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Ş. KURT, H.G. CEYLAN

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The Effects of Plant Fibers on Improving the Properties of Meat Emulsion

Ş. Kurt, H. G. Ceylan

Department of Food Engineering, Faculty of Engineering, University of Adıyaman, Adıyaman, Turkey

ABSTRACT: The effects of plant fibers (1%; pea, wheat, apple, carrot, lemon, oat, inulin, cellulose) on the emulsion stability (ES), capacity (EC), density (ED), activity (EA), viscosity (EV) and apparent yield stress of emulsion (AYSe) and emulsion gel (AYSg) of beef were studied using a model system. The fibers had significant (p<0.05) effect on the emulsion properties. Apple and lemon fibers increased EA values and addition of carrot and wheat fibers increased ED values. Carrot, lemon and oat fibers increased ES values while lemon fiber increased emulsion storage stability the most. Inulin and apple fibers decreased AYSe values while other fibers increased. AYSg values increased with the addition of wheat fiber, but decreased with the addition of other fibers. However, the fibers did not significantly (p>0.05) improve emulsion capacity. On the other hand, the added fibers improved the emulsion viscosity.

Keywords: beef, plant fiber, meat emulsion, apple, lemon, car1rot

Corresponding Authors:
Şükrü Kurt, Department of Food Engineering, Faculty of Engineering, University of Adıyaman, Adıyaman, Turkey
E-mail address: sukrukurt@hotmail.com

Huriye Gözde Ceylan, Department of Food Engineering, Faculty of Engineering, University of Adıyaman, Adıyaman, Turkey
E-mail address: hgyildiz@adiyaman.edu.tr

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INTRODUCTION

Plant-derived products can be used in various meat products (Hughes et al., 1997; Steenblock et al., 2005; Aleson-Carbonell et al., 2005). One of them is fiber. Fibers can be used to improve the technological properties and quality of meat products (Thebaudin et al., 1997; Rodriguez et al., 2006; Kilincceker and Yilmaz, 2019). Fibers are naturally occurring compounds present in different kinds of plants. They affect the water-binding capacity, oil adsorption capacity, viscosity, gel forming properties of meat products (Biswas et al., 2011). Dietary fiber plays an important role in the prevention of some diseases. They have a positive effect on health since its consumption has been related to a decreased incidence of several types of cancer (Fernández-Ginés et al., 2005; Rodriguez et al., 2006). Plant fibers have been studied in meat products to improve texture and maintain juiciness in the products due to the water retention ability (Rodriguez et al., 2006; Moller et al., 2011). Different types of fibers have different effects, depending on their chemical and physico-chemical properties that affect the behaviour of proteins in food systems during preparation, processing, storage and consumption, and contribute to the quality and organoleptic attributes of food systems (Thebaudin et al., 1997). They have been used as fat replacer, fat reducing agent, volume enhancer, binder, bulking agent and stabilizer (Ang and Miller, 1991; Hughes et al., 1997; Aleson-Carbonell et al., 2005). In particular, their hydration and fat binding properties are important in terms of functionality related to chemical and physico-chemical factors such as solubility. Hydration properties of fibers are described by water-holding capacity, water-binding capacity, swelling and solubility (Thebaudin et al., 1997). Meat processors generally use purified soluble fibers up to the 1 % for their functional properties (Thebaudin et al., 1997).

The technological properties of meat proteins and non-meat additives such as plant fibers affect emulsion stability, viscosity, gel strength and oil and water holding properties (Rodriguez et al. 2006; Moller et al., 2011). These properties can be predicted by the model system. Some plant fibers influence on emulsified meat products have been studied so far by only a few researchers, so there is some information available. The objective of this study was to determine the effects of eight different plant fibers on the emulsion properties of beef.

