



Preliminary assessment of black soldier fly (*Hermetia illucens*) larval meal in the diet of African catfish (*Clarias gariepinus*): Impact on growth, body index, and hematological parameters

Ayodeji A. Adeoye¹ | Yemi Akegbejo-Samsons¹ |
Femi J. Fawole² | Simon J. Davies³

¹Department of Aquaculture and Fisheries Management, Federal University of Agriculture, Abeokuta, Nigeria

²Department of Aquaculture and Fisheries, University of Ilorin, Ilorin, Nigeria

³Department of Animal Production, Welfare and Veterinary Sciences, Harper Adams University, Newport, UK

Correspondence

Ayodeji A. Adeoye, Department of
Aquaculture and Fisheries Management,
Federal University of Agriculture,
P.M.B. 2240, Abeokuta, Nigeria.
Email: adeoyeaa@funaab.edu.ng

Abstract

A study was conducted to evaluate the effect of black soldier fly (*Hermetia illucens*) larval meal (BSF) in practical diets of African catfish (*Clarias gariepinus*). Four diets were formulated to contain levels of fishmeal replacement at 0, 25, 50, and 100% with BSF. A total of 360 fingerlings (2.67 ± 0.0 g/fish) were randomly distributed into 12 tanks (30-L capacity) containing 30 fish each and fed with the respective diet to apparent satiation. After 6 weeks of feeding, growth performance and nutrient utilization indices of the groups fed 25 and 50% BSF diets were not significantly different ($p > .05$) from the group fed the fishmeal-based control diet. However, further increase in the replacement of fishmeal with BSF (100%) led to a significant ($p < .05$) reduction in the growth, feed intake, and protein efficiency ratio of the catfish, whereas body index and survival were not affected. The hematological parameters among the BSF fed groups showed no significant variation ($p > .05$) compared with the control group. From the current study, it was clear that fishmeal could be replaced with BSF up to 50% without

affecting the growth performance, nutrient utilization, survival, and welfare of *C. gariepinus* fingerlings.

KEYWORDS

African catfish, insect meal, performance, sustainability, welfare

1 | INTRODUCTION

Aquaculture production (110.2 million tons in 2016), facilitated in part by the availability of aquafeed, has been responsible for significant growth in the supply of fish for human consumption (FAO, 2018). Fishmeal is considered an important and essential protein source for use in the manufacture of aquafeeds. This is mainly because of its high-quality protein content, excellent amino and fatty acids profile, high nutrient digestibility, general lack of antinutritional factors, palatability, component concentration, and other attributes that contribute to feed intake, health, and immune function in fish (Drew, Borgeson, & Thiessen, 2007; Gatlin et al., 2007; Tacon & Metian, 2013). However, the finite nature, seasonal variation, and rising cost of fishmeal are limiting factors that will continue to affect the continuous supply of fishmeal to support the growth of aquaculture production (Golden et al., 2016). As the growing aquaculture industry cannot continue to rely on the finite stocks of wild-caught fish, the identification, development, and use of sustainable and alternate protein sources to fishmeal remain a high priority.

