LAYING PERFORMANCE OF 'DEKALB WHITE' STRAIN SUPPLEMENTED WITH VARIOUS AMOUNTS OF DRIED BLACK SOLDIER FLY (*HERMETIA ILLUCENS*) LARVAE

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ABSTRACT

This experimental study was conducted to determine the laying performance of layer chickens supplemented with various amounts of dried black soldier fly larvae. The experiment was conducted at Upper Lagnas, San Pedro, Rizal, Occidental Mindoro from April to August 2025. A total of 144 heads of layer chickens were reared in the experiment layout in Completely Randomized Design (CRD) using four treatments and three replications. The layer chickens were managed following the recommended rate of commercial feeds and DBSFL except for the Treatment 0 (Control). Treatment 1 (96% CF + 4% DBSFL), Treatment 2 (92% CF + 8% DBSFL), Treatment 3 (88% CF + 12% DBSFL). Analysis of variance in Completely Randomized Design (CRD) was used to test the statistical significance among treatments. Results showed that DBSFL supplementation had comparable effects on laying performance indicators, total egg production, feed conversion ratio, hen-day egg production, mortality rate, egg size, egg yolk color, eggshell thickness, net income and profitability. Although no significant differences among treatments, the 12% inclusion level produced the most favorable performance and achieved the highest return on investment at 20.56%. These findings suggest that incorporating 12% DBSFL in layer diets can enhance productivity and profitability without negatively affecting overall performance.

Keywords: *black soldier fly, larvae, layer, laying performance*

SDG: *SDG 2 - Zero Hunger; SDG 12 - Responsible Consumption and Production*

INTRODUCTION

The growing global demand for poultry products necessitates continuous improvement and innovation in poultry nutrition to ensure sustainable production. Traditional protein sources like soybean meal and fish meal have been fundamental components in poultry diets due to their favorable amino acid profile and digestibility (Allahoki, 2023). However, a major problem has arisen as the search for alternative protein sources. Environmental impacts from conventional protein production, together with the escalating pressure on global protein resources, have intensified the need for sustainable options that can adequately support the nutritional demands of layer chickens (Greenhalgh et al., 2020). Among these alternatives, black soldier fly larvae have garnered significant attention due to their nutrient profile and sustainable production characteristics.

Black soldier fly larvae are characterized by high protein content, typically ranging between 35% and 45% on dry matter basis, along with a balanced spectrum of essential amino acids for poultry growth and egg production. In addition to protein, BSFL provides beneficial fatty acids and essential materials such as calcium, iron, copper, and zinc that contribute to overall health and metabolic function in poultry (Lu et al., 2022). The nutritional qualities of BSFL make them promising partial or full substitutes for conventional protein ingredients in layer diets without compromising the bird's performance.

Beyond their compositional advantages, BSFL have been found to exert positive effects on poultry health. Studies show that including BSFL in poultry feed can enhance gut health by promoting a balanced microbial community. The larvae meal helps to reduce pathogenic bacteria such as Enterobacteriaceae and Clotriduim species while fostering beneficial bacteria like Lactobacillus, which supports intestinal integrity and immune function (Saidani et al., 2025). These changes in gut microbiota can ultimately optimize nutrient absorption and improve growth performance and egg production in laying hens.

In fact, in some cases, performance indicators such as weight gain, feed conversion ratio, and immune responses have shown improvement relative to conventional diets (Osuch et al., 2024). Importantly, BSFL also delivers an ideal calcium-to-phosphorus ratio supporting eggshell quality and bone development, a critical factor in layer management.

In view of the potential of dried black soldier fly larvae, this study aimed to determine the effects of dried black soldier fly larvae on the laying performance of layer chickens. The result of this study will help poultry raisers and feed developers to discover alternative protein sources for poultry animals.

MATERIALS AND METHODS

Experimental Site, Animals, Design, and Management Procedures

The study was conducted at Upper Lagnas, San Pedro, Rizal, Occidental Mindoro, Philippines from May to August 2025. Each battery cage was occupied by 3 layers following the recommended space required for layers.

A total of 144 heads of ready-to-lay pullets were procured from Bulacan, Philippines. Layers were bought in their 16 weeks of age after hatching ranging 1.3 to 1.5 kilograms, have bright red comb and wattles and have alert eyes.

