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Growth performance of colored broiler chicken (Gallus domesticus) supplemented with varying levels of blacksoldier fly larvae (*Hermetia illucens*) under free-range condition

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Key words: Frozen black soldier fly larvae, Growth performance, Colored broiler chicken

Abstract

The study was conducted atcmU Poultry Project, Musuan, Bukidnon, with a duration of 60 days to evaluate the effect of black soldier flies as a supplemental protein source on the growth performance of colored broiler chicken. A total of forty-eight heads of day-old chicks regardless of sex were used in the study. Chicks were randomly distributed into four dietary treatments. Treatments were replicated three times with four birds per replication following the Complete Randomized Design. Statistical differences of treatment mean comparison was made with Duncan Multiple Range Test. The treatments were as follows: T1 (control), T2 (95% commercial feeds = 5% BSFL), T3 (90% commercial feeds + 10% BSFL), T4 (85% commercial feeds + 15% BSFL). The study revealed a highly significant difference ($P<0.01$) observed in the average feed consumption and treatment consumption of frozen black soldier fly larvae while return above feed cost showed an encouraging profit. Therefore, supplementation of frozen black soldier fly larvae to colored broiler chicken showed better growth performance of the birds. Treatment 2, 3, and 4 consistently showed good performances as far as the final weight, total weight gained, and average daily gained is concerned. It recommends supplementing frozen black soldier fly larvae as supplementation to a commercial feed of colored broiler chicken in levels applied in Treatment 2,3 and 4 because it is good support for the growth of the chicken, it adds profit and has a beneficial effect on the birds as revealed in the return above feed cost.

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Introduction

The broiler industry provides a large part of increasing demand for animal protein, cash income, and creating employment opportunities. Poultry meat contributes approximately 37% of the total animal protein supplied in the country. There is a great possibility of growth and enlargement of this sector both at the domestic and commercial level. But, broiler producers are facing many difficulties with the availability and the higher prices of feed ingredients. Feed cost account for 65-70% of the total poultry rearing cost (Bhuiyan, 1998), and protein cost accounts for 15% of feed cost (Banerjee, 1992 and Singh, 1990). The animal protein source is the costliest ingredient for the formulation of poultry diets than any other source of nutrients. The most limiting one in the diet of Filipinos is protein. This limitation could best be patched-up by animal protein sources. Of the animal protein sources, the broiler is one of the most efficient converters of feeds to meat and its production is considered a quick measure to supply the demand of today's increasing population, as cited by Intong (1988).

At present, the production cost of broiler has enormously increased due to the interminable rising price of broiler feeds which contributes to, 60-80% (FAO, 2007), and fishmeal makes up a substantial stake of the cost. This situation demands the exploration of the possible materials believed to have nutritional value, not only for broiler but for other species of domesticated livestock as well, as cited by Intong (1988). Today many researchers had endeavored much in establishing alternative ingredients, particularly that of protein sources since commercially prepared protein sources are very costly. Black soldier fly larvae (*Hermetia illucens*) is one of the materials that need to be explored for livestock feeding. It is found to be a good source of protein (Stankus, 2013, Alvarez, 2012). Stankus, (2013) cited that black soldier fly larvae are an attractive animal feed which is high in protein that accounts for 48.96% on a dry matter basis. The larvae have been successfully fed to rainbow trout, swine and poultry, and catfish. Hence, the researcher was conceived recognizing the need to establish an alternative source of protein for livestock production. It sought to determine the supplemental effect of black soldier fly larvae to colored broiler chickens in free-range conditions. This study was conducted to evaluate the potential of black soldier fly as supplement to colored broiler chicken. Also, it would help livestock and poultry producers evaluate the cost-effectiveness and nutritional value of available feed ingredients to supply a nutritionally-balanced diet at a minimal cost.

Materials and methods

Culture Media Facilities

The materials needed were weighing scale (digital), seven (7) basins, PVC pipe, and elbow (2 inches), net, rubber band, 6-liter plastic container, packaging tape, salmon can, plastic cellophane, and record book.

Poultry Facilities

The poultry facilities and equipment that were used in the study include the brooding house, rearing pens, feeding and drinking troughs, weighing scale, electric bulbs (50 watts incandescent), old newspaper, and an empty sack which was used as curtains to cover the brooding area for maintenance of heat during brooding time.

