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Production and Characterization of Black Soldier Fly Larva Meal on Harvest Age and Processing Method as a Potential Alternative Protein Source for Fishmeal in Broiler Chicken Diets

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***Abstract*— The unbridled increasing price of feed ingredients especially the conventional protein sources is a great challenge to profitability in poultry industry. To overcome this issue, insect meals like black soldier fly (BSF) are one of these alternative protein sources. This study is aimed at the production and characterization of Black soldier fly larva meal on harvest age and processing method as a potential alternative protein source for fishmeal in broiler chicken diets. Taking advantage of the study of a life cycle of insects, BSF pupae was procured, conditioned and allowed to pupate to larvae. The BSF laid eggs and the eggs were further favourably conditioned to hatch to larvae (BSFL). The larvae were harvested at two (2) different ages (day 8 and 12), and samples from each age of harvest were divided into two (2) and process independently by sun drying and roasting. The four (4) samples were milled to meals (BSFLM) and presented for chemical analysis. The best meal in optimal protein retention was identified and combined with a procured Fish meal (FM) whose proximate composition and amino acid profile had been determined to form a blend (FM:BSFLM% ; 75:25, 50:50 and 25:75). The proximate composition of black soldier fly (BSF) larvae meal was significantly influenced by both the age at harvest and the processing method, as well as their interaction. Also, the comparison between the proximate composition of FM and BSFLM showed that FM had a significantly higher crude protein content (66.87%) compared to BSFLM (34.82%). FM is numerically higher in ASH and conversely lower in NFE (3.39%), Crude fibre (0.56%), Fat (10.62) and Moisture (10.34%) compared to BSFLM; 33.21, 1.20, 16.43 and 10.69% respectively. Further studies to corroborate the effect of dietary BSF on growth performance, carcass characteristics, gut morphology and caecum microbiota are required to standardize the inclusion levels in feeds for higher performance of poultry.*

***Keywords*— Amino acid, Black soldier fly, Fish meal, Lavae, Proximate Composition**

I. INTRODUCTION

The global population is projected to reach 10 billion by 2050, and the demand for animal protein is estimated to rise by 60–70% compared to current demand (FAO, 2023). Poultry production, a popular source of affordable protein, faces rising challenges due to its reliance on conventional feed ingredients such as fish meal (FM). While FM is known for its high protein content and amino acid profile, its increasing cost, environmental unsustainability, and competitiveness with human food supplies weaken its functionality in (Abd El-Hack et al., 2020; Cockcroft, 2018).The unstable price of fish meal and its unaffordability demand the urgent need for cheaper, eco-friendly, and sustainable protein alternatives. In this context, insects, like the black soldier fly (Hermetia illucens) have emerged as a viable solution. Black soldier fly larvae (BSFL) efficiently convert low-value organic waste, such as agricultural by-products and food scraps, into nutrient-rich biomass, offering high protein content (34–77%), essential amino acids, and reduced environmental footprints compared to FM (Schiavone et al., 2017; Van Huis, 2022). Unlike regular animals rearing, BSFL needs little land and water, making it a good option for places with limited resources. However, the nutritional quality of BSFL-derived meal (BSFLM) can change, it fluctuates significantly depending on the larvae's harvest age and post-harvest processing methods (Dabbou et al., 2018). Despite these findings, there is still need for research on how these factors interaction affect BSFL meal's effectiveness in poultry birds' diets. There is a need to addresses these critical gaps by evaluating how harvest age and processing method affect the proximate composition and amino acid profile of BSFLM.

II. MATERIALS AND METHODS

2.1 Location of Research

The experiment was carried out at the Insect-hub Unit of the Teaching and Research Farm. The laboratory analysis to determine the proximate compositions and amino acid profiles were carried out at the Nutritional Laboratory of the Department of Animal Production and Health, The Federal University of Technology Akure, Nigeria, located between latitude 07°161 and 07°181 N and longitude 05°091 and 05°111 E. There is a bimodal rainfall patterns which start from February to July and September to October with an average rainfall of 1,556 mm per annum. The ambient temperature range is about 30 – 32°C with a relative humidity of 80% (NCEI, 2018).

