RESEARCH ARTICLE

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Research on the characteristics of model meat systems with emulsion gels including different legume flours

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Abstract

In this study, it was aimed to decrease the animal fat content of the meat products without changing the quality of the products. To this end, emulsion gels prepared with sunflower oil and legume (pea, lentil, bean and chickpea) flours were utilized in place of 50% and 75% animal fat in the model meat system. The moisture (%) of the control was 71.28, but in the treatments the values were between 72.84 and 74.27. The protein amounts of the samples containing emulsion gels were in the range of 69.30-72.28 g /100 g dw, whilst the amount of control was 65.63 g /100 g dw. According to these results the moisture and protein amounts of the samples containing emulsion gels were similar to each other ($p>0.05$), but higher than the control ($p<0.05$). The fat content lowered in the experimental samples as expected ($p<0.05$). The pH values of the samples were 6.27-6.41 and similar to control in most of the samples ($p>0.05$). No significant difference was determined among the color (L * and b *) values and the water holding capacity (WHC) of the samples. The texture values (hardness, binding, flexibility, chewiness) of the products were similar to the control ($p>0.05$). NMR studies showed that there were differences in T_2 relaxation times which is related to free moisture in the product ($p<0.05$). Morphological images of the treatments were observed by Scanning Electron Microscope (SEM). In general, substitution of animal fat with emulsion gels prepared with vegetable oil and legume flours at these amounts improved the nutritional properties of the products by increasing the protein amount and decreasing the fat content. Moreover, no undesirable effect was observed in the products such as water and oil leakage.

Keywords: Emulsion gel, Model meat system, Low fat meat product, Legume flour

INTRODUCTION

Recently, the relationship between nutrition, food and health has gained prominence. Remarkably, recent studies have focalized on daily fat intake, and its strong association with coronary heart diseases, obesity and some types of cancer (Phillips et al., 2012; Yang et al., 2017; Jiao et al., 2018; Bhupathi et al., 2020). The World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) emphasized that 15-30% of total daily energy intake should be met with fats, and at most 10% of this should be saturated fats (WHO, 2003; FAO, 2010; Hooper et al., 2015). Moreover, a maximum of 300 mg daily cholesterol intake is recommended (Gray and Griffin, 2009). It is known that consuming more than the specified percentages of saturated fats and cholesterol increases the amount of LDL (Low-density lipoprotein), also known as "bad cholesterol", in the body. In addition, the relationship between high LDL levels and the saturated fat ratio increases coronary heart diseases

(Mensink et al., 2003; Joris and Mensink, 2016). These health concerns have influenced purchasing habits, consumer perception and created a substantial demand for products with reduced fat content. In this case, meat products with high nutritional value and protein sources pose a significant health risk due to their saturated fat content. This situation reveals the necessity of fat reduction studies in meat products as in various foods. Therefore, the enrichment of the unsaturated fatty acid profile by reducing saturated fat and cholesterol in emulsified meat products without changing their physical and chemical properties have been conducted in many studies (Pintado et al., 2016; Herrero et al., 2017; de Souza Paglarini et al., 2019). Using vegetable oil (hazelnut, soybean, sunflower, olive oil, etc.) as an animal fat replacer can be considered one strategy; however, due to its distinctive texture, mouthfeel, and flavor, the replacement of animal fat is very challenging. Also, using 30-40% saturated fats in emulsified meat products is essential to achieve the desired texture, rheological structure, technological and sensory properties. However, recent studies showed that integrating vegetable oils in the form of emulsion gel can reduce the animal fat amount without quality problems (Serdaroğlu and İpek, 2019). For instance, a study conducted on frankfurter type sausages showed that replacing animal fat with emulsion gels prepared by olive oil, fish oil, flaxseed oil, soy protein isolate, sodium caseinate, and microbial transglutaminase did not affect the shelf life and quality of the products adversely (Delgado-Pando et al., 2010). Moreover, in the study in which an oil/water emulsion gel prepared using flaxseed oil and carrageenan was used in salami, it was stated that the sensory properties did not change, and a product rich in unsaturated fatty acids was obtained (Poyato et al., 2014). Therefore, emulsion gels prepared with vegetable oils to enrich the product composition of mono and polyunsaturated fatty acids have gained popularity.

Legumes are among the most important food groups in the world due to their carbohydrate, protein, vitamin and mineral content. Legumes are low in fats and do not contain cholesterol. They are known as low glycemic index foods. With these features, it has very important benefits in the treatment of diabetes through nutrition and on the proper functioning of lipid and sugar metabolism. It has been observed that legumes are significantly therapeutic on diabetes, cardiovascular diseases, obesity, and some skeletal cancer types (Tharanathan and Mahadevamma 2003, Hera et al. 2012). Today, legume flour is used as a food ingredient due to its high protein content and functional properties (Singh et al. 2017, 2020). The performance of legume flour as a food ingredient is dependent on functional properties that contribute to the final product, such as foaming, emulsification, gelling, water and oil absorption capacities, and viscosity (Adebowale and Lawal 2004).

