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Effects of dried black soldier fly (*Hermetia illucens*) larvae feed on growth performance and cost efficiency in crossbred village chickens

Pengaruh pakan larva kering lalat tentara hitam (Hermetia illucens) terhadap performa pertumbuhan dan efisiensi biaya pada ayam kampung kacukan

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Abstract. This study aimed to evaluate the effects of incorporating dried black soldier fly (*Hermetia illucens*) larvae into commercial feed on the growth performance and cost efficiency of crossbred village chickens. A total of 30 day-old chicks were randomly assigned to three treatment groups (n = 10 each): T1 (control, commercial concentrate), T2 (commercial concentrate with 5% dried larvae), and T3 (commercial concentrate with 10% dried larvae). The experiment was conducted over a period of 9 weeks (63 days). Body weight and feed intake were recorded weekly. At the end of the trial, final body weights were measured and feed cost was analyzed. Results showed no significant difference ($p > 0.05$) in final body weight among the groups; however, the inclusion of dried black soldier fly larvae significantly improved feed conversion ratio (FCR) ($p < 0.001$), with T2 and T3 showing improvements of 15.15% and 16.67% respectively compared to the control. Feed costs increased slightly with larvae inclusion, but the 10% inclusion level led to better net profit compared to the other groups. In conclusion, supplementing commercial diets with 10% dried black soldier fly larvae enhances feed efficiency and economic returns without increasing daily feed costs, making it a viable and sustainable alternative protein source for crossbred village chicken production.

Keywords: black soldier fly larvae, commercial diet, cost analysis, growth performance, *Hermetia illucens*

Abstrak. Penelitian ini bertujuan untuk mengevaluasi pengaruh penambahan larva kering lalat tentara hitam (*Hermetia illucens*) ke dalam pakan komersial terhadap performa pertumbuhan dan efisiensi biaya pada ayam kampung kacukan. Sebanyak 30 ekor anak ayam umur sehari dibagi secara acak ke dalam tiga kelompok perlakuan (n = 10 per kelompok): T1 (kontrol, pakan komersial murni), T2 (pakan komersial dengan 5% larva kering), dan T3 (pakan komersial dengan 10% larva kering). Penelitian dilakukan selama 9 minggu (63 hari). Bobot badan dan konsumsi pakan dicatat setiap minggu. Pada akhir penelitian, bobot badan akhir diukur dan analisis biaya pakan dilakukan. Hasil penelitian menunjukkan bahwa tidak terdapat perbedaan yang signifikan ($p > 0,05$) dalam bobot badan akhir antar kelompok; namun, penambahan larva kering lalat tentara hitam secara signifikan meningkatkan rasio konversi pakan (FCR) ($p < 0,001$), dengan kelompok T2 dan T3 menunjukkan perbaikan masing-

masing sebesar 15,15% dan 16,67% dibandingkan kelompok kontrol. Biaya pakan sedikit meningkat seiring dengan penambahan larva, namun tingkat inklusi 10% menghasilkan keuntungan bersih yang lebih tinggi dibandingkan kelompok lainnya. Sebagai kesimpulan, suplementasi pakan komersial dengan 10% larva kering lalat tentara hitam meningkatkan efisiensi pakan dan keuntungan ekonomi tanpa menambah biaya harian pakan, sehingga menjadikannya sumber protein alternatif yang layak dan berkelanjutan untuk produksi ayam kampung kacukan.

Kata kunci: larva lalat tentara hitam, pakan komersial, analisis biaya, performansi pertumbuhan, *Hermetia illucens*

INTRODUCTION

Malaysia has achieved full self-sufficiency in the poultry industry since 1984 (Department of Veterinary Services, 2012). Poultry meat is an important source of high-quality proteins, minerals and vitamins, essential for a balanced human diet (Ravindran, 2009). The increasing demand for poultry meat, driven by population growth and heightened nutritional awareness, exerts significant pressure on the poultry sector to improve production efficiency. Currently, Malaysia supplies 81% of the protein consumed domestically, producing approximately 1.8 million broiler chickens daily (Department of Veterinary Services, 2014).

However, the poultry industry is currently challenged by multiple external factors including the COVID-19 pandemic, geopolitical conflicts such as the Russia-Ukraine war, and climate change impacts. These issues led to a chicken shortage in 2022 and rising food prices, which have caused public dissatisfaction, especially regarding chicken affordability (Iskandar, 2022; BERNAMA, 2022). The increased cost of conventional feed ingredients such as maize, fish meal, meat and bone meal, soybean meal and groundnut cake is a major contributing factor, with competition and price volatility further complicating feed supply in developing countries (Swain *et al*., 2014). Consequently, identifying alternative, cost-effective and sustainable feed sources has become imperative to reduce feed costs and maintain industry viability.

