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# EVALUATION OF ALTERNATIVE PROTEIN SOURCES IN POULTRY FEED FORMULATION

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**Abstract**

*The increasing demand for ecologically and economically sustainable poultry production has heightened the quest for feasible alternatives to traditional protein sources, such as soybean meal and fishmeal. This study assessed the nutritional and economic effectiveness of specific alternative protein sources–Black Soldier Fly Larvae (BSFL) meal, Spirulina (Arthrospira platensis), fermented rapeseed meal, and dried brewer's yeast–in the formulation of grill feed. Two hundred Cobb-500 grill chicks were randomly allocated to five feeding regimens in a completely randomized manner and observed over a 42-day duration at Univerisity of Agriculture, Faisalabad, Punjab, Pakistan. Growth performance, feed conversion ratio (FCR), cost efficiency, and proximate nutrient analyses were evaluated. The findings indicated that broilers consuming diets with BSFL and Spirulina demonstrated markedly greater body weight gains (2505 g and 2450 g, respectively) and reduced feed conversion ratios (1.58 and 1.66) than those on the conventional soybean-based control diet (FCR: 1.74). Moreover, these diets reduced the cost per kilogram of weight gain despite comparatively elevated ingredient expenses, indicating enhanced feed efficiency and economic viability. In contrast, rapeseed meal resulted in relatively inferior performance, possibly due to the presence of remaining anti-nutritional components. Nutritional analysis verified that all experimental meals satisfied the necessary crude protein and energy standards. These results highlight the potential of incorporating insect and*

*algal proteins into poultry nutrition programs to improve production and sustainability. Additional research is advised to enhance inclusion levels and evaluate the long-term health implications and market viability. This study contributes to the growing body of evidence supporting the use of alternative proteins in commercial poultry systems.*

## INTRODUCTION

The global poultry industry is expanding to meet the growing demand for animal protein, and broiler production is a significant contributor to meat supplies in both developed and developing countries (Gaylal & Dorjee, 2024). Feed cost accounts for 60–70% of the total cost of poultry production, and protein sources (soybean meal and fishmeal, in particular) represent the most expensive component (Makkar et al., 2014). Nevertheless, the dependency on traditional protein sources has become increasingly unsustainable due to rising and unstable prices, environmental issues, and competition with the human food and aquaculture industries (Ravindran, 2013).

To address this problem, research has shifted toward alternative protein sources, such as insect meals, algae, legumes, microbial proteins, and agro-industrial by-products (Gasco et al., 2020). These alternatives are nutritionally adequate and align with the principles of the circular economy, as they utilize waste streams and contribute to reducing the environmental footprint (Henry et al., 2015). Notably, meals made from Black Soldier Fly (Hermetia illucens) have received increased attention for their high protein content, digestibility, and scalability. Similarly, microalgae, including Spirulina platensis, have a composition of essential amino acids, vitamins, and bioactive components that contribute to the health and growth of poultry (Dabbou et al., 2018).

However, the use of these ingredients in commercial feed formulations is limited by disparities in nutrient composition, processing expenses, and non-uniform inclusion levels. Therefore, this study aimed to assess the performance, efficiency, and economics of BSFL, Spirulina, rapeseed meal, and yeast as alternative protein sources in comparison to conventional soybean-based diets for broilers. This study will support effective and sustainable poultry production programs, providing information on applicable feeding innovations in the global animal sector (Guo et al., 2022).

## 3. MATERIALS AND METHODOLOGY

### 3.1. Experimental Design

A completely randomized design (CRD) was employed at University of Agriculture, Faisalabad, Punjab, Pakistan, to evaluate the effects of alternative protein sources on the growth performance and feed efficiency of broiler chickens. A total of 200 day-old Cobb-500 broiler chicks were randomly assigned to five dietary treatment groups, with four replicates per treatment and 10 birds per replicate.

### 3.2. Experimental Diets

Five isonitrogenous and isoenergetic diets (22% crude protein and 3000 kcal/kg ME) were formulated:

| Treatment | Protein Source |
|---|---|
| T1 (Control) | Conventional Soybean Meal |
| T2 | Black Soldier Fly Larvae (BSFL) Meal |
| T3 | Spirulina (Algae) Powder |
| T4 | Fermented Rapeseed Meal |
| T5 | Dried Brewer's Yeast (Single-Cell Protein) |

All diets were formulated using standard NRC (1994) nutrient requirements. The diets were pelleted and stored under dry conditions.

