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Exploration of Black Soldier Fly Larvae Degraded Manure (DM) as an Alternative Enzyme Source Feed on Growth and Production Performance of Japanese Quail (*Coturnix coturnix japonica*) in the Layer Phase

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ABSTRACT

Background: This study aimed to evaluate the effect of Degraded Manure (DM) meal derived from the biodegradation of poultry manure by *Hermetia illucens* L. larvae as a partial replacement for fish meal in the diet of laying quails (*Coturnix coturnix japonica*).

Methods: A total of four dietary treatments were formulated, consisting of a control diet (R0) and diets containing 4% (R1), 8% (R2) and 12% (R3) DM meal. Parameters measured included feed intake, body weight gain, feed conversion efficiency, egg production and the activity of enzymes (amylase, lipase and protease) in the resulting DM meal.

Result: The results showed that increasing the level of DM meal in the diet significantly influenced feed intake (p<0.01), with higher consumption observed in treatments containing DM. However, no significant differences (p>0.05) were found in body weight gain or feed conversion efficiency among treatments, indicating stable nutrient utilization across diets. Egg production (number of eggs and total egg weight) demonstrated comparable or improved values in the DM-containing treatments, particularly at 8% and 12% inclusion levels. Enzyme activity analysis confirmed the presence of active amylase, lipase and protease in DM meal, suggesting enhanced nutrient digestibility potential. These findings indicate that DM meal can be included at up to 12% in the diet of laying quails without negative effects on performance, while offering added value through functional enzymes and improved feed sustainability. DM meal represents a viable, economical and environmentally responsible protein alternative in poultry feeding systems.

Key words: Alternative protein, DM meal, Egg production, Enzyme activity, Feed efficiency, *Hermetia illucens* L. larvae, Laying quail, Sustainable feed.

INTRODUCTION

Japanese quail (*Coturnix coturnix japonica*) is widely cultivated as a source of meat and eggs due to its rapid growth rate, early onset of lay and relatively low maintenance cost. However, the productivity and product quality of quail are closely influenced by feed composition, particularly protein availability and digestive efficiency. closely influenced by feed composition, particularly protein availability and digestive efficiency. A common issue encountered in quail production is the relatively firm texture of the meat, which is associated with suboptimal nutrient utilization. At the same time, the dependence on conventional protein sources, such as fish meal and commercial concentrates, contributes to high feed costs, thereby reducing economic returns for farmers. This situation underscores the need for alternative, affordable and nutritionally functional feed ingredients that can support production performance while lowering feed expenses (Cullere *et al.*, 2018; Wang, 2019). Effect of energy to protein ratio using alternative feed ingredients on growth performance and nutrient digestibility in broilers (Alqazzaz *et al.*, 2019).

One promising approach in sustainable feed development is the utilization of degraded manure (DM) produced through the bioconversion activity of Black Soldier Fly (*Hermetia illucens* L.) larvae. These larvae are capable of degrading organic waste, transforming it into a nutrient-rich substrate containing proteins, minerals and active enzymes such as protease, amylase and lipase. The enzymatic properties of DM are of particular interest, as they may enhance nutrient breakdown and absorption, thereby

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improving feed efficiency and physiological performance in poultry.

Additionally, DM is locally available and inexpensive to produce, making it a potential feed ingredient aligned with sustainable agricultural practices (Čičková *et al*., 2015). Black Soldier Fly (*Hermetia illucens* L.) can affect shading and pore closure as its prepupa develops (Toar *et al*., 2023).

Despite increasing interest in the use of *Hermetia illucens L.* derived products, research has predominantly focused on the use of larval meal as a protein substitute and very limited studies have examined DM specifically as a natural enzyme source in the diets of laying-phase Japanese quail. Moreover, the relationship between digestive enzyme activity provided by DM and quail production outcoms especially feed intake, growth, feed conversion efficiency and egg production performance has not yet been systematically evaluated. This gap highlights the need to determine whether incorporating DM at varying inclusion levels can produce measurable improvements in biological and production responses (Liu and Zhao, 2019).

