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Effect of traditional fat replacement by oleogel made of beeswax and canola oil on processed meat (steak type) quality

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Abstract

Oleogel (OG) has become an alternative fat ingredient for many foods as well as meat and its related meat products due to its health beneficial effects. The objective of this study was to characterize the processed meat properties as well as analyse the trends of consumer acceptability of meat products by using OG utilization as a fat replacer. Processed meat samples were prepared for 3 groups including i) processed meat (only red part) without any additive addition: control, ii) 50% beef tallow adding: BT, and iii) 50% OG, obtained from beeswax and canola oil mixture, substituting of BT: OG. All meat samples determined the physical, physicochemical, and lipid profiles as well as sensorial properties. The results found that OG treatment showed desirable physical and physicochemical characteristics. The soft texture of the meat sample was observed in the OG group when compared with other treatments. Furthermore, OG replacing the traditional fat in processed meat has significantly reduced the percentage of total saturated fatty acid (SFA, 68.37±2.19) and increased the total unsaturated fatty acid (USFA, 31.63±1.63) ($p < 0.05$) when compared with BT group treatment (SFA: 79.52±3.72 and USFA: 20.48±0.31). OG treatment also showed improvement in processed meat through the significantly higher score of overall liking from the consumer evaluation ($p < 0.05$). The results of this study could be used as preliminary results for the development of healthy meat model products, contributing to driving meat consumption together with the reduction of risk factors of metabolic diseases.

1. Introduction

Processed meat is classified as the meat that is transformed through the preparation of curing, salting, smoking, drying, fermentation, or with the addition of food additive substances (Zeng *et al.,* 2019). These preparation processes have resulted in changing the meat and the meat product quality, which include aroma, nutritional content, texture properties, and sensory attribution. According to meat and related products, the easiness of use is mostly produced via several methods in view of minimal preparation time in conjunction with the shelf-life, which is a concern at the household level (Leroy and Degreef, 2015). A previous study reported that the top five types of processed meat that were consumed by the American people, include luncheon meat (39.3%), sausages (24.3%), hot dogs (9.4%), ham (9.4%), and bacon (4.6%), accounted for over 85% of the total processed meat consumption in the United States from 2015 to 2016 (Zeng *et al.,* 2019).

Currently, there are meat productions and related products that have continually launched either traditional forms and/or innovative meat products in the market due to the increase the rate of consumer demand in accordance with the growing rate of the population in the world (Leroy and Degreef, 2015; Lynch *et al.,* 2018; Lang, 2019; Milford *et al.,* 2019; Zeng *et al.,* 2019). Even though meat is a good source of protein for the human body, it contains a high ratio of saturated fatty acids (SFA) compared to unsaturated fatty acids (USFA) (Lucarini *et al.,* 2018; Richards, 2019). Also, the excessive consumption of meat and the related meat products may affect health functionality or cause the

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exertion of the risk factors associated with metabolic-related diseases, such as obesity, diabetes, colon cancer, and cardiovascular disease (CVD) (Becerra-Tomás *et al.,* 2016; Kitada *et al.,* 2019; Varraso *et al.,* 2019). According to the FAO (2009), global meat production is expected to increase by 16% by 2025 from the base period of 2013 to 2015. Consequently, the animal protein intake has dramatically increased by about 61 g/person/day from the previous decade until presently (Lynch *et al.,* 2018). According to the statistical number of meat production and consumption in the world from the FAO (The Food and Agriculture Organization of the United Nations) and the trends in healthy food, the number of people who have health problems concerns has continually risen, therefore the development of healthy meat via an innovative technology along with a study of satisfying the consumer acceptance of new meat products in the social perspective is of vital necessity.

Fat content composed in meat and its products has been focused on by several researchers presently due to its health functionality role. The reduction of the fat content in the meat and the meat products may affect the meat quality and consumer acceptance because the fat provides the tenderness of the product, which also decreases the yield during cooking, and it enhances the way the meat feels in your mouth, which also enhances sustainable meat consumption (Papadomichelakis *et al.,* 2017; Oh *et al.,* 2019; da Silva *et al.,* 2019; Alejandre *et al.,* 2019). Oleogel (OG) is a type of alternative unsaturated solid fat, which is produced using the gelation process, to reduce the saturated solid fat in food products (Marangoni and Co, 2012). Furthermore, it has been promoted as an innovative fat ingredient used to reduce the risk of many health problems. Even though OG is made from different sources of organic materials, which include natural waxes or hydrocolloid groups, and plant oils have been applied in several food products, such as bakery products (Oh and Lee, 2018), instant noodles (Lim *et al.,* 2017), some dairy products (Zulim Botega *et al.,* 2013), and confectionery products (Doan *et al.,* 2016), the report about the application and the effect of OG obtained by mixing beeswax and canola oil that is used in processed meat and the related meat products have not yet been extensively researched. The study by Wolfer *et al.* (2018) demonstrated the effect of OG formed from a combination of soybean oil and rice bran wax with the frankfurter-sausage properties. The meat product showed healthier fatty acid profiles by reducing the amount of SFA. Moreover, it improved the texture of the frankfurter sausages. da Silva *et al.* (2019) also discovered and noted a similar effect with OG applied in bologna-type sausages regarding the nutritional and health aspects, which can reduce the risk factor of metabolic diseases and the consumer acceptance of meat products.

