

Physico-chemical and Sensory Characteristics of Beef Sausage with the Addition of Modified Porang Glucomannan (*Amorphophallus muelleri* Blume) Oleogel

I Wayan Rai Widarta^{1,3}, Ambar Rukmini², Umar Santoso³, S. Supriyadi³, Sri Raharjo^{3*}

¹Department of Food Technology, Faculty of Agricultural Technology, Udayana University, Bali, Indonesia

²Study Program of Food Technology, Faculty of Science and Technology, Widya Mataram University, Yogyakarta, Indonesia

³Department of Food and Agricultural Product Technology, Faculty of Agricultural Technology, Universitas Gadjah Mada, Yogyakarta, Indonesia

*Corresponding author: Sri Raharjo, Email: sraharjo@ugm.ac.id

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ABSTRACT

Fat is capable of affecting the physico-chemical and sensory characteristics of beef sausage. However, the use of beef fat can increase the cholesterol content, showing the need for suitable substitute such as oleogel. Therefore, this research aimed to evaluate the ability of rice bran oil oleogel prepared with modified porang glucomannan as a substitute for beef fat in sausage formulations. Analysis was also carried out to obtain beef sausage with the best characteristics (similar to commercial sausage/comparison formulation) which were made by substituting beef fat using rice bran oil oleogel. Sausage formulas were made with low-fat (10% oleogel or beef fat, w/w) and high-fat (20% oleogel or beef fat w/w), with beef fat serving as control. Another sausage formula with 20% (w/w) beef fat and tapioca was prepared representing the commercial beef sausage. The findings revealed that both the fat content and the replacement of beef fat with oleogel had a significant effect ($p < 0.05$) on cooking loss and the proximate composition (moisture, ash, fat, and protein) of beef sausages. Significant effects were also observed on the texture (hardness, cohesiveness, springiness, gumminess, and chewiness) and sensory properties of the sausages. Substituting 20% of beef fat with oleogel resulted in the most favorable sensory characteristics, closely resembling those of the control formulation containing 20% beef fat combined with tapioca. In conclusion, rice bran oil oleogel formed from porang glucomannan as an oleogelator could be used as a substitute for beef fat in sausage processing.

Keywords: Beef sausage; modified porang glucomannan; oleogel; rice bran oil

INTRODUCTION

The formation of oleogel is highly dependent on the oleogelator, which in this case is produced from porang glucomannan (*Amorphophallus muelleri* Blume) modified with octenyl succinic anhydride (OSA). Modifying porang glucomannan with OSA can change their characteristics to become amphiphilic, which is

essential for forming oleogel (Doan et al., 2015). The amphiphilic characteristics of porang glucomannan OSA-modified (PGOS) can be observed from the increase in capacity and stability of the o/w emulsion, the degree of OSA substitution in the glucomannan molecule, and the contact angle showing high hydrophobicity. Furthermore, FT-IR analysis shows that high PGOS carbonyl intensity at 1734 cm^{-1} is attributed to the esterification of the OSA

group in the porang glucomannan molecule (Widarta et al., 2022).

PGOS is used as oleogelator in the formation of rice bran oil oleogel. The method of emulsion template is applied for making oleogel, which is adapted to the ability of PGOS to form o/w emulsions. Specifically, oleogel is made by comparing 2 types of oil with different polyunsaturated fatty acid profile. Compared to palm oil, the higher polyunsaturated fatty acid of rice bran oil suggests the potential to form a stronger oleogel (Widarta et al., 2022). Rice bran oil is easily obtained in tropical countries such as Indonesia. Using rice bran oil as raw material produces oleogel with low oil loss, with PGOS concentration showing significantly reduced low concentrations at 1%. This shows that oil containing polyunsaturated and long-chain fatty acids are more effective as raw materials for making oleogel, according to Gravelle et al. (2016); Ferro et al., (2019); and Yang et al. (2018). In soybean oil, Zheng et al. (2021) stated that unsaturated fatty acids and long-chain unsaturated fatty acids (C13-18) caused particles in the emulsion to repel each other and increase the strength of attraction, alongside emulsion stability. Characteristics of fatty acids such as the size of the polar head, charge, and the accumulation of chains at the oil-water interface influence the stability of emulsion.

Oleogel formed from 1% PGOS in rice bran oil has good stability with low oil loss (Widarta, 2022-unpublished), but has not been applied in food processing. At low oil loss characteristics, oleogel has the potential to be applied in the formulation of food products, particularly sausage to

reduce cooking loss. Therefore, this research aimed to evaluate the ability of rice bran oil oleogel prepared with modified porang glucomannan as a substitute for beef fat in sausage formulations. Analysis was also carried out to obtain sausage with the best characteristics similar to commercial sausages/comparison formulation, which were made by substituting beef fat using rice bran oil oleogel.

METHODS

Materials

In this research, ingredients used were PGOS obtained from previous results as reported by Widarta et al. (2022). These ingredients included beef, beef fat, rice bran oil (Oryza Grace, Thailand), sodium tripolyphosphate (STPP), tapioca (Rose Bran, Indonesia), salt, ice, sausage casings, and skimmed milk powder (Lactona, Indonesia) purchased from supermarkets in Yogyakarta.

The process of making oleogel was reported by Patel et al. (2014a). Initially, 1% PGOS of rice bran oil (w/w) was weighed in a beaker, added with water (60 g), and heated at a temperature of 60 °C on a hotplate for 20 minutes while stirring at 400 rpm. The PGOS solution was cooled to room temperature. Subsequently, 40 g of rice bran oil was added to the PGOS solution and homogenized with an ultra-turrax homogenizer (T50 Basic IKA WERKE, Germany) at 10,000 rpm for 5 minutes to produce oleogel emulsion. The resulting oleogel was used in beef sausage formulations as shown in Table 1.

