p-ISSN 2615-787X e-ISSN 2615-790X
Accredited by Directorate General of Higher Education, Research, and Technology, Republic of Indonesia, No. 225/E/KPT/2022

**Tropical Animal Science Journal, March 2024, 47(1):104-111**
DOI: https://doi.org/10.5398/tasj.2024.47.1.104
Available online at https://journal.ipb.ac.id/index.php/tasj

# Utilization of Dietary Maggot Frass on the Performance, Carcass Percentage, Digestive Organs, and Economic Value of Muscovy Ducks

**C. S. Utama[a,*], R. I. Cahya[b], & B. Sulistiyanto[a]**
[a]Department of Animal Science, Faculty of Animal and Agricultural Sciences, Universitas Diponegoro,
[b]Graduate Student of Magister Animal Sciences Program, Faculty of Animal and Agriculture Sciences, Universitas Diponegoro,
Semarang 50275, Central Java, Indonesia
*Corresponding author: cahyasetyautama@gmail.com
*(Received 12-07-2023; Revised 03-12-2023; Accepted 19-12-2023)*

## ABSTRACT

**This study aimed to examine the effect of using maggot frass level inclusion in the diet on the performance, digestive organs, immune organs, and economic value of Muscovy Ducks. The study employed a completely randomized design with four treatments and five replications. The treatments used were: T0= 100% basal feed, T1= 80% basal feed + 20% maggot frass, T2= 60% basal feed + 40% maggot frass, and T3= 40% basal feed + 60% maggot frass. This study involved 300 Muscovy ducks aged 4 days, weighing 40.52 ± 4.81 gram/bird, and spanning a rearing period of 8 weeks. The obtained data was subjected to analysis of variance, followed by Duncan's test (p<0.05) for significance. The results showed that the increase in body weight, final weight, income over feed and duck cost (IOFDC), N retention, and carcass percentage decreased along with increasing maggot frass content. There was an increase in feed consumption, AME, TME, and crude fiber digestibility when giving maggot frass. There is a tendency for performance to decrease as the percentage of maggot frass in duck feed increases, but maggot frass can still be used at a percentage of 40%. Based on the study's findings, the use of maggot frass up to 40% can reduce feed operational costs and positively affect the IOFDC value.**

*Keywords: digestion; feed; maggot frass; Muscovy duck*

## INTRODUCTION

Poultry meat products continue to dominate the market for satisfying people's need for animal protein. Among the poultry species, the Muscovy duck is recognized as a meat producer. Muscovy ducks exhibit good feed consumption levels, body weight gain, and feed conversion ratio. Additionally, Muscovy ducks can digest crude fiber well (Tadjong *et al.,* 2020). In Indonesia, the duck population (*Cairina moschata*) reached 58,243,335 birds in 2020, representing a 1.7% increase from the total duck population in 2019 (BPS, 2021). To maximize duck growth, it is vital to consistently give them high-quality feed that is economical and has nutrients that can meet their nutritional needs.

Energy source feed ingredients are important components that must be considered when preparing poultry rations. Currently, rice bran serves as the primary energy source in animal feed. However, fluctuating rice bran prices and limited supply might increase feed costs, particularly during the dry season. To ensure the sustainability of duck farming, it is crucial to explore alternative energy sources for animal feed apart from rice bran. One potential alternative for Muscovy ducks is maggot frass, which has the potential to serve as an energy source. Maggot frass, a by-product of maggot cultivation or Black Soldier Fly (BSF) larvae, consists of a mixture of loose maggot outer shell layers, maggot dung, dead maggots, and remaining organic waste used as maggot feed (Klammsteiner *et al*., 2020). Maggot frass is available continuously, relatively inexpensive, and contains nutrients that can meet livestock needs. It has a metabolic energy content ranging from 2318.52 to 2617.45 kcal/kg (Utama *et al.,* 2023a).

Despite its potential, maggot frass has not been widely used as an energy source feed ingredient for poultry. It is commonly employed as a plant fertilizer. Given the nutritional content of maggot frass, further studies are needed to examine its effects as a feed ingredient on the performance, physiology, and economic value of duck farming. This study aims to investigate the impact of utilizing maggot frass as a feed ingredient for energy sources in Muscovy ducks, assessing its effects on performance, digestive organs, immune organs, and economic value.

## MATERIALS AND METHODS

All procedures carried out in this study involving animals have followed ethical standards and were approved by the Faculty of Animal and Agriculture Sciences, Universitas Diponegoro, with number 59-07/A-17/KEP-FPP.

The study was conducted using a completely randomized design with 4 treatments and 5 replications. Each replication contained 15 Muscovy ducks unsexed aged 4 days with a weight of 40.52 ± 4.81 gram/bird. The four treatments consisted of the following: 1) T0: 100% basal feed + 0% Maggot frass; 2) T1: 80% basal feed + 20% Maggot frass; 3) T2: 60% basal feed + 40% Maggot frass; 4) T3: 40% basal feed + 60% Maggot frass (Table 1). The research activities underwent three stages: pre-research, implementation, and data analysis. The pre-research stage involved analyzing the frass content, preparing the frass, and preparing the rations. Frass was obtained from maggot breeders in Semarang City for IDR 1,500/kg. The implementation stage included the cultivation of Muscovy ducks for 8 weeks, and on the 8$^{th}$ week, a total collection was carried out.

### Observed Variables

**Feed intake.** Feed intake was recorded daily and accumulated weekly. The remaining feed was subtracted from the feed given to calculate feed consumption. The remaining feed and feed given were measured using a sitting scale.

**Body weight gain.** Body weight was measured using a hanging scale. Body weight gain (BWG) was determined by dividing the difference between the final and initial body weights by the duration of the maintenance period.