MATERIALS AND METHODS

Materials

The meat source used in this study was beef (*M. semimembranosus* muscle). Meat and refined sunflower oil were obtained from local markets. Apple (*M. domestica*), lemon (*C. limon)*, pea (*P. sativum*) and oat (*A. sativa*) fibers were obtained from Arosel Gida (Istanbul Turkey). Cellulose and carrot fibers were obtained from Kimbiotek Kimyevi Maddeler (Istanbul Turkey). Inulin and wheat fibers were obtained from Smart Kimya (Izmir, Turkey). Analytical grade chemicals were used.

Methods

Meat sample and homogenate preparation

The meat was ground using a grinder (Tefal, Le Hachoir 1500, France) with a 3 mm diameter hole plate. Each meat sample was divided into equal lots and packaged by using three layers of medium polyethylene and this was stored as –20 °C until it was used.

Homogenate was prepared as; 0.45 M NaCl solution was prepared and standardised to a pH of 6.5. 100 ml of NaCl solution (4°C), 25 g ground meat and fiber were placed into a blender (Waring 80011S, USA) jar and comminuted for 1 min at 18 000 rpm. The fiber rate was adjusted to be 1% in the emulsion.

Emulsion preparation

One hundred and thirty ml of homogenate solution and 100 ml of oil (as the amount of starting oil) were placed in the blender (Kenwood KM010, UK). During emulsification at 6 500 rpm, 100 ml of oil was added at a rate of 0.5-0.6 ml/s. After all the oil was added, the emulsion was mixed for an additional 5 s.

pH determination

The pH of the prepared NaCl solution, homogenates and emulsions were measured by a pH meter (Hanna 2215, USA) equipped with a temperature probe.

Emulsion capacity (EC)

EC is the maximum amount of oil emulsified by a unit of protein. It was determined by using a model system described by Ockerman (1985). The end point was determined as described by Webb et al. (1970). 12.5 ml homogenate, 37.5 ml of 0.45 M NaCl and 50 ml of oil were placed into the blender (Kenwood KM010, UK) jar at first. During emulsification at 6500 rpm, oil was added at a rate of 0.5-0.6 ml/sec until the emulsion broke. Water was circulated around the burette as to maintain the oil at a constant temperature of 20ºC. The electrical conductivity of the emulsion was monitored with a microprocessor. At the breaking point of the emulsion, conductivity rapidly dropped and the addition of oil was stopped. The amount of oil added, including the first 50 ml, was recorded as the EC.

Emulsion stability and storage stability

Meat emulsions are not stable forever (Gökalp et al., 1999). Heat treated emulsions can be separated over time into the oil and water phase. ES was determined using model systems, as described by Ockerman (1985). Raw emulsion (10 g) was weighed into a centrifuge tube, which was capped and immediately heated at 80°C in a water bath for 30 min. The tubes were transferred in a cold water bath immediately and cooled to approximately 25°C. Then, the emulsion was held for temperature standardisation for 1h at ambient conditions and then centrifuged at 350 x g for 20 min. The water and oil separations were measured, and emulsion stability (ES) was calculated using the following equations:

ES (%) = 100 - (SW + SO)

SW (%) = ml of water separated x 10

SO (%) = ml of oil separated x d x 10 (d: specific gravity)

Storage stability of emulsion (ESs) was determined as described above with storage process. After the emulsion cooled to 25°C, they were stored at 4°C during 45 days.

Emulsion density

ED measurement is one of the simplest methods of determining emulsion properties. It can be required inexpensive equipment that is available in many laboratories (Mcclements, 1999). Emulsion of 20 ml was pipetted with enlarged mouth side of the pipette and weighed. ED was determined as the weight of 20 ml of emulsion.

Apparent yield stress of emulsion

Apparent yield stress was determined by using a cone penetrometer (Yüksel Kaya Makina, YKM-S216, Turkey). In rheological studies, it is recommended that the penetration depths are converted to "apparent yield stress" (AYS) values for a sharp-ended cone. A special conical head (with a 22° cone angle weighing 18.75 g) was placed just above the surface of the emulsions and released. Penetration depth was read after 5 s of penetration. Three replicates were performed for each sample. Then, apparent yield stress (AYS) was calculated as:

$$\text{AYS (N/m}^2) = \frac{g.w}{\pi.d^2.\tan^2(\varepsilon)}$$

Where; g is acceleration due to gravity, w is the weight of the cone assembly, ε refers to the cone angle and d is the penetration depth (Wright et al., 2001).

