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Performance, Carcass Quality and Physiological Organ Assessment of Broilers Fed *Zophobas morio* Caterpillar in the Diet

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ABSTRACT

This study aims to find out how to feed the *Zophobas morio* caterpillar (ZmC) so that broiler diets do not need as much fish meal. The study focused on performance, carcass quality, and physiological organs (liver, gizzard, heart, and intestine). This research utilized 200 broilers of the MB 202 strain. The study employed an experimental approach, utilizing a completely randomized design (CRD) with four treatments and five replications. The intervention involved the incorporation of ZmC into the diet: RA (0% ZmC), RB (2% ZmC), RC (4% ZmC), and RD (6% ZmC). The measured variables included feed intake, weight gain, feed conversion ratio, live weight, carcass percentage, physiological organs' weights (liver, gut, heart, and gizzard), and the percentage of abdominal fat in broilers. Variance analysis indicated that ZmC in the ratio had no statistically significant impact (P>0.05) on feed intake, body weight gain, feed conversion, live weight, carcass percentage, abdominal fat percentage, or physiological organ percentage. This study suggests that ZmC can be incorporated into the diet at up to 6% while sustaining broiler performance and carcass quality.

Key words: Broiler, *Zophobas morio*, Performance, Carcass, Physiological organ.

INTRODUCTION

A broiler is a cost-effective and easily accessible source of animal protein. Broilers are chickens characterized by a placid temperament, substantial body size, rapid growth, and white skin with feathers that adhere closely to the body. Broilers are chickens characterized by a quick growth rate within a brief period. The body weight growth rate of broilers dictates their performance. Growth significantly determines body weight development performance. Growth significantly determines body weight development (Prayogo et al. 2017; Obike et al. 2020).

The feed intake significantly affects the increase in broiler body weight. A crucial aspect of operating a broiler farming enterprise is high-quality, nutritionally rich feed. Feed is) crucial in the broiler industry since it accounts for 60–70% of production expenses. Providing a nutritionally rich diet will enhance chicken productivity. The high cost of nutritionally rich feed in the chicken industry is primarily attributable to the reliance on imported feed ingredients, particularly those that are protein-based. Protein significantly contributes to the expense of poultry feed, as protein sources represent the second-greatest component poultry requires (Sjofjan et al. 2022). Fishmeal is a commonly utilized feed source of animal protein.

Fishmeal is a high-protein animal feed source that contains 50% protein (Jassim 2010) and is highly digestible, making it capable of fulfilling the nutritional requirements of livestock, particularly poultry. However, farmers occasionally face difficulties due to the uncertain quality of fishmeal, which originates from various sources and frequently experiences limited availability, affecting the feed's quality and cost. Therefore, finding alternative feed ingredients, such as the ZmC, is crucial to replacing fishmeal as an animal protein source.

Zophobas morio serves as an alternate source of animal protein for poultry feed. The ZmC is the King Mealworm (Santoso et al. 2017; Slimen et al. 2023; Lee et al. 2024; Montero-Prado et al. 2024; Fu et al. 2024). Its body size can reach up to twice that of the Tenebrio molitor caterpillar, and it typically possesses superior nutritional value for animal feed relative to the Tenebrio molitor caterpillar (Finke 2015; Medvedev et al. 2023).

The substrate in which ZmC cultivate significantly influences their nutritional composition. The substrate composition significantly influences nutrient uptake and

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utilization in ZmC, affecting their growth, survival and metabolic efficiency. Diets rich in specific nutrients, such as proteins and fats, affect the larvae's growth rates and overall health (Medvedev et al. 2023).

Nuraini's research from 2024 shows that the fresh weight of the ZmC was 328.11 grams and it had a crude protein content of 51.35%, nitrogen retention of 64.27%, chitin content of 12.54%, crude fat of 16.31% and crude fat digestibility of 80.36%. The tofu pulp media was used for this research. The amino acid composition of the ZmC includes all necessary amino acids in considerable quantities except methionine. *Zophobas morio* larvae contain a higher crude protein content than Tenebrio molitor, with notable increases in essential amino acids such as lysine, valine, and leucine, which are crucial for growth and development (Medvedev et al. 2023). ZmC have a significantly elevated lipid composition, ranging from 35.0 to 43.6%, surpassing that of other insect species considered as nutritional sources (Barroso et al. 2014). Research indicates that the lipid content in *Z. morio* larvae can range significantly based on several factors, including diet and rearing conditions. The lipid content of *Z. morio* larvae has been measured at 170g/kg DM (lower range) up to 390g/kg DM (upper range) (Adámková et al. 2016).

ZmC rich in minerals, including calcium (31.9-70.8mg/100), magnesium (39.2-118.3mg/100), sodium (104.1- 112.8mg/100), and zinc (2.5 -8.2 mg/100) and several vitamins (Finke 2015). There are between 38.8 and 44.6% saturated fatty acids (SFA), 32.1 to 42.4% monounsaturated fatty acids (MUFA), 15.7 to 24.0% polyunsaturated fatty acids, 29.1 to 32.4% palmitic acid, 31.1 to 38.0% oleic acid, 1.0 to 3.2% palmitoleic acid, 6.4 to 8.8% stearic acid, 15.6 to 23.4% linoleic acid and omega-6 fatty acids (Barroso et al. 2014; Finke 2015). Broiler diets incorporate *Z. morio* larvae up to 6%. The impact of ZmC inclusions in the diet on broiler performance and carcass characteristics remains unclear.

MATERIALS AND METHODS

Ethical approval

Ethical approval was required because a broiler was used in this study. The Research Ethics Committee of the Faculty of Medicine, Universitas Andalas, granted consent to use experimental animals (No. 82/UN.16.2/KEPFK/2024).

Duration and site of study

The Technical Implementation Unit and Nutrition Laboratory of the Faculty of Animal Husbandry, Andalas University, Indonesia, conducted this study from October 2024 to December 2024. The temperature in this area during the research ranged from 25 to 27°C.