**Final body weight.** The final weight measurement was conducted by weighing the body weight at the end of the cultivation period, specifically at week 8.

***Feed Conversion Ratio* (FCR).** The feed conversion ratio (FCR) is calculated by comparing the feed consumed with the increase in body weight at the end of the production period (Kokoszyński *et al.,* 2019).

**Income over feed duck cost.** Income over feed duck cost (IOFDC) was calculated using the method of Tanwiriah *et al.* (2019). It involved determining the difference between the income from the sale of live birds and the average expenditure per duck, which included the cost of feed and day-old ducks (DOD).

**Carcass percentage.** The carcass weight was determined by removing the feathers, head, legs, viscera, blood, and neck from the carcass. Each part was weighed using a sitting scale and a Kern ABJ-220 analytical balance. Meanwhile, the carcass percentage was calculated by comparing the carcass weight to the live weight and multiplying the result by 100%, as described by Liu *et al.* (2019).

**Abdominal fat.** Liu *et al.* (2019) provide the method for determining the percentage of abdominal fat,

Table 2. Nutrient contents of maggot frass

| Nutrition | Values |
|---|---|
| Moisture (%) | 46.26 |
| Ash (%) | 13.16 |
| Crude protein (%) | 16.37 |
| Crude fiber (%) | 17.14 |
| Ether extract (%) | 2.70 |
| Metabolic energy (kcal/kg) | 2617.45 |

Source: Utama *et al*., 2023a.

Table 1. Feed formulation and nutrient contents of Muscovy duck feed containing maggot frass at different levels

| Feed material | Treatments | | | | Feed stuff price (IDR/Kg) |
|---|---|---|---|---|---|
| | T0 | T1 | T2 | T3 | |
| Feed composition (%) | | | | | |
| Oilcake copra | 12.5 | 3.5 | 0.5 | 0 | 4,200 |
| Corn gluten feed | 40 | 39 | 35 | 20.5 | 4,800 |
| Corn grind | 18 | 12 | 2 | 0 | 10,000 |
| Oilcake soya bean | 25 | 21 | 18 | 15 | 8,000 |
| L-Methionine | 0.25 | 0.25 | 0.25 | 0.25 | 65,000 |
| Lysine | 0.25 | 0.25 | 0.25 | 0.25 | 45,000 |
| Minerals | 1.5 | 1.5 | 1.5 | 1.5 | 10,000 |
| Oil palm | 2 | 2 | 2 | 2 | 28,000 |
| NaCl | 0.5 | 0.5 | 0.5 | 0.5 | 6,000 |
| Maggot frass | 0 | 20 | 40 | 60 | 1,500 |
| Total | 100 | 100 | 100 | 100 | |
| Feed price/kg (IDR) | 7,260 | 6,214 | 4,956 | 4,099 | |
| Nutrition content | | | | | |
| Moisture | 9.4 | 9.3 | 8.61 | 9.1 | |
| Ash | 8.53 | 8.67 | 10.89 | 10.92 | |
| Crude protein | 22.02 | 22.04 | 22,14 | 22,20 | |
| Crude fiber | 9.82 | 9.91 | 9.98 | 10.01 | |
| Ether extract | 4.12 | 4.11 | 3.97 | 3.95 | |
| Metabolic energy [3)] | 3183.83 | 3175.22 | 3087.7 | 3084.69 | |

Note: [1)] Source: Results Analysis Laboratory Knowledge Nutrition Livestock, Universitas Diponegoro (2022). [2)] T0= 100% Basal feed + 0% Maggot frass, T1= 80% Basal feed + 20% Maggot frass, T2= 60% Basal feed + 40% Maggot frass, T3= 40% Basal feed + 60% Maggot frass. [3)] Energy metabolic use Balton formula: Energy metabolism= 40.81 (0.87[ Crude protein + 2.25 Crude fat + Ingredients extract without nitrogen] + 2.5).

which involves isolating the fat that comprises the proventriculus, abdominal cavity, intestines, and bursa of Fabricius. The resulting weight should then be compared to the measured abdominal fat percentage.

**Crude fat digestibility.** The data on crude fat digestibility was obtained by using the method described by Gariglio *et al.* (2019). This involved conducting a total collection, analyzing the fat content of the feed and excreta, and calculating the fat digestibility by comparing the fat content in the feed with the fat content in the excreta.

**Crude fiber digestibility.** The data on crude fiber digestibility involved conducting a total collection, analyzing the crude fiber content of the feed and excreta, and calculating the digestibility of fiber by comparing the fiber content in the feed with the crude fiber content in the excreta (Tadjong *et al.*, 2020).

**Nitrogen retention.** Nitrogen retention (N) was determined according to the method outlined by Linh *et al.* (2022). This involved conducting a total collection, analyzing the nitrogen content of the feed and excreta, and calculating the percentage of nitrogen retention by comparing the nitrogen content in the feed with the nitrogen content in the excreta.

**Apparent metabolizable energy.** Apparent metabolizable energy (AME) measurements were carried out according to the method described by Wang *et al*. (2021). The total collection method was employed, and the gross energy content in both feed and excreta was analyzed. AME was then calculated by comparing energy consumption with the energy remaining in the body.

**True metabolizable energy.** Measurement of true metabolizable energy (TME) followed the method outlined by Matin *et al.* (2021). The total collection method was also utilized, wherein the gross energy content in the feed, excreta, and endogenous excreta was analyzed. TME was calculated by comparing energy consumption with the energy left in the body, considering endogenous energy correction.

**Digestive organ percentage.** Data on the percentage of relative weight of the heart, the duodenum, jejunum, ileum, cecum, and large intestine were obtained by dissecting the ducks and separating the digestive organs. The weight of each digestive organ was then measured using an analytical balance. The percentage of organ weight was calculated by comparing the weight of each digestive organ with the live weight of the ducks.