Model meat systems provide to make meat and meat products in a more convenient and economical way. In model meat systems, industrial meat products are imitated particularly using their basic ingredients in a laboratory scale. There are many studies on model meat systems in the literature such as Cofrades et al. (2013), Schmiele et al. (2015), Han and Bertram (2017), Câmara et al. (2020), Öztürk-Kerimoğlu et al. (2021). In our study, model meat products were prepared using the fundamental ingredients of a typical frankfurter type sausage.

It is quite difficult to produce meat products which vegetable oils are used instead of animal fat, because vegetable oils have a low melting point and lead to leakage. Also, replacing the animal based proteins with plant proteins probably cause to poor texture problems in the product. This study aimed to investigate the use of vegetable oil (sunflower oil) and legume flours (pea, lentil, navy bean and chickpea) in emulsion based product formulation. By that way, products with higher protein content and lower animal fat could be obtained without leading to any undesirable effect such as water/oil leakage or unacceptable appearance and texture.

MATERIALS AND METHODS

Materials

Ground beef and tail fat used in the research were obtained from Ankara Meat and Milk Board. Sunflower oil (Yudum) was purchased from a local supermarket. Gluten-free pea flour, gluten-containing bean flour, lentil flour (Değirmencibaşı, Smart Kimya, Türkiye) and gluten-free raw chickpea flour (Vegrano, Kimbiotek, Türkiye) were purchased from the market. Soy lecithin was purchased from Alfosol, Istanbul.

Preparation of emulsion gels

Emulsion gels were prepared according to the method described by Alejandre et al (2016) with some modifications. In the preliminary trials, emulsions were formed at 10%, 15%, 20% (Sunflower oil) oil ratios by using 1% and 2% lecithin. Following several preliminary trials, emulsions were prepared with 20% sunflower oil + 12% legume flour + 67% water and 1% lecithin on a dry basis. Later, emulsions were kept in a water bath at 80˚C for 30 minutes and then placed in an ice bath to obtain gel formation. The selection of the appropriate gel formulation to be used in the study was determined by evaluating the data obtained from particle size and texture (hardness) analysis.

Model Meat System Preparation

To prepare model meat systems, three different formulations were pre-tested without using emulsion gel (control). The pretested formulations were:
Formulation A: 70% meat, 10% animal fat and 20% water
Formulation B: 75% meat, 10% animal fat and 15% water
Formulation C: 33% meat, 52% animal fat and 15% water.

These formulations were prepared as 200 g batches in a blender. After mixing in the blender and obtaining an emulsion structure, they were stuffed in a 50 ml Falcon tube. The mixture was cooked in a hot water bath at 80˚C for 30 minutes. The formulation of the control samples to be used in the study was decided based on the naked eye appearance and textural properties of the samples. Accordingly, the composition of the control sample was determined as 75% meat, 10% animal fat and 15% water (Formulation B). This formulation was chosen because it gave the best appearance and structure. Afterwards, model meat systems were created by adding 25%, 50%, 75% and 100% vegetable oil in place of animal fat. Considering the appearance and texture values obtained, it was decided to use 50% and 75% emulsion gels in place of animal fat in the samples. Model meat systems prepared according to the trial design given in Table 1 were cooked in a hot water bath at 80˚C for 30 minutes as in control (with an internal temperature of 72˚C measured by using thermocouples).

Table 1. Formulation of model meat systems

Sample	Legume Flour	Meat (%)	Fat (%)		Water (%)
			Animal Fat	Emulsion Gel	
C	-	75	10	-	15
P50	Pea	75	5	5	15
P75	Pea	75	2.5	7.5	15
L50	Lentil	75	5	5	15
L75	Lentil	75	2.5	7.5	15
B50	Navy Bean	75	5	5	15
B75	Navy Bean	75	2.5	7.5	15
CP50	Chickpea	75	5	5	15
CP75	Chickpea	75	2.5	7.5	15

Analyzes of Emulsion Gels

Particle size of emulsions

The particle sizes of the prepared ungelled emulsions were measured using equipment working with the laser diffraction principle (Malvern Instruments, mastersizer 3000, Malvern, UK).

Parameters used: Mixer speed: 2500 rpm, refractive index (Sunflower oil): 1.464-1.474, absorption index: 0.01, olive oil density 0.924 g/cm^3, acceptance range (5-15). The prepared gel was added slowly to the mixer and reading was conducted between the limit values (Pocan et al., 2019).

