OPEN ACCESS Journal of Animal Health and Production

Research Article

Use of Black Soldier Fly (*Hermetia illucens*) Larvae Meal in the Diet of *Clarias gariepinus* (Burchell, 1882) Fingerlings Reared in Controlled Environments

Diane N. S. Kpogue Gangbazo[1,2*], Dogbè Clément Adjahouinou[1,2], Arnauld S.M. Djissou[2,3], Théophile Godome[2], Ephrem C. Tossavi[2], Ndong Diegane[4], Jean Fall[5], André B. Aboh[6]

[1]Unité de Recherches en Aquaculture et en Gestion des Pêches (URAGeP), Ecole d'Aquaculture, Université Nationale d'Agriculture, Bénin; [2]Laboratoire d'Hydrobiologie et de Recherches sur les Zones Humides, Faculté des Sciences et Techniques, Université d'Abomey-Calavi, Bénin; [3]Département de Pêche et Aquaculture, Institut Supérieur des Sciences et de Médecine Vétérinaire de Dalaba, Guinée; [4]Département de l'Agriculture, des Ressources en Eau et de l'Environnement, Direction des Ressources Animales et Halieutiques, Commission de l'UEMOA, Ouagadougou, Burkina Faso; [5]Institut Universitaire de Pêche et d'Aquaculture, UCADII Bâtiment Pédagogique, Rez de chaussée, BP 5005 Dakar, Sénégal; [6]Unité de Recherches Zootechniques et Système d'élevage, Ecole de Gestion et d'Exploitation des Systèmes d'Elevage, Université Nationale d'Agriculture, Bénin.

Abstract | To reduce the use of fishmeal in the feed of *Clarias gariepinus* fingerlings, a study was carried out for 56 days using four experimental isoproteic, isolipidic, and isoenergetic diets (T_0, T_1, T_2, and T_3) which were formulated and manufactured based on local ingredients. Increasing levels of black soldier fly larvae meal (*Hermetia illucens*) were incorporated into these diets as a substitute for fish meal. Each experimental feed was tested in triplicate. Fish with an average initial weight of 9.7±0.02 g were used during the experiment. The results obtained at the end of the experiment revealed that the best growth and feed utilization performances ($p>0.05$) were obtained with feeds containing high levels of black soldier fly larvae (BSFL) meal. Likewise, the best production and economic income were obtained with feeds containing BSFL meal. Furthermore, the total substitution of fish meal with BSFL meal did not adversely affect the zootechnical and economic performance of *C. gariepinus* fingerlings.

Keywords | *Clarias gariepinus* fingerlings, Economic profitability, Feed, *Hermetia illucens*, Zootechnical performance

Received | February 06, 2025; **Accepted** | April 26, 2025; **Published** | July 03, 2025
***Correspondence** | Diane N. S. Kpogue Gangbazo, Unité de Recherches en Aquaculture et en Gestion des Pêches (URAGeP), Ecole d'Aquaculture, Université Nationale d'Agriculture, Bénin; **Email:** senami_diane@yahoo.fr
Citation | Gangbazo DNSK, Adjahouinou DC, Djissou A, Godome T, Tossavi E, Diegane N, Fall J, Aboh AB (2025). Use of black soldier fly (*Hermetia illucens*) larvae meal in the diet of *Clarias gariepinus* (burchell, 1882) fingerlings reared in controlled environments. J. Anim. Health Prod. 13(3): 632-641.
DOI | https://dx.doi.org/10.17582/journal.jahp/2025/13.3.632.641
ISSN (Online) | 2308-2801

INTRODUCTION

The major constraint to the emergence of fish farming in developing countries is the feed cost (Siddhuraju and Becker, 2003), and the availability of aquaculture feed that meets the nutritional requirements of farmed fish remains a major issue (FAO, 2016). In other words, the high cost of fishmeal and fish oil, which remain the main sources of essential amino acid and fatty acid in fish feed, limits their use by fish farmers. The lack of fish feed is often seen as a barrier to production growth in developing countries (Odjo *et al*., 2019). To solve this issue, Hasan and New

(2013) highlight the need for aquaculture to optimize feed production as well as feed management on-site. In terms of charge, feed represents around 50-70% of the production cost of farmed fish (Gourène *et al*., 2002) due to the use of fishmeal as the main protein source (Hardy, 2010; Burel and Médale, 2014). This has a negative impact on the sector's profitability. So, aquaculture production can only be profitable if fish farmers have access to balanced feed at competitive prices (Djissou *et al*., 2017). Given fishmeal is becoming scarce and expensive, it is necessary to find substitutes to limit aquaculture's dependence on this ingredient (Burel and Médale, 2014) and lower the cost of producing aquaculture species.

Research has been conducted to explore the utilization of new local and unconventional protein sources in fish feed. Recent studies have identified insects as a raw material that meets the requirements of animal and fish. Insect meals have high protein levels and interesting fatty acid profiles (Kenis *et al*., 2014; Caparros *et al*., 2015; Henry *et al*., 2015). Studies by Gasco *et al.* (2020) suggest that insect-based meals can sustainably replace conventional fish or plant protein meals used in fish feeds, as insects have the ability to valorise low quality organic matter, have undergone fewer resources and have a lower selected carbon footprint, resulting in reduced greenhouse gas emissions (Van Huis *et al*., 2013). Shifting to insect-based aquafeeds offers opportunities for a biocircular economy that improves environmental health by recycling bio-waste (Ermolaev *et al*., 2019; Mertenat *et al*., 2019). Among the insect species identified, the black soldier fly (*Hermetia illucens*) is a prime candidate due to its nutritional quality (Oonincx *et al*., 2015; Parolini *et al*., 2020). The black soldier fly (BSF), *Hermetia illucens*, is a valuable insect species whose larvae have enormous potential for converting organic waste into compost (Ewusie *et al*., 2019). According to the same authors, large quantities of larvae will need to be produced to meet the demand for using them as a protein source to formulate feeds for animals, including fish (Ewusie *et al*., 2019). The maggots and larvae of black soldier fly (*H. illucens*) are favoured because of the easiness of their production and the size of their biomass (Pomalégni *et al*., 2016; Odjo *et al*., 2019; Herawati *et al*., 2023). Elsewhere, in animal feed, there are two types of BSFL: defatted and full fat. The primary difference being in fat and saturated fatty acid content. The average crude protein content of BSFL are 414.7 g/kg, ranging from 216 g/kg (Yildirim-Aksoy *et al*., 2020) to 655 g/kg (Schiavone *et al*., 2017), which are lower than a conventional soybean meal (CSBM) (494.4 g/kg) and fish meal (675.3 g/kg) (Council, 2012). The protein content of full-fat BSFL is relatively similar, but the protein content after defatting is very different (from 216 g/kg to 655 g/kg) (Lu *et al*., 2022). however, as protein raw materials, insects such as BSFL, mealworm larvae (*Tenebrio molitor* L.), and crickets (*Orthoptera: Gryllidae*) are the focus of emerging research fronts and are already used as alternative nutrient sources for poultry and swine feed because they contain nearly 100 percent of the edible portion of protein (Schiavone *et al*., 2017; Gasco *et al*., 2019; Oonincx and De Boer, 2012). The feed conversion rate of BSFL is better than that of mealworms and crickets, and its survival rate and nitrogen and phosphorus composition do not change greatly with a change in diet (Oonincx *et al*., 2015). BSFL are characterized by a high food conversion rate, short reproductive cycle, and high content of fat, protein, minerals, and vitamins (El-Hack *et al*., 2020; Spranghers *et al*., 2017). Insect based meals have a high nutrition al content and are environmentally friendly, with low water and carbon footprints and land requirements (Tschirner and Kloas, 2017; Makkar, 2017). The black soldier fly larvae, in particular, contains high quality amino acids and lipids with fatty acids when grown in substrates of good quality (Rumpold and Schluter 2013; Gasco *et al*., 2018). The BSF larvae are cheap, easy to rear using domestic organic waste and can provide high value protein with a better amino acid content that can enhance fish growth (Tran *et al*., 2015). Trials to replace fish and soya meal with black soldier fly larvae in the diet of *Ictalurus punctatus* and *Oreochromis aureus* have given satisfactory results (Bondari and Sheppard, 1987). But, few studies have investigated the use of BSFL meal produced from substrates not enriched with long-chain polyunsaturated fatty acids in aquaculture feed. Therefore, the present study was initiated to address this gap.

