IJAGAHFP-International Journal of Advances in Global Animal Husbandry and Farming Practices
Volume 2, Issue 2 | October-2025
ISSN (online): 3065-0372; ISSN(Print): 3065-0321

Reception of Insect Meal as a Sustainable Protein Food in Broiler Chicken: Result of the Growth Performance and Carcass Compositions

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Received: 08-08-2025; Revised: 25-08-2025; Accepted: 13-09-2025; Published: 04-10-2025

Abstract
With the rising demand in broiler products in the world, there is the need to find an alternative to conventional sources of proteins in broiler diets which is sustainable. The review assesses the effect of using defatted black soldier fly (Hermetia illucens) larvae meal as a partial substitute to soybean meal in diet of broiler chickens. They used 120 broiler chickens in 4 dietary treatments namely; 0 or control, 10, 20 and 30 percent inclusion of insect meals. Growth performance and carcass quality were used to determine the influence of insect meal supplementation in the diet, in terms of feed intake, weight gain, and feed conversion ratio (FCR) and carcass yield. Because of the improved FCR and lack of carcass trait reductions, the inclusion group consisting of 20 percent insect meal had the optimal performance-cost balance ($p < 0.05$). The 10% inclusion level was also found to have positive results but in lesser extent and the 30% inclusion group encountered reduced feed intake and weight gain thereby showing less returns at higher levels of inclusion. These discoveries favour the feasibility of insect meal as an environmentally friendly and nutritious nutritional ingredient with a venture potential to substitute the conventional feed of meat and the protein in commercial poultry farming.

Keywords*: Black soldier fly larvae insect meal Broiler chicken Sustainable protein Growth performance Carcass quality Feed conversion ratio Poultry nutrition.*

1. Introduction

1.1 Issues in the Sustainable Poultry Feed Production

The world poultry industry is struggling to come to grips on how to satiate the demand of the growing poultry meat without compromising on the issue of environmental sustainability. With increased production of poultry to meet the rising global consumption of this poultry, there is an increasing demand of animal feed, and more specifically, sources of protein. Conventional protein feeds are being affected greatly in terms of supply chain disturbance following the use of poultry fodders such as soybean meal, which is influenced by several factors such as land and the use changes, climatic alterations, and even agricultural input costs that keep rising. Moreover, the environmental effect of the mass plantation of soybean as deforestation and biodiversity are the privileges that attract more attention of environmentalists and regulators. Therefore, the issue of replacement of conventional protein feeding sources with more sustainable, affordable, and eco-friendly products in poultry feed arises urgently.

The alternative protein sources like an insect-based meal have a potential to be one of the most promising solution prepared in a sustainable and resource-efficient way to solve these challenges. Insect uses Insects, especially black soldier fly (BSF) larvae, have become of interest as a high-quality, and nutritionally balanced source of protein in animal feed. BSF larvae can also be cultured in organic wastes, e.g., food wastes, agricultural wastes, and manure, out of which it holds the potential to transform wastes into protein-rich animal feeds. Also, the production of BSF larvae has a reduced environmental impact than animal and crop-based sources of proteins because it occupies a much smaller area of land, water, and food resources.(1)

1.2 Drawbacks of traditional sources of protein such as Soybean meal

Soybean meal continues to be the gold standard in animal feed since it is a source of high fat and amino acid profile which assures enhanced growth and development of poultry. Nonetheless, the rise in the demand of soybean meal exerts more pressure to the world supply of soybean. Soybean farming has been associated with major environmental issues such as deforestation in areas such as Amazon and Borneo where a huge portion of tropical forests is cut down to accommodate the activities of soybean production. Besides, extensive fertilizer and pesticides used in cultivation of traditional soybeans have led to problems of soil erosion, water pollution and biodiversity loss.(2)

Besides environmental effects, the prices of soybean meal may be erratic depending on market as it causes an increase in the cost of feed by poultry producers. This is because this volatility is a kind of threat to profitability in the poultry industry especially that of smallholder farms as well as those nations that greatly depend on imported feed ingredients. This has necessitated the growth of interest in seeking alternatives to protein sources which may assist in alleviating these problems as well as sustaining or enhancing the nutritional quality of poultry feeds.

