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Effects of Dietary Inclusion of Maggot (*Hermetia illucens*) and Corn on Productivity of Starter-Stage Native Chickens

Sabrang Panuntun, Cahya Utama*, and Bambang Sulistiyanto

Faculty of Animal and Agricultural Science, Diponegoro University, Semarang, Indonesia

*Corresponding author's Email: cahyasetyautama@gmail.com

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ABSTRACT

Native chickens require innovative feeding strategies to enhance productivity. This study aimed to examine the dietary effects of using maggot and corn meal (MCM) on the performance and feed digestibility of native chickens. The study used a complete randomized design, with a total of 200 one-day-old native chicks randomly allocated into four groups, each with five replicates. The first group received 100% basal feed (T0). The second group received 95% basal feed and 5% MCM (T1), the third group received 90% basal feed and 10% MCM (T2), and the fourth group received 85% basal feed and 15% MCM (T3). Group T1 exhibited significantly higher live weight, daily body weight gain, crude protein digestibility, crude fiber digestibility, and crude fat digestibility compared to other treatments. The T3 group showed the highest feed intake, whereas the best feed conversion ratio (FCR) was observed in the T0 group. It is concluded that a 5% inclusion of MCM in the feed has beneficial effecta on growth performance and digestibility of native chickens.

Keywords: Black soldier fly, Combination feed, Corn, Digestibility, Native chicken, Performance

INTRODUCTION

According to the BPS-National Statistics (2023), the total population of native chickens in Indonesia has recently been increasing, serving as an important alternative protein source. The population of native chickens in Indonesia rose from 300.1 million in 2018 to 308.6 million in 2022 (BPS, 2023). Despite their significance, native chickens have exhibited relatively slow growth and high feed conversion values (Promket and Ruangwittayanusorn, 2021). Feed quality is the main factor that supports the growth of native chickens. Low feed quality prevents native chickens to grow and develop optimally (Jachimowicz et al., 2022). The high price of manufactured feed encourages farmers to seek affordable yet nutritionally adequate alternatives (Alshelmani et al., 2021). Developing innovative feeds using the advantages of locally available ingredients presents a viable solution. As an energy source, maize can be combined with protein sources to meet nutritional sufficiency (Barszcz et al., 2022). Black Soldier Fly (BSF) larvae (*Hermetia illucens*), also known as maggots, are a promising protein source, containing 44.26% protein content and equipped with various types of essential amino acids (Schiavone et al., 2019). Compared to soybean meal, maggot exhibits superior amino acid content, including histidine (2.91% vs. 1.23%), leucine (6.79% vs. 3.65%), lysine (8.25% vs. 2.88%), methionine (1.84% vs. 0.62%), threonine (3.86% vs. 1.84%), and valine (5.54% vs. 2.3%) (Surendra et al., 2020; Aguirre et al., 2024). However, the Black soldier fly maggot has a limiting factor in chitin content derived from the exoskeleton (Purkayastha and Sarkar, 2020). High-pressure heating is expected to loosen the bonds in chitin and bring out the resistant starch of maize. Chitin will then look like a surface with large pores and dense piles of microfibrils. After steaming, the surface of chitin becomes smooth without microfibrils, and the pores increase in depth and spread over the entire surface (Tan et al., 2015). Resistant starch can be utilized by intestinal microflora as a food substrate during the digestive process, so it has the potential to become a prebiotic (Qin et al., 2020).

The current study aimed to evaluate the dietary effects of BSF maggot and corn, processed by high-pressure heating, on the productivity of native chicks. This study utilizes maize as an energy source and BSF maggot as a protein source, combined via high-pressure heating.

MATERIALS AND METHODS

Ethical approval

All procedures involving animals were approved by the Faculty of Animal and Agricultural Science, Diponegoro University, Semarang, Indonesia (Approval No. 61-04/A-08/KEP-FPP).

