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Research Article

Physicochemical, Microbiological, and Organoleptic Properties of Quail (*Coturnix-coturnix Japonica*) Meat Fed with Black Soldier Fly Maggot Meal Added Diet

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Abstract: Feed is one of the important factors that support quail productivity. One of the sources of feed protein that is usually used in quail feed is Meat Bone Meal (MBM). Meat Bone Meal (MBM) is a feed ingredient that serves as a source of animal protein as well as minerals, particularly calcium (Ca) and phosphorus (P), which play a crucial role in the growth and health of livestock. MBM is an imported product, causing it to be expensive. One of the alternatives to replace MBM is by utilizing local feed ingredients, namely black soldier fly (BSF) maggots. This study aims to evaluate the physicochemical, microbiological, and organoleptic characteristics of quail meat given BSF maggot flour in feed. The quail used are female birds quail with a laying period of 44-50 weeks. Research procedures include maintaining and making BSF maggot flour, producing feed, preparing and maintaining cages, slaughtering, and testing meat's physicochemical, microbiological, and organoleptic characteristics. The treatment given is R0 (feed containing MBM) and R1 (feed containing black soldier fly maggot). The data obtained was analyzed using a two-sample t-test. The results showed that quail fed diets containing the main protein source of black soldier fly maggot produced physical and microbiological characteristics of meat that were not different from quail fed diets containing MBM. Quail fed with maggot produced meat with a significantly lower cholesterol content and a more savory taste and preferred color.

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1. Introduction

Quail is one of the potential poultry livestock to be developed. Quail are cultivated in Indonesia mainly as egg producers. In addition to eggs, quail meat is also rich in protein, like other poultry meat. Quail productivity for both egg and meat production is influenced by genetic and environmental factors

(Sembor and Tinangon, 2022). Ecological factors consist of rearing management, microclimate, and feed.

Feed is a crucial factor for achieving quail productivity, accounting for 60%-80% of operational costs associated with feed (Kurniati and Vaulina, 2021). In general, quality feed is feed that contains nutrients such as energy, protein, fat, vitamins, minerals, crude fiber, and amino acids. The feed provided must be according to the needs of the livestock. One of the nutrients that has an important role in feed is protein. The protein required for the quail laying period is at least 17% (BSN, 2006). Protein functions for the growth of new tissues, repairing damaged tissues, and productivity (Wang et al., 2022).

The main protein source commonly used in poultry feed is soybean meal, while Meat Bone Meal (MBM) serves more as a supplementary protein source and a source of minerals. MBM has a high crude protein content of 47.35% (Citra et al., 2019). MBM is rich in essential amino acids such as lysine (3.87 g 100 g^{-1} protein), methionine (1.18 g 100 g^{-1} protein), isoleucine (2.18 g 100 g^{-1} protein), leucine (4.41 g 100 g^{-1} protein), and tryptophan (0.63 g 100 g^{-1} protein) (Barua et al., 2020). The disadvantages of MBM include its risks, such as the potential spread of infectious diseases, contamination with pathogenic bacteria or toxins due to improper processing, and its impact on animal health and food safety. Additionally, MBM is an imported and expensive ingredient, leading to high feed prices. Therefore, efforts are needed to reduce feed costs. One alternative is to replace MBM with local raw materials that have a similar protein content, such as black soldier fly maggots.