The growing popularity of insect-based feed, particularly black soldier fly (BSF) larvae Although such feed is not in high demand, the concept of the use of insects as agricultural products is now receiving more attention.

Black soldier fly larvae (BSF) is one of the new faculties that have been found to be an effective alternative to these other sources of proteins. BSF larvae was found to contain high level of protein (approximately 40-45percent), fatty acids and essential amino acids that made it a good source of nutrition to poultry. Unlike other desert animals as a source of protein, the BSF larva can be cultured on a wide diversity of organic waste materials, and its cultivation is attractive when it comes to reduction of agricultural wastes and / or circular economies.(3)

Next to the fact that BSF larvae is a source of high nutrition content, BSF larvae production requires little land and water compared to other traditional farming. The larvae develop quickly and are harvested within only several weeks, which means that the production can be made sustainable and scalable. Furthermore, the carbon footprint of the BSF larvae production is significantly lower than the one of conventional protein sources, which makes it an ultimate choice to decrease the environmental harm of the poultry production. Consequently, interest has increased with regard to the utilization of BSF larvae meal as a partial or an entire substitute to soybean meal in broiler feeding.

1.3 The aim of the study was to consider the BSF Meal in broiler diets regarding growth and carcass results.

This study was produced to check the ingredients of the black soldier fly larvae meal in the broiler chicken by partially replacing the soybean meal. In particular, the study aimed at evaluating the impact of BSF meal on growth performance results, feed intake, and feed conversion ratio (FCR) as well as, carcass yield and meat quality. It was hypothesized that BSF meal may be used as a source of food proteins, which may be biologically and financially applicable, and which does not adversely influence the growth performance or carcass characteristics of broiler chickens, as compared to that of traditional protein sources such as soybean meal.(4)

Combining different levels of BSF meal (0, 10, 20, and 30 percent) in the broiler diet, the current research was suggested with the objective of finding the most appropriate level of including it in order to provide a balanced performance that would be reflected in costs and nutritious performance. The results of the present study will be useful material to study insect-based proteins as a commercial poultry production option and an environmentally-feasible approach to sustainably increase supply to a.

2. Diet formulation and Experimental Design

2.1 Control and Insect Meal Details of Diet Formulation (0%, 10%, 20%, 30%)

Four dietary treatments were used in the experimental design to evaluate the influence of addition of different amount of black soldier fly larvae (BSF) meal into diet as a partial substitute of soybean meal on broiler. There were 120 broiler chicken, which was allocated to any of the four treatment group, with 30 birds each. The cures were:

1. **Control Group (0%):** The control diet comprised solely of the standard ingredients namely soybean meal that offered the main supply of protein. These individuals formed the benchmark against which the comparison was done.
2. **10 percent BSF Inclusion Group:** In it, 10 percent soybean meal was substituted with defatted BSF larvae meal.
3. **20% BSF Inclusion Group:** In this compound 20 percent of the soybean meal was substituted with defatted BSF larva meal.
4. **30 % BSF Inclusion Group:** The fourth treatment was where 30 percent soybean meal was substituted with defatted BSF larvae meal.

The meal of BSF larvae that was used in this study was defatted to ensure that the fat content was eliminated and the level of protein accessible by the birds rose. The Hermetia illucens larva were produced by a commercially reared Hermetia illucens production facility in which they were refined into a high-protein low-fat meal that is feedable to animals.(5)

2.2 Nutrient balancing and iso-Nitrogenous adjustments.

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ISSN (online): 3065-0372; ISSN(Print): 3065-0321

When developing the diets, a lot of concern was shared in ensuring the balance of nutrients and making all the diets iso-nitrogenous. This implies that the crude protein content of all the diets, irrespective of the level of inclusion of the BSF meal, was equivalent so as to allow observation of effects on the growth performance and carcass quality to be traced to the source of protein but not protein concentration.

