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Physical properties of ground beef dendeng added with different levels of black soldier fly maggot meal

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Abstract
Insect meal can be easily introduced to market in the form of dried products. Beef dendeng has high potential to be further developed because of public interest in the product, one of which can be done is diversifying beef dendeng with the addition of black soldier fly (BSF) maggot meal. Maggot meal can be an additional ingredient in the diversification of beef dendeng. The purpose of this study was to determine the effect of various levels of BSF maggot meal addition on the physical quality of beef dendeng and to determine the proper addition level in making beef dendeng. This study used a completely randomized design with 4 different BSF maggot meal addition levels (0%, 5%, 10%, and 15%) and with 5 replications. Data were analyzed using analysis of variance and continued with Duncan's multiple range test. The results showed that the addition of BSF maggot meal increased pH, hardness and reduced color intensity without altering yield, lightness, redness, yellowness and hue angle. Among treatments, the addition level of 5% is suggested for introducing maggot BSF meal use in beef dendeng manufacture without altering too much its physical traits.

Keywords: Beef, Black Soldier Fly, Dendeng, pH, Tenderness.

Introduction

Beef is one of the food commodities that has contributed to the fulfillment of nutrition, especially animal protein (Umboh *et al*., 2023) [27]. Badan Pusat Statistik (2024) [5] reported that beef consumption in 2023 reached 816.79 thousand tons, far exceeding domestic production of 503,506.80 tons. This figure indicates that there is a high interest in beef. Although beef has high nutritional value, the disadvantage of beef is that it rots quickly. This is because the complete nutrient content and high water content in meat can be a good medium for the growth of rotting bacteria (Beti *et al*., 2020) [6]. Therefore, a way is needed to overcome this problem by processing beef into dendeng. Dendeng is one of the most widely used alternatives for preserving meat in order to increase the shelf life of the product.

Dendeng has great potential to be developed for the purpose of food diversification because it is easily accepted by consumers and contains high protein. Dendeng is processed by thinly slicing or grinding meat and mixing it with spices then forming it into a certain size, drying it, then serving it by frying it. The type of dendeng used in this study is ground dendeng. The selection is based on the advantages of ground dendeng, namely a stronger taste because the spices are more absorbed due to being mixed directly with the meat. Processing beef into dendeng aims to extend the shelf life, as well as improve the taste that suits consumer tastes. One thing that can be done is the introduction of sustainable insect-based protein, namely black soldier fly (BSF) maggot meal, in beef dendeng products.

Food diversification is the diversification of the availability of types of food ingredients. The purpose of food diversification is so that people can consume more types of food (Sudrajat, 2023) [24]. Maggots come from the larvae of the black soldier fly (*Hermetia illucens*) or commonly known as the black soldier fly. Maggot meal can be an additional ingredient in the diversification of beef dendeng because it has good enough nutrients to be combined. Strengthened in the research of Lestari *et al*. (2023) [18] that BSF maggot meal has the highest nutritional content in the form of protein of 48,36%. In addition, the easy availability of ingredients and lower cost of ingredients compared to other types of protein make BSF maggot meal an alternative high-protein ingredient that can be used. This effort also contributes greatly to supporting the national food diversification and security program because it can improve the image and added value of local food products and increase the potential for sustainable use of BSF maggot meal.

Newly created innovative processed products need to go through several stages of quality testing before the product is proven to be suitable for consumption or sale. The quality of beef dendeng can be determined based on physical quality tests. The physical quality of food greatly determines the quality of the product and consumer acceptability of the food to be consumed. Beef dendeng can experience changes in quality during product preparation, product manufacturing, storage and distribution (Hernando *et al*., 2015) [12]. Therefore, testing the color, pH, tenderness, and yield of beef dendeng added with black soldier fly (BSF) maggot meal is important to understand the impact of adding this meal on the physical quality of the product.

