**Nutritional Evaluation of Black Soldier Fly Larvae: A Proximate Analysis for Aquaculture**

**Abstract**

Aquaculture relies significantly on fish meal and fish oil, which are abundant in proteins, amino acids and fatty acids; nevertheless, their elevated costs, raw material requirements, and environmental issues have necessitated the exploration of alternative protein sources. Black Soldier Flu Larvae (BSFL) have surfaced as a feasible alternative to fish meal owing to their analogous nutritional composition, especially their protein levels, rendering them a cost-efficient and sustainable choice in aquafeeds. BSFL grow in decaying organic materials and have been employed for waste management in commercial swine and poultry industries. Their life cycle, characterised by the effective transformation of waste into protein, amplifies their significance in sustainable agriculture. This study aimed to evaluate proximate composition of BSFL produced from household waste. The proximate analysis of the BSFL samples indicated a moisture content of 54.78±0.02%, a protein content of 45.29±0.52%, a lipid content of 4.12±0.01%, and an ash content of 9.03±0.02%. There were significant difference in moisture, protein, fat, and ash content among all diets (p < 0.05), with BSFL having the highest values in all components. BSFL's high protein concentration makes it a prospective alternative protein source for aquaculture, while its balanced composition suggests that it could be used a variety of animal feed applications. The study emphasizes the importance of optimizing BSFL diets to improve their nutritional content and promote sustainable farming practices, particularly in light of the growing demand for alternative protein sources.

**Keywords :-** Black Soldier Fly (BSFL), Waste conversion, Sustainable farming, Environmental sustainability, Nutritional composition, Aquaculture, Feed, Insects culture

**Introduction**

Aquaculture is a significant sector in global food production, providing a substantial portion of the world’s fish and seafood. However, the industry heavily relies on fish meal and fish oil as key ingredients in aquafeed, given their rich nutritional profile, which includes essential proteins, amino acids, and fatty acids. These nutrients are critical for the growth and health of farmed fish. Despite their high nutritional value, the use of fish meal and fish oil in aquaculture has several challenges. The high cost of fishmeal production, the increasing demand for raw materials, and growing environmental concerns over overfishing and the sustainability of marine resources have driven the need for alternative protein sources in aquafeeds. One such alternative gaining attention is Black Soldier Fly Larvae (BSFL) meal. BSFL has emerged as a viable and sustainable substitute for traditional fish meal. The larvae of the Black Solidier Fly contain a high percentage of protein, along with essential amino acids and fatty acids making them an ideal replacement for fish meal in aquaculture diets. Additionally, BSFL is a cost-effective solution due to its ability to be produced in large quantities and its relatively low production costs. The shift towards BSFL meal is seen as a way to address both environmental concerns and the economic challenges facing the aquaculture industry (Kannan Mohan, 2022). BSFL are particularly well-suited to waste management, as they thrive on decaying organic matter, such as animal waste or plant material. This characteristic has led to their utilization in waste processing facilities, especially in the commercial swine and poultry industries (Newton, 2005). The larvae feed on organic waste, converting it into protein-rich biomass that can then be harvested and processed into meal for aquaculture or animal feed. While adult BSFL are not known to be disease vectors, they can carry pathogens mechanically, which is a consideration for proper handling and processing (Newton, 2005).

The life cycle of Black Soldier Flies is highly efficient, making them a promising option for sustainable farming practices. The life cycle begins when female flies lay their eggs near decaying organic matter. The egg hatch into larvae within 3 to 4 days. During the larval stage, which lasts 14–18 days, the larvae consume organic waste converting it into protein , fats, and biofertilizer. After the larvae reach maturity, they transition into the pupal stage, which lasts 5–10 days. The adult flies emerge from the pupae, live for a brief period of 5–8 days, and focus primarily on reproduction. The entire life cycle is rapid, and the larvae are capable of converting large amounts of organic waste into high-quality protein in a short period.

Optimizing the conditions under which BSFL are raised—such as temperature, humidity, and feeding materials—can further enhance their productivity. By carefully controlling these factors, the efficiency of waste conversion and protein production can be maximized, making BSFL a valuable and sustainable asset for both waste management and aquaculture feed production. As aquaculture continues to grow and demand for sustainable, high-quality feed ingredients increases, BSFL meal presents a promising solution that benefits both the environment and the aquaculture industry. The adoption of Black Soldier Fly Larvae meal in aquafeeds represents a significant step toward more sustainable and cost-effective food production. With its high nutritional value, efficient production process, and potential to recycle waste materials, BSFL offers a promising future for the aquaculture industry and broader agricultural sustainability initiatives.

**Methods and Material**

The BSF Larvae production with Household waste and their Proximate analysis.

**Proximate Analysis**

Proximate analysis of the BSF Larvae, (pooled treatment wise in triplicets) were analysed as per AOAC (2005). All the samples were analysed in triplicate in order to minimize error. Moisture content in the sample was analysed using the oven-drying method (AOAC official method 930.15). Approximately 30.0 g of homogenized sample was Transfer to a pre-weighed petri dish and dried in a hot air oven at 105°C until a constant weight was achieved. The dried sample was cooled in a desiccator, weighed, and the moisture content was calculated as the weight loss (H₂O) using the formula:

Moisture (%) = [(Wet sample weight – Dried sample weight) × 100] / Wet sample weight.