One promising alternative is the use of Black Soldier Fly Larvae (BSFL), *Hermetia illucens*, which have shown potential to replace up to 15% of conventional feed ingredients in broiler diets, reducing feed costs by approximately 19% compared to soybean and fish meal diets in some countries (Ongsogo *et al.*, 2018). BSFL are saprophytic insects that thrive on organic waste such as plant residues, animal manure and agricultural by-products (Nguyen, 2015). Their ability to convert organic waste into high-quality protein and fat, combined with their wide habitat range in tropical and subtropical regions including Malaysia, makes them a valuable resource (Guo et al., 2021).

The rising global demand for animal protein and increased living standards in developing countries have driven up prices of traditional feed components such as fishmeal, fish oil, soybean meal, and cereals. The ongoing global economic downturn has further intensified these challenges, creating a need for innovative feed solutions to meet future environmental, social and economic demands in animal production, particularly poultry. BSFL possess high protein and lipid content, along with abundant vitamins and minerals, positioning them as a promising substitute for conventional protein sources like soybean meal or fishmeal (Khan *et al*., 2018).

BSFL have several advantageous biological traits including a short reproductive cycle, high feed conversion efficiency, and resilience across different diets without compromising nutrient composition (El-Hack *et al*., 2020; Oonincx *et al*., 2015). The larval and pupal stages of BSFL are nutritionally richest, containing between 18–33% fat and 32–53% protein, depending on diet quality (Chippindale *et al*., 2004). Additionally, BSFL are not vectors of disease, making them safe for inclusion in animal feed (Sheppard *et al*., 2002).

Previous studies have demonstrated that diets supplemented with BSFL improve growth performance and digestibility in poultry and pigs, compared to conventional protein feeds (Veldkamp, 2015; Widjastuti *et al*., 2014). In poultry, inclusion rates of 5% to 15% BSFL have been shown to enhance feed intake, feed conversion ratio (FCR), and health status while reducing feed costs. However, a significant knowledge gap remains regarding the effects of BSFL supplementation on the growth performance and feed cost efficiency of crossbred village chickens in Malaysia, a native poultry type valued for its adaptability, resilience, and role in rural livelihoods. Studying BSFL inclusion in this chicken breed is crucial, as it may offer a sustainable and cost-effective feeding strategy for small-scale farmers and contribute to food security in rural areas.

Therefore, this study aims to evaluate the impact of dried BSFL supplementation on feed costs and growth performance in crossbred village chickens. This research intends to provide novel insights into the viability of BSFL as a sustainable and economical protein source for poultry feed in Malaysia, potentially contributing to food security, environmental sustainability, and economic benefits for local farmers.

MATERIALS AND METHODS

Location

The feeding trial was conducted at the Ladang Pengajar dan Keusahawanan Veterinar, Faculty of Veterinary Medicine, Universiti Malaysia Kelantan, Bachok, Malaysia (5°59'35.8"N 102°24'10.1"E).

Experimental Design

The study employed a completely randomized design (CRD) involving thirty crossbred village chickens. These birds were randomly allocated into three dietary treatment groups, with ten birds per group (n = 10). Each individual bird was considered as an experimental unit. The feeding trial lasted for 63 days. All groups received a standard commercial starter diet during the initial 21 days. From day 22 to day 63, the birds were transitioned to grower diets that incorporated different levels of black soldier fly larvae (BSFL) meal. The treatment groups were formulated as follows: T1 (control) consisted of 100% commercial concentrate, T2 contained 5% dried BSFL and 95% commercial concentrate, while T3 included 10% dried BSFL and 90% commercial concentrate.

Sample Preparation

Dried BSFL were obtained from two suppliers: HK Leong Sdn Bhd (Malaysia) and Bioloop Sdn Bhd (Malaysia). The larvae were sun-dried and subsequently ground to produce a moderately coarse powder. The resulting powder was stored in airtight containers at room temperature (25–27°C) until use. The commercial basal diets used for the trial were Gold Coin 201C (starter) and 202P (grower), both manufactured by Gold Coin Feedmills (M) Sdn Bhd (Malaysia).

