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Influence of replacement of fishmeal by black soldier fly *Hermetia illucens* larvae meal supplemented with ginger *Zingiber officinale* in the diet, on some zootechnical characteristics of the african catfish *Clarias gariepinus* (Burchell, 1822) fingerlings in Western Cameroon

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Key words: *Clarias gariepinus, Hermetia illucens, Zingiber officinale*, Zootechnical parameters

Abstract

The aim of this paper is to find an alternative replacement of fish meal for fingerlings on fish diets. The effect of black soldier fly larvae meal supplemented with ginger powder on zootechnical parameters of *Clarias gariepinus* juveniles was studied from March to July 2022 in Western Cameroon. A total of 1260 fish were randomly divided into seven (7) groups of 60 fish each of *C. gariepinus* (30 ± 2 g/fish) with 3 replications and placed in 21 plastics tanks of 0.6 m3 capacity. Seven isonitrogenous diets were formulated. Three of the treatments represented the group of individuals fed with diets substituted at 70%, 85%, 100% larvae of black soldier flies meal respectively, three other treatments followed the same levels of substitution but with 1% ginger powder added, and the last treatment represented the control experiment with 100% fish meal. At the end of the trial, three individuals (150 ± 5g/fish) were randomly selected per treatment and used for the bromatological and haematological analysis. The results show that survival rate varied between 96.67±1.67 and 99.44±0.96 %, growth, bromatological and haematological characteristics were comparable between treatments. The allometric coefficient b was greater than 3 (b >3), showing a positive allometric growth for all the treatments, except treatment T1 that showed an isometric growth. The condition factor K varied from 0.94 to 1.25%. It appears that a meal of black soldier fly larvae can effectively replace fish meal in the diet of *C. gariepinus* juveniles with or without ginger.

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Introduction

The consumption per inhabitant of fish intended for human consumption increased from 9.0 kg in 1961 to 20.2 kg in 2015, and continued to increase to approximately 20.3 kg in 2016 and 20.5kg in 2017 (FAO, 2018). This growth has been facilitated by the increasing use of the intensive farming system based on feed, as well as the reduction of wastage (FAO, 2018). In this production system, fishmeal is considered an important source of protein and essential for the manufacture of aqua-feed. This is mainly due to its high quality protein content, excellent amino acids and fatty acids profile, the general absence of anti-nutritional factors, its high nutrient digestibility, palatability, component concentration and other attributes contributing to food intake, health and immune function of fish (Adéoye *et al*., 2020). The current growth being experienced in the aquaculture industry requires a sustainable supply of fishmeal, meanwhile this resource under tremendous pressure due to increasing demand but limited supply thereof (Fawole *et al*., 2020). This situation has oriented research works toward alternative sources of protein, in particular towards those that are not directly used for human consumption (FAO, 2013).

Actually, a few species of edible insects have been proposed for aquafeed (van Huis *et al*., 2013; Lock *et al.,* 2016; Wang *et al.,* 2017) among which, the larvae of black soldier flies were chosen as ideal candidates for alternative protein source in animal feed. This is due to their ability to convert organic waste into a high value protein (37-63% DM) containing essential amino acid patterns relatively similar to fishmeal, their high fat content (7-39% MS) with an excellent lipid profile, their very high capacity for multiplication, their capacity to control certain harmful bacteria and their non-harmful action on human health, as well as their relatively lower cost than conventional protein sources (Henry *et al*., 2015; Ssepuuya *et al*., 2017; Wang and Shelomi, 2017; Fonseca *et al*., 2017, Nana *et al*., 2018). The potential benefits of *Hermetia illucens* larvae meal have been demonstrated in many aquaculture species as fishmeal substutute (Li *et al*., 2017; Liu *et al*., 2018). Belghit *et al.* (2019) reported that *H. illucens* larvae meal can completely replace fishmeal in the diet of the Atlantic salmon without any negative impact on fish performance and digestibility. However, Kroeckel *et al.* (2012) reported a reduction in food consumption and reduced growth, yield and feed conversion rate in *Psetta maxima* juvéniles as the inclusion level of black soldier fly larvae meal increases. The same effect occurred with Fawole *et al.* (2020) from 75% replacement level of fish meal with black soldier fly larvae meal in African catfish (*Clarias gariepinus*). This could be due to its strong odor linked to the mode treatment that can affect the palatability of the fish. The supplementation of certain phyto-additives to *Hermetia illucens* is likely to show potential for a total substitution of fishmeal in diets with high protein content. Indeed, these additives have the ability to strengthen the immune system, stimulate growth through their antioxidant properties, to enhance the taste and are excellent immunomodulating agents for humans and animals, including fish (Mansoub, 2011; Apines-Amar *et al*., 2012 and Talpur *et al*., 2013). It has been demonstrated by several researchers that the incorporation of *Z. officinale* in fish dsiets up to 2% and 3% helps to improve growth performances, immunohaematological parameters, food utilization, as well as disease resistance (Jahanjoo *et al*., 2018; Stanley *et al*., 2018; Adegbesan *et al*., 2019). However, information on the effect of Black Soldier Flies larvae meal supplemented with ginger is not yet available. Meanwhile this could have made it possible for high or complete substitution of fish meal by black soldier fly larvae meal, thus considerably reducing the part of production cost related to feed. It is with this in mind that this work was initiated with the aim to evaluate according to the level of substitution and supplementation the effect of flour black soldier fly larvae meal associated with ginger on survival rate, growth performance, haematological and bromatologycal characteristics of the flesh of *C. gariepinus* juveniles.

