment (p<0.05) where beef fat was completely replaced with GE. C, GE30 and GE50 samples had higher ES but no significant differences were observed between these treatments (p>0.05). Both inulin and gelatin present in GE have been found to posses fat and water binding capacity, therefore no significant differences were found in ES results of GE30 and GE50 with C samples. Amphiphilic character of gelatin might probably the factor for GE30 and GE50 samples to keep ES similar to C samples due to stabilization of emulsion and also might keep fat and oil in pre-emulsion also MSME. In meat emulsions, gelatin acts as a stabilizer, reduce fat and/or water loss when it is used with an adequate amounts of 0.5-3.0 g/100 g (Stevens, 2010). The lowest emulsion stability result was observed in GE100 which has the highest olive oil concentration. Increasing olive oil concentration of sample and also having high amount of unsaturated fatty acid in the system may reduce emulsion stability because of low melting point of oil (Martin *et al.*, 2008).

Cooking yield

Cooking yield is one of the most important and also practical test to predict product's behaviour during process. In our experiment cooking yield results show similarity with WHC results (Table 5). The lowest yield was found in GE100 (p<0.05) with respect to decrease in WHC and increase in TEF%. The highest cooking yields were recorded in GE30 and GE50 while no significant differences were found between these two groups (p>0.05). These findings are probable sign of the potential of GE to increase cooking yield by using gelatin and inulin in GE 30 and GE50 samples. It has also been reported that using pre-formed emulsions could reduce cooking losses (Jridi *et al.*, 2015). Gelatin and also inulin have the property to absorb liquid in the product, the proportional relationship between process yield, gelatin and inulin addition contributes to the reduction of water losses. On the other hand, yield of product could be affected during heating process while gel forms since heating process affects water and fat molecular mobility (Bertram *et al.*, 2005). Increasing gelatin concentration resulted decrament in cooking yield since gelatin might melted out and could not interact with protein in MSME treatments during cooking.

Color

Color is one of the most essential factors on consumer's attitude toward meat and meat products. The color parameters of the MSME treatments were shown in Table 6. The results showed that CIE L* and CIE b* values were significantly affected by the presence of GE. The highest CIE L* values were found in GE50 and GE100 treatments and these two treatments showed significant differences from other treatments (p<0.05). This could be explained by the presence of gelatin and inulin caused lighter color in MSME treatments. Another reason for higher CIE L* values could be smaller diameter of GE droplets reflecting more light than larger animal fat globules. Similar results were obtained by Poyato *et al.*(2014). CIE a* values of treatments were found similar (p>0.05). Addition of GEcaused higher CIE b* values and the lowest CIE b* value was observed in C samples (p<0.05). This could be related to the difference in color between the beef fat and olive oil; although beef fat is creamy white and olive oil has a yellow-green color. Similar results were found by other authors (Delgado-Pando *et al.*, 2011; Pintado *et al.*, 2015a; Pintado *et al.*, 2015b; Poyato *et al.*, 2014).

Table 6. Color (CIE L*, a*, b*) of MSME treatments

Sample	CIE L*	CIE a*	CIE b*
C	51.36^{c} ±0.86	10.54±1.07	8.09^{a} ±0.33
GE30	54.94^{b} ±1.04	9.30±0.54	10.37^{b} ±0.62
GE50	58.32^{a} ±0.91	9.24±0.75	10.69^{b} ±0.55
GE100	60.38^{a} ±3.40	9.64±1.23	10.73^{b} ±0.49

Data are presented as the mean values of 3 replications ± SD.
$^{a-c}$Means with the different letter in the same column are significantly different (p<0.05).

Texture profile analysis

The results of texture profile analysis (TPA) are presented in Table 7. Adding GE affected all the textural properties of MSME except springiness. In GE treatments, increase in emulsion concentration showed lower values in hardness, gumminess and chewiness. It has been reported that adding GE, depend on the concentration, could improve hardness values (Poyato *et al.*, 2014). Addition high amount of gelatin can produce non-homogenous texture during cooking (Stevens, 2010). Using gelatin can help protein network formation in samples but having low amount of olive oil could cause higher hardness values in GE30 treatment (p<0.05), this could be related on beef fat and olive oil characteristics. Freire *et al.* (2015) stated that the differences in textural properties between fat containing and fat-replaced meat systems are determined mainly by the type and characteristics of lipid source and its role in the meat protein matrix. In our study significant differences were recorded in hardness values (p<0.05) while

Table 7. Texture profile analysis of MSME treatments

Sample	Hardness (N)	Springiness (mm)	Cohesiveness	Gumminess (N)	Chewiness (N×mm)
C	13.75^{b} ±0.60	0.90±0.07	0.85^{ab} ±0.08	11.68^{b} ±0.35	10.56^{b} ±0.49
GE30	15.77^{a} ±0.83	0.95±0.03	0.87^{a} ±0.03	13.82^{a} ±0.35	13.29^{a} ±0.75
GE50	10.06^{c} ±0.22	0.95±0.04	0.89^{a} ±0.03	9.04^{c} ±0.49	9.04^{c} ±0.80
GE100	3.71^{d} ±0.07	0.94±0.04	0.81^{b} ±0.05	3.01^{d} ±0.26	2.86^{d} ±0.37

Data are presented as the mean values of 3 replications ± SD.
$^{a-d}$Means with the different letter in the same column are significantly different (p<0.05).

GE100 samples has shown the lowest hardness values because of the lowest emulsion stability results. Chain length of inulin is an important factor on texture. It can decrease binding properties and affects tenderness of products since the longer fiber chain, the higher probability of its fewer interactions with medium (Lopez-Lopez *et al.*, 2010). Replacing beef fat with GE showed no significant differences on springiness values (p>0.05) while showed significant differences on cohesiveness values (p<0.05). Gumminess and chewiness values of MSME showed similar trend with hardness values and all of the treatments showed significant differences (p<0.05).

Conclusion

Using pre-emulsion based systems to achieve nutritionally improved meat products is one of the current approaches in meat industry. In our study, GE (prepared with olive oil, gelatin and inulin) which is one of the novel pre-emulsion systems was used as partial or total fat replacer in model system meat emulsions. The results of the study showed that partial replacement of beef fat with GE could be used for improving cooking yield without significant effects on water holding capacity and emulsion stability compared to C samples when replacement level is up to 50%. However, replacement of all the beef fat (100%) with GE showed negative effects on textural and technological properties. Significant effects were found on TPA values with respect to emulsion addition level. It was a feasible strategy to achieve high-stability in meat matrices by using GE especially at 30% and 50% as beef fat replacers. Further studies can be done to determine the effects of GE on functional, technological and also sensory properties of real systems such as meat products.

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