Study design

The study employed a complete randomized design with 200 one-day-old unsexed native chicks sourced from Balai Pembibitan Ternak Maron, Indonesia, having an initial body weight of 29.01 ± 2.16 g. They were randomly allocated into four groups with five replicates. The first group received 100% basal feed (T0). The second group received 95% basal feed and 5% MCM (T1), the third group received 90% basal feed and 10% MCM (T2), and the fourth group received 85% basal feed and 15% MCM (T3). The study was conducted for 28 days at the starter-stage native chicken (Nuningtyas et al., 2024). One-day-old chicks were divided into 20 pens (4 groups with 5 replications; 10 chickens/1 m^2). Rearing was conducted at the Faculty of Animal and Agricultural Science's teaching farm (Diponegoro University, Semarang, Indonesia). Postal cages were used by applying sanitation and health measures, with no vaccinations or antibiotics administered during the rearing period. The day-old-chicks (DOCs) were weighed on arrival to obtain the initial weight and then divided into pens according to the groups. They were given sugar water to restore body energy lost during transportation. Feed and water were provided *ad libitum* during the treatment. Residual feed was weighed every day, and the chicks were weighed every week. Lighting duration was set for 20 hours/day, using a 2700K bulb per pen. The experiment was carried out for 28 days before data collection. The variables measured in this study included the final weight, Daily Body Weight Gain (DBWG), Feed Intake (FI), Feed Conversion Ratio (FCR), crude protein digestibility, crude fiber digestibility, crude fat digestibility, and nitrogen retention.

Treatment feed preparation

The MCM feed was made using 18-21-day-old fresh maggot (prepupal stage) and ground corn in a 50:50 ratio. Fresh maggot was obtained from STIP Farming, Semarang, for IDR 4500/kg. Maggot and corn were blended using a blender. Then they were put into 0.8 thickness plastic bags and autoclaved based on the method suggested by Utama et al. (2017), i.e., placing the feed in the autoclave until the temperature reaches 121ºC under 1.5 atm pressure. After reaching this stage and waiting for 15 minutes, the autoclave was turned off. Upon cooling the autoclave, the feed was removed from the plastic bags and dried in an oven dryer at 50°C for ± 48 hours. After drying, the dried MCM was reground to pass through a 30-mesh sieve to ensure consistent particle size before dietary incorporation. Diet formulations adhered to the nutritional requirements for starter-phase native chickens (Indonesian National Standard SNI 7783.1:2013). Proximate analysis was conducted to verify nutritional content (Table 1).

Table 1. Feed composition and nutrient content of diet in starter-stage native chickens per treatment

Feed \ Treatments	T0	T1	T2	T3
		--------------%--------------		
Copra meal	10	10	10	9
Corn gluten feed	29	18	19	25
Yellow corn	18	21	15	8.5
Soybean meal	22	20	15	10
MCM	0	5	10	15
L-Lysine	0.25	0.25	0.25	0.25
DL-Methionine	0.25	0.25	0.25	0.25
Rice bran	17	19	21	21
Minerals	1.5	1.5	1.5	1.5
Fish meal	2	5	8	9.5
Nutrient content				
Crude protein* (%)	21.17	21.04	21.28	21.18
ME* (kkal/kg)	2924	2914	2990	3107
Crude fiber* (%)	6.87	6.75	6.6	6.74
Crude fat* (%)	3.49	3.94	3.93	3.42

The composition was formulated according to the ration needs of starter-stage native chickens: SNI 7783.1:2013. *The results of the Proximate Analysis of Biology Laboratory, Atma Jaya University Yogyakarta (2024). The first group received 100% basal feed (T0). The second group received 95% basal feed and 5% MCM (T1), the third group received 90% basal feed and 10% MCM (T2), and the fourth group received 85% basal feed and 15% MCM (T3).

Final weight

The final body weight measurement was carried out by weighing via a digital scale at the end of the rearing period (on the 28th day).

Daily body weight gain

Body weight was measured using digital scales. Measurement of Daily Body Weight Gain (DBWG) in g/chicken/day was calculated following Formula 1 (Utama et al., 2020):

$$DBWG = \frac{\text{Final weight} - \text{initial weight}}{28 \text{ (days of observation)}} \quad \text{(Formula 1)}$$

Feed intake

Feed intake data were collected daily by calculating the difference between the given feed and the residual feed. Weighing of residual feed was done before feeding in the morning.