### 3.3. Management of Experimental Birds

The birds were raised in a well-ventilated open-sided poultry house on deep litter floors. All standard management practices including vaccination, biosecurity, and lighting were uniformly followed

across groups. Clean drinking water and feed were provided ad libitum.

- **Brooding Period:** 1–14 days
- **Grower-Finisher Period:** 15–42 days

### 3.4. Data Collection

**a) Feed Intake (FI):**
Measured weekly by subtracting the remaining feed from the offered quantity.

**b) Body Weight Gain (BWG):**
Birds were weighed weekly to calculate average weight gain per bird.

**c) Feed Conversion Ratio (FCR):**
Calculated as:
FCR=Total Weight Gain / Total Feed Intake

**d) Mortality Rate:**
Recorded daily; dead birds were necropsied to identify any feed-related causes.

**e) Cost of Production:**
Cost per kg of feed and per kg weight gain was calculated for each treatment.

**f) Nutrient Analysis:**
Representative samples of all diets were analyzed for proximate composition (CP, CF, EE, Ash) using AOAC (2016) methods.

### 3.5. Statistical Analysis

Data were analyzed using One-Way ANOVA in SPSS Version 26. Significant differences between treatment means were determined using Tukey's HSD test at $p < 0.05$.

## 3. RESULTS

### 3.1. Growth Performance

The growth performance of broiler chickens fed different protein sources is summarized in Table 1. Birds fed with BSFL (T2) and Spirulina (T3) showed significantly ($p < 0.05$) higher body weight gain (BWG) compared to the control (T1). The lowest FCR (i.e., most efficient feed conversion) was also observed in T2 (1.58), indicating superior nutrient utilization.

**Table 1: Growth Performance of Broiler Chickens (Day 1–42)**

| Treatment | Final Body Weight (g) | Total Feed Intake (g) | Body Weight Gain (g) | FCR | Mortality Rate (%) |
|---|---|---|---|---|---|
| T1 (Control) | 2320 ± 45b | 3950 ± 50 | 2270 ± 48b | 1.74b | 2.5 |
| T2 (BSFL) | 2505 ± 52a | 3975 ± 60 | 2455 ± 49a | 1.58a | 2.5 |
| T3 (Spirulina) | 2450 ± 47a | 3980 ± 40 | 2400 ± 45a | 1.66a | 2.0 |
| T4 (Rapeseed) | 2280 ± 50b | 3960 ± 45 | 2230 ± 46b | 1.78b | 3.5 |
| T5 (Yeast) | 2355 ± 48b | 3955 ± 42 | 2305 ± 44b | 1.71b | 2.0 |

Values are means ± standard deviation; different superscripts (a, b) within a column indicate significant difference at $p < 0.05$.

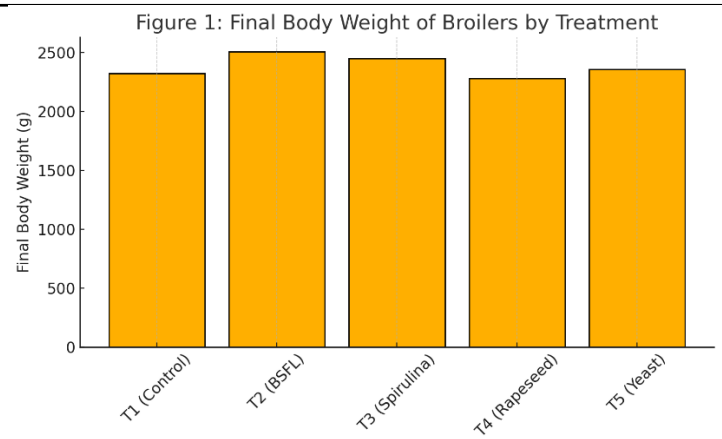


**Figure 1: It illustrates the comparative final body weight across treatments, highlighting the superior performance of BSFL and Spirulina groups.**

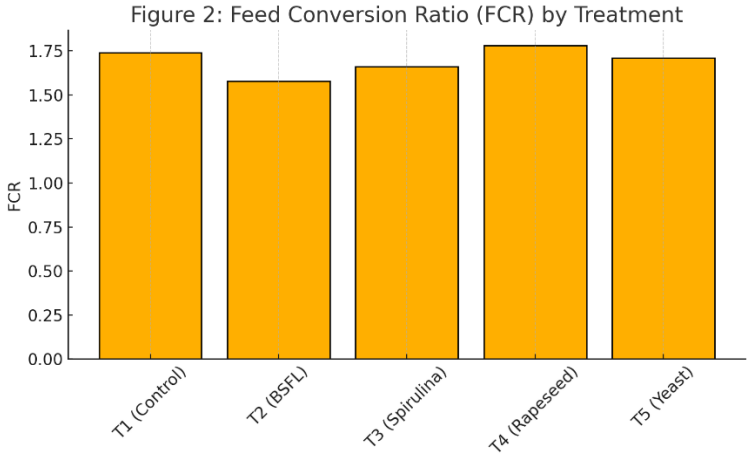


**Figure 2: It presents the feed conversion ratio (FCR) for each treatment group, with the BSFL-based diet showing the most efficient feed utilization.**