Material and methods

Study area

The study was carried out from April 25 to July 4, 2022 within a production unit in Foto, located in Dschang Sub-division, Menoua Division, and West region of Cameroon (Fig. 1). Dschang is a mountainous town located between latitude 5° 10' and 5° 38' North, and between longitude9°50' and 10° 26' East, with an altitude fluctuating between 1400 and 2100m.

Fig. 1. Geographical localisation of study area

Biological material

1260 juveniles of *Clarias gariepinus* with an average weight of 30 ± 2 g, resulting from artificial reproduction were purchased from Mub's Aqua Fish Center in Douala city. The fish were transported in an 80-liter black plastic bucket by vehicle to the Foto farm where they were acclimatised in a 1 m^3 plastic tank for 21 days. They were then randomly distributed into groups of seven in 21 plastics thanks of 0.6 m^3 each.

Experimental diets and feed manufacturing

Hermetia illucens larvae

Hermetia illicens larvae used during the experiment were produced under the same substrate within the production unit. The transformation process consisted first of by harvesting of the larvae obtained between 14 and 18 days after obtaining the eggs. These larvae were then cleaned and killed by bleaching according to the method of Bazinet and Castaigne (2011), then dried using a locally made electric dryer at 60°C and defatted with an oil press at 70 °C; and then finely ground using a mill (DESTA brand) before being incorporated into the fish diet.

Zingiber officinale powder

Zingiber officinale rhizomes purchased at the local market were washed, sliced, dried at room temperature for 5 days, then ground in a mill (DESTA brand) to obtain a fine powder before use in feed manufacture.

Formulation of experimental diets

Apart from the larvae meal (LM) and ginger powder (GP) which were obtained in situ, the other raw materials were purchased from a feed mill in the local market. During feed manufacturing, each ingredient was ground using a mill, then weighed in accordance with the treatments. The experimental diets were formulated to be isonitrogenous containing 45% crude protein (Table 1), according to the nutritional needs of the fish and analyzed according to the protocol described by the AOAC 1990 (Table 2).

After weighing, the smallest ingredients in terms of quantity were gradually introduced and mixed in a container in order to obtain a substantial mixture before introduction into the mixer. Ingredients common to all formula were introduced into a blender for 10 minutes for better homogenization. Then the mixture was evenly divided into 7 groups and the individual ingredients were gradually weighed and mixed into each group corresponding to the different treatments. Finally, each food was individually introduced into an extruder then dried and coated.

Experimental set up and data collection

Survival and growth characteristics

During the trial, the water in the tanks was completely renewed each morning and the fish were fed twice a day. Parameters control was made every 14 days and all the fish were caught using a dip net, then counted manually per treatment. The fish in each tank were weighed using a 5 kg capacity scale balance (accuracy 0.1g) "Digital scale" brand. Then, 10 individuals from each treatment were randomly sampled for individual weight measurement, total and standard lengths using a local made ichthyometer. Preceding this each tank was immediately cleaned before fish were reintroduced. Dead fish were removed daily, counted and their weights recorded.