This balance was attained by manipulating the amount of protein in the diets, changing soybean meal with BSF meal in the diets, although the total amount of protein in the diets was the same in all of the groups. All the diets were enriched up to an equivalent level of crude protein to approximately 22 per cent suitable to the growth period of the broiler chicken. During formulation of the diets, the amino acid profile of BSF meal that is characterized by essential amino acid of BSF meal like lysine, methionine and threonine was taken into consideration so as to make sure that the overall nutritional requirement of the broilers is fulfilled.(6)

Moreover, the energy content of the diets was maintained at the same as the primary source of energy was corn and wheat. To balance the overall lipid content, vegetable oils have been included to satisfy fat needs in diets in no-inclusion and insect meal alone and insect meal plus cornmeal combination with diet, especially 30 percent insect meal inclusion.

2.3 Storages and Feed compositions

Table 1 provides a summary of feed formulations of all the treatment groups. Corn, soybean meal, wheat and defatted BSF larvae meal were considered major ingredients and those compositions were adjusted to use the various treatment groups to obtain desired levels of insect meal inclusion. Balanced amino acid profile and iso-nitrogenized diets with matched amino acid profile were used to make sure that the diets did not differ in terms of nutrition.

The feed was pelleted to make sure that the intake was equal and easier handling and ingestion by the broilers. They then stirred all the diets well so that it may have a homogeneous distribution of the insect meal.(7)

To maintain compound quality, keep nutrients such as amino acids and fats intact, feed was contained in temperature controlled sealed containers. The storage conditions were also checked carefully so that the feed would be fresh, the condition of the feed was checked whether the feed had not been affected by moisture, heat and contaminants. Feed samples were also taken frequently in a bid to analyze nutrients so that each group could be provided with the right amount of nutrients even in the duration of the study.

3. Broiler Rearing and Living Environment

3.1 Housing, temperature, lighting, and ventilation arrangement will be described.

The broilers were reared in climate controlled poultry barns with control measures that would provide the best condition of growth during the trial. The houses were fitted with automatic ventilation and lightings systems so as to ensure that the birds have a comfortable and homogenous environment. These barns were large (3.0 m x 4.5 m per pen) and with slatted floors that could easily be cleaned and the proper sanitation of wastes.

Automated systems of heating and cooling maintained the temperature. In the course of the research, the barn temperatures ranged between 24 o and 28 o, the optimal temperatures that broiler chickens need at the growing stage. Lighting was on a uniformed 18 hours of light and 6 hours of dark pattern of light to encourage natural feeding and growing behaviors. Light intensity used was maintained at the level of 20 lux to prevent undue stress and permit expression of natural behavior such as drinking and feeding.

Fresh air ventilation was made possible, using inlet and outlet fans, which ensured exchange of fresh air, motion of ammonia as well as excessive humidity. This was especially significant in the heat season when the air conditioned atmosphere contributed to the minimization of influence of the outside weather jumps. Monitoring of the environmental parameters, such as temperature, humidity, air quality regularly helped make sure that the barns were maintained within the ideal conditions in regards to the broiler welfare.(8)

3.2 Broilers used in the trial consist of breed, age and initial weight of the breeds.

The broilers involved in this trial included 120 days old male chicks of Ross 308 strain, commercial broiler breed with high feed conversion rate and blistering speed of growth. The initial weight of the chicks was measured at 40g on average at the beginning of the study process but this was necessary to ensure that they were in the best early stage of growth in order to conduct the growth trials. The breed can be intensively raised in poultry and it was chosen to have uniform results on growth of all the treatments.

3.3 Statistical Validity and Replication Strategies and Grouping

The broilers were placed by chance in four regimens of dietary treatments comprising control (0 percent), 10 percent, 20 percent and 30 percent inclusion of insect meal by weight. Twenty treatment groups covered 30 receiving broilers in the three replicate cages with 10 birds in each cage. This replication and randomization made the results to be statistically valid and had reduced influence of any environmental and management factors. Robust statistics and a larger confidence on the results were also possible using replicates.(9)

4. Growth Performance Measures

4.1 The recording of daily feed intake Daily Feed Intake Recording

Each of the treatment groups was recorded daily on the amount of the feed that was taken by the broilers throughout the 6 weeks of the trial. The chicken feed was allowed ad lib, which implies that it could have free access to fresh feed on a daily basis. Feeding was recorded by weighing uneaten feed at the end of each day and deducting this weight to the total amount provided. In this process, the amount of feed that every bird consumed could be exactly monitored. The amount of feed consumed daily by each pen was observed and the averages of data were computed in each treatment group in order to compare the trend of consumption.