Color is the main indicator of the freshness and quality of processed meat. Good color provides visual appeal to consumers. In addition, dark or uneven color can reduce the impression of quality, so it is important to ensure that the addition of BSF maggot meal does not have a negative effect on the color of dendeng. The addition of maggot meal can change the texture of dendeng due to its protein, fat, and fiber composition. Dendeng that is too hard or too soft can reduce product quality and consumer acceptance, so it is necessary to conduct a tenderness test on dendeng added with BSF maggot meal. Color and tenderness are parameters that can be directly seen by consumers, consumers tend to like food products with appetizing colors and tender meat (Arziyah *et al*., 2022 [3]; Fadhila & Darmawati, 2017) [8].

The pH value affects the tenderness, color, and shelf life of dendeng. Optimal pH conditions can support product quality degradation such as contamination during storage and distribution. Therefore, pH testing is important to ensure product stability and physical quality. Yield is an indicator of production process efficiency, namely how much dendeng is produced compared to the initial weight of raw meat. High yield indicates good production efficiency, while too low yield can indicate the loss of important components (water, fat or protein) which can affect the shelf life and texture of dendeng. The purpose of this study was to determine the effect of various levels of BSF maggot meal addition on the physical quality of beef dendeng.

Materials and Methods

1. Maggot Meal Preparation

The making of BSF maggot meal begins with the age of harvesting maggots at the age of 25 days with fruit and vegetable feed. The weight of BSF maggots before the blanching and drying process is 15 kg, the weight of the blanched BSF maggots is 20 kg, and the weight of the dried BSF maggots is 10 kg. The final weight of the dry BSF maggots after the flouring process is 3,4 kg. In this study, the BSF maggot meal needed is 5%, 10%, and 15% of the weight of the dough.

Cleaning is carried out on the harvested maggots by filtering using a plastic filter to separate the maggots from the media and their feed and the cleaning process is carried out 2 times. Then continued with storing the maggots in a container and weighing them. Then, a pan containing 2 liters of water is prepared and boiled for the blanching process by placing a large filter cloth containing maggots then putting it in boiling water for 60 seconds and draining it. After the blanching stage, the maggots are placed in a large container to be reweighed. After that, the maggots are spread out on a tarpaulin/large plastic for the drying stage in the sun for 2 days to reduce the water content of the blanching results. The half-dry BSF maggots are then packed using plastic to be continued with drying by ovening in the laboratory.

The maggots from the drying process are continued with the ovening stage. Before ovening, the maggots are placed on a baking sheet that has been lined with aluminum foil. Then the oven is carried out at a temperature of 50°C for 24 hours. The maggots are removed from the oven, then the maggots are aired until the temperature of the maggots decreases to room temperature and the maggots are weighed again. The dried maggots are then ground using a food processor until they form fine grains like flour. The maggot meal is then packed in labeled zip plastic and stored in the freezer until used.

2. Beef Dendeng Preparation

The stages in processing ground beef dendeng begin with the preparation of tools and ingredients including 50 grams of meat, 25% brown sugar, 15% white sugar, 5% coriander, 2% galangal, 5% salt, 15% tapioca flour, 15% garlic, 2% bay leaves, and 2% lemongrass of the weight of the meat. After that, the fat is cleaned from the beef and then cut into smaller sizes and weigh 50 grams. The pieces of beef are ground using a food processor until the texture changes. Then sauté the garlic, bay leaves and lemongrass spices, after which all the spices from the weighing are mixed into a food processor containing ground beef and then ground again until evenly mixed. After that, the treatment of adding maggot meal with different concentrations (0%, 5%, 10% and 15%) is given and ground again until evenly mixed. The treated dough is then weighed to determine the weight before cooking, then dendeng dough is transferred to a baking sheet to be flattened with a thickness of 4 mm. Dendeng is baked for 30 minutes at a temperature of 80°C and dendeng is turned over to the other side, and then the oven is returned for 15 minutes at a temperature of 80°C. After the baking is complete, the weight of the dendeng produced is reweighed and recorded.