Table 1. Composition of the experimental diets

Variables	FM	BSF LM without GP			BSF LM with GP		
Experimental diets	0%	70%	85%	100%	70%	85%	100%
Quantity (Kg)	100	100	100	100	101	101	101
Basic formulation							
Variable ingredients	40	40	40	40	41	41	41
Fish meal	40	12	6	0	12	6	0
Larvae meal	0	28	34	40	28	34	40
Ginger	0	0	0	0	1	1	1
Ingredients standards	60	60	60	60	60	60	60
Soybean meal	25	25	25	25	25	25	25
Groundnut meal	15	15	15	15	15	15	15
Corn flour	10	10	10	10	10	10	10
Cassava flour	3	3	3	3	3	3	3
Additives							
Palm oil	4	4	4	4	4	4	4
Kitchen salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Complete Vita (ADEK)	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Lysin	1	1	1	1	1	1	1
Dicalcium phosphate	0.75	0.75	0.75	0.75	0.75	0.75	0.75

FM: fish meal; BSF: black soldier fly; LM: larvae meal; GP: ginger powder

Table 2. Bromatological composition of the experimental diets

Samples	DM	Constituents (%DM)					Kcal/ kg DM	
		CL	Ash	CP	CL	CL	Ash	ME
FM	92.78	88.11	11.88	FM	92.78	88.11	11.88	FM
LM	92.52	94.96	5.04	LM	92.52	94.96	5.04	LM
To	91.30	90.80	9.20	To	91.30	90.80	9.20	To
T1	90.05	92.61	7.19	T1	90.05	92.61	7.19	T1
T'1	92.08	92.91	7.09	T'1	92.08	92.91	7.09	T'1
T2	90.12	93.41	6.59	T2	90.12	93.41	6.59	T2
T'2	91.24	92.55	7.54	T'2	91.24	92.55	7.54	T'2
T3	89.57	93.65	6.65	T3	89.57	93.65	6.65	T3
T'3	89.92	93.78	6.08	T'3	89.92	93.78	6.08	T'3

To: diet containing fish meal; T1-T2-T3: diets containing 70%, 85% and 100% BSF LM respectively; T'1-T'2-T'3: diets containing respectively 70%, 85% and 100% BSF LM with ginger; DM: dry matter; CL: crude lipid; CP: crude protein; CF: crude fiber; GE: gross energy; ME: metabolic energy; LM: larvae meal; BSF: black soldier fly; GP: ginger powder

Physical and chemical parameters

The physico-chemical parameters of the water were recorded in situ at the beginning of the experiment and every three days before and after each control: a pH meter, "Voltcraft" brand was used for pH measurement and a multi-parameter, "EZ-9905A" brand for temperature, alkalinity and conductivity measurements.

Haematological characteristics

At the end of the trial, 2% of the fish from each tank (average weight: 150 ± 5 g) were randomly selected for blood collection. To realise this operation, the fish were anaesthetized with 100 mg L–1 clove oil in an anesthetic bath based on the oil before blood collection at the upper part of the spine. The blood collected was immediately transferred into an EDTA-coated tube, maintained under 4°C temperature and taken to the laboratory for haematological investigations. Hemoglobin, erythrocyte count, total white blood cell count and differential proportions of leukocytes were determined according to the standard methods (Bain *et al.*, 2017). Mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH) and mean corpuscular hemoglobin concentration (MCHC) were calculated as described by Haney *et al.* (1992).

Bromatological characteristics of the flesh

After the blood sample, the flesh of the muscles of each treatment was taken from the same fish samples, then weighed and dried at 45° to constant weight.

Then, it was ground in a Moulinex and packaged in aluminum foil for analysis. Bromatological analyses of the flesh were carried out in the Nutrition laboratory of the University of Dschang. The nutritional properties of the flesh were analysed using the methods proposed by AOAC (1990).

Studied parameters

Survival rate and Growth characteristics

Survival rate (SR): SR (%)= {(Total number of fish harvested)/(Total number of fish stocked)}×100

Weight gain (WG): WG (g)= final body weight - initial body weight

Average weight gain (AWG): AWG (g/day) = (final bdy zeight- initial body weight)/(number of feeding days)

Consumption index (CI) : CI (g) = (Total quantity of feed given)/(Average weight gain)

Specific growth rate (SGR): SGR (%) = {(ln final body weight -ln initial body weight)/(number of feeding days)}×100

Where, ln = neperian logarithm

Condition factor (K): $K = (TW/TL^3) \times 100$ (Ricker, 1975)

Weight- length relationship (TW): $TW= (aTL)^b$ (Le Cren, 1951)

Where, TW = Average total weight of the fish (g), TL = Average total length of the fish (cm), a = Ordinate at the origin; b = Allometric coefficient.