MATERIALS AND METHODS

Experimental Set-Up and Diets Formulation

All experimental protocols were setup in line with the international ethical standard. The trial was conducted in circular plastic tanks, each with a volume of 40 litres. A total of 240 *C. gariepinus* fingerlings with a mean initial weight of 9.7±0.02 g was used. These fingerlings were distributed in 12 concrete ponds. The stocking density was 0.5 fingerlings/l of water. The trial lasted 56 days. Four (04) experimental diets (T0, T1, T2 and T3) formulated and manufactured with locally available raw materials (Table 1) were tested during the experiment. These diets were isoproteic, isolipidic, and isoenergetic and contained, among other ingredients, BSFL meal at increasing levels of incorporation (0%, 33%, 66% and 100%). Each experimental diet was tested in triplicate. The price per kg of each experimental diet was calculated taking into account the cost of the quantity of each ingredient used.

Manufacturing and Proximal Composition of the Ingredients and Experimental Diets

Apart from the BSFL meal, all ingredients used in the manufacturing of the experimental diets were purchased from the local market. The BSFL was produced using a substrate (Table 2) recommended by Atchamou *et al.* (2024).

Table 1: Formulations, cost, and proximate chemical compositions of the experimental diets.

Ingredients (%)	Treatments			
	T0 (0%)	T1 (33%)	T2 (66%)	T3 (100%)
Maize meal	10.00	10.00	10.00	10.00
Fish meal [a]	46.00	30.66	15.33	0.000
Cottonseed meal	20.00	20.00	20.00	20.00
Soybean meal	20.00	20.00	20.00	20.00
BSFL meal	0.00	15.30	30.66	46
Soya oil	2.00	2.00	2	2
Mineral–vitamin premix[b]	1.50	1.50	1.5	1.5
Lysine [b]	0.25	0.25	0.25	0.25
Methionine [b]	0.25	0.25	0.25	0.25
Total	100	100	100	100
Diet cost ($US/kg) [c]	0.98	1.14	1.13	0.71
Nutritional values				
Protein	40.71	40.05	40.74	40.10
Lipid	7.71	7.77	7.83	7.81
Gross Energy (KJ/g)[d]	14.16	14.22	14.35	14.48
Protein/ Energy ratio [d]	21.38	21.63	21.10	21.16

[a]PIASA feed (Productora Industrial Acuasistemas, La Paz, B.C.S. MX); [b]Drugstore, premix (vitamin – mineral) contains (‰): Vitamin A 4 000 000 U.I; Vitamin D 800 000 U.I; Vitamin E 40 000U.I; Vitamin K_3 1600 mg; Vitamin B_1 4 000 mg; Vitamin B_2 3 000 mg; Vitamin B_6 3 800 mg; Vitamin B_{12} 3 mg; Vitamin C 60 000 mg; Biotin 100 mg; Inositol 10 000 mg Pantothenic acid 8 000 mg; Nicotinic acid 18 000 mg; Folic acid 800 mg; Cholin chloride 120 000 mg; Colbat carbonate 150 mg; Ferrous sulphate 8 000 mg; Potassium iodide 400 mg; Manganese oxide 6 000 mg; Cuivre 800 mg; Sodium selenite 40 mcg; Lysine 10 000 mg; Methionin 10 000 mg; Zinc sulphate 8 000 mg. [c] Diet cost ($US/Kg) = Σ (Kg cost of each ingredient x Incorporation rate); [d]calculated from nutrient content: 23.01 Kj/g protein; 38.07 Kj/g lipid and 17.15 Kj/g carbohydrates.

Table 2: Composition of substrates used for black soldier fly larvae production.

Ingredients	Composition (%)
Soybean Okara	30
Palm kernel cake	25
Brewing grains	25
Marine fish viscera	20
Total	100

Source: Atchamou *et al.* (2024).

Fourteen days after BSF egg incubation in the substrate, the BSFL larvae were harvested, steam-killed, and dried using a dehydrator set at 30°C for 24 hours. The dried larvae were then ground into meal before being incorporated into the experimental diets. Tables 3 and 4 present the essential amino acids (EAA) profiles of the ingredients and the experimental diets, respectively. While the amino acid composition of BSFL is presented in Table 5.

Table 3: Composition of essential amino acids (EAA) of the main ingredients (g $100g^{-1}$ dry matter) of diet.

Composition	Fish meal	Soybean meal	Cotton-seed meal	BSFL	Maize meal
Threonine	2.31	0.76	0.45	4.43	2.00
Valine	2.77	0.56	0.50	6.79	3.00
Methionine	1.94	0.24	0.20	2.12	0.90
Isoleucine	2.45	0.52	2.50	4.73	2.53
Leucine	3.79	1.72	0.95	7.83	8.82
Phenylalanine	3.74	1.36	1.10	7.76	3.50
Histidine	1.75	0.64	0.70	3.25	2.00
Tryptophan	0.57	0.32	0.40	3.41	1.50
Lysine	4.22	1.20	0.50	6.82	1.80
Arginine	3.43	2.04	2.15	5.47	3.82

Table 4: Proximate essential amino acids (EAA) composition (g $100g^{-1}$ of diet) of experimental diets after analysis*.

Parameters	T0 (0%)	T1 (33%)	T2 (66%)	T3 (100%)	C. gariepinus requirements*
Threonine	1.30	1.60	2.00	2.30	1.05 – 1.10
Valine	1.50	2.10	2.70	3.40	0.78 – 1.50
Methionine	1.00	1.00	1.00	1.10	0.75 – 1.00
Isoleucine	1.70	2.10	2.40	2.80	0.87 – 1.00
Leucine	2.30	3.00	3.60	4.20	0.95 – 1.90
Phenylalanine	2.30	2.90	3.50	4.10	1.05 – 1.60
Histidine	1.10	1.30	1.60	1.80	0.48 – 1.00
Tryptophan	0.40	0.30	0.30	0.20	0.28 – 0.30
Lysine	2.30	2.70	3.10	3.50	1.43 – 1.60
Arginine	2.50	2.80	3.10	3.40	1.18 – 1.20

* EAA requirements of according to NRC (1993, 2011).