Furthermore, the laying phase of quail production represents a critical period where nutritional balance must be maintained to support sustained egg output and reproductive metabolism. During this stage, dietary components that enhance digestive efficiency are highly valuable, as they can improve nutrient partitioning toward egg formation rather than mere maintenance or growth. Given the presence of active digestive enzymes in DM, it holds potential to act not only as a nutrient source but also as a biological feed additive that improves digestive performance. Enhancing enzymatic activity in the digestive tract may lead to higher feed conversion efficiency, improved nutrient utilization and increased egg yield and quality (Čičková *et al*., 2015; Li, 2025).

Therefore, this study aims to evaluate the effect of DM inclusion (0-12%) as a partial substitute for basal feed on feed intake, body weight gain, feed conversion ratio, egg production, egg weight and enzyme activity in Japanese quail during the laying phase. The findings of this research are expected to provide a practical and environmentally responsible feed solution that supports the reduction of feed costs and promotes sustainable quail farming practices.

The novelty of this study lies in its evaluation of DM n ot only as a nutrient component but also as a functional source of digestive enzymes and specifically in its application to quail in the egg-producing phase rather than broiler-type poultry. Based on the nutritional and functional characteristics of DM, it is hypothesized that the inclusion of up to 12% DM in quail diets does not negatively affect performance and may improve feed utilization efficiency and egg production outcomes (Heuel, 2023; Bovera, 2018).

MATERIALS AND METHODS

Research location and duration

This study was conducted at the Poultry Production Unit, Faculty of Animal Science, Sam Ratulangi University, Manado, Indonesia. The experimental period, including adaptation and feeding treatment, lasted for 6 weeks.

Experimental animals and housing

A total of 200 Japanese quails (*Coturnix coturnix japonica*) in the early laying phase (around 6 weeks old) were used in this study. The quails were randomly divided into 40 cage units measuring 50 × 40 × 35 cm, with 5 quails in each cage. Each cage was equipped with a feeder and a waterer, with drinking water provided ad libitum. Lighting and ventilation were regulated routinely every day.

Experimental design

The experiment was conducted using a Completely randomized design (CRD/RAL) consisting of four dietary treatments and five replications, with each replication consisting of five birds, resulting in 40 experimental units. The dietary treatments were as follows:

Treatment	Feed composition
R0	100% basic feed (control)
R1	96% basic feed + 4% DM (Degraded Manure)
R2	92% basic feed + 8% DM (Degraded Manure)
R3	88% basic feed + 12% DM (Degraded Manure)

Variables measured

The following performance and physiological parameters were observed:

1. Feed intake (g/bird/day)

Feed consumption was recorded daily and calculated as the difference between feed offered and feed refused.

2. Body weight gain (g/bird)

Body weight was recorded at the beginning and end of the experimental period.

3. Feed conversion ratio (FCR)

Calculated as total feed intake divided by total weight gain or egg mass.

4. Egg production (%) and egg weight (g)

Eggs were collected daily, counted and weighed using a digital scale.

5. Digestive enzyme activity (Protease, Amylase, Lipase)

Enzyme activity was analyzed using the DNS (Dinitrosalicylic Acid) colorimetric method for amylase and corresponding standard assays for protease and lipase according to laboratory procedures.

Statistical analysis

The data obtained from the experiment were tabulated and analyzed using analysis of variance (ANOVA) based on the completely randomized design (CRD) model. Statistical analysis was performed using the SPSS software package to determine the effect of dietary treatments on the observed variables. When a significant effect was found ($p<0.05$), Duncan's multiple range test was applied to compare the differences among treatment means (Steel and Torrie, 1994). The mathematical model used in this study is as follows:

$$Y_{ij} = \alpha + T_i + \varepsilon_{ij} Y_{ij}$$

Where,

Y_{ij} = Observation value for the treatment i and replication j.