Investigative resources

This study utilized 200 two-day-old, unsexed MB 202 strain broilers raised by PT Japfa Comfeed Indonesia. This study used boxes containing 20 cage units, each measuring 80x80x100cm, to house 10 chickens, equipped with feeds, drinkers, and digital scales. This research used a 60-watt incandescent lamp to heat and illuminate the hens. The components of the diet in this trial included ground maize, soybean meal, fish meal, *Z. morio* larvae, fine bran, coconut oil, and a top mix. Table 1 displays the feed ingredients, nutritional composition, and metabolic energy of the ration components. The ration formulated Iso energy standards of 2900kcal/kg and Iso protein standards of 21. Table 2 and Table 3 present the formulation of the research diet and composition of dietary Items (%) and metabolic energy (kcal/kg) of the experimental diet, respectively.

Table 1: Feed ingredients, food substance content (%) and metabolic energy (kcal/kg) of ration constituents (as fed)

Feed ingredients	Crude Protein	Fat	Crude Fiber	Ca	P	Energy Metabolizable
Ground corn	9.58	2.66	3.70	0.38	0.19	3300
Soybean meal	43.76	2.49	3.50	0.63	0.36	2240
Fish meal	46.00	2.84	3.40	5.10	2.39	2540
ZmC	44.67	14.19	6.23	0.21	1.00	2400c
Fine bran	12.34	5.09	14.50	0.69	0.26	1630
Coconut oil	-	100	-	-	-	8600
Bone meal	-	-	-	24.00	12.00	-
Top mixed	-	-	-	0.06	-	-

Table 2: Feed formulation

Feed ingredients	Treatment (%)			
	A	B	C	D
Ground Corn	56.00	55.00	54.50	54.00
Soybean Meal	22.00	22.25	22.50	22.75
Fishmeal	8.00	6.00	4.00	2.00
ZmC	0.00	2.00	4.00	6.00
Fine Bran	8.50	9.25	9.75	9.75
Coconut oil	4.00	3.75	3.50	3.50
Bone meal	1.00	1.25	1,25	1.50
Top mix	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00

Description: ZmC = *Zophobas morio* Caterpillar.

Table 3: Dietary substance content and metabolic energy of feed formulation

Food content (%) and Metabolizable Energy (kcal/kg)	Treatment			
	A	B	C	D
Protein	20.08	20.07	20.08	20.02
Fat	6.70	7.24	7.79	8.56
Crude fiber	4.49	4.63	4.74	4.78
Ca	0.90	0.90	0.85	0.85
Available P	0.48	0.49	0.48	0.49
ME	3026.55	3007.12	3000.11	3006.45

Description: Calculated based on Table 1 and 2.

Research methodologies

For this study, an entirely randomized design (CRD) was used for the experiments. There were four treatments with different amounts of ZmC and five replications, with ten hens in each cage unit. The treatments included: (RA 0% ZmC), (RB 2% ZmC), (RC 4% ZmC) and (RD 6% ZmC). The parameters evaluated based on the inclusion of ZmC in these diets were feed intake, broiler weight gain, feed conversion ratio, carcass yield, belly fat percentage, and physiological organ metrics. We statistically analyzed all acquired data using analysis of variance, based on the Complete Randomized Design (CRD) framework, via SPSS 23.0.

Execution of research

Zophobas morio caterpillar cultivation

The culture media for ZmC was prepared (500g), adhering to the specified composition for the treatment. Initially, the tofu pulp (14% moisture content) was dehydrated; thereafter, incorporated 1,000 ten-day-old *Z. morio* larvae. The temperature was documented every morning and evening until harvest time. Every two days, fresh young papaya measuring 5x5x0.5cm at nine different locations on the culture medium. Every two days, the desiccated immature papaya was replaced with a fresh one. The ZmC molted on the 15th day, and we detached the skins from the substrate every three days by fanning and lifting. Then the *Z. morio* was cultivated.

Feed formulation

This study utilized feed materials, including ground maize, soybean meal, fish meal, ZmC, fine bran, coconut oil, bone meal, and top mix. Ingredients were measured based on the treatment and then homogenized. Started the stirring process with the smallest quantity of material and worked up to the largest, aiming to achieve a homogenous mixture. Each week, the rations were prepared according to the broilers' requirements.

Assessed variables quantifiable characteristics

The treatment commenced when the broiler attained 14 days of age. Feed consumption during a four-week trial period (up to 42 days of age) by documenting the discrepancies between the provided and withheld food. The average weekly feed intake for each bird was determined by dividing the total amount of feed provided by the total number of feed rejections during the experiment. The average weekly weight gain was determined by subtracting the mean initial body weight from the mean final body weight and dividing the difference by the number of experimental weeks. The feed conversion was also calculated. The body weight was assessed after the 42-day trial period. The birds had a 12-hour fasting periods prior to weighing. A single bird randomly from each pen was chosen to assess its body weight. After the experiment, the carcass fraction percentage was assessed by randomly picked one broiler from each replication. Following a 12-hour fasting interval, the slaughter and weighing of the broiler was executed. After that, all internal organs of the slain broiler, including the head, shank, trachea, heart, liver, gizzard, and skin. The carcass weight (grams), excluding the lungs and kidneys, was recorded. The carcass percentage was determined by dividing the carcass weight (grams) by the body weight (grams) and multiplying the quotient by 100%. The percentage of the abdominal fat pad was calculated by dividing its weight by the total body weight and multiplying the quotient by 100%. The weights non-carcass components were documented, including the heart, liver, gizzard, and intestine. The percentage of the heart, liver, gizzard, and intestine was calculated by dividing their weights by the total body weight and then multiply the result by 100.

RESULTS

Effect of treatment on performance

Table 4 depicts the average performance of broilers, encompassing feed intake, weight gain and feed conversion, affected by incorporating ZmC in their diets until 6 weeks of age. The statistical analysis revealed that the inclusion of ZmC in the diet did not significantly affect (P>0.05) feed intake, weight gain, or feed conversion in broilers. The feed intake of broilers did not significantly influence the incorporation of ZmC into the diet (P>0.05). Feed consumption in the 0% ZmC treatment was 562.21g per week, while increasing ZmC usage to 6% led to a comparable feed consumption of 566.20g per week.