Insects have been adjudged to be an ecofriendly, renewable, and sustainable alternate protein source with an appealing quantity, quality, and acceptable nutritional composition for the production of aquafeeds (Henry, Gasco, Piccolo, & Fountoulaki, 2015; Sánchez-muros, Barroso, & Manzano-Agugliaro, 2014). Protein meal from insects is highly nutritious with high fat, protein, and mineral contents depending on the species (Rumpold & Schlüter, 2013). It is easily digestible and has been reported to have a high protein efficiency ratio, in addition to being relatively cheaper than conventional protein sources (Ssepuuya et al., 2017). Larvae of insects such as locusts (*Locusta migratoria*), grasshoppers (*Zonocerus variegatus*), termites (*Macrotermes* spp.), yellow mealworms (*Tenebrio molitor*), Asiatic rhinoceros beetles (*Oryctes rhinoceros*), domesticated silkworms (*Bombyx mori*), housefly (*Musca domestica*), mosquitoes (*Culex pipiens*), and black soldier fly (*Hermetia illucens*) have been tested and found to be suitable as an alternate protein source in the diets of farmed fish species (Alegbeleye, Obasa, Olude, Otubu, & Jimoh, 2012; Ani-ebo, Erundu, & Owen, 2009; Fasakin, Balogun, & Ajayi, 2003; Gasco et al., 2016; Henry et al., 2015; Ipinmoroti, Akanmu, & Iyiola, 2019; Kroeckel et al., 2012; Magalhães et al., 2017; Ogunji, Kloas, Wirth, Neumann, & Pietsch, 2007; Piccolo et al., 2017; Sogbesan & Ugwumba, 2008; Wang et al., 2017; Xiao et al., 2018).

Among other insects, black soldier fly (*H. illucens*) larval meal (BSF) has patterns of essential amino acids that are relatively similar to fishmeal (Henry et al., 2015), and the black soldier fly is an ideal candidate for sustainable mass production (Ssepuuya et al., 2017). The potential benefits of BSF have been demonstrated in many aquaculture species as a fishmeal replacement. Improved growth performance and immune indices have been reported when BSF was used to replace fishmeal (at 48% inclusion level) in the diet of yellow catfish, *Pelteobagrus fulvidraco* (Xiao et al., 2018). In a similar vein, there were no significant differences in the growth performance and nutrient utilization of Jian carp, *Cyprinus carpio* var. Jian (Li, Ji, Zhang, Zhou, & Yu, 2017; Zhou, Liu, Ji, & Yu, 2018), and European seabass, *Dicentrarchus labrax* (Magalhães et al., 2017), fed fishmeal-based diets and BSF-based diets. The BSF has also been demonstrated as a valid alternate protein source capable of replacing up to 50% fishmeal in the diet of rainbow trout (*Oncorhynchus mykiss*) without impairing organosomatic indices or fillet yield (Bruni, Pastorelli, Viti, Gasco, & Parisi, 2018). However, Kroeckel et al. (2012) reported reduced feed intake and reduced growth performance and feed conversion ratio in juvenile turbot (*Psetta maxima*) as the inclusion level of BSF increases.

Despite the potential of protein meal from BSF for the manufacture of sustainable aquafeeds, little information exists on its effects and utilization in African catfish (*C. gariepinus*), an important and dominant aquaculture species in sub-Saharan Africa. Although meals from insects such as the shea caterpillar (*Cirina butyrospermi*), housefly (*Musca domestica*), and variegated grasshopper (*Zonocerus variegatus* L.) have been included in the diets of African catfish (*C. gariepinus*) as alternate protein sources (Alegbeleye et al., 2012; Aniebo et al., 2009; Anvo et al., 2017; Fasakin et al., 2003; Olaleye, 2015), to the best of the authors' knowledge, no study has been reported on the dietary inclusion of BSF in diets of African catfish (*C. gariepinus*). Furthermore, several studies conducted on insect protein basically neglect blood indices, a fundamental tool often used in assessing the welfare and health status of animals in response to diets (Fawole et al., 2017; Jahanbakhshi, Imanpoor, Taghizadeh, & Shabani, 2013). Therefore, the objective of the study is to determine the effects of dietary inclusion level of BSF on the growth performance and hematological parameters of African catfish (*C. gariepinus*).

2 | MATERIALS AND METHODS

2.1 | Experimental design and diets preparation

The trial was carried out in a freshwater flow-through aquaculture system (2.5 L/min flow rate into the fish tank) of the Department of Aquaculture and Fisheries Management, Federal University of Agriculture, Abeokuta, Nigeria. The flow-through system contains 12 rectangular tanks (30-L capacity each) and were supplied with freshwater from a deep well. A total of 360 African catfish (*C. gariepinus*) fingerlings of a mean weight of 2.67 ± 0.0 g obtained from a reputable fish hatchery were randomly distributed (30 fish per tank) into the 12 tanks after 2 weeks of acclimatization. The photoperiod (~12 hr:12 hr, light:dark) and water temperature ($30.34 \pm 0.15^\circ\text{C}$) were maintained at ambient condition throughout the experimental period.