Feed conversion ratio

Feed Conversion Ratio (FCR) was calculated based on the ratio between the amount of ration consumed and the measured weight gain.

$$FCR = \frac{\text{Amount of feed consumed (g)}}{\text{Body weight gain (g)}} \quad \text{(Formula 2)}$$

Digestibility values

Measurement of digestibility values was performed on 28-day-old chicks by sampling 2 chickens per replicate. Total collection methods were conducted according to Utama et al. (2020). Each replicate group of chickens was kept in a battery cage (2 chickens/repetition/cage), and 6 chickens were placed in each cage to get endogenous excreta. Chickens were moved to the battery cage and allowed to adjust to the conditions for 12 hours by providing feed and water. The transfer of chickens to battery cages was done at night and under low temperatures to minimize stress on the chickens. Afterwards, all treated and endogenous chickens were fasted for 24 hours to eliminate feed residues in the digestive tract. Chickens were fed 100 g of treatment feed, and the excreta were collected for 48 hours. Chickens for endogenous excreta collection were kept fasted and given water *ad libitum*. Endogenous chicken excreta were collected for 44 hours. Excreta were sprayed once every hour with 1N HCl to capture and reduce nitrogen evaporation. The collected excreta were cleaned of contaminants, then dried by natural drying for 2 days at 28-34°C. During the drying process, the excreta were covered using an insect net to prevent flies and other contaminants from entering, and were still routinely sprayed with HCl. The samples were then ground and put into plastic clips according to the replication to be tested for crude protein, crude fiber, crude fat, and nitrogen content.

Crude Protein Digestibility (CPD), Crude Fiber Digestibility (CFD), and Crude Fat Digestibility/Ether Extract Digestibility (EED) were calculated following Formulas 3-5, respectively (Moningkey et al., 2019). The nitrogen retention (NR) was calculated using Formula 6 (Sibbald, 1980):

(Formula 3)

$$CPD\ (\%) = \frac{(\text{CP consumption} - \text{CP excreta})}{\text{CP consumption}} \times 100\%$$

(Formula 4)

$$CFD\ (\%) = \frac{(\text{CF consumption} - \text{CF excreta})}{\text{CF consumption}} \times 100\%$$

(Formula 5)

$$EED\ (\%) = \frac{(\text{EE consumption} - \text{EE excreta})}{\text{EE consumption}} \times 100\%$$

(Formula 6)

$$NR\ (\%) = \frac{(Fd \times Nf) - ([E \times Ne] - [En \times Nen])}{(Fd \times Nf)} \times 100\%$$

where Fd is the feed consumed (g), Nf is the nitrogen feed (%), Ne is the nitrogen excreta (%), E is the total excreta (g), En is the total excreta endogenous (g), and Nen is the nitrogen endogenous (%).

Data analysis

Data were analyzed using SPSS, version 23.0. The data were tested for normality and homogeneity and were analyzed using analysis of variance (ANOVA). Significant differences ($p < 0.05$) identified via one-way ANOVA were further analyzed using Duncan's Multiple Range Test (DMRT).

RESULT AND DISCUSSION

Growth performance

The dietary inclusion of maggot-corn meal (MCM) significantly influenced ($p < 0.05$) the final weight, daily body weight gain (DBWG), feed intake (FI), and feed conversion ratio (FCR) of starter-stage native chickens (Table 2).

Table 1. Effects of different dietary MCM levels on final weight, daily body weight gain, feed intake, and feed conversion in the starter-stage of native chickens

Parameter \ Treatment	T0	T1	T2	T3
Final weight (g/chicken) *	374.7 ± 26.14^{ab}	384.6 ± 4.32^{a}	367.6 ± 7.72^{ab}	359.3 ± 18.6^{b}
Daily body weight gain (g/chicken/day) *	12.71 ± 0.94^{ab}	12.34 ± 0.16^{a}	12.06 ± 0.28^{ab}	11.8 ± 0.65^{b}
Feed intake (g/chicken/day) *	21.21 ± 0.32^{d}	24.38 ± 0.17^{c}	25.51 ± 0.18^{b}	26.1 ± 0.12^{a}
Feed conversion*	1.59 ± 0.01^{a}	1.78 ± 0.03^{b}	1.95 ± 0.04^{c}	2.04 ± 0.1^{c}

Source: Primary research data (2024); *Different superscript letters in each row show significant differences ($p < 0.05$). The first group received 100% basal feed (T0). The second group received 95% basal feed and 5% MCM (T1), the third group received 90% basal feed and 10% MCM (T2), and the fourth group received 85% basal feed and 15% MCM (T3).