From the point of view of the application of OG as a fat substitute in food products, the author hypothesizes and tries to determine the effect of OG prepared by edible beeswax for this study on the processed meat characteristic as well as its quality regarding healthy meat production. According to FAO/WHO Technical Report Series (Joint FAO/WHO, 2006) noted that the ADI (Acceptable daily intake) of beeswax should be less than 650 mg/person/day with no adverse effect on dietary exposure and health implication. Therefore, the objective of this study was to characterize the processed meat (steak portion) quality using OG utilization as a fat replacer. The meaning of OG in this part of the study was specified as “beeswax canola oil-OG”.

2. Materials and methods

2.1 Sample preparation and chemical reagents

Beeswax and canola oil were purchased from SINABT (Korea) and local supermarkets in Korea, respectively. The boron trifluoride-methanol solution (BF_3) was purchased from Sigma-Aldrich Company (St. Louis, MO, USA) via the local Korean agency firm for fatty acid analysis.

Oleogel (OG) was prepared by mixing beeswax with canola oil at a ratio of 1.2:100 (w/w), and then the mixture was incubated at 70°C for 20 mins. with continuous stirring followed by cooling down at room temperature overnight. The obtained OG was kept in refrigerator condition before use as the ingredient in processed meat.

The processed meat samples were prepared and received by the KTS food manufacturer (KTS, Seoul, KOREA). The sample was prepared and divided into 3 groups of treatment (1 kg of meat sample per group) including i) processed meat (only red part) without any additive addition: control, ii) 50% beef tallow adding: BT, and iii) 50% OG, obtained from beeswax and canola oil mixture, substituting of BT: OG. The samples were kept in the freezer at -18°C until further analysis. However, before analysis, meat samples were left at room temperature for 2 hrs. before the determination of meat characteristics.

2.2 Physical and physio-chemical properties investigation

2.2.1 Colour measurement

The colour of the processed meat sample was performed by using a colour detection instrument (COLOR READER CR-10 Plus, KONICA MINOLTA, INC. JAPAN) which was calibrated using a white plate. The CIE system was used, and the reading value of samples was presented as *L*, a*, b**. The experiment was measured three times, and the data was recorded (slightly modified from the method of da Silva *et al.,* 2019).

2.2.2 pH determination

pH value of meat samples was determined by using the pH meter (pH meter P25, EcoMet, iSTE company, Korea). The sample of about 20 g was poured into a 100 mL beaker, then dissolved with distilled water (50 mL) and homogenized until homogeneous. After obtaining the homogenous form, the pH of the sample was measured and recorded (da Silva *et al.,* 2019).

2.2.3 Cooking loss determination

The processed meat samples were weighed before the cooking process. After the cooking, all the samples were cooled at room temperature and weighed for the cooking loss. The cooking loss of the meat sample was calculated according to the method of the previous study (da Silva *et al.,* 2019) as follows: (weight of the sample before cooking - weight of the sample after cooking) / (weight of the sample before cooking × 100). Three replications of the trial were performed, and the result was recorded.

2.2.4 Water holding capacity determination

The water holding capacity (WHC) of meat samples was determined by the centrifugation method according to the method by Paglarini *et al.* (2018) and Zheng *et al.* (2018) with slight modification. Samples were prepared into 1 cm with cylinders shape, weighed (Initial weight), and covered with a filter paper. Afterwards, the meat sample was conducted to centrifuge at 10000×*g* for 10 mins at 10°C. Then, the filter paper was removed, and the sample was carried out for the second weighing (end weight). The centrifugal loss was calculated and reported as the percentage of water loss to the total weight as following the equation below:

Centrifugal loss (%) = [(Initial weight - End weight) / Initial weight] × 100

2.3 Texture profile analysis

The method used to measure the texture properties of processed meat samples was slightly adapted from da Silva *et al.* (2019) and Heck *et al.* (2019). All the sample treatment was approximately sliced into a small cube (2×2×2 cm), totalling nine samples. Then, the TPA measurement was performed by texture analyzer (TA-XT plus, Stable Micro Systems, Surrey, UK) at room temperature. The cylindrical probe (45 mm diameter) was used for compressing at 50% of the original height of the meat sample, and the moving speed was set at a constant rate of 1 mm/s. The four parameters (including: hardness, springiness, cohesiveness, and chewiness) were investigated for identifying the texture properties of meat samples composed of beef tallow and oleogel fat.