During the manufacturing of the tested feeds, the raw ingredients were finely ground, weighed, and mixed until a homogeneous blend was obtained. Subsequently, purified amino acids (lysine and methionine), vitamins, minerals, and palm oil were added. Water was then added at 50% of the dry matter content to form a malleable dough. This dough was shaped into spaghetti-like strands using a hand-operated mincer. The strands were passed through a 1 mm sieve of the mincer and, after drying in a dehydrator at 30°C for 36 hours, were manually broken into small pellets. The resulting pellets were stored in small containers and kept refrigerated at 4°C until distribution.

Table 5: Amino acid composition of BSFL (g kg^{-1} dry matter basis)*.

BSFL								**CSBM**	**FM**
Essential amino acids									
Type	FF_a	DF_b	FF_c	FF_d	FF_e	FF_f	FF_g		
Arginine	19.9	20.7	21.1	54.7	62.0	21.9	18.7	35.7	41.0
Histidine	13.8	16.3	13.5	32.5	48.0	9.8	13.7	14.2	15.4
Isoleucine	19.1	24.0	17.7	47.3	48.0	19.1	20.6	22.1	27.3
Leucine	30.6	36.7	27.8	78.3	77.0	32.1	29.4	38.6	47.7
Lysine	23.0	25.2	28.1	68.2	74.0	27.2	25.9	31.1	48.7
Methionine	7.1	8.56	8.0	21.2	6.0	6.0	7.1	6.8	18.5
Phenylalanine	16.4	21.8	16.4	77.6	62.0	18.3	18.7	25.5	26.4
Threonine	16.2	21.8	16.3	44.3	45.0	26.5	16.7	19.8	27.5
Tryptophan	5.4					5.6	6.3	6.6	6.7
Valine	28.2	34.5	25.0	67.9	67.0	28.7	28.8	21.7	32.7
Non-essential amino acids									
Alanine	27.8	43.7	25.6	82.1	62.0		26.6	21.6	41.9
Aspartic acid	36.9	48.8	38.7	73.0	103.0		35.6	55.0	57.7
Cysteine	2.2	0.2	3.5	7.6	5.0	4.2	3.2	7.7	6.5
Glycine	25.2	30.3	24.6	61.5	54.0	26.8	24.8	21.3	50.3
Glutamic acid	45.8	63.7	46.1	131.0	102.0		38.4	88.6	84.1
Proline	25.1	32.7	23.6	66.8	62.0		23.1	27.4	30.8
Serine	15.9	26.8	17.6	48.8	41.0	19.2	15.2	24.1	25.9
Tyrosine		34.1		67.1	60.0	26.5	26.9	15.5	20.1

CSBM = conventional soybean meal, DF = defatted fat, FM = fish meal, FF = full fat.

In Lu *et al.* (2022) : $_a$Spranghers *et al.* (2017) ; $_b$Shiavone *et al.* (2017) ; $_c$Onsongo *et al.* (2018) ; $_d$Rawsi *et al.* (2020) ; $_e$Müller *et al.* (2017) ; $_f$Shal *et al.* (2022) ; $_g$Romano *et al.* (2022)

Feeding and Experimental Monitoring

The *C. gariepinus* fingerlings were fed at a daily ration of 5% of their biomass. This ration was distributed 3 times a day at 8 am, 1 pm and 6 pm. Before feeding, the pellets were crushed in order to adapt their size to the mouth of the fingerlings. A control sampling was carried out every 7 days. At each control sampling, the fingerlings were counted and the biomass per experimental pond was assessed in order to adjust the feed ration.

To monitor water quality, physicochemical parameters such as temperature, dissolved oxygen, and pH were measured using a portable multimeter (Calypso ORCHIDIS SN-ODEOA 2138) every morning before the first feeding.

Biochemical Analysis

Biochemical analysis (proteins, amino acids, lipids, ash, and dry matter) were carried out in triplicate using the standard methods of the AOAC (1999) and involved the ingredients, the experimental feed, and the homogenized carcasses of whole fish taken randomly from each pond at the beginning and at the end of the experiment. For fish carcass analysis purpose, 12 fingerlings were sampled per diet.

Crude protein was determined by the Kjeldahl method (%N x 6.25) and lipids by the hot Soxhlet method. For lipid extraction, a mixture of chloroform and methanol (2:1 v/v) was used (Folch *et al.*, 1957). Dry matter was determined by measuring weight loss after drying for 24 hours in an oven at 105°C, and ash by incinerating the samples in an oven at 550°C for 16 hours. The gross energy of the experimental diets was calculated according to Shiemann *et al.* (1971), Azaza *et al.* (2006). The amino acids content of the ingredients and diets was determined by high-performance liquid chromatography using the method of Bosh *et al.* (2006).

These analyses were carried out at Central Laboratory for Food Safety and Health (Benin) and the Animal Nutrition Laboratory of Kagoshima University (Japan).

Growth Performance, Feed Efficiency and Economic Parameters

Growth performances, diet nutrient utilization, and the productivity were appreciated using specific growth rate (SGR), biomass gain (BG), feed efficacity (FE), protein efficiency ratio (PER), lipid efficiency rate (LER), survival rate (SR), production (P), Annual Production (AP). The economic profitability was assessed using economic conversion ratio (ECR), annual gross production cost (AGPC), total cost of feed distributed (TCFD), total selling price of fish (TSPF), gross profit margin (GPM). These parameters were calculated using the following formula:

$$BG\ (g) = FB\ (g) - IB\ (g)$$

Where; IB and FB are initial biomass and final biomass, respectively.

$$FE = \frac{Biomass\ Gain\ (g)}{feed\ intake\ (g)}$$

$$SGR\ (\%/day) = \frac{100 \times (ln[FBW] - ln[IBW]}{Duration\ of\ experimentation}$$

Where; IBW and FBW are initial body weight and final body weight, respectively.

$$FE = \frac{BG\ (g)}{feed\ intake\ (g)}$$

$$PER = \frac{Wet\ body\ weight\ gain}{protein\ intake}$$

$$LER = \frac{Wet\ body\ weight\ gain}{Lipid\ intake}$$

$$SR(\%) = \frac{100 \times Final\ number\ of\ fish}{Initial\ number\ of\ fish}$$

$$P\ (kg/ha) = \frac{10000 \times (Bf - Bi)}{Surface\ area\ of\ each\ tank}$$

Where; Bi and Bf are initial biomass and final biomass of fish, respectively.

$$AP\ (kg/ha/year) = \frac{P \times 365}{duration\ of\ experimentation\ (in\ days)}$$

ECR ($US)= Feed cost × FE^{-1}
AGPC ($US)= AP × ECR
TCFD ($US)= AGPC × total quantity of feed distributed
TSPF ($US)= AP × 2.5 $US
GPM ($ US)= TSPF - (TCFD + Purchase Price of Fish).