Experimental Animal and Design

A total of forty-eight (48) heads of day-old chicks, regardless of sex, were used in the study. The chicks were randomly distributed into four (4) dietary treatments. Each treatment was replicated three times with four (4) birds per replication following the Complete Randomized Design (CRD). Commercial feeds were used in feeding the birds supplementing of different levels of black soldier fly larvae to obtain bodyweight and to sustain the nutrients needed by the birds.

Experimental Treatments

Black soldier fly larvae (BSFL) was supplemented in the commercial ration at varying levels which correspond to the different treatments as follows:

Treatment 1 = 100% commercial feed (control)
Treatment 2 = 95% commercial feed + 5% BSFL
Treatment 3 = 90% commercial feed + 10% BSFL
Treatment 4 = 85% commercial feed + 15% BSFL

Table 1. Ingredient Composition of Chick Booster Mash.

Particulars			
Ingredients			
	Corn	Meat and Bone Meal	Lysine Sulphate
	Cassava Meal	Brewer's Dried Grains and Yeast	DL-Methionine
	Soybean Meal	Crude Coconut Oil	Choline Chloride
	Full Fat Soya	Crude Palm Oil	Vitamin & Mineral Premix
	Rice Bran	Molasses	Enzymes
	Wheat Pollard	Limestone	Toxin Binders
	Fish Meal	Inorganic Phosphate	Mold Inhibitor
	Pork Meal	Iodized Salt	Antioxidants
	Poultry Meal	L-Lysine and L-Threonine	
Guaranteed Analysis			
	Crude Protein	24.00% min.	
	Crude Fiber	5.00% max.	
	Crude Fat	3.00% min.	
	Calcium	0.90% min.	
	Phosphorus	0.55% min.	
	Moisture	12.00% max.	

Source: B-MEG (2013)

Table 2. Ingredient Composition of Broiler Starter Crumble.

Particulars			
Ingredients			
	Corn	Meat and Bone Meal	Lysine Sulphate
	Cassava Meal	Brewer's Dried Grains & Yeast	DL-Methionine
	Soybean Meal	Crude Coconut Oil	Choline Chloride
	Full Fat Soya	Crude Palm Oil	Vit. & Min. Premix
	Rice Bran	Molasses	Enzymes
	Wheat Pollard	Limestone	Toxin Binders
	Fish & Pork Meal	Inorganic Phosphate	Mold Inhibitor
	Copra Meal	Iodized Salt	Antioxidants
	Poultry & Feather Meal	L-Lysine and L-Threonine	
	Corn Bran	Corn Gluten Feed	
	Corn Germ & Gluten Meal		
Guaranteed Analysis			
	Crude Protein	21.00% min.	
	Crude Fiber	6.00% max.	
	Crude Fat	4.00% min.	
	Calcium	0.90% min.	
	Phosphorus	0.55% min.	
	Moisture	12.00% max.	

Source: B-MEG (2013)

Table 3. Experimental Rations Composition and Calculated Analysis of Broiler Starter Crumble (BSC).

Particulars	Treatment			
	1	2	3	4
Commercial Ration (g)	1000	950	900	850
Black Soldier Fly Larvae (g)	0	50	100	150
Total (g)	1000	1000	1000	1000
Calculated Analysis				
Crude Protein (%)	21.00	22.398	23.796	25.194
Crude Fiber (%)	6.00	6.155	6.31	6.465
Crude Fat (%)	4.00	5.1145	6.229	7.3435
Calcium (%)	0.9	0.968	1.036	1.104
Phosphorus (%)	0.55	0.556	0.562	0.568
Moisture (%)	12.00	14.5495	17.099	19.6485

Table 4. Current Proximate Analysis of Black Soldier Fly Larvae.

Total Nitrogen (%)	Crude Protein (%)	Ash (%)	Dry Matter (%)	Moisture content (%)
5.16	32.25	11.28	37.46	62.54

Source: Soil and Plant Analysis Laboratory, 2014

Preparation of the Black Soldier Fly Larvae.

Kitchen wastes were used as cultured media for the black soldier fly larvae. The Black Soldier Fly Eggs were introduced and reared at the kitchen wastes cultured media at a certain period; the media weighed ten (10) kilograms. The black soldier fly larvae were harvested at a certain period. It was stored in the refrigerator for preservation.

Data Gathered

The following data were gathered for statistical analysis with their corresponding formula:

Initial Weight - Weight of the experimental birds at the start of the feeding period.

