



## The Effects of Using Pomegranate (*Punica granatum*) Seed Powder on Quality Parameters of Model System Chicken Meat Emulsions

Meltem Serdaroğlu<sup>1,a,\*</sup>, Özlem Yüncü<sup>1,b</sup>, Hülya Serpil Kavuşan<sup>1,c</sup>,  
Elnaz Sharefiabadi<sup>1,d</sup>, Sahar Seyedhosseini<sup>1,e</sup>

<sup>1</sup>Food Engineering Department, Engineering Faculty, Ege University, 35100, Bornova/İzmir, Turkey

\*Corresponding author

ARTICLE INFO	ABSTRACT
<p><i>Research Article</i></p> <p>Received : 12/03/2021 Accepted : 03/06/2021</p> <p><b>Keywords:</b> Antioxidant Chicken meat emulsion Pomegranate seed Meat quality Functional ingredient</p>	<p>This study aimed to investigate the effects of using 1%, 3% and 5% pomegranate seed powder (PSP) on model system chicken meat emulsion (CME) quality parameters. For this purpose, the properties of the emulsion samples prepared using different amounts of PSP were compared with the control group prepared with 70% chicken breast meat, 18% chicken skin, 10% water, 1.5% salt and 0.5% sodium tripolyphosphate (STPP). Chemical composition, pH, emulsion stability, water holding capacity, cooking yield, and color were analyzed in emulsion samples. TBARs and peroxide values of the samples were determined on days 0, 3, 5 and 7 during storage. Use of pomegranate seed powder in emulsion formulation resulted a decrease in <math>b^*</math> and <math>a^*</math> values. At the same time, with the addition of pomegranate seed powder, there was no difference in the protein values of the raw samples and the moisture, ash and pH values of the cooked samples. It was also observed that pH values, water holding capacity and cooking efficiency of emulsions increased with the increasing levels of PSP. Both peroxide and TBARs values were lower in emulsion samples formulated with PSP on 7 d compared to the control group.</p>

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## Model Sistem Tavuk Eti Emülsiyonlarında Nar (*Punica granatum*) Çekirdeği Tozu Kullanımının Kalite Özellikleri Üzerine Etkileri

MAKALE BİLGİSİ	ÖZ
<p><i>Araştırma Makalesi</i></p> <p>Geliş : 12/03/2021 Kabul : 03/06/2021</p> <p><b>Anahtar Kelimeler:</b> Antioksidan Tavuk eti emülsiyonu Nar çekirdeği Et kalitesi Fonksiyonel bileşen</p>	<p>Bu çalışmada %1, %3 ve %5 oranlarında kullanılan nar çekirdeği tozunun model sistem tavuk eti emülsiyonunda ürün kalitesi üzerine etkilerinin incelenmesi amaçlanmıştır. Bu amaçla %70 tavuk göğüs eti, %18 tavuk derisi, %10 su, %1,5 tuz ve %0,5 oranında sodyum tripolifosfat kullanılarak hazırlanan kontrol grubu ile farklı oranlarda nar çekirdeği tozunun kullanılmasıyla hazırlanan emülsiyon örneklerinin özellikleri karşılaştırılmıştır. Emülsiyon örneklerinde kimyasal kompozisyon, pH, emülsiyon stabilitesi, su tutma kapasitesi, pişirme verimi ve renk analizleri gerçekleştirilmiştir. Depolama süresince 0., 3., 5. ve 7.günlerde örneklerin TBARs ve peroksit değerleri belirlenmiştir. Nar çekirdeği tozunun formülasyona eklenmesi, <math>b^*</math> ve <math>a^*</math> değerlerinin azalmasına neden olmuştur. Aynı zamanda nar çekirdeği tozu ilavesi ile çiğ örneklerin protein değerlerinde, pişmiş örneklerin ise nem, kül ve pH değerlerinde bir farklılık görülmemiştir. Formülasyondaki nar çekirdeği tozu oranının artmasıyla emülsiyon örneklerinin pH değerleri, su tutma kapasitesi ve pişirme veriminin arttığı gözlenmiştir. 7. günde peroksit ve TBARs değerlerinin nar çekirdeği tozu eklenen emülsiyon örneklerinde kontrol grubuna kıyasla daha düşük olduğu belirlenmiştir.</p>

<sup>a</sup> [meltem.serdaroglu@ege.edu.tr](mailto:meltem.serdaroglu@ege.edu.tr)

<sup>c</sup> [hulyaserpilkavusan94@gmail.com](mailto:hulyaserpilkavusan94@gmail.com)

<sup>e</sup> [saharseyedhosseini.1373@gmail.com](mailto:saharseyedhosseini.1373@gmail.com)

<sup>id</sup> <https://orcid.org/0000-0003-1589-971X>

<sup>id</sup> <https://orcid.org/0000-0003-2928-8020>

<sup>id</sup> <https://orcid.org/0000-0001-5059-1417>

<sup>b</sup> [ozlem.yuncu@hotmail.com](mailto:ozlem.yuncu@hotmail.com)

<sup>d</sup> [el\\_sharefi@yahoo.com](mailto:el_sharefi@yahoo.com)