Statistical Analysis

The data from the experimentation were subjected to one-way analysis of variance after checking the normality and variance homogeneity of the data with the Statviews software (version 5.01). Fisher's LSD (Least-Significant-Difference) test was used to make a pairwise comparison of the means. The significance threshold considered was 5%.

RESULTS AND DISCUSSION

Physicochemical Conditions of the Fish Rearing

Table 6 shows the average values of the physicochemical parameters in the ponds according to the treatments during the trial. The assessed water quality parameters did not present no significant difference among the treatment.

Growth, Survival and Feed Utilization Parameters

The growth and survival parameters of *C. gariepinus* fingerlings are presented in Table 7. The mean final body weight varied significantly among treatments ($p < 0.05$). Globally, the mean final body weights obtained with the BSFL meal-based diets (T_1, T_2, and T_3) were significantly higher than that from control diet T_0 based on fishmeal.

The survival rate was 100% for all treatments (Table 7) throughout the experimentation. Biomass gain and specific growth rate increased significantly as the incorporation rate of BSFL meal increased. Therefore, the highest values for these parameters were obtained for fish fed diet T_3 ($p < 0.05$).

Table 6: Average values of the physicochemical parameters of water used in each treatment.

Parameters	T_0	T_1	T2	T_3
pH	7.27 ± 0.04^a	7.25 ± 0.08^a	7.25 ± 0.08^a	7.30 ± 0.01^a
Temperature (°C)	29.68 ± 0.05^a	29.65 ± 0.10^a	29.63 ± 0.03^a	29.64 ± 0.05^a
Dissolved oxygen (mg/l)	7.46 ± 0.04^a	7.47 ± 0.59^a	7.46 ± 0.92^a	7.46 ± 0.50^a

Mean ± SD values in the same line followed by the same superscript are not significantly different ($p < 0.05$).

Table 7: Zootechnical performance parameters of *C. gariepinus* fingerlings during the trial.

Treatment	T0	T_1	T_2	T_3
IBW (g)	9.70±0.02	9.74±0.02	9.70±0.02	9.76±0.02
FBW (g)	22.61±0.47^a	25.15±0.49^b	26.99±0.36^c	27.89±1.40^d
BG (g)	645.67 ± 24.13^a	770.33 ± 24.13^b	864.67 ± 18.93^c	906.67 ± 9.45^d
SGR (%/j)	1.51±0.75^a	1.69±0.38^b	1.83±0.45^c	1.88±0.23^d
SR (%)	100	100	100	100

IBW: Initial body weight; **FBW:** Final body weight; **BG:** Biomass gain; **SGR:** Specific growth rate; **SR:** Survival rate. Mean ± SD values in the same line followed by the same superscript are not significantly different ($p < 0.05$).

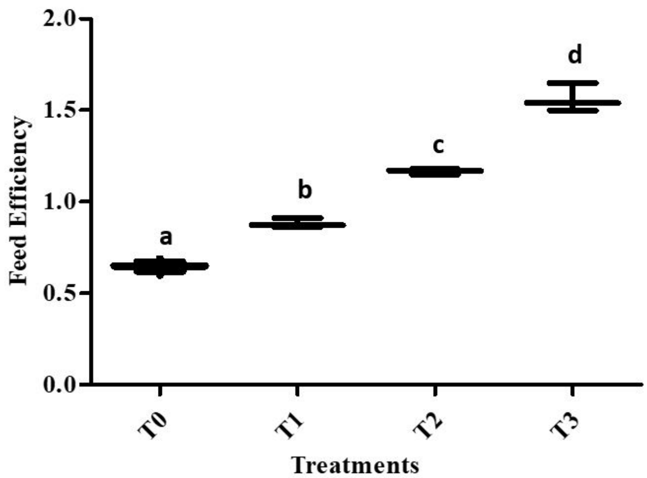

Figure 1: Variation in feed efficiency across treatments.

Feed utilization parameters evaluated during the experiment not varied significantly according to the treatments ($p < 0.05$) except feed efficiency. Therefore, feed efficiency (FE) increased as the rate of incorporation of BSFL meal increased showing that the diets containing BSFL meal (T_1, T2 and T_3) perform better ($p < 0.05$) than the control diet (T0) containing fishmeal (Figure 1). The best FE was therefore noticed with T3. On the contrary, the highest Lipid Efficiency Ratio (LER) were observed in treatment T_3 (Figure 2) without significantly difference compared to the other treatments (p > 0.05). In Figure 3, the same observation has made with protein efficiency ratio (PER). No significant difference was noticed among the treatments (p > 0.05).

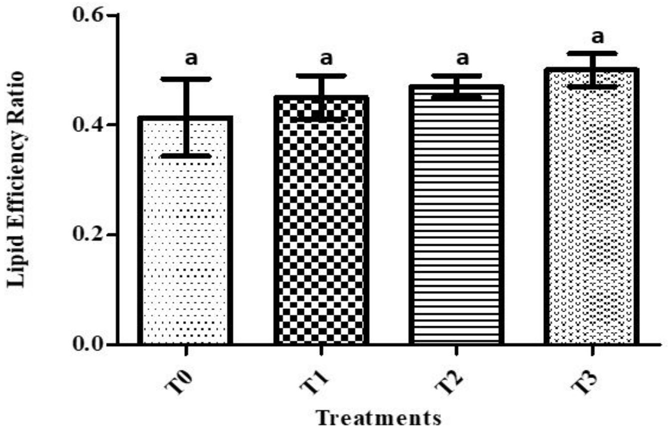

Figure 2: Variation in lipid efficiency rate according to the treatments.

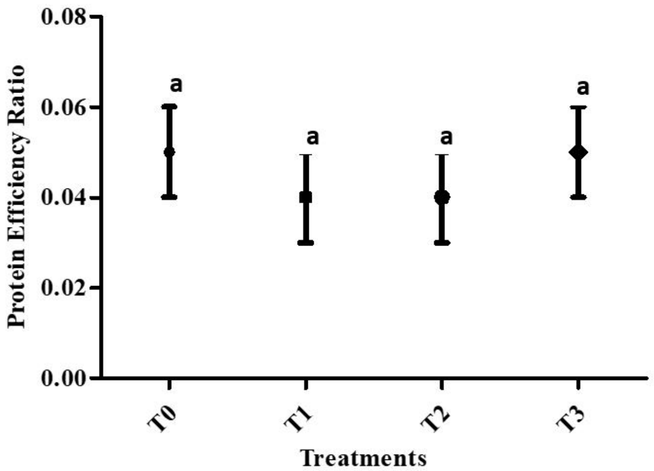

Figure 3: Variation in protein efficiency rate according to the treatment.

Table 8: Carcass composition of *C. gariepinus* fingerlings during the trial.

Composition (% dry weight)	Initial	T0	T1	T2	T3
Dry matter	21.20 ± 0.30	23.90 ± 0.15	23.50 ± 0.15	26.30 ± 0.12	24.10 ± 0.16
Protein	12.60 ± 0.10	14.60 ± 0.03^a	14.20 ± 0.12^b	14.09 ± 0.04^b	14.63 ± 0.07^a
Lipid	4.60 ± 0.13	7.84 ± 0.22^a	8.10 ± 0.01^a	8.31 ± 0.10^{ab}	8.50 ± 0.31^b
Ash	3.80 ± 0.13	3.97 ± 0.05	4.50 ± 0.09	4.10 ± 0.19	4.47 ± 0.11

Mean ± SD values in the same line followed by the same superscript are not significantly different (p < 0.05).