Final Weight - Weight of the experimental birds at the end of the feeding period.

Gain Weight- Final Weight – Initial Weight

$$\text{Average Daily Gain (ADG)} = \frac{\text{Final Weight} - \text{Initial Weight}}{\text{Number of feeding days}}$$

Feed Consumption = Total weight of feed offered – total weight of feed leftover

Treatment Consumption = Feed consumed x% Black soldier fly larvae

$$\text{Feed Efficiency} = \frac{\text{Total weight of feed consumed}}{\text{Total weight gain of birds}}$$

Return Above Feed C%%ost = Gross Income – Total Feed Cost.

Statistical Analysis

All data were gathered, organized, tabulated, and subjected to statistical analysis using Analysis of Variance (ANOVA) in Completely Randomized Design (CRD). Duncan's Multiple Range Test (DMRT) was used to compare any significant differences among treatments.

Results and discussion

Average Initial Body Weight

The average initial body weight of the experimental birds is presented in Table 6 where non-significant difference was observed among the four treatments. Treatment 1 however had 861.67 grams followed by Treatment 2 (850 grams), Treatment 3 (848.33 grams), and Treatment 4 (835 grams). The non-significant differences indicated homogeneity of the chicks.

Table 5. Average initial weight (g) of colored broiler chicken supplemented with varying levels of black soldier fly larvae under free-range condition.

Treatment	Observation			Mean^{ns}
	1	2	3	
1	795	880	910	861.67
2	800	895	855	850.00
3	830	840	875	848.33
4	870	815	820	835.00

CV = 5.039%

ns = Not significant

Average Final Body Weight

As shown in Table 7, the average final body weights of the experimental birds in Treatment 4 were 2574 grams which were slightly substantial compared to the other treatments. Treatment 3 with 2534 grams, Treatment 2 with 2495.33 grams, and Treatment 1 with 2429 grams. These differences, however were not significant indicating that the supplementation of black soldier fly larvae with commercial ration to the colored broiler chicken did not harm the birds. As reported by Stankus (2013), black soldier fly larvae have no significant anti-nutritional factors that make differences in their weight.

The crude protein content of black soldier fly larvae greatly affects the growth of colored broiler chicken as the inclusion rate increases, although it is not significant. According to the analysis by the Soil and Plant Analysis Laboratory (SPAL), the crude protein (CP) black soldier fly larvae were 32.25% dry matter basis compared to Stankus, (2013) which has 48.96% in a dry matter basis, it is lesser, which may be due to some factors to consider.

The crude fat of the black soldier fly larvae was 26.29% (dry matter basis) by Stankus, (2013) compared to Newton *et al.*, (2005) having 34.8% (dry matter basis). Just like carbohydrates and proteins, fats were used as energy. The excess fats were deposited in the adipose tissue for future use (Guyton and Hall, 2006).

In the Textbook of "Medical Technology" by Guyton and Hall (2006), growth hormone (somatotropin or somatotropic hormone) has a specific effect in causing the release of fatty acids from adipose tissue and, therefore, increasing the concentration of fatty acids in the body fluids. Besides, in tissues throughout the body, growth hormone enhances the conversion of fatty acids to acetyl coenzyme A (acetyl-CoA) and its subsequent utilization for energy. The growth hormone's ability to promote fat utilization, together with its protein anabolic effect, causes an increase in lean body mass. This explains the principle of free-ranging having, as the area extends it promotes exercise for the birds.

St. Hilaire *et al.*, (2007) reported that the black soldier fly larvae fed with fish offal has an average of 30% lipid and approximately 3% of this lipid was omega-3 fatty acids (α-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA). These omega-3 fatty-acid-enhanced pre-pupae may be a suitable fish meal and fish oil replacement for carnivorous fish and other animal diets. The lipid content of black soldier fly pre-pupae can be increased and be manipulated to include desirable fatty acids, such as ALA, EPA, and DHA, by feeding the larvae waste material from fish processing plants.

Table 6. Average final body weight (g) of colored broiler chicken supplemented with varying levels of black soldier fly larvae under free-range condition.