2.4 Proximate composition and total cholesterol analysis

All meat samples were determined for total moisture, ash, lipid, protein, as well as total cholesterol content which was carried out according to the standard method of the Association of Official Analytical Chemists (AOAC, 2000) by the Foundation of Agri. Tech. Commercialization and Transfer (Jeollabuk do, Iksan, KOREA). For total nitrogen content, a conversion factor of 6.25 was used for calculating the amount of protein content (da Silva *et al.,* 2019).

2.5 Fatty acid profiles

The fatty acids composition of processed meat prepared with beef tallow and oleogel was performed by using Gas Chromatography with Flame-Ionization Detection (GC-FID) (GC-2010 Plus Series, SHIMADZU CORPORATION, Tokyo, Japan) according to the method of AOAC (2005). The meat sample preparation was prepared following the method of Oh *et al.* (2019) and Papadomichelakis *et al.* (2017) with some modifications. In brief, samples of about 10 g were collected and mixed with the ratio of chloroform to methanol (2:1, v/v) to a final volume of 100 mL and then filtered with a Whatman filter paper (No. 41). Afterwards, about 5 mL of distilled water was added to the obtained solution and centrifuged at 3000 rpm for 10 mins. The upper layer of the solution was removed, and the chloroform phase was evaporated and conducted for further investigation. The methanol-BF_3 (14% boron trifluoride) for fatty acid methyl esters (FAMEs) was applied for detecting the FFA in processed meat samples. A metal capillary column HP-INNOWAX, 30 m length × 0.250 mm i.d. × 0.25 µm (Agilent Technologies, J and W GC columns, Santa Clara, CA, USA) was used to separate the 37 FAMEs standard and samples. The column temperature was set under specified conditions following the previous study (1 min at 140°C, raised by 2.5°C/min to 200°C, then to 230°C by 1°C/min and held for 1 min, and finally to 240°C by 4°C/min and held for 10 mins). The helium gas was used for carrier gas at constant pressure, and the injector temperature was set at 250°C. The FFA in samples were identified and quantified by comparison with the FFA standards (FAME 37 Component and BAME Mix; Sigma-Aldrich Co. Supelco, IL, USA) purchased from Sigma-Aldrich Company. The internal standard (Tridecanoic acid methyl ester, C13:0) was achieved using FA quantification. The experiment was conducted in three replication and the results were recorded.

2.6 Sensorial evaluation

The sensory evaluation was conducted under the approved protocol by the Institutional Review Board (IRB No. SJU-HRE-2018-005) of Sejong University. The processed meat sample was cooked with the traditional cooking method until well done, and the sample was prepared as a small piece, placed in a small cup, and labelled with a three-digit number for sensory evaluation. All cooked meat sample was tested for sensory preference using a 9-point hedonic scale (1: strong disliking, 5: moderate liking, and 9: strong liking) with 30 untrained panellists from the student and staff (male = 19 and female = 11) of the department of food science and biotechnology at Sejong university to determine the appearance, colour, odour, flavour, oiliness, juiciness, firmness, springiness, and overall liking. All the result was interpreted and conducted for further analysis. (da Silva *et al.,* 2019; Oh *et al.,* 2019).

2.7 Statistical analysis

The determination in this experiment was performed in three replications (n = 3) and the results were presented as Mean±SD. The significant difference of data was analyzed and interpreted by the SPSS program (SPSS 16.0 for Windows, SPSS Inc., Chicago, IL) with the analysis of variance (ANOVA) and Duncan's multiple range tests at $p < 0.05$.

3. Results and discussion

3.1 Effect of oleogel on the physical and physio-chemical properties of processed meat

The pH value, the colour, the water holding capacity, and the cooking loss of the processed meat are shown in Figure 1A-1D. The pH value is one of the important parameters for food products that directly affect the product's shelf-life (Musavu and Lebert, 2018). The pH of the meat samples ranged from 6.91 to 7.18 (Figure 1A), which was impacted by the BT and the OG treatment when compared to the control group ($p < 0.05$). Increasing the pH value in the OG group treatment compared to the control group but lower than the BT group may be caused by the composition of the OG substitution in the processed meat samples. Generally, beeswax contains a lot of different compounds, and some of them are present in the acidic amount in nature, which contain a pH value of around 4.0 to 6.0 (Bernal *et al.,* 2005). However, this edible wax has an initial different pH value based on the sources, the preparation, or the extraction process, which results in their properties when applied to food products (Serra and Orantes, 2012). According to da Silva *et al.* (2019), who applied the OG obtained from high oleic sunflower oil and pork skin on the meat product, which is bologna type sausage, the pH of gel emulsion before and after it was applied in the meat products was presented for 5.8 and 6.17-6.34, respectively. The different pH values observed in this study on the meat samples may also affect the colour characteristic of the processed meat.