Proximate Analysis

The proximate composition of BSFL and formulated diets was analyzed according to the official methods of AOAC (2007). Moisture content was determined by oven drying at 105°C until a constant weight was achieved (AOAC 934.01). Ash content was measured by incinerating the sample in a muffle furnace at 550°C (AOAC 942.05). Crude protein content was estimated using the Kjeldahl method (AOAC 984.13), in which the nitrogen content was multiplied by 6.25. Crude fiber was analyzed using a Fibretherm FT 12 fibre analyzer (C. Gerhardt GmbH, Königswinter, Germany) via sequential digestion with 1.25% H_2SO_4 and 1.25% NaOH. Crude fat content was measured by Soxhlet extraction using petroleum benzene as a solvent (AOAC 920.39).

Growth Performance Parameters

Individual body weight and feed intake were recorded on a weekly basis. Body weight gain (BWG), average daily gain (ADG), feed conversion ratio (FCR), and feed cost analysis (FCA) were calculated using the following equations:

Body weight gain (BWG):
BWG = (Final body weight - Initial body weight) / Duration (weeks)

Average daily gain (ADG):
ADG = (Final body weight - Initial body weight) / Days

Feed conversion ratio (FCR):
FCR = Total feed consumed / Total body weight gain

Feed Cost Analysis

Feed cost analysis (FCA) was calculated based on the total feeding cost per kilogram of live weight gain of crossbred village chickens. The calculation included the cost of commercial concentrate starter and grower feeds, and dried BSFL used as a feed supplement. Prices were based on prevailing market rates (RM/kg) and focused on the cost of live crossbred village chicken, commercial concentrate diet starter, commercial concentrate diet grower, dried BSFL, starter diet mixed with 5% dried BSFL, grower diet mixed with 5% dried BSFL, starter diet mixed with 10% dried BSFL and grower diet mixed with 10% dried BSFL.

Statistical Analysis

Data collected from the trial were entered into Microsoft Excel (Microsoft Corporation, Redmond, WA, USA) for preliminary processing and later analysed using IBM SPSS Statistics for Windows, Version 27.0 (IBM Corp., Armonk, NY, USA). One-way analysis of variance (ANOVA) was used to evaluate treatment effects, with means compared using Tukey's Honest Significant Difference (HSD) test at a significance level of $p < 0.05$. The assumptions of normality and homogeneity of variances were verified prior to conducting ANOVA.

Ethical Considerations

All procedures involving animals were conducted in accordance with ethical guidelines, and the experimental protocol was reviewed and approved by the Ethical Committee for the Experimental Use of Animals, Faculty of Veterinary Medicine, Universiti Malaysia Kelantan (UMK/FPV/ACUE/RES/018/2024).

RESULTS AND DISCUSSION

Nutritional Composition

Table 1 presents the nutritional composition of the feed across groups T1, T2, and T3. The energy content (kcal/100g) indicates that dried Black Soldier Fly Larvae (DBSFL) are lower in energy (219 kcal/100g) compared to the starter feed (346 kcal/100g) and grower feed (370 kcal/100g) under T1. However, incorporating 5% and 10% DBSFL into the commercial concentrate diets resulted in a slight increase in energy content in groups T2 and T3. Additionally, crude fat and crude fiber levels increased slightly with the inclusion of DBSFL in T2 and T3 compared to T1, accompanied by a modest rise in ash content. Moisture content was lower in DBSFL, and the feed samples in groups T2 and T3 showed moderately reduced moisture compared to T1.

Table 1. Nutritional composition of the feed

Parameter	Group		
	T1	T2	T3
Starter (Day 1 – Day 21)			
Energy (kcal/100g)	346.00	357.00	362.00
Crude Protein (%)	23.90	23.20	23.50
Crude Fat (%)	3.50	4.80	6.30
Crude Fiber (%)	1.30	1.80	1.80
Ash (%)	5.60	5.40	5.70
Moisture (%)	12.40	11.40	11.60
Grower (Day 22 – Day 63)			
Energy (kcal/100g)	370.00	374.00	373.00
Crude Protein (%)	19.30	20.60	21.00
Crude Fat (%)	5.50	6.30	7.00
Crude Fiber (%)	1.50	1.80	2.10
Ash (%)	4.40	4.80	5.90
Moisture (%)	10.00	9.60	9.60

Note: T1 = (Control), T2 = (5% Dried BSFL, 95% Commercial Concentrate Diet), T3 = (10% Dried BSFL, 90% Commercial Concentrate Diet)

Proximate analysis was conducted to evaluate the nutritional composition of the crossbred village chicken feed. Cherian (2020) highlights that nutrient analysis is essential for assessing feed quality and determining animal requirements, thereby enabling producers and researchers to optimize nutrient utilization, improve animal performance, and reduce production costs.