3. Yield Measurement

The yield testing procedure was carried out referring to the research of Anwar *et al*. (2022) [2]. The initial sample weight before processing was weighed using an analytical balance, then the sample was reweighed after the processing process to obtain the final weight. Yield measurement was calculated using the formula:

$$\textbf{Yield (\%)} = \frac{\textbf{final weight}}{\textbf{initial weight}}\ \boldsymbol{x}\ \mathbf{100}\%$$

4. pH Value Measurement

The pH test procedure was carried out referring to the research of Irmayani *et al*. (2019) [14]. The pH measurement was carried out using the Meat pH Meter Test YY-1030. The cathode was calibrated with pH 4 buffer solution, pH 7 buffer, and pH 10 buffer by pressing the "CAL" button. After the calibration was complete, the cathode was inserted into the sample and left until the numbers listed on the digital measurement did not change anymore, this treatment was repeated 3 times. The pH meter cathode was rinsed with distilled water and dried before being used again.

5. Tenderness Measurement

The tenderness test conducted in this study used a tool called Texture Analyzer TMS-Pro (Food Tech Corp, USA) with a 500 N load cell with multiple needle probes and the test results are presented in the form of curves and numbers with N units. The configuration is set as follows, 50 mm/minute for test speed, and initial pressure of 0,10 Newton. The sample dimensions are 5 x 5 x 2 cm.

6. Color Measurement

The color test procedure was carried out referring to the research of Karuniasari & Purbasari (2022) [15]. The Precise Colorimeter AMT 501 tool was used to take color values. Color values were taken at 3 different points so that the brightness (L*), redness (a*) and yellowness (b*) values were known. The calculation of chroma values (color intensity) and hue angle (color degree) used the following formula:

$$\textbf{Chroma (C*)} = \sqrt{(\boldsymbol{a}*)^2 + (\boldsymbol{b}*)^2}$$

$$\textbf{Hue (h°)} = \textbf{arctan}\left(\frac{\mathbf{b}*}{\mathbf{a}*}\right)$$

7. Research Methods and Design

The study used an experimental method with a completely randomized design with one factor. There were four treatments, and each treatment was repeated 5 times so that 20 experimental units were obtained in this study. The treatment used was the addition of BSF maggot meal levels (0%, 5%, 10%, 15%).

8. Statistical Analysis

The yield, pH, tenderness, and color data obtained were analyzed quantitatively using a completely randomized design (CRD) variance analysis test with a Duncan's further test at a 5% significance level.

Result and Discussion

1. The Effect of Adding Black Soldier Fly Maggot Meal on the Yield, pH and Tenderness of Beef Dendeng

Table 1: Results of the Effect of Adding BSF Maggot Meal on the Yield, pH and Tenderness of Beef Dendeng

Treatment	BSF Maggot Meal Level			
	0%	5%	10%	15%
Yield (%)	84,59 ± 2,25	83,55 ± 2,01	85,02 ± 2,56	84,11 ± 0,87
pH	5,63 ± 0,03[a]	5,81 ± 0,02[b]	5,89 ± 0,05[c]	5,93 ± 0,01[d]
Tenderness	16,51 ± 3.43[a]	30,27 ± 7,69[b]	35,91 ± 8,40[b]	34,86 ± 4,05[b]

Description: Different letter notations indicate significant differences (p<0,05)

Table 1 shows that the yield value of beef dendeng ranges from 83,55-85,02%. The lowest average yield value was in the treatment of adding 5% BSF maggot meal and the highest average was in the treatment of adding 10% BSF maggot meal. The results show a relatively small fluctuating yield, so it can be said that the yield tends to be stable or slightly increased. Statistical results using the analysis of variance test showed that the addition of BSF maggot meal did not have a significant effect (p>0.05) on the yield of beef dendeng produced.

Research by Lemke *et al*. (2023) found that the addition of 20% BSF maggots to processed meat products resulted in higher cooking losses than without the addition or the addition of 10%. Meanwhile, the research by Ho *et al*. (2022) stated that the yield in sausages with the addition of 10% cricket meal was higher than the control sausage. Kim *et al*. (2016) [16] explained that this may be due to a decrease in water content and an increase in solid content in the meat emulsion formulation containing insect meal. The yield can also be affected by the high amount of protein in BSF maggot meal, which affects the yield value.