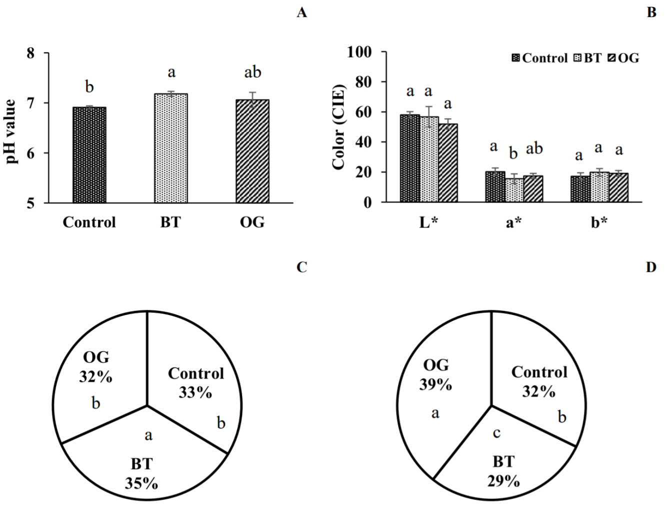

Figure 1. The effect of oleogel substitution on pH value (A), colour (B), water holding capacity (C) and cooking loss (D) of processed meat. N = 3. Different alphabet notations are significantly different at $p < 0.05$. BT: beef tallow, OG: Oleogel.

In general, colour is a major consideration of consumers regarding whether to purchase a package of meat or reject it, because the colour of meat is commonly associated with meat spoilage. The colour characteristic of processed meat has been observed and reported with L^* (lightness from black to white), a^* (from green to red), and b^* (from blue to yellow) values in this experiment. The L^*, a^*, and b^* are the values of the control group (58.0±3.40, 20.2±1.70 and 17.2±1.90, respectively), the BT (56.7±2.10, 15.5±2.50, and 19.8±2.30, respectively), and the OG (51.9±6.80, 17.4±3.30, and 19.1±2.50, respectively) are presented in Figure 1B. No significant differences were observed in the L^* and b^* values with the meat sample even in the BT and the OG treatments compared to the control group ($p > 0.05$) except for a^* value ($p < 0.05$). The oxidation of myoglobin, which is an abundant pigment found in meat, resulted in the formation of metmyoglobin, which contributed to the meat discolouration property (Nair *et al.,* 2014). Furthermore, Nair *et al.* (2014) noted that the redox stability of oxymyoglobins in the meat samples, which included beef, pork, and horse meat, was observed when the pH of the meat sample changed during the 14 days storage time. A previous study by da Silva *et al.* (2019) found a contrast to the lightness of the meat product after OG made from pork skin but not with a^* and b^*. On the other hand, a similar result to our study on the colour property was reported by Heck *et al.* (2019) who illustrated low-fat burgers made from a hydro-gelled emulsion, which included a chia and linseed oils mixture. Moreover, the application of sesame oil OG based on beeswax as a fat replacer with concentrations of 5%, 7.5%, and 10% in the beef burger was also described by Moghtadaei *et al.* (2018). They illustrated that they were no effect on the colour change of the meat products observed when the concentration of OG increased. Alejandre *et al.* (2019) found a slight improvement in the lightness of meat batters after canola oil hydrogels and organogels supplementation. Therefore, our results can imply that changing the pH may generate the metmyoglobin formation in processed meat, which directly or indirectly directs the interaction between the composition of the OG and the myoglobin in the colour stabilization mechanisms, which contribute to discolouration. However, the next application of OG obtained from beeswax in this study should investigate the initial pH value to confirm the effect of OG as a fat substation on processed meat.