Preparation of emulsion gel and measurement of apparent yield stress

The emulsion was immediately transferred into the jars. After heat treatment at 80°C in a water bath for 30 min, the emulsion was transferred immediately to a cold water bath and cooled to approximately 25°C. Then, the emulsion gel (cooked emulsion) was held for temperature standardisation for 1h at ambient conditions and apparent yield stress was determined as described above for emulsion testing.

Emulsifying activity

Emulsifying activity was determined using the method of Neto et al (2001). The raw emulsion was immediately transferred into the tubes. After the centrifugation at 350 g for 20 min, the height of emulsified layer and that of the total contents in the tube was measured. The emulsifying activity (EA) was calculated as:

$$EA = \frac{\text{(Height of emulsified layer in the tube) x 100}}{\text{Height of the total contents in the tube}}$$

Emulsion viscosity

The viscosity of emulsion was measured with a rheometer (Brookfield DV3T). A spindle (type RV-3, viscosity range= 100-200 000 mPa.s) was used to measure the viscosities. The spindle was set to rotate at 15 rpm. The rheometer was checked with a calibration fluid (Brookfield, 4 700 cp at 25 ºC). Each sample was equilibrated for at least 3 hours to allow reaching the required temperature (25 ºC).

Statistical analysis

Analyzes were performed four times for each parameter. The study was repeated twice. The data were subjected to analysis of variance (ANOVA), and the results were expressed as mean ± standard deviation (SD). When there were differences among the samples, the differences were compared by using Duncan's multiple-range tests; a probability value of $p<0.05$ was considered significant.

RESULTS AND DISCUSSION

The mean values of the effects of the fibers on the emulsion properties are given in Table 1. The effects of fibers on the pH values of the homogenate (pH-h) and emulsion (pH-e) were found to be significant ($p<0.05$). The pH-h and pH-e values varied between 4.69-5.54 and 4.65-5.60, respectively (Table 1, Figure 1). Oat fiber increased pH-h value the most compared to control. However, fibers were not increased significantly pH-e values. Apple, carrot and lemon fibers decreased pH-e values. In particular, lemon fibers reduced pH-h and pH-e to the lowest levels. Aleson-Carbonell et al. (2005) reported that pH values of raw, dehydrated raw and dehydrated cooked lemon albedo were 4.53, 3.73 and 4.64 respectively. As shown in Figure 1, pH values of emulsion were found to be higher than homogenate. The increase in pH-e might have influenced by the emulsification process.

The effects of fibers on the EC values were found to be significant ($p<0.05$). Oat, cellulose, pea and wheat fibers increased EC values significantly (Table 1, Figure 2). Their oil binding capabilities were found to be higher than other fibers. However, carrot, lemon and apple fibers decreased EC values compared to the control. Thebaudin et al. (1997) reported that fat-absorption capacity of wheat-bran were higher than apple, pea and carrot fibers. Moreover, they stated that insoluble fibers can retain up to a few times their mass in oil. Lower pH values of emulsions with carrot, lemon and apple fibers might be resulted from lower pH values. Emulsion capacity is the maximum amount of oil which can be emulsified by proteins. It is strictly related to protein solubility which can be affected by pH values (Ockerman, 1985). However, hydrophilic and lipophilic characteristics and the balance between them played an important role on EC values. These characteristics of proteins reduced interfacial tension between oil and water allowing the formation of emulsion with a much reduced energy input (Elizalde et al., 1988). Also, Biswas et al. (2011) stated that oil binding properties of fiber related to its chemical composition, but is more largely a function of the porosity of fiber structure. However, hydrated fiber reduces oil-binding because water occupies pores.