α = Overall mean.

T_i = Effect of treatment.

ε_{ij} = Experimental error.

Experimental procedures

Preparation of DM (Degraded manure)

The manure produced was subjected to biodegradation by *Hermetia illucens* L. larvae. Once the degradation phase was complete, the resulting substrate (DM) was collected and sun-dried until it reached a stable moisture level suitable for storage. The dried substrate was then ground into a fine powder to obtain DM meal, which was subsequently incorporated into the formulated experimental diets alongside standard feed ingredients including yellow corn, rice bran, soybean meal, coconut meal and fish meal, according to the established dietary composition. The research flowchart is included in the research procedure; Fig 1, flowchart of the biodegradation process of poultry manure by Hermetia illucens larvae and experimental workflow for the application of degraded manure (DM meal) in the diet of laying quails. The sample preparation was only taken from 20 cage units, the rest are kept as reserve.

Enzyme extraction procedure

The extraction of digestive enzyme fractions from the DM meal was carried out as follows:

1. DM samples were finely homogenized using a blender.
2. For every 1 g of sample, 5 mL of 0.2 M acetate buffer (pH 5) was added.
3. The mixture was stored for 10 minutes, with intermittent shaking and then filtered using sterile cotton.
4. The filtrate was centrifuged at 2,000 rpm for 20 minutes at 5°C.
5. The resulting supernatant (enzyme extract) was collected, measured for final volume and stored in sterile microtubes for enzymatic activity assays.
6. Further analyses were conducted to determine enzyme activity levels.

Enzyme activity assay (DNS Method, Modified AOAC)

The enzymatic activity of the extracts was analyzed using the 3,5-dinitrosalicylic acid (DNS) method, adapted for carbohydrate hydrolysis evaluation:

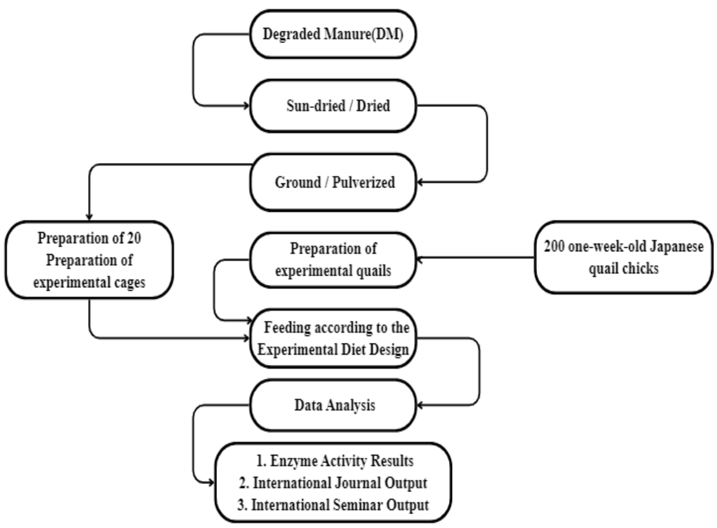
1. The extracted enzyme solution was incubated with the DM substrate at 30°C for 3 minutes, allowing hydrolysis to occur and the release of reducing sugars.
2. The reaction was terminated by adding DNS reagent, which reacts with reducing sugars to form a measurable color complex.
3. The mixture was boiled briefly to accelerate the reaction, then cooled under running water.
4. The sample was diluted with 20 mL of distilled water.
5. The absorbance was measured at 550 nm using a spectrophotometer.

A glucose standard curve was constructed to determine the concentration of reducing sugars released, which was then used to calculate enzyme activity (U/mL).

$$\frac{\text{Enzyme activity} = C \times 1/T \times 1 \text{ unit}}{1 \text{ micromole}}$$

Where,

C = Concentration of maltose per mL of enzyme extract (micromole).