Table 4: Feed consumption, body weight gain and feed conversion as affected by the provision of ZmC in broiler diets until 6 weeks of age

Treatments	Feed Consumption (g/head/week)	Body Weight Gain (g/head/week)	Feed conversion
A (0% ZmC)	562.21±2.20	372.97±8.01	1.70±0.42
B (2% ZmC)	564.19±9.64	365.55±9.82	1.76±0.88
C (4% ZmC)	567.91±2.39	369.80±10.03	1.76±0.70
D (6% ZmC)	566.20±1.55	369.78±9.15	1.73±0.63

ns = Non - significant (not significantly different (P>0.05), ZmC = Zophobas morio Caterpillar.

The average weight gain of broilers varied from 365.55 to 372.97g per hen per week. The variability analysis indicated that the incorporation of ZmC in the food exerted an inconsistent influence, which was not statistically significant (P>0.05), on the weight gain of broilers. The FCR for broilers ranged from 1.73 to 1.76. The analysis of variance revealed that the inclusion of ZmC in the diet did not exert a statistically significant effect (P>0.05) on broiler feed conversion.

Effect of treatment on broiler carcass/organs

Table 5 illustrates the impact of ZmC supplementation in broiler diets on average carcass yield, encompassing live weight, carcass percentage and abdominal fat percentage, at 6 weeks of age. The intervention affects the body weight of broilers. The live weight of the broilers ranged from 1410.06 to 1443.38 grams per individual. The analysis of variance indicates that the inclusion of ZmC did not significantly impact the average live weight of the hens (P>0.05).

Table 5: Average live weight, carcass percentage, and abdominal fat percentage of broilers at 6 weeks of age

Treatment	Live Weight (g/head)	Carcass Percentage	Abdominal Fat Percentage
A (0% ZmC)	1443.38±9.40	68.24±3.57	2.01±0.42
B (2% ZmC)	1419.08±6.77	67.79±4.02	1.87±0.22
C (4% ZmC)	1404.82±9.49	66.71±4.49	1.59±0.36
D (6% ZmC)	1410.06±4.45	66.44±3.36	1.03±0.65

ns = Non-significant (not significantly different (P>0.05), ZmC = Zophobas morio Caterpillar.

Including ZmC in broiler feed did not significantly (P>0.05) affect the carcass percentage. The carcass percentage in the 0% ZmC treatment (68.24%) was similar to that in the 6% ZmC treatment (66.44%). The average abdominal fat percentage ranged from 1.03 to 2.01%. The variance analysis indicates that including ZmC in the diet does not significantly affect (P>0.05) the quantity of abdominal fat in broilers.

Table 6 presents the average percentages of physiological organs (liver, gizzard, heart, and intestine) and intestinal length in broilers at 6 weeks of age, as affected by incorporating ZmC in their diet. The mean percentage of broiler liver ranged from 1.63 to 2.03%. The variance analysis indicated that including ZmC in the broilers' diet did not substantially influence their liver percentage (P>0.05).

The minimum percentage of broiler gizzards was 2.29% in Treatment B, whereas the maximum was 2.63% in Treatment C. The analysis of variance indicated that the inclusion of ZmC in the diet did not significantly affect

Table 6: Average non-carcass weight (liver, gizzard, heart, intestine) of broilers at 6 weeks of age

Treatment	Liver Weight (%)	Gizzard Weight (%)	Heart Weight (%)	Intestinal Weight (%)	Intestinal length (cm/head)
A (0% ZmC)	2.00±0.34	2.54±0.61	0.42±0.42	3.18±0.81	160.84±1.44
B (2% ZmC)	1.63±0.59	2.29±0.84	0.28±0.03	3.40±1.31	160.98±1.29
C (4% ZmC)	2.03±0.45	2.63±0.72	0.47±0.22	3.29±0.58	161.48±1.00
D (6% ZmC)	1.74±0.23	2.50±0.90	0.36±0.40	3.40±0.89	162.32±0.82

ZmC: Zophobas morio Caterpillar, All values (mean+SD) in a column differ non-significantly (P>0.05).

(P>0.05) the quantity of broiler gizzards. The increased inclusion of ZmC in the diet augmented the proportion of broiler gizzards. The therapy alters the cardiac percentage in broilers we have looked at how therapy affects the cardiac percentage of broilers. The average heart percentage of broilers ranged from 0.28 to 0.47%. The variance analysis results demonstrated that the inclusion of ZmC in the diet did not significantly (P>0.05) affect broiler heart weight.

The intestinal weight percentage of the typical broiler ranged from 3.18 to 3.40%. The variance analysis demonstrated that the inclusion of ZmC in the diet had no significant effect (P>0.05) on broiler intestinal weight. Treatment A demonstrates the minimum mean broiler intestine length at 160.84cm, whereas treatment E displays the maximum at 162.32cm. The variance analysis results indicated that including fermented durian fruit waste into the broilers' diet had no significant influence (P>0.05) on intestinal length.