Table 1. Beef sausage formulation

Ingrident composition	Treatment				
	K10	F10	K20	F20	K20T
Beef (% , b/b)	67	67	57	57	49
Beef fat (% , b/b)	10	0	20	0	20
Oleogel (% , b/b)	0	10	0	20	0
skim milk powder (% , b/b)	15	15	15	15	15
STPP (% , b/b)	0,5	0,5	0,5	0,5	0,5
Salt (% , b/b)	1,5	1,5	1,5	1,5	1,5
Ice (% , b/b)	6	6	6	6	12
Tapioca (% , b/b)	0	0	0	0	2
Total	100	100	100	100	100

Note: 10% (w/w) beef fat (K10), 10% (w/w) oleogel (F10), 20% (w/w) beef fat (K20), 20% (w/w) oleogel (F20), and 20% (w/w) beef fat with the addition of tapioca (K20T)

Sausage were formulated with low-fat (10%, w/w) and high-fat (20%, w/w). Oleogel was used as a fat substitute and beef fat as a control. For making a comparison formula, 20% (w/w) beef fat mixed with tapioca was used and added to commercial sausage. The procedure for sausage-making was carried out as reported by Sujarwanta et al. (2016). Beef was cut into small pieces, cleaned of connective tissue, and finely ground using a grinder. The ground beef was added with a binder, namely skim milk, STPP, beef fat, or oleogel according to the treatment, ice, and salt. Subsequently, the mixture was mashed using a chopper for 5 minutes, placed in sausage casing, and processed using the boiling method. At a water temperature of 80 °C, the sausage was added and cooked until the core temperature reached 72 °C which was maintained for 1 minute (Panagiotopoulou et al., 2016; Sousa et al., 2017). The sausage was removed, drained, and the process was repeated 3 times for each treatment, as shown in Table 1. The parameters observed at this stage were texture analysis by texture analyzer (Lloyd Instruments, TA1 Ametek, UK) (Yang et al., 2017), color by colorimeter (CR 400, Minolta Co., USA), (Park et al., 2015), and Scanning Electron Microscopy (SEM) (JSM-6510LA, Japan). Cooking loss was determined by calculating the weight difference between raw and cooked sausages, divided by the raw weight, and then multiplied by 100% (El-Nashi et al., 2015). Other parameters observed included moisture content (AOAC 925.10, 1998), ash (AOAC 923.03, 1998), protein (AOAC 960.52, 1998), as well as fat (AOAC 920.93, 1998), and descriptive sensory by scoring tests (Lawless and Heymann, 2010).

Sensory Analysis of Beef Sausage

The sensory characteristics of beef sausage were explained using descriptive tests to determine the intensity or degree of sausage characteristics by

providing an assessment that describes the sample on a scale of 1 to 5. The results of sensory evaluation scores for beef sausages are shown in Table 2.

A total of 15 trained panelists were selected from postgraduate students in the field of food science who already understood sensory science. Furthermore, trained panelists are determined based on their sensory acuity for basic characteristics (colors, odors, textures, and tastes) as well as the ability to discriminate among products. Panelist screening was also observed based on the ability to detect the threshold of sensory characteristics given to determine sensitivity. Panelists consistency was checked and considered reliable based on the ability to produce 2 out of 3 time-intensity records on the same taste stimulus that did not differ more than 40% (Lawless and Heymann, 2010). Following selection, panelists underwent a 4-hour training session to acquire background knowledge about the food products being evaluated and the assessment method (Barton et al., 2020). Training was carried out to introduce the sensory characteristics of commercial beef sausages including color, aroma, elasticity, juiciness, taste, and mouthfeel. The color characteristics tested were the color of the inside of the sausage from dark brown to very pale, the aroma and taste from very uncharacteristic of beef to very typical. Toughness is defined as the ability of the sausage when pressed and able to return to its original shape. Juiciness is the sensation of increasing free fluid in the mouth during chewing. Creamy mouthfeel is characterized by the impression of being soft or easy to chew. Sausage samples cooked by boiling were cooled to room temperature, presented in pieces 3 cm long, and served in transparent plastic cups lined with white tissue paper. The assessments were sorted starting from color, followed by aroma, chewiness, juiciness, taste, and mouthfeel.

Table 2. Sensory evaluation scores for beef sausages

Score	Color	Aroma	Chewiness	Juiciness	Flavor	Mouthfeel
1	Dark brown	Very uncharacteristic of beef	Not very chewy	Not very juicy	Very uncharacteristic of beef	Very not creamy
2	Brown	Uncharacteristic of beef	Not chewy	Not juicy	Uncharacteristic of beef	Not creamy
3	A bit brown	Rather typical beef	A bit chewy	A bit juicy	Rather typical beef	A bit creamy
4	Pale	Typical beef	Chewy	Juicy	Typical beef	Creamy
5	Very pale	Very typical beef	Very chewy	Very juicy	Very typical beef	Very creamy



Figure 1. Beef sausage formulated using 10% (w/w) beef fat (K10), 20% (w/w) oleogel (F20), 10% (w/w) oleogel (F10), 20% (w/w) beef fat (K20), and 20% (w/w) beef fat with added tapioca (K20T)