BSF (MagMeal™ 50) was obtained from AgriProtein, South Africa, and used for the study. The proximate and amino acid compositions of BSF are presented in Table 1. Four diets were formulated as follows: control (0% fishmeal replacement with MagMeal™ 50), 25% BSF (25% fishmeal replacement with MagMeal™ 50), 50% BSF (50% fishmeal replacement with MagMeal™ 50), and 100% BSF (100% fishmeal replacement with MagMeal™ 50) diets (Table 2). The feed ingredients were thoroughly mixed to form a homogenous blend, moistened (200 ml/kg), and then cold pressed to produce 2-mm pellets (flat die pelleting machine, CAPSFEED Nigeria). The diets were sun dried and stored in airtight containers prior to use. Fish were fed twice a day (08.00 hours and 16.00 hours) to apparent satiation for 6 weeks. The proximate composition of the diet was analyzed (Table 2) using Association of Official Analytical Chemists (AOAC) protocols (AOAC, 1995). Briefly, the moisture content was determined by drying the samples in an oven set to 105°C until a constant weight was achieved and then cooling in a desiccator. For ash analysis, samples were weighed and placed in a muffle furnace at 550°C for 8 hr, and ash content was determined. The Soxhlet ether method was used for lipid analysis. The Kjeldahl method was used to determine the nitrogen content of the samples, and the crude protein content was determined. All samples were analyzed in triplicate.

2.2 | Growth, feed utilization, and somatic indices

At the end of the trial, growth performance, feed utilization, and somatic indices were assessed by final body weight (FBW), specific growth rate (SGR), metabolic growth rate (MGR), feed conversion ratio (FCR), and protein efficiency ratio (PER). Three fish per tank ($N = 9$) were randomly collected and euthanized with an overdose of clove oil followed by brain destruction, after which they were sampled for liver weight, intestinal weight, and total length for the determination of hepatosomatic index (HSI), viscerosomatic index (VSI), and condition factor, respectively. All calculations were carried out using the formulae described below:

TABLE 1 Proximate composition (% DM) and amino acids profile of black soldier fly (*Hermetia illucens*) larval meal (g 100 g⁻¹ DM)

Variables	Black soldier fly larval meal
Crude protein	42.6
Crude fat	23.0
Moisture	8.2
Ash	10.5
Crude fiber	10.8
NFE	4.9
Energy (kJ/kg)	5,218
Calcium	3.34
Phosphorus	0.56
Indispensable amino acids (g/100 g)	
Arginine	1.29
Histidine	1.68
Isoleucine	2.36
Leucine	3.43
Lysine	3.91
Methionine	1.08
Phenylalanine	2.07
Threonine	1.84
Tryptophan	0.97
Valine	2.94
Dispensable amino acids (g/100 g)	
Alanine	3.78
Aspartic acid	4.16
Cysteine	2.43
Glutamic acid	5.64
Glycine	2.63
Proline	2.82
Serine	2.23
Tyrosine	4.35

Source: AgriProtein, South Africa.

$$SGR \left(\% \text{day}^{-1} \right) = 100 \times (\ln \text{ final body weight (g)} - \ln \text{ initial body weight (g)}) / \text{feeding days},$$

$$MGR \left(\text{gkg}^{-0.8} \text{day}^{-1} \right) = (\text{net weight gain in g}) / \left[\left\{ (\text{initial body weight in g}/1,000)^{0.8} + (\text{final body weight in g}/1,000)^{0.8} \right\} / 2 \right] / \text{feeding days},$$

$$FCR = \text{feed intake (g)} / \text{wet weight gain (g)},$$

$$PER = \text{wet weight gain (g)} / \text{protein ingested (g)},$$

$$\text{Condition factor} = 100 \times \text{wet weight (g)} / \text{total length (cm)}^3,$$