DISCUSSION

Effect of treatment on performance of broiler

The feed consumption in treatments B, C and D was not substantially different from that in treatment A. This indicates that including 6% ZmC into broiler diets yields a flavor profile comparable to treatment A (0% ZmC). Notably, despite the inclusion of 6% fish meal in treatment D (6% ZmC), the broilers preferred this treatment due to the presence of 6% ZmC. ZmC generates a desirable flavor that aligns with the palatability of the control diet. According to Abdollahi et al. (2018), feed intake is influenced by palatability. Palatability refers to the appeal of a feed component that stimulates appetite, encouraging consumption. The glutamic amino acids in the ration were consumed at the same rate in the RA treatment with RB, RC, and RD. In the RA treatment, the broiler feed contained 3.80% glutamic amino acids, nearly identical to the 3.83% found in the RD treatment ration. The RA treatment sourced glutamic amino acids from fishmeal, while the RB, RC, and RD treatments substituted fishmeal with ZmC to compensate for the glutamic amino acid content. Li et al. (2011) state that fishmeal comprises 7.29% glutamic acid. Nuraini et al. (2024) report that the amino acid concentration of the ZmC is notably high, with glutamic acid being 6.90% of its composition. Adriani et al. (2014) assert that glutamic acid is the most significant nonessential amino acids for flavor enhancers or flavorings. Glutamic amino acids provide a savory flavor to the feed, stimulating chickens to consume larger quantities, potentially leading to increased feed intake (Muliani 2006). The presence of glutamic amino acids may also influence gut microbiota composition, which is crucial for nutrient absorption and overall health, further impacting feed intake (Taylor-Bowden et al. 2024).

There is no substantial difference in the feed consumption of broilers across treatments B, C and D, which include ZmC, compared to treatment A, which does not. This indicates that the rations exert an equivalent influence on the birds' physiology concerning their feed consumption. The feed consumption in the 0% ZmC treatment yields a diet coloring corresponds to the 6% ZmC treatment, making it advantageous for the animals. Samadian et al. (2019) observed that livestock prefers bright and light-colored feed. The findings of this study are likewise inferior to those reported by Zulfan and Zulfikar (2020), indicated that the feed consumption of the MB-202 broiler strain up to 6 weeks of age was 681.17 g/head/week.

Impact of intervention on weight gain

Body weight augmentation does not significantly vary across treatments B, C, D and E, which incorporate up to 6% ZmC in the diet, in contrast to treatment A, which excludes ZmC. All four treatments exhibited a comparable protein intake among the broilers. This indicated that the protein concentrations in the diets utilized for tissue development were consistent, resulting in unchanged body weight gain in the broilers. Treatment A achieved a protein intake of 96.25g per individual weekly; Treatment B, 95.79g per individual weekly; Treatment C, 97.23g per individual weekly; and Treatment D, 94.12g weekly. Huda et al. (2019) states that broilers exhibit a rapid development rate, necessitating high-quality feed to fulfill their nutritional requirements, particularly for protein. Wattiheluw et al. (2023) assert that metabolic energy and crude protein are essential nutrients required by broilers for growth, including weight gain. The availability of metabolic energy and crude protein provides energy for standard functions and aids in the assimilation of proteins rich in necessary amino acids, increasing body weight. Broilers necessitate high-quality feed for optimal growth. Fishmeal is responsible for the improved quality of rations in treatment A. Furthermore, even though these ingredients are used less in treatments B, C, and D, the formulation still produces rations of the same quality when ZmC is present. The concentration of the amino acid lysine similarly affects the increase in body weight. In the RA therapy, the amino acid lysine in the diet was 1.14%, nearly identical to the 1.1% of lysine in the RD treatment. The RD treatment's comparable lysine amino acid amount suggests that ZmC, which is rich in the important amino acid lysine, could replace the protein content of fish meal.

Finke (2015) reports that the German caterpillar contains 2.9% lysine, an important amino acid comparable to the 5.00% lysine concentration in fishmeal, as Scott et al. (1982) reported. The lysine amino acid requirement for broilers in the finisher phase is at least 1% (NRC 1994). Dita et al. (2020) assert that feeding rations enriched with lysine can enhance weight gain and expedite growth rates in chickens. Cafe and Waldroup (2006) assert that the availability and balance of amino acids in hens' diets affect their weight. Linoleic essential fatty acids also influence the weight increase of broilers. Finke (2015) states that German caterpillars possess linoleic essential fatty acids ranging from 15.6 to 23.4%, above the 8.30% found in fishmeal, as Zahroh et al. (2015) reported linoleic acid is required in poultry diets at a minimum concentration of 1% to facilitate growth (NRC 1994).

The body weight growth of broilers in treatments B, C, D, and E, which included ZmC, was not significantly different from treatment A, which excluded ZmC products. Animal growth is contingent upon feed. The elevated nutritional composition in feed enables livestock to attain a specified body weight at a younger age. Weight gain signifies the accumulation of nutrients contributing to the development of body tissues. According to Boyd et al. (2022), body weight gain is influenced by the amount of protein in meat and other essential nutrients for tissue growth. Subjected to treatment D (20% ZmC), the MB-202 broiler strain from PT Japfa Comfeed Indonesia showed a weekly weight growth of 369.78g per individual until reaching 6 weeks of age. This study's broiler weight gains surpassed than the findings reported by Zulfan and Zulfikar (2020). Their findings showed a weekly weight rise of 376.16g/head for the MB-202 strain until 6 weeks of age.

Effect of treatment on feed conversion efficiency

The feed conversion rates in treatments B, C and D, including up to 6% ZmC in the diet, do not significantly differ from treatment A's (control). The elevated feed consumption, closely correlated with significant body weight growth across all five treatments, results in comparable feed conversion rates. In treatment A, increased feed consumption is associated with considerable body weight gain, which did not significantly differ from the feed conversion ratios in treatments B, C and D. We calculate feed conversion by dividing ration consumption by body weight growth, which suggests that both the amount of ration consumed and the increase in body weight impact this metric. Borey et al. (2020) contends that the digestibility of broilers influences the feed conversion ratio, the quality of the consumed feed, and the consistency of food component quantities in the feed. Davison et al. (2023) asserts that the feed conversion ratio reflects the feed necessary for each kilogram of weight increase. A reduced feed conversion rate indicates improved feed quality. Decreasing feed conversion signifies that animals use less feed to attain the same growth rate, hence reducing feed costs and improving farmer profitability. Feed conversion factors encompass quality, ambient circumstances, stress levels, animal health, water availability, and ration quality. According to Li et al. (2023), the quality of feed raw materials significantly influences ration conversion efficiency. Using raw materials with low nutritional value or contamination may impair broiler production performance. The study established a mean feed conversion ratio of 1.73 for treatment D (6% ZmC). This study's broiler ration conversion was better than that of Nuraini et al. (2022), who reported an MB 202 broiler FCR to be 1.78. Zulfan and Zulfikar (2020) reported that the FRC for the MB-202 broiler strain up to 6 weeks of age was 1.82.