2.2 Black Soldier Fly Larvae (BSFL) Production

The black soldier fly larvae (BSFL) life cycle consists of five stages (1) egg; which hatches approximately in four days, (2) larva; this stage consists of five instars over a period ranging between 13 and 18 days, (3) pre-pupa; the sixth and final instar that consists of approximately seven days, (4) pupa; varies from 10 days to 30 days depending upon favorable conditions to become an adult one, and (5) adult; normally survives from five to eight days. Based on the above, the production of BSFL commenced with the procurement of pupa of black soldier fly from a reputable black soldier fly breeding farm. Before the arrival of the pupae, the love net (mating chamber) had been constructed, and positioned to receive the pupae. From the day of arrival, the pupae pupated to flies in 10 days. From 2 days after pupation, an attractant (sliced water melon waste), below a suspended egg pallets were placed in the love net. The flies mated, lay eggs in the suspended egg pallets and died between 5-8 days, since they were non-feeding flies. The eggs started to hatch to larvae in 4 – 5 days under a favourable environmental conditions (25 – 30^{0}C), but at every 24 hours, the hatched larvae were transferred to a substrate (fruit processors wastes) and an energy source (kitchen waste) and marked, based on the date and day (age of larvae). For the purpose of this study, the larvae were harvested at days 8 and 12.

2.3 Black Soldier Fly Larvae Meal Production

The live black soldier fly larvae harvested were washed to remove the debris. After washing, the larvae were poured into heated water at about 60 - 70ºC and stirred for about 2 – 3 minutes in order to make the larvae inactive. Filtered dead larvae, based on the two (2) ages of harvest were divided into two (2), and one part was sun dried, while the other part was dried by roasting. The four (4) dried black soldier fly larvae (BSFL) samples (sample A- 8 days harvested and sundried; sample B- 8 days harvested and roasted; sample C- 12 days harvested and sundried, and sample D- 12 days harvested and roasted) were milled separately to produce black soldier fly larvae meals (BSFLM), and stored in an air-tight container separately, prior to subjecting each sample to proximate analysis to ascertain the best age of harvest and processing method, in order to get optimum nutrient composition.

2.4 Chemical analysis of fish and black soldier fly larvae meal fly larvae meal

The proximate compositions of the fish meal (FM) and black soldier fly larvae meal (BSFLM) were determined at the Nutrition Laboratory of Julius Okojie Central Laboratory, Federal University of Technology, Akure Nigeria using AOAC (2019) method.

4.5 Amino acid profile of BSFL meal and the FM

The amino acid profile of the meals were independently determined at the Central Laboratory of International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The amino acid profile of the samples (BSFL meal and the fish meal) were determined using methods described by Benitez (1989). The samples were dried to constant weight, hydrolyzed, evaporated in a rotary evaporator and loaded into the Applied Biosystems PTH Amino Acid Analyzer.

III. RESULTS AND DISCUSSION

The proximate composition of black soldier fly (BSF) larvae meals from two different harvest ages and processing methods were significantly influenced by both the age at harvest and the processing method (sun drying or roasting), as well as their interaction. As shown in Table 1, crude protein content decreased significantly from 33.06% at day 8 to 31.29% at day 12 ($P < 0.05$). This result is consistent with previous findings that older larvae allocate less resources toward protein storage (Diener et al., 2009; Barragan-Fonseca et al., 2017). The fat content also declined significantly with age, from 17.34% at day 8 to 15.40% at day 12 ($P < 0.05$), thereby contradictory to common finding of increase fat deposition with age. However, Wang and Shelomi (2017) reported similar result and attributed it to difference in metabolic activity, feeding rate, or physiological fat mobilization during the late instar stage. Ash content showed a significant increase with age (3.43% to 4.04%), suggesting a higher mineral accumulation as the larvae approached the prepupal stage. A dissimilar trend for nitrogen-free extract (NFE), which decreased significantly from 33.06% to 31.29% was reported by Van Huis (2013), indicating a possible trade-off between structural (ash) and non-structural (carbohydrate) components as the larvae matured as the reason. Processing method significantly altered nutrient composition, particularly crude protein and NFE. Sun drying preserved significantly more crude protein (32.78%) compared to roasting (30.06%) ($P < 0.05$), likely due to protein denaturation at higher roasting temperatures (Zhao et al., 2016). Conversely, roasted larvae had a higher fat content (16.54%) than sun-dried ones (16.33%), although the the difference was not statistically significant. Roasting also resulted in a significantly higher NFE (38.37%) compared to sun drying (34.99%) ($P < 0.05$), which may suggest some loss of heat-labile carbohydrates, and this corroborates the report of Rumpold & Schlüter (2013). The interaction between age and processing method had significant effects across all proximate parameters. The highest crude protein (34.82%) and fat (18.25%) content were observed in 8-day-old sun-dried larvae, while the lowest (28.82% and 14.83% respectively) in 12-day-old roasted larvae (28.82%). This emphasizes the compounding effects of age-related nutrient dilution and thermal degradation during roasting (Makkar *et. al.*, 2014). Fiber was relatively stable but with slightly increase with age.