According to Liur *et al*. (2022) [19], the higher the protein content, the lower the water content of the material. This then affects the yield, where the lower the water content in the material can increase the yield because less material is evaporated. In addition to protein content, the yield of dendeng can also be affected by drying, where the longer the drying, the lower the yield of dendeng tends to decrease. In this study, this condition is thought to be due to the imperfect drying process, causing fluctuating yields in each treatment and the influence of fat contained in maggot meal. This opinion is in line with the research of Anwar *et al*. (2022) [2] that the yield of dendeng is influenced by the manufacturing method, drying method, drying time and temperature. This is what causes the addition of BSF maggot meal not to affect the yield of beef dendeng.

Based on the pH value, it shows that the pH value of beef dendeng ranges from 5,63-5,93. The lowest average pH value was in the treatment without the addition of 0% BSF maggot meal and the highest average was in the treatment with the addition of 15% BSF maggot meal. Statistical results using the analysis of variance test showed that the addition of BSF maggot meal had a significant effect (p <0.05) on the pH of the beef dendeng produced. The results of the Duncan test showed a significant difference between all treatments, where the 0% treatment was significantly different from the 5%, 10%, 15% treatments and so on with the other treatments. The results showed that the higher the level of BSF maggot meal addition, the higher the pH of the beef dendeng produced. Lim *et al*. (2012) stated that the pH value of beef dendeng generally ranges from 5,94-6,28. So it can be said that all treatments produce beef dendeng with an acceptable pH.

The increase in the pH of ground beef dendeng can be due to the pH of BSF maggot meal being higher than the pH of beef. Maggot meal has a pH of 6.9. The normal pH value of beef ranges from 5,46-6,29 (Daerobi *et al*., 2020) [7]. In addition, it can also be due to the high amount of protein in BSF maggot meal which affects the pH value. This is in line with the research of Rizqiati *et al*. (2020) [22] which states that materials containing high protein can affect pH, this is because protein has a hydroxyl group that can bind water. Compounds that have a hydroxyl group (-OH) can cover the acidic properties contained in the material. The higher the protein content of the material, the more alkaline the pH of the resulting material will be. In addition, the research of Lemke *et al*. (2023) regarding the addition of *Tenebrio molitor* and *Hermetia illucens* to the physical and chemical quality of meat obtained results that processed meat products with the addition of *Hermetia* levels of 10% and 20% had a much higher pH value than cooked meat products from all other treatment groups. Furthermore, meat products with the addition of 20% had a significantly higher pH value compared to the addition of 10% *Hermetia* and the control.

Based on the tenderness value, it shows that the tenderness value of beef dendeng ranges from 16,51-35,91. The lowest average tenderness value was in the treatment without the addition of 0% BSF maggot meal and the highest average was in the treatment with the addition of 10% BSF maggot meal. Statistical results using the analysis of variance test showed that the addition of BSF maggot meal had a significant effect (p <0.05) on the tenderness of the beef dendeng produced. The results of the Duncan test showed differences between treatments, where the 0% treatment was significantly different from the 5%, 10% and 15% treatments, but the 5% treatment was not significantly different from the 10%, 15% treatments and vice versa.

The results showed that the addition of BSF maggot meal tended to increase the hardness of beef dendeng. This condition is thought to be because BSF maggot meal contains high dry matter so that it affects the tenderness level of dendeng. Oktasari *et al*. (2020) [20] stated in their research that protein content affects meat tenderness, high protein content in meat causes an increase in the ability to retain water in meat so that the binding power is higher. This causes the meat to not be tender. However, the lower the protein, the lower the water binding power which then causes the meat fibers to open and the meat to become more tender. In line with the research of Wulang *et al*. (2024) [28] which states that the higher the average tenderness value, the tougher the meat and vice versa, the lower the average value, the more tender the meat. According to similar research on the addition of insect meal to food, it shows that substitution of mealworm meal in cereal by 10% produces a good texture so that it is acceptable, but at a level of 20% it causes a decrease in texture caused by the fat content in the larvae which is too high (Azzollini *et al*., 2018) [4]. Furthermore, in the research of Roncolini *et al*. (2019) [23] tested the addition of mealworm meal (*Tenebrio molitor* L.) as much as 5% and 10% as a substitute for wheat flour in bread dough. The results showed that mealworm meal decreased the softness of the dough as its level increased.