This study was conducted using Completely Randomized Design (CRD). Layers were randomly distributed randomly to different treatments and replicated three times containing 12 heads of layer chickens per experimental unit.

The breeder of Black Soldier Fly was procured from Gabutero Organic Farm in Labonan, Bongabong, Oriental Mindoro, Philippines. Adult flies were cultured in a greenhouse set up with proper management to control the temperature and able to grow flies faster and healthily (Chassouant, 2019). To make sure that BSF grows strong and healthy, it was given with high quality waste products like fruit and vegetable peels (Kumar et al., 2020). The larva was harvested at 15 days of larval stage to ensure high protein content. The harvested larvae were killed through blanching in boiled water (Sandec, 2021). Before sun drying, blanching serves as a fast-killing method, which helps reduce microbial contamination, conserve nutrient quality, prevent degeneration of the end product, and maintain a bright color (Zhen et al, 2020). Following the blanching, the larvae were laid out in a single layer on drying trays or mats for them to be evenly exposed to sunlight.

Dried black soldier fly larvae were mixed into commercial layer feeds following every treatment inclusion level. The feeds were manually mixed to ensure uniform distribution of the larvae. A gradual adaptation period of two days was implemented prior to the experimental feeding to minimize stress. Birds were fed twice daily at 6:00 AM and 5:00 PM under a restricted feeding regime, with a feeding rate of 105 g per bird per day.

Upon arrival, birds were provided with drinking water supplemented with 3 tablespoons of sugar per liter to alleviate transport stress. After one-week, clean water was provided ad libitum. Watering systems were regularly checked and sanitized. General health monitoring and sanitation practices were maintained throughout the experimental period.

Eggs were collected daily at 5:00 PM and classified according to weight categories: pewee (40–44 g), pullet (45–49 g), small (50–54 g), medium (55–59 g), large (60–64 g), extra-large (65–69 g), and jumbo (≥70 g).

Data Collection

Data were collected over a 90-day period to evaluate the laying performance of the birds. Eggs was collected were manually measured in digital weighing scale intended for egg which categorized based on weight ranges: 40-44 grams (pewee), 45-49 grams (pullet), 50-54 grams (small), 55-59 grams (medium), 60-64 grams (large), 65-69 grams (extra-large), and 70 grams and above (jumbo). Feed conversion ratio was obtained by calculating feed consumption by dividing the total weight of feed consumed by the total weight of eggs produced. Eggshell thickness was recorded in millimeter (mm) by measuring the thickness of eggshell using thickness ruler gauge. It was measured twice during the middle and the last part of the experiment. Egg yolk color is the density of color which was evaluated using the Roche Yolk Color Fan (RYCF), a standardized color scale ranging from 1 (light yellow) to 16 (deep orange-red). Four samples in each replication were evaluated. The data were gathered twice, the first data collection was on June 14, 2025, and the last data collection was on August 22, 2025. Total egg production is a total number of eggs produced divided by the number of days of the experimental period and multiplied by 100. Hen-day egg production (%) is the percentage of eggs produced by laying hens in one day relative to the total number of hens present. It was used to measure and compare the daily egg-laying performance of layer chickens under different treatments. Mortality rate is the layer chickens that died within the 90 days experimental period. A net income was computed per hen by subtracting the total expenses from the total sales. Return on Investment (ROI) was calculated by dividing net income by total expenses, then multiplying by 100.

Sanitation and Waste Management

The experimental area was cleaned regularly to avoid the occurrence of pathogens and the presence of ammonia gas. An improvised crate and a shovel were used during cleaning, and carbonized rice hulls were placed beneath the cages where the dropping feces accumulated to help reduce odor. Chicken feces were collected every three days.

Statistical Analysis

Data were analyzed using Analysis of Variance (ANOVA) under a Completely Randomized Design at a 5% level of significance. When significant differences were detected, treatment means were compared using Tukey's Honest Significant Difference (HSD) test.

Scope and Limitations

This study was focused on the laying performance of 'Dekalb White' supplemented with various amounts of dried Black Soldier fly larvae. The laying performance was limited to the parameters; egg size, egg yolk color, eggshell thickness, total egg production, and feed conversion ratio. The profitability was limited to the parameters; net income and return on investment. There was no proximate analysis conducted for every treatment, and no moisture meter was used during the drying of black soldier fly larvae in this study.