The water holding capacity (WHC) and the cooking loss of the processed meat sample were positively correlated, and they and shown in Figures 1C and 1D, respectively. The highest percentage of WHC was observed in the BT (35%) group, which is followed by the control (33%) and the OG (32%) group treatments ($p < 0.05$) (Figure 1C). Meanwhile, the lowest percentage of cooking loss was indexed with the BT (29%) treatment, which is followed by the control (32%) and the OG (39%) group treatment ($p < 0.05$) as shown in Figure 1D. According to a previous study, it was noted that a high percentage of water holding capacity leads to the prevention of the product yield when cooking meat or related products using traditional and/or advanced thermal methods (Jimenez-Colmenero *et al.,* 2015). The WHC of each gel type based on the fat, the protein, or the polysaccharide gelled (hydrocolloid group) formation has provided a different ability to hold the water inside of the edible emulsion gel (O'Sullivan *et al.,* 2016). According to Oh *et al.* (2019), the replacement of beef tallow with 50% and 100% HPMC OG resulted in a reduction in the percentage of cooking loss with meat patties. However, our results suggest that the decrease in the percentage of cooking loss in the OG supplementation in processed meat might be caused by the amount of WHC in the meat sample.

3.2 Effect of oleogel supplementation on texture profiles of processed meat

The texture properties of food are an important factor in determining food quality including meat or its related meat products (de Souza Paglarini *et al.,* 2019; Franco *et al.,* 2019; Gómez-Estaca, Herrero, Herranz *et al.,* 2019; Gómez-Estaca, Pintado, Jiménez-Colmenero *et al.,* 2019). There are many researchers who focus on developing and improving the quality of meat products to meet the needs and satisfaction of consumers. As a consequence, healthy meat has been emphasized by replacing animal fats with hydro- or organo-gel emulsions, which have different composition and preparation processes, due to their physical, and nutritional properties as well as consumer preference. However, this processed meat or its related meat products still requires a lot of quality in terms of texture attributes because they are provided with a different characteristic compared to the traditional one that contains only animal fat (Paglarini *et al.,* 2018).

The textural properties of processed meat utilization by beef tallow and beeswax OG were determined and demonstrated in terms of hardness, springiness, chewiness, and cohesiveness (Figure 2A-2D). Significant differences were observed with the hardness (Figure 2A) and the chewiness (Figure 2C) values among the treatment groups ($p < 0.05$), which included BT and OG, but not with the springiness and cohesiveness attributes. A comparison between the treatment and the control of the toughness and the chewiness showed a significant decrease in both parameters when they were quantified and compared with the control group. However, the OG treatment showed a soft texture with the processed meat (Figure 2A) when compared to the other treatments. As expected, the meat sample that utilized the OG substitution led to a change in the final characteristics of the meat products, which contributed to the loss of texture stability that is beneficial to promote a soft texture after the meat cooking processes. Hence, the positive correlation between the toughness and the chewiness was observed clearly, which presented similar trends to the results of the meat sample applied with beeswax OG as a partial fat replacer. The springiness and the cohesiveness properties of the processed meat sample have consistent results, which were caused by a palatially traditional fat and lipid-based oil structuring with the edible waxes for fat replacement in the meat product. Nevertheless, around a 50% substitution of BT by OG into the processed meat sample in this trial didn't show any significant differences between the BT and the OG treatment ($p > 0.05$), but a significant increase in these texture values that include springiness, which is shown in Figure 2B, and cohesiveness, which is shown in Figure 2D, were observed when compared to the control group ($p < 0.05$).

In the current year, a researcher illustrated the effect of canola oil hydrogels and organogels to reduce the solid fat in meat batters, which substituted only canola oil, exerted the toughness of meat products when compared with a beef fat treatment. On the other hand,

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the application of organogels obtained from using 12% ethylcellulose has generated a desirable meat batters sample, which included, in particular, a tenderness parameter, that was described by Alejandre *et al.* (2019). This occurrence further explains the lipid-based emulsion structuring delivery system in the meat batter. Moreover, this reformulated meat product may also give rise to a nutritional profile that includes fatty acid compositions, which is shown in Table 2. Serdaroğlu *et al.* (2016) also reported a similar exploration of emulsion gel characteristics as beef fat replacers on the chemical and textural properties of the meat system. After lipid-based emulsion was added to the meat samples and the meat quality was determined, the meat texture was observed through the toughness, chewiness, springiness, and gumminess aspects. In 2017, Serdaroğlu *et al.* (2017) reported that the texture properties of chicken patties had improved by replacing the beef fat with an olive oil emulsion gelled for 25% but not over 75% of the total animal fat. Also, Franco *et al.* (2019) found a consistent result with frankfurter sausages that were supplemented with linseed OG at 25% on the toughness, the gumminess, and the chewiness reduction but not with the springiness. Meanwhile, the organogels that were prepared using 10% ethylcellulose for an animal fat substitution in meat processing, which generated good texture properties of processed beef and other physical characteristics, were noted and described by Barbut and Marangoni (2019). Besides, Cengiz and Gokoglu (2007) and Rahman *et al.* (2019) reported that traditional animal fat is a vital role in the textural and sensory quality of processed meat products, which is representing around 20-30% of the overall composition of meat. Based on our findings, using even a 50% beeswax OG substation in processed meat also appeared to provide a toughness and a chewiness reduction, which is a definite confirmation of the impact of an OG replacement of animal fat with the improvement of processed meat quality. Moreover, it also showed an increase in marbling in the meat sample. This occurrence may explain the reason for controlling the phase partitioning in meat composition after the replacement of the animal fat with OG and decrease the mobility of the lipid phase, which contributes to the solid -like properties without the high levels of SFA (Martins *et al.,* 2018). However, a high amount of beef tallow utilizing processed meat may promote adverse health implications due to its high SFA level (Tajima *et al.,* 1995). It can also suggest that the partial substitution of an alternative fat gel emulsion for the health aspect is affecting the internal structure or the reformulated texture stability of the processed meat. Consequently, based on our results, it could be concluded that the application of OG into processed meat or its related meat products resulted in the improvement of texture properties, and in particular the tenderness of the meat products.