2. The Effect of Adding Black Soldier Fly Maggot Meal on the Color of Beef Dendeng

Table 2: Results of the Effect of Adding BSF Maggot Meal on the Color of Beef Dendeng

Treatment	BSF Maggot Meal Level			
	0%	5%	10%	15%
L*	38,74 ± 0,64	36,57 ± 1,14	35,88 ± 0,94	37,00 ± 3,23
a*	4,35 ± 0,30	4,23 ± 1,63	3,18 ± 0,26	2,86 ± 0,83
b*	15,07 ± 0,77	13,79 ± 0,90	13,67 ± 0,77	13,34 ± 1,33
*C**	15,69 ± 0,80^b	14,50 ± 0,83^ab	14,04 ± 0,78^a	13,65 ± 1,46^a
h°	1,29 ± 0,01	1,27 ± 0,11	1,34 ± 0,02	1,36 ± 0,05

Description: Different letter notations indicate significant differences (p<0,05)

Table 2 shows that the L* (lightness) value of beef dendeng ranges from 35,88-38,74. The lowest average lightness value was in the treatment of adding 10% BSF maggot meal and the highest average was in the treatment without adding 0% BSF maggot meal. Statistical results using the analysis of variance test showed that the addition of BSF maggot meal did not have a significant effect (p>0,05) on the lightness of the beef dendeng produced. According to Fadlilah *et al*. (2022) [9], L* or lightness is an indicator for the level of brightness with a scale of 0-100. The lower the lightness value, the lower the brightness level of the material, and vice versa, if the lightness is higher, the brighter the material produced. Based on the results, the brightness level of beef dendeng tends to be darker because it has a low lightness value. The results obtained are in line with the research of Gantner *et al*. (2022) [11] who used mealworm meal in wheat bread, where the higher the level of mealworm meal, the lower the L* value. Furthermore, this condition is thought to be due to the dark color of BSF maggot meal. Research by Supartini *et al*. (2024) [26] stated that the results of maggot meal flouring were brownish. In addition, the use of other ingredients in making dendeng such as brown sugar which has a darker color causes the addition of BSF maggot meal to dendeng to have no significant effect on brightness.

Based on the a* (redness) value, the a* value of beef dendeng ranges from 2,86 to 4,35. The lowest average a* value was in the treatment of adding 15% BSF maggot meal and the highest average was in the treatment without adding 0% BSF maggot meal. The results of the study showed a tendency for a* values to decrease with increasing levels of added BSF maggot meal. The a* color indicator is an indicator of reddish color which has positive and negative values with a range of 0-80. If the value obtained is positive (0-80), it indicates red, but if the value is negative (-0) to (-80), it indicates green (Fadlilah *et al*., 2022) [9]. Based on the results, the a* value obtained a positive result, indicating a reddish color. Statistical results using the analysis of variance test showed that the addition of BSF maggot meal did not have a significant effect (p>0.05) on the redness of the resulting beef dendeng. These results are in line with the research of Lemke *et al*. (2023) which states that after cooking meat products, there was no effect of adding *Hermetia* insects at various levels on the a* value of the product. This condition is thought to be due to the color of the raw materials used, in making beef dendeng using beef and brown sugar which contribute to the reddish color produced so that the addition of BSF maggot meal does not have a significant effect on the redness of dendeng. In addition, the ovening process causes the dendeng to have a dark brown color, this is due to non-enzymatic browning or Maillard reaction (Sugiarto & Marfuah, 2023) [25].

