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Cost-Benefit Analysis of Replacing Fish Meal with Black Soldier Fly (*Hermetia illucens*) Larvae Meal in Broiler Diets

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ABSTRACT

Rising inflation and overfishing have increased the cost and reduced the sustainability of fish meal, prompting the search for alternative protein sources in poultry production in Nigeria. This study evaluates the cost-benefit and performance outcomes of using black soldier fly larvae meal (BSFLM) as a substitute for fish meal in broiler diets. Fifty (50) broilers were assigned to five dietary treatments (T1, T2, T3, T4 and T5) with 0%, 25%, 50%, 75%, and 100% inclusion levels of BSFLM replacing fish meal over eight weeks. Data on daily feed intake, weekly body weight, and total feed cost were collected. Growth performance and some economic indices of the birds, such as return on investment and cost–benefit ratio, were determined. The results indicated that the inclusion of BSFLM in diet contributed to a reduction in feeding costs without compromising the health and growth of the birds, especially between 25% and 75% levels of inclusion. Thus, feed cost per 25 kg bag decreased from ₦ 33,317.50 ($20.95) in the fish-meal based diet (T1) to ₦ 18,525.00 ($11.65) in the diet containing the highest BSFLM inclusion (T5). This already represents evidence of financial benefit. Return on investment was highest in T4, 96.49%, followed by T5, 83.54%, and both treatments were above the control treatment, T1, 61.15%. Birds in T1 recorded the highest feed intake and weight gain, although birds in T2 and T3 grew relatively well to suggest that partial replacement of fish meal with BSFLM may not negatively affect growth performance. The study demonstrates that BSFLM is a cost-saving and sustainable protein source for broiler production that has the potential to support food security and environmentally responsible agriculture.

Keywords: Alternative protein, Black soldier fly larvae meal, Broiler production, Cost-benefit-Ratio, Fish meal replacement, Return on investment, Sustainable protein source.

Introduction

Background of the Study

Poultry production in Nigeria is increasingly deteriorating due to inflation and rising prices of imported feed ingredients, particularly fish meal (CBN, 2024). Despite the fact that fish meal remains an extremely nutritious protein source to this day (Saleh *et al*., 2022), its use is becoming increasingly unsustainable because of growing demand, over-exploitation of fisheries, and constrained supply.

Problem Statement

Fish meal is a major protein source in livestock production but the high cost and the issue of its sustainability create pressures to seek nutritionally adequate alternatives. One promising and sustainable option is BSFL, which can convert organic waste

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into high-quality protein and are being studied as a substitute for fish meal in animal feeds.

Justification

The BSFL meal production is a sustainable option with no current competition in human diet in Nigeria. The BSFL meal further resonates with key global development imperatives like Zero Hunger (SDG 2) and Life Below Water (SDG 14) (Moruzzo *et al*., 2021). This helps in the recycling of waste, promotes the models of circular economies, and could reduce feed costs-beneficial elements relevant to resource-limited settings like Nigeria.

Knowledge Gap and Contribution

Although a good deal of research has demonstrated the nutritional and environmental virtues of BSFL meal in poultry production, very little information is available concerning its economic viability and real performance when incorporated into broiler diets under real-world conditions in developing countries especially Nigeria. There are few empirical studies that report costs, returns on investment, and growth outcomes across different levels of BSFL inclusion as to replacement of fish meal. This study bridges this gap by carrying out a cost-benefit analysis of diets replacing fish meal with BSFL meal, considering feed cost, profitability, and growth performance of broilers. The results are expected to deliver useful insights to farmers, feedmillers, and policy makers in search of viable alternatives toward more sustainable models of production as to rich protein source.

Aim and Objectives

The aim of this study was to evaluate the economic and growth performance outcomes of substituting fish meal with black soldier fly larvae meal (BSFLM) in broiler diets. The specific objectives were:

i. To compare feed costs when BSFLM is used instead of fish meal.
ii. To determine the return on investment (ROI) for each dietary treatment.
iii. To assess growth performance of broilers across five dietary treatments.

The general hypotheses that guided the research were:

i. BSFLM will not negatively affect broiler growth performance.
ii. BSFLM as an animal-based protein source is more cost-effective than fish meal.