Texture analysis of emulsion gels

The texture values of the samples were determined with a texture analyzer (TA.HD Plus Texture Analyzer Texture Technologies Corp., Hamilton, MA, USA). Compression was applied to the samples with a cylinder probe. Trigger load and test speed were set as 0.1 N and 0.50 mm/s, respectively. A cylinder probe (TA10) with a length of 13.93 mm and a diameter of 14.11 mm was used for measurements.

Analyzes in Cooked Model Meat Systems

Proximate analyzes

Moisture, fat and protein contents of model meat systems were determined following AACC Methods (AACC, 2000). The moisture content was measured by drying the samples in an oven at 105˚C. Measurements were conducted in quadruplicate for each treatment. Then, these dried samples were used to carry out the fat and protein analysis by the Soxhlet extraction method and the modified Kjeldahl method, respectively.

Analysis of pH

The pH-meter was calibrated with buffer solutions prior to analyses. In pH measurements, 1 g of sample was homogenized with 9 ml of distilled water and reading was performed by immersing the pH-meter electrode into this mixture (Pintado and Cofrades, 2020).

Water Holding Capacity (WHC)

To determine the water holding capacity of the sample (Bowker and Zhuang, 2015), 15 ml of 0.6 M NaCl solution was added to 10 g of meat and mixed for 1 minute. After the sample was kept at 4 °C for 15 minutes, it was centrifuged at 4000 rpm for 25 minutes, and the volume of the supernatant was measured. The following equation was applied to calculate water holding capacity (WHC) (%):

$$WHC\ (\%) = \frac{V_2 - V_1}{V_1} x\ 100$$

where V1 and V2 are the volumes of NaCl solution before and after centrifuge, respectively.

Color analysis

The color analysis of samples was conducted by the CIELAB method (Ilhan et al., 2020). The L* (lightness), a* (red-green), and b* (yellow-blue) values were recorded via Konica Minolta spectrophotometer (CM-5, Tokyo,

Japan).

Texture Profile Analysis

The texture values of meat samples were determined with a texture analyzer (TA.HD Plus Connect, Texture Technologies Corp., MA, USA). Compression tests were applied to the samples with a cylinder probe. Trigger load and test speed were set to 0.1 N and 0.50 mm/s, respectively, and a cylinder probe (TA10) with a length of 13.93 mm and a diameter of 14.11 mm was used to measure hardness, cohesiveness, springiness, and chewiness (Hjelm et al., 2019).

Time-Domain Nuclear Magnetic Resonance (TD-NMR) Relaxometry

T2 relaxation times of control and samples were measured via a 0.5 T (20.34 MHz) benchtop TD-NMR system (Spin Track, Resonance Systems GmbH, Kirchheim/Teck, Germany). CPMG (Carr-Purcell-Meiboom-Gill) pulse sequence for T2 measurements and saturation recovery pulse sequence with appropriate acquisition parameters were applied. Mono-exponential fitting was performed by MATLAB (R2019b, The MathWorks Inc., USA) to calculate the relaxation times (Bitik et al., 2019).

Field Emission Scanning Electron Microscopy (FE-SEM)

The morphologic analysis was carried out by a field emission scanning electron microscope (FE-SEM) (QUANTA 400F, Field Electron and Ion Company, OR, USA). The surface morphology of the samples was analyzed at 20 kV, and the images were examined in 1000x and 2000x magnitudes (Claver et al. 2010).

Statistical Analysis

In the study, analyses were performed in four replicates in moisture (%), pH, water holding capacity, color, texture, NMR analyzes and the average value of the data for each sample was presented. It was studied as three replicates in fat analysis and two replicates in protein analysis, and the averages of the values were taken. Statistical evaluations were carried out in Minitab (Version 19, Minitab Inc., Coventry, UK) package program. One-way analysis of variances (ANOVA) method was used in the statistical evaluation of the differences between the samples. Primarily, it was examined whether the obtained data provided a normal distribution. Then the equality of variance analysis was performed and its suitability for ANOVA was tested. Tukey's multiple comparison test was applied at 95% confidence interval to determine the significant differences between the samples.

RESULTS AND DISCUSSION

Moisture, Fat and Protein Contents

The moisture, fat and protein values of the control sample and the samples containing emulsion gel formed with pea, lentil, bean and chickpea flour are presented in Table 2. When the moisture contents of the samples were examined, the values of control and CP50 were found to be lower than the other samples ($p<0.05$). This is thought to be due to the water content of the emulsion gels. Considering that 10% animal fat was replaced with 50% and 75% emulsion gel in the model meat system in the study, it is an expected result that emulsion gel with high moisture content entering the structure instead of oil causes this situation. Except for CP50, there was no significant difference between the moisture values of all samples containing emulsion gel ($p>0.05$).