Table 3. Results of cooking loss and proximate analysis (%w/w) of beef sausages

Treatment	Cooking loss (%)	Proximate (%)									
		Moisture content		Ash Content		Fat content		Protein content			
K10	21.24 ± 0.90 ^a	55.87	± 0.57 ^d	3.00	± 0.04 ^b	11.05	± 0.08 ^c	21.21	± 0.10 ^a		
F10	21.35 ± 1.58 ^a	57.35	± 0.15 ^c	3.01	± 0.03 ^b	10.26	± 0.02 ^d	21.16	± 0.15 ^a		
K20	23.00 ± 0.77 ^a	54.65	± 0.08 ^e	3.15	± 0.04 ^a	14.75	± 0.01 ^b	19.55	± 0.02 ^b		
F20	23.23 ± 0.80 ^a	58.99	± 0.19 ^a	2.90	± 0.02 ^c	11.12	± 0.03 ^c	19.50	± 0.04 ^b		
K20T	13.74 ± 0.36 ^b	58.14	± 0.37 ^b	2.86	± 0.01 ^c	15.10	± 0.04 ^a	15.94	± 0.04 ^c		

Note: 10% (w/w) beef fat (K10), 10% (w/w) oleogel (F10), 20% (w/w) beef fat (K20), 20% (w/w) oleogel (F20), and 20% (w/w) beef fat with the addition of tapioca (K20T)

Different letters in the same column represent significant differences (n=3, Tukey test, $p < 0.05$)

Statistical Analysis

The experiment was carried out using a completely randomized design and each treatment was repeated 3 times. Texture, color, cooking loss, and proximate test data were analyzed using Analysis of Variance (ANOVA). When there was an influence between treatments, it was continued with the Tukey test at a 5% confidence level using the IBM SPSS Statistics 23. Meanwhile, data analysis for the sensory test was carried out using a nonparametric descriptive test by IBM SPSS Statistics 23. Statistical tests used Kruskal Wallis to determine the

effect of treatment on sensory properties. When there was an effect of treatment on sensory characteristics, the Mann Whitney test was carried out to determine the level of difference between treatments.

RESULTS AND DISCUSSION

The oleogel used as a substitute for beef fat in this research was obtained from previous results. Specifically, the oleogel was formed using rice bran oil and PGOS as an oleogelator. By using emulsion template

method, oleogel was made through the formation from a mixture of water and rice bran oil with a ratio of 60:40. Furthermore, PGOS concentration used was 1% in line with the weight of the rice bran oil. The application of oleogel emulsion in this sausage formulation was determined based on considerations of lower production costs compared to using a freeze dryer. The sausage formulations included low-fat with the addition of 10% (w/w) fat and high-fat with 20% (w/w) fat. Beef sausage was formulated using 10% (w/w) beef fat (K10), 10% (w/w) oleogel (F10), 20% (w/w) beef fat (K20), 20% (w/w) oleogel (F20), and 20% (w/w) beef fat with the addition of starch (K20T) as a comparison formulation in Figure 1.

Cooking Loss

Marapana et al. (2018) define cooking loss as the system's capacity to retain water and fat following protein denaturation and aggregation. This shows the amount of liquid lost from the sample during cooking. ANOVA results in Table 3 showed a significant influence ($p < 0.05$) of sausage formulation on cooking loss and proximate (moisture, ash, fat, and protein content)

Table 3 showed that the highest cooking loss value for beef sausage was obtained in the F20, namely 23.23% (w/w), which was not significantly different from K20, K10, and F10, but varied from K20T. This showed that oleogel could be used as a fat substitute because it did not affect cooking loss. PGOS used as an oleogelator showed potential as surfactant with an amphiphilic structure, thereby preventing the loss of oil and water during sausage cooking. Wolfer et al. (2018) also reported that the substitution of pork fat with oleogel did not affect the yield of sausages produced. Lu et al. (2017) reported that cooking loss for patties ranged from 20.30-24.75%.

The lowest cooking loss value was obtained in K20T, namely 13.74% (w/w). The cooking loss in K20T was similar to beef sausage made with the addition of red pomegranate peel flour (El-Nashi et al., 2015). Furthermore, the use of tapioca in sausage formulation reduced the cooking loss of beef sausage. According to Pereira et al. (2020), incorporating starch as a filler and binder helps retain more water within the protein matrix, preventing its release during gel formation. Mbougung et al. (2015) reported that starch added as a food ingredient could act as an emulsion stabilizer, water retainer, gel former, and binder. Tapioca is a type of starch that is good for processing beef products due to the production of a smooth texture and neutral taste. Its application in making sausage can produce higher emulsion stability and yield, and a more uniform and stronger

gel network structure compared to rice flour and glutinous rice flour (Pereira et al., 2020). Prabpree and Pongsawatmanit (2011) reported that the water-holding capacity of fish sausages increased with high amount of tapioca used in sausage formulation. Based on the results, cooking loss also decreased at higher tapioca usage.

Moisture Content

Table 3 showed that sausage formulation had a significant effect on the moisture content of beef sausage ($p < 0.05$). The highest moisture content of beef sausage was obtained from the formulation with 20% oleogel (F20), namely 58.99% (w/w) which was significantly different from other treatments. The lowest moisture content was in formulation with 20% (w/w) beef fat. (K20), namely 54.65%. This showed that in beef sausage formulated with 20% (w/w) oleogel, more water was retained because of a higher amount of PGOS. The oleogel used was also formed with an oil/water ratio of 40:60, leading to a higher amount of water. Additionally, the PGOS used has amphiphilic characteristics, showing the potential to bind water in sausage dough. Beef sausage formulated with 20% (w/w) oleogel (F20) was able to produce higher water content than beef fat (20% w/w) with the addition of starch (K20T). This can be influenced by the protein content, where the protein content in F20 is higher than in K20T. Beef as a source of protein also plays a role in binding water in the sausage dough. According to Pereira et al. (2020), the interaction of muscle protein with added ingredients such as polysaccharides directly influences structural and physicochemical properties such as water binding, fat stabilization, and producing the desired texture.