Crude Protein content was determined using Kjeldahl method (Nitrogen × 6.25) as per AOAC official method 954.01, employing a Kjeltech system. For each triplicate sample, 500 mg of the sample was digested with 2 g of a digestive mixture (CuSO₄:K₂SO₄ = 1:9) and 15 ml of concentrated H₂SO₄ in a Kjeldahl digesting apparatus. The digested sample was diluted to 100 ml, and 5 ml of this solution was distilled using 40% NaOH. The released ammonia was trapped in a boric acid solution with Tashiro's indicator and titrated with 0.1N H₂SO₄ until the color changed from green to pink.

Total nitrogen (%) was calculated as (Volume of 0.1 N H₂SO₄ × 0.0014 × 100) / (Aliquot taken × Weight of sample), and

protein content (%) as Total Nitrogen × 6.25.

Crude lipid content was estimated using the Soxhlet extraction method (AOAC official method 920.39), with 1.0 g of dry sample placed in an extraction thimble and extracted with 80ml petroleum ether (60°-80°C BP). After extraction and solvent evaporation, the flask was dried in an oven at 60-70°C, and the lipid content was calculated gravimetrically as

Crude Lipid (%) = (Oil weight × 100) / Sample weight.

Ash content was determined by the dry ashing method (AOAC official method 942.05) where 1.0 g of moisture-free sample was charred, ashed in a muffle furnace at 550°C for 6 hours, cooled, and weighed.

Ash content (%) was calculated as (Ash weight × 100) / Sample weight.

**Result**

**Proximate composition**

Proximate composition of BSFL produced has moisture content, protein , Lipid and Ash were recorded 54.78±0.02, 45.29±0.52, 4.12±0.01 and 9.03±0.02 respectively in %.

There was significant difference in the moisture percentage among the diets among the diets (p <0.05) and ranged between 50.58 – 54.78%. BSFL showed significantly higher value of moisture (54.78±0.02%).

There was significant difference in the Protein percentage among the diets (p <0.05) and ranged between 42.78 – 45.29%. BSFL showed significantly higher value of moisture (45.29±0.52%).

There was significant difference in the lipid percentage among the diets (p <0.05) and ranged between 4.01- 4.12%. BSFL showed significantly higher value of moisture (4.12±0.01 %).

There was significant difference in the ash percentage among the diets (p <0.05) and ranged between 9.00-9.03%. BSFL showed significantly higher value of moisture (9.03±0.02 %).

**Discussion**

The Proximate composition of Black Soldier Fly Larvae (BSFL) is a critical aspect in understanding its nutritional profile and its potential use in various applications, such as animal feed, waste management, and human consumption. The study reports that the moisture content, protein, lipid, ash of BSFL were found to be 54.78±0.02%, 45.29±0.52%, 4.12±0.01%, and 9.03±0.02%, respectively.

**Moisture Content**

The moisture content of BSFL was observed to be the highest among the analyzed proximate components, with a significant variation in moisture content observed among different diets (p < 0.05). The range of moisture content in the diets varied from 50.58% to 54.78%, with BSFL having the highest recorded value. High moisture content is typical for insect larvae and may influence the dry weight yield and overall energy density of the larvae (Van Huis et al., 2013). This is important in practical applications where dehydration may be necessary for long-term storage or incorporation into dry animal feeds.

**Protein Content**

The protein content of BSFL was recorded at 45.29±0.52%, and significant differences were noted across the various diets, with values ranging from 42.78% to 45.29%. This is consistent with previous studies that have reported BSFL as a rich source of high-quality protein (Makkar et al., 2014). The relatively high protein content makes BSFL an attractive alternative protein source for animal feed, particularly for aquaculture, poultry, and livestock (Henry et al., 2015). The variation in protein levels may be due to differences in the substrates provided to the larvae, as their diet can directly influence their nutritional composition.

**Lipid Content**

BSFL exhibited a lipid content of 4.12±0.01%, with significant differences observed between diets (p < 0.05). Lipid content ranged from 4.01% to 4.12%, with BSFL showing the highest value. Lipids are crucial for providing energy, and the relatively low lipid content in BSFL suggests that they may be a more balanced nutritional option compared to other insect species like mealworms, which are often higher in fat (Ghosh et al., 2017). The lipid profile can vary significantly depending on the dietary input, which highlights the importance of optimizing the diet for specific applications.

**Ash Content**

The ash content in BSFL was recorded at 9.03±0.02%, with significant differences observed across diets, ranging from 9.00% to 9.03%. The ash content generally reflects the mineral composition of the larvae, which can be valuable in providing essential micronutrients such as calcium, phosphorus, and magnesium. However, the high ash content can also indicate that a significant portion of the larvae's mass is composed of non-nutrient material, which may affect its digestibility and suitability for certain feed applications.

**Conclusion**

Overall, BSFL is a promising candidate as a sustainable source of protein, lipids, and minerals, particularly given its high protein content and balanced composition. The significant differences in nutritional composition across diets suggest that diet optimization could enhance the nutritional value of BSFL. As the demand of alternative protein sources grows, particularly in the context of environmental sustainability and the circular economy, BSFL could serve as a viable option for livestock and aquaculture feed.

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