Table 2. The moisture, fat, and protein contents (%) of the control and emulsion gel containing samples

Sample	Moisture Content (%)	Fat (%) (g /100 g dw)	Protein (%) (g /100 g dw)
C	71.28 ± 0.57 ^{b}	27.77 ± 0.30 ^{a}	65.63 ± 1.11 ^{b}
P50	73.47 ± 0.27 ^{a}	21.89 ± 0.51 ^{c}	69.39 ± 0.50 ^{a}
P75	74.09 ± 0.59 ^{a}	19.72 ± 0.06 ^{d}	71.09 ± 0.06 ^{a}
L50	73.55 ± 0.95 ^{a}	22.62 ± 0.29 ^{c}	71.93 ± 0.62 ^{a}
L75	73.56 ± 0.16 ^{a}	18.86 ± 0.22 ^{d}	72.28 ± 0.50 ^{a}
B50	74.27 ± 0.30 ^{a}	24.68 ± 0.28 ^{b}	70.92 ± 0.93 ^{a}
B75	73.74 ± 0.53 ^{a}	19.54 ± 0.16 ^{d}	71.40 ± 1.61 ^{a}
CP50	72.84 ± 0.73 ^{b}	22.81 ± 0.50 ^{c}	69.30 ± 0.62 ^{a}
CP75	73.97 ± 0.62 ^{a}	19.61 ± 0.36 ^{d}	71.05 ± 0.62 ^{a}

Values are expressed as mean ± SE (n=3). In each column different letters represent significant differences ($p < 0.05$).

Pintado and colleagues reported that the moisture content of the reduced-fat sausages in which the animal fat was replaced with emulsion gels containing chia flour, oat bran and olive oil was higher than that of the control sample (Pintado et al., 2018). In another study where amorphous cellulose fiber was substituted to reduce the fat content in model meat systems, the moisture content was found to be high due to introducing a high amount of water into the formulations than control samples (Schmiele et al., 2015).

In the fat analysis, the oil content of the control sample was higher than the other samples ($p<0.05$). It can also be explained by replacing fat with emulsion gels in model meat systems. Significant differences were found between the fat contents of the samples containing

Table 3. pH, L*, a* and b* values of the control and emulsion gel containing samples

Sample	pH	L*	a*	b*
C	6.36 ± 0.03 ^{ab}	47.13 ± 0.83 ^{a}	9.7 ± 0.91 ^{ab}	20.48 ± 0.52 ^{a}
P50	6.41 ± 0.02 ^{a}	49.03 ± 1.67 ^{a}	7.53 ± 0.05 ^{d}	19.83 ± 0.44 ^{a}
P75	6.37 ± 0.03 ^{ab}	50.15 ± 1.82 ^{a}	8.00 ± 1.14 ^{d}	20.58 ± 1.28 ^{a}
L50	6.31 ± 0.06 ^{bc}	49.45 ± 2.07 ^{a}	9.87 ± 1.48 ^{ab}	19.60 ± 0.90 ^{a}
L75	6.34 ± 0.02 ^{abc}	46.37 ± 1.46 ^{a}	8.57 ± 0.64 ^{cd}	18.97 ± 1.18 ^{a}
B50	6.27 ± 0.05 ^{c}	49.18 ± 2.35 ^{a}	9.33 ± 1.57 ^{bc}	19.75 ± 1.12 ^{a}
B75	6.36 ± 0.03 ^{ab}	47.85 ± 2.39 ^{a}	10.47 ± 1.10 ^{a}	19.40 ± 1.15 ^{a}
CP50	6.27 ± 0.04 ^{c}	50.18 ± 2.07 ^{a}	5.80 ± 2.25 ^{e}	18.28 ± 1.93 ^{a}
CP75	6.29 ± 0.02 ^{bc}	48.03 ± 0.73 ^{a}	9.18 ± 0.56 ^{bc}	19.35 ± 0.59 ^{a}

Values are expressed as mean ± SE (n=3). In each column different letters represent significant differences ($p < 0.05$).

emulsion gels ($p<0.05$). While the lowest fat content was found in L75, P75, B75 and CP75 samples, the highest fat value was observed in B50 after the control ($p<0.05$). A significant similarity was found between the oil values of the other samples (P50, L50 and CP50) ($p>0.05$). Pintado and Cofrades (2020) indicated that oleo gel and emulsion gel induced fermented sausages and had higher moisture and low-fat content than control.

Protein contents of the legume flours which were used in this study had been determined in a previous study (Tas et al., 2022). The protein contents of pea, lentil, navy bean and chickpea flours were 25.03, 27.03, 23.19 and 23.67 g/100 g dw, respectively.