<sup>id</sup> <https://orcid.org/0000-0002-9112-1427>

<sup>id</sup> <https://orcid.org/0000-0002-4382-0469>



## Introduction

In recent years food consumption trends of consumers have been changed dramatically since they are aware of the strong relationship between diet and health. High dietary fiber, mineral, vitamin, and bioactive compounds intake can reduce the risk of cardiovascular diseases, stroke, hypertension, diabetes, obesity, and some gastrointestinal diseases (Anderson et al., 2009). Due to the high amounts of saturated fat, cholesterol and synthetic additives in their formulation meat products are particularly important in this regard. Therefore, the meat industry has been attempting to reformulate the products with healthier ingredients derived from natural sources. When all the aforementioned reasons take into consideration, it is obvious that the popularity of meat products with reduced fat and sodium contents, calories as well as enriched with functional ingredients such as dietary fibers has increased (Jimenez-Colmenero and Delgado-Pando, 2013). The overextending of meat products with plant sources (vegetables, fruits, seeds), and their fibers have the potential to increase the water-holding and fat binding capacities, reduces formulation costs, modifies the texture, improves storage stability, reduces cooking losses, and these sources have a neutral taste (Ekici and Ercoşkun, 2007; Sayago-Ayerdi et al., 2009; Petracci et al., 2013).

Apple pulp (Verma et al., 2010), bambara groundnut flour (Alakali et al., 2010), tomato (Cava et al., 2012), carrot (Eim et al., 2008; Grossi et al., 2011), *Cyperus rotundus* L. rhizome powder (Eltilib et al., 2016), moringa seed flour (Al-Juhaimi et al., 2016), apricot pomace (Purma Adıbelli and Serdaroğlu, 2017), dried pumpkin pulp and seed (Serdaroğlu et al., 2018), pepper seed (Lee et al., 2019; Kim, 2020), cowpea seed powder (Ebrahiem et al., 2020) have been utilized as dietary fiber sources in the formulation of various meat products.

Pomegranate (*Punica granatum*) is from the Punicaceae family, originated in Iran, and is widely produced in Iran, India, America, Near, and the Far East countries. After the juice is squeezed, pomegranate fruit contains 67% pulp and 78% of the pulp consists of the peel and 22% of the seed (Baysal and Taştan, 2018). Pomegranate seed contains significant amounts of oil, protein, dietary fiber, phenolic substances, minerals, and vitamins. Pomegranate peel is a significant source of tannins, anthocyanins, and flavonoids. Gil et al. (2000) stated that pomegranate seed and peel are predominantly containing punicalagin and its isomers (2,3-hexahydroxydiphenol-4,6-gallagylglucose) ellagitannins, small amounts of punikaline (4,6 gallagglucose), gallic acid, ellagic acid, and ellagic acid glycosides (hexicide, pentoside, rhamnoside). Pomegranate seed also contains punic acid, conjugated linoleic acid, linolenic acid, and oleic acid in composition (Okumuş, 2016). When the mineral content is examined, it is seen that the elements with the highest rate are phosphorus, calcium, magnesium, and potassium. Therefore, pomegranate by-products can find various applications such as functional food ingredients, food additives, nutraceuticals and supplements, and diets rich in phenolics, and can be used as a substrate to produce nutritionally valuable and biologically active ingredients (Jalal et al., 2018).

Various studies have been done on the effects of using pomegranate peel or rind in meat product formulations (Li et al., 2006; Naveena et al., 2008; Devatkal et al., 2014; Turgut et al., 2017; Smaoui et al., 2019; Garrido-Cruz et al., 2020; Sharma and Yadav, 2020; Zago et al., 2020; Gullón et al., 2020). However, pomegranate seed powder was only used in chicken nuggets (Kaur et al., 2015), goat meatball (Devatkal and Naveena, 2010; Devatkal et al., 2010), and beef patties (Kurt, 2017).

The aforementioned researches showed that up to this date a few researchers have only implemented the enhancement of meat products with pomegranate seeds, thereby a limited number of studies are available. That's why, the goal of this research was to evaluate the effect of pomegranate seed powder on chemical composition, color, functional properties, and lipid oxidation of model system chicken meat emulsion. It is thought that the results obtained in the study will contribute to future research and shed light.

## Materials and methods

### Materials

Pomegranate seed powder (defatted, 0.25 µm particle size, pH:5.91,  $L^*$ :47.89,  $a^*$ :8.32,  $b^*$ :17.38) was supplied from Başak Tarım Ltd. Co. and stored at room temperature until used. Fresh boneless chicken breast muscles (*Pectoralis major*) and chicken skin were purchased from a local butcher just before the production without breaking the cold chain.

### Preparation of Model System Chicken Meat Emulsion

Preparation of chicken meat emulsion (CME) was carried out in duplicate according to Cofrades et al. (2008) with some modifications. The production steps of CME are presented in Figure 1. Four different batches were prepared by using 0% (C), 1% (P1), 3% (P3), and 5% (P5) PSP, and the formulation CME is seen in Table 1. Chicken breast meat and chicken skin grounded through a grinder with a 3 mm plate. Minced meat was mixed for 60 s. in Thermomix (Vorwerk, Wuppertal, Germany), then chicken skin, ice, NaCl, STPP (sodium tripolyphosphate), PSP were added and emulsified at 2500 rpm for 5 min. more. The temperature of the emulsion was kept lower than 12°C during the processing to avoid emulsion breakage. Prepared emulsions were filled into tapped centrifuge tubes (50 mL), then were heated for 30 min. at 70°C and followed by centrifugation for 1 min. at 2500 rpm to remove the air bubbles from the matrix. Heat-treated samples were cooled and stored for 7 d in polypropylene cases under refrigerator conditions (+4°C).