Final weight and daily body weight gain

The various levels of MCM in the diets had a significant effect ($p < 0.05$) on the final weight and daily body weight gains of starter-stage native chicks. The highest final weight and DBWG values were found in the second group (T1) (384.6 ± 4.32 g/chicken and 12.34 ± 0.16 g/chicken/day) whereas the lowest final weight and DBWG indexes were found in the fourth treatment group (T3) (359.3 ± 18.6 g/chicken and 11.8 ± 0.65 g/chicken/day). This suggests that MCM is effective as an alternative feed only up to a 5% inclusion level. Factors that can affect final weight are body weight gain and feed conversion. Utama et al. (2024) noted that the final weight is related to both feed conversion and body weight gain, as the more feed nutrients are converted into tissues that form organs, which can increase body weight gain, so that the final weight increases. Maggot and corn meal levels of 10 and 15% in the diet decreased the final weight. This can be attributed to the chitin content in MCM. Kastalani et al. (2021) stated that chitin can inhibit protein digestion because it can form complex bonds with proteins and bind nitrogen in amino acids. According to Ramdani et al. (2018), chickens need protein for metabolism in the meat formation process. Warisman et al. (2024) also stated that the 5.4% of chitin in steamed maggot decreased the digestibility value and nutritional parameters of the chicken ration. A decreased level of digestibility will affect the feed conversion.

Feed intake

The effect of different levels of MCM on the diet had a significant effect ($p < 0.05$) on the feed intake of starter-stage native chicken. The addition of MCM to the diet tends to increase the ration consumption of native chickens. Feed intake increased with MCM inclusion, peaking in T3 (26.1 g/head/day) and then T2 (25.51 g/head/day) and T1 (24.38 g/head/day) compared to the control (21.21 g/head/day). It is assumed that the chitin content is increased by increasing the content of MCM in the diet. According to Daniar and Herdyastuti (2019), chitin is grouped among the animal fibers whose structure is similar to cellulose, with a crude fiber content of 72.52%. An increase in crude fiber will trigger the rate of digesta in the intestine so that feed quickly leaves the digestive tract, the livestock feed hungry, and continue to consume rations (Jha and Misshra, 2021). Chitin will increase the digesta rate, so that the chickens will quickly feel hungry and continue to consume feed.

Feed conversion ratio (FCR)

The feed conversion ratio of starter-stage native chickens was also influenced by various MCM levels. The control group (T0) achieved the best FCR (1.59 ± 0.01), while T3 had the poorest (2.04 ± 0.1). The usage of MCM in the ration tends to increase FCR. This can be attributed to the values of nitrogen retention. Abun et al. (2023) stated that higher nitrogen retention results in more efficient feed conversion. Utama et al. (2024) added that high nitrogen retention values indicate high quality feed protein containing balanced essential and non-essential amino acids, which are easily absorbed and converted into body weight. This is relevant to the nitrogen retention value in Table 3, showing that higher nitrogen retention values lead to higher FCR values.

Table 3. Effect of different dietary MCM levels on crude protein, crude fiber, crude fat digestibility, and nitrogen retention in the starter-stage of native chickens

Parameter \ Treatment	T0	T1	T2	T3
Crude protein digestibility*	80.73 ± 0.69^{b}	83.35 ± 0.9^{a}	81.75 ± 0.8^{b}	78.27 ± 1.11^{c}
Crude fiber digestibility*	45.72 ± 1.82^{b}	53.01 ± 1.49^{a}	47.6 ± 0.85^{b}	39.64 ± 1.55^{c}
Crude fat digestibility*	81.78 ± 0.95^{c}	92.33 ± 1.35^{a}	91.5 ± 0.69^{a}	85.48 ± 1.39^{b}
Nitrogen Retention*	88.10 ± 1.38^{a}	88.75 ± 0.4^{a}	83.26 ± 0.68^{b}	80.71 ± 2.75^{b}

Source: Primary research data (2024); *Different superscript letters in each row show significant differences ($p < 0.05$). The first group received 100% basal feed (T0). The second group received 95% basal feed and 5% MCM (T1), the third group received 90% basal feed and 10% MCM (T2), and the fourth group received 85% basal feed and 15% MCM (T3).

Feed digestibility

The findings revealed that there were significant effects ($p < 0.05$) arising from the type of treatment on crude protein digestibility, crude fiber digestibility, crude fat digestibility, and retention of nitrogen, as presented in Table 3.