The Table 8 shows that the carcass protein and lipid composition of the reared *C. gariepinus* fingerlings varied significantly among treatments (p<0.05) while their dry matters and ash are statistically similar (p>0.05).

Productivity and Economic Profitability

Productivity and economic profitability parameters are present in Table 9. It indicates that the Economic Conversion Ratio (ECR), production, and economic profitability varied among treatments. The ECR, representing the production cost per kilogram of fish, decreased as the incorporation rate of Black Soldier Fly Larvae (BSFL) meal increased in the experimental diets. It ranged from \$0.77 for treatment T_3 to \$1.51 for treatment T_0. Accordingly, the lowest ECR values were achieved with diets formulated using BSFL meal. Similarly, the highest production levels and economic profitability were obtained with diets containing the highest BSFL meal incorporation rates (T3).

Table 9: Productivity and economic profitability of experimental diets.

Treatments	T_0	T_1	T_2	T_3
ECR	1.51	1.46	1.31	0.77
P (kg/ha)	3951.468	4714.38	5291.74	5548.78
AP(kg/ha/year)	8535.17258	10183.0649	11430.1542	11985.3562
AGPC($US)	13131.0347	13055.2114	13290.877	13027.5611
TCFD($US)	9179.56595	8824.35584	8060.67078	4644.08427
TSPF($US)	21337.9315	25457.6622	28575.3856	29963.3905
GPM($US)	2612.9155	7087.85634	10969.2648	15773.8562

ECR: Economic conversion ratio; **P:** Production; **AP:** Annual Production; **AGPC:** Annual gross production cost; **TCFD:** Total cost of feed distributed; **TCPF:** Total selling price of fish; **GPM:** Gross profit margin.

Clarias gariepinus requires a good water quality for its survival and growth (Anusuya, 2017). The physicochemical parameters (pH, temperature, dissolved oxygen) of water, assessed during the present study were around 7, 29°C and 7 mg/l, respectively. The water pH was therefore close to its optimal value (7) and within its tolerance range (6 to 9) for *C. gariepinus* (Viveen *et al*., 1985; Edéa *et al*., 2019). Likewise, temperature values comprised between 28 and 30°C, was also optimal for the reared species (Teugels, 1986). As for dissolved oxygen, its values were higher than 3 mg/l representing the lowest requisite level for *C. gariepinus* (Viveen *et al*., 1985). Overall, all the water quality parameters surveyed, revealed that the fish were reared in good abiotic conditions.

All the experimental diets were accepted by the *C. gariepinus* fingerlings during the experiment. The results revealed clearly that feeds without fishmeal had no negative effect on the zootechnical performance (growth, survival, feed utilization) and production profitability of *C. gariepinus* fingerlings. The growth performances (biomass gain, final average weight, and specific growth rate) of fish fed T_1, T_2, and T_3 were significantly higher than those obtained with the control diet (T_0). These results are in accordance with those of some previous study that reported that BSFL meal meal can be used to validly substitute fishmeal at a rate even up to 50% (Adeoye, 2020) and 75% (Fawole *et al*., 2020) in the diet of *C. gariepinus* fingerlings without compromising their zootechnical performance, feed utilization, and health status of *C. gariepinus*. Similar results have been reported in *Oreochromis niloticus* (Gougbedji *et al*., 2021) and other aquaculture species fed diets containing black soldier fly larvae meal (Li *et al*., 2017; Magalhães *et al*., 2017; Bruni *et al*., 2018; Zhou *et al*., 2018).

Fish, like other animals, synthesize body proteins from amino acids provided in their diet. Essential amino acids must therefore be supplied through the diet, as organisms are unable to synthesize them independently. A deficiency in any essential amino acid in the diet can impair growth and induce metabolic disorders (Furuya *et al*., 2023). Consequently, when formulating feed based on local dietary resources, ensuring the supply of essential amino acids is critical to address various challenges, including optimizing the utilisation of sustainable raw materials, reducing feed costs, and minimizing nitrogen discharge into the environment (Médale *et al*., 2013). In this study, the essential amino acid requirements of the *C. gariepinus* are almost met by all experimental diets (Table 2). The tryptophan deficiency observed in the T_3 treatment, which included 100% BSFL meal as a replacement for fish meal, did not adversely affect the growth performance or feed utilization of reared *C. gariepinus* fingerlings. This finding indicates that tryptophan does not appear to be a limiting factor in the utilization of BSFL meal in the diet of *C. gariepinus*.

On the other hand, a high inclusion of insect meal in fish feed can result in elevated chitin levels, which may interfere with digestive processes, thereby reducing feed efficiency and intake and subsequently impairing growth (Barroso *et al*., 2014). In our experimentation, it noticed an improvement in zootechnical parameters such as growth, survival and feed utilization as the incorporation rate of black soldier fly larvae (BSFL) meal increased. This enhancement may be attributed to the essential amino acid profile of BSFL, which was closely similar to that of fishmeal considered as the benchmark protein source since it has the best essential amino acids profile for fish (Tacon and Metian, 2013; Henry *et al*., 2015).

Additionally, the developmental stage at which BSFL are harvested significantly influences their nutritional value and chitin content (Wohlfahrt and Sandrock, 2023). In this study, the BSFL used was harvested the 14th day of the culture according to Wohlfahrt and Sandrock (2023) who recommend to harvest BSFL between the 12th and 16th days of their production cycle. This, combined with the nutrient composition of the production substrate and the BSFL meal processing technique, likely underpins the obtained performance. Previous studies reported that substrate composition affects the nutritional quality of BSFL. For instance, substrates with a favourable profile in essential amino acids and polyunsaturated fatty acids can yield BSFL of high nutritional value (Djissou *et al*., 2016; Kpoguè *et al*., 2022; Sègnon *et al*., 2024). This underscores the potential of tailored substrates to enhance the nutritional properties of BSFL meal.

The economic feasibility of aquaculture heavily depends on feed costs. To evaluate the economic performance of *C. gariepinus* fry production, we calculated key parameters related to production costs. Diets with the highest fishmeal substitution rates using BSFL meal exhibited the most favourable relative cost trends (ECR) and profit margins. Similar findings were reported by Djissou *et al*. (2016) using earthworm and maggot meals as total fishmeal replacements in the diet of *C. gariepinus* fingerlings. Mastoraki *et al*. (2020) also noticed comparable results with various insect meals in the diet of *Dicentrarchus labrax* fry. Additionally, Djossou *et al*. (2021) demonstrated that incorporating *Spirodela polyrhiza* into the diet of *Oreochromis niloticus* fry enhanced both zootechnical performance and economic profitability. These outcomes can be attributed to the lower cost per kilogram of feeds based on alternative protein sources.