The progress of lipid oxidation was examined on days 0, 3, 5, and 7 during 7-day storage in 3 replicates by monitoring peroxide value and TBARs analysis.

### Physicochemical Analyses Carried on PSP

pH value of PSP was measured by a method stated by Lee et al. (2008). To determine the water absorption capacity (WAC), one gram of PSP was added with 15 mL of distilled water and kept 12 hours at 22°C. Then, to remove excessive water from matrix, centrifugation is applied to the PSP-distilled water mixture at 15,000×g for 15 min. Lastly, the water absorbed by PSP was calculated. WAC was stated as g water/g sample (McConnell et al., 1974).

Table 1. Formulation of model meat emulsions

Treatments	Chicken breast meat (%)	Chicken skin (%)	Pomegranate seed powder (PSP) (%)	Ice (%)	Salt (%)	STPP (%)
C	70	18	-	10	1.5	0.5
P1	69	18	1	10	1.5	0.5
P3	67	18	3	10	1.5	0.5
P5	65	18	5	10	1.5	0.5

\*C: emulsion formulated with 0% PSP, P1: emulsion formulated with 1% PSP, P3: emulsion formulated with 3% PSP, P5: emulsion formulated with 5% PSP

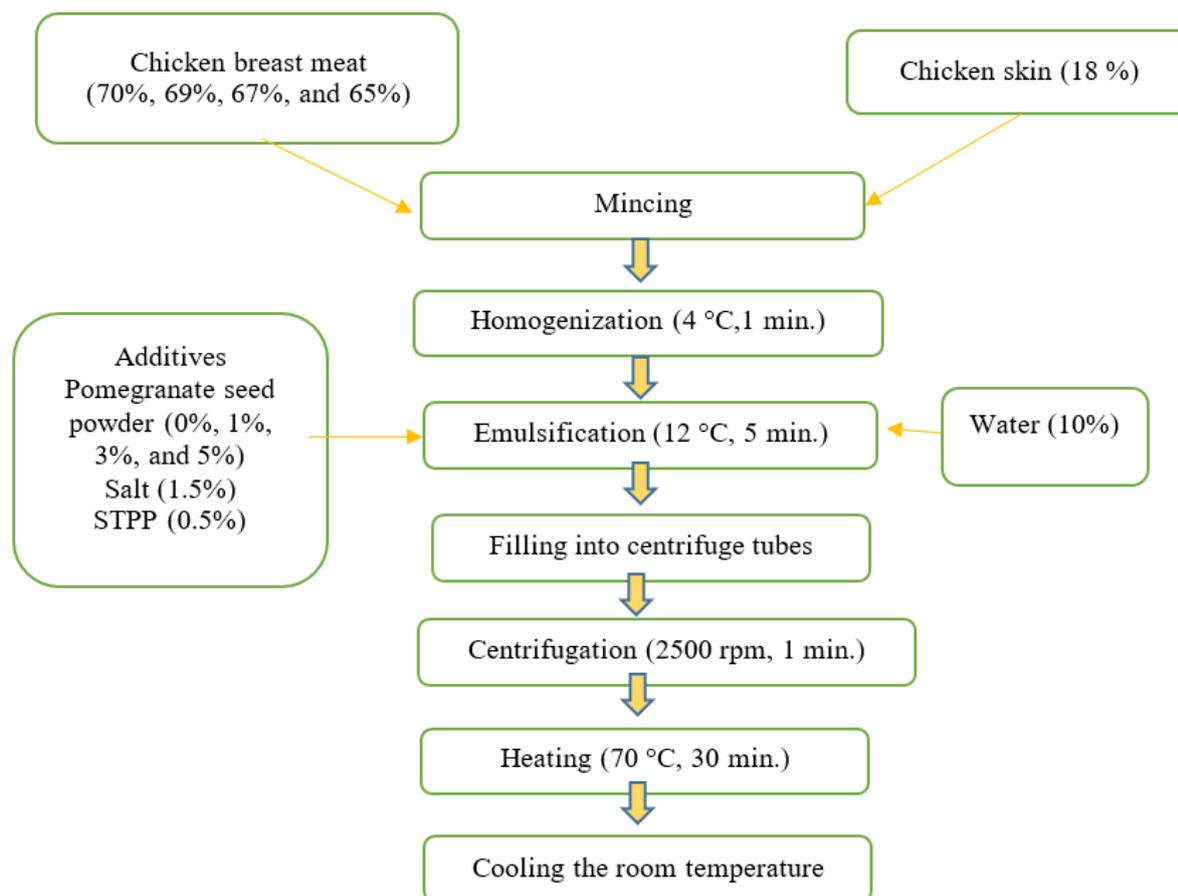


Figure 1. Production of model system chicken meat emulsions

The capacity of PSP to hold oil was specified by using a method of Lin et al. (1974) with modifications. One gram PSP was added with 10 mL sunflower oil and stirred with a vortex mixer for 30 min., then centrifugation was carried out at 4°C for 10 min. with 15,000xg. The supernatant was detracted from mixture, and tube was turned round for 25 min. to evacuate the oil and the residue weighed ( $W_r$ ). Oil holding capacity (OHC) was calculated by the equation given below.

$$\text{OHC (g oil /g sample)} = W_r / W_i$$

Where  $W_i$  was the sample weight (g)