### Data Analysis

The research data obtained were analyzed using ANOVA to determine the effect of treatment with a significance level of 5%. If there was a significant effect ($p<0.05$), Duncan's Multiple Range Test was used for further examination. The FCR value and IOFDC value parameters were analyzed descriptively.

## RESULTS

The research results with frass maggot treatment are shown in Tables 3, 4, and 5. Analysis of variance showed significant effects ($p<0.05$) on feed intake, body weight gain, and final body weight. The feed intake increased with the increase of frass maggot inclusion in the diet, but body weight gain and final body weight decreased.

Analysis of variance showed significant effects ($p<0.05$) on nitrogen retention, crude fat digestibility, and crude fiber digestibility. The frass maggot inclusion decreased N retention in T2 and T3, but not in T1. The crude fiber digestibility increased in all treatments (T1, T2, T3), while crude fat digestibility decreased only in T3. However, there were no significant differences in the parameters AME and TME (Table 4).

Analysis of variance showed a significant effect ($p<0.05$) on carcass percentage, liver relative weight percentage, jejunum relative weight percentage, and ileum relative weight percentage. The frass maggot treatments decreased the carcass percentage of Muscovy ducks. There were no significant differences in abdominal fat and duodenum (Table 5).

## DISCUSSION

### Feed Intake

The results of the analysis of variance show that the use of maggot frass has a significant effect ($p<0.05$) on feed intake. Presumably, eliminating 60% maggot frass from the feed results in alterations to the aroma, flavor, and consistency, consequently diminishing the

Table 3. Feed intake, body weight gain, final body weight, and feed conversion ratio of Muscovy duck fed diets containing maggot frass

| Variables | Treatments | | | |
|---|---|---|---|---|
| | T0 | T1 | T2 | T3 |
| Feed intake (gram/bird/week) | 524.92±81.12$^{ab}$ | 538.33±91.67$^{a}$ | 572.90±43.12$^{a}$ | 520.01±66.03$^{b}$ |
| Body weight gain (gram/bird/week) | 193.95±31.88$^{a}$ | 165.99±26.42$^{ab}$ | 164.89±24.66$^{ab}$ | 140.60±12.21$^{b}$ |
| Final body weight (gram/bird) | 1592±257.11$^{a}$ | 1367.2±210.55$^{ab}$ | 1359±198.82$^{ab}$ | 1167.4±99.59$^{b}$ |
| Feed conversion ratio | 2.92±0.39 | 3.48±0.31 | 3.78±0.54 | 4.02±0.75 |
| IOFDC (IDR) | 20652.57±9696.04 | 14262.6±6197.83 | 17940.9±8563.93 | 14980.8±5835.24 |

Note: [1)]Means in the same row with different superscripts differ significantly ($p<0.05$). [2)]T0= 100% Basal feed + 0% Frass, T1=80% Basal feed + 20% Frass, T2= 60% Basal feed + 40% Frass, T3= 40% Basal feed + 60% Frass. IOFDC= Income over feed and duck cost.

Table 4. Nitrogen retention, apparent metabolizable energy (AME) and true metabolizable energy (TME), crude fat digestibility, and crude fiber digestibility of Muscovy duck fed diets containing maggot frass

| Variables | Treatments | | | |
|---|---|---|---|---|
| | T0 | T1 | T2 | T3 |
| N Retention (%) | 86.65±3.70[a] | 85.79±3.44[a] | 80.08±2.03[b] | 71.29±4.95[c] |
| AME (Kcal/Kg) | 2410.16±179.10 | 2431.69±107.44 | 2422.77±91.18 | 2249.91±202.77 |
| TME (Kcal/Kg) | 2562.46±180.63 | 2598.57±85.44 | 2580.31±146.19 | 2415.51±205.13 |
| Crude fiber digestibility (%) | 23.28±2.82[b] | 58.33±3.65[a] | 52.80±3.02[a] | 55.37±6.59[a] |
| Crude fat digestibility (%) | 94.86±2.47[a] | 95.69±3.15[a] | 94.14±1.18[a] | 81.52±3.31[b] |

Note: [1)]Means in the same row with different superscripts differ significantly ($p<0.05$). [2)]T0= 100% Basal feed + 0% Frass, T1=80% Basal feed + 20% Frass, T2= 60% Basal feed + 40% Frass, T3= 40% Basal feed + 60% Frass. IOFDC= Income over feed and duck cost. AME= Apparent Metabolizable Energy. TME= True Metabolizable Energy.

Table 5. Carcass percentage, abdomen, and digestive organ percentage of Muscovy duck fed diets containing maggot frass

| Variables | Treatments | | | |
|---|---|---|---|---|
| | T0 | T1 | T2 | T3 |
| Carcass percentage (%) | 54.37±3.32[a] | 53.96 ±1.59[ab] | 49.43±4.45[c] | 49.81±2.25[b] |
| Abdominal fat (%) | 0.33±0.57 | 0.16±0.27 | 0.43±0.63 | 0.17±0.38 |
| Liver (%) | 2.88±0.35[a] | 2.63±0.23[a] | 3.48±0.27[b] | 3.42±0.28[b] |
| Duodenum (%) | 0.40±0.11 | 0.42±0.15 | 0.54±0.06 | 0.48±0.11 |
| Jejunum (%) | 0.95±0.16[ab] | 0.85±0.14[b] | 1.20±0.14[a] | 1.19±0.26[a] |
| Ileum (%) | 0.81±0.07[b] | 0.83±0.13[b] | 1.05±0.15[a] | 1.15±0.25[a] |