The low water content in K20 is due to the fat used being 100% beef fat with the addition of the same amount of water as F20. According to Wolfer (2018), the moisture content of sausages is approximately 59-60%. Based on SNI 3820:2015 concerning beef sausage, the maximum water content of meat sausages is 67% (w/w). Therefore, the beef sausage produced in this research met the Indonesian National Standards (SNI).

Ash Content

The highest sausage ash content was obtained in sausage formulation using beef fat of 20% (w/w) (K20), namely 3.15% (w/w) which was significantly different from other treatments (Table 3). The lowest sausage ash content was obtained in K20T, namely 2.86% (w/w), which was not significantly different from F20 at 2.90% (w/w). The ash content shows

the mineral content of the sausage. Furthermore, ash content in K20 is higher than others, especially F20 and K20, which can be caused by the addition of higher levels of fat and beef. Cunningham et al. (2015) reported that the addition of fat increased several minerals such as sodium, calcium, iodine, and iron in sausage. Beef fat also contains other minerals such as zinc, sodium, selenium, magnesium, and phosphorus. It was further reported that higher protein levels could also cause greater ash content. In this research, the ash content in beef sausage with formula F20 slightly exceeded the maximum limit of 3% set by SNI 3820:2015.

Fat Content

The highest fat content was obtained in K20T with the addition of 20% (w/w) beef fat and tapioca, namely 15.10% (w/w) which was significantly different from other treatments. Meanwhile, the lowest was obtained in the F10 with the addition of 10% oleogel (w /b) which was 10.26% (w/w) and significantly different from other treatments (Table 3). Urgu-Öztürk et al. (2020) reported that adding starch could maintain the fat content of beef sausage due to the ability to inhibit the release of fat in food products during cooking. The high fat content in the K20T treatment is due to the greater amount of fat and the addition of starch which is capable of acting as a binder and emulsion stabilizer (Mbougoung et al., 2015). This is also by the cooking loss data, which is the lowest compared to other treatments. Meanwhile, the low-fat content in F10 is caused by the smallest amount of oil added compared to other treatments because 10% of the oleogel is added where the oleogel is formed from an oil/water ratio of 40:60. This also results in the substitution of 100% beef fat with

oleogel to produce sausages with lower fat content. Based on SNI 3820:2015, the maximum fat content in meat sausages is 20% w/w, so the fat content in the beef sausages produced meets SNI. Urgu-Öztürk et al. (2020) also reported that the fat content of beef sausage ranges from 11-17%.

Protein Content

Table 3 showed that the highest protein content in the beef sausage was obtained from K10, namely 21.21% (w/w), which was not significantly different from F10, namely, 21.16% (w/w). Meanwhile, the lowest protein content was obtained in F20, namely 19.50% (w/w), which was not significantly different from K20, namely 19.55% (w/w). The high protein content in K10 and F10 is caused by the addition of more meat compared to other treatments. The addition of a lower amount of fat results in a higher use of meat in the beef sausage formulation. Huda et al. (2010) and Wolfer et al. (2018) also reported that lower protein levels were caused by a smaller amount of meat used. Based on the results, the protein content in beef sausage produced met the limit set by SNI 3820:2015.

Texture

The texture characteristics of beef sausages are shown in Table 4. The ANOVA results indicated a significant effect ($p < 0.05$) of the sausage formulation on the texture attributes (hardness, cohesiveness, springiness, gumminess, and chewiness) of the beef sausages. The inclusion of starch led to a reduction in all these texture parameters. Similarly, Urgu-Öztürk et al. (2020) reported that the addition of polysaccharides to beef sausage formulations could reduce texture characteristics.

Table 4. The texture characteristics of beef sausages

Treatment	Texture														
	Hardness (N)			Cohesiveness			Springiness (N)			Gumminess (N)			Chewiness (N)		
K10	23.59	±	1.89 ^b	0.36	±	0.03 ^b	0.87	±	0.01 ^a	8.47	±	1.45 ^b	6.86	±	0.49 ^c
F10	32.88	±	1.29 ^a	0.43	±	0.01 ^a	0.89	±	0.00 ^a	15.44	±	0.19 ^a	13.73	±	0.55 ^a
K20	10.11	±	0.61 ^c	0.31	±	0.00 ^c	0.78	±	0.02 ^b	3.11	±	0.20 ^c	2.43	±	0.22 ^d
F20	22.35	±	0.47 ^b	0.44	±	0.01 ^a	0.88	±	0.01 ^a	9.42	±	0.59 ^b	8.04	±	0.55 ^b
K20T	8.14	±	0.64 ^c	0.36	±	0.01 ^b	0.72	±	0.02 ^c	2.95	±	0.23 ^c	2.12	±	0.23 ^d

Note:

- 10% (w/w) beef fat (K10), 10% (w/w) oleogel (F10), 20% (w/w) beef fat (K20), 20% (w/w) oleogel (F20), and 20% (w/w) beef fat with the addition of tapioca (K20T)
- Different letters in the same column represent significant differences (n=3, Tukey test $p < 0.05$)

Hardness

The hardness of beef sausages made with the addition of beef fat is lower than oleogel at the same amount of fat/oleogel. However, adding higher levels of fat or oleogel can reduce the hardness value of beef sausage produced. This is in line with the report by Essa and Elsebaie (2022) where the hardness of beef hamburger made with 20% fat was lower than the 10% fat formulation. The hardness values of beef sausage produced in this research ranged from 8.14 to 32.88 N. Similarly, Urgu-Öztürk et al. (2020) reported that the highest hardness value for beef sausage was 33.31 N.