#### Emulsion Stability (ES)

ES was calculated regarding the equation given below in terms of the total expressible fluid (TEF) and the expressible fat (EFAT). Twenty-five grams of chicken meat emulsion was centrifuged at 2,634×g for one minute and heated in 30 minute in water bath at 70°C. Later,

emulsion samples were centrifuged again at 2,634×g for 3 min. The pellets were separated, and then the supernatants were dried (Hughes et al., 1997).

$$\text{TEF} = (\text{WCT} + \text{WS}) - (\text{WCT} + \text{WP})$$

WCT: Weight of centrifuge tube

WS : Weight of sample

WP : Weight of pellet

$$\text{TEF}(\%) = \frac{\text{TEF}}{\text{WS}} \times 100$$

$$\text{EFAT}(\%) = \frac{(\text{WC} + \text{WDS}) - (\text{WCT} + \text{WS})}{\text{TEF}} \times 100$$

WC : Weight of crucible

WDS : weight of dried supernatant

WCT : Weight of centrifuge tube

WS : Weight of sample

**Water Holding Capacity (WHC)**

The capacity of emulsion to hold the water was analyzed according to Hughes et al. (1997) with modifications. Ten grams of batter (W1) was put into a 90°C water bath for 10 min. Subsequently, cooled samples surrounded with cotton gauze then centrifuged at 323×g for 15 min. The final weight (W2) of the samples was measured and the equation given below was used to calculate the water holding capacity.

$$\text{WHC (\%)} = \left(1 - \frac{W1 - W2}{\text{TMCS}}\right) \times 100$$

TMCS: Total moisture content of sample

**Cooking Yield (CY)**

The cooking yield was counted from the weight alterations of the chicken meat emulsions previous and after the cooking process by using the equation below (Murphy et al., 1975):

$$\text{Cooking yield (\%)} = \frac{\text{WCS}}{\text{WUS}} \times 100$$

WCS : Weight of cooked sample

WUS : Weight of uncooked sample

**Chemical Composition**

Moisture (948.12; AOAC, 2007) and ash (945.46; AOAC 2007) contents were analyzed for total solids of cooked and uncooked samples. The fat content of the chicken meat emulsions was determined by using a method stated by Flynn and Bramblett (1975). An automatic nitrogen analyzer (FP 528, LECO, Michigan, USA) was used for measuring protein content according to Dumas method.

**pH**

The pH of chicken meat emulsions was measured by using a pH-meter (pH 3110 set 2, WTW, Weilheim, Germany) fitted out a drilling electrode.

**Peroxide Value (PV)**

The PV of the emulsion was analyzed by using titrimetric method according to Koniecko (1979). Titration was performed with 0.01 N sodium thiosulfate and results were calculated by using the equation below. Results are expressed as meq O<sub>2</sub>/kg chicken meat emulsion.

$$\text{PV} \left( \frac{\text{mEqO}_2}{\text{kg}} \right) = \frac{S \times N}{\text{WS}} \times 1000$$

S : Volume of sodium thiosulfate used for titration

N : The normality sodium thiosulfate solution

WS : Weight of the sample

**Thiobarbituric Acid Reactive Substances (TBARs)**

TBARs was measured based on a method established by Witte et al. (1970) to measure the oxidation of lipids throughout storage time. Briefly, the method is aimed to measure the concentration of the malonaldehyde (MA) accumulated throughout the lipid oxidation reactions. MA reacts with 2- thiobarbituric acid at 80°C for 35 min. and the amount of MA is determined spectrophotometrically at

532 nm based on the intensity of resulted pink-colored compounds. 5.2 multiply the obtained absorbance value. Results are expressed as mg malonaldehyde/kg (mg MA/kg) chicken meat emulsion.

**Color**

A portable colorimeter (Chromameter CR400, Minolta, Tokyo, Japan) was used to obtain cross-sectional area colors of chicken meat emulsions. Color parameters measured according to CIELAB color system as CIE L\*, a\*, and b\* means lightness, redness, and yellowness, respectively. Four repetitions were taken for each chicken meat emulsion group.

**Statistical Analyses**

Statistical analyses were applied by using SPSS program (IBM, version 21.0, USA). A one-way ANOVA was used to assess the effects of PSP ratio on the technological parameters such as ES, WHC, CY, chemical composition, pH, and lipid oxidation (peroxide and TBARs) of chicken meat emulsion. To examine the effect of PSP and storage days on peroxide and TBARs, treatments (C, P1, P3, and P5) and storage days (0, 3, 5, and 7) were assigned as fixed factors. Significant differences are examined by Duncan multiple tests at a 95% confidence level.

**Results and Discussion**

The results indicated that the pH of pomegranate seed powder was 5.9. Water absorption capacity refers to the ability of the material to absorb water when immersed in it. Water absorption capacity was 4.3 g/g sample. Our result for water absorption capacity is similar to the findings of Jalal et al. (2018) who reported WHC of PSP as 4.45 g/g sample. The oil holding capacity is a functional property linked to the chemical composition of the plant polysaccharides (Fernandez-Lopez et al., 2009). The oil holding capacity of PSP was 3.7 g oil/g sample. It was seen that OHC value was found lower than a study (5.81 g/g, Gölükçü et al., 2008). This finding is lower than the oil holding capacity of pomegranate bagasse (5.9 g oil/g dry fiber, Viuda-Martos et al., 2012) and tiger nut by-product (6.90 g oil/g fiber, Sanchez-Zapata et al., 2010). These differences could be due to the processing methods and hydrophobic nature of the fiber particle.