The effects of fibers on the EA and ED values were found to be significant ($p<0.05$). EA values of the emulsions with lemon and apple fibers were found to be higher than control (Table 1, Figure 3). As shown in Figure 1, the pH-h values of these two fibers were found to be lower than others. As pH moves away from the isoelectric point of muscle proteins, the net electrical charge increases. This causes an increase in polarity (Gokalp et al., 1999). Neto et al. (2001) reported that the emulsion activity related to pH values. The hydration and swelling properties of the fibers might have affected the emulsion volume. The additions of fibers without lemon fiber were caused significant differences on the ED values compared to control (Table 1, Figure 4). While carrot and wheat fibers increased ED values, inulin, apple, cellulose, oat and pea fibers decreased ED values significantly. Emulsion density might be affected by the size of oil globules and air inclusion because of lower density of oil and air.

The effects of fibers on the ES and ESs (storage stability of the emulsion) values were found to be significant ($p<0.05$). The highest ES and ESs values of beef emulsions were found with lemon fiber (Table 1, Figure 5). Lemon fiber improved stability and storage stability of beef emulsion. Saricoban et al. (2008) reported that raw and dehydrated lemon albedo increased emulsion stability of mechanically deboned chicken meat. Moreover, Aleson-Carbonell et al. (2005) reported that dehydrated lemon albedo increased water retention of meat products. Carrot and oat fibers increased ES values and wheat fiber increased ESs values significantly (Table 1, Figure 5). Researchers (Hughes et al., 1997; Steenblock et al., 2001) stated that oat fiber increased water holding capacity and stability of emulsified meat products. Moller et al. (2011) reported that the addition of carrot fiber has a positive effect on water-binding capacity of processed meat products. Han and Bertram (2017) observed that the addition of dietary fibers improved water binding capacity of the meat batter. Thebaudin et al. (1997) reported that the thickening and gelling properties and the water-retention ability of the polysaccharides contribute to the stabilization of the structure of foods (dispersions, emulsions and foams) by modifying the rheological properties of the continuous phase. Moreover, the thermal process affects globular protein structure and protein-polysaccharide interactions at the surface of protein-coated droplets, with significant implications for stability and rheology (Dickinson, 2003). When ES compared to ESs, the stabilities of beef emulsions containing carrot, lemon or oat decreased during the storage period (Figure 5).

However, stability of beef emulsions containing other fibers increased during the storage period. Storage conditions and duration of the emulsion could affect the emulsion stability.

The effects of the fibers on the EV, AYSe and AYSg values were found to be significant ($p<0.05$). Each fiber without inulin increased viscosity of the beef emulsion significantly (Table 1, Figure 6). Highly soluble fibers such as inulin and oligosaccharides have low viscosity (Biswas et al., 2011). Of all the fibers, lemon fiber increased emulsion viscosity the most. Elleuch et al. (2011) reported that water soluble fibers are the major component that would influence the viscosity of a solution. However, Thebaudin et al. (1997) reported that owing to their water-retention ability and swelling properties, insoluble fibers can influence rheological properties of foods. The protein solution rheological properties, particularly viscosity, are a function of molecular size, shape, flexibility, degree of hydration and intermolecular interactions (Elizalde et al., 1988).