This study was conducted in Upper Lagnas, Barangay San Pedro, Rizal, Occidental Mindoro from May to August 2025.

RESULTS

Laying performance

Table 1. Laying performance of layer chickens fed with different levels of DBSFL.

Treatment	R1	R2	R3	Total	Mean
Total egg production (90 days)					**1010.83**
T0 (100% CF)	992	988	990	2970	990.00[b]
T1 (96% CF + 4% DBSFL)	1001	1027	998	3026	1008.67[a b]
T2 (92% CF + 8% DBSFL)	987	940	1015	2942	980.67[b]
T3 (88% CF + 12% DBSFL)	1034	1083	1075	3192	1064.00[a]
Total				12130	
Feed Conversion Ratio (FCR)					**1.96**
T0 (100% CF)	1.89	2.06	1.94	5.88	1.96
T1 (96% CF + 4% DBSFL)	2.03	1.94	2.02	5.98	1.99
T2 (92% CF + 8% DBSFL)	1.95	2.03	2.00	5.98	1.99
T3 (88% CF + 12% DBSFL)	1.92	1.86	1.93	5.71	1.90
Total				23.55	
Hen-Day Egg Production (HDEP)					**94.96**
T0 (100% CF)	99.09	92.77	94.92	286.78	95.59
T1 (96% CF + 4% DBSFL)	94.16	97.22	96.38	287.76	95.92
T2 (92% CF + 8% DBSFL)	94.58	86.85	91.94	273.37	91.12
T3 (88% CF + 12% DBSFL)	94.58	99.44	93.63	291.65	97.22
Total				1139.56	
Mortality Rate					**0.33**
T0 (100% CF)	1.00	0.00	1.00	2.00	0.67
T1 (96% CF + 4% DBSFL)	0.00	0.00	0.00	0.00	0.00
T2 (92% CF + 8% DBSFL)	1.00	1.00	0.00	2.00	0.67
T3 (88% CF + 12% DBSFL)	0.00	0.00	0.00	0.00	0.00
Total				4.00	
Egg Size					**60.60**
T0 (100% CF)	57.27	55.79	63.28	176.34	58.78
T1 (96% CF + 4% DBSFL)	59.99	62.71	61.24	183.94	61.31
T2 (92% CF + 8% DBSFL)	61.00	59.53	61.46	181.99	60.66
T3 (88% CF + 12% DBSFL)	63.50	62.48	58.97	184.95	61.65
Total				727.22	
Egg Yolk Color					**15.54**
T0 (100% CF)	15.25	15.00	15.50	45.75	15.25
T1 (96% CF + 4% DBSFL)	15.50	15.75	15.50	46.75	15.58
T2 (92% CF + 8% DBSFL)	15.75	15.75	15.50	47.00	15.67
T3 (88% CF + 12% DBSFL)	15.75	15.50	15.75	47.00	15.67
Total				186.50	
Eggshell Thickness					**0.36**
T0 (100% CF)	0.34	0.35	0.35	1.04	0.35
T1 (96% CF + 4% DBSFL)	0.34	0.36	0.38	1.08	0.36
T2 (92% CF + 8% DBSFL)	0.38	0.33	0.40	1.11	0.37
T3 (88% CF + 12% DBSFL)	0.36	0.38	0.37	1.11	0.37
Total				4.34	

Means with the same superscript are not significantly different at p>0.05.