CONCLUSIONS AND RECOMMENDATIONS

This study highlights the advantage of the valorization of BSFL meal in the diet of *Clarias gariepinus* fingerlings. The highest zootechnical and economic performance was observed in fingerlings fed with diets containing BSFL meal. A 100% incorporation rate of BSFL meal, entirely replacing fishmeal, demonstrated no adverse effects on survival rates, growth performance or feed utilization efficiency. Furthermore, the most favourable economic outcomes were achieved with BSFL-based diets, particularly that formulated without fishmeal. This alternative protein source in aquafeeds represents a promising step towards the sustainable development of aquaculture by reducing reliance on conventional feed ingredients and enhancing resource efficiency.

ACKNOWLEDGMENTS

The authors are grateful for the discussions with Muhammad Syahrul and the generous technical assistance provided by members of his laboratory staff.

NOVELTY STATEMENT

Feeding black soldier fly larvae can improve the performance, carcass quality, and digestibility of farmed fish.

AUTHOR'S CONTRIBUTIONS

Diane N. S. Kpogue Gangbazo: Concept of research, laboratory work, data collection and data analysis.
Dogbè Clément Adjahouinou and Arnauld S.M. Djissou: Laboratory work.
Théophile Godome: Edit and revise the manuscript.
Ephrem C. Tossavi. Design concept.
Ndong Diegane, Jean Fall and André B. Aboh: Write a script.

Conflict of Interest

The research results are a mutual agreement, and there is no conflict of interest, be it funding and work.

REFERENCES

Adeoye AA, Akegbejo-Samsons Y, Fawole FJ, Davies SJ (2020). 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. J. World Aquacult. Soc., 51: 1024-1033. https://doi.org/10.1111/jwas.12691

AOAC (1999). Official Methods of Analysis (16th Edition, 5th Revision). Association of Official Analytical Chemists, Arlington, VA, USA.

Anusuya M (2017). A study on factors influencing "switching behavior" among telecom consumers. https://www.researchgate.net/publication/368425703_ANUSUYA_2017-18

Atchamou JBO, Tonoukouen R, Kpogue DNS, Ogoudele M, Djissou A, Aboh BA, Sohou Z, Ndong D, Fall J, Mensah GA (2024). Impact of Different Organic Substrates on the Productivity and Nutritional Composition of Black Soldier Fly Larvae (*Hermetia illucens*). Eur. J. Nutr. Food Saf., 16 (11): 240-251. https://doi.org/10.9734/ejnfs/2024/v16i111589

Azaza MS, Mensi F, Kraiem MM (2006). Grossissement du Tilapia du Nil (*Oreochromis niloticus*, L., 1758) en bassin dans les eaux géothermales du sud tunisien et en cages flottantes dans la retenue du barrage de Sidi Saad (centre de la Tunisie).

Barroso FG, Haro C, De. Sánchez-muros M, Venegas E, Martínez-sánchez A, Pérez-bañón C (2014). The potential of various insect species for use as food for fish. Aquaculture, 422-423. 193-201. https://doi.org/10.1016/j.aquaculture.2013.12.024

Bondari K, Coastal DCS, Experiment P (1987). Soldier fly *Hermetia illucens* L. larvae as feed for channel catfish *Ictalurus punctatus* (Rafinesque) and blue tilapia *Oreochromis aureus* (Steindachner). Aquacult. Fish. Manage., 209-220. https://doi.org/10.1111/j.1365-2109.1987.tb00141.x

Bosch J, Venter E, Han Y, Boshoff C (2006). The impact of brand identity on the perceived brand image of a merged higher education institution: Part one. Management Dynamics, 15 (2)

Bruni L, Pastorelli R, Viti C, Gasco L, Parisi G (2018). Characterization of the intestinal microbial communities of rainbow trout (*Oncorhynchus mykiss*) fed with *Hermetia illucens* (black soldier fly) partially defatted larva meal as partial dietary protein source. Aquaculture, 487 : 56-63. https://doi.org/10.1016/j.aquaculture.2018.01.006

Burel C, Médale F (2014). Guide de l'utilisation des protéines d'origine végétale en aquaculture. OCL, 21 (4) D406: 2-15. https://doi.org/10.1051/ocl/2014013

Caparros Megido R, Alabi T, Larreché S, Alexandra L, Haubruge É, Francis F (2015). Risques et valorisation des insectes dans l'alimentation humaine et animale. Ann. Soc. Entomologique Fr., (N.S.), 51 (3): 215-258. https://doi.org/10.1080/00379271.2015.1122911

Council NR (2012). Nutrient Requirements of Swine; Natl Acad Press: Washington, DC, USA.

Davies SJ (2020). 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. J. World Aquacult. Soc., 51: 1024-1033. https://doi.org/10.1111/jwas.12691

Djissou ASM, Adjahouinou DC, Koshio S, Fiogbe ED (2016). Complete replacement of fish meal by other animal protein sources on growth performance of *Clarias gariepinus* fingerlings. Int. Aquat. Res., 8: 333–341. https://doi.org/10.1007/s40071-016-0146-x

Djissou ASM, Ochiai A, Koshio S, Fiogbé ED (2017). Effect of total replacement of fishmeal by earthworm and *Azolla filiculoides* meals in the diets of Nile tilapia *Oreochromis niloticus* (Linnaeus. 1758) reared in concrete tanks. Indian J. Fish., 64 (1): 31-36. https://doi.org/10.21077/ijf.2017.64.1.55317-05

Djossou SMB, Kpogue Gangbazo DNS, d'Almeida AFM, Aboh AB, Montvhowui E, Fiogbe ED (2021). Valorization of the duckweed (*Spirodela polyrhyza*) in the feeding of mono sex male fry of *Oreochromis niloticus*: zootechnical performance and economic profitability. Int. J. Agron. Agric. Res., 19 (3): 9-16

Djissou ASM, Ochiai A, Koshio S, Fiogbé ED (2017). Effect of total replacement of fishmeal by earthworm and Azolla filiculoides meals in the diets of Nile tilapia Oreochromis niloticus (Linnaeus. 1758) reared in concrete tanks. Indian J. Fish., 64 (1): 31-36. https://doi.org/10.21077/ijf.2017.64.1.55317-05

Edéa OG, Hinvi L C, Abou Y, Gbangboché AB (2019). Synthèse bibliographique sur des paramètres biologiques et zootechniques du poisson-chat Africain *Clarias gariepinus* Burchell, 1822. Eur. Sci. J., 15 (27): 54 - 88. https://doi.org/10.19044/esj.2019.v15n27p54

El-Hack A, Mohamed E, Shafi ME, Alghamdi WY, Abdelnour SA, Shehata AM, Noreldin AE, Ashour EA, Swelum AA, Al-Sagan AA (2020). Black soldier fly (*Hermetia illucens*) meal as a promising feed ingredient for poultry: A comprehensive review. Agriculture, 10: 339. https://doi.org/10.3390/agriculture10080339

Ermolaev E, Lalander C, Vinnerås B (2019). Greenhouse gas emissions from small scale fly larvae composting with *Hermetia illucens*. Waste Manage., 96: 65 74. https://doi.org/10.1016/j.wasman.2019.07.011