**Technological Properties of Chicken Meat Emulsion**

Functional properties of CME formulated with different levels of pomegranate seed powder (PSP) are presented in Table 2. WHC, which is the capability of meat to retain moisture is a significant quality indicator associated with ES (Öztürk et al., 2017). WHC values varied 70.43-74.08%, PSP increased the WHC (P<0.05) regardless of the addition level. This situation could be elucidated by the high dietary fiber content of pomegranate seed samples. According to the findings of Gül and Şen (2017), pomegranate seed powder contains 52.22% of total dietary fiber on a dry matter. Jalal et al. (2018) reported that pomegranate seed powder has a water holding capacity of 4.45 times its weight and it has also been reported that the emulsifying capacity and emulsion stability of PSP is higher than the pomegranate peel powder. An important increase was observed in the crude fiber content of the products with the increase in the level of adding PSP and

tomato powder to chicken nuggets (Kaur et al., 2015). In addition to the nutritional properties of fiber-enriched chicken nuggets, it was concluded that the ingredients added as dietary fiber could also be used for technological improvements such as improving rheological properties and texture in meat products. The pH and WHC values of uncooked samples increased with the addition of PSP ( $P<0.05$ ). In parallel with the increase of pH of meat, load balance changes, the ripening degree of meat increases, it gains a tender structure, and its WHC improves (Anar, 2017).

The percent cooking yield of emulsion samples after heat treatment is seen in Table 2. The cooking efficiency of emulsion samples varies between 96.86% and 99.95%, the addition of PSP significantly increased cooking yield ( $P<0.05$ ). It has been well demonstrated that formulating meat products with ingredients that have high amounts of dietary fiber could increase cooking yield (Kurt, 2017; Kumar et al., 2019; Santhi et al., 2020). Our results were similar to the results of Al-Juhaimi et al. (2016) who also stated an increase in yield as well as WHC, fat, and moisture retention in beef burgers incorporated with moringa seed flour. It could be said that PSP increased protein-fat and water interaction and resulted in low water and fat release during the cooking process. Opposite to our findings, Kaur et al. (2015) reported that with the increase in the ratio of pomegranate seed powder added to chicken nuggets, there was a significant decrease in emulsion stability and cooking efficiency. This result was associated with a decrease in pH and hence in the water holding capacity. Pomegranate seed powder had no significant effect on the cooking yield of chicken patties (Kurt, 2017).

Emulsion stability is defined as the absence of phase separation in the emulsion and the resistance of its characteristics to change according to ambient conditions (Öztürk and Serdaroğlu, 2018). ES of the treatments in terms of TEF and EFAT is presented in Table 2. Utilization of PSP in the formulation resulted in a decrease in total expressible fluid and expressible fat ( $P<0.05$ ). Such a decrease implies that PSP could contribute to the stabilization of chicken meat emulsion. This finding also could be explained by the oil holding capacity of PSP. Jalal et al. (2018) reported that PSP showed an oil holding

capacity of 5.81 g oil/g powder. Correspondingly with our results, beef patties added with pumpkin pulp and seed powder enhanced fat retention (Serdaroğlu et al., 2018). It was observed that the expressible amount of fluid and fat was the lowest in the samples formulated with PSP where water holding capacity and cooking efficiency were higher than control ( $P<0.05$ ).

#### Chemical Composition and pH

Compositional analysis of uncooked and cooked emulsion samples formulated with various amounts of PSP is seen in Table 3. The moisture, protein, fat, and ash contents of raw CME changed from 67.03% to 70.50%, from 17.49% to 18.92%, from 7.41% to 8.10%, and from 2.55% to 2.84% respectively. No differences were obtained in protein content of uncooked samples with the addition of PSP, on the other hand, fat and ash contents decreased in comparison with the control group ( $P<0.05$ ). Incorporating with PSP at levels of 3% and 5% decreased moisture content of emulsion samples. Debnath et al. (2020) and Ebrahiem et al. (2020) also recorded similar findings in cooked sausages. Moisture, protein, fat, and ash contents of cooked emulsions changed from 65.04% to 67.84%, from 18.03% to 19.04%, from 6.84% to 7.88%, and from 2.06% to 2.82% respectively. With the use of 5% pomegranate seed powder in the formulation protein content increased while fat content decreased ( $P<0.05$ ). The decrease in fat content could be explained by the addition of defatted PSP instead of chicken breast meat. No important differences were observed in the moisture and ash content of cooked emulsions ( $P>0.05$ ). The use of moringa seed flour up to 6% in the beef burger formulation did not affect the chemical composition (Al-Juhaimi et al., 2016).

As shown in Table 3 increasing amounts of PSP increased pH values of uncooked samples ( $P<0.05$ ). The high pH value (6.5) of PSP can be the reason for a slight increase in the pH values by the addition of PSP. Nevertheless, the addition of PSP did not change the pH of cooked emulsions, pH values are consistent with others reported for sausage emulsions (Eltilib et al., 2016; Lee et al., 2019), chicken loaves (Sajad et al., 2020), and chicken patties (Sharma and Yadav, 2020).