Total egg production (90 days), treatment 3 (88% CF + 12% DBSFL) got the highest mean egg production at 1064.00, followed by Treatment 1 (96% CF + 4% DBSFL) with a mean of 1008.67, and Treatment 0 (100% Commercial feeds) with total of 990.00. Treatment 2 (92% CF + 8% DBSFL) recorded the lowest egg production percentage with a mean of 980.67 The overall mean of all the treatments was 92. 52%. Feed Conversion Ratio (FCR), treatment 3 (88% CF + 12% DBSFL) obtained the lowest mean FCE value (1.90), followed by Treatment 0 (100% CF) with a mean of 1.96, while Treatments 1 (96% CF + 4% DBSFL) and 2 (92% CF + 8% DBSFL) recorded the highest mean FCE (1.99). A lower FCE value reflects better feed efficiency, meaning birds required less feed to produce the same amount of egg mass. Hen-Day Egg Production (HDEP), treatment 3 (88%CF + 12% DBSFL) recorded the top mean egg production (97.22%), and Treatment 1 (96% CF + 4% DBSFL) with a mean of 95.92% was the next highest. A mean of 95.59% was recorded by Treatment 0 (100% CF), and the lowest mean egg production of 91.12% was from Treatment 2 (92% CF + 8% DBSFL). Mortality Rate, treatments 1 (96% CF + 4% DBSFL) and 3 (88% CF + 12% DBSFL) had no mortality (0.00%) hence the birds were very much alive. On the other hand, Treatments 0 (100% CF) and 2 (92% CF + 8% DBSFL) had a mean mortality rate of 0.67%, respectively. The overall total mean mortality rate across all treatments was 0.33%, which pointed to a very healthy environment during the days of the experiment. Egg Size, treatment 3 (88% CF + 12% DBSFL) recorded the highest mean egg size of 61.65 g, followed by Treatment 1 (96% CF + 4% DBSFL) with 61.31 g, Treatment 2 (92% CF + 8% DBSFL) with 60.66 g, and the lowest mean value of 58.78 g was obtained from Treatment 0 (100% CF), which served as the control group. Egg Yolk Color, treatment 2 (92% CF + 8% DBSFL) and Treatment 3 (88% CF + 12% DBSFL) recorded the highest and equal mean yolk color scores of 15.67, followed by Treatment 1 (96% CF + 4% DBSFL) with a mean of 15.58, while the control group (T0 = 100% CF) obtained the lowest mean yolk color score of 15.25. The grand mean for yolk color across all treatments was 15.54. Eggshell Thickness, treatment 2 (92% CF + 8% DBSFL) and Treatment 3 (88% CF + 12% DBSFL) both obtained the highest mean eggshell thickness of 0.37 mm, followed by Treatment 1 (96% CF + 4% DBSFL) with a mean of 0.36 mm. The control group (T0 = 100% CF) recorded the lowest mean of 0.35 mm. The grand mean across all treatments was 0.36 mm

Analysis of variance

Table 2. Analysis of variance (CRD) for total egg production.

Source	DF	SS	MS	F-value	p-value
Total egg production					
Treatment	3	13503.60	4501.19	8.40	0.0074**
Error	8	4285.30	535.67		
Total	11	17788.90			
Feed conversion ratio					
Treatment	3	0.01683	0.00560	1.71	0.2421 ns
Error	8	0.02627	0.00280		
Total	11	0.04309			
Hen-day egg production					
Treatment	3	0.68180	0.22727	2.34	0.1501 ns
Error	8	0.77847	0.09731		
Total	11	1.46027			
Mortality rate					
Treatment	3	0.22413	0.07471	2.67	0.1189 ns
Error	8	0.22413	0.02802		
Total	11	0.44827			
Egg size					
Treatment	3	14.7832	4.92774	0.81	0.5218 ns
Error	8	48.5037	6.06297		
Total	11	63.2870			
Egg yolk color					
Treatment	3	0.35417	0.11806	3.78	0.0589 ns
Error	8	0.25000	0.03125		
Total	11	0.60417			
Eggshell thickness					
Treatment	3	0.0011	0.00036	0.80	0.5279 ns
Error	8	0.0036	0.00045		
Total	11	0.0047			

***Highly significant at p < 0.01*
CV = 2.29%

The total egg production computed p-value of 0.0074 was lower than the 0.01 level of significance. The feed conversion ratio computed p-value (0.2421) exceeded the 0.05 significance level, indicating no significant difference among treatments. The Hen-day egg production computed p-value of 0.15 indicates no significant difference existed among treatments in terms of hen-day egg production. The differences in mortality rate among treatments were not statistically significant (p = 0.1189). Since the p-value is greater than 0.05, the null hypothesis is accepted. The egg size computed p-value of 0.5218 indicates no significant difference among the treatments in terms of egg size. The egg yolk color computed p-value of 0.0589) indicates no significant difference among the treatments. The p-value of 0.5279 for eggshell thickness indicates no significant difference among the treatments.