Note: [1)]Means in the same row with different superscripts differ significantly ($p<0.05$). [2)]T0= 100% Basal feed + 0% Frass, T1=80% Basal feed + 20% Frass, T2= 60% Basal feed + 40% Frass, T3= 40% Basal feed + 60% Frass. IOFDC= Income over feed and duck cost.

duck's palatability. Reduced feed intake results from diminished palatability. Farghly *et al.* (2018) state that the aroma and texture of feed affect palatability. The first requirement for a material to be used as a feed ingredient is to have good palatability. The group that received the T2 treatment consumed the most feed per week, or 572.9 grams. Palatability is not compromised due to the utilization of frass, amounting to 40%, which has no discernible impact on flavor, aroma, or texture. A decrease in feed intake will cause a decrease in the consumption of protein and other nutrients, resulting in lower body weight gain. Gariglio *et al.* (2019) report decreased duck body weight gain when feed consumption decreased. The feed intake observed in this study is comparable to that of the Muscovy ducks studied by Kukusiyah *et al.* (2022), which consumed 574 grams of feed per week.

### Body Weight Gain

The results of the analysis of variance show that the use of frass in the ration has a significant effect ($p<0.05$) on body weight gain. This is related to the feed conversion value. Gariglio *et al.* (2021) report that the more efficient the FCR, the higher the body weight gain. The feed conversion at T0 is the maximum, resulting in the greatest weekly body weight gain of 193.95 grams. The results of the research by Kukusiyah *et al.* (2022) involving ducks that consumed 574 grams of feed per week and gained 198 grams of body weight per week are comparable to the results of the body weight gain at T0. Meanwhile, according to Abdel-Hamid & Abdelfattah (2020), ducks aged 8 weeks have a body weight gain of 174.02 grams per week. The decrease in body weight gain, along with the addition of frass, was due to an increase in the feed conversion value.

### Final Body Weight

The results of the analysis of variance show that the average duck body weight is significantly different ($p<0.05$) when using frass. Factors that affect livestock body weight are body weight gain and feed conversion value. Nha & Thuy (2022) state that the final body weight of livestock is affected by high or low body weight gain. Farghly *et al.* (2018) report that the more efficient the feed conversion value, the higher the final weight of the ducks. T0 shows the highest final weight of 1592 grams. This was because the T0 treatment had a better growth rate, indicated by higher body weight gain compared to T1, T2, and T3. Banaszak *et al.* (2020) state that an 8-week-old Muscovy duck weighs 2417 grams. The final weight is related to feed conversion because the more feed nutrients are converted into tissues that make up organs, the higher the body weight gain and final weight.

### Feed Conversion Ratio

Research shows the feed conversion ratio value of T0= 2.92, T1= 3.48, T2= 3.78, and T3= 4.02. The use of basal feed (T0) shows the best feed conversion ratio value. This is related to the value of nitrogen retention. A high nitrogen retention value indicates good quality protein feed containing balanced essential and non-essential amino acids, making it easily absorbed by the body and converted into body weight. The presence of chitin in maggot frass, which is difficult for Muscovy ducks to use, causes a decline in the percentage of feed conversion ratio with each increased level of maggot frass. According to Song *et al.* (2021), frass contains chitin from the maggot exoskeleton. Nha & Thuy (2022) show a relationship between nitrogen retention and feed conversion values. The higher the nitrogen retention, the more efficient the feed conversion value, resulting in better body weight gain and final weight. Nitrogen is one of the constituent elements of protein, and protein is found in every cell and is involved in every physiological process of the body. Protein from feed is broken down into peptides and amino acids, which are then used for cell and body tissue formation. The average feed conversion ratio value in this study is rated as more efficient than Castillo *et al.* (2020), who report a feed conversion value of 4.61 for 8-week-old ducks. A lower feed conversion value indicates better feed efficiency. Low feed conversion indicates that less feed is needed to increase 1 kilogram of body weight.

### Income Over Feed Duck Cost

The results of this study indicate that the Income Over Feed Duck Cost (IOFDC) for T0, which used basal nutrition, was the highest at IDR20652.57, while T1 had the lowest at IDR14262.6. In contrast, the feed conversion ratio and IOFDC show dissimilar patterns on account of feed price variations. T0 has the highest live weight at the expense of the most expensive feed, whereas T2 has the lowest live weight at the expense of a less expensive feed. According to Biesek *et al.* (2022), IOFC is affected by feed costs, feed conversion ratio, and price per kg live weight. IOFDC is a parameter used to determine the benefits of each treatment. It is obtained by subtracting the average expenditure per one animal, including DOE and feed costs, from the sale of 1 Muscovy duck. According to Dela Cruz *et al.* (2019), the income over feed chick cost analysis aims to determine the treatment that provides the highest profit. The highest IOFDC was obtained by T0, namely IDR20652.57. This is because T0 shows the best feed conversion value and the highest final weight. Mulatu *et al.* (2019) report that IOFC is closely related to feed prices and final weight, as feed costs have the largest percentage of production costs. Production costs include DOD prices, feed, and operational costs.

### Nitrogen Retention

T0 showed the highest nitrogen retention, namely 86.65%. This can be attributed to the consumption and digestibility of protein. Kumar *et al.* (2017) state that reduced nitrogen excretion results from increased protein digestibility and increased protein deposition in the muscles. The decrease in the percentage of nitrogen retention at each additional level of maggot frass is thought to be caused by the presence of chitin in maggot frass, which is difficult for Muscovy ducks to utilize. Frass, a mixture of maggot feces, organic waste substrate residue, and the exoskeleton fallout from the maggot outer skin (Klammsteiner *et al.*, 2020), contains chitin derived from the maggot exoskeleton (Song *et al.*, 2021). Purkayastha & Sarkar (2019) show that the chitin content in the maggot exoskeleton is 9%. Chitin works by binding nitrogen from amino acids, which are the building blocks of protein, making protein difficult to digest. Additionally, nitrogen retention can also be affected by the pH of the proventriculus. According to Ibrahim *et al.* (2020), acidic conditions in the proventriculus and ventricles will affect the protein digestion process because the pepsinogen enzyme is active in acidic conditions. The process of breaking down protein begins when the pepsinogen enzyme is active, enabling absorption and retention by the body. This study demonstrates higher nitrogen retention compared to Linh *et al*. (2022), who report nitrogen retention of 68.1%-77.3% in their study on 8-week-old duck.