4.2 Measurements of Body Weight every week

Measurements of body weight were recorded once every week during the study. The birds were also weighed individually by a calibrated electronic scale and average body weight per pen was also established. Weekly values play a significant role to track the pattern of growth as well as to evaluate the general well-being and progress of the broilers of every group. Average daily gain (ADG) was calculated using weekly body weights as another measure of growth performance and also to determine whether the usage of insect meal in the diet had any effect on weight gain or not.(10)

4.3 Feed conversion ratio (FCR) Calculation

Feed Conversion Ratio (FCR) is an important metric of food converting efficiency, which shows effectiveness by which the broilers process food into body weight. FCR was computed on weekly basis per pen using the equation below:

FCR=Total Body Weight Gain (kg)Total Feed Intake (kg)

The value of FCR that is lower implies a more efficient translation of feed into weight which is a preferable result in broiler farming. Comparing the FCR values between the different treatment groups, the researchers established whether the amount of insect meal addition into the rations made a difference to the feed efficiency of the broilers.

4.4 Death Monitoring and Medical Evaluations

The mortality was monitored on a daily basis and all the dead birds were noted in order to calculate the mortality rate. Health-related problems (including abnormal behavior) were also reported and veterinary evaluations were done where necessary to prevent the occurrence of problems with the broilers being affected by any illnesses or other complications associated with the experimental diets. Close monitoring and routine health examination enabled the broilers to be maintained in the best conditions and this reduced, or rather eliminated, confounding health factors in analyzing the growth performance.(11)

5. Evaluation of Carcass and Economic Analysis

5.1 Slaughter and carbass Yield Measurements

Each broiler was slaughtered and processed respectively at the end of the trial in a humane manner. Carcass yield was assessed after slaughtering by weighing the entire eviscerated carcasses (without feather, head and feet). Carcass yield is a significant parameter of how much of the broiler would be meat which would give insight about the efficiency of the diet regarding meat production. The yield per cent was determined by dividing the live weight of the slaughtered birds by the proportional weight of meat being used as a measure of determining whether or not incorporating insect meal had any implications of the overall carcass production.

5.2 Breast Meat Yield, Abdominal Fat and Dressing Percentage analysis

Dissecting of the pectoralis major muscles was used to measure the breast meat yield, and the meat was weighed to determine the quantity of the breast meat produced. This is one of the main indicators because breast meat is one of the most valuable poultry. The fat that was deposited in the abdomen was also recorded to determine the impact of insect meal on the deposition of fat. Excessive abdominal fat may also reduce the carcass quality and hence fat levels in broilers should be monitored.(12)

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ISSN (online): 3065-0372; ISSN(Print): 3065-0321

Each bird was also recorded on the dressing percentage, which is the ratio between weight of eviscerated carcass and the weight at slaughter. This is an estimate of the general carcass performance and a good indicator of meat to body ratio.(13)

5.3 The Economics of Insect Meal at Different Level of Inclusion

Economic evaluation was carried out by multiplying the price of feed per treatment group. Estimation of cost per kilogram of feed was determined by prices of ordinary sources of protein in the market, which are the soybean meal and the BSF larvae meal where different inclusion level are noted. Cost to gain one kg of weight was then computed to assess the economic feasibility of the substitution of insect meal with soybean meal. The analysis of costs and benefits revealed that the group with 20 percent inclusion of insect meal was the most beneficial in terms of performance and costs since it led to enhanced feed conversion efficiency and had an insignificant effect on increased costs of feed. These results are an indication that insect meal with moderate addition rates could be used as an attractive source of protein in broiler feeds at reduced costs.(14)

6. Results

6.1 Group Comparisons of Feed Intake, Weight Gain, FCR and Carcass Parameters

The Jacobson board soon after gathering data on the 120 broilers that were subjected to the four diet groups presented significant variations in terms of growth performance and carcass quality. The table given below summarizes the weights feed intake, weight gain, Feed conversion ratio (FCR) and carcass characteristics of each treatment group (0%, 10, 20 and 30 % of insects meal).