The lowest hardness value was obtained in K20T, namely 8.14N, which was significantly different from other treatments. The hardness of beef sausage correlates with the amount of meat used. The addition of more meat tends to produce higher hardness. According to Panagiotopoulou et al. (2016), the texture of sausages is significantly influenced by proteins that are denatured during the cooking process. The effect of substituting beef fat with oleogel on increasing hardness is because the oleogel is added in the same amount as beef fat, but with a lower oil composition. The oleogel used is formed from 40% (w/w) rice bran oil in an emulsion. According to Huda et al. (2010), higher hardness can be caused by the high protein content in sausage and the lower added fat. Hardness is considered the most important to consumers, as it plays a key role in determining the commercial value of meat.

Cohesiveness

The cohesiveness value of beef sausage with the addition of oleogel is higher than formulation with beef fat. The addition of 10% (w/w) oleogel (F10) produced a cohesiveness that was not significantly different from 20% (w/w) oleogel (F20). Adding higher levels of beef fat reduced the cohesiveness value of beef sausage. Wang et al. (2018) reported that fat in beef products played an important role in forming stable emulsions, enhancing water-holding capacity and binding ability contributes to the development of rheological and structural properties, thereby influencing product texture. Essa and Elsebaie (2022) reported that the addition of higher fat (20%) in making beef burgers can reduce the stability of the dough emulsion, thereby increasing cooking loss. The oleogel used in making beef sausage uses rice bran oil which is rich in polyunsaturated fatty acids to maintain a more stable emulsion. According to Lu et al. (2017), a high polyunsaturated fatty acid content produced small fat globules in meat emulsions causing stronger fat-protein interactions and high cohesiveness value

of beef sausage. Adding oleogel in emulsion form facilitates dispersion into beef to increase physical stability and fat binding capacity (Kang et al., 2016).

Springiness

The highest springiness/elasticity value for beef sausage was obtained with the addition of 10% (w/w) oleogel (F10), namely 0.89 N, which was not significantly different from F20 and K10, while the lowest value was obtained for the sausage formulation with the addition of 20% beef fat (w/w) and tapioca (K20T) namely 0.72 N. This is caused by higher cooking loss and protein values in sausages without the addition of starch. Essa and Elsebaie (2022), reported that water loss during cooking, along with protein denaturation, resulted in a denser and firmer internal structure of beef burgers. Higher fat content can reduce the springiness value of beef sausage. It was also reported by Koca and Metin (2004) that the springiness of full-fat cheese was found to be significantly lower than that of low-fat cheese. The addition of oleogel to beef sausages results in a smaller amount of added fat, so the springiness value is higher. The springiness values of the resulting beef sausages were almost the same as those reported by Urgu-Öztürk et al. (2020), namely approximately 0.84-0.86 N.

Gumminess

Table 3 shows that the addition of oleogel can increase the gumminess value of beef sausage. The addition of higher levels of oleogel and beef fat causes a decrease in the gumminess value. This is because oleogel is more plastic than beef tallow (Gao et al., 2021). The highest gumminess value was obtained with the addition of 10% oleogel (F10), which was significantly different from the other treatments, while the lowest gumminess value was obtained with the K20T treatment, namely the addition of 20% (w/w) beef tallow and tapioca.

Chewiness

The chewiness value also shows the same pattern as gumminess. A similar thing was also reported by Huda et al. (2010) and Essa and Elsebaie (2022) that gumminess and chewiness have the same behavior and depend on hardness. Chewiness is the energy needed for mastication (Kouzounis et al., 2017). The addition of oleogel can increase the chewiness value of beef sausage. The highest chewiness value was obtained from the addition of 10% (w/w) oleogel (F10) which was significantly different from the other treatments, while the lowest chewiness value was obtained from K20T, namely the addition of 20% (w/w) beef tallow and tapioca which was not significantly

Table 5. The color characteristics of beef sausage

Treatment	Color								
	L			a			b		
K10	47.28	±	0.23 ^c	2.58	±	0.07 ^b	10.80	±	0.16 ^a
F10	48.18	±	0.35 ^b	2.64	±	0.16 ^b	10.33	±	0.53 ^a
K20	47.18	±	0.18 ^c	2.56	±	0.07 ^b	10.18	±	0.08 ^a
F20	48.26	±	0.28 ^b	2.97	±	0.18 ^a	10.33	±	0.20 ^a
K20T	49.07	±	0.35 ^a	2.31	±	0.18 ^b	10.66	±	0.15 ^a
									ΔE
									1.83 ± 0,43 ^a
									1.17 ± 0,59 ^a
									1.98 ± 0,19 ^a
									1.14 ± 0,57 ^a
									0 ± 0,00 ^b

Note:

- 10% (w/w) beef fat (K10), 10% (w/w) oleogel (F10), 20% (w/w) beef fat (K20), 20% (w/w) oleogel (F20), and 20% (w/w) beef fat with the addition of tapioca (K20T)
- Different letters in the same column represent significant differences (n=3, Tukey test, $p < 0.05$)

different from the addition of oleogel 20% (K20). de Carvalho et al. (2020) also reported that replacing lard with vegetable oil in sausage formulations would increase the chewiness value. The addition of oleogel and beef fat in higher quantities causes a decrease in the chewiness value. Similarly, Essa and Elsebaie (2022) reported that the addition of 20% (w/w) beef fat resulted in lower chewiness compared to adding 10% beef fat to beef burgers. Based on definition, the chewiness value is proportional to the springiness and gumminess values (Panagiotopoulou et al., 2016). The decrease in chewiness value in higher fat or oleogel addition formulations is caused by the smaller amount of meat used. Therefore, the denatured protein matrix which is one of the main components that forms the texture of sausages is also lower. The addition of oleogel caused a higher chewiness value compared to the control (K10 and K20). This was caused by the amount of fat/oil added being less than the control. Additionally, the presence of PGOS in the oleogel formulation can stabilize the beef mixture emulsion that is formed.