Protein analysis of the meat samples was also performed on dried samples. According to the results obtained, the protein content of the control sample was found to be lower than the other samples ($p<0.05$), but no significant difference was observed between the other samples ($p>0.05$). This was due to the high protein content in pea, lentil, navy bean and chickpea flours used in the formulation. Therefore, substituting emulsion gels containing legume flours can be considered effective in increasing the protein amount in model meat systems. Pintado et al. (2018) stated that the protein values of the reduced-fat sausages to which they added emulsion gels prepared with chia flour, oat bran and olive oil instead of animal fat were similar to those of the sausages prepared with animal fat and without reduced fat ($p<0.05$). It was also mentioned in another study that the protein content increased when emulsion gels containing using chia flour, olive oil and alginate was utilized in frankfurters instead of animal fat (Herrero et al., 2017). Salcedo-Sandoval et al. (2013) stated that the moisture and protein content of the sausages increased, while the fat content decreased ($p<0.05$), in the study where they replaced animal fat by emulsion gels containing olive oil, flaxseed oil, fish oil and konga flour ($p<0.05$).

pH and Color Analysis

As given in Table 3, the pH values of the samples ranged from 6.27 to 6.41. Although statistical differences were observed in some samples, all the pH values were consistent with products of this kind (Salcedo-Sandoval et al., 2013; Scapin et al., 2015; Herrero et al., 2017; Pintado et al., 2016, 2018).

The color (L*, a*, b*) values of the samples are presented in Table 3. No significant difference was observed in color values L* and b* ($p>0.05$), but a* values were significantly different ($p<0.05$). L*, a* and b* values vary between 46.37-50.18, 5.80-10.47 and 18.28-20.58, respectively. In general, model meat systems containing emulsion gels were less red than the control except for B75 sample. Less redness might be due to the substitution of fat by emulsion gels (Jiménez-Colmenero et al., 2012; Pintado et al., 2018). The most suitable color can be easily obtained by several strategies which focuses on modulating the color of the ingredients in emulsion gels.

Water Interactions

No significant difference was observed between the water holding capacity (WHC) values of the samples ($p>0.05$) (Table 4). Although the moisture values of the samples containing emulsion gel were found to be higher than the control ($p<0.05$), the use of emulsion gel instead of oil caused only minor numerical differences in the water holding capacity of the samples but did not cause a statistical difference ($p>0.05$). This may be due to the relatively low content of legume flours in the whole mass of the model meat system. Moreover, the pH values could influence the WHC of the samples. At the isoelectric point of the muscle proteins (5.8 for beef), WHC is expected to be minimum, and studies showed that as pH increases, WHC also increases (Nacak et al., 2021). However, according to a study that focuses on cooked pork and beef sausages (Puolanne et al., 2001), the effect of a further increase in pH after 6.1 was trivial, and the pH values of cooked sausages tend to be between 6.0 and 6.5 (Korkeala and Johanna Björkroth, 1997). Therefore, the WHC of the samples in this study was expected to be similar due to the slight differences in pH values (pH range: 6.27 to 6.41).

T2 relaxation times of the samples are given in Table 4. Based on results, significant differences were found between the values ($p<0.05$). The lowest T2 relaxation time was observed in control sample while the highest was observed in the B75 sample ($p<0.05$). As the amount

Table 4. Water holding capacity (WHC) (%) and T_2 relaxation times of the control and emulsion gel containing samples

Sample	WHC (%)	T_2 relaxation time (ms)
C	65.33 ± 1.22 [a]	141.82 ± 7.75 [d]
P50	65.83 ± 1.48 [a]	160.66 ± 11.61 [bcd]
P75	65.33 ± 1.22 [a]	187.42 ± 10.46 [b]
L50	64.50 ± 0.33 [a]	165.15 ± 0.81 [bcd]
L75	66.67 ± 0.00 [a]	165.73 ± 13.68 [bcd]
B50	65.00 ± 0.39 [a]	173.46 ± 21.05 [bc]
B75	66.00 ± 1.44 [a]	237.17 ± 13.12 [a]
CP50	66.33 ± 0.39 [a]	152.85 ± 9.25 [cd]
CP75	65.33 ± 1.33 [a]	169.17 ± 11.32 [bcd]

Values are expressed as mean ± SE (n=3). In each column different letters represent significant differences ($p < 0.05$).

of free water in the sample increases, T2 time is expected to increase. The model meat systems had complex and heterogeneous structures containing different components such as fat and protein along with water, thus components other than water may also have an impact on relaxation times. Since the samples containing emulsion gels contain more water molecule than the control as can be seen from the moisture content results, observing the lowest T2 relaxation time in control was expected.