Apple fiber and inulin decreased and other fibers increased AYSe values significantly (Table 1, Figure 7). Of all the fibers, carrot fiber increased AYSe values the most. However, wheat fiber increased and other fibers decreased AYSg values significantly (Table 1, Figure 7). Solubility and chemical structure of fibers plays an important role on the rheological and textural properties of meat products (Biswas et al., 2011). Moreover, viscosity and apparent yield stress of emulsion are changed with coalescence of oil globules or the oil retention ability of protein matrix. Moreover, behaviour of non-protein additives might be influence the behaviour of proteins in meat emulsions. Partial unfolding of globular proteins may make them susceptible to complex formation with hydrocolloids (Dickinson, 2003). The addition of fibers into foods modifies the rheological properties as a function of the processing condition (Thebaudin et al., 1997; Aleson-Carbonell et al., 2005; Fernández-Ginés et al., 2005; Steenblock et al., 2005). The rheological properties of such foods are related to the solubility and hydration (swelling) properties of fibers (Thebaudin et al., 1997). When AYSe values compared to AYSg values, AYSg values were found to be higher than AYSe (Figure 7). An important functional characteristic of proteins is gel forming ability. Myofibrillar proteins play an important role in gel formation after heat treatment. Gel formation contributes to the desirable texture and oil-water stabilisation in emulsified meat products. Also, during gel formation, some components can be retained inside the protein matrix (Ziegler and Acton, 1984). Non-meat proteins, gums and fibers can control and improve the texture and stability of meat emulsions (Meullenet et al., 1994; Lin and Huang, 2003). Decrease AYSe and increase AYSg values might have some advantages in practice. Decreased AYSe values cause easier automation and increasing AYSg values give a strong gel structure.

Table 1. Effects of added fibers on the pH values of homogenate (pH-h) and emulsion properties of beef

Fiber	pH-h	pH-e	EC	EA	ED	ES	ESs	EV	AYS_e	AYS_g
Control	5.49±0.01 ^{abc}	5.59±0.01 ^{a}	80.50±2.12 ^{a}	55.78±1.93 ^{b}	0.908±0.000 ^{bc}	60.97±1.82 ^{bc}	64.50±1.77 ^{ab}	1739±51.62 ^{e}	265.17±4.38 ^{e}	649.06±1.76 ^{b}
Pea	5.35±0.01 ^{c}	5.53±0.03 ^{a}	79.85±1.77 ^{a}	55.77±1.34 ^{b}	0.902±0.002 ^{e}	59.86±0.81 ^{c}	65.00±3.18 ^{ab}	2109±60.10 ^{d}	285.05±3.31 ^{c}	622.98±5.40 ^{c}
Wheat	5.47±0.06 ^{abc}	5.56±0.02 ^{a}	79.95±1.06 ^{a}	50.34±2.16 ^{c}	0.912±0.002 ^{b}	59.99±2.84 ^{c}	63.94±2.21 ^{b}	2085±92.63 ^{d}	273.31±3.03 ^{d}	689.20±1.49 ^{a}
Apple	4.56±0.04 ^{d}	4.65±0.01 ^{c}	71.95±0.78 ^{b}	59.83±1.49 ^{a}	0.906±0.004 ^{bce}	60.14±1.75 ^{c}	63.63±1.59 ^{bc}	2110±65.05 ^{d}	255.74±1.45 ^{f}	379.32±1.74 ^{f}
Carrot	5.37±0.11 ^{bc}	5.43±0.04 ^{b}	67.90±1.84 ^{c}	49.85±0.22 ^{c}	0.921±0.002 ^{a}	72.36±2.32 ^{a}	62.63±0.18 ^{bc}	3112±42.43 ^{b}	315.24±4.69 ^{a}	634.16±6.97 ^{c}
Lemon	4.69±0.04 ^{d}	4.70±0.05 ^{c}	68.10±0.57 ^{c}	60.49±1.27 ^{a}	0.910±0.004 ^{bc}	75.88±1.41 ^{a}	68.38±1.24 ^{a}	3678±97.58 ^{a}	299.10±3.54 ^{b}	571.31±6.98 ^{e}
Oat	5.54±0.11 ^{a}	5.57±0.01 ^{a}	81.10±1.56 ^{a}	53.13±1.47 ^{bc}	0.904±0.003 ^{ce}	64.47±1.46 ^{b}	61.19±2.21 ^{bc}	2101±80.61 ^{d}	276.84±1.96 ^{d}	580.88±6.89 ^{de}
Inulin	5.51±0.05 ^{ab}	5.60±0.05 ^{a}	74.75±0.49 ^{b}	54.30±1.10 ^{b}	0.908±0.001 ^{bce}	58.63±0.18 ^{c}	59.25±1.06 ^{c}	1763±6.36 ^{e}	262.60±4.38 ^{ef}	619.64±8.80 ^{c}
Cellulose	5.48±0.02 ^{abc}	5.58±0.01 ^{a}	81.40±0.57 ^{a}	52.86±0.83 ^{bc}	0.906±0.002 ^{bce}	60.35±0.40 ^{c}	61.01±1.24 ^{bc}	2358±84.85 ^{c}	287.62±3.58 ^{c}	588.31±9.27 ^{d}