Treatment	Observation			Mean^{ns}
	1	2	3	
1	2492	2374	2421	2429
2	2374	2468	2644	2495.33
3	2352	2782	2468	2534
4	2432	2544	2746	2574

CV = 6.213%

ns = Not significant

Weekly Weights of Experimental Birds

The average weekly weights of colored broiler chicken supplemented with varying levels of black soldier fly larvae under free-range conditions are presented in Table 8 and Fig. 3. From the first to fifth weeks of growth and rearing, weights of the birds are competitively increasing in four treatments. Birds on Treatment 4 showed relatively heavier among all treatments.

Birds fed a ration with higher black soldier fly larvae inclusion (5, 10, and 15% black soldier fly larvae) having substantial weights. Those fed pure commercial rations had the lowest weight gain since the black soldier fly larvae have a crude protein (CP) of 32.25% in dry matter (DM) basis. During this week, it indicated that better weight gain was provided by the black soldier fly larvae to the growing chickens.

The above mentioned weekly weights were sustained for the whole week of the study. The black soldier fly larvae were made available months before the researcher reared and produced because the pre-pupal stage was 22-24 days (Alvarez, 2012). But according to Zhang *et al.*, (2010), the larval and pupal development of black soldier fly will reach 15 to 18 days approximately, if the temperature ranges to 28°C. Also, St. Hilaire *et al.* (2007) pointed out that it is possible that the lower temperature used to grow the larvae in this study (i.e., 22 C) contributed to the slower development of the larvae.

Table 7. Weekly weights (g) of colored broiler chicken supplemented with varying levels of black soldier fly larvae under free-range condition.

Treatment	Observations (weeks)					Mean
	1	2	3	4	5	
1	1128	1395.33	1690	2066.67	2391	1734.2
2	1134.67	1398.33	1717	2094.67	2407.67	1750.47
3	1183.67	1431.33	1733.33	2112.67	2444	1781
4	1201.33	1446.67	1750.33	2128.67	2569.33	1819.2

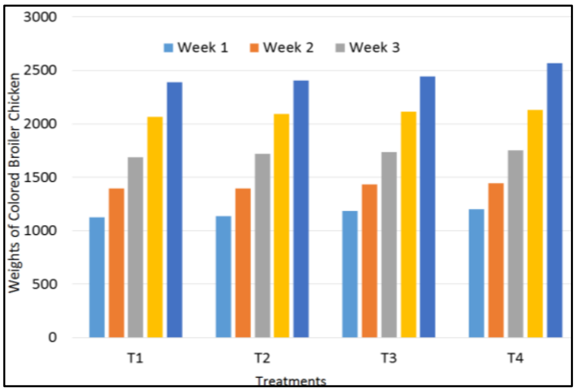

Fig. 4. Weekly weights (g) of colored broiler chicken supplemented with varying levels of black soldier fly larvae under free-range condition.

Average Total Weight Gain

The total weight of experimental birds raised for 38 days are presented in Table 9 shows no significant differences among the four treatment means.

Based on the result of the study, it is indicated that Treatment 4 has the highest total weight gain with 1739 grams, followed by Treatment 3 with 1685.67 grams, Treatment 2 with 1645.33, and Treatment 1 has the lowest weight gain a total of 1567.33 grams. But according to the report of Stankus (2013) entitled "Preliminary study of Black Solider Fly Larvae (BSFL) as Feed for Hong Kong Catfish" showed that the catfish survived and grew by eating 100% unprocessed black soldier fly larvae.

However, the growth rate was less than that of control since the unprocessed BSFL is primarily of water having 62.99% while from the analysis of SPAL (2014), it has 62.54% and it was greatly comparable. This means that 60% of larvae weight was a non-nutritive though it fills the stomach and limits further ingestion (Stankus, 2013). However, these findings were not convincing because Stankus (2013) also pointed out that the trial was too short and it could be suggested that the growth between treatments would be different over time.

Then the fish stopped feeding for over 2 weeks. Furthermore, the outdoor aquaponic set up had a serious disadvantage in that it was difficult to observe and to quantify the feeding because the sides of the tank was coated with dark algae that made it difficult to see the BSF larvae. Some of the BSF larvae sank, and it was difficult to measure the amount that sank and remained un-eaten, whereas floating feed was easy to quantify (Stankus, 2013). Then one obvious reason why it is not a positive result from Stankus, (2013) is that the digestive tract of chicken is different from catfish and it has different nutrient requirements.

Table 8. Total weight gain (g) of colored broiler chicken supplemented with varying levels of black soldier fly larvae under free-range condition.