TABLE 2 Formulation and composition of the experimental diets

Ingredients (g kg ⁻¹)	0% BSF	25% BSF	50% BSF	100% BSF
Fishmeal (72% CP)	150.00	112.50	75.00	0.00
MagMeal™ 50 ^a	0.00	37.50	75.00	150.00
Krill meal	10.00	10.00	10.00	10.00
Soybean meal (solvent extracted)	400.00	400.00	400.00	400.00
Poultry meal	212.00	221.00	230.00	247.90
Maize	152.90	148.90	144.90	140.00
Vegetable oil	50.00	45.00	40.00	27.00
Vitamins minerals premix ^b	20.00	20.00	20.00	20.00
Antioxidant ^c	0.10	0.10	0.10	0.10
Binder (cassava flour)	5.00	5.00	5.00	5.00
Total	1,000	1,000	1,000	1,000
Composition (% dry weight)				
Moisture	8.83	7.60	8.13	8.07
Crude protein	42.60	42.35	42.86	41.25
Lipid	13.19	12.86	9.89	8.70
Ash	7.11	7.48	7.66	7.69
Calculated EAA content (g/100 g diet) ^d				
Arginine	2.89	2.84	2.79	2.69
Histidine	1.15	1.17	1.18	1.20
Isoleucine	1.64	1.65	1.66	1.67
Leucine	3.00	2.99	2.97	2.95
Lysine	2.57	2.56	2.55	2.54
Methionine	0.75	0.73	0.71	0.68
Phenylalanine	1.79	1.79	1.79	1.79
Threonine	1.58	1.56	1.55	1.52
Valine	2.00	2.02	2.03	2.07

^aMagMeal™ 50—larval meal of black soldier fly (*H. illucens*) produced by AgriProtein.

^bVitamins minerals premix contains (per 2.5 kg) 20,000,000 IU vitamin A, 4,000,000 IU vitamin D3, 200,000 vitamin E, 8,000 mg vitamin K3, 20,500 mg vitamin B1, 15,000 mg vitamin B2, 19,500 mg vitamin B6, 15mcg vitamin B12, 90,000 mg nicotinic acid, 40,000 mg pantothenic acid, 500 mg folic acid, 600,000 mcg biotin, 40,000 mg choline chloride, 4,000 mg iron, 500 mg copper, 30,000 mg manganese, 40,000 mg zinc, 2,000 mg iodine, 200 mcg selenium, 300,000 mg coated vitamin C, 50,000 mg inositol, 750 mg cobalt, 50,000 mg lysine, 50,000 mg methionine, and 125,000 mg antioxidant.

^cAntioxidant contains food-grade sodium metabisulfite.

^dCalculated based on amino acid composition of fishmeal, krill meal, poultry meal, soybean meal, and maize (NRC, 2011).

$$\text{HSI} = 100 \times (\text{liver weight (g)} / \text{body weight (g)}),$$

$$\text{VSI} = 100 (\text{visceral weight (g)} / \text{body weight (g)}).$$

2.3 | Hematological parameters

At the end of the feeding trial, three fish per tank ($n = 9$) were randomly selected for blood collection via the caudal arch using a 1-mL syringe that was previously rinsed with 10% ethylene diamine tetra acetic acid (EDTA) solution.

The fish were anesthetized with clove oil (100 mg/L) before blood collection. The collected blood was immediately transferred to an EDTA-coated bottle and used for hematological analysis. Packed cells volume (PCV), hemoglobin, red blood cells (RBC), white blood cells (WBC), and differential leucocyte proportions were determined according to standard methods as described by Rawling, Merrifield, and Davies (2009).