### True Metabolizable Energy and Apparent Metabolizable Energy

The results of the analysis of variance show that the use of maggot frass on duck feed has no significant effect on the True Metabolizable Energy (TME) parameter. This is due to the similarity of energy absorbed in the digestive tract. TME is the metabolized energy value with endogenous energy correction. According to Wei *et al.* (2020), endogenous energy refers to energy that does not come from feed. It originates from the body in the form of residual catabolic processes, gastric juices, and the remnants of epithelial cells of the intestinal mucosa. The TME value reflects the amount of pure energy derived from feed that is utilized by the body. A higher value of digested energy indicates good digestibility of the feed content (Park & Carey, 2019). Particularly due to its greater feed consumption in comparison to T0, T1, and T3, T2 exhibited the highest TME value of 2598.57 kcal/kg. The findings of this study are higher compared to the research by Wang *et al.* (2021), where Muscovy ducks showed a TME value of 2247.92 kcal/kg. Additionally, this difference can be attributed to the better nutritional balance and ease of digestibility in the feed used in the study. The factors influencing TME include the nutritional balance of the feed and the duck's condition. Xie *et al.* (2023) indicate that increasing metabolized energy leads to an increase in body weight caused by increased body fat.

The results of the analysis of variance show that the use of maggot frass in Muscovy duck feed has no significant effect on the Apparent Metabolizable Energy (AME) parameters. This is related to food consumption and energy utilization by the body. AME at T3 is relatively lower than other treatments, and feed consumption decreases at T3. Xie *et al.* (2023) state that energy intake will increase along with increasing ration consumption. On the other hand, energy intake will decrease along with decreasing ration consumption. AME or what is usually called apparent metabolic energy is the difference between the gross energy of feed consumed and the gross energy released with excreta. Utama *et al.* (2023b) state that the metabolic energy value content of a feed will influence animal feed consumption.

### Crude Fiber Digestibility

With a crude fiber digestibility of 58.33%, T1 demonstrated the highest. The duck may have discovered a form of unrefined fiber present in maggot frass that was more easily digestible. The maggot frass used in this study was derived from maggot cultivation with fruit and vegetable organic waste as feed. Fruits and vegetables contain cellulose and hemicellulose, types of crude fiber. Hemicellulose is easier to digest as it can be hydrolyzed into simpler and more digestible forms. The factor causing the low digestibility of crude fiber in the T0 is thought to be due to the large percentage of copra meal used in the ration (12.5%). Copra meal contains lignin, which is difficult for intestinal microorganisms to digest. This is consistent with the opinion of Rungruangsaphakun *et al.* (2022) that the digestibility of crude copra meal fiber is low because this material contains high lignin. Lignin is a part that functions as a reinforcement for plant cell walls by binding cellulose and hemicellulose, making it difficult to digest.

### Crude Fat Digestibility

Among the treatments, T1 exhibited the highest crude fat digestibility at 95.69%, while T3 showed the lowest digestibility. The lower digestibility of fat is presumed to be related to the digestibility of protein, which can be predicted based on the nitrogen retention results. The presence of chitin interferes with protein digestion, and it has a negative effect on fat digestion. The low digestibility of crude fat in the T3 treatment was due to the activity of the lipase enzyme, which is related to the content of saturated and unsaturated fatty acids. According to Adhami *et al.* (2021), lipase activity related to unsaturated fatty acids causes fat digestibility to increase. Maggot frass contains more saturated fatty acids. The saturated fat content is thought to come from the remains of BSF larvae mixed in the frass. Marco *et al*. (2021) state that the proportion of saturated fatty acids in BSF is 20.20%.

### Carcass Percentage

The variation in carcass percentage is attributed to differences in final weight. Castillo *et al.* (2020) state that live weight influences carcass percentage, as an increase in live weight leads to an increase in carcass percentage. The highest percentage of duck carcasses is observed in T0, reaching 54.37%. T0 achieves the highest carcass percentage due to its highest final body weight. This correlation can be attributed to age, weight, and protein digestibility, which impact carcass percentage. Protein digestibility can be estimated by examining nitrogen retention values. Contrary to the findings presented by Castillo *et al.* (2020), which indicate a carcass percentage of 58.5% in ducks, the results of this study are comparatively lower. The disparity can be attributed to higher feed consumption and lower feed conversion ratio (FCR), which affect live weight and carcass percentage.

### Abdominal Fat Percentage

The use of maggot frass in duck feed has no significant effect on abdominal fat. The percentage of abdominal fat is related to the availability and utilization of energy by the body, so the percentage of abdominal fat correlates with the values of apparent metabolizable energy and true metabolizable energy. Fouad & Senousey (2014) state that excess metabolic energy will affect the growth of fat tissue, thereby influencing the amount of fat in the abdominal area. T2 had the largest percentage of abdominal fat, 0.43%, most likely due to its higher feed consumption. Despite identical energy consumption, lower quantities of digestible nutrients may contribute to a higher percentage of abdominal fat. The reported range for the abdominal fat of geese in a study by Liu *et al.* (2019) was 1.61% to 2.00%. The low percentage of abdominal fat indicates that the condition of the resulting carcass fat is relatively better.