Textural Properties

When the texture values of the samples given in Table 5 were analyzed, it was found that the hardness and chewiness values of the samples were similar to those of control samples ($p>0.05$). The highest hardness and chewiness values were observed in P75, and C75 samples, whereas the lowest value was observed in the L50 sample. Also, the cohesiveness and springiness values of all samples were statistically indifferent ($p>0.05$). Considering similar formulations of model meat systems, the difference in the hardness and chewiness of samples would appear to be due to emulsion gels fortified as a fat replacer (de Souza Paglarini et al., 2019). During cooking, a gel matrix that retains the components (e.g. additives, polysaccharides) inside is created from the meat protein. The emulsion gel components (sunflower oil, animal fat and plant protein) are also expected to be trapped in this matrix, causing an increase in the hardness and chewiness of the samples (Gao et al., 2015). Furthermore, the better dispersion of sunflower oil droplets and the protein-polysaccharide interaction in legume flours could affect the textural properties of samples (Matsumura et al., 1993; Mcclements et al., 1993; Dickinson, 2013; Pintado et al., 2015; Herrero et al., 2017). Several studies complied with the results and showed that the model systems in which emulsion gels were utilized as a fat replacer had higher hardness and chewiness than the control (Pietrasik and Janz, 2010; Sanjeewa et al., 2010; Shahiri Tabarestani and Mazaheri Tehrani, 2014).

Microstructural Properties

SEM images of the samples captured at 20 kV with magnifications of 1000x and 2000x are presented in Figures 1 and 2. In Figure 1, the typical morphology of a meat product having a three-dimensional cooked gel network could clearly be observed in control samples. The main characteristic of this product consisted of the formation of several cavities and a rough and coarse structure where irregular shapes could be seen due to the expansion of fat, air and water constituents (Ayadi et al., 2009; Salcedo-Sandoval et al., 2013; Nacak et al., 2021). On the other hand, compared to control samples, P50 and B50 had a smoother gel network containing more small cavities. Sample L50 showed a more fringed structure. CP50 seemed more compact with smaller cavities. These images indicated the formation of new connections along with the already existed gel network due to the crosslinking reaction between polysaccharides, proteins, and water molecules (Ayadi et al., 2009).

In Figure 2, P75 had smaller cavities than those of control. B75 exhibited the smoothest image of all. L75 sample

Table 5. Texture values of the control and emulsion gel containing samples

Sample	Hardness (N)	Cohesiveness	Springiness (mm)	Chewiness (g.cm)
C	10.71 ± 0.67 [ab]	0.63 ± 0.01 [a]	8.43 ± 0.64 [a]	577.00 ± 78.48 [ab]
P50	8.44 ± 0.35 [ab]	0.67 ± 0.04 [a]	8.45 ± 1.71 [a]	482.00 ± 49.50 [ab]
P75	12.67 ± 2.18 [a]	0.66 ± 0.05 [a]	8.56 ± 0.49 [a]	738.33 ± 183.63 [ab]
L50	7.03 ± 0.37 [b]	0.66 ± 0.04 [a]	8.40 ± 0.18 [a]	393.00 ± 7.07 [b]
L75	10.04 ± 1.42 [ab]	0.66 ± 0.11 [a]	8.96 ± 0.91 [a]	614.67 ± 150.41 [ab]
B50	11.89 ± 2.01 [ab]	0.69 ± 0.08 [a]	8.08 ± 0.48 [a]	671.33 ± 90.67 [ab]
B75	10.16 ± 2.24 [ab]	0.64 ± 0.06 [a]	8.06 ± 0.38 [a]	527.67 ± 70.87 [ab]
CP50	12.70 ± 0.40 [ab]	0.67 ± 0.04 [a]	8.84 ± 0.73 [a]	774.50 ± 136.47 [ab]
CP75	13.55 ± 2.26 [a]	0.68 ± 0.06 [a]	8.46 ± 0.78 [a]	791.00 ± 121.51 [a]

Values are expressed as mean ± SE (n=3). In each column different letters represent significant differences ($p < 0.05$).