Table 1: Proximate composition of black soldier fly larvae meal based on ages of harvest and processing Methods

Age (Days)		**Composition (%)**					
	Processing Method	**Moisture**	**Crude protein**	**Fat**	**Crude fibre**	**Ash**	**NFE**
8		10.27	33.06^{a}	17.34^{a}	17.34^{a}	3.43	33.06^{a}
12		10.39	31.29^{b}	15.40^{b}	15.40^{b}	4.04	31.29^{b}
SEM		0.01	0.01	0.01	0.01	0.02	0.02
P-Value		0.06	0.02	0.05	0.04	0.07	0.04
	Sun drying	10.27	32.78^{a}	16.33	1.36	4.28	34.99^{b}
	Roasting	10.21	30.06^{b}	16.54	1.27	3.56	38.37^{a}
	SEM	0.01	0.01	0.02	0.01	0.02	0.02
	P-value	0.08	0.01	0.09	0.06	0.06	0.01
Interaction							
8	Sun drying	10.69^{b}	34.82^{a}	16.43^{b}	1.20	3.65^{bc}	33.21^{c}
	Roasting	9.85^{a}	31.29^{ab}	18.25^{a}	1.15	3.21^{c}	36.25^{b}
12	Sun drying	10.22^{ab}	33.75^{a}	15.97^{bc}	1.57	4.17^{a}	34.34^{c}
	Roasting	10.57^{b}	28.82^{b}	14.83^{c}	1.39	3.91^{ab}	40.48^{a}
SEM		0.01	0.01	0.02	0.01	0.02	0.02
P-value		0.05	0.02	0.05	0.06	0.05	0.03

[abc] Means in the same column bearing different superscripts are significantly different (P<0.05) NFE= Nitrogen Free Extract.

The comparison between fish meal (FM) and black soldier fly larvae meal (BSFLM) proximate composition in Table 2 reveals distinct differences in proximate composition. These differences have significant implications for their application in animal feed formulations, particularly in poultry. FM had a significantly higher crude protein and Ash contents (66.87% and 8.20%), compare to BSFLM (34.82% and 3.65%). The result of this study corroborated the finding of Alemu et al., 2017, with a report that fish meal is known to contain high levels of bioavailable minerals such as calcium and phosphorus, making it a valuable ingredient in mineral fortification of diets. One of the most striking differences observed was in the fiber and nitrogen-free extract (NFE), which were substantially higher in BSFLM (33.21% and 1.20%) than in fish Meal (3.39% and 0.56%). NFE comprises the soluble carbohydrate fraction and some digestible non-protein, non-fat organic matter. This may be due to residual substrate or endogenous carbohydrate components retained in the larvae after processing