2.4 | Statistical analysis

All data are presented as mean $\pm$ standard deviation. Data were analyzed using one-way analysis of variance (ANOVA). Multiple comparisons were performed using Tukey post-hoc test. Differences were considered significant at a value of $p < .05$. Statistical analysis was carried out using SPSS for Windows (SPSS Inc., 24.0, Chicago, IL).

3 | RESULTS

The growth performance, feed utilization, and somatic indices of African catfish (*C. gariepinus*) fed different experimental diets are shown in Table 3. There were no significant differences ($p > .05$) in the FBW, SGR, MGR, FCR, and PER in fish fed the control (i.e., 100% fishmeal-based) diet and those fed diets containing 25 and 50% BSF fishmeal replacement. However, the fish fed the diet containing 100% fishmeal replacement with BSF displayed a significantly ($p < .05$) lower performance (in terms of their FBW, SGR, FCR, and PER) when compared with those fed 0, 25, and 50% BSF diets.

The somatic indices (condition factor, HIS, and VSI) and survival of the African catfish (*C. gariepinus*) fed different experimental diets are shown in Table 3. The condition factors, HSI and survival among the various groups showed no differences ($p > .05$) compared with fish fed the control (100% fishmeal-based) diet.

The hematological parameters of African catfish (*C. gariepinus*) fed the experimental diets are shown in Table 4. Hematological parameters, such as hemoglobin, RBC counts, PCV, WBC counts, and differential leucocytes showed no significant difference ($p > .05$) between the fish fed the control (100% fishmeal-based) diet and those fed the BSF (fishmeal replacement) diets.

TABLE 3 Growth, feed utilization, and somatic indices of *C. gariepinus* fed the experimental diets

	0% BSF	25% BSF	50% BSF	100% BSF	<i>p</i> value
IBW (g fish ⁻¹)	2.67 $\pm$ 0.00	2.67 $\pm$ 0.00	2.67 $\pm$ 0.00	2.67 $\pm$ 0.00	.000
FBW (g fish ⁻¹)	13.82 $\pm$ 0.18a	10.54 $\pm$ 1.34a	11.37 $\pm$ 0.28a	5.47 $\pm$ 0.32b	.002
SGR (% day ⁻¹)	5.48 $\pm$ 0.06a	4.55 $\pm$ 0.60a	4.83 $\pm$ 0.10a	2.39 $\pm$ 0.27b	.001
MGR (g kg ^{-0.8} day ⁻¹)	18.02 $\pm$ 0.14a	14.93 $\pm$ 1.42a	15.86 $\pm$ 0.27a	7.69 $\pm$ 0.64b	.014
FI (g fish ⁻¹)	13.16 $\pm$ 1.43a	11.04 $\pm$ 1.04a	11.74 $\pm$ 0.42a	7.62 $\pm$ 1.07b	.001
FCR	1.22 $\pm$ 0.1a	1.41 $\pm$ 0.24a	1.29 $\pm$ 0.05a	2.96 $\pm$ 0.3b	.002
PER	1.55 $\pm$ 0.20a	1.28 $\pm$ 0.29a	1.41 $\pm$ 0.07a	0.41 $\pm$ 0.08b	.003
HSI	1.06 $\pm$ 0.18	1.13 $\pm$ 0.13	1.03 $\pm$ 0.11	1.35 $\pm$ 0.18	.340
VSI	8.56 $\pm$ 0.54	7.47 $\pm$ 0.35	8.77 $\pm$ 0.93	10.71 $\pm$ 1.83	.225
Condition factor	0.80 $\pm$ 0.07	0.83 $\pm$ 0.07	0.90 $\pm$ 0.09	0.86 $\pm$ 0.08	.567
Survival (%)	83.33 $\pm$ 3.33	81.67 $\pm$ 1.67	88.33 $\pm$ 5.00	76.67 $\pm$ 3.33	.905

Note: Means in the same row with different superscripts are significantly different ($p < .05$).