Impact of treatment on broiler carcass yield

The research indicates that incorporating 6% ZmC into the diet and replacing 75% of imported fish meals enables broilers to achieve equivalent live weight gain as those fed the control diet (0% ZmC with 75% fish meal). The disparity in broiler live weight between treatment A (utilizing 75% fish meal without ZmC) and treatments B, C and D, which incorporated ZmC, is attributable to all four treatments consuming identical quantities of feed. Uniform feed intake provides the same nutrients for tissue development, leading to a stable live weight in the produced broilers. Quintana et al. (2023) argument aligns with this; an increase in consumption leads to a corresponding increase in body weight, and vice versa. Zhou et al. (2024) asserted that the amount and quality of feed ingested influence live weight.

The uniform protein consumption in each treatment accounts for the equal life weight of broilers. The protein consumption aligns with the protein concentration in the rations for each treatment, varying from 22 to 22.08%. Protein consumption in treatment D (6% ZmC/75% fish meal replacement) was 94.12g/head/week, almost identical to treatment A's (0% ZmC/75% fish meal) at 96.25 g/head/week. According to Yulianti et al. (2020), the degrees of protein synthesis in the body correlate with protein consumption, influencing broiler growth, including live weight. The little variations in broiler live weight between treatments A, B, C and D indicate that the protein quality of the diets is consistent among all five treatments. The protein quality in treatment D (6% ZmC, substituting 75% fish meal) can match the protein quality in treatment A (0% ZmC, 75% fish meal). The dietary lysine amino acid concentration for treatment A is 1.14%, sourced from imported fish meal, soybean meal, fine bran and ground maize. The lysine content is as follows: fish meal contributes 5.00% (Scott et al. 1982), soybean meal contributes 2.60%, fine bran contributes 0.77%, and crushed maize contributes 0.20% (Nuraini et al. 2023). In treatment D (6% ZmC/replacement of 75% fish meal), the lysine amino acid concentration in the diet is 1.1%, nearly identical to treatment A's. Treatment D includes *Z. morio* larvae, soybean meal, fine bran, and crushed maize, which supply the amino acid lysine.

According to Nuraini et al. (2024), *Z. morio* larvae contains 4.75% lysine amino acid. Dey et al. (2024) contends that the amino acid lysine is crucial for growth and meat production. Administering lysine at a concentration of 1.06% during the finisher phase can improve the growth and development of chicken breast. Furthermore, Onbaşılar et al. (2024) posited that the weight of chickens is influenced by the availability and equilibrium of amino acids in their food. Essential fatty acids, such as linoleic acid (omega-6), significantly affect broiler longevity. In the D treatment, the linoleic acid content of the ration is 5.86% greater than that of the rations in treatment A, which is 2.76%. Nuraini et al. (2024) indicate that the ZmC possesses necessary fatty acids, notably with a linoleic acid concentration of 34.24%. The fish meal comprises 8.30% linoleic acid. NRC (1994) asserts that essential fatty acids, particularly linoleic acid, are crucial for the growth of cattle and poultry. Broiler diets must include at least 1% linoleic acid. The chitin content of the ZmC was 12.54%, whereas in treatment D, it rose to

0.75%. Broilers may endure treatment D (6% ZmC/75% fish meal replacement) with a chitin content of 0.75%, demonstrating no adverse effects on broiler live weight. Onbaşılar et al. (2024) states that incorporating 1.98% chitin-containing flour waste shrimp into the diet is still suitable for broilers.

The live weight of the chickens across all treatments was approximately uniform, resulting in comparable percentages of deceased chicks. The carcass weight of broilers is closely associated with their live weight. Horhoruw and Kewilaa (2024) posited a strong correlation between carcass weight and live weight, indicating that an animal's live weight directly affects its carcass weight and vice versa. This corresponds with Animashahun et al. (2022) claim that broilers' fat content dictates carcasses' height and quality. The percentage of belly fat directly correlates with the metabolizable energy content. The different amounts of belly fat in broilers given treatments A, B, C and D can be explained by the fact that the diets have the same amount of metabolizable energy, meaning that the animals store the same amount of energy as fat. Kim and Voy (2021) asserts that excessive energy intake leads to fat development, while the age of animals is responsible for fat buildup. Tchablémane et al. (2024) asserts that the ineffectiveness of treatment of belly fat arises from consistent feed consumption across all treatments. Chen et al. (2023) contends that the feed provided to livestock affects the overall formation of belly fat in broiler chickens' distribution of body parts. The live weight of broilers exhibits no significant variation among the four treatments, leading to an identical amount of belly fat. Abdominal adiposity develops together with the growth in the body mass of broilers. Liu et al. (2023) asserts that live weight affects belly fat weight, corresponding with the broiler's growth cycle, which initiates the formation of bones, muscles, and fat. Adipose tissue develops subsequently after the creation of skeletal and muscular structures. The predominant components of broilers' live weight are bones and muscles.

Impact of treatment on organs

Incorporating ZmC at 6% in the diet does not affect the relative weight of the broiler liver. Nasoetion et al. (2019) contends that dietary protein levels influence liver mass. This study maintains the feed protein at a constant 21% while varying ZmC in the ratio from 0 to 6%, thereby not affecting broiler liver weight. A protein-enriched diet typically elevates the hepatic mass of broiler chickens. This results from the liver's function in protein metabolism, wherein it processes and stores amino acids obtained from feed (Kurniawan et al. 2021). Besides protein, the composition of the diet, which includes fat and fiber, also influences liver weight. Consumption of high-fat diets may result in hepatic fat storage, potentially leading to an unhealthy increase in liver mass. Conversely, a high-fiber diet can support digestive health and avert aberrant liver enlargement (Prasetyo et al. 2021). This study found that the administration of 6% ZmC resulted in a liver weight percentage of 1.74. This result is inferior to the 1.81 (Amir et al. 2022).