Black soldier fly maggot is one type of insect larvae that is widely found. Maggots can also be produced easily and at low cost. According to Jayanegara et al. (2017), black soldier fly maggot contains nutrients including crude protein 44.9%, crude fat 29.1%, crude fiber 16.4%, and ash content 8.1%. Essential amino acids contained in black soldier fly maggot protein include lysine (4.23 g 100 g-1 protein), methionine (1.82 g 100 g^{-1} protein), isoleucine (3.05 g 100 g^{-1} protein), leucine (6.35 g 100 g^{-1} protein) and tryptophan (3.17 g 100 g^{-1} protein) (Djissou et al., 2018). Harianja et al. (2024) examined the quail laying period by adding black soldier fly maggot flour to feed. The parameters observed were quail egg quality. The levels of maggot flour were 0%, 15%, 20% and 25%. The optimal results were achieved with an egg weight of 10.93 g per grain and a yolk index of 0.62, which was significant at the 25% level. Meanwhile, Siregar and Warisman (2023) examined the quail laying period by adding black soldier fly maggot flour in feed. The parameter observed was quail performance. The levels given were 0%, 3%, 6%, 9% and 12%. The best results were obtained at the 6% level with a feed conversion value of 2.04. Until now, it is still difficult to find information about studies that evaluate the physicochemical, microbiological, and organoleptic characteristics of quail meat fed with black soldier fly maggot flour in feed. Therefore, this study aimed to evaluate the feeding of black soldier fly maggot meal in feed on the physicochemical, microbiological, and organoleptic characteristics of quail meat.

2. Material and Methods

This study was conducted for 5 months, from April to August 2024. The barn preparation took 1 month, feed preparation took 1 month, rearing until maggot meal production took 1 month, rearing with treatments lasted for 6 weeks, and parameter observation took 2 weeks. Maintenance was carried out at Arkan Quail Farm, Ciampea, Bogor Regency, West Java. Physical tests, microbiological tests, organoleptic tests, pH values, and MDA levels of meat were carried out at the Animal Product Technology Laboratory of the Department of Animal Production Science and Technology, Faculty of Animal Husbandry, IPB University. The meat cholesterol test was conducted at the Integrated Laboratory of the Bogor Agro Industry Center.

The tools used in the study consisted of tools for maintenance and tools for laboratory analysis. The materials used in this study were 100 female quails of the egg-laying period aged 44-50 weeks, drinking water, black soldier fly maggot, feed ingredients, and laboratory analysis materials tailored to the parameters observed. This research was approved by the Animal Ethics Committee School of Veterinary Medicine and Biomedicine, IPB University, with number 198/KEH/SKE/IV/2024.

2.1. Raising and producing black soldier fly maggot meal

Maggot rearing begins with egg hatching, enlargement, and harvesting (Citra et al., 2019). Preparation of maggot meal involves sorting, cleaning, and roasting (120 ˚C for 10-20 minutes) (Dortmans et al., 2021). Maggots were ground and sieved to a particle size of 100 mesh.

2.2. Feed production

The feed was prepared from ingredients including corn, rice bran, soybean meal, MBM, BSF maggot meal, CPO (Crude Palm Oil), $CaCO_3$, DCP, salt, L-Lysine, DL-Methionine, and premix. Feed is self-prepared on an iso-protein and iso-energy basis. Feed is prepared according to the nutrient requirements of quail for the egg-laying period (BSN, 2016). Maggot meal completely replaces MBM as the protein source in the feed.

2.3. Cage preparation, rearing, and slaughter

The feed used consisted of two types: feed containing 6% MBM and feed containing 12% BSF maggot. This study consisted of two treatments, R0 and R1. Each treatment was repeated 5 times. The rearing period lasted for 6 weeks, starting from 44 weeks of quail age until they reached 50 weeks of age. The cages used for rearing were 10 cage plots. Each plot was filled with 10 quails and the placement was randomized. Before use cages were cleaned and disinfected. The average initial body weight of quail was 190 ± 9.66 g $bird^{-1}$. Feed and drinking water were provided *ad libitum*. Temperature recording is carried out every day, namely morning (06.00-07.00 WIB), afternoon (12.00-13.00 WIB), and evening (16.00-17.00 WIB).

The quails were reared for 6 weeks, starting at 44 weeks of age, with the first 2 weeks for feed adaptation, followed by 4 weeks of treatment feed administration until they reached 50 weeks of age. On 50 weeks of age, the birds were weighed and then slaughtered. Quail samples were randomly taken from each plot at 30% (3 birds), where 1 bird was used for physical and chemical variables, and 2 birds were used for microbiological and organoleptic variables. Before slaughter, quails were fasted for 12 hours (Citra et al., 2019). Slaughter was by CAC/GL 24-1997 (BSN, 2009).