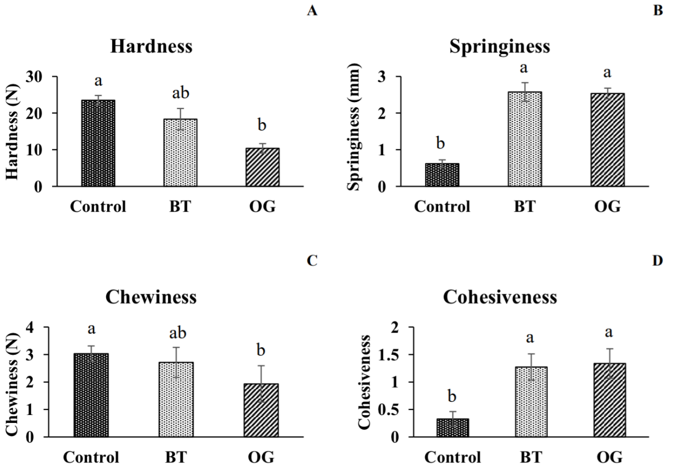

Figure 2. The effect of oleogel substitution on textural profiles of processed meat. Hardness (A), springiness (B), chewiness (C), and cohesiveness (D). N = 3. Different alphabet notations are significantly different at p < 0.05. BT: beef tallow, OG: Oleogel.

3.3 Effect of oleogel on the chemical and lipid profile of processed meat

The proximate composition, the total cholesterol, and the calories of the processed meat substituted by the partial BT and OG are shown in Table 1. The BT treatment had the highest percentage of moisture content (70.76±0.40%), which is followed by the control (66.13±0.26%), the OG (65.78±0.12%), and the group treatments ($p < 0.05$). This result has supported the WHC (Figure 1C) and the cooking loss (Figure 1D) of the meat samples. A significant reduction of the crude fat content

Table 1. Nutritional composition, total cholesterol content, and calories of processed meat

Parameters	Samples		
	Control	BT	OG
Moisture (%)	66.13±0.26^{ab}	70.76±0.40^{a}	65.78±0.12^{b}
Protein (%)	13.76±0.08^{a}	13.21±0.04^{a}	11.56±0.19^{a}
Fat (%)	14.35±0.10^{b}	18.30±0.06^{a}	8.40±0.09^{c}
Ash (%)	0.87±1.30^{a}	0.75±0.01^{ab}	0.58±3.61^{b}
Total cholesterol (mg/100 g)	45.74±2.77^{b}	49.21±3.08^{a}	47.96±0.98^{ab}
Calories (cal/g)	2216.00±58.73^{b}	2531.00±16.97^{a}	1913.00±65.05^{c}

Values are presented as mean±SD, N = 3. Values with different superscript within the same row are significantly different $p <$ 0.05. BT: beef tallow, OG: oleogel