Crude protein digestibility

Dietary MCM inclusion significantly affected ($p < 0.05$) Crude Protein Digestibility (CPD) in starter-stage native chicks. with the highest CPD observed in T1 (83.35 ± 0.9%) and the lowest in T3 (78.27 ± 1.11%). This shows that MCM is effective up to 5%, and the higher levels will reduce protein digestibility. In comparison, increasing the composition of MCM and reducing the composition of soybean meal in the diet also affected protein digestibility. This is thought to be due to the chitin content in MCM. Chitin can form complex bonds with proteins and bind amino acid nitrogen (Kastalani et al., 2021). A study by Warisman et al. (2024) showed that the steamed maggot decreased the digestibility values and the nutritional parameters of the chicken ration due to the chitin content. Sánchez-Muros et al. (2014) stated that poultry lack chitinase enzymes, limiting their ability to absorb chitin.

Crude fiber digestibility

Different MCM levels in the diet had a significant effect ($p < 0.05$) on Crude Fiber Digestibility (CFD) among starter-stage native chicks. As presented in Table 3, the highest CFD was observed in the second group (T1) at 53.01%t, with the third group (T2) at 47.6%, the first group (T0) at 45.72%, and finally reaching at 39.64% in the fourth group (T3) as the lowest CFD. This finding shows that the addition of MCM at 10% and 15% levels tends to reduce the level of crude fiber digestibility in native chickens. It seems the reason is the fact that the chitin content at 10% and 15% MCM level causes an increase in digesta rate, so that the process of digesting crude fiber by intestinal microbes only lasts for a short time. Chitin in feed will accelerate the rate of digesta; the faster the digesta rate is. the shorter the digestion process will be (Has et al., 2013; Nirwana et al., 2021). Morgan et al. (2022) noted that an extremely short digestion rate leads to a short time available for digestive enzymes to degrade nutrients, which can reduce feed digestibility.

Crude fat digestibility

Varying MCM levels in diets significantly affected ($p < 0.05$) Crude Fat Digestibility (CFD) in starter-stage native chicks. The highest CFD was obtained in the second group (T1) at 92.33%, followed by the third group (T2) at 91.5%, and then the fourth group (T3) at 85.48%, finally achieving 81.78% as the lowest in the first group (T0). Using MCM in the ration effectively increased crude fiber digestibility up to 10%, but it decreased CDF at a 15% level. The MCM feeding significantly increased crude fat digestibility compared to the control treatment ($p < 0.05$). This is probably because maggot has a type of fat that is easily digested. Black soldier fly larvae contain 37.34% monounsaturated fatty acids and 20.45% polyunsaturated fatty acids and are dominated by medium-chain fatty acids (C8-C12) (Kim and Rhee, 2016; Alifian et al., 2019). Unsaturated fatty acids can also affect the performance of lipase enzymes to increase fat absorption (Adhami et al., 2021).

Nitrogen retention

Nitrogen retention (NR) was highest in T1 (88.75%) and lowest in T3 (80.71%). According to Sibbald and Wolynetz (1985), a factor that helps increase nitrogen retention value is the production of quality feed, which is easily converted into weight. This indicates that the use of MCM at the 5% level can improve feed quality, seen from the nitrogen retention value perspective. The decrease in nitrogen retention value in T2 and T3 is thought to be due to the chitin content in the MCM. The addition of MCM results in an increase in the chitin content in the feed. Kastalani et al. (2021) stated that chitin can bind nitrogen from amino acids, reducing the digestibility value of protein. Belluco et al. (2013) and Lee et al. (2022) argue that chitin causes a decrease in the digestibility of feed ingredients and can bind the nutrients needed.

CONCLUSION

It is suggested that maggot and corn meal be replaced with soybean meal up to 5% to increase live weight, daily weight gain, and digestibility values of crude protein, crude fiber, and crude fat of native chickens. Further studies on changes in the micronutrient structure of MJS are needed to determine its potential as a functional feed ingredient.

DECLARATIONS

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Author's contributions

Sabrang Panuntun conducted the research, collected and analyzed the data, and drafted the manuscript. Cahya Utama and Bambang Sulistiyanto reviewed and edited the manuscript. All authors have read and approved the final version of the manuscript.

Competing interests

The authors have declared that no competing interests exist.

Ethical considerations

Plagiarism, consent to publish, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been checked by all the authors.

Availability of data and materials

All data generated during the study are included in this article. Any additional information is available upon reasonable request.

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