2.4. Testing of physical characteristics of meat

The meat samples tested were taken from the breast. One sample was taken for each replicate. The meat samples tested were taken from the breast. One sample was taken for each replicate. The physical characteristics of the meat tested included a_w (water activity), cooking shrinkage, and tenderness. The aw value was measured using an aw meter (Saledja et al., 2014). Cooking shrinkage (%) was measured by subtracting the weight before and after cooking divided by the initial weight (Bouton et al., 1971). Meat tenderness was measured using a texture analyzer (Soeparno, 2005).

2.5. Testing of meat chemical characteristics

The chemical characteristics of the meat tested included pH, cholesterol content, meat MDA (malondialdehyde) content, and protein content. The pH value of meat was measured with a meat pH meter (Petracci and Baeha, 2011). Determination of meat cholesterol levels was carried out by Liebermen-Burchard method (Sahriawati et al., 2019) using a spectrophotometer at the highest wavelength. Meat MDA levels were measured using a spectrophotometer at a wavelength of 532 nm and calculated the concentration with the TEP standard curve (Singh et al., 2008). Protein content testing was conducted using the Kjeldahl method.

2.6. Testing of meat microbiological characteristics

The microbiological characteristics of meat analyzed were TPC (Total Plate Count) and *Salmonella sp.* content. TPC analysis was conducted using the spread plate method (Yusuf et al., 2016). Determination of the number of colonies was based on the Bacteriological Analytical Manual (BAM) method. *Salmonella sp.* content was tested by following the Badan Standarisasi Nasional (2008) method.

2.7. Testing of meat organoleptic characteristics

Organoleptic tests conducted include hedonic and hedonic quality assessments of color, texture, aroma, and taste. The test was conducted on meat in raw condition (color, aroma, texture) and cooked (color, aroma, texture, taste) by 30 semi-trained panelists using a questionnaire (Smith et al., 2012). Panelists were asked to assess with a score of 1-5.

2.8. Data analysis

The treatments in this study were R0 (feed containing MBM) and R1 (feed containing black soldier fly maggot). Each treatment was repeated 5 times and each replicate consisted of 10 quails. Each treatment was repeated 5 times, and each replicate consisted of 10 quails. The total number of quails used was 100. Organoleptic test data were analyzed using the Kruskal-Wallis test, while physicochemical characteristics test data and microbiological test data were analyzed using t-tests according to Mattjik and Sumertajaya (2013).

$$t_{hit} = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\frac{(n_1-1)S_1^2 + (n_2-1)S_2^2}{n_1+n_2-2}\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}} \quad (1)$$

t : t-value;
$\bar{x}1$: average of quail treated with feed containing MBM;
$\bar{x}2$: average of quail treated with feed containing maggot;
S1 : standard deviation of quail-fed diets containing MBM;
S2 : standard deviation of quail-fed diets containing maggot;
n1 : number of quail samples fed with feed containing MBM
n2 : number of quail samples fed with feed containing maggot.

3. Results and Discussion

The temperature of the quail rearing environment during the study was recorded in the morning 23.7-27.0 °C, afternoon 25.3-37.0 °C, and evening 24.1-32.8 °C. According to Ulupi et al. (2016), a comfortable ambient temperature for quail is in the range of 20-24 °C. During rearing, part of the time from morning to evening showed an ambient temperature that was above the comfort zone for quail. This causes heat stress, which is characterized by panting, indicating that the quail is experiencing oxidative stress. Oxidative stress is a condition that occurs when free radicals exceed the ability of the body's antioxidant system leading to cell and tissue damage. During oxidative stress, the production of ROS increases beyond the ability of the body's antioxidant system (SOD) to neutralize them. As a result, ROS damages lipids in the cell membrane and produces MDA as a by product (Zaboli et al., 2019).