pH-h: pH of homogenate, pH-e: pH of emulsion, ES: Emulsion stability, EC: Emulsion capacity, ED: Emulsion density, EA: Emulsion activity, EV: Emulsion viscosity, AYSe: Apparent yield stress of emulsion, AYSg: Apparent yield stress of emulsion gel (AYSg).
$^{a\text{-}f}$: Different lowercase letters in a column show significant differences between the groups ($p<0.05$)

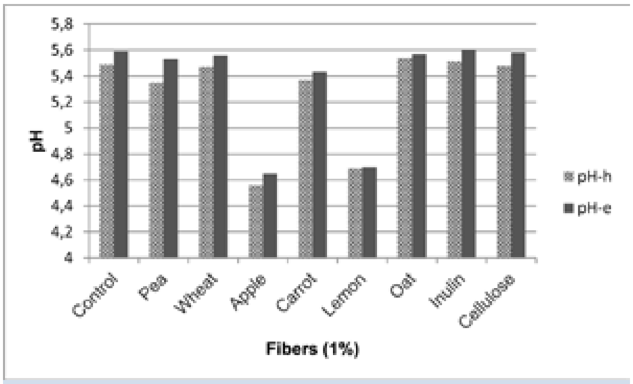

Figure 1. Effects of added fibers on the pH values of homogenate (pH-h) and emulsion (pH-e)