### Liver Percentage

The use of frass in duck feed had a significant ($p<0.05$) effect on liver percentage. This is thought to be related to the amount of energy stored in the form of glycogen. Zhang *et al.* (2021) state that the liver functions as a storage site for energy in the form of glycogen, and when it reaches its maximum capacity, it is stored as fat. The glycogen content in the liver can affect its weight. The results show that T2 has the highest percentage of liver weight, namely 3.48%. This is believed to be caused by higher feed consumption than T0, T1, and T3. In addition, this increase in relative liver weight is thought to be caused by the crude fiber content in the feed. One type of crude fiber content in frass is chitin, which causes the liver to work harder to digest crude fiber, thereby increasing liver weight. This is consistent with the findings of Zhong *et al*. (2020), who report that a high crude fiber content in the feed causes the liver to work harder. The liver weight percentage observed in this study is higher than the figure reported by Castillo *et al.* (2020), who noted that the heart weight, when fed with 22.4% protein, was 1.80%. According to Kokoszyński *et al.* (2018), the relative liver weight percentage in ducks typically ranges from 1.8% to 2.1% of the body weight.

### Duodenum Percentage

The results show that the use of maggot frass has no significant effect on the relative weight of the duodenum. This is thought to be related to the type of feed consumed, as the rations have relatively the same crude fiber content. Naderinejad *et al.* (2016) state that the weight of the small intestine is not static quantities and can be influenced by the quantity and type of feed consumed. The duodenum, as the initial part of the small intestine, contracts in response to the stretching caused by the feed entry. The relative weight percentage of the duodenum in this study is higher compared to Rotiah *et al.* (2019), with the relative weight percentage of chickens reaching 0.25%. Factors such as body size, sex, age, health status, and feed quality influence the microanatomical structure of the duodenum.

### Jejunum Percentage

The analysis of variance results shows that the use of maggot frass has a significant effect (p<0.05) on the relative weight of the jejunum. The relative weight of the jejunum increases with the increasing use of frass. It is suspected that frass contains a type of fiber that causes the jejunum to work longer, so the weight of the jejunum also increases. The crude fiber content of lignin is thought to take a long time to digest, thus affecting the size and weight of the jejunum. The highest percentage of the jejunum is observed in T2. This is thought to be related to the higher feed consumption in T2, which results in a higher intake of crude fiber (1.20%). The relative weight percentage of the jejunum in this study closely aligns with the figure Gariglio *et al.* (2019) reported for Muscovy ducks, which is 1.41%.

### Ileum Percentage

The analysis of variance results shows that the use of maggot frass has a significant effect (p<0.05) on the relative weight of the ileum. Factors that can influence the relative weight of the ileum are the nutrients contained in the feed. According to Wang *et al.* (2018), the ileum, located at the end of the intestine, plays an important role in nutrient absorption. The ileum is present in the highest percentage in T3 treatment, particularly 1.15%. However, the relative weight percentage of the ileum in this study is lower than that found by Rotiah *et al*. (2019), where the relative weight percentage in chickens ranged from 0.55% to 0.79%.

## CONCLUSION

Based on the research findings, it is recommended that maggot frass be added at a rate of 40% to Muscovy duck feed. Using maggot frass up to 40% can successfully reduce feed operations costs, contributing positively to the IOFDC (income over feed and duck cost) value.

## CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial, personal, or other relationships with other people or organizations related to the material discussed in the manuscript.

## ACKNOWLEDGEMENT

Thank you to the Institute for Research and Community Service, Universitas Diponegoro, for facilitating the assignment of RPP activities No. 225-06/UN7.D2/PP/IV/2023. We also extend our gratitude to the assistance of Sabrang Sinawung, Andri Eldia, and Ali Nastain for their assistance in research activities and preparation of activity reports.

## REFERENCES

**Abdel-Hamid, S. E. & E. M. Abdelfattah.** 2020. Effect of different dietary protein levels on some behavioral patterns and productive performance of Muscovy duck. Adv. Anim. Vet. Sci. 6:661-667. https://doi.org/10.17582/journal.aavs/2020/8.6.661.667

**Adhami, B., A. K. Amirkolaei, H. Oraji, M. Kazemifard, & S. Mahjoub.** 2021. Effects of lysophospholipid on rainbow trout (*Oncorhynchus mykiss*) growth, biochemical indices, nutrient digestibility and liver histomorphometry when fed fat powder diet. Aquac. Nutr. 27:1779-1788. https://doi.org/10.1111/anu.13315

**BPS (Badan Pusat Statistik).** 2021. Populasi Itik/Itik Manila menurut Provinsi (Ekor), 2020-2022. Badan Pusat Statistik, Jakarta.

**Banaszak, M., J. Kuźniacka, J. Biesek, G. Maiorano, & M. Adamski.** 2020. Meat quality traits and fatty acid composition of breast muscles from ducks fed with yellow lupin. Animals 14:1969-1975. https://doi.org/10.1017/S1751731120000610

**Biesek, J., M. Banaszak, M. Grabowicz, S. Wlaźlak, & M. Adamski.** 2022. Production efficiency and utility features of broiler ducks fed with feed thinned with wheat grain. Animals 12:3427. https://doi.org/10.3390/ani12233427

**Castillo, A., A. Schiavone, M. G. Cappai, J. Nery, M. Gariglio, S. Sartore, A. Franzoni, & M. Marzoni.** 2020. Performance of slow growing male Muscovy ducks exposed to different dietary levels of quebracho tannin. Animals 10:979. https://doi.org/10.3390/ani10060979