Physical characteristics testing included cooking shrinkage, a_w (water activity), and tenderness. The results of the analysis of the physical characteristics of quail breast meat are presented in Table 1.

Table 1. Physical characteristics of quail breast meat fed with different main protein sources

Variable	R0	R1
Cooking shrinkage (%)	37.16 ± 1.62	37.24 ± 2.01
a_w (water activity)	0.86 ± 0.01	0.85 ± 0.01
Tenderness (kg cm^{-2})	1.55 ± 0.05	1.61 ± 0.04

Notes: R0 = feed containing MBM as the main protein source, R1 = feed containing black soldier fly maggot as the main protein source.

The different main protein sources of feed between treatments R0 and R1 did not affect the percentage of quail meat cooking shrinkage produced. This was due to the same age and breed of the animals in both treatments. According to Nurwanto & Mulyani (2003), the age of livestock is one of the factors that affect cooking shrinkage. The cooking shrinkage value in this study was still in the normal range. According to Soeparno (2005), the cooking shrinkage value of meat in general for all types of meat varies between 1.5%-54.5% with a normal range of 15%-40%.

The a_w value is the amount of free water that can be used to grow microorganisms. The a_w value of quail meat showed no significant difference between the R0 and R1 treatments. Age correlates with water holding capacity and the composition of connective tissue in muscles. Both are closely related to the amount of free water. The a_w value in this study was below the minimum limit for bacterial growth. Bacteria have a minimum a_w value to grow, which is 0.91 (Beuchat, 2002). This condition means that the a_w value in the research results is not a good value for bacterial growth.

The tenderness value of quail breast meat fed with different main protein sources (MBM for R0 and maggot meal for R1) showed no significant difference. Warner et al. (2021) opine that various factors, such as species, age, management practices, and gender, affect the tenderness of meat. The meat tenderness value of both treatments is in the range of very tender meat tenderness values. Nurcahaya et al. (2022) mentioned that tenderness is classified according to its value, namely very soft (<3.3 kg cm^{-2}), soft (3.3- 5.0 kg cm^{-2}), somewhat soft (5.0-6.71 kg cm^{-2}), somewhat tough (6.71-8.42 kg cm^{-2}), tough (8.42-10.12 kg cm^{-2}), and very tough (>10.12 kg cm^{-2}).

The chemical characteristics observed in this study include pH, cholesterol, meat MDA, and protein content. The chemical characteristics of the meat are presented in Table 2.

Table 2. Chemical characteristics of quail breast meat fed with different main protein sources

Variable	**R0**	**R1**
pH	5.78 ± 0.13	5.77 ± 0.18
Cholesterol (mg 100 g^{-1})	68.77 ± 2.33^{a}	50.27 ± 3.92^{b}
MDA (µg g^{-1})	1.15 ± 0.04	0.92 ± 0.25
Protein content (%)	20.70 ± 0.75	21.71 ± 0.53

Notes: Different superscripts on the same line indicate significant differences (P<0.05); R0 = feed containing MBM as the main protein source, R1 = feed containing black soldier fly maggot as the main protein source.

The results of the analysis of the pH value of quail meat fed with different main protein sources showed no significant difference. This may be because both rations consist of isoprotein and isoenergy. These conditions have an impact on body weight which is relatively the same so that the muscle glycogen produced is the same. According to Kim et al., (2014) one of the factors that affect the pH value is muscle glycogen. Nkukwana et al. (2015) reported the range of pH values as <5.7 (PSE meat), 5.7-6.1 (standard meat), and >6.1 (DFD meat). The pH value of meat in this study is still in the normal/standard category reported by Nkukwana et al. (2015). DFD (Dark, Firm, and Dry) meat is dark-colored, firm-textured, and appears dry due to a high pH (>6.1) after slaughter. Meanwhile, PSE meat (Pale, Soft, and Exudative) is pale in color, has a soft texture, and releases a lot of liquid due to a drastic drop in pH (<5.7) after slaughter.