Color

The color of beef sausage tested using a chromameter showed that the formulation had a significant effect ($p < 0.05$) on the brightness level (L) and redness value (a). However, there was no significant effect ($p > 0.05$) on the yellowness value (b) of the beef sausage. The b value of beef sausage produced in this research ranged from 10.18 to 10.80. Urgu-Öztürk et al. (2020) reported that the b value for beef sausage ranged from 9.40-10.17. As shown in Table 5, the highest brightness value was obtained by K20T, namely 49.07, which was significantly different from the other treatments. Meanwhile, the lowest

brightness value was obtained in the treatment by adding 10% or 20% beef fat, namely 47.28 and 47.18. The addition of oleogel can increase the brightness of the beef sausage produced.

Wolfer et al. (2018) reported that replacing lard with oil or oleogel could increase the brightness value of frankfurter sausages. de Carvalho et al. (2020) also reported that replacing fat with oil in sausage formulations would produce a lighter color to increase the L value. The diameter of the oil globules in an emulsion is smaller compared to animal fat, causing a greater light reflection. Meanwhile, Pereira et al. (2020) reported that the use of starch such as tapioca, apart from providing a soft texture and neutral taste, can also increase the shine on the surface of the sausage. Lu et al. (2017) stated that moisture content also affected the brightness level of the sausage produced. Moisture content has a positive correlation with the brightness of beef products. Furthermore, the moisture content of sausage with the addition of oleogel is higher than beef fat, which contributes to the lighter color.

According to Lu et al. (2017), the a value indicates the level of redness of the sausage. The presence of heme pigment, containing 90-95% myoglobin in muscle causes the red color of beef. The highest a value of 2.97 was obtained in F20, which was significantly different from other treatments. This is because the oleogel added is higher than others, providing a brighter color impact. At lower amounts, the myoglobin contained in beef is also lower which contributes to minimum browning reaction. Lu et al. (2017) reported that meat products (patties) made by substituting lard with olive, sunflower, and grapeseed oil after cooking produced higher values than control made with the addition of lard. Previous reports also showed that the value of patties ranged from 1.43 to 3.24%.

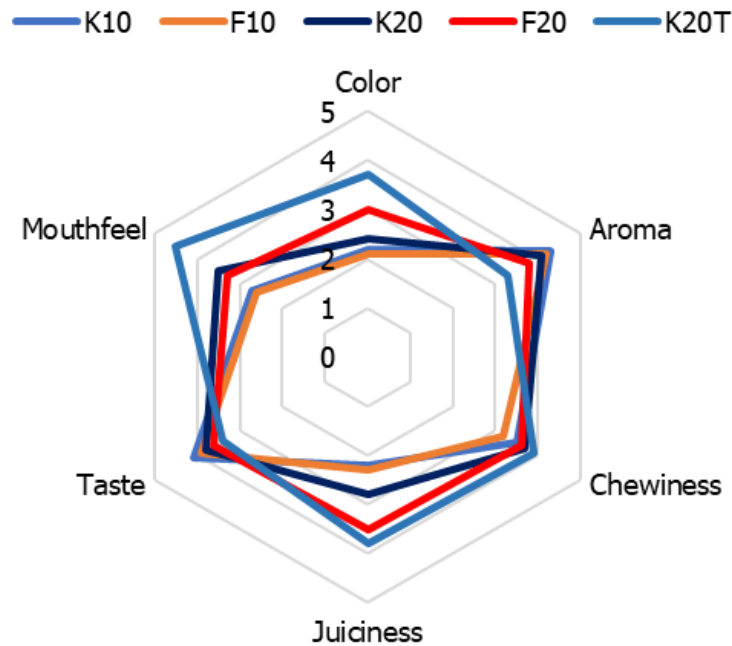


Figure 2. The characteristics of sensory of beef sausages formulated using 10% (w/w) beef fat (K10), 10% (w/w) oleogel (F10), 20% (w/w) beef fat (K20), 20% (w/w) oleogel (F20), and 20% (w/w) beef fat with the addition of tapioca (K20T)

Based on the research by Huda et al. (2010), heating meat causes changes in myoglobin and hemoglobin to metmyoglobin which produces a brown color. Therefore, the color of beef will become darker after heating. Lu et al. (2017) stated that there was no significant difference in the b value between patties formulated with lard or vegetable oil.

The ΔE value shows the difference in overall sausage color. In this research, the ΔE value of sausages with the addition of beef fat and oleogel in amounts of 10% and 20% was not significantly different, but it varied significantly from K20T. This can be caused by tapioca being able to increase the brightness (L) of sausages significantly compared to other treatments. The increase in the brightness of sausages formulated with the addition of tapioca is related to the ability to act as a binder, stabilizer, and hold water in the sausage. Therefore, the moisture content becomes higher and has an impact on increasing the brightness of the sausage (Lu et al., 2017).

The sensory characteristics of beef sausage

Sensory evaluation of beef sausage was carried out on color, aroma, chewiness, juiciness, taste, and mouthfeel using a scoring test on a scale of 1-5. Figure 2 shows sensory characteristics of beef sausages observed in this research. The results of non-parametric tests using the Kruskal Wallis test showed that sausage

formulation had a significant effect ($p < 0.05$) on the sensory characteristics of beef sausage including color, aroma, chewiness, juiciness, taste, and mouthfeel.