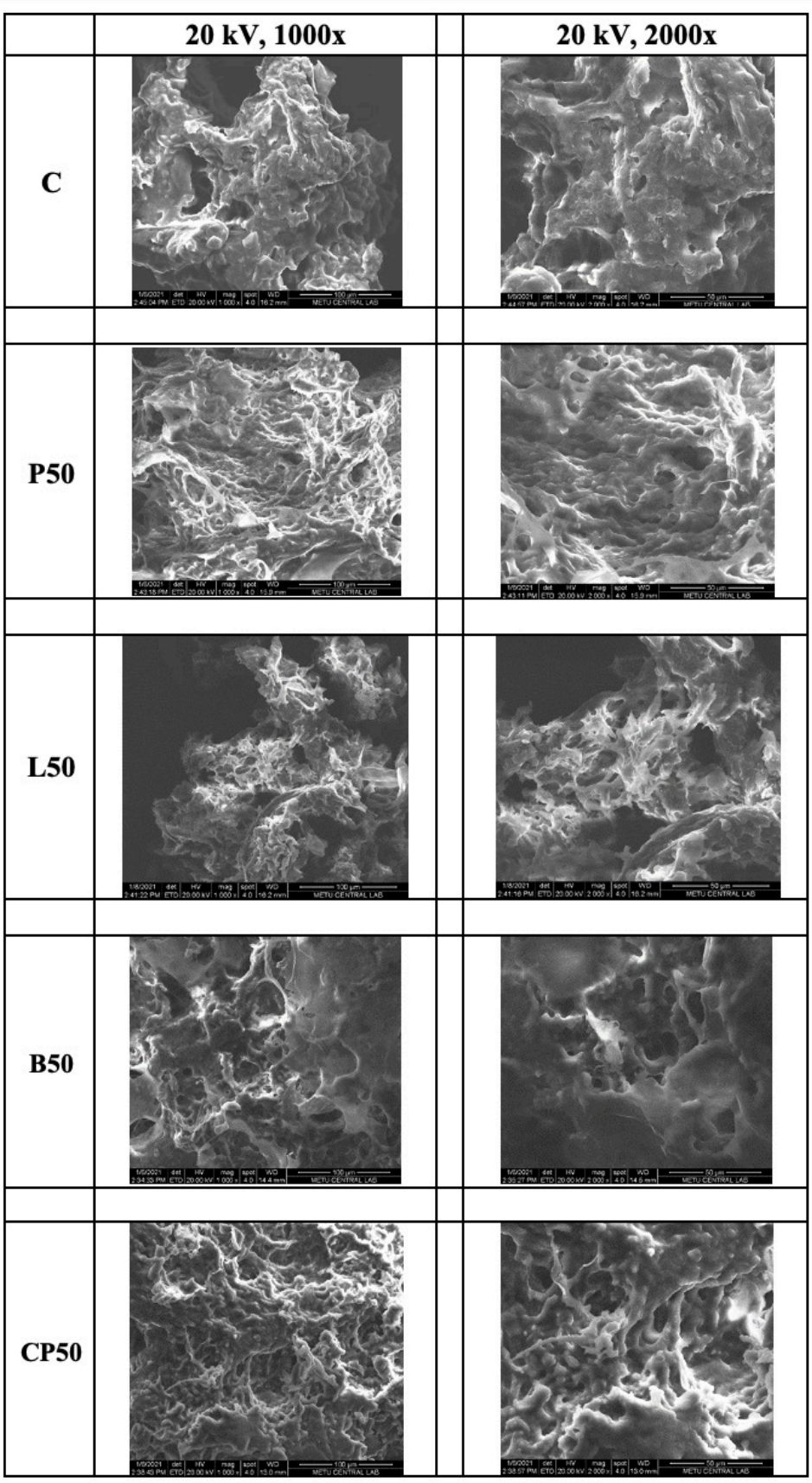

Figure 1. Scanning electron microscopy (SEM) images of control, P50, L50, B50 and CP50 samples captured at 1000× and 2000x magnification