Source: Author's original illustration based on research implementation (2025).

Fig 1: Flowchart of the biodegradation process of poultry manure by *Hermetia illucens L* larvae and experimental workflow for the application of degraded manure (DM meal) in the diet of laying quails.

Table 1: Nutrient composition of feed ingredients used in the experimental diets.

Feed ingredient	Protein (%)	Fat (%)	Crude fiber (CF) (%)	Calcium (Ca) (%)	Phosphorus (P) (%)	M.E (kcal/kg)
Yellow corn	8.80	3.90	0.00	0.02	0.30	3370
Rice bran	12.00	13.00	12.00	0.12	1.50	1630
Fish meal	60.00	9.00	1.00	5.50	2.80	3080
Concentrate	22.00	7.00	7.00	3.20	1.00	2800
DM meal	51.10	52.75	2.06	9.84	3.20	2940

Source: Calculated based on feed ingredient nutrient values.

T = Incubation time (minutes).

1 unit of enzyme = The amount of enzyme required to release 1 micromole of maltose per minute per mL of enzyme extract.

Table 1, presents the nutrient composition of the feed ingredients used in the experimental diets. The feed components include yellow corn, rice bran, fish meal, commercial concentrate and degraded manure (DM Meal). Fish meal contains the highest protein level (60%), making it the primary protein source in the diet. Meanwhile, the DM Meal also contains relatively high protein (51.10%), indicating its potential role as an alternative protein source. The highest fat content is observed in the DM Meal (52.75%), which may contribute significantly to the energy supply in the diet. Rice bran has the highest crude fiber content (12%), indicating its role in providing dietary fiber. In terms of mineral levels, fish meal contains relatively high calcium (5.50%) and phosphorus (2.80%), which are crucial for bone development, metabolism and eggshell formation. Yellow corn contributes the highest metabolizable energy (3370 kcal/kg) and therefore serves as the primary energy source in the feed formulation.

Table 2, the figure illustrates the proportion of each feed ingredient used in the four experimental diets (R0-R3) for Japanese quails. Based on the data, yellow corn remains the dominant component in all treatments, consistently comprising 53.5% of the total ration, which serves as the primary energy source. The proportion of rice bran (7%), coconut meal (7%) and soybean meal (20%) also remains constant across all treatments, indicating these ingredients were used as stable sources of fiber, energy and plant-based protein.

The major difference among the treatments lies in the proportion of fish meal and DM Meal (Degraded Manure Meal). In the control group (R0), only fish meal (12%) was used as the main animal protein source, with no DM meal inclusion. As the treatment levels increased (R1-R3), fish meal content decreased gradually (from 12% in R0 to 0% in R3), while DM Meal inclusion increased proportionally (from 0% in R0 to 12% in R3). This substitution demonstrates the experimental objective to evaluate the effect of replacing fish meal with DM Meal derived from black soldier fly larvae biodegradation.

Table 3, shows that the crude protein content from waste broken down by *Hermetia illucens L* larvae reaches around 51.15% (Manangkot, 2014). There is also a protein concentration of 44.01% when larvae are raised on palm kernel cake substrate. In addition, dried prepupae have been shown to contain up to 42% protein, indicating that bioconversion through *Hermetia illucens* L larvae can consistently produce high-protein biomass suitable for poultry feed (Bruno, 2025) and DM can affect the weight gain of local chickens through supplementation with a combination of turmeric and BSF *(Black Soldier Fly)* meal, in this case *Hermetia illucens* L. (Toar *et al.*, 2019).

Table 2: Ingredient composition (%).

Ingredient	R0	R1	R2	R3
Yellow corn	53.5	53.5	53.5	53.5
Rice bran	7.0	7.0	7.0	7.0
Coconut meal	7.0	7.0	7.0	7.0
Soybean meal	20.0	20.0	20.0	20.0
Fish meal	12.0	8.0	4.0	0.0
DM meal	0.0	4.0	8.0	12.0
Premix A	0.5	0.5	0.5	0.5
Total	100	100	100	100

Source: This study (2025).