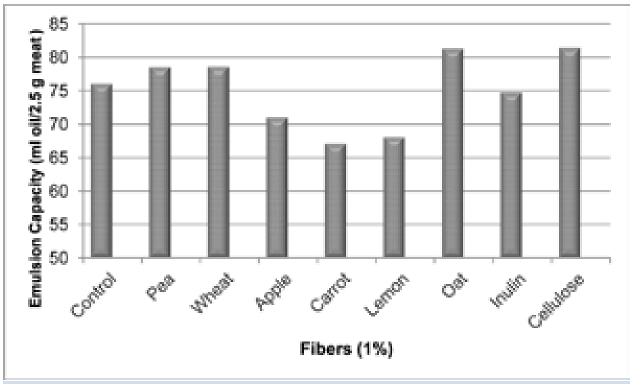

Figure 2. Effects of added fibers on the emulsion capacity

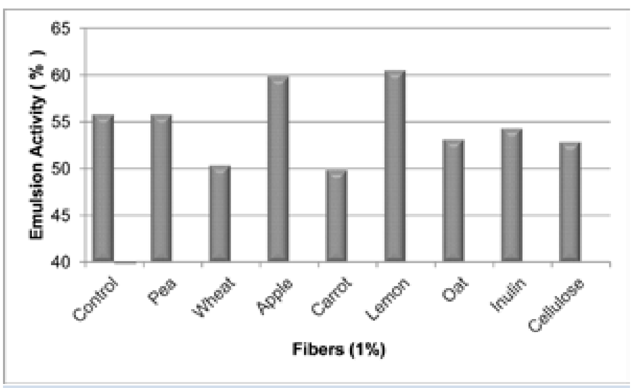

Figure 3. Effects of added fibers on the emulsion activity

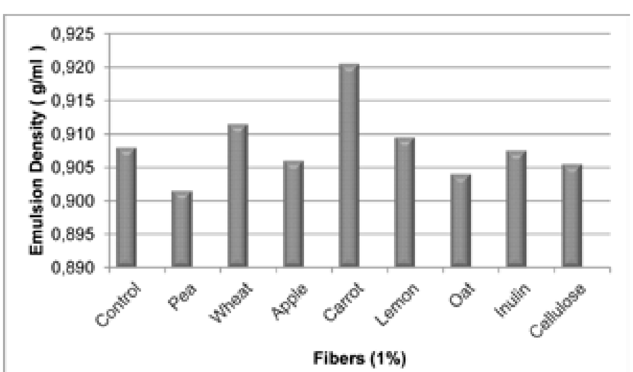

Figure 4. Effects of added fibers on the emulsion density

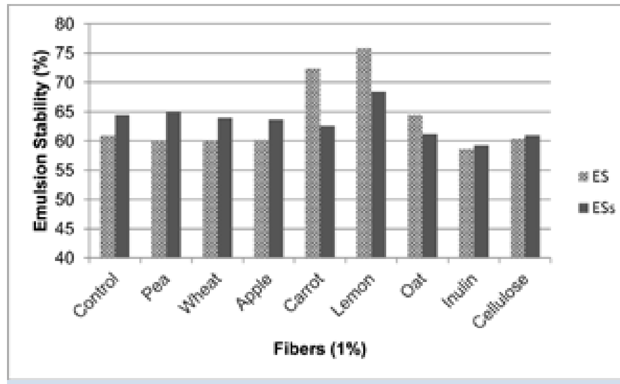

Figure 5. Effects of added fibers on the emulsion stability (ES) and emulsion storage stability (ESs)

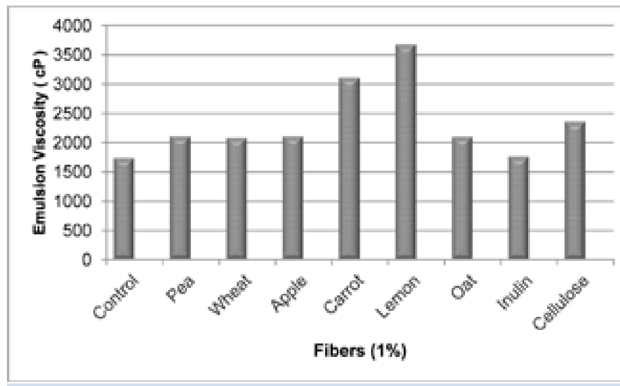

Figure 6. Effects of added fibers on the emulsion viscosity

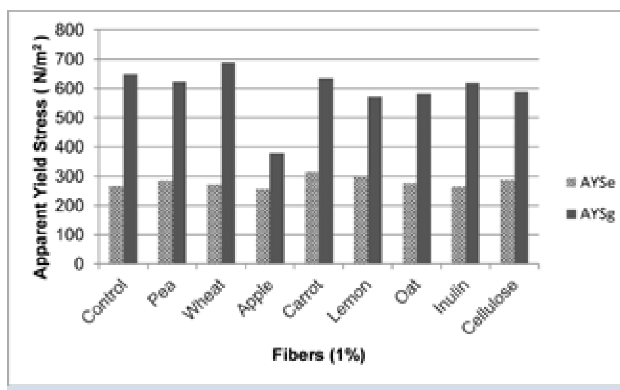

Figure 7. Effects of added fibers on the apparent yield stress values of emulsion (AYSe) and emulsion gel (AYSg)

CONCLUSION

Although oats and cellulose had a positive effect, it was found that the fibers did not improve the emulsion capacity. Emulsion activity was improved by the use of apple and lemon fibers. However, wheat and carrot fibers had a significant effect on the increase of ED. Although the lemon fiber decreased the pH values of the homogenate, it was the fiber that increased the EV and ES values the most. The highest increase in AYSE and AYSg values was caused by carrot and wheat fibers, respectively.

Plant fibers can be used as functional ingredients in emulsified meat products to improve beef emulsion activity, stability, rheology and texture properties. Each fiber has different effects on the different parameters of emulsion. They can be selected according to the emulsion type or desired properties of emulsified products.

CONFLICT OF INTEREST

None declared by the authors.

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