Size heterogeneity was evaluated using the variation coefficient (VC) following the formula: VC (%) = Sx/ X × 100

Where, Sx = Standard deviation and X= Averages of the total lengths)

Feed efficiency ratio (FER): FER = (Average weight gain)/ (Feed quantity consumed)

Protein efficiency ratio (PER): PER = (Average weight gain)/ (Protein diet fed)

Where, Protein diet fed = (Final quantity of feed consumed × protein content in diet)/100

Haematological characteristics

The characteristics studied were hemoglobin, the number of erythrocytes, the total number of leukocytes and the differential proportions of leukocytes according to the standard methods described by Bain *et al.* (2017); Mean Corpuscular Volume (MCV), mean corpuscular hemoglobin (MCH) and mean corpuscular concentration hemoglobin (MCHC) calculated as described by Haney *et al.* (1992).

Bromatological characteristics of the flesh

Dry matter determination

% DM = ((Pf – Pc)) / Po) × 100

Where: pf= weight of the crucible + sample after overnight in the oven; Pc= weight of the empty crucible; Po= sample weight

Ash determination

% Ashes = ((Pf – Pc)) / Po) × 100

Where: pf= weight of crucible + sample after 6 hours in oven; Pc= weight of the empty crucible; Po=sample weight

Organic matter (OM) was determined by subtracting ash from dry matter (DM)

OM (%MS) = 100 –A where: A (%DM) = ashes.

Crude protein determination

The nitrogen content was determined by the Kjeldhal method (AOAC, 1990) which successively includes mineralization, distillation and titration.

N (%DM)= $((V - V0)\ x\ 100\ x\ 0.14\ x\ (10)^{(-3)})/(m\ x\ Ve)$

Where, V= Volume of HCL used for sample titration; V0= Volume of HCL used for the titration of the blank; Ve=Volume of the mineralisate used for the distillationand m= Weight of the mineralized sample.

Knowing that: 1 liter of HCL (N) neutralizes 14 g of nitrogen, 1 ml of HCL (N) neutralizes 14x103g of nitrogen, and 1 ml of HCL (0.01N) neutralizes 14x103 x102 g of nitrogen ; crude protein content (CP) was obtained by multiplying the nitrogen content by the coefficient 6.25.

Lipids determination

Lipids (% DM) = $((Pf – P_o)/m_o)\times 100$

Where: Po= weight of empty crucible, Pf= weight of crucible after drying and mo= mass of the sample

Statistical analyzes

Descriptive statistics (mean standard deviation, percentage) was used. The T-student test was used to compare the b-values of the weight-length relationships to the isometric value b=3. Growth and survival data were subjected to analysis of variance (ANOVA) to test the effect of treatments. When there were significant differences between the means, these were separated by Tukey's multiple tests. The five per cent (5%) probability threshold was used. All these analyses were performed using the statistical software SPSS 20.0. The graphs were drawn using MicroSoft Office Excel, 2020 version.

Results

Effects of black soldier fly larvae meal supplemented with ginger on the survival rates of Clarias gariepinus juveniles

It appears from Fig. 2 that the survival rate of juveniles was not significantly influenced (p>0.05) by the effect of the treatments.

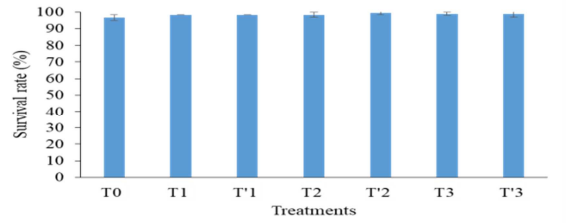

Fig. 2. Survival rate of *C. gariepinus* juveniles fed at different levels incorporation of black soldier fly