Treatment	Observation			Mean^{ns}
	1	2	3	
1	1697	1494	1511	1567.33
2	1574	1573	1789	1645.33
3	1522	1942	1593	1685.67
4	1562	1729	1926	1739

CV = 10.08%

ns = Not significant

Average Daily Gain

As shown in Table 10, among the treatments, birds in Treatment 4 has the highest average daily gain with a total of 45.76 grams, following Treatment 3 with 44.36 grams, Treatment 2 with 43.30 grams, and Treatment 1 with 41.25 grams. However, it showed no significant differences but comparable to each other. These could be explained due to the ash or mineral content of the black soldier fly larvae that inhibit ingestion. According to the analysis of SPAL (2014), black soldier fly larvae have 11.28% ash and it is greater than Stankus (2013) with 2.91% all on a dry matter basis. The primary mineral present in the larvae are calcium (Ca) having 2.26% (dry matter basis) (Stankus, 2013) while Newton, *et al.*, (2005) has a 5% (dry matter basis). But Finke (2007) reported that BSFL has a 2.41% Ca (dry matter basis) comparable to Stankus (2013). The exoskeleton of most insects primarily composed of protein and chitin, although some insects, including soldier fly larvae, have a mineralized exoskeleton that explains their high calcium content (Finke, 2007).

Table 9. Average daily gain (g) of colored broiler chicken supplemented with varying levels of black soldier fly larvae under free-range condition.

Treatment	Observation			Mean^{ns}
	1	2	3	
1	44.658	39.316	39.763	41.25
2	41.421	41.395	47.79	43.30
3	40.053	51.105	41.921	44.36
4	49.105	45.5	50.684	45.76

CV = 10.08%

ns = Not significant

Feed Consumption

A. Black Soldier Fly Larvae Consumption

The total black soldier fly larvae consumption of the experimental birds are shown in Table 11 where highly significant differences ($P<0.01$) were observed among treatments. Those birds in Treatment 4 consumed significantly higher in a volume of treatment of about 530.15 grams on a dry matter basis, followed by Treatment 3 (364.84 grams dry matter basis), and Treatment 2 with 188.02 grams on a dry matter basis. The dry matter (DM) of the black soldier fly larvae as analyzed by the Soil and Plant Analysis Laboratory (SPAL), has 37.46% and it was comparable to the proximate analysis by Stankus (2013) having 37.01%.

All larvae given to the birds were consumed. This indicates that the BSFL is highly palatable. Newton *et al.*, (2005) reported also the high palatability of larvae in the pigs, which prefer BSFL to soybean diet without added fat.

Table 10. Total black soldier fly larvae consumption (g) of colored broiler chicken (Dry matter basis).

Treatment	Observation			Mean**
	1	2	3	
1	0	0	0	0[a]
2	187.82	188.21	188.04	188.02[b]
3	365.40	362.59	366.55	364.84[c]
4	533.18	528.56	528.69	530.15[d]

CV = 0.62%

** = Highly significant

Means with no common letter are significantly different (DMRT)

B. Total Feed Consumption

The total feed consumption of colored broiler chicken supplemented with varying levels of black soldier fly larvae under free-range condition are shown in Table 12 where highly significant differences ($P<0.01$) were observed among treatments.

Birds in Treatment 1, 2, and 3 consumed a significantly higher volume of feeds of about 3875.22, 3760.46, and 3648.44 grams on a dry matter basis as compared to Treatment 4 with 3534.31 grams dry matter basis. As the inclusion rate of black soldier fly larvae increases the feed consumption of the experimental bird decreases. However, as reported by Ponte *et.al* (2008), pasture intake of free-range broilers promoted an increase in the consumption of the cereal-based feed, both in the spring and autumn experiment. And he suggested that differences in the levels of cereal-based feed consumption may be related to the composition or levels of pasture intake, or both.

Table 11. Total feed consumption (g) of colored broiler chicken supplemented with varying levels of black soldier fly larvae under free-range condition.

Treatment	Observation			Mean**
	1	2	3	
1	3871.41	3880.21	3874.05	3875.22[a]
2	3756.35	3764.27	3760.75	3760.46[b]
3	3654.01	3625.86	3665.46	3648.44[c]
4	3554.55	3523.75	3524.63	3534.31[d]

CV = 0.37%

** = High significant

Means with no common letter are significantly different (DMRT).