Based on the b* (yellowness) value, it shows that the b* value of beef dendeng ranges from 13,34-15,07. The lowest average b* value was in the treatment of adding 15% BSF maggot meal and the highest average was in the treatment without adding 0% BSF maggot meal. The b* indicator shows a yellowish color, where the b* scale has positive and negative values ranging from 0-70. Positive values 0-70 indicate yellow, while negative values indicate blue (Fadlilah *et al*., 2022) [9]. Statistical results using the analysis of variance (ANOVA) test showed that the addition of BSF maggot meal did not have a significant effect (p>0,05) on the yellowness of the beef dendeng produced. The b* value in the study showed a yellowish color because it was in the positive range. Based on the results, the higher the level of BSF maggot meal, the lower the b* value of beef dendeng. Strengthened by Gantner *et al*. (2022) [11], the yellowish color (b* value) decreased significantly in the treatment of adding 10% and 15% mealworm meal. This is due to the color of the insect meal used. This condition is in line with the addition of BSF maggot meal to beef dendeng, the insignificant results are due to the color of BSF maggot meal not being stronger than the reddish color of beef and brown sugar and oven baking causing a decrease in the b* value.

Based on the C* (chroma) value, the C* value of beef dendeng ranges from 13,65 to 15,69. The lowest average C* value was in the treatment of adding 15% BSF maggot meal and the highest average was in the treatment without adding 0% BSF maggot meal. Statistical results using the analysis of variance (ANOVA) test showed that the addition of BSF maggot meal had a significant effect (p <0,05) on the chroma of the beef dendeng produced. The results of the Duncan test showed differences between treatments, where the 0% treatment was not significantly different from the 5% treatment but was significantly different from the 10% and 15% treatments. Meanwhile, the 5% treatment was not significantly different from the 10% and 15% treatments. Chroma describes the intensity of the color of a food product or food ingredient (Alhanannasir *et al*., 2021) [1]. The higher the chroma value, the brighter the color will be, while the lower the chroma value, the duller the color. Based on the research results, the chroma value produced in beef dendeng tends to be low along with the increasing level of BSF maggot meal, this indicates a faded product color. This is thought to be due to the high protein content in BSF maggot meal, which affects the chroma value of food. High protein levels can trigger the Maillard reaction, where the Maillard reaction occurs in reducing sugars and amino acids, proteins, and substances containing nitrogen when heated together (Fitriyaningtyas & Widyaningsih, 2015) [10]. These results are in line with research by Rahmawati &

Wahyuni (2021) [21] which states that the higher the protein content of the material, the lower the C* value.

Based on the h° (hue) value, it shows that the h° value of beef dendeng ranges from 1,27-1,36. The lowest average h° value was in the treatment of adding 5% BSF maggot meal and the highest average was in the treatment of adding 15% BSF maggot meal. The hue value is a value that represents the dominant wavelength that will determine whether the color is red, green or yellow in food, a hue value of 0° indicates a red hue that reflects the color hue of the dendeng product (Rahmawati & Wahyuni, 2021) [21]. According to the results obtained, the h° value in the study showed a tendency towards red because it was not far from the 0° angle. Statistical results using the analysis of variance test showed that the addition of BSF maggot meal did not have a significant effect (p>0,05) on the hue of the beef dendeng produced. This condition is thought to be because the red color that arises is not caused by the addition of BSF maggot meal but because of the color of other raw materials such as beef and brown sugar. In addition, drying or ovening in the stages of the dendeng making process affects the red hue of the product. Strengthened by Sugiarto & Marfuah (2023) [25], the reddish brown color of dendeng is caused by non-enzymatic browning which causes the meat color to darken because the temperature and duration of the oven can accelerate the breakdown of myoglobin and the occurrence of dark color.

Conclusion

The results showed that the addition of black soldier fly maggot meal with different levels had a significant effect on pH, tenderness and C* (chroma), but had no significant effect on yield, L* (lightness), a* (redness), b* (yellowness) and h° (hue). The addition of 5% BSF maggot meal is recommended because it does not change the physical properties of beef dendeng too much.

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