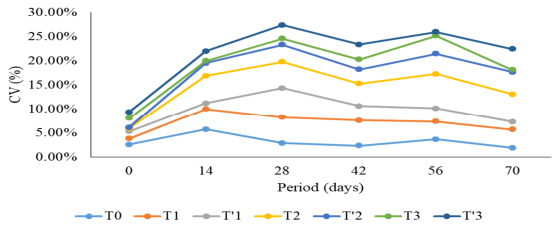

Fig. 3. Size heterogeneity in *C. gariepinus* juvenile fed at different levels of black soldier

Growth performance of Clarias gariepinus juveniles fed with different levels of black soldier fly larvae meal supplemented with ginger

Results in Table 3 show that whatever the treatment, no significant difference (p>0.05) was observed between the characteristics studied. However, the results obtained were comparable (p>0.05) with those of the groups fed only with fishmeal.

Weight/length relationship in C. gariepinus juveniles fed at different levels of black soldier fly larvae meal supplemented with ginger in relation to treatments

It appears that the determination coefficient R2 varied from 0.9644 (T3) to 0.9816 (T2), and was significantly elevated (P< 0.05) regardless of treatment (Table 4). The allometric coefficient b varied from 3.046 (T1) to 3.29 (T'1) and growth was positive allometric in all treatments including fish fed only fish meal, except in T1 where it was isometric. Growth was positive allometric in the total population.

Size heterogeneity in C. gariepinus juvenile fed at different levels of black soldier fly larvae meal supplemented with ginger

It appears from Fig. 3 that the coefficient of variation has greatly varied (p<.05) during trial and almost in the same way whatever the treatment. It was significantly lower (p<.05) in the control treatment To compared to the others. It was significantly (P< 0.05) higher with T'3 compared to the others. However, it decreased in all treatments including the control treatment on the 70th day, but this decrease was more pronounced in fish fed the T3 diet.

Haematological characteristics of C. gariepinus juveniles fed different levels of BSF larvae meal supplemented with ginger powder

Results in Table 5 show that whatever the characteristic studied, variations in the values of certain characteristics were observed according to the treatments. However, no significant difference was observed in the treatments applied including the control experiment (p>0.05).

Bromatological characteristics of the flesh of C. gariepinus juveniles fed different inclusion levels of BSF LM supplemented with ginger powder

It appears from Table 6 that each constituent varied from one diet to another regardless of the nature of the flesh (fresh or dry). However, no significant difference (p>0.05) was observed with the values of the characteristics obtained whatever the diet used.

Table 3. Growth characteristics of *Clarias gariepinus* juveniles fed with different levels of black soldier fly larvae meal supplemented with ginger

Growth traits	Treatments							*p*-value
	To	T1	T'1	T2	T'2	T3	T'3	
BWi (g)	29.46±0.76	32.76±1.76	30.21±0.82	30.69±0.24	30.11±0.30	31.17±0.11	30.05±0.69	/
BWf (g)	138.11±9.71	163.86±14.23	133.90±6.11	162.33±17.96	132.86±15.34	131.48±14.66	129.52±5.41	/
TLi (mm)	144.77±1.27	144.00±3.24	147.77±1.96	145.50±1.05	147.40±0.61	146.97±2.47	148.23±2.27	/
TLf (mm)	244.60±8.35	257.17±7.64	236.37±4.09	252.00±13.22	237.97±10.76	237.63±0.58	237.63±10.34	/
WG (g)	108.66±8.96	131.10±15.89	103.69±6.68	131.64±17.71	102.76±15.55	100.31±14.73	99.47±5.17	1.000
AWG (g/J)	1.47±0.12	1.77±0.21	1.40±0.09	1.78±0.24	1.39±0.21	1.36±0.20	1.34±0.07	1.000
SGR (%)	2.09±0.06	2.17±0.19	2.01±0.09	2.24±0.14	2.00±0.17	1.94±0.15	1.97±0.05	1.000
K	0.94±0.06	0.96±0.05	1.01±0.03	1.01±0.06	1.15±0.06	1.18±0.15	1.25±0.04	0.166
CI	1.28±0.09	1.14±0.03	1.11±0.02	1.08±0.02	1.15±0.06	1.18±0.15	1.25±0.04	0.084
FE	0.80±0.05	0.89±0.03	0.91±0.02	0.94±0.02	0.87±0.04	0.87±0.12	0.81±0.03	0.629
PEC	1.92±0.18	2.35±0.28	1.86±0.11	2.35±0.30	1.86±0.29	1.81±0.25	1.79±0.09	1.000