**Dela Cruz, P. J. D., C. T. Dagaas, K. M. M. Mangubat, A. A. Angeles, & O. D. Abanto.** 2019. Dietary effects of commercial probiotics on growth performance, digestibility, and intestinal morphometry of broiler chickens. Trop. Anim. Health Prod. 51:1105-1115. https://doi.org/10.1007/s11250-018-01791-0

**Farghly, M. F. A., M. E. Abd El-Hack, M. Alagawany, L. M. Saadeldin, & A. A. Swelum.** 2018. Wet feed and cold water as heat stress modulators in growing Muscovy ducklings. Poult. Sci. 97:1588-1594. https://doi.org/10.3382/ps/pey006

**Fouad, A. M. & H. K. E. Senousey.** 2014. Nutritional factors affecting abdominal fat deposition in poultry. Asian Australas. J. Anim. Sci. 27:1057–1068. https://doi.org/10.5713/ajas.2013.13702

**Gariglio, M., S. Dabbou, L. Biasato, M. T. Capucchio, E. Colombino, F. Hernández, J. Madrid, S. Martínez, F. Gai, C. Caimi, S. B. Oddon, M. Meneguz, A. Trocino, R. Vincenzi, L. Gasco, & A. Schiavone.** 2019. Nutrional effects of the dietary inclusion of partially deffated *Hermetia illucens* larva meal in Muscovy duck. J. Anim. Sci. Biotechnol. 10:37. https://doi.org/10.1186/s40104-019-0344-7

**Gariglio, M., S. Dabbou, F. Gai, A. Trocino, G. Xiccato, M. Holodova, L. Gresakova, J. Nery, S. Bellezza Oddon, I. Biasato, L. Gasco, & A. Schiavone.** 2021. Black soldier fly larva in Muscovy duck diets: Effect of duck growth, carcass, property and meat quality. Poult. Sci. 100:101303. https://doi.org/10.1016/j.psj.2021.101303

**Ge, X. K., A. A. Wang, Z. X. Ying, L. G. Zhang, W. P. Su, K. Cheng, C. C. Feng, Y. M. Zhou, L. L. Zhang, & T. Wang.** 2019. Effects of diets with different energy and bile acids levels on growth performance and lipid metabolism in broilers. Poult. Sci. 98:887-895. https://doi.org/10.3382/ps/pey434

**Ibrahim, D., A. A. Hasan, A. H. Arisha, M. A. L. Reda, Azis, W. R. I. A. S. Sherief, S. H. Adil, R. E. Sayed, & A. E. Metwally.** 2020. Impact of feeding anaerobically fermented feed supplemented with acidifiers on its quality and growth performance, intestinal villi and enteric pathogens of mulard ducks. Livest. Sci. 242:104299. https://doi.org/10.1016/j.livsci.2020.104299

**Klammsteiner, T., V. Turan, M. Fernández-Delgado Juárez, S.**

**Oberegger, & H. Insam.** 2020. Suitability of black soldier fly frass as soil amendment and implication for organic waste hygienization. Agronom. 10:1578. https://doi.org/10.3390/agronomy10101578

**Kokoszyński, D., M. Saleh, Z. Bernacki, M. Kotowicz, M. Sobczak, J. Z. Kujawska, & K. Stęczny.** 2018. Digestive tract morphometry and breast muscle microstructure in spent breeder ducks maintainedin a conservation programme of genetic resources. Arch. Anim. Breed. 61:373-378. https://doi.org/10.5194/aab-61-373-2018

**Kokoszyński, D., R. Wasilewski, M. Saleh, D. Piwczyński, H. Arpášová, C. Hrnčar, & M. Fik**. 2019. Growth performance, body measurements, carcass and some internal organs characteristics of Pekin ducks. Animals 9:963. https://doi.org/10.3390/ani9110963

**Kumar, P., A. K. Patra, G. P. Mandal, I. Samanta, & S. Pradhan.** 2017. Effect of black cumin seeds on growth performance, nutrient utilization, immunity, gut health and nitrogen excretion in broiler chickens. J. Sci. Food Agric. 11:3742-3751. https://doi.org/10.1002/jsfa.8237

**Linh, N., N. T. K. Dong, & N. V Thu.** 2022. Effect of dietary lysine and energy on apparent nutrient, nitrogen, and amino acids digestibility of Local Muscovy Ducks. Adv. Anim. Vet. Sci. 10:253–262. https://doi.org/10.17582/journal.aavs/2022/10.2.253.262

**Liu, Z. L., X. F. Huang, Y. Luo, J. J. Xue, Q. G. Wang, Y. M. Wang, & C. Wang**. 2019. Effect of dry and wet feed on growth performance, carcass traits, and apparent nutrient digestibility in geese. J. Appl. Poult. Res. 4:1115-1120. https://doi.org/10.3382/japr/pfz074

**Matin, N., P. Utterback, & C. M. Parsons.** 2021. True Metabolizable energy and amino acid digestibility in black soldier fly larvae meals, cricket meal, and mealworms using a precision fed roster assay. Poult. Sci. 100:101146. https://doi.org/10.1016/j.psj.2021.101146

**Marco, A., R. R. Ramzy, & H. Ji.** 2021. Influence of substrate inclusion of quail manure on the growth performance, body composition, fatty acid and amino acid profiles of black soldier fly larvae (*Hermetia illucens*). Sci. Total Environ. 772:145528. https://doi.org/10.1016/j.scitotenv.2021.145528

**Mulatu, K., N. Ameha, & M. Girma.** 2019. Effect of feeding different levels of baker's yeast on performance and hematological parameters in broiler chickens. J. Worlds Poult. Res. 9:38–49. https://doi.org/10.36380/jwpr.2019.5