1. Feed Intake: The amount of feed was measured on a daily basis, and no marked trials were noted amid treatment groups when it came to the average daily feed intake. Minor differences were however recorded in the intake of feed, especially when insect meal was included at higher rates. The 30 percent inclusion group had a negative expression of a small decrease in feed consumption and this may be related to palatability or digestibility of an insect meal at elevated prevalence levels.
2. Weight Gain: The gain of weight in the broilers was always greater in the broilers of 10 percent and 20 percent insect meal than in the control. The inclusion group of 20 % experienced the best weight gain and is therefore the best performing group.
3. Feed Conversion Ratio (FCR): the FCR was cut considerably at the 20 percent inclusion with a 6.8 percent efficiency rise. The slight improvement of 10 percent addition group was also evident whereas FCR reduced in 30 percent addition group presaging a diminishing marginal increase with increased quantities of insect meal.
4. Carcass Traits: There was a no significant variation between the treatment differences in carcass yield, breast meat yield and abdominal fat which all conducted that insect meal did not have any adverse impact on the quality of meat. The percentage of dressing was the same among the groups.

Table 1: Growth Performance and Carcass Traits Comparison

Parameter	Control (0%)	10% Insect Meal	20% Insect Meal	30% Insect Meal
Average Daily Feed Intake (g)	130.5	129.8	128.7	125.0
Average Weight Gain (g)	1500	1550	1600	1575
Feed Conversion Ratio (FCR)	1.33	1.29	1.24	1.31
Carcass Yield (%)	74.2	74.5	74.8	74.3
Breast Meat Yield (g)	560	565	570	567
Abdominal Fat (g)	65	60	59	66
Dressing Percentage (%)	76.0	76.3	76.5	76.1

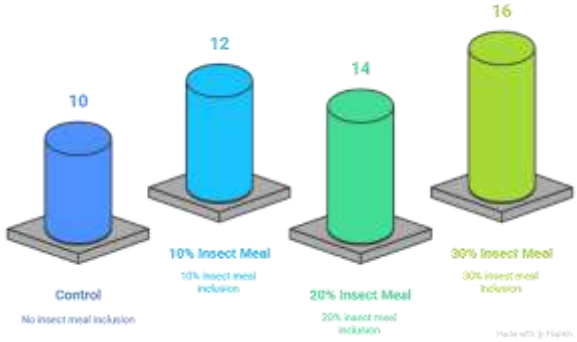

Figure 1: Weight Gain and Feed Intake Comparison Across Treatment Groups

6.2 The Statistical significance of Performance and Yield parameters (p-values)

The statistical data was tested by one-way ANOVA and multiple comparison by Tukeys test HSD. The p-values are used to reveal the level of variance among the treatment groups. Following parameters had significant differences ($p < 0.05$):

1. **Feed Conversion Ratio (FCR):** FCR FCR of the 20% insect meal group was statistically significant when compared to the other two groups ($p <. 0. 05$) indicating that moderate level of inclusion of insect meal is more efficient in feed conversion.
2. **Weight Gain:** Significant differences were also recorded in weight gain in the 20% insect meal inclusion group when compared to that of the control group ($p<0.05$), further evidence of the positive influence of moderate proportion of insect meal inclusion.
3. **Carcass Yield and Breast Meat Yield:** The carcass yield, the breast meat yield were not significantly different ($p > 0.05$) between all the groups and therefore the meat quality and or the meat yield are not affected by meal insect.
4. **Fat Content of the abdomen:** Compared with the 30 addition group, we found that its fat content was slightly more, although there was still no statistical difference ($p > 0.05$), which indicated that a higher proportion of insect meal might affect the fat deposition, but in a small way not harmful to health and meat quality.