To: diet containing fish meal; T1-T2-T3: diets containing 70%, 85% and 100% BSF LM respectively; T'1-T'2-T'3: diets containing 70%, 85% and 100% BSF LM respectively with ginger; BWi: initial body weight; bwf: final body weight; TLi: initiale total length; TLf: final total length; WG: weigth gain; AWG: average weight gain; SGR: specific growth rate, K: condition factor; CI: consumption index; FE: feed efficiency; PEC: protein efficiency coefficient; a: no significant difference between the values (p<0,05)

Table 1. Weight/length relationship in *C. gariepinus* juveniles fed at different levels of black soldier fly larvae meal supplemented with ginger in relation to treatments

Treatments	Length-Weight relationships parameters						TC
	N	Equation	R^2	A	B	Ts	
To	60	$PT = 3E\text{-}06LT^{3.1461}$	0.9769	3E-06	3.1461	0.5603	A+
T1	60	$PT = 5E\text{-}06LT^{3.046}$	0.9799	5E-06	3.046	0.2765	I
T'1	60	$PT = 1E\text{-}06LT^{3.2927}$	0.9748	1E-06	3.2927	0.9053	A+
T2	60	$PT = 2E\text{-}06LT^{3.1939}$	0.9816	2E-06	3.1939	0.8421	A+
T'2	60	$PT = 2E\text{-}06LT^{3.2066}$	0.9744	2E-06	3.2066	0.9156	A+
T3	60	$PT = 2E\text{-}06LT^{3.2372}$	0.9644	2E-06	3.2066	0.8322	A+
T'3	60	$PT = 2E\text{-}06LT^{3.2257}$	0.9798	2E-06	3.2257	0.9110	A+
Total	1260	$PT = 2E\text{-}06LT^{3.1812}$	0.9754	2E-06	3.1812	0.9753	A+

To: diet containing fish meal; T1-T2-T3: diets containing 70%, 85% and 100% BSF LM respectively; T'1-T'2-T'3: diets containing 70%, 85% and 100% BSF LM respectively with ginger, R2= detrmination coefficient, a= constant, b= allometric coefficient, TC= type of growth; ts= t-student test, A+= positive allometric, I = isometric

Table 5. Haematological traits of *C. gariepinus* juveniles fed *H. Illucens* supplemented with *Z. officinale*

Haematological traits	Treatments							*p*-value
	To	T1	T'1	T2	T'2	T3	T'3	
Hb (g/dl)	9.17±2.29	9.35±2.19	10.40±0.92	10.50±1.66	10.80±1.45	10.57±0.97	11.87±1.20	0.494
RBC (1012 L−1)	1.92±0.42	2.09±0.57	2.29±0.28	2.42±0.37	2.41±0.39	2.26±0.24	2.59±0.28	0.406
H (%PCV)	23.87±6.33	25.25±6.29	28.83±3.95	29.63±3.56	31.33±4.90	29.23±4.56	32.73±2.6	0.327
WBC (10^9 L−1)	178.86±36.48	190.92±36.82	207.87±29.19	207.68±20.9	223.56±42.17	211.58±16.09	238.96±17.01	0.325
Neutrophil (%)	0.71±0.86	0.68±0.84	13.15±21.26	1.07±1.14	1.65±0.91	1.16±0.92	18.60±30.39	0.615
Lymphocyte (%)	93.83±1.43	91.43±3.89	77.54±24.94	89.55±7.33	86.50±10.79	89.97±6.13	75.15±31.49	0.776
Basophil (%)	0.00±0.00	0.00±0.00	0.49±0.85	0.07±0.13	0.01±0.01	0.02±0.04	0.26±0.45	0.650
Eosinophil (%)	0.34±0.35	0.16±0.00	0.33±0.17	0.19±0.15	0.41±0.26	0.39±0.38	0.29±0.18	0.887
Monocyte (%)	5.11±0.69	7.74±3.05	8.48±2.82	9.13±6.09	11.44±9.62	8.46±4.81	5.69±0.56	0.774
MCV (fL)	123.67±7.79	121.15±2.76	126.43±4.80	123.33±4.20	130.10±0.87	129.23±6.89	126.53±6.07	0.490
MCH (pg)	47.40±1.66	44.75±1.63	45.53±1.80	43.33±0.55	44.77±1.31	46.80±0.85	45.70±2.25	0.093
MCHC (g/dl)	38.47±1.40	37.05±0.49	36.10±1.87	35.17±1.27	34.43±0.96	36.30±2.60	36.13±0.78	0.128