Net Income

Treatment 3 (88% CF + 12% DBSFL) achieved the highest net income of Php 148.06, followed by Treatment 1 (96% CF + 4% DBSFL) with Php 123.83, and Treatment 2 (92% CF + 8% DBSFL) with Php 108.75. The lowest net income was recorded in the control group (T0: 100% CF) at Php 50.48 [table 3].

Table 3. Net income per head of layer chickens fed with various levels of DBSFL (90-day supplementation)

ITEMS	T0 100% CF	T1 96% CF + 4% DBSFL	T2 92% CF + 8% DBSFL	T3 88% CF + 12% DBSFL
Inputs				
Stocks (Php)	430.00	430.00	430.00	430.00
Commercial Feeds (Php)	274.05	263.09	252.13	241.16
DBSFL (Php)	0.00	11.71	23.44	35.15
Electricity (Php)	2.08	2.08	2.08	2.08
Miscellaneous fees (Php)	2.60	2.60	2.60	2.60
Total Inputs (Php)	708.73	709.48	710.25	710.99
Output				
Sales (Php)	759.21	833.31	819.00	859.05
Net Income (Php)	50.48	123.83	108.75	148.06

Notes: Price of egg per piece = Php 8.00; Cost of feeds (kg) = Php 29.00

Black Soldier Fly Larvae Production Cost

The expenses include containers, plastics, BSFL breeders, labor, raw materials, and other miscellaneous items, resulting in a total production cost of Php 8,667. A total of 280 kilograms of BSFL was produced during the experiment. Based on this, the computed production cost per kilogram of BSFL is approximately Php 30.95 [table 4].

Table 4. Production cost of black soldier fly larvae (BSFL)

Items	Quantity	Unit Cost (Php)	Total Cost (Php)
BSFL plastic container	3	90	270.00
Plastic drum	1	1,400	1,400.00
BSFL breeder	10 kg	180	1,800.00
Labor	31 days	150/week	4,700.00
Raw material	3	100	300.00
Net (substrate mesh)	20 meters	9.85	197.00
Total Production Cost			**8,667.00**

Computed production cost per kg: Php 8,667 ÷ 280 kg ≈ Php 30.95/kg

Return on Investment (ROI)

Treatment 3 (88% CF + 12% DBSFL) obtained the highest ROI of 19.26%, followed by Treatment 1 (96% CF + 4% DBSFL) with 12.27%, and Treatment 2 (92% CF + 8% DBSFL) with 12.00%. The lowest ROI (7.12%) was recorded in Treatment 0 (100% CF), which contained no DBSFL supplementation [table 5].

Table 5. Return on investment of layer chickens fed with various levels of DBSFL

Treatment	Production Cost (Php)	Net Income (Php)	ROI (%)
T0 = 100% CF	708.73	50.48	7.12
T1 = 96% CF + 4% DBSFL	709.48	123.83	16.68
T2 = 92% CF + 8% DBSFL	710.25	108.75	14.87
T3 = 88% CF + 12% DBSFL	720.28	148.06	20.56

DISCUSSION

The improved egg production in DBSFL-supplemented diets could be linked to the high nutritional value of black soldier fly larvae, which are rich in high-quality protein, essential amino acids, and lipids required for egg production. Insect meals such as BSFL have balanced amino acid profiles comparable to conventional protein sources, which may enhance reproductive performance in poultry (Makkar et al., 2014). The inclusion of black soldier fly larvae meal in the diet of layer animals significantly affected egg production, while most egg quality parameters remained unaffected (Suparman et al., 2020). A partial substitution of soybean meal with BSFL meal improved laying performance and egg production in laying hens. The better performance observed in T3 indicates that higher inclusion rates of DBSFL may optimize nutrient utilization without impairing productivity (Dabbou et al., 2018). A moderate to high inclusion levels of insect meal improved feed conversion efficiency and egg production due to enhanced digestibility and nutrient bioavailability (Kierończyk et al., 2018). Furthermore, BSFL contains bioactive compounds such as antimicrobial peptides and lauric acid, which may improve gut health and nutrient absorption, thereby contributing to increased egg production (Schiavone et al., 2017).

The addition of Black Soldier Fly larvae to laying hen diets is not harmful to their feed conversion ratio as it exhibits both linear and quadratic reductions in FCR when BSFL levels are raised. Besides, the hens become more productive and the eggs are heavier. Essentially, DBSFL has been demonstrated as a viable and environmentally alternative protein source for layer chickens, keeping feed efficiency at the level of commercial feeds. The findings point to the fact that dried black soldier fly larvae have the potential to tap into profitable business in the layer chicken sector with the highest inclusion level (12%) registering the top economic performance (Nassar et al., 2023).