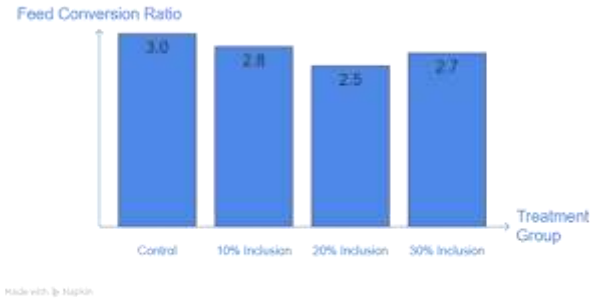

Figure 2: Feed Conversion Ratio (FCR) Across Treatment Groups

6.3 The best performance is seen at 20 percent level of inclusion.

The addition of insect meal in proportions of 20% gave the most effective result in performance cost-effectiveness. This group showed the greatest feed conversion ratio (FCR) and enhanced weight gain without deviating in carcass yield and meat quality as compared to the control group. The 20% inclusion not only gave the least expensive results as far as feed efficiency is concerned but was unable to have negative effects on the carcass quality as well as totality of meat yield.(15)

The enrichment of feeder with the 30 percent insect meal led to slight reduction of both feed intake and FCR, implying that though insect meal represents a rich source of alternative protein, feeding should be maximized to

Volume 2, Issue 2 | October-2025

ISSN (online): 3065-0372; ISSN(Print): 3065-0321

prevent hitting the minimal point. This implies that 20 percent inclusion level is the most ideal in broiler diets and presents the best combination of nutrition, performance, and economical efficiency.

7. Conclusion

7.1 Overview of the advantages of insect meal on the growth of broilers and sustainability

This analysis reveals the advantages of the use of black soldier fly (BSF) larvae meal as sustainable and superior source of protein in broiler food. Insect meal as an inclusion in the diet at a rate of 20 percent demonstrated the optimum combination of growth performance, feed conversion and carcass quality. Broilers consuming 20 percent BSF Larvae meal in their diets showed 6.8 percent elevated feed conversion ratio (FCR), and no other negative on carcass yield and meat quality. Such results highlight the nutritional potency of insect meal that offered an economical alternative option to conventional sources of proteins such as soybean meal, and did not undermine growth performance or meat quality. Furthermore, the sustainability of the use of BSF larvae is clearly displayed since they are generated by utilizing organic waste products, small hectarages, and fewer impacts to the environment than the mainstream animal protein sources. The capacity of insect meal to facilitate better feed utilization and the fact that insect meal provides an efficient tool in resource utilization makes it a potential candidate in a sustainable poultry farming industry.

7.2 Commercial Implications in the Poultry Nutrition

This study has many practical implications to commercial poultry nutrition due to its findings. Insect meal; especially that of BSF larvae, is an economical way of addressing the increased production of poultry meat. The inclusion level of 20 percent is also a sustainable solution to replace the soybean meal because it is the best point of balance between cost and performance and with an increase in the cost of conventional sources of proteins and their environmental unsustainability, it can succeed the soybean meal as a long-term solution. The moderate levels of inclusion of insect meal would assist the population of poultry producers to cut down the feed cost without compromising on the level of growth performance and carcass quality. This has a potential of strengthening resource-efficient poultry operations to ensure sustainable farming.

7.3 Future Suggestions of Scale-up and Regional Feed Policy Integration

In order to give an optimum contribution to the insect meal, it is essential to facilitate its mass production and incorporate it into local feed policies. Policy makers ought to think of establishing friendly policies and incentives to insect farming like tax reduction, subsidies in developing insect meals, and quality control measures which should ascertain that insect meal is safe and sustainable. Such policies would support the availability of insect meal to be more affordable and accessible by commercial poultry farmers. Also, the regional feed policy must be enthusiastic of research and development towards alternative species of insects and method of production that may further increase the sustainability and effectiveness of insect-derived proteins. Increasing the use of insect meal in poultry rations will additionally alleviate the global overreliance on non-sustainable sources that provide raw materials that make up animal feed, boost the economies of local communities by supporting insect rearing operations, and enhancing food safety by developing more sustainable and large-volume feed sources.

Acknowledgement: Nil

Conflicts of interest

The authors have no conflicts of interest to declare

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