Table 2. Functional properties of model meat emulsion formulated with PSP

Treatments	Water holding capacity (%)	Cooking yield (%)	Total expressible fluid (%)	Total expressible fat (%)
C	70.43±1.44 <sup>b</sup>	96.86±0.37 <sup>c</sup>	5.12±0.52 <sup>a</sup>	6.86±1.81 <sup>a</sup>
P1	73.01±0.64 <sup>a</sup>	97.42±0.34 <sup>b</sup>	3.83±0.24 <sup>b</sup>	3.86±1.61 <sup>b</sup>
P3	74.08±0.36 <sup>a</sup>	99.95±0.03 <sup>a</sup>	3.61±0.77 <sup>b</sup>	3.64±0.39 <sup>b</sup>
P5	73.30±0.51 <sup>a</sup>	99.81±0.17 <sup>a</sup>	3.52±0.15 <sup>b</sup>	1.69±0.39 <sup>b</sup>

Mean values ± standard deviation, <sup>a-c</sup>: different letters in the same column means significant differences ( $P<0.05$ ).

Table 3. Chemical composition and pH value of model meat emulsions formulated with PSP

Treatments	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	pH	
Uncooked	C	70.50±1.30 <sup>a</sup>	17.49±0.76	8.10±0.24 <sup>a</sup>	2.84±0.04 <sup>a</sup>	6.26±0.01 <sup>d</sup>
	P1	69.61±0.82 <sup>a</sup>	17.83±1.23	7.70±0.10 <sup>b</sup>	2.73±0.06 <sup>ab</sup>	6.31±0.01 <sup>c</sup>
	P3	67.82±0.51 <sup>b</sup>	18.58±0.38	7.44±0.05 <sup>b</sup>	2.55±0.15 <sup>c</sup>	6.55±0.03 <sup>a</sup>
	P5	67.03±0.23 <sup>b</sup>	18.92±0.12	7.41±0.21 <sup>b</sup>	2.66±0.02 <sup>bc</sup>	6.44±0.01 <sup>b</sup>
Cooked	C	67.84±1.92	18.03±0.36 <sup>c</sup>	7.88±0.08 <sup>a</sup>	2.79±0.00	6.43±0.06
	P1	66.97±1.49	18.54±0.34 <sup>b</sup>	7.39±0.36 <sup>ab</sup>	2.82±0.06	6.43±0.06
	P3	66.48±0.08	18.27±0.05 <sup>bc</sup>	6.95±0.51 <sup>ab</sup>	2.06±0.46	6.50±0.01
	P5	65.04±0.75	19.04±0.06 <sup>a</sup>	6.84±0.71 <sup>b</sup>	2.30±1.52	6.43±0.01

Mean values ± standard deviation, <sup>a-c</sup>: different letters in the same column means significant differences ( $P<0.05$ ).

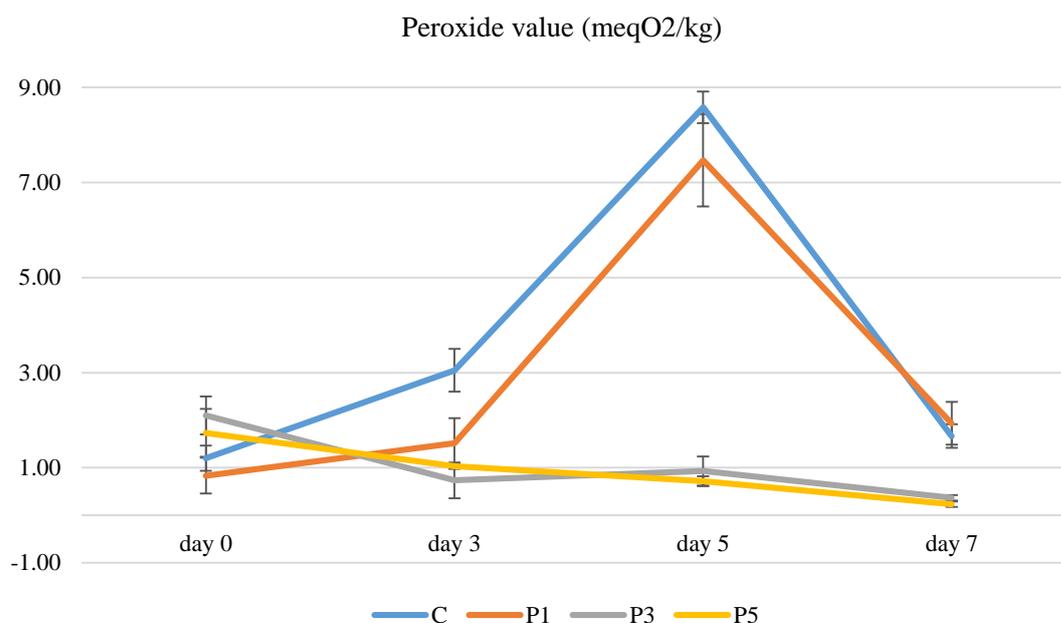


Figure 2. Changes in Peroxide values of model meat emulsion during storage

\*C: emulsion formulated with 0% PSP, P1: emulsion formulated with 1% PSP, P3: emulsion formulated with 3% PSP, P5: emulsion formulated with 5% PSP