Table 2. Effect of oleogel substitution on fatty acids profile of processed meat

Fatty acids	Samples (%)		
	Control	BT	OG
Caproic acid (C10:0)	0.29±0.10	0.24±0.03	0.24±0.01
Lauric acid (C12:0)	0.51±0.02	0.45±0.02	0.55±0.01
Myristic acid (C14:0)	0.82±0.03	0.89±0.03	0.90±0.01
Palmitic acid (C16:0)	17.02±0.19**	20.50±0.14*	16.14±0.17**
Palmitoleic acid (C16:1)	7.92±0.27	10.42±0.38	8.09±0.08
Stearic acid (C18:0)	42.84±0.51**	47.02±0.83*	42.45±0.33**
Oleic acid (C18:1- cis (n9))	20.38±0.25*	13.88±0.42**	21.33±0.43*
Elaidic acid (C18:1- trans (n9))	0.55±0.03	0.61±0.16	0.10±0.02
Linoleic acid (C18:2 - cis (n6))	1.71±0.16	1.95±0.04	1.68±0.04
Linolelaidic acid (C18:2 - trans (n6))	0.63±0.21	0.28±0.14	0.38±0.11
α-Linolenic acid (C18:3 (n3))	1.88±0.15**	0.68±0.02***	3.42±0.16*
Arachidic acid (C20:0)	0.74±0.04	0.70±0.03	1.06±0.01
Arachidonic acid (C20:4 (n6))	0.10±0.04	0.46±0.10	0.10±0.05
EPA (C20:5 (n3))	1.26±0.01	0.15±0.01	0.57±0.01
Behenic acid (C22:0)	0.53±0.06	0.25±0.05	0.10±0.02
DHA (C22:6 (n3))	2.82±0.09	1.53±0.08	2.92±0.06
Saturated fatty acid (SFA)	69.40±1.02***	79.52±3.72*	68.37±2.19**
Unsaturated fatty acid (USFA)	30.60±0.60**	20.48±0.31***	31.63±1.63*

Values are presented as mean of percentage±SD by GC-FID instrument, N = 3. BT: beef tallow, OG: oleogel
*, **, *** was significantly different at $p < 0.05$

was dramatically observed in the OG (8.40±0.09%) group compared to the BT (18.30±0.06%) group treatment ($p < 0.05$). Similarly, the amount of the total cholesterol was consistent with the percentage of the crude lipid in the processed meat. However, there was no significant difference was found in the protein content in all the treatments ($p > 0.05$). Based on our results, the addition of OG in the meat products resulted in changing the crude fat content, which leads to preventing metabolic diseases caused by fat, such as obesity, diabetes, and atherosclerosis effects.

Generally, the fatty acid compositions were expressed with the percentage of the interested peak areas from all the peaks (Issara and Rawdkuen, 2018). Both SFA and USFA have been observed in the processed meat samples. The percentage of the fatty acids profiles of the processed meat prepared by BT and OG substitution is shown in Table 2. The stearic acid (47.02%), which is bad fat, was found in abundance with the BT addition into the processed meat sample, while the control and the OG treatment observed at approximately 42.84% and 42.45%, respectively (Table 2). Focusing on the mono-USFA and the poly-USFA composition, the OG treatment was significantly adjusted by increasing the USFA content when compared to the BT and the control group treatment ($p < 0.05$). A comparison between the BT and the OG showed that the OG significantly enhanced the amount of the omega-3 derivative fatty acids group (α-Linolenic acid, EPA and DHA) ($p < 0.05$), which promotes a health benefit to reduce the risk factors of several diseases. In addition, the reduction of the total percentage of SFA after the OG was added to the processed meat sample was observed. The nutritional characteristic of the meat sample in this study (Table 2) suggests that OG prepared with beeswax and canola oil may help deliver a health benefit via the alteration of the nutritional composition in processed meat and its related products.

According to Gómez-Estaca, Pintado, Jiménez-Colmenero *et al.* (2019), the proximate composition of meat products and pork burger enriched USFA have not shown a significant difference in protein content, but a significant reduction was observed in the total fat and moisture content after the ethyl cellulose and beeswax OG was substituted into the meat product. Moreover, the effect of those OG results enhances the total USFA in pork burger compared with pure animal fat utilization. Franco *et al.* (2019) also explained the nutritional quality aspect with their study of frankfurter sausages that were supplemented with a beeswax-based OG formation. At 25% and 50% of traditional animal fat substitution rates, OG fat has promoted a good fatty acid that is desirable among of mono-USFAs and poly-USFAs, and reduces the SFA in the meat product, which is the biomarker to exert the risk factors of metabolic diseases development (Franco *et al.,* 2019). da Silva *et al.* (2019) studied and demonstrated that from the upper 50% to the completed 100% of the substitution of OG-based sunflower and pork skin preparation, it is classified as a protein-based OG structuring, which helps to modify the amount of

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fatty acid in the Bologna-type sausages through the reduction of the USFA to SFA ratios. In addition, the influence of hydroxypropyl methylcellulose OG at 50% and 100% instead of beef tallow on the meat patties also reported a similar finding with the total SFA, which decreased, the USFA, which increased, and the USFA/SFA proportion, which also decreased (Oh *et al.,* 2019). Likewise, we observed results that were consistent with the previous research in terms of the nutritional composition of the processed meat incorporated beeswax and canola oil OG-based. Thus, it can conclude that alternative solid fat replacers, such as OG has the potential for animal fat substitution as well as to promote desirable nutrition properties in processed meat and related meat products, which would contribute to the development of healthy meat products that concern consumer health.