Treatment 3 (88% CF + 12% DBSL) showed the highest mean hen, day egg production, which means that the addition of DBSFL at 12% can effectively support the egg laying performance of layer chickens. The increased egg production in the treatment is an indication that DBSFL can supply the necessary nutrients for the optimum productivity of chickens, which is at least comparable or even slightly better than that of the conventional feed alone. Therefore, this result shows that layers can make good use of DBSFL without their laying ability being negatively affected. The incorporation of black soldier fly larvae in layer diets did not adversely affect egg production of laying hens. In general, adding DBSFL in layer diets illustrates its potential as a sustainable and alternative protein source that can keep or even increase egg production while making less use of conventional feed ingredients (Bejaei and Cheng, 2023).

The inclusion of dried black soldier fly larvae (DBSFL) in layer diets showed no significant effect on mortality, indicating that DBSFL is a safe and non-toxic feed ingredient up to 12% inclusion. The absence of mortality is likely due to the larvae's beneficial nutrients, including lauric acid (Makkar et al. 2014; Schiavone et al., 2017), and chitin (Hu et al., 2024), which enhance gut health and immunity. Overall, DBSFL can safely replace part of conventional feed ingredients without affecting flock survival, supporting its use as a sustainable protein source for poultry production.

Including DBSFL in layer diets at level 12% had no significant effect on egg size in layer chickens. Even though the difference was not statistically meaningful, hens that received DBSFL tended to produce slightly larger eggs compared to those in the control group. This trend implies that DBSFL can provide additional nutrients, but the commercial feed used in the study is already nutritionally adequate for optimal egg formation. Hence, DBSFL is more of a substitute protein source that works effectively rather than a direct egg size enhancer (Rumpold & Schluter 2013; Makkar et al., 2014). Tahamtani et al., (2021) who have checked the effect of insect-based proteins such as BSFL in layer diets on egg traits, also found no negative impact on egg weight and size. Rather, insect derived meals can completely substitute protein sources such as soybean meal or fishmeal without production performance being reduced. The findings demonstrate the value of DBSL to be a sustainable and low-cost protein source replacement in chicken nutrition. Since DBSFL can be obtained from organic waste and produced with less environmental impact, it is an environmentally friendly alternative to feed formulations. Most importantly, adding it to the diet does not reduce egg size, thus it is a viable ingredient for a layer production system that is environmentally considerate and financially efficient (Van Huis et al., 2013).

Even though supplementation of dried black soldier fly larvae (DBSFL) up to 12% in the diet of laying hens did not significantly alter yolk color. There was a hint of color enhancement at higher levels of inclusion. This slight alteration could be related to carotenoid pigments in the larvae which, however, were at such low levels that the effect of commercial feeds was not surpassed. Yolk color in this research is the egg yolk pigmentation intensity, measured by a standard color scale similar to the Roche Yolk Color Fan (RYCF), where 1 represents pale yellow and 16 deep orange, red. Grain of truth, wise, DBSFL positive trend to improved yolk color was noticed and thus a protein source from insect larvae that can be utilized besides conventional ones without discriminatory impact on egg parameters was even part of the argumentation. Pigment supplementation and microencapsulation studies such as those with canthaxanthin have illustrated that yolk color determined by the Roche/DSM 16, point fan gets deeper as the fan score goes up, hence stronger pigment deposition and yolk appearance that consumers usually perceive as richer (Bejaei and Cheng, 2023). Furthermore, this is in agreement with Sulaiman et al., (2023) who observed that even the latest studies on poultry and egg quality still refer to the 1, 16 DBSM/Roche yolk color fan, and research results indicate that higher scores, particularly those approaching 16, are interpreted as indicators of deeper and more intense yolk pigmentation, which scientists regard as a good outcome when the objective is to enhance yolk color.