Treatments A, B, C and D exhibited identical gizzard weights (0-6% ZmC in the broiler feed). Feed types influence gizzard mass, including mash, crumble, and pellets. Chickens consuming pelleted feed generally exhibit greater gizzard weights than those fed mash or crumble feed. The meal's denser texture facilitates digestion, enhancing gizzard activity (Herlinae et al. 2022). The gizzard weight percentage in this study, at 2.50%, is below the standard range. Jha and Mishra (2021) states that the average gizzard weight ranges from 1.6 to 3.03%.

Incorporating up to 6% of ZmC into the diet did not affect the proportion of heart weight. Numerous factors, including live weight, nutrient composition of feed, type of feed and supplementation, presence of anti-nutrients, age, and sex, affect the heart weight of broiler chickens. A positive correlation exists between live weight and heart weight, whereby an increase in heart weight typically coincides with an increase in live weight. Protein-enriched feed promotes cardiac development, whereas feed high in fat may result in adipose accumulation within the heart. Moreover, feed additives and the impact of anti-nutritional factors are significant contributors. Appropriate feeding techniques can enhance digestion efficiency and promote organ development (Nilawati and Gustian 2023). This study demonstrated that applying 6% ZmC yielded a cardiac weight percentage of 0.36. This outcome is inferior to Amir et al. (2022) research, which reported a value of 0.50. For including *Z. morio* in broiler diets. Effect of Treatment on Intestinal Weight Proportion in Broilers Incorporating ZmC at a maximum concentration of 6% in the diet did not influence the gut weight percentage. Various factors, such as feed type and quality, genetic variations among strains, environmental temperature and airflow, and population density, influence the gut weight of broilers (Hartcher and Lum 2019).

Diets with elevated protein levels, namely 18% or greater, may extend the length of the small intestine. This results from enhanced digestibility and improved nutritional absorption, which fosters intestine growth (Farida 2022). Subsequently, Farida (2022) elucidates that gut length likewise augments with the age of the chicken. Older hens often possess elongated intestines as a result of the continuous growth and maturation of the digestive system.

Conclusion

This study concludes that *Zophobas morio* caterpillar can be used at up to 6% in the diet, resulting in a 75% reduction in fish meal usage while preserving performance and carcass output. No adverse impact on physiological organs enhances the quality of broiler meat.

Author's Contribution: NN was responsible for formulating the study and assessing the manuscript. NN, MM, YSN, KMS, I, FH. They conducted field and laboratory investigations and gathered information. NN, MM and YSN conducted the data analysis and wrote and polished the manuscript. All authors have reviewed, assessed, and approved the final manuscript.

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REFERENCES

Abdollahi MR, Zaefarian F and Ravindran V, 2018. Feed intake response of broilers: Impact of feed processing. Animal Feed Science and Technology 237: 154-165. https://doi.org/10.1016/j.anifeedsci.2018.01.013

Adámková A, Kouřimská L, Borkovcová M, Kulma M and Mlček J, 2016. Nutritional values of edible coleoptera (*Tenebrio molitor, Zophobas morio* and *Alphitobius diaperinus*) reared reared in the Czech Republic. Potravinarstvo 10(1): 663–671. https://doi.org/10.5219/609

Adriani L, Rochana A, Yulianti AA, Mushawwir A and Indrayani N, 2014. Profile serum glutamate oxaloacetate transaminase (SGOT) and glutamate pyruvate transaminase (SGPT) level of broiler that was given noni juice (Morinda citrifolia) and palm sugar (Arenga piata). Lucrari Stiintifice Seria Zootehnie 62: 101–105

Akram MZ, Sureda EA and Comer L, 2024. Assessing the impact of the hatching system and body weight on the growth performance, caecal short-chain fatty acids, microbiota composition and functionality in broilers. Animal Microbiome 6: 41. https://doi.org/10.1186/s42523-024-00331-6

Amir YS, Siregar R, Lutfi UM, Fati N, Kunia D and Malvin T, 2022. Physiological organ performance of broilers with the addition of ginseng (Talinum paniculatum Gaertn) leaf meal mix in the diet. Jurnal penelitian pertanian Politeknik Pertanian Payakumbuh 21(2): 54-60. https://doi.org/10.32530/lumbung.v21i2.569

Animashahun RA, Aro SO, Onibi GE, Alabi OO, Okeniyi FA, Olawoye SO and Falana MB, 2022. Carcass indices and meat quality of broiler chickens fed diets containing fortified fermented cassava stump. Chilean Journal of Agricultural & Animal Sciences 38(1): 124-132. https://doi.org/10.29393/CHJAAS38-12CIRM70012

Barroso FG, de Haro C, Muros MJS, Venegas E, Sánchez AM and Bañón CP, 2014. The potential of various insect species for use as food for fish. Aquaculture 422–423: 193–301. https://doi.org/10.1016/j.aquaculture.2013.12.024

Borey M, Estelle J and Caidi A, 2020. Broilers divergently selected for digestibility differ for their digestive microbial ecosystems Plos One 5(5): e0232418. https://doi.org/10.1371/journal.pone.0232418

Boyd CE, McNevin AA and Davis, 2022. The contribution of fisheries and aquaculture to the Global protein supply. Food Security 14(3): 805–827. https://doi.org/10.1007/s12571-021-01246-9

Cafe MB and Waldroup PW, 2006. Interactions between levels of methionine and lysine in broiler diets changed at typical industry intervals. International Journal of Poultry Science 5(11): 1008–1015. https://doi.org/10.3923/ijps.2006.1008.1015

Chen Y, Akhtar M, Ma Z, Liu UT and Liu H, 2023. Chicken cecal microbiota reduces abdominal fat deposition by regulating fat metabolism. Biofilms and Microbiomes 9(1): 28. https://doi.org/10.1038/s41522-023-00390-8