RESULTS AND DISCUSSION

Feed intake

The results of feed intake measurements showed clear differences among the dietary treatments throughout the experimental period. The average daily feed intake per bird increased as the inclusion level of degraded manure (DM) meal in the diet increased. Analysis of variance (ANOVA) indicated that the addition of DM meal had a highly significant effect on feed intake ($p<0.01$). Further comparison using Duncan's Multiple Range Test revealed that R0 did not differ significantly from R2 and R3, but differed significantly from R1. Likewise, R2 did not differ significantly from R3, but both differed from R1.

Table 4, the increased feed intake observed in R1, R2 and R3 may be attributed to the physical characteristics of DM meal, which has a finer particle texture, making the feed easier to consume and potentially more palatable. The average feed intake recorded in this study ranged from 24.77 to 24.89 g/bird/day.

Several factors influence daily feed intake in poultry, including environmental temperature, body weight development, feathering stage, stress levels and overall activity (Cullere *et al.*, 2018). In this study, the increase in feed intake observed with increasing DM levels suggests that the diets remained acceptable and physiologically manageable for the birds and that the enzymatic and physical characteristics of DM meal likely supported feed consumption behavior without adverse effects (He, 2021).

Body weight gain

Analysis of variance (ANOVA) results showed that the treatment the average daily body weight gain of quails during the experimental period did not differ significantly among treatments (p>0.05). The mean body weight gain ranged from 5.66 to 6.97 g/bird/day (Table 2). Although the statistical analysis indicated no significant difference, a slight numerical increase in body weight gain was observed in treatments R1, R2 and R3 compared to the control diet. This pattern is consistent with the observed feed intake, where increases in consumption did not translate proportionally into weight gain (Makkar *et al.*, 2014; Tian, 2025).

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This finding suggests that the nutrients consumed by the birds were primarily allocated toward egg production rather than somatic growth, which is typical for quails in the laying phase. The inclusion level of DM meal remains safe up to 12% without negatively impacting growth performance. Furthermore, DM meal contains protease, amylase and lipase, which may improve nutrient digestibility and the availability of amino acids. However, improved digestion does not necessarily result in increased body mass during the laying period because energy and protein utilization are redirected toward reproductive metabolism rather than muscle accretion (Serra *et al.*, 2024).

Therefore, the absence of significant differences in weight gain across treatments indicates that DM meal did not disrupt metabolic balance and replacing fish meal up too 12% in the diet can be done without compromising quail body weight stability during the laying period (Okyere, 2023).

Feed conversion efficiency

Analysis of variance (ANOVA) results of the study showed that the inclusion of Degraded Manure (DM) meal in the diet of laying quails had no significant effect (p>0.05) on feed conversion efficiency. The mean efficiency values among treatments were relatively similar, indicating that replacing fish meal with DM meal up to a level of 12% did not impair the ability of the birds to convert feed into productive output. This suggests that the metabolizable energy and nutrient utilization derived from the diets remained adequate across all treatments.

Efficiency of feed utilization depends on how well the diet is digested and absorbed, influencing productive performance rather than growth in mature birds (Beale, 2022). The lack of significant differences in body weight gain also reflects the stable physiological regulation of protein metabolism, where endocrine factors such as

Table 3: Nutrient composition of diets.

Nutrient	R0	R1	R2	R3
Crude protein (%)	25.65	25.21	25.36	25.50
Crude fiber (%)	5.42	5.01	5.15	5.29
Crude fat (%)	4.00	4.21	4.14	4.07
Ash (%)	11.73	12.31	12.11	11.92
NFE (BETN) (%)	46.80	46.75	46.76	46.78
Calcium (%)	1.11	1.12	1.12	1.11
Phosphorus (%)	1.10	1.17	1.15	1.13
Gross energy (kcal/kg)	4167.38	4107.52	4127.62	4147.73
Metabolizable energy (M.E.) (kcal/kg)	3334.26	3286.02	3302.10	3318.18

Source: Calculated based on feed ingredient nutrient values.