Materials and Methods

Fifty (50) day-old broiler were randomly assigned to five treatment groups (T1, T2, T3, T4 and T5) with BSFLM replacing fish meal at 0%, 25%, 50%, 75%, and 100% respectively. Each treatment had ten (10) birds divided into two (2) replicates. The study was conducted at Bowen University Teaching and Research farm in Iwo, Osun State, Nigeria, from mid-October to mid-December, running a feeding trial for a total of 8 weeks using Completely Randomized Design.

Feeding and Diet Composition: For the first two weeks during brooding, the birds were fed conventional diet, hence the experiment fully commenced at the third week. The growing birds were fed two different formulated diets at various weeks to meet their nutritional standards; starter diets (week 1 – 4) and finisher diets (week 5–8). Major ingredients included maize, soybean meal, fish meal, BSFLM, wheat offal, bone meal, oyster shell, salt and premix. Feed and water were provided *ad libitum.*

Data Collection and Analysis: Metrics collected includes feed cost, feed intake, body weight gain, mortality, and total production cost. Economic indices such as Cost-Benefit Ratio (CBR) and Return on Investment (ROI) were calculated following De-Pach (2012).

Results and Discussion

Feed Cost Analysis

Feed cost in Table 1 declined as BSFLM inclusion increased from T1 to T5. The total feed cost spent on 50 birds during the study period for T1 (0%

BSFLM) was ₦66,635, while T5 (100% BSFLM) was ₦37,050. The total cost of feed decreased as the quantity of BSFLM in diets increased. These results are in agreement with Sumbule *et al*. (2021) found that higher inclusion of BSFLM reduces feed costs significantly.

Table 1. Total Feed Cost per Dietary Treatment of Broilers chickens fed BSF-based diets

Treatment	BSFLM Inclusion (%)	Total Feed Cost (₦)
T1	0	66,635
T2	25	56,860
T3	50	48,050
T4	75	42,430
T5	100	37,050

Return on Investment (ROI) and Cost Benefit Ratio (CBR)

The Cost-Benefit Ratio (CBR) in Table 2 calculated as the ratio of revenue to cost, indicates profitability, where a value greater than 1 suggests that the project's benefits outweigh its costs (De-pach, 2012). Therefore, the greater the value, the greater the project benefits outweigh the costs. T4 had the highest CBR at 1.96 meaning that for the money spent, the gains greatly outweigh the cost.

Conversely, ROI (Table 2) measured the profitability of the investment by comparing the net gain to the amount invested. A higher ROI indicates a more financially viable project (De-pach, 2012). T4 had the highest ROI at 96.49%, followed by T5 at 83.54%. This confirms the economic benefit of BSFLM over fish meal, validating Hypothesis ii.

Table 2: Return on Investment (ROI) and Cost Benefit Ratio (CBR) by Treatment

TREATMENT	ROI (%)	CBR
T1 (0% BSFLM)	61.15	1.61
T2 (25% BSFLM)	61.33	1.61
T3 (50% BSFLM)	69.43	1.69
T4 (75% BSFLM)	96.49	1.96
T5 (100% BSFLM)	83.54	1.84

Growth Performance

In Table 3 and Figure 1, the feed intake across the different dietary treatments were relatively similar throughout the study, the impact on body weight varied noticeably among the groups.

Table 3. Feed Intake/Week/Bird of Broilers Chickens Fed BSF-based Diets

	FEED INTAKE/WEEK/BIRD (g)				
WEEK	T1 (0% BSFLM)	T2 (25% BSFLM)	T3 (50% BSFLM)	T4 (75% BSFLM)	T5 (100% BSFLM)
1	162	162	174	174	174
2	289	318	318	318	313
3	482	475	458	459	463
4	461	498	469	460	451
5	651	655	538	601	604
6	722	745	700	676	729
7	1020	1031	999	998	1004
8	1750	1750	1750	1750	1750

Treatment 1 (0% BSFLM) recorded the highest final body weight, with a gradual decrease observed from T2 all the way to T5 as the inclusion level of BSFLM increased. This indicates that while the birds consumed almost equivalent quantities of feed, the efficiency with which the nutrients were converted into body mass differed based on the diet composition.