Color

Sensory evaluation of the color of beef sausage showed a significant difference. Sausage with the addition of 20% beef fat and tapioca (K20T) produced a pale color, according to the results of color analysis which showed the highest level of brightness (L value). Beef sausage with the F10 formulation produces a color that is not significantly different from K20. Similarly, the color of K20 is not significantly different from F20, but F10 and F20 show variation from K20T. The ΔE value also shows that the color of K20T is significantly different from other treatments. This can be caused by the smallest amount of meat used due to the addition of tapioca in the formulation. The smaller the amount of fat or oleogel added, the browner the resulting color. This can be caused by the increasing amount of meat used with the decreasing amount of fat added. The more meat, the more myoglobin and hemoglobin which turns into metmyoglobin after heating and produces a brown color (Huda et al., 2010). Apart from that, the addition of starch to sausage formulations can also produce a paler product (Pereira et al., 2020). Swastike et al. (2020) reported that adding more tapioca would produce a paler chicken sausage product.

Aroma and Taste

The highest aroma of beef sausage obtained in K10 is typical of beef which is not significantly different from the aroma of F10 beef sausage. Likewise, the K20 is not significantly different from the F20. This showed that replacing beef fat with oleogel will not affect the change in the aroma of beef sausage. The lowest aroma value was obtained in K20T, which was somewhat typical of beef, and significantly different from K20. This shows that the addition of starch results in a decrease in the distinctive aroma of beef in sausages, this is because the addition of starch correlates with a decrease in the amount of beef used. The aroma value of K20T is not significantly different from F20, which shows that replacing beef fat with high amounts of oleogel (20%) can reduce the typical beef aroma in sausages.

The same thing can also be seen in the highest score of beef sausage obtained from K10, namely the typical beef taste which is not significantly different from F10. Similarly, the K20 is not significantly different from the F20. This shows that the substitution of beef fat with oleogel does not affect changes in the taste of beef sausage in low or high amounts. The lowest taste assessment was obtained for K20T which was not significantly different from F20 and K20. This is caused by the lowest amount of beef used in the formulation compared to other treatments. A smaller

amount of beef in the sausage formulation will reduce the unique taste. Elbakheet et al. (2017) reported that the addition of higher protein caused aroma and taste assessments. Beef and related products processed at high temperatures would produce a more intense aroma and taste. This was because heating caused a chemical reaction that occurs between reducing sugars and amino acids or proteins without the involvement of enzymes through the Maillard reaction producing compounds that affect taste and aroma (Kašpar and Buchtová, 2015).

Chewiness

The chewiness value of beef sausage in K10 was not significantly different from F10, as well as K20 and F20. This showed that the substitution of beef fat with oleogel did not affect the elasticity of beef sausage. A similar thing was also reported by Panagiotopoulou et al. (2016) that partial substitution of lard with oleogel in sausage formulations produced elasticity that was not significantly different from the control. The highest firmness of beef sausage was obtained from K20T which was not significantly different from K20 and F20. The results showed that the use of higher amounts of fat or oleogel could increase the elasticity of beef sausage. This is because fat has plastic properties which affect the texture of food products (Stahl et al., 2018). The resulting oleogel can provide plastic properties similar to products that use animal fat.

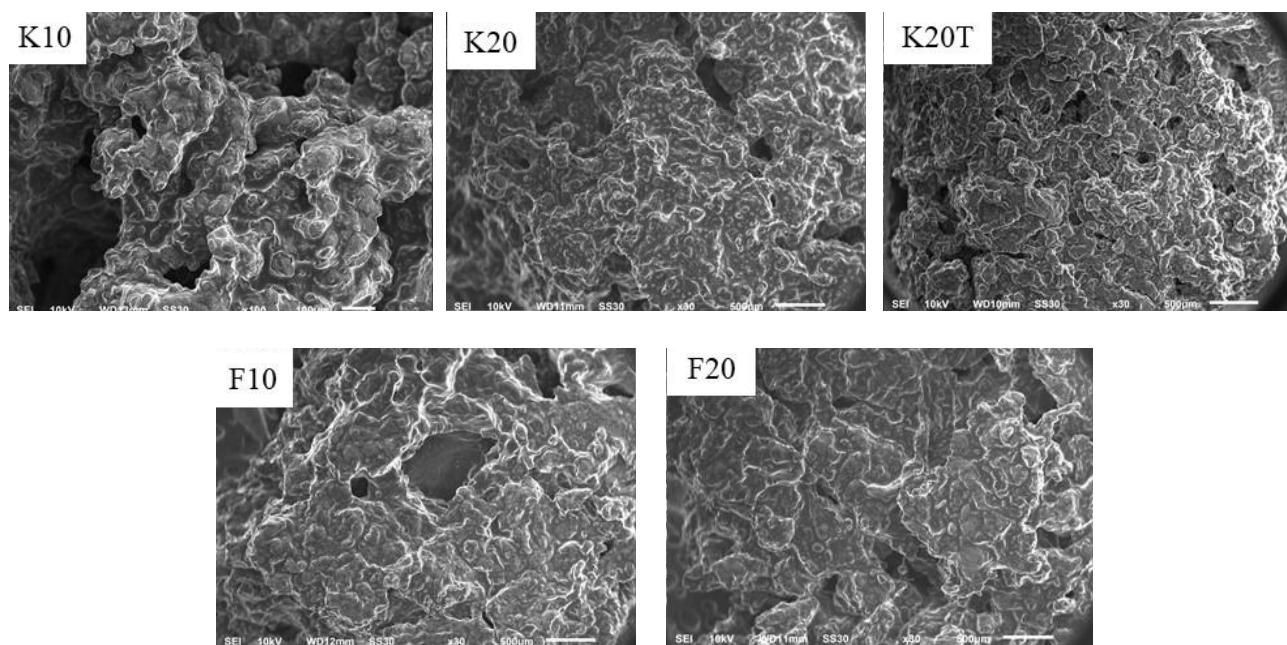


Figure 3. Microstructure of beef sausages formulated using 10% (w/w) beef fat (K10), 20% (w/w) beef fat (K20), 20% (w/w) beef fat with added starch (K20T), 10% (w/w) oleogel (F10), and 20% (w/w) oleogel (F20)