Quail fed diets containing black soldier fly maggot meal produced meat with a cholesterol level 26.9% lower than quail fed diets containing MBM (P<0.05). The results of the analysis showed that the two treatments were significantly different. This may be because black soldier fly maggot contains chitin, which is the main component of maggot skin (exoskeleton). Chitin plays a role in lowering cholesterol because it has hypocholesterolemic properties that function to inhibit fat absorption (Silva et al., 2021).

MDA (malondialdehyde) is an indicator to assess the severity of oxidative stress (Cordiano et al., 2023). The analysis of meat MDA levels showed no significant difference in both treatments. The MDA value of meat in both treatments was lower than the research conducted by Bulbul et al. (2021) on the meat of quail breast meat, which was 1.21 µg g^{-1}. This means that the meat in both treatments has a lower level of oxidative damage than the results of the study by Bulbul et al. (2021), so the quality is better and safer for consumption.

Different main feed protein sources did not affect the meat protein content (P>0.05). This is due to the same total feed protein content in both treatments. Based on the calculation, both treatments produce protein intake is almost the same. Protein levels in quail meat range from 18 to 23% (Genchev et al., 2008). This shows that the protein content of the tested quail meat is still within the reported range.

The microbiological characteristics of meat analyzed in this study were TPC and *Salmonella sp.* content. The results of the analysis of microbiological characteristics are presented in Table 3.

Table 3. Microbiological of quail breast meat fed with different main protein sources

Variable	**R0**	**R1**
Salmonella sp.	negative	negative
Total Plate Count (TPC) log CFU g^{-1}	6.22 ± 0.64	6.20 ± 0.23

Notes: R0 = feed containing MBM as the main protein source, R1 = feed containing black soldier fly maggot as the main protein source.

Based on the test results of *Salmonella sp.* content of quail meat given different feed protein sources, the results showed no *Salmonella sp.* contamination in both treatments. This means that the meat has met the requirements set by the Indonesian National Standard (SNI) 7388:2009. The maximum limit of *Salmonella sp.* contamination in fresh poultry meat is negative 25 g^{-1} (BSN, 2009). The negative *Salmonella sp.* content in both treatments is due to the feed used of the same quality not contaminated with pathogenic contaminants (*Salmonella sp.*) and the process of raising and cutting is carried out hygienically by the applicable SOP. Diyana et al. (2021) believe negative *Salmonella sp.* content can be influenced by factors including good hygiene and sanitation and the quality of feed free from *Salmonella sp.* contamination.

Different feed protein sources did not significantly affect the total bacterial colonies. This may be explained by the a_w values of the two groups. We know that there is a correlation between the aw value and the total bacteria. A_w value is the free water used to grow microorganisms, including bacteria (Eskin and Robinson, 2010). The average TPC content of quail meat is within the BSNI (2009) standard limit of 1 x 10^6 CFU g^{-1} (6 Log CFU g^{-1}). This means that the quail meat meets microbiological safety standards with TPC within safe limits, making it suitable and safe for consumption.

Organoleptic testing includes hedonic test and hedonic quality on raw and cooked meat which is presented in Table 4. The results of the hedonic quality assessment of cooked and raw meat by panelists showed that meat from quail fed with feed containing black soldier fly maggot meal was more reddish in color than quail meat fed with feed containing MBM. The difference in meat color can be seen in Figure 1. It is possible that the reddish color in the R1 treatment is due to the higher Fe content (iron) of the maggots of the black soldier fly compared to MBM. Fe is contained in myoglobin. The pigment that gives red color to meat is myoglobin (Suman and Joseph, 2013). Higher Fe will result in a redder meat pigment.