The introduction of DBSFL into the commercial concentrate diet altered the nutritional profile regarding energy, crude protein, crude fat, crude fiber, ash, and moisture relative to the control group (T1). DBSFL contains a high fat content, which serves as an energy source during pupation, accounting for the increased fat levels in diets containing DBSFL (Oluokun, 2000). The nutrient composition of BSFL varies with growth stage; crude fat increases significantly from day 4 to day 14, reaching up to 28.4%, while crude protein decreases concurrently. Liu *et al*. (2017) reported that in adult BSFL, crude protein can reach a maximum of 57.6%, whereas crude fat declines to approximately 21.6%.

Moisture levels influence the physical and chemical properties of feed, such as freshness and stability during long-term storage (Afolabi *et al.*, 2021). The low moisture content of DBSFL incorporated into commercial diets reduces susceptibility to microbial spoilage, thereby improving feed stability.

DBSFL is a well-established high-protein alternative for crossbred village chickens. However, the nutrient composition of BSFL depends on the quality and quantity of its diet (Nguyen *et al*., 2015). BSFL can constitute up to 50% of their dry weight in protein, making them a sustainable alternative to conventional protein sources in animal feeds (Shumo *et al*., 2019). Chu *et al*. (2020) demonstrated that inclusion of 3% full-fat BSFL in poultry diets significantly improved crude protein digestibility.

In crossbred village chicken diets, DBSFL also serves as a rich source of minerals and vitamins. Seyedalmoosavi (2022) noted that BSFL contains high calcium levels, reaching up to 9% of dry matter. Conversely, excessive ash content in poultry diets has been associated with crystal

formation in the urinary tract, as well as bone and joint disorders during the grower phase (Afolabi *et al.*, 2021). High ash levels have not been shown to be beneficial for broilers and layers in prior studies.

Insect-based diets increase fiber content depending on the BSFL growth stage, which can stimulate feed intake (Mwaniki *et al*., 2018). Fiber enhances cecal fermentation in birds, promoting improved nutrient absorption and growth (Bovera *et al*., 2016). However, while low levels of dietary fiber are beneficial, levels exceeding 3% have been shown to negatively affect voluntary feed intake and nutrient digestibility, ultimately impairing bird performance (Tejeda *et al*., 2021).

Growth Performance

The growth performance of all crossbred village chickens is summarized in Table 2. There was no statistically significant difference ($p > 0.05$) in body weight gain and average daily gain among groups T1, T2, and T3. Feed conversion ratio (FCR) was significantly improved ($p < 0.001$) in chickens fed diets containing dried Black Soldier Fly Larvae (BSFL) compared to the control group. The control group (T1) recorded the highest FCR at 1.32, while T2 (5% BSFL) and T3 (10% BSFL) recorded significantly lower FCRs of 1.12 and 1.10, respectively. This represents a 15.15% improvement in T2 and a 16.67% improvement in T3 compared to the control.

Table 2. Growth performance of crossbred village chickens

Parameter	Group			SEM	*p*-Value
	T1	T2	T3		
Initial BW (g)	41.70	42.80	44.30	1.80	0.167
Final BW (g)	1577.80	1565.00	1725.00	205.28	0.250
BWG (g)	1536.10	1522.20	1680.70	204.86	0.292
ADG (g/day)	24.38	24.16	26.67	13.11	0.333
FI (g)	2027.65	1703.86	1848.77	-	-
FI per day (g/day)	32.17	27.04	29.34	-	-
FCR	1.32^{a}	1.12^{b}	1.10^{b}	0.03	<0.001

Note: T1 = (Control), T2 = (5% Dried BSFL, 95% Commercial Concentrate Diet), T3 = (10% Dried BSFL, 90% Commercial Concentrate Diet)
Means with different superscripts within the same row differ significantly at ($p < 0.05$)

The inclusion of dried BSFL in commercial concentrate diets demonstrated a positive impact on growth performance, consistent with previous findings that reported improvements in body weight, body weight gain, and FCR in poultry fed insect-based diets (De Souza Vilela *et al.*, 2021). FCR is a key indicator of feed efficiency, where lower values reflect better conversion of feed into body mass (Huang *et al*., 2022).