Table 4: Effect of MHD meal supplementation on feed intake, body weight gain and feed efficiency of laying quails.

Variable	R0	R1	R2	R3
Feed intake (g/bird/day)	24.89	17.48	24.65	24.77
Body weight gain (g/bird/day)	6.97	6.15	7.65	5.66
Feed efficiency (gain/feed)	0.28	0.35	0.31	0.22

Source: This study (2025).

growth hormone from the anterior pituitary and thyroid hormones play a crucial role in protein synthesis and tissue maintenance (García-Vaquero and Álvarez, 2024). Higher protein intake supports body weight gain, muscle cell development occurs early in life and continues through gradual regeneration in adulthood (Wang, 2019). Therefore, the absence of significant differences in weight gain across treatments indicates that DM meal did not disrupt metabolic balance and replacing fish meal up too 12% in the diet can be done without compromising quail body weight stability during the laying period (Okyere, 2023).

That diets with excessively high crude fiber content may reduce nutrient digestibility, depress growth and lower feed conversion efficiency (Pleissner and Rumpold, 2018). However, the DM levels used in this experiment did not introduce excessive fiber, which explains why feed efficiency remained unaffected. The stable efficiency values indicate that DM did not introduce any anti-nutritional effects or digestibility constraints when used as a protein source. Taken together, these findings show that DM meal can be included at up to 12% of the diet without compromising feed conversion efficiency, making it a functionally and economically viable alternative to conventional protein sources in laying quail diets (DalleZotte *et al.*, 2024).

Significance of increased egg production at higher DM levels

Table 5, egg production during the experimental period was evaluated based on both the number of eggs produced per bird and the total egg weight expressed in kilograms. Fractional values greater than 0.5 were rounded up to the nearest whole number for standardized comparison. Table 5 presents the mean egg production per bird across treatments over the duration of the study.

The primary factors influencing egg production are the level of feed intake and the nutritional composition of the diet (Qu *et al.*, 2025; Turchini *et al.*, 2022). Protein is one of the most critical dietary components, as it directly affects both body growth and reproductive performance in poultry (Rotinsulu, 2020). The amino acids contained within dietary protein also play an essential role in supporting immune system function, which contributes to the physiological stability and overall health of laying quails (Secci *et al.*, 2021; Gómez, 2019; Williams *et al.*, 2016).

Therefore, the variation in egg production observed among treatments in this study can be linked to differences in nutrient utilization and amino acid availability, demonstrating that dietary protein quality is closely associated with reproductive efficiency in laying quails (Laca and Diaz, 2021). Effect of dietary supplementation of acid ensiled fish waste on production performance, egg quality and serum biochemistry in layer Japanese quail (*Coturnix coturnix japonica)* (Tanuja *et al.*, 2017).

Activity (Amylase, Lipase and Protease) at different manure ages and larvae

Table 6, the results of the enzyme activity analysis indicate that amylase, lipase and protease enzymes were present in the manure substrate following biodegradation by *Hermetia illucens* L. larvae. The activity levels varied

Table 5: Effect of MHD meal supplementation on egg production and total egg weight of laying quails.

Treatment	Number of eggs (eggs/bird)	Rounded number (eggs)	Total egg weight (kg/bird)
R0	46.70±4.59[b]	47±5	0.47±0.046[b]
R1	37.10±4.81[a]	37±5	0.38±0.05[a]
R2	44.30±4.42[b]	44±4	0.46±0.04[b]
R3	46.80±3.15[b]	47±3	0.49±0.03[b]

Note: Different superscripts (a, b) in the same column indicate significant differences ($p<0.05$).

Source: This study (2025).