3.4 Effect of oleogel substitution on sensory attributes of processed meat

To improve meat product quality for meeting the consumer requirement, the processed meat sample prepared by BT and beeswax + canola oil OG substitution were conducted for sensorial assessment. Also, the control sample (only processed meat without any substitution obtained from the same company) was compared to the treatment in this study. The sensorial properties of the meat sample are shown in Figure 3. There is no significant difference was observed in the colour, appearance, and springiness in all treatments ($p > 0.05$). Comparative between BT and OG treatment, the OG group was lower marked in the odour and flavour attributes ($p < 0.05$). Meanwhile, the OG treatment had the highest score of oiliness, juiciness, and firmness when compared with BT. However, in the overall liking score, OG provided more desirable satisfaction to the consumer than BT treatment. Generally, the addition of emulsion OG obtained from natural substances in processed meat or its related products has extensively affected the oiliness and juiciness of meat products due to the quantity of different fatty acids profiles (Paglarini *et al.,* 2018; Serdaroğlu *et al.,* 2016). Oh *et al.* (2019) reported that the replacement of 50% of HPMC oleogel in meat patties provided a significant increase in juiciness, tenderness, and overall acceptability of consumers. Likewise, the application of OG rich in oleic acid from 25% to 100% into bologna-type sausages has influenced to improve the colour, aroma, flavour, texture as well as overall acceptance which was studied by da Silva *et al.* (2019). The same product category has been illustrated by Franco *et al.* (2019) that replacing pork backfat with linseed OG in frankfurter sausages contributes to reducing the hardness and juiciness score after 50% of OG supplementation, but not reduce in appearance, odour, and taste of meat product. However, the different sources of natural compounds become OG platforms and the utilization of alternative fat in meat products nowadays results in different meat characteristics as well as the consumer's purchasing responses to the meat and its related products (Ramalingam *et al.,* 2019). According to the results (Figure 3), it can be suggested that processed meat supplemented by beeswax + canola oil OG has promoted good attributes, as well as it was enhanced the overall liking score from the consumer evaluation, which is affecting the increase in the rate of consumers acceptance. Nevertheless, these findings could be used as preliminary results for the development of healthy meat prepared by OG replacement that meets consumer quality requirements.

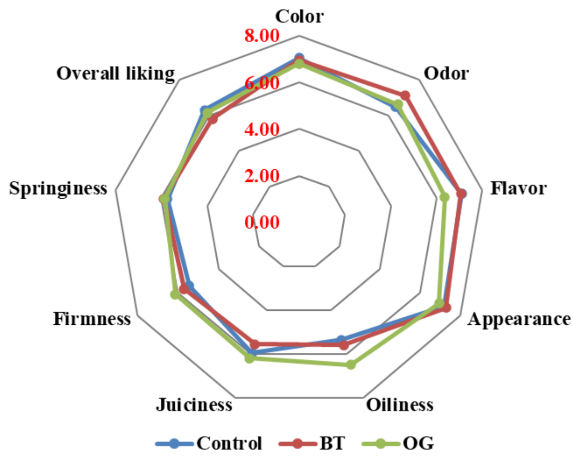

Figure 3. The effect of oleogel substitution on sensorial profiles of processed meat compare with beef tallow substitution and original processed meat sample. N = 30. BT: beef tallow, OG: Oleogel.

Basically, the colour and soft texture of meat are vital parameters of processed meat products. Gómez *et al.* (2020) reported that the physical and chemical changes in processed meat may cause molecular interactions during the thermal process applied, food additives used, or the long storage condition. Moreover, when the chemical structures of bio-substance are added as the food ingredient will respond to an organoleptic attribute or nutritional value in the final meat product. Although several researchers try to remove all the fat in meat or meat products, to produce clean meat, which leads to a decrease in the overall scoring of the product, however, based on meat properties supplemented with the OG instead of animal fat showed desirable characteristics which were relevant and consistent between the physical properties, physicochemical properties, and sensory assessment of consumer.

4. Conclusion

According to the results, the utilization of lipid-based OG made of beeswax and canola oil which is abundant in omega 3 and polyunsaturated fatty acids, obtained from an innovative process for producing an alternative fat ingredient, in processed meat are provide good quality processed meat in this study through via the improvement of hardness reduction, providing a desirable with colour, cooking loss, and water holding capacity reduced the total saturated fat and increased the total unsaturated fat, as well as enhancing the score of consumer satisfaction and acceptance. Even though many attributes of meat samples need to realize and improve after the substitution of traditional animal fat with OG, these findings could be preliminary results for the development of healthy meat model products in the future, contributing to driving meat consumption together with the reduction of risk factors of metabolic diseases.

Conflict of interest

The authors declare no potential conflict of interest.

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