### 3.2. Economic Analysis

The economic evaluation is presented in Table 2. Despite higher ingredient cost in T2 and T3, their cost per kg weight gain was lower than the control due to better FCR.

**Table 2: Economic Evaluation of Alternative Protein Sources**

| Treatment | Feed Cost (USD/kg) | Feed Cost per Bird (USD) | Cost/kg Weight Gain (USD) |
|---|---|---|---|
| T1 (Control) | 0.48 | 1.90 | 0.84 |
| T2 (BSFL) | 0.56 | 2.23 | 0.74 |
| T3 (Spirulina) | 0.60 | 2.39 | 0.78 |
| T4 (Rapeseed) | 0.45 | 1.78 | 0.80 |
| T5 (Yeast) | 0.50 | 1.98 | 0.79 |

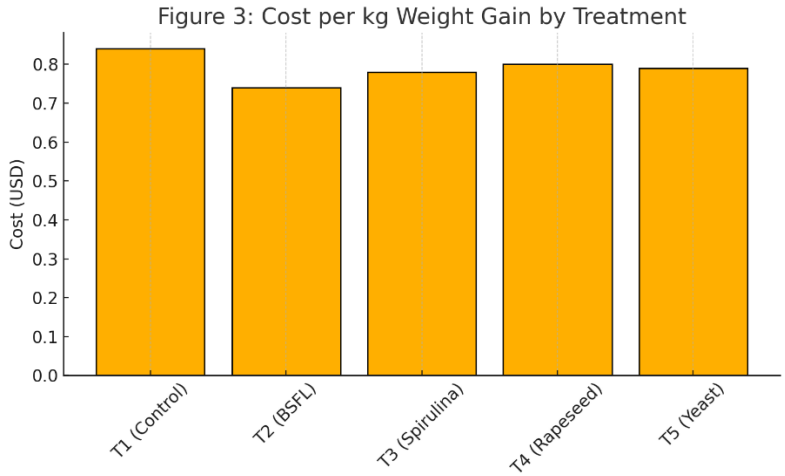


**Figure 3: It compares the cost per kg of weight gain among the treatments, where BSFL again proved the most economical.**

### 3.3. Nutrient Analysis of Experimental Diets:

All experimental diets met the desired crude protein and energy levels, with slight variations in fiber and fat contents.

**Table 3: Proximate Composition of Experimental Diets (%)**

| Parameter | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|
| Crude Protein | 22.1 | 22.3 | 22.4 | 22.0 | 22.2 |
| Crude Fiber | 3.5 | 4.2 | 3.8 | 5.0 | 4.0 |
| Ether Extract (Fat) | 5.1 | 9.8 | 7.2 | 4.3 | 5.9 |
| Ash | 7.0 | 6.8 | 7.5 | 6.9 | 7.1 |
| ME (kcal/kg) | 3000 | 3002 | 2998 | 2995 | 3001 |