Table 6: Enzyme activity (Amylase, Lipase and Protease) at different manure ages and larval growth stages.

Enzyme activity (U/L)	Larval Age (days)	Manure age 1 week	Manure age 2 weeks	Manure age 3 weeks	Manure age 4 weeks
Amylase(U/L)	4 h	14.13±9.57	17.56±11.68	12.36±6.43	11.32±5.21
	8 h	24.06±13.36	12.55±8.53	14.85±8.42	12.11±9.08
	12 h	10.25±2.06	8.27±3.18	10.49±6.13	11.71±6.30
Lipase (U/L)	4 h	5.97±2.11	6.63±2.53	6.06±2.12	5.93±3.93
	8 h	4.91±3.56	4.84±3.57	5.03±3.59	3.94±3.49
	12 h	5.85±3.40	5.86±2.77	5.19±3.41	4.77±3.09
Protease (U/L)	4 h	13.61±5.09	15.69±6.45	17.53±3.85	14.03±3.92
	8 h	22.33±4.85	15.74±4.55	17.53±3.85	13.96±4.63
	12 h	18.98±2.88	13.68±4.92	16.36±4.86	14.64±5.12

Note: h = hours of larval age; U = enzyme unit; L = liter.

Source: This study (2025).

according to both manure age and larval developmental stage. In general, enzyme activity tended to be higher at earlier manure ages (1-2 weeks) and during the intermediate larval stages (particularly at 8 hours), before gradually declining as manure substrate quality decreased and larvae approached later developmental phases.

There are 3 types of enzymes in manure resulting from the degradation by *Hermetia illucens* L. larvae that help the digestion and metabolism process in quail at the layer phase: amylase, lipase and protease. Amylase activity fluctuates depending on the age of the manure and the larval stage, with the highest activity seen in larvae that are 8 hours old in one-week-old manure. This shows that carbohydrate hydrolysis is most active when substrate nutrients are still abundant. Lipase activity is relatively stable and lower compared to amylase and protease, indicating a steady but less dominant role in lipid breakdown during the degradation process. In contrast, protease shows consistently higher activity values than amylase and lipase across all treatments, indicating that protein degradation is the main metabolic pathway in manure conversion by *Hermetia illucens* L. larvae. This reflects the naturally high protein content of poultry manure, which serves as a key nitrogen source for larval growth (Xu, 2025; Raksasat, 2020).

The persistence of enzymatic activity in the final processed material (DM meal) indicates that partial hydrolysis of macromolecules has already occurred during biodegradation, potentially enhancing nutrient digestibility when DM is incorporated into quail feed (Romano, 2018). The presence of protease is particularly advantageous, as it supports improved amino acid availability, while amylase and lipase contribute to carbohydrate and lipid utilization, respectively.

These findings confirm that *Hermetia illucens L.* larvae function not only as converters of manure into high-protein biomass, but also as biological agents that enrich the residual substrate with functional enzymes, thereby increasing its value as a sustainable feed ingredient (Bovera, 2018; Manangkot, 2019). This further supports the suitability of DM meal as a viable protein replacement for fish meal in poultry diets, without compromising nutrient digestibility or production performance (Rotinsulu, 2020). Augmenting feeding value of rice distillers dried grain with solubles through dietary addition of enzymes in broilers (Dinani *et al.*, 2022).

CONCLUSION

Animal feed made from degraded animal manure (DM), produced through the bioconversion of chicken manure by Hermetia illucens larvae up to 12% in Japanese laying quail feed, can boost appetite without affecting weight gain or feed conversion efficiency. Egg production and egg weight remain stable or even increase at a 12% DM level. Additionally, DM feed contains active amylase, lipase and protease, showing its potential as an alternative protein source and functional feed ingredient. These findings suggest that DM feed can replace part of the basic feed in laying quail diets while supporting production performance and contributing to a sustainable poultry feeding system.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

There was no conlict of interest associated with this research by any of the authors.

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