Davison C, Michie C and Tachtatzis C, 2023. Feed Conversion Ratio (FCR) and performance group estimation based on predicted feed intake for the optimization of beef production. Sensors 23(10): 4621. https://doi.org/10.3390/s23104621

Dey B, Akhter S, Hasan HA, Tanim LK, Sikder MR and Ahammed M, 2024. Inclusion of dietary lysine on growth, carcass yields, and serum biochemical indices in broiler chickens. Bangladesh Journal of Animal Science 53(2): 68-76. https://doi.org/10.3329/bjas.v53i2.74541

Dita INAB, Rukmini NK and Yudiastari NM, 2020. Effect of lysine and methionine in the ration on the performance of native chickens. Sustainable Environment Agricultural Science 4(2): 157-161. http://dx.doi.org/10.22225/seas.4.2.2322.157-161

Farida, 2022. Effect of fishmeal feeding on relative weight and length of broiler intestine.Jurnal Ilmiah Peternakan Halu Oleo 4(2): 125–126. https://doi.org/10.56625/jipho.v4i2.25069

Fu C, Cheema WA, Mobashar M, Shah AA and Alqahtani MM, 2024. Insects as Sustainable Feed: Enhancing animal nutrition and reducing livestock environmental impression. Journal of Animal Physiology and Animal Nutrition. https://doi.org/10.1111/jpn.14055

Finke MD, 2015. Complete nutrient content of four commercially available feeder insects fed enhanced diets during growth. Zoo Biology 34: 554–564. https://doi.org/10.1002/zoo.21246

Hartcher KM and Lum HK, 2019. Genetic selection of broilers and welfare consequences: a review. World's Poultry Science Journal 76(1): 154-167. https://doi.org/10.1080/00439339.2019.1680025

Herlinae H, Kusuma ME and Yulli Y, 2022. Carcass and giblet weight of broiler chickens with the addition of fermented feed of Kelakai and rice bran in commercial feeds. Journal of Tropical Animal Science 11(2): 41-47.

Horhoruw W and Kewilaa AI, 2024. Correlation between live weight and carcass weight and giblet weight in broiler chickens given white turmeric extract. Advances in Social Humanities Research 2(11): 1245-1250. https://doi.org/10.46799/adv.v2i11.308

Huda S, Mahfudz LD and Kismiati S, 2019. Effect of protein step down and acidifier addition in feed on performance. Jurnal Sain Peternakan Indonesia 14(4): 404-410. https://doi.org/10.31186/jspi.id.14.4.404-410

Jassim JM, 2010. Effect of local fish meal (Liza abu) as protein concentration in broiler diets. Journal of Poultry Science 9(12): 1097–1099. https://doi.org/10.3923/ijps.2010.1097.1099

Jha R and Mishra P, 2021. Dietary fiber in poultry nutrition and its effects on nutrient utilization, performance, gut health, and the environment. Journal of Animal Science and Biotechnology 12(51): 2–16. https://doi.org/10.1186/s40104-021-00576-0

Kim M and Voy BH, 2021. Fighting fat with fat: N-3 polyunsaturated fatty acids and adipose deposition in broiler chickens. Frontiers in Physiology 12: 1-8. https://doi.org/10.3389/fphys.2021.755317

Kurniawan J, Tugiyanti E and Susanti E, 2021. Effect of feed additive addition as a substitute for antibiotics against feed consumption and body weight gain of broiler chickens. Journal of Animal Science and Technology 3: 134-140. https://doi.org/10.20884/1.angon.2021.3.2.p134-140

Lee HN, Yeom GL, Kim YB, Yum KH, Park JY, Lee WT, Seo HS, Lee SY and Kim JH, 2024. Prospects of using insects as alternative protein sources in broiler diets. Journal of Insects as Food and Feed 10: 1–35. https://doi.org/10.1163/23524588-00001140

Li X, Rezaei R, Li P and Wu G, 2011. Composition of amino acids in feed ingredients for animal diets. Amino Acids 40(4): 1159–1168. https://doi.org/10.1007/S00726-010-0740-Y

Li X, Wu X, Ma W, Xu H, Chen W and Zhao F, 2023. Feeding behavior, growth performance and meat quality profile in broiler chickens fed multiple levels of xylooligosaccharides, Animals 13(16): 2582. https://doi.org/10.3390/ani13162582

Liu X, Wong C, Wang Y, Wang C, Sun X, Zhu Y, Yang X, Zhang L and Liu Y, 2023. Age-associated changes in the growth development of abdominal fat and their correlations with cecal gut microbiota in broiler chickens. Poultry Science 102(9): 102900. https://doi.org/10.1016/j.psj.2023.102900

Medvedev AY, Vasiliev AA, Guseva Yu A, Smetankina VG and Figurak SN, 2023. Efficiency of rearing Tenebrio molitor and Zophobas morio larvae as a feed protein source. Glavnyj zootehnik (Head of Animal Breeding) 9: 37–48. https://doi.org/10.33920/sel-03-2309-04

Muliani H, 2006. Growth spurrer power of monosodium glutamic and it's side effect on chicken's kidney. Jurnal Kimia Sains dan Aplikasi 9: 45-54. https://doi.org/10.14710/jksa.9.2.45-54

Montero-Prado P, Montero R and Atencio-Valdespino R, 2024. Insects as protein supplements in the livestock production animals: A sustainable and efficient alternative. Agronomia Mesoamericana 35: 60354. https://doi.org/10.15517/am.2024.60354

Nasoetion MH, Atmomarsono U, Sunarti D and Suthama N, 2019. Growth performance and lipid profile of broilers fed different levels of purple sweet potato extract and raised under different stocking densities. Livestock Research for Rural Development 31(7): 97.

Nilawati N and Gustian A, 2023. Percentage of broilers' liver, heart, and abdominal fat with Areca nut powder in the diet. Wahana Peternakan 7(2): 126-134. https://doi.org/10.37090/jwputb.v7i2.1008

NRC, 1994. Nutrient Requirments of Poultry. Ninth Revised Edition. National Academy Press Washington, DC.