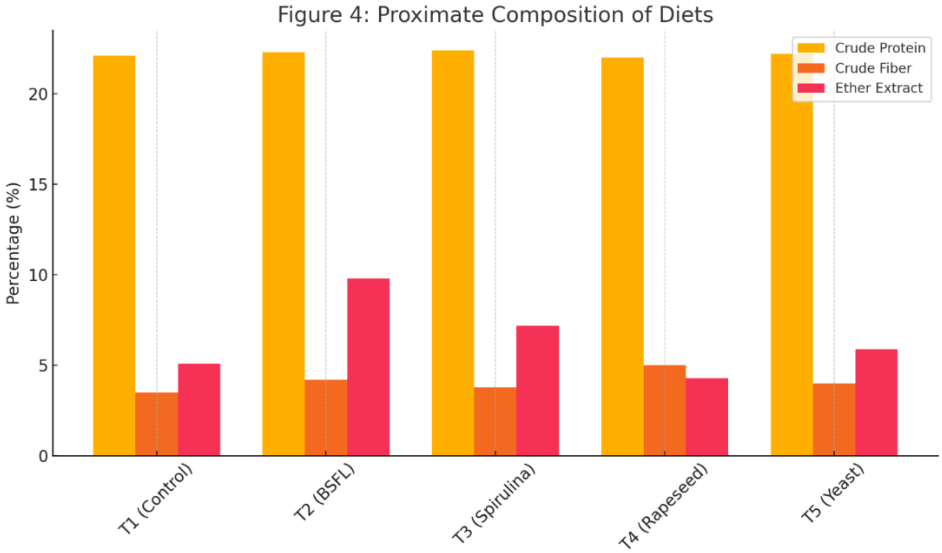


**Figure 4: It summarizes the proximate composition (Crude Protein, Fat, Fiber) across the five diets, confirming the nutritional adequacy of all treatments**

## .4. DISCUSSION

The objective of this study was to compare different potential alternative protein sources with soybean meal (SBM) in broiler diets, focusing on growth performance, nutrient balance, variation in total serum weight (TSW), and economic return in broilers. The results indicated that the final body weight and feed conversion ratio (FCR) were significantly improved by the BSFL meal (T2) and Spirulina (T3) diets compared to the control group, which received traditional soybean meal.

These results are consistent with those of Uushona (2015), who observed better growth performance and gut health in broilers fed diets with BSFL. The latter authors also pointed out the good digestibility and AA balance of insect protein, which may have contributed to the better FCR (1.58) observed in the present trial for T2. The present results are also in agreement with the findings of Holman et al., who reported improved growth performance in birds fed a Spirulina diet (T3). (2019) also reported an increase in the weight gain of Nile tilapia-fed Spirulina, in addition to an increase in immune response caused by this supplement due to its high antioxidant content. This would account for T3 performing second best (BWG = 2400 g, FCR = 1.66) with a 2% lower mortality rate.

Group T4 (rapeseed meal) had the worst feed efficiency (FE); this could result from the presence of remnants of anti-nutritional factors, such as glucosinolates. These results confirm those of Khajali and Slominski (2012), who advised against using unprocessed and inadequately fermented rapeseed meal in poultry due to its poor digestibility and the presence of inhibitors. Economically, despite the higher per kilogram feed cost of BSFL and Spirulina, the reduction in feed conversion ratio (FCR) resulted in a lower cost per kilogram of weight gain, supporting similar findings by Delgado et al. (2023), who observed the economic competitiveness of insect diets in broiler production systems. The lower mortality and improved weight gain in these groups make them more profitable, particularly under intensive farming systems.

For proximate analysis, all diets met the requirements for crude protein and energy. However, the high-fat content of BSFL (9.8%) may have contributed to a higher energy density and improved performance, which aligns with the results of Barragan-Fonseca et al. (2017), who reported enhanced energy utilization in broilers fed insect-based diets. In conclusion, the findings support the partial or full replacement of conventional protein sources with insect- or algal-proteins for improved sustainability and performance. However, long-term health, environmental impact, and consumer acceptance require further evaluation.

## 5. CONCLUSION

This study aimed to investigate the effects of various alternative protein sources on growth performance, feed efficiency, and profitability in broiler chickens. Of all the ingredients tested, Black Soldier Fly Larvae (BSFL) meal and Spirulina were the most promising replacements for normal soybean meal. Birds fed these diets showed higher body weight gain and better feed conversion efficiency than the control, which had a lower cost per kilogram of weight gain despite the increase in feed cost per bag. These results are consistent with earlier reports that have demonstrated the nutritional quality and digestibility of insect and algal proteins. The highest overall performance experienced by the BSFL diet was likely due to its high energy content , as well as its very balanced amino acid profile. Rapeseed meals, on the other hand, were less efficient, which may be related in part to the presence of residual anti-nutritional factors, highlighting the need for additional processing or supplementation. The study also demonstrated that all alternative diets met the required levels of crude protein and metabolizable energy, thereby substantiating their suitability for use as feed for broiler chickens. In general, the findings of this study highlight the potential of using sustainable and traditionally underutilized protein sources, such as insects, algae, and yeast, in poultry feed. The integration of this technology not only has the potential to lead to increased productivity and profitability but also makes livestock production more environmentally sustainable. Future investigations should examine the long-term health effects and consumer acceptance of livestock products from alternative protein sources.

## 6. AUTHORS CONTRIBUTION

All authors contributed equally.

**7. FUNDING**
Not applicable

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