Feed Efficiency

Feed efficiency is the ratio between the total feed consumed over the total weight gained of birds. The lower the value, the more efficient are the birds in converting feed to live weight. Table 13 shows the feed efficiency of the experimental birds. Although not significantly different, feed efficiency was observed but numerically, those consuming commercial rations with 15% black soldier fly larvae supplementation resulted in better efficiency, having the only 2.05kg of feed to produce a kilogram of live weight those in Treatment 1 needed 2.48kg feed for a kilogram of weight. There were no significant differences between the feed efficiency of birds subjected to the free-ranged condition. This suggests that bird performance primarily depends on the cereal-based feed and the treatment rather than from grazing (Ponte *et al.*, 2008). Crude fiber also affects the efficiency of the bird having 9.1% (dry matter basis) (Stankus, 2013), also Newton *et al.*, (2005) pointed out the ash (14.6% DM basis) and fiber (7% DM basis) levels were higher for the black soldier fly diets, suggesting that the chitinous cuticle of the larvae was analyzed as fiber. These chitin's (linear polymer of β-(1-4) N acetyl-D-glucosamine units) are similar structurally to cellulose (linear polymer of β-(1-4)-D-glucopyranose units) which also explains the ingestion inhibits.

Table 12. Feed Efficiency of colored broiler chicken supplemented with varying levels of black soldier fly larvae under free-range condition.

Treatment	Observation			Mean[ns]
	1	2	3	
1	2.28	2.60	2.56	2.48
2	2.39	2.39	2.10	2.29
3	2.40	1.87	2.30	2.19
4	2.28	2.04	1.83	2.05

CV = 9.62%

ns = Not significant

Return Above Feed Cost

The return above feed cost in raising colored broiler chicken greatly dependent on the weight gain, the total amount of feed, and the cost of feed consumed. Table 14 shows the return above feed cost of colored broiler chicken supplemented with varying levels of black soldier fly larvae under free-range conditions. Treatment 4 obtained the higher return above feed cost (Php. 157.11) followed by Treatment 3 (Php. 145.54), Treatment 2 (Php. 135.18), and Treatment 1 with Php. 118.54.

Table 13. Return above feed cost (Php.) of colored broiler chicken supplemented with varying levels of black soldier fly larvae.

Particulars	Treatment			
	1	2	3	4
Final live weight,kg.	2.43	2.50	2.53	2.57
Price perkg., Php	150	150	150	150
Gross return per head, Php	364.5	375	379.5	385.5
Cost of day-old chick per head, Php	40	40	40	40
Feed consumption per head,kg.	6.8	6.49	6.2	5.92
Chick booster mash	2.92	2.92	2.92	2.92
Broiler starter crumble	3.88	3.57	3.28	3
Price perkg. feed, Php				
Chick booster mash	32	32	32	32
Broiler starter crumble	29	29	29	29
Total feed cost, Php	205.96	196.97	188.56	180.44
Chick booster mash	93.4	93.44	93.44	93.44
Broiler starter crumble	112.52	103.53	95.12	87
Total BSFL consumed,kg.	0	0.19	0.36	0.53
Price perkg. of BSFL. Php	0	15	15	15
Total BSFL cost, Php	0	2.85	5.4	7.95
Return above feed & supplementation Cost, Php	118.54	135.18	145.54	157.11

Conclusion and recommendation

This study was conducted at thecmU Poultry Project, Musuan, Maramag, Bukidnon from December 05, 2013, to February 05, 2014, which aimed to determine the growth performance of colored broiler chicken supplemented with varying levels of black soldier fly larvae under free-range condition, particularly the initial weight, the final weight, total weight gained, average daily gained, feed consumption, treatment consumption, feed efficiency, and return above feed cost.

A total of forty-eight (48) heads of day-old chicks regardless of sex were used in the study. The chick was randomly distributed into four (4) dietary treatments. Each treatment was replicated three times with four (4) birds per replication following the Complete Randomized Design (CRD).

The four dietary treatments were as follows:

Treatment 1 = 100% commercial feed (control)

Treatment 2 = 95% commercial feed + 5% BSFL

Treatment 3 = 90% commercial feed + 10% BSFL

Treatment 4 = 85% commercial feed + 15% BSFL

The data gathered in the study consisted of an initial weight, final weight, total weight gain, average daily gain, feed consumption, treatment consumption, and feed efficiency. All variables were analyzed using Duncan's Multiple Range Test (DMRT) to compare treatments with significant differences.

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