**Naderinejad, S., F. Zaefarian, M. R. Abdollahi, A. Hassanabadi, H. Kermanshahi, & V. Ravindran.** 2016. Influence of feed form and particle size on performance, nutrient utilisation, and gastrointestinal tract development and morphometry in broiler starters fed maize-based diets. Anim. Feed Sci. Technol. 215:92-104. https://doi.org/10.1016/j.anifeedsci.2016.02.012

**Nha, P. T. & L. T. Thuy.** 2022. Effects of supplementing shrimp soluble hydrolyte extracts on growth performance and digestion of hoa lan ducks. Adv. Anim. Vet. Sci. 2:286-291. https://doi.org/10.17582/journal.aavs/2022/10.2.286.291

**Park, J. & J. B. Carey.** 2019. Dietary enzyme supplementation in duck nutrition. J. Appl. Poult. Res. 28:587–597. https://doi.org/10.3382/japr/pfz041

**Purkayastha, D. & S. Sarkar.** 2019. Physicochemical structure analysis of chitin extracted from pupa exuviae and dead imago of wild black soldier fly (*hermetia illucens*). J. Polym. Environ. 28:445-457. https://doi.org/10.1007/s10924-019-01620-x

**Rotiah, R., E. Widiastuti, & D. Sunarti.** 2019. Relative weight of small intestine and lymphoid organ of finisher period broiler chicken at different rearing temperatures. J. Appl. Anim. Res. 1:6-10. https://doi.org/10.22219/aras.v1i1.8299

**Rungruangsaphakun, J., M. Nakphaichit, & S. Keawsompong.** 2022. Nutritional improvement of copra meal for swine feed. Biocatal. Agric. Biotechnol. 39:102273. https://doi.org/10.1016/j.bcab.2021.102273

**Song, M., F. Zhang, L. Chen, Q. Yang, H. Su, X. Yang, H. He, M. Ling, J. Zheng, C. Duan, & X. Lai.** 2021. Dietary chenodeoxycholic acid improves growth performance and intestinal health by altering serum metabolic profiles and gut bacteria in weaned piglets. Anim. Nutr. 7:365-375. https://doi.org/10.1016/j.aninu.2020.07.011

**Song, S., A. W. Liang, J. K. N. Tan, J. C. Cheong, Z. Chiam, S. Arora W. N. Lam, & T. H. T. Wan.** 2021. Upcycling food waste using black soldier fly larvae: Effects of futher composting on *Frass* quality, fertilising effect and its global warming potensial. J. Clean. Prod. 288:125664. https://doi.org/10.1016/j.jclepro.2020.125664

**Tadjong, R. N., K. J. Raphael, Y. M. D. Doriane, K. Yves, E. N. L. Wilfried, & T. Alexis.** 2020. Growth performance of muscovy ducks (*Cairina moschata*) fed palm kernel meal based diets. Open J. Anim. Sci. 10:346-361. https://doi.org/10.4236/ojas.2020.103021

**Tanwiriah, W., Nurlina, D. Garnida, & Sujana.** 2019. Performance and income over feed cost of rambon duck that given the ration containing gold snail (*Pomaceae canaliculata*) and noni fruit (*Morinda cifrifolia L*) flour. IOP Conf. Ser. Earth Environ. Sci. 334:012009. https://doi.org/10.1088/1755-1315/334/1/012009

**Utama, C. S., B. Sulistiyanto, B. Marifah, & R. I. Cahya.** 2023[a]. The organoleptic, chemical and microbiological quality of maggot frass, as alternative poultry feed ingredient. Online Journal Animal Feed Research 13:340–347. https://doi.org/10.51227/ojafr.2023.49

**Utama, C. S., B. Sulistiyanto, & M. F. Haidar.** 2023[b]. The feasibility of Sorghum (*Sorghum vulgare)* fodder as poultry feed ingredients seen from growth performance, nutrient content and fiber profile of Sorghum fodder. J. Adv. Vet. Anim. Res. 10:222-227. https://doi.org/10.5455/javar.2023.j672

**Wang, S., L. I. Chen, M. He, J. Shen, G. Li, Z. Tao, R. Wu, & L. Lu.** 2018. Different rearing conditions alter gut microbiota composition and host physiology in shaoxing ducks. Sci. Rep. 1:7387. https://doi.org/10.1038/s41598-018-25760-7

**Wang, H., X. F. Zhang, S. S. Zhai, J. J. Yuan, W. C. Wang, Y. W. Zhu, & L. Yang.** 2021. The comparative study of energy utilization in feedstuffs for Muscovy ducks between in vivo and in vitro. Poult Sci. 100:1004–1007. https://doi.org/10.1016/j.psj.2020.11.037

**Wei, J., M. Xie, J. Tang, Y.B. Wu, Q. Zhang, & S. S. Hou.** 2020. The feasibility of enzyme hydrolysate gross energy for formulating duck feeds. Poult. Sci. 99:3941-3947. https://doi.org/10.1016/j.psj.2020.03.046

**Xie, M., R. Z. Meng, J. Tang, M. Guo., W. Huang, & Zhang.** 2023. Apparent metyabolizable energy requirement of feed-restricted white pekin duck breeder pullets. Anim. Feed Sci. Technol. 295:115508. https://doi.org/10.1016/j.anifeedsci.2022.115508

**Zhang, H., J. Ma, K. Tang, & B. Huang.** 2021. Beyond energy storage: Roles of glycogen metabolism in health and disease. FEBS J. 288:3772-3783. https://doi.org/10.1111/febs.15648

**Zhong, Y. F., C. M. Shi, Y. L. Zhou, Y. J. Chen, S. M. Lin, & R. J. Tang.** 2020. Optimum dietary fiber level could improve growth, plasma biochemical indexes and liver function of largemouth bass, *Micropterus salmoides*. Aquaculture. 518:734661. https://doi.org/10.1016/j.aquaculture.2019.734661