Abbreviations: FBW, final mean body weight; FCR, feed conversion ratio; FI, feed intake; HSI, hepatosomatic index; IBW, initial mean body weight; MGR, metabolic growth rate; PER, protein efficient ratio; SGR, specific growth rate; VSI, viscerasomatic index.

TABLE 4 Hematological parameters of *C. gariepinus* fed the experimental diets

	0% BSF	25% BSF	50% BSF	100% BSF	<i>p</i> value
Hemoglobin (g/dl)	10.18 ± 1.23	10.20 ± 1.36	10.42 ± 1.79	10.40 ± 0.81	.905
RBC (10 ¹² L ⁻¹)	2.84 ± 0.35	2.91 ± 0.39	2.85 ± 0.55	2.97 ± 0.20	.988
Hematocrit (%PCV)	30.50 ± 3.73	31.83 ± 3.44	31.17 ± 5.61	30.67 ± 2.29	.877
WBC (10 ⁹ L ⁻¹)	140.10 ± 30.06	130.48 ± 33.82	125.37 ± 49.20	151.93 ± 30.75	.758
Neutrophil (%)	33.00 ± 8.76	29.67 ± 10.06	27.17 ± 15.50	37.83 ± 12.00	.689
Lymphocytes (%)	62.50 ± 8.08	65.50 ± 9.36	69.67 ± 16.98	59.00 ± 11.65	.703
Basophil (%)	1.00 ± 0.00	2.00 ± 0.00	1.00 ± 0.00	1.25 ± 0.43	.344
Eosinophil (%)	2.80 ± 1.47	2.50 ± 1.50	1.60 ± 0.49	1.50 ± 0.50	.276
Monocytes (%)	2.00 ± 1.15	3.33 ± 1.49	2.25 ± 0.83	1.60 ± 0.80	.147
MCV (fL)	107.82 ± 6.36	110.15 ± 5.20	110.02 ± 8.62	103.30 ± 4.03	.435
MCH (pg)	35.98 ± 1.70	35.32 ± 3.23	36.83 ± 2.85	35.05 ± 1.48	.540
MCHC (g/dl)	32.42 ± 1.63	32.13 ± 3.28	31.42 ± 1.81	33.85 ± 0.16	.435

Notes: There are no significant differences ($p > .05$) across the treatments.

Abbreviations: %, mean percentage of total leucocytes; MCH, mean corpuscular hemoglobin (hemoglobin [g/dl] × 10)/RBC (10¹² L⁻¹); MCHC, mean corpuscular hemoglobin concentration (hemoglobin [g/dl] × 100)/hematocrit (%PCV); MCV, mean corpuscular volume (hematocrit (%PCV) × 10)/RBC (10⁹ L⁻¹); PCV, packed cells volume; RBC, red blood cells; WBC, leucocytes.

4 | DISCUSSION

This study is the first trial (to our knowledge) of the evaluation and assessment of BSF in the diet of African catfish (*C. gariepinus*), an important and dominant aquaculture species in sub-Saharan Africa. In this study, a partial replacement of fishmeal with BSF up to 50% level of inclusion did not impair the growth performance of African catfish (*C. gariepinus*). Similar findings have been reported in other aquaculture species fed diets supplemented with BSF (Bruni et al., 2018; Li et al., 2017; Magalhães et al., 2017; Xiao et al., 2018; Zhou et al., 2018). The growth performance observed could be attributed to the pattern of essential amino acids of BSF, which is relatively similar to that of fishmeal (Henry et al., 2015), which is considered to be the gold-standard protein with the best essential amino acids profile for fish (Tacon & Metian, 2013).