Ewusie EA, Kwapong PK, Ofosu-Budu G, Sandrock C, Akumah AM, Nertey EK, Teye-Gaga C, Agyakwah SK (2019). The black soldier fly, *Hermetia illucens* (Diptera: Stratiomyidae): Trapping and culturing of wild colonies in Ghana. Sci. Afr., 5: e00134 https://doi.org/10.1016/j.sciaf.2019.e00134

FAO (2016). Situation mondiale des pêches et de l'aquaculture. 214p chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://openknowledge.fao.org/server/api/core/bitstreams/146a8ae7-f238-4c0b-a747-2473f0a18b46/content

Fawole FJ, Adeoye AA, Tiamiyu LO, Ajala KI, Obadara SO, Ganiyu IO (2020). Substituting fishmeal with *Hermetia illucens* in the diets of African catfish (*Clarias gariepinus*): Effects on growth. nutrient utilization. haemato-physiological response. and oxidative stress biomarker. Aquaculture, 518: 734849. https://doi.org/10.1016/j.aquaculture.2019.734849

Folch J, Lees M, Sloane Stanley GH (1957). A simple method for the isolation and purification of total lipides from animal tissues. The Journal of Biological Chemistry, 226(1), 497–509.

Furuya WM, Cruz TPd, Gatlin DMIII (2023). Amino Acid Requirements for Nile Tilapia: An Update. Animals, 13: 900. https://doi.org/10.3390/ani13050900

Gasco L, Acuti G, Bani P, Dalle Zotte A, Danieli PP, De Angelis A, Piccolo G (2020). Insect and fish by products as sustainable alternatives to conventional animal proteins in animal nutrition. Ital. J. Anim. Sci., 19 (1): 360 37 2. https://doi.org/10.1080/1828051X.2020.1743209

Gasco L, Dabbou S, Trocino A, Xiccato G, Capucchio MT, Biasato I, Dezzutto D, Birolo M, Meneguz M, Schiavone A (2019). Effect of dietary supplementation with insect fats on growth performance, digestive efficiency and health of rabbits. J. Anim. Sci. Biotechnol., 10: 4. https://doi.org/10.1186/s40104-018-0309-2

Gasco L, Finke M, Van Huis A (2018). Can diets containing insects promote animal health? J. Insects Food Feed, 4 (1): 1- 4. https://doi.org/10.3920/JIFF2018.x001

Gougbedji A, Agbohessou P, Lalèyè PA, Francis F, Caparros Megido R (2021). Technical basis for the small-scale production of black soldier fly. *Hermetia illucens* (L. 1758). meal as fish feed in Benin. J. Agric. Food Res., 4: 100153. https://doi.org/10.1016/j.jafr.2021.100153

Gougbedji A, Agbohessou P, Lalèyè PA, Francis F, Megido RC (2020). Inventaire des coproduits agricoles potentiellement utilisables pour la production de pupes de mouche *Hermetia illucens* (L. 1758) pour l'alimentation piscicole au Bénin. Tropicultura, 38 (3–4): 1–18. https://doi.org/10.25518/2295-8010.1587

Gougbedji A, Detilleux J, Lalèyè PA, Francis F, Caparros Megido R (2022). Can Insect Meal Replace Fishmeal? A Meta-Analysis of the Effects of Black Soldier Fly on Fish Growth Performances and Nutritional Values. Animals, 12(13): 1700. https://doi.org/10.3390/ani12131700

Gourène G, Kobena KB, Vanga AF, (2002). Etude de la rentabilité des fermes piscicoles dans la région du moyen Comoé. Abidjan, Côte d'Ivoire, Université Abobo-Adjamé : Rapport Technique. 41 pp.

Hardy RW (2010). Utilization of plant proteins in fish diets: effects of global demand and supplies of fishmeal, Aquacult. Res., 41: 770-776. https://doi.org/10.1111/j.1365-2109.2009.02349.x

Hasan MR, New MB (2013). On-farm feeding and feed management in aquaculture. Document technique sur les pêches et l'aquaculture n°583. Rome. FAO. 67.

Henry M, Gasco L, Piccolo G, Fountoulaki E (2015). Review on the use of insects in the diet of farmed fish: Past and future. Anim. Feed Sci. Technol., 203 (1) : 1-22. https://doi.org/10.1016/j.anifeedsci.2015.03.001

Herawati VE, Elfitasari T, Darmanto YS, Anggraeni N, Windarto S (2023). Effect of different ratios of maggot meal (*Hermetia illucens*) on growth performance and body composition of vannamei shrimp (*Litopennaeus vannamei*) post larvae. AACL Bioflux, 16(2): 768-779.

Iga-Iga R (2008). Contribution à la mise au point d'aliments pour tilapia *Oreochromis niloticus* à base d'intrants locaux : cas du Gabon. Mémoire de fin d'études. Agro-Campus Ouest. 47.

Kenis M, Koné N, Chrysostome CAAM, Devic E, Koko GKDD, Clottey VA, Nacambo S, Mensah GA (2014). Insects used for animal feed in West Africa. Entomologia, 2 (2): 107-114. https://doi.org/10.4081/entomologia.2014.218

Kpogue DNS, Vodounnou JV, Sanoussi S, Montchowui E, Fiogbé ED (2022). Utilization of marine fish viscera in African snakehead fish fingerlings (*Parachanna obscura*. Gunther. 1861) feeding: Zootechnical parameters and body composition. Int. J. Biol. Chem. Sci., 16(5): 2330-2339.

Li S, Ji H, Zhang B, Zhou J, Yu H (2017). Defatted black soldier fly (*Hermetia illucens*) larvae meal in diets for juvenile Jian carp (*Cyprinus carpio* var. Jian): Growth performance, antioxidant enzyme activities, digestive enzyme activities, intestine and hepato-pancreas histological structure. Aquaculture, 477. 62-70. https://doi.org/10.1016/j.aquaculture.2017.04.015

Lu S, Taethaisong N, Meethip W, Surakhunthod J, Sinpru B, Sroichak T, Archa P, Thongpea S, Paengkoum S, Purba RAP, Paengkoum P (2022). Nutritional Composition of Black Soldier Fly Larvae (*Hermetia illucens* L.) and Its Potential Uses as Alternative Protein Sources in Animal Diets: A Review. Insects, 13: 831. https://doi.org/10.3390/insects13090831

Magalhães R, Sánchez-López A, Leal RS, Martínez-Llorens S, Oliva-Teles A, Peres H (2017). Black soldier fly (*Hermetia illucens*) pre-pupae meal as a fish meal replacement in diets for European seabass (*Dicentrarchus labrax*). Aquaculture, 476: 79-85. https://doi.org/10.1016/j.aquaculture.2017.04.021

Makkar H (2017). Opinion paper: Food loss and waste to animal feed. Animal, 11 (7): 1093-1095. https://doi.org/10.1017/S1751731117000702

Mastoraki M, Mollá Ferrándiz P, Vardali S C, Kontodimas D C, Kotzamanis Y P, Gasco L, Chatzifotis S, Antonopoulou E (2020). A comparative study on the effect of fish meal substitution with three different insect meals on growth. Body composition and metabolism of European sea bass (*Dicentrarchus labrax* L.). Aquaculture, 528 : 735511. https://doi.org/10.1016/j.aquaculture.2020.735511