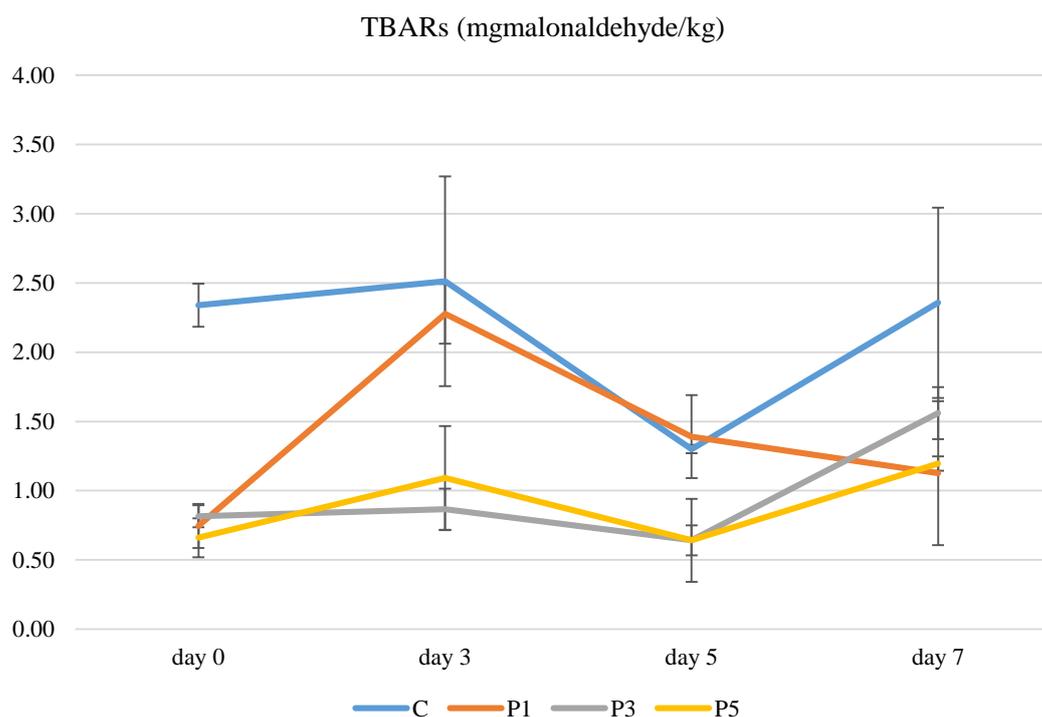


Figure 3. Changes in TBARS values of model meat emulsion during storage

\*C: emulsion formulated with 0% PSP, P1: emulsion formulated with 1% PSP, P3: emulsion formulated with 3% PSP, P5: emulsion formulated with 5% PSP

### Lipid oxidation

Lipid oxidation is one of the most significant factors that reduce the nutritional value, deteriorate quality, and limited the shelf life of meat and meat products containing high unsaturated fatty acids. Processing steps of meat such as grinding and cooking disintegrate the muscle cell membranes and promoting the interaction of lipids with pro-oxidants such as non-haem iron, accelerating lipid oxidation

leading to rapid quality losses (Tichivangana and Morrissey, 1985). The peroxide value indicates the concentrations of peroxides and hydroperoxides that are produced during the early stages of lipid oxidation (Sarabi et al., 2017). The alterations in peroxide values of the emulsions by different concentrations of PSP are given in Figure 2. Initial PV values of C, P1, P3, and P5 samples were 1.20, 0.83, 2.10,

and 1.73 meq O<sub>2</sub>/kg, respectively. Peroxide value was significantly affected by the addition of PSP and storage period ( $P < 0.05$ ). All peroxide values were lower than 25 meq O<sub>2</sub>/kg, which is a limit for fatty food products (Evranoz, 1993). Barimah et al. (2017) concluded that the *Taraxacum officinale* has great antioxidant potential as well or better than pomegranate juice and PSP. Also, the PV of samples increased during storage.

After the 5th d, the PVs of treatments sharply decreased. This trend was probably sourced from the destruction of hydro-peroxides into secondary oxidation products, particularly aldehydes in the later phase of lipid oxidation. The primary oxidation products are unstable compounds, therefore peroxides and hydroperoxides are divided into volatile products such as aldehydes, ketones, and alcohols (Lee et al., 2010; Uçak, 2020). At the end of the storage period, the lowest PVs were belonging to the P3 (0.36 meq O<sub>2</sub>/kg) and P5 (0.23 meq O<sub>2</sub>/kg) treatments. Similar findings were observed by Hazra et al. (2012), Ramchandra (2016), and Qureshi (2017) in different meat products added with pomegranate seed powder. The lowest peroxide values were obtained in trout burgers enriched with pomegranate seed extract at 0.5% and 1% levels at the end of the storage (Uçak, 2020).

The thiobarbituric acid reactive substances can also be measured as products of the decompositions of lipid peroxide. TBARs analysis is applied to determine the level of lipid oxidation in meat products and TBARs values of emulsion samples are shown in Figure 3. At d 0 control sample showed the highest TBARs value (2.34 mg MA/kg), while no significant differences between the other samples were reported ( $P < 0.05$ ). During the storage, TBARs values of all samples increased but with different intensities. TBARs values of control samples had higher values at each evaluation period. Besides that 2 mg MA/kg limit value for TBARs (Witte et al., 1970) were not exceed by samples formulated with PSP during whole storage except P1 on day 3. The effect of using PSP in emulsion samples on TBARs values was found to be statistically significant ( $P < 0.05$ ). The highest TBARs value (2.51 mg MA/kg) was recorded in control samples, while P3 and P5 treatments had the lowest TBARs value (0.64 mg MA/kg) ( $P < 0.05$ ). P1 treatments showed a sharp increase on the 3rd d of storage ( $P < 0.05$ ). The increase in TBARs values during storage could be explained by the oxidation of meat lipid. These results agreed with the findings of Debnath et al. (2020) in pork sausage and Naveena et al. (2008) in cooked chicken patties, Devatkal and Naveena (2010) in goat meat. Uçak (2020) found that oxidative changes were delayed and shelf life increased 9 d in fish burgers enriched with pomegranate seed extract. On 7th d storage, the highest concentration of TBARs value (2.36 mg MA/kg sample) was recorded in C samples ( $P < 0.05$ ). TBARs values were considerably lower in P3 and P5 samples than