The amino acid profile comparison between FM and BSFLM as represented in Table 3 showed that FM typically contains high levels of essential amino acids (EAAs), particularly lysine and methionine. Lysine content in FM, 7.9% of crude protein, compared to 4.13% in BSFLM. Similarly, methionine is higher in FM (2.76) than in BSFLM (1.7%). This disparity can influence growth and protein deposition in fast-growing monogastric animals such as broilers, where lysine and methionine are critical for muscle development and feather formation, respectively. Tacom and Metian (2008), reported that fish meal contains a higher proportion of essential amino acids (EAAs),approximately 5.5-7.9% lysine, 2.5–3.0% methionine, and 4.0–4.5% threonine on dry matter basis than BSFLM, also Makkar et al (2014) study reported that though BSFLM has a lower overall crude protein content, yet, it offers a surprisingly rich amino acid composition relative to its protein level as their study showed that BSFLM contains about 3.5–4.5% lysine, 1.0–1.5% methionine, and 2.0–3.0% threonine. The result of this study presented a better and similar result to that of the two authors. One of the advantages of BSFLM is its relatively high content of branched-chain amino acids (BCAAs) such as valine, leucine, and isoleucine, which are critical for muscle protein synthesis and energy metabolism. Furthermore, BSFLM has been reported to contain appreciable levels of arginine and histidine, which are essential for younger animals and fish species (Spranghers et al., 2017). Their study result stated that Crude protein content offers surprisingly rich amino acid composition relative to its protein level, about 3.5–4.5% lysine, 1.0–1.5% methionine, and 2.0–3.0% threonine. The result of this study presented a better but similar result to that of the two authors. One of the advantages of BSFLM is its relatively high content of branched-chain amino acids (BCAAs) such as valine, leucine, and isoleucine, which are critical for muscle protein synthesis and energy metabolism. Furthermore, BSFLM has been reported to contain appreciable levels of arginine and histidine, which are essential for younger animals and fish species (Spranghers et al., 2017).

Table 2: Proximate composition (%) of fish meal and black Soldier fly larvae meal

Parameters	FM	BSFLM
Moisture	10.34	10.69
Crude protein	66.87	34.82
Fat	10.62	16.43
Crude fibre	0.56	1.20
Ash	8.20	3.65
NFE	3.39	33.21

FM= Fish meal.

BSFLM = Black Soldier Fly Larva Meal.

NFE = Nitrogen Free Extract.

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IV. CONCLUSION

The proximate composition of black soldier fly (BSF) larvae meals from two different harvest ages and processing methods showed that larvae should be harvested at day eight (8) and processed by sun-drying if the optimal protein retention for the purpose of it being used as a potential alternative protein source in broiler chicken diets is the objective for its production. While fish meal remains superior in terms of total amino acid content and digestibility, BSFLM presents a promising protein alternative due to its moderately rich amino acid profile, particularly arginine, histidine and BCAAs. Strategic use of BSFLM in feed formulations, coupled with amino acid supplementation, can reduce reliance on fish meal without compromising animal performance. Moreover, the eco-friendly environmental benefits of BSFLM, such as low water use, greenhouse gas emission reduction, and ability to upcycle organic waste significantly supports its use as an alternative protein source in sustainable monogastric animal agriculture.

Table 3: Amino acid profile (g/16g N) of fish meal and black soldier fly larvae meal

Parameters	FM	BSFLM	±SEM	P-Value
Essential Amino Acid				
Arginine	5.57	5.81	0.09	0.18
Histidine	2.17	2.65	0.11	0.01
Isoleucine	4.90	3.85	0.23	0.03
Leucine	7.34	6.76	0.13	0.02
Lysine	7.90	4.13	0.84	0.02
Methionine	2.76	1.71	0.24	0.02
Phenylalanine	4.36	3.60	0.17	0.03
Threonine	4.67	3.27	0.31	0.01
Tryptophan	1.05	0.44	0.14	0.01
Valine	5.60	4.19	0.32	0.03
Non – Essential Amino Acid				
Alanine	6.39	5.97	0.09	0.03
Aspartic acid	9.29	6.57	0.61	0.01
Cystine	0.69	1.07	0.08	0.03
Glutamic acid	13.50	10.05	0.77	0.02
Glycine	6.05	4.60	0.33	0.01
Ornithine	0.13	0.07	0.01	0.01
Proline	4.45	4.50	0.03	0.47
Hydroxylysine	0.30	1.4	0.26	0.01
Serine	4.56	2.90	0.37	0.02
Tyrosine	3.48	4.03	0.12	0.04

FM: Fish meal, BSFLM: black soldier fly larvae meal.

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