Médale F, Le Boucher R, Dupont-Nivet M, Quillet E, Aubin

J, Anserat J (2013). Des aliments à base de végétaux pour les poissons d'élevage. INRA Prod. Anim., 26 (4): 303-316. https://doi.org/10.20870/productions-animales.2013.26.4.3159

Mertenat A, Diener S, Zurbrügg C (2019). Black Soldier Fly biowaste treatment Assessment of global warming potential. Waste Manage., 84: 173 181. https://doi.org/10.1016/j.wasman.2018.11.040

Odjo IN, Djihinto GA, Vodounnou DSJV, Djissou ASM, Bonou C, Mensah GA, Fiogbe ED (2019). Organic waste management for the maggots production used as a source of protein in animal feed: A review. IJFAS; 7(2): 122-128.E-ISSN: 2347-5129. https://doi.org/10.17582/journal.sajls/2019/7.1.14.18

Oonincx DG, De Boer IJ (2012). Environmental impact of the production of mealworms as a protein source for humans–a life cycle assessment. PLoS ONE, 7: e51145. https://doi.org/10.1371/journal.pone.0051145

Oonincx DG, Van Broekhoven S, Van Huis A, van Loon JJ (2015). Feed conversion, survival and development, and composition of four insect species on diets composed of food by-products. PLoS ONE, 10: e0144601. https://doi.org/10.1371/journal.pone.0144601

Oonincx DGAB, Van Broekhoven S, van Huis A, van Loon JJA (2015). Feed Conversion, Survival and Development and Composition of Four Insect Species on Diets Composed of Food By-Products. PLoS ONE 10(12): e0144601. https://doi.org/10.1371/journal.pone.0144601

Parolini M, Ganzaroli A, Bacenetti J (2020). Earthworm as an alternative protein source in poultry and fish farming: current applications and future perspectives. Sci. Total Env., 734 (139460): 1-8.

Pomalégni SCB, Gbemavo DSJC, Kpadé CP, Babatoundé S, Chrysostome CAAM, Koudandé OD, Kenis M, Glèlè Kakaï RL, Mensah GA (2016). Perceptions et facteurs déterminant l'utilisation des asticots dans l'alimentation des poulets locaux (*Gallus gallus*) au Bénin. J. Appl. Biosci., 98: 9330 –9343. https://doi.org/10.4314/jab.v98i1.9

Rumpold BA, Schluter OK (2013). Nutritional composition and safety aspects of edible insects. Mol. Nutr. Food Res., 57: 802 - 823. https://doi.org/10.1002/mnfr.201200735

Schiavone A, Cullere M, De Marco M, Meneguz M, Biasato I, Bergagna S, Dezzutto D, Gai F, Dabbou S, Gasco L (2017). Partial or total replacement of soybean oil by black soldier fly larvae (*Hermetia illucens* L.) fat in broiler diets: Effect on growth performances, feed-choice, blood traits, carcass characteristics and meat quality. Ital. J. Anim. Sci., 16: 93–100. https://doi.org/10.1080/1828051X.2016.1249968

Schiavone A, De Marco M, Martínez S, Dabbou S, Renna M, Madrid J, Hernandez F, Rotolo L, Costa P, Gai F (2017). Nutritional value of a partially defatted and a highly defatted black soldier fly larvae (*Hermetia illucens* L.) meal for broiler chickens: Apparent nutrient digestibility, apparent metabolizable energy and apparent ileal amino acid digestibility. J. Anim. Sci. Biotechnol, 8: 51. https://doi.org/10.1186/s40104-017-0181-5

Schiemann, R.; Nehring, K; Hoffmann, L.; Jentzsch, W. and Chudy, A. (1971): Energetische. Futterbewertung und Energienormen. VEB Deutscher Landwirtschaftsverlag; Berlin

Siddhuraju P, Becker K (2003). Comparative nutritional evolution of differentially processed mucuna seeds (*Mucuna pruriens* (L.) DC. Var. utilis (Wall ex Wight) (Baker ex Burck) on growth performance. Feed utilization and body composition in Nile tilapia (*Oreochromis niloticus* L.). Aquacult. Res., 34: 487-500. https://doi.org/10.1046/j.1365-2109.2003.00836.x

Spranghers T, Ottoboni M, Klootwijk C, Ovyn A, Deboosere S, De Meulenaer B, Michiels J, Eeckhout M, De Clercq P, De Smet S (2017). Nutritional composition of black soldier fly (*Hermetia illucens*) prepupae reared on different organic waste substrates. J. Sci. Food Agric., 97: 2594–2600. https://doi.org/10.1002/jsfa.8081

Tacon AG, Metian M (2013). Fish matters importance of aquatic food in human nutrition and global food supply. Rev. Fish. Sci., 21: 22-38. https://doi.org/10.1080/10641262.2012.753405

Teugels GG (1986). A systematic revision of the African species of the genus *Clarias* (Pisces: Clariidae). Annales Musee Royal de l'Afrique Centrale. Sci. Zoolgiques, 247 : 1-199.

Tran G, Heuze, Makkar PS (2015). Insects in fish diets. Anim. Front., 5 (2): 37 44.

Tschirner M, Kloas W (2017). Increasing the sustainability of aquaculture systems: Insects as alternative protein source for f ish diets. GAIA Ecol. Perspect. Sci. Soc., 26 (4): 332-340. https://doi.org/10.14512/gaia.26.4.10

Van Huis A, Van Itterbeeck J, Mertens E, Halloran A (2013). Edible insects Future prospects for food and feed security. 201p. FAO Forestry Paper 171Publisher: Food And Agriculture Organization of the United NationsEditor: FAO and Wageningen URISBN: 978-92-5-107595-1

Viveen WJAR, Richter CJJ, Van Ordt PGWJ, Janseen JAL, Huisman EA (1986). Practical manual for the culture of the African catfish (*Clarias gariepinus*). The Netherlands Ministry for Development Corporation, Section for Research and Technology, The Hague, The Netherlands, 128.

Viveen WJAR, Richter CJJ, Oordt PGWJv, Janssen JAL, Huisman EA (1985). Manuel pratique de pisciculture du poisson-chat africain (*Clarias gariepinus*). Départment de Pisciculture et de Pêche de l'Université

Wohlfahrt J, Sandrock C (2023). Instructions pour l'élevage et l'engraissement de la mouche soldat noire Production de protéines alimentaires à partir de résidus d'origine végétal Fiche technique 2023 Édition Suisse:172.

Yildirim-Aksoy M, Eljack R, Beck BH (2020). Nutritional value of frass from black soldier fly larvae, *Hermetia illucens*, in a channel catfish, *Ictalurus punctatus*, diet. Aquac. Nutr., 26: 812–819. https://doi.org/10.1111/anu.13040

Zhou J, Liu S, Ji H, Yu H (2018). Effect of replacing dietary fish meal with black soldier fly larvae meal on growth and fatty acid composition of Jian carp (*Cyprinus carpio* var. Jian). Aquacult. Nutr., 24: 424-433. https://doi.org/10.1111/anu.12574