The improved FCR observed may be attributed in part to the chitin content of BSFL (4.62% dry matter), which has been proposed to act as a prebiotic in the intestinal tract, enhancing gut health and nutrient utilization, as previously described by Bovera *et al*. (2016). Supporting this, Dabbou *et al*. (2018) reported that inclusion of BSFL at lower levels (5–10%) in the diets of Ross 308 broilers resulted in minimal changes in feed intake, FCR, and body weight gain, whereas inclusion at 15% led to a significant reduction in body weight gain.

Feed Cost Analysis

The total cost and cost analysis of rearing crossbred village chickens across different groups during a 63-day feeding trial is presented in Table 3 and Table 4 respectively. The fixed cost

remained constant at RM 35.00 for all groups. However, the variable cost associated with starter and grower feeds showed a slight decrease with the inclusion of dried BSFL in groups T2 and T3. This reduction was offset by the additional cost of incorporating dried BSFL into the feed, leading to a higher total feed cost in T2 and T3 compared to the control group T1.

The findings of this study contrast with those reported by Onsongo *et al*. (2018), who observed a reduction in feed cost with increasing inclusion levels of BSFL meal as a replacement for conventional fish meal in broiler diets. In contrast, Chia *et al*. (2019) noted that higher inclusion levels of BSFL meal improved economic performance, supporting the potential of BSFL as a sustainable and viable alternative protein source to address nutrient deficits in the animal feed sector. Ultimately, the economic viability of incorporating BSFL into poultry diets depends on the farmer's objectives and production goals.

Overall, the inclusion of 10% dried BSFL in the diet of crossbred village chickens improved profitability without increasing daily feed cost relative to the control. While 5% BSFL reduced feed cost, it did not translate into improved income or net profit. These findings suggest that 10% BSFL inclusion is a more economically beneficial feeding strategy, likely due to enhanced growth performance and feed efficiency.

Table 3: Total cost of rearing crossbred village chickens during a 63-day feeding trial

	T1	**T2**	**T3**
Fixed Cost			
Day Old Chick (RM3.50/chick)	35.00	35.00	35.00
Variable Cost			
201p Starter (kg)	10.50	10.20	9.90
202p Grower (kg)	235.40	212.00	194.30
Dried BSFL (kg)	-	30.30	60.20
Total Variable Cost (RM)	245.9	252.50	264.40

Note: **T1** = (Control), **T2** = (5% DBSFL, 95% Commercial Concentrate Diet), **T3** = (10% DBSFL, 90% Commercial Concentrate Diet), Starter 201p = RM 2.90/kg, Grower 202p = RM 2.90/kg, Dried BSFL =RM 7.50/kg, Crossbred Villages Chicken = RM 3.50/chick

Table 4: Cost analysis (RM) of crossbred village chicken rearing during a 63-day feeding trial

	T1	T2	T3
A. Income from live weight gain (RM/day/ chicken)	20.83	18.74	22.92
B. Cost of feeding in 63 days (RM/day/ chicken)			
Starter Feed	0.10	0.10	0.10
Grower Feed	0.60	0.20	0.50
Dried BSFL		0.05	0.10
Total feed cost (RM/day/chicken)	0.70	0.35	0.70
C. Fixed cost in 63 days			
Chicks	3.50	3.50	3.50
D. Gross return over feed cost (RM/day/ chicken)	20.13	18.39	22.22
E. Net profit from live weight gain (RM/day/ chicken)	16.63	14.89	18.72
F. Net profit from live weight (RM/day/ chicken)	21.00	21.20	23.40

Note: **T1** = (Control), **T2** = (5% DBSFL, 95% Commercial Concentrate Diet), **T3** = (10% DBSFL, 90% Commercial Concentrate Diet), Starter 201p = RM 2.90/kg, Grower 202p = RM 2.90/kg, Dried BSFL =RM 7.50/kg, Live Crossbred Villages Chicken = RM 16.00/kg

CONCLUSION

The inclusion of dried Black Soldier Fly Larvae (BSFL) as an alternative protein source in poultry diets significantly improved feed efficiency in crossbred village chickens. Both 5% and 10% BSFL inclusion levels resulted in lower feed conversion ratios (FCR), with improvements of approximately 15.15% and 16.67% respectively, compared to the control group. While the use of BSFL slightly increased feed costs relative to commercial concentrate diets alone, the enhanced feed efficiency and favorable economic returns particularly at 10% inclusion support its use in poultry production. This study is among the first to evaluate BSFL supplementation in crossbred village chickens under semi-intensive systems, demonstrating its potential not only to enhance productivity but also to reduce reliance on conventional protein sources. Therefore, dried BSFL is recommended as a sustainable and effective alternative protein source for crossbred village chicken farming.

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