Table 4. Organoleptic characteristics of raw and cooked quail meat fed diets with different main protein sources

Variable	Raw Meat		Cooked Meat	
	R0	R1	R0	R1
Hedonic Quality				
Color	3.27 ± 0.78	4.17 ± 0.75	2.77 ± 0.57	3.43 ± 0.50
Texture	3.37 ± 0.67	3.27 ± 0.69	3.67 ± 0.55	3.63 ± 0.81
Aroma	2.77 ± 1.10	3.67 ± 0.96	2.90 ± 1.06	3.50 ± 0.86
Hedonic				
Color	2.90 ± 0.66	3.73 ± 0.74	3.07 ± 0.74	4.07 ± 0.78
Texture	3.17 ± 0.59	3.33 ± 0.71	3.30 ± 0.60	3.37 ± 0.72
Aroma	4.13 ± 0.51	4.17 ± 0.53	4.23 ± 0.50	4.13 ± 0.57
Flavor	-	-	3.00 ± 0.95	4.20 ± 0.55

Notes: R0 = feed containing MBM as the main protein source, R1 = feed containing black soldier fly maggot as the main protein source. Hedonic quality (product quality based on panelist assessment); color brightness: 1:very pale, 2:pale, 3:slightly pale, 4:slightly reddish bright, 5:reddish bright; texture hardness level 1:very hard, 2:hard, 3:slightly soft, 4:soft, 5:very soft; aroma level 1:very fishy, 2:fishy, 3:slightly fishy, 4:not fishy/no aroma, 5:typical meat aroma; taste level 1:very bland, 2:bland, 3:slightly tasty, 4:tasty, 5:very tasty. Hedonic (degree of panelist liking): 1:dislike, 2:somewhat like, 3:like, 4:very like, 5:very much like.

Figure 1. Differences in quail meat color in R0 and R1 fed different protein sources in the diet.

The organoleptic data analysis using the Kruskal-Wallis method showed no significant differences ($p > 0.05$) between the treatment groups in the assessment of taste, aroma, texture, and color of quail meat fed with black soldier fly maggot meal compared to the control feed. The observation data in Table 4 shows that the panelists' assessment of meat texture has the same hedonic quality value of slightly tender in both raw and cooked conditions. The hedonic test on the meat texture of both treatments was equally favored by panelists in both raw and cooked conditions. Panelists liked both raw and cooked conditions.

Hedonic quality assessment of meat aroma in raw and cooked conditions showed that panelists stated that quail meat fed with black soldier fly maggot flour was not more fishy than quail meat fed with MBM as the main protein source. This is due to differences in MBM and maggot flour processing methods. Based on the hedonic test results, panelists gave the same assessment of the meat aroma of both treatments, which was very like (both in raw and cooked conditions).

Organoleptic testing of flavor is only done on cooked meat. In the assessment of the level of savor (hedonic quality), panelists considered that the taste of quail meat fed with feed containing black soldier fly maggot flour was more savory than quail meat fed with feed containing MBM. This may be due to the difference in the glutamic acid content of the two types of meat. Glutamic acid is the determinant of savory taste in meat. Based on the glutamic acid analysis in the laboratory Saraswanti Indo Genetech laboratory, it is known that the glutamic acid content in black soldier fly maggot is 3.42% and in MBM is 0.92%. Hedonic test results showed that panelists preferred quail meat fed with maggot meal because of its more savory taste. This was indicated by the higher hedonic test score of hedonic test score which was higher than quail meat fed with MBM in the feed.

Conclusion

Quail fed diets containing the main protein source of black soldier fly maggot produced physical and microbiological characteristics of meat that were not different from quail fed diets containing the main protein source of MBM. Quail fed with maggot as the main protein source produced meat with a significantly lower cholesterol content and a more savory taste and preferred color. Research suggests that black soldier fly maggots can be a primary protein source in quail feed to replace MBM.

Ethical Statement

Ethical approval for this study was obtained from Animal Ethics Committee School of Veterinary Medicine and Biomedicine, IPB University, with number 198/KEH/SKE/IV/2024.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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Author Contributions

The authors contributed equally.

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