When dried black soldier fly larvae (DBSFL) were added in the layer diets, eggshell thickness was not significantly different. However, there were slight numerical increases in eggshell thickness. The result indicates that DBSFL, which is a source of additional nutrients, were not included at levels that were sufficient to improve shell formation. Inclusion of BSFL in the layer diet does not negatively affect eggshell thickness because the birds fed the standard commercial feeds produce eggs with shell thickness comparable to those of the BSFL, fed birds. In summary, DBSFL is capable of being a sustainable protein substitute without affecting eggshell quality (Mat et al., 2021).

Supplementing layer chicken diet with dried black soldier fly larvae had a beneficial effect on net income. Of the various treatments, Treatment 3 (88% CF + 12% DBSFL) yielded the greatest net income (148.06). It therefore, signals that 12% inclusion level is able to provide the best mix of nutrient upgrade and feed cost cutting resulting in higher profitability. Close to that are Treatment 1 (96% CF + 4% DBSFL) and Treatment 2 (92% CF + 8% DBSFL) that also resulted in higher net incomes against the control. The figures, Php 123.83 and Php 108.75 respectively, imply that even minimal DBSFL addition levels are still able to give financial gains. On the other side, Treatment 0 (100% CF) reaped the lowest net income. This serves to show that consumption of solely commercial feeds is less cost effective than incorporating DBSFL as an alternative protein source.

Integrating dried black soldier fly larvae (DBSFL) in layer feed as a protein source up to 12%, gave a boost to return on investment (ROI) work. The layer 12% DBSFL group, among others, exhibited the highest ROI at 19.26%. This means that, both the 12% DBSFL group's profit and cost efficiency are significantly higher than those of the control. Most probably, the main factor behind this superior performance is the high nutritional value of DBSFL and its lower price. Hence, DBSFL can be used as an alternative to expensive protein sources such as fishmeal and soybean meal. Several other researchers have also shown that insect meal notably improves feed cost efficiency and production performance. Besides, DBSFL can be grown on organic waste which significantly helps the economy and is environmentally friendly. Insect meal can enhance feed efficiency and at the same time sustain or even increase production performance in poultry. Overall, the trend shows that increasing DBSFL inclusion improves net income, with the most profitable option. This demonstrates the economic advantage of using DBSFL in layer diets, particularly as a sustainable and lower-cost protein ingredient (Waithaka et al., 2022).

CONCLUSIONS

The supplementation of dried black soldier fly larvae had a highly significant effect on total egg production, indicating that its inclusion in the diet positively influenced the overall egg output of the laying hens. However, no significant differences were observed in feed conversion ratio, hen-day egg production, and mortality rate among the different treatments, suggesting that the supplementation did not adversely affect feed efficiency, daily laying rate, or survivability of the birds. The inclusion of dried black soldier fly larvae on the feed supplement of the layer has no significant difference effect on the laying performance of the experimental birds. The results showed that the inclusion of dried black soldier fly larvae in the diets of layer chickens did not significantly affect egg quality parameters, such as egg size, egg yolk color, and eggshell thickness. This implies that the supplementation maintained normal egg quality characteristics across all treatments. The results of the study shows that supplementation of dried black soldier fly larvae has significant effects on total egg production. However, results show that there are no significant effects on, feed conversion ratio, hen-egg production, mortality, egg size, egg yolk color and eggshell thickness. Indicating that supplementation has no negative effects on laying performance and egg quality of layer chickens. Inclusion of 12% dried black soldier fly on the feed diet of the layer produced the best laying performance of the birds. The inclusion of 12% of dried black soldier fly larvae gained the highest return on investment in total of 20.56%.

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DECLARATION OF CONFLICT OF INTEREST

The authors say they do not have any conflict of interest.

DECLARATION OF AI USE

Grammarly was utilized to check and edit the language of the work. All results have been reviewed and validated by the authors, who are fully responsible for the contents.

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AUTHOR CREDIT STATEMENT

Gonzales, R.: data collection, data feeding of experimental chicken and writing & editing, drying of black soldier fly larvae, cleaning and maintenance of the experimental area; **Gado, C.J.:** observation, data recording, daily feeding of experimental chickens; **Celestino, E.:** data collection, data recording, daily feeding of experimental chickens, cleaning and maintenance of the experimental area, drying of black soldier fly larvae; **Bermudo, PD.:** animal care and management, cleaning and maintenance of the experimental area, writing and editing; **Rabanal, MA.:** cleaning and maintenance of the experimental area, data recording.