C and P2 samples throughout the storage period ( $P < 0.05$ ). According to the results of Naveena et al. (2008), pomegranate peel powder inhibited lipid oxidation to a much greater extent than BHT. This situation may be associated with the fact that pomegranate seed powder is rich in phenolic compounds. Pomegranate seeds may contain total phenolic substances up to 73 mg/g (Derakhshan et al., 2018), also mean total tannin, flavonoid, and anthocyanin contents of pomegranate seed were reported as 29.85 µg tannic acid equivalent/mg extract, 15.82 µg quercetin equivalent/mg extract and 0.266 µg · 10<sup>-2</sup> Cy-3 gluc/mg extract (Orak et al., 2012). Results showed that PSP at levels of 3% and 5% exhibited antioxidant properties capable of retarding lipid oxidation in cooked chicken meat emulsion samples.

Devatkal et al. (2010) used pomegranate peel, pomegranate seed, and kinnow peel powder extracts in goat meat. They reported that the lowest TBARs value in the samples formulated with pomegranate peel powder and the highest DPPH value in the samples containing pomegranate seed powder.

### Color

Changes in the cross-sectional color of treatments are exhibited in Table 4.  $L^*$ ,  $a^*$ , and  $b^*$  of treatments is between 65.25-68.29, 1.75-3.23, and 10.16-16.84 respectively. The addition of PSP led to significant differences in all the color parameters ( $P < 0.05$ ). The lowest  $L^*$  (lightness) value was observed in P1 compared with the other groups ( $P < 0.05$ ). The decrease in the  $L^*$  value might be attributed to the color of PSP which is light brown. Anthocyanins have a significant role in the color of the pomegranate seeds (Legua et al., 2000). Yellowness ( $b^*$ ) values of emulsions showed a decreasing incorporating with PSP. The present findings agreed with the results of El-Gharably and Ashoush (2011), who reported a decrease in  $b^*$  values of beef sausages added with beetroot powder or pomegranate peel powder and beetroot powder mixture. Devatkal et al. (2010) also reported decreased color parameters ( $L^*$ ,  $a^*$  and  $b^*$ ) in goat patties containing pomegranate rind and seed powder extracts.  $a^*$  values of samples decreased with the addition of 3% and 5% PSP, on the other hand, there is no change between control and P1 groups. P1 samples had a similar redness value with C samples. Similar to our findings Al-Juhaimi et al. (2016) reported that the use of moringa seed flour in beef burger formulation decreased  $a^*$  values. The changes recorded in color parameters could be possibly derived from the high amount of myoglobin that exists in the control treatment and the color of PSP. Pomegranate juice and peel powder chicken patties resulted in lower  $a^*$  values (Naveena et al., 2008). Decreased ' $L^*$ ', ' $a^*$ ' and ' $b^*$ ' values reported for goat meat marinated in a solution contained 4% PSP (Narsaiah et al., 2011).

Table 4. Color parameters of model meat emulsion formulated with PSP

Treatments	Color parameters		
	$L^*$	$a^*$	$b^*$
C	68.29±0.54 <sup>a</sup>	3.17±0.40 <sup>a</sup>	16.84±0.29 <sup>a</sup>
P1	65.25±1.11 <sup>b</sup>	3.23±0.34 <sup>a</sup>	14.68±0.44 <sup>b</sup>
P3	67.95±0.64 <sup>ab</sup>	1.75±0.53 <sup>b</sup>	11.13±1.00 <sup>c</sup>
P5	65.55±1.48 <sup>ab</sup>	1.97±0.23 <sup>b</sup>	10.16±0.35 <sup>c</sup>

Mean values ± standard deviation, <sup>a-c</sup>: different letters in the same column means significant differences ( $P < 0.05$ ).

## Conclusion

In conclusion, it has been observed that the incorporation of pomegranate seed powder is a compatible enrichment strategy of the chicken meat emulsion formulation. Enrichment of chicken meat emulsion with different levels of pomegranate seed powder resulted in improved technological properties such as water holding capacity, emulsion stability, and cooking yield. Pomegranate seed powder was able to retard the oxidative changes due to its composition. As a conclusion, it was seen that PSP could have the potential to be a functional ingredient in meat product formulations as both dietary fiber source and antioxidant.

## Conflict of interest

The authors declared that this research has no conflict of interest with any organization.

## Author contribution:

Conceptualization: Serdaroğlu M.

Formal analysis: Yüncü Ö. Sharefiabadi E. Seyedhosseini S.

Methodology: Serdaroğlu M.

Writing - original draft: Serdaroğlu M. Yüncü Ö. Kavuşan HS.

Writing - review & editing: Serdaroğlu M. Yüncü Ö. Kavuşan HS.

## Ethics Approval

This article does not require IRB/IACUC approval because there are no human and animal participants.

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