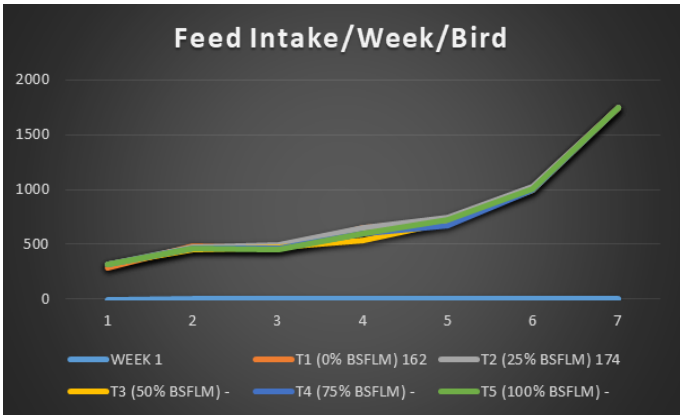

Figure 1. Feed Intake/Week/Bird of Broilers chickens fed BSF-based diets

In Table 4 and Figure 2, T1 yielded the highest weight gain, but T2 and T3 showed similar trends, suggesting up to 50% BSFLM inclusion does not adversely affect growth in broilers. The partial replacement-maintained broiler performance and is consistent with works of Lu *et al*. (2022) and Makkar *et al*. (2014).

However, the differences in final weight gain across treatments were not excessively large. Although birds in Treatment 5 (100% BSFLM) recorded the lowest final weight, their performance was still satisfactory, especially considering the substantial reduction in feed cost. This suggests that BSFLM, even at full replacement of fish meal, can maintain acceptable growth in broilers. From the farmers' point of view, the slight drop in weight is compensated by the major savings in feed cost, making 0% Fish meal and 100% BSFLM inclusion a realistic alternative for farmers operating in cost-sensitive or resource-limited environments.

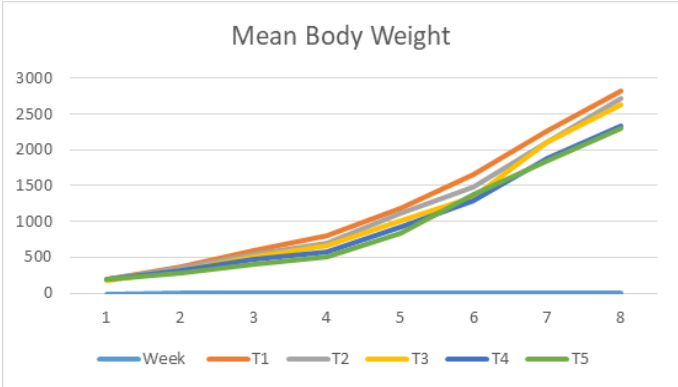

Figure 2: Mean body weight (in grammes) and age (in weeks) of broilers chickens fed BSFL meal-based diets

Table 4. Mean Body Weight of Broilers Chickens Fed BSF-Based Diets

	MEAN BODY WEIGHT/BIRD (g)				
Week	**T1 (0% BSFL)**	**T2 (25% BSFL)**	**T3 (50% BSFL)**	**T4 (75% BSFL)**	**T5 (100% BSFL)**
1	188	190	176	200	185
2	366	341	314	316	281
3	594	537	498	464	407
4	796	696	654	576	504
5	1178	1116	1013	930	830
6	1649	1476	1344	1285	1381
7	2266	2104	2104	1881	1848
8	2823	2714	2623	2343	2304

These findings confirm that BSFLM is an adequate alternative for fish meal in broiler diets. Although birds fed Treatment 1 (0% BSFLM) achieved the highest final body weight, the cost of feeding was the highest, while the return on investment was lowest. Treatments 3 and 4, however, supported similar growth while significantly reducing feed cost. The highest overall financial return came from Treatment 4, with an ROI of 96.49% and a cost-benefit ratio of 1.96, hence making it the most profitable inclusion level. Treatment 5 had a very good return on investment of 83.54% with the lowest feed cost, indicating that total substitution is feasible without loss of economic efficiency.