However, the reduced growth performance observed in the 100% BSF group could be associated with low feed intake and poor acceptability of the diet by the fish, hence resulting in reduced protein and energy intake required for African catfish (*C. gariepinus*) growth. Low acceptability and intake because of reduced palatability have been reported when fishmeal is substantially or completely replaced in fish diets (Day & Gonzalez, 2000; Espe, Lemme, Petri, & El-Mowafi, 2007; Fournier, Huelvan, & Desbruyeres, 2004; Nagel et al., 2012, 2012). This finding is similar to the observation of Kroeckel et al. (2012), who reported reductions in dietary feed intake (at ≥33% inclusion levels of BSF) and growth performance of juvenile turbot (*Psetta maxima*) when fed diets supplemented with increasing levels of BSF (at 49% level of inclusion) as a replacement for fishmeal. In addition, a relative decreased level of methionine in the diet of 100% BSF group could contribute to the growth decline observed as reported by Xiao et al. (2018)—that low level of methionine or lysine could cause reduced feed efficiency and growth in fish; hence, dietary supplementation with methionine at higher inclusion levels may be necessary. Furthermore, chitin, an indigestible unbranched polymer of N-acetylglucosamine, has been reported to hinder digestibility in fish (Kroeckel et al., 2012; Magalhães et al., 2017), thereby reducing nutrient absorption, potentially partially explaining the sharp decline in growth noticed in the 100% BSF group.

The insignificant difference ($p > .05$) observed in the values of the somatic indices among the various groups could possibly indicate that feeding BSF to African catfish (*C. gariepinus*) had no negative impact on the liver

functionality and no excessive hepatic accumulation of fat or carbohydrate as the values were within the normal range (1–2%) (Piccolo et al., 2017). This observation is in accord with previous findings when fishmeal was replaced with BSF in the diets of yellow catfish (Xiao et al., 2018). Conversely, Piccolo et al. (2017) and Zhou et al. (2018) observed an increasing trend in HSI value for gilthead sea bream (*Sparus aurata*) and Jian carp (*Cyprinus carpio* var. Jian) as the level of yellow mealworm (*T. molitor*) meal and BSF increased, respectively. Furthermore, the condition factor and survival among the various groups showed no differences ($p > .05$) compared with the control group; thus, it could be said that feeding BSF to African catfish (*C. gariepinus*) would not adversely impair the liver and survival of African catfish (*C. gariepinus*).

Hematological indices are important tools in monitoring the health and physiological conditions of fish in relation to ingredient assessment and suitability of feed (Fagbenro, Adeparusi, & Jimoh, 2013; Fawole et al., 2017). For instance, any alteration or decrease in the level of erythrocyte and hemoglobin would impair the oxygen-carrying capacity of the blood and would hence impact fish health negatively. A decreased level of hematological parameters with increasing addition of sesame meal was reported in *Clarias gariepinus* associated with the presence of anti-nutritional factors in the seed meal (Fagbenro et al., 2013). However, in the present study, all hematological parameters, such as hemoglobin, RBC counts, and PCV (which are indicators of health status in fish) (NRC, 2011), as well as parameters such as WBC counts and differential leucocytes (important parameters in the nonspecific immunity of fish), were not markedly different among the various groups. This possibly indicates that the dietary replacement of fishmeal with BSF (even at 100%) does not have deleterious effects on African catfish (*C. gariepinus*) health and welfare. Similar observations were made by Ogunji et al. (2007) in Nile tilapia fed a maggot meal-based diet.

In conclusion, this study indicates that up to 50% fishmeal can be replaced with BSF without having an adverse effect on the growth performance, survival, and welfare of African catfish (*C. gariepinus*). Thus, BSF can be utilized as a potential alternative to fishmeal in the diets of African catfish (*C. gariepinus*). The authors do, however, recognize that digestibility trials would have been very informative for further assessment and evaluation of the suitability of BSF as an ingredient in the diet of African catfish (*C. gariepinus*). As the current study results are preliminary, a further, more comprehensive study is warranted that is expanded in scope.

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ORCID

Ayodeji A. Adeoye  <https://orcid.org/0000-0002-8732-1741>

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