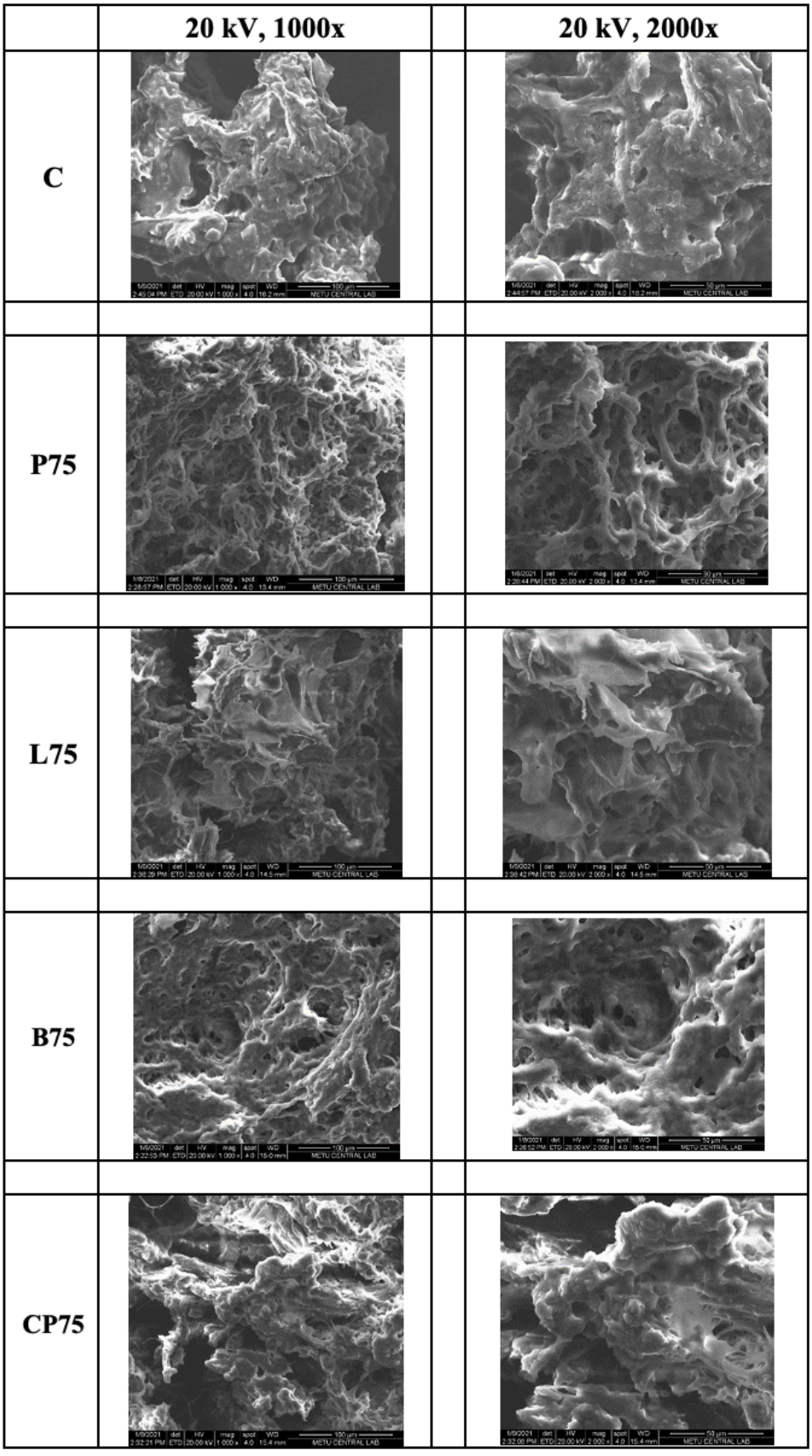

Figure 2. Scanning electron microscopy (SEM) images of control, P75, L75, B75 and CP75 samples captured at 1000× and 2000x magnification

seemed to be fringy without round cavities. Sample containing emulsion gels prepared with chickpea flour (CP75) presented the most irregular and indented structure.

In general, it can be deduced that a stable and homogenous structure similar or better than control may also be obtained by emulsion gels as seen in literature (Ayadi et al., 2009; Afoakwah et al., 2015; Wang et al., 2018).

CONCLUSION

Addition of vegetable oils into meat products usually cause some technological problems such as oil leakage. The basic aim of this study was to solidify the oils by forming emulsion gels. Emulsion gels were prepared using sunflower oil and different leguminous flours (pea, lentil, bean and chickpea flours) and the prepared gels were used in place of animal fat at the amounts of 50% and 75% in the model meat system. The secondary aim was to increase the protein content of the whole product by legume proteins. The moisture content (%) of the majority of the samples to which emulsion gel was added was higher than the control sample ($p<0.05$). Considering that emulsion gels contain a high percentage of water, this was a predicted outcome. It was determined that the amount of oil in the samples including emulsion gel was significantly less than the control sample, but on the contrary, the protein amounts were higher than the control ($p<0.05$). Although there were significant differences in the pH values of the products, extreme changes were not observed. The water holding capacity values of all products were found to be similar ($p>0.05$) despite the high water content of the emulsion gels. Emulsion gels and leguminous proteins are likely have an effect on this situation and no adverse effect on the product such as water release was observed. However, there were significant differences ($p<0.05$) in the relaxation times of T_2 by NMR analysis. No significant changes were found in the L* and b* values among all the samples ($p>0.05$). According to texture analysis, the hardness, cohesiveness, springiness and chewiness values were similar to the control ($p>0.05$). With the morphological images obtained by SEM analysis, the effects of different emulsion gels on the internal microstructure of the products were examined. In conclusion, addition of emulsion gels prepared by using different leguminous flours did not change the quality properties properties of the products according to the results of the conducted analyses. Moreover, products with low animal fat and high protein content were obtained. In the future, utilization of emulsion gels in meat products would be an attractive application for the industry. Many products based on new formulations can be obtained using different organic polymers and gelling agents.

COMPLIANCE WITH ETHICAL STANDARDS

Peer-review

Externally peer-reviewed.

Conflict of interest

The authors declared that for this research article, they have no actual, potential or perceived conflict of interest.

Author contribution

This study is the part of the master thesis of DD. She (DD) conducted experiments, data analysis. EBO created and designed the study, supervised DD and wrote the manuscript. UE and OT assisted and led DD while doing the experiments and wrote the manuscript. MHO supervised DD. All the authors reviewed the manuscript.

Ethical approval

Ethics committee approval is not required.

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Not applicable.

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Not applicable.

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