Feed intake was relatively uniform across the treatments, with minor differences in final body weight. These latter differences were minor compared to the economic advantages offered by adding BSFLM. Even at full replacement, BSFLM supported adequate weight gain and clear cost benefits, further strengthening the value proposition that BSFLM is a strategic feed ingredient.

Beyond the economic benefits, BSFLM contributes to sustainability goals by using organic streams of waste, hence reducing environmental burden and fostering circular agriculture and economy. By lowering dependence on fish meal, it further reduces pressure on marine resources. Therefore, BSFLM provides farmers with an option for cost savings and a more environmentally responsible way of sourcing protein.

The goal of the present study was to assess the economical and growth-performance impacts of replacing fish meal with black soldier fly larvae meal in broiler diets. The main conclusions derived are those diets with BSFLM at 50-75% inclusion level (Treatment 3 and Treatment 4) maintained growth performance compared to the control group, reduced feed cost, and increased return on investment. In Treatment 4, where BSFLM was fed at 75%, broilers attained a growth rate near to that of the control (fed 0% BSFLM), with a highly reduced feed cost, translating into the highest ROI of 96.49%. The partial replacement of fish meal with BSFLM seems to provide a good balance between performance and economy. Even though the 100% BSFLM feeding resulted in the minimum weight gain compared to the other treatments, its reduction in feed cost and acceptable ROI of 83.54% make it practical under resource-constrained conditions.

These observations indicate that BSFLM can replace fish meal without severe performance compromise, particularly when cost considerations dominate. Earlier studies have identified the nutritional and environmental potential of BSFL as a protein source. Gao *et al*. (2019) and Shumo *et al*. (2019) also assessed BSFL as a sustainable alternative protein in livestock especially poultry production. Our results expand that work by showing BSFLM can be economically viable under commercial-type broiler production in Nigeria. The findings of this study are in agreement with the fact that insect-derived proteins forms alternative sources and hence diversify the conventional animal-derived proteins without compromising performance.

This means that inclusion of BSFLM at 50-75% replacement of fish meal presents a good feed formulation option for commercial poultry producers in Nigeria and other economies with similar characteristics, which will reduce production cost, improve profitability, and help attain the goal of sustainability. Feed manufacturers may opt for such re-formulation of diets, while policy makers may include insect-based protein production in national food security and circular economy programs especially for livestock production.

Despite these benefits, a number of limitations should be acknowledged. First, this experiment was conducted under controlled conditions and might not reflect all challenges of on-farm production, for instance, disease pressure or seasonal variability. Second, only broiler growth performance and some economic indices were measured, while other parameters such as meat quality and palatability (sensory evaluation), health biomarkers, and

consumer acceptance were not considered. Third, the study focused on a limited set of BSFLM inclusion levels and a single production cycle, while longer-term trials and different breeds and strains of chickens may yield further insights into this area.

Conclusion and Recommendation

BSFLM inclusion in broiler diets at levels of 50-75% proved to be an efficient balance between growth performance and profitability especially for commercial production of Broilers. These inclusion levels decrease feed costs, increase financial returns, and ensure sustainable production practices. In view of the above facts, poultry farmers, feed manufacturers, and policymakers should consider BSFLM as a viable alternative protein source in their efforts to meet production costs and enhance food security and resilience within the poultry sector in Nigeria.

This study generally confirms that BSFLM is cost-effective and performance-feasible as an alternative to fish meal in broiler diets. Especially at 50-75% inclusion levels, it offers the optimal trade-off between growth, cost, and sustainability. Its adoption in poultry feed formulations could contribute toward making feed cheaper, thereby increasing profitability and sustainability in poultry production with lower resources.

Future studies should investigate the impact of BSFLM inclusion on meat quality, carcass characteristics, nutrient digestibility and poultry gut health at a commercial farm level. Assessment of local BSFL production in Nigeria, scaling-up, the cost structure and substrate variation will also be useful. Finally, the life-cycle and seasonal availability and assessment comparing both BSFLM and fish meal regarding their environmental impact will improve the sustainability claim.

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