Nuraini, Mirzah, Nur YS and Harnentis, 2022. Improving Azolla microphylla through fermentation lignocellulolytic fungi and its application in Broiler feed. Advances in Animal and Veterinary Sciences 10(5): 1090-1100. http://doi.org/10.17582/journal.aavs/2022/10.5.1090.1100

Nuraini N, Nur YS, Djulardi A, Amizar R and Sari YC, 2023. The effect of dietary supplementation of Hongkong caterpillar (Tenebrio molitor) on quail egg quality. Journal of World Poultry Research 13(2): 253-260 https://doi.org/10.36380/jwpr.2023.28

Nuraini, Mirzah, Nur YS, Harnentis, Jalil A and Widiati I, 2024. Protein quality, crude fat and chitin of Zophobas morio caterpillar with different compositions of cultivated media. Animal Science Faculty, Universitas Andalas.

Obike OM, Nosike R, Onunkwo DN, Obi OC, Obasi E and Ofo M, 2020. Growth rate, phenotypic correlation and repeatability estimates of body weight and linear body traits of Cobb and Arbor Acre broiler strains. Nigerian Journal of Animal Production 44(1): 39–47. https://doi.org/10.51791/NJAP.V44I1.459

Onbaşılar EE, Gündoğar UC, Çapar AH, Yalçın S, Ahlat O, Yüceer ÖB, Özbeyaz C, Bundur A, Gebeş ES, Yucer-Ozkul B, Unal N and Ozbeyaz C, 2024. The effects of shrimp waste added to broiler diets on growth performance, slaughter and carcass characteristics, intestinal morphology, bone traits, and fatty acids in the meat. Journal of Animal Physiology and Animal Nutrition. https://doi.org/10.1111/jpn.14064

Prasetyo B, Mahfudz LD and Nasoetion MH, 2021. Physical quality of broiler meat reared in closed-house cages at different altitudes. Jurnal Sain Peternakan Indonesia 16(1): 61-67. https://doi.org/10.31186/jspi.id.16.1.61-67

Prayogo WP, Suprijatna E and Kurnianto E, 2017. Comparison of two growth models in analyzing the growth of Magelang ducks in Banyubiru non-ruminant livestock breeding and cultivation center. Kabupaten Semarang. Jurnal Sain Peternakan Indonesia 12(3): 239–247. https://doi.org/10.31186/jspi.id.12.3.239-247

Quintana OGA, Alfaro WMC, Oviedo REO, Ruiz RJR, Bernal ALC and Martinez BGD, 2023. Data analytics of broiler growth dynamics and feed conversion ratio of broilers raised to 35 d under commercial tropical conditions. Animals 13(15): 2447. https://doi.org/10.3390/ani13152447

Samadian F, Eskandari JM and Behzadi MRB, 2019. Preference of broiler chickens for feed 604 color. Research in Animal Production10 (25): 1-7. https://dx.doi.org/10.29252/RAP.10.25.1

Santoso EP, Afrila A and Fitasari E, 2017. Improve German caterpillar production by utilizing market vegetable waste in different feed media formulations. Buana Sains 17(1): 33–42. http://doi.org/10.33366/bs.v17i1.576

Scott ML, Nesheim MC and Young RJ, 1982. Nutrition of the Chicken. New York: Ithaca.

Slimen I, Yerou H, Larbi MB, M'hamdi N and Najar T, 2023. Insects as an alternative protein source for poultry nutrition: a review. Frontiers in Veterinary Science 10: 1200031. https://doi.org/10.3389/fvets.2023.1200031

Sjofjan O, Adli DN, Natsir MH, Nuningtyas YF and Budianto AD, 2022. Comparison predicted using the nonlinear model using the nonlinear model and in vivo studies of broiler growth production after feeding different levels of fermented tamarind flour used to replace soya bean meal. IOP Conference Series: Earth and Environmental Science 1041: 012010. https://doi.org/10.1088/1755-1315/1041/1/012010

Taylor-Bowden T, Bhogoju S, Khwatenge CN and Nahashon SN, 2024. The impact of essential amino acids on the gut microbiota of broiler chickens. Microorganisms 12(4): 693. https://doi.org/10.3390/microorganisms12040693

Tchablémane Y, Tchabltien S, Claude KC, Tchilabalo P, Simplice KD and Wéré P, 2024. Effects of palm (Elaeis Guineensis) oil on performance, thermotolerance, and Welfare broiler chickens in heat stress conditions. Journal of World's Poultry Research 14(1): 12-22. https://doi.org/10.36380/jwpr.2024.2

Wattiheluw MJ, Joris L, Wiesje MH and Shirley F, 2023. Effect of using fish waste to support broiler performance. Jurnal Ilmiah Keagamaan dan Kemasyarakatan 17(2). https://doi.org/10.35931/aq.v17i2.2010

Yulianti S, Yuanita I, Suthama N and Wahyumi HI, 2020. Protein digestibility and meat protein mass in broiler chickens fed a combination of dayak onion extract and Lactobacillus acidophilus. Seminar Nasional PSDA-PegApi, Corpus ID: 213823761

Zahroh NF, Edison and Sumarto, 2015. Characteristics and fatty acid profile jelawat fish meal (Lepbarbus hoevenii) with different cooking methods. Jurnal Online Mahasiswa Fakultas Perikanan dan Ilmu Kelautan Universitas Riau 2(2): 1-11.

Zhou S, Watcharaanantapong P, Yang X, Thornton T, Gan H, Tabler and Zhao Y, 2024. Evaluating broiler welfare and behavior as affected by growth rate and stocking density. Poultry Science 103(4): 103459. https://doi.org/10.1016/j.psj.2024.103459

Zulfan and Zulfikar, 2020. Evaluation of performances and income over feed & chick cost (IOFCC) of three broiler chicken strains commonly marketed in Aceh. Jurnal Agripet 20 (2): 136-142. http://doi.org/10.17969/agripet.v20i2.15410