Juiciness

The lowest juiciness value was shown in K10 which was not significantly different from F10. This showed that the substitution of beef fat with oleogel in a lower amount (10%) does not affect the juiciness of beef sausages. The addition of beef fat and oleogel in higher quantities can increase the juiciness value of beef sausages. The juiciness value of beef sausage with F20 is higher than K20. This correlates with the water content of F20 being also higher than K20. The juiciness value of F20 is not significantly different from K20T. This showed that the use of PGOS as an oleogel in oleogels production can provide the same effect as adding starch to sausage formulations. PGOS has amphiphilic properties to bind oil and retain water in the sausage mixture. This can be seen in the water content of sausages made with the addition of oleogel which is higher than the control to provide a juiciness effect on beef sausages. Prabpree and Pongsawatmanit (2011) reported that starch is an ingredient added to meat mixture that acts as an adhesion, binding, gelling, and moisture-retaining agent, thereby maintaining the juiciness and tenderness of meat products. Kouzounis et al. (2017) reported that juiciness is a sensory attribute of meat that is influenced by fat content. Panagiotopoulou et al. (2016) reported that fat is generally added to processed meat products and has a major role, including improving the structure and juiciness of the product. The high juiciness value in K20T can also be caused by the lowest cooking loss compared to other treatments. Marapana et al. (2018) reported that lower cooking loss will produce juicier products. The juiciness value of K20 is significantly different from K20T, where the juiciness of K20 is lower than K20T. This is caused by a lack of stabilizers or binders that can prevent the loss of water in sausages such as starch or emulsifiers.

Mouthfeel Creamy

Sensory evaluation showed that the creamy value of sausage with K10 formulation was not significantly different from F10. The creamy value of K20 is also not significantly different from F20. This showed that the substitution of beef fat with oleogel does not affect the creamy properties of beef sausage. Formulation with the addition of 20% beef fat (w/w) and tapioca (K20T) produced the highest creamy value, which was significantly different from K20 and F20. Furthermore, there is a correlation between sensory assessment (creamy) and chewiness value. A higher chewiness value produces a less creamy product, and vice versa. The creamy value of sausages is influenced by the fat content, which shows the highest value in K20T compared to other treatments. Meanwhile, the fat

content in K10 and F10 is lower than others, causing a reduced creamy value.

Microstructure of Beef Sausage

SEM was used to observe the morphology or microstructure of sausage samples made with several different formulations. Figure 3 showed that sausage samples made with a lower amount of fat, namely 10% (w/w) (K10 and F10) had a larger and non-uniform cavity structure compared to higher fat formulation, 20% (K20, F20, and K20T). Similar results were also reported by Ferro et al. (2021) that a smaller amount of lard in making bologna sausage produced larger pores. Substitution of 100% lard with oleogel was able to produce a more compact network which was associated with higher hardness of bologna sausage.

Sausages formulated using oleogel (F10 and F20) produced a smoother, more compact structure, and smaller cavities than beef fat (K10 and K20). Zhang et al. (2021) also reported that occurrence during the application of oleogel in making surimi. The addition of oleogel in making surimi stimulated the formation of a specific network structure in the surimi gel which could increase its elasticity and water trapping ability. The control had a larger hollow structure and a less uniform network compared to the treatment with the addition of oleogel. The structure of beef sausages formulated with higher fat or oleogel appeared more compact than lower fat or oleogel, as reported by Lu et al. (2021). The denser and more compact structure of the sausage with the addition of higher levels of oleogel can be influenced by the greater amount of PGOS in the oleogel emulsion. In this context, PGOS acts as an emulsifier in making the oleogel emulsion. The substitution of OSA in porang glucomannan observed in the FT-IR test has changed the characteristics of porang glucomannan to become amphiphilic, thereby acting as emulsifier (Widarta et al., 2022). Lu et al. (2021) also reported that adding an emulsifier to surimi sausage emulsions facilitated the development of a gel network structure.

Beef sausage formulated using starch produces a structure similar to F20, namely smaller, more uniform pores and compact. This is because the added starch can act as a stabilizer, filler, gelling agent, and binder in sausages (Mbougoung et al., 2015). Lu et al. (2021) also reported that the addition of fat mimetics in the form of polysaccharides was able to increase the density of the sausage emulsion structure. The role of PGOS and starch is similar, where PGOS and starch are gel-forming components in sausage processing. The ability of PGOS to form gels is due to the hydrophilic part of PGOS which can bind with water molecules. However, PGOS has advantages over starch because it has

amphiphilic properties, showing potential as emulsifier in sausage processing. The addition of an emulsifier in sausage making can produce a better gel network structure. Liu et al. (2019) reported that the addition of an emulsifier significantly increased the structural density of surimi sausage. This led to the reduction of myosin in the emulsification process, thereby that more myosin is included in the gelation process forming the gel network structure.

CONCLUSION

In conclusion, this research showed that substituting 20% (w/w) beef fat with oleogel prepared from modified porang glucomannan in the sausage formulation resulted in desirable sensory characteristics. The characteristics observed were similar to the commercial beef sausage formulated with 20% (w/w) beef fat and tapioca. Based on the characteristics of the sausage produced, oleogel could be used as a substitute in processing beef sausages.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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