To: diet containing fish meal; T1-T2-T3: diets containing 70%, 85% and 100% BSF LM respectively; T'1-T'2-T'3: diets containing 70%, 85% and 100% BSF LM respectively with ginger pouder, RBC: number of erythrocytes; WBC: total white blood cell count; MCV: mean corpuscular volume; MCH: mean corpuscular hemoglobin; MCHC: mean corpuscular hemoglobin concentration; H= hematocrite; a: values are not significantly different (p<0.05).

Table 6. Bromatological characteristics of *C. gariepinus* juveniles fed BSF LM supplemented with ginger according to the different treatments

Treatments	FW	DW	Components (%dry weight)					Components (%fresh weight)				
			DM	Ash	OM	CP	Lipids	H_2O	Ash	OM	CP	Lipids
T0	154	32	94.27	5.49	94.50	66.67	21.62	79.22	1.28	19.50	14.8	3.94
T1	145	38	94.71	5.94	94.05	72.16	16.46	73.61	1.66	24.73	20.11	4.59
T'1	173	44	93.94	5.97	94.02	65.92	18.53	74.57	1.62	23.81	17.85	5.02
T2	170	44	94.27	5.49	94.50	66.67	21.62	74.12	1.51	24.37	18.31	5.94
T'2	160	36	92.76	5.8	94.20	66.27	15.6	77.5	1.40	21.09	16.08	3.78
T3	150	36	93.67	5.09	94.90	67.49	17.89	76.00	1.31	22.69	17.29	4.59
T'3	170	34	94.67	6.25	93.74	66.37	20.31	78.06	145	20.48	15.38	4.71

T0: diet containing fish meal; T1-T2-T3: diets containing 70%, 85% and 100% BSF LM respectively; T'1-T'2-T'3: diets containing 70%, 85% and 100% BSF LM respectively with ginger powder, FW= fresh weight, DW= dry weight, DM= dry matter, OM= organic matter, H_2O: water

Discussion

At the end of 70 days of experiment, the survival rate, which is the ability of fish to resist death under of farming conditions, was higher in individuals subjected to 85% of LM with 1% of GP added to it and lower in those receiving 100% FM. The improvement in survival rate values can be attributed to the presence of bioactive molecules such as sesquiterpenes, flavonoids and polyphenols which, according to Lynda and Meryem (2017), have healing properties likely to protect the body against oxidative damage and many diseases. These values are close to the results (93.29%) of Baßmann *et al.* (2023) obtained with 12 g juveniles of *C. gariepinus* in commercial production. They are however, higher than the results of 60 to 80% of Adeoye *et al.* (2020) in *Clarias gariepinus* fingerlings fed 75% MSN larvae meal for 42 days, to those (76.67 ± 3. 33 to 88.33 ± 5.00) of Fawole *et al.*, (2020) obtained after 60 days of study in juvenile *C. gariepinus*, as well as those to 70.00 ± 10, 86.67 ± 3.33, 76.67 ± 6.67, 63.33 ± 12.02 and 70.00 ± 5.7% of Ude *et al.* (2018) respectively, obtained in juvenile *C. gariepinus* fed for 70 days with a supplementation level of 0%, 0.5%, 1.0%, 1.5% and 2.0% ginger powder.

The growth characteristics were also comparable according to the treatments whatever the characteristic considered. The improvement of these characteristics could be due to the pre-treatment of the larvae which would have the capacity to hinder the harmful effects (high fat content) of the BSF LM, thus improving the feed intake and therefore the growth performance. As for the mean average weight gain, which represents the daily increase in weight so as to assess growth rate over a given period, the values obtained were higher in individuals receiving the T2 diet. These values are higher than those of Adegbesan *et al.* (2019) who obtained an AWG of 0.21 ± 0.90; 0.19 ± 1.06 and 0.21 ± 1.07g/day respectively with a supplementation levels of 1, 2 and 3% ginger powder against 0.14 ± 1.16g/day obtained without supplementation. Similarly, an AWG of 0.52 ± 0.01; 0.31 ± 0.07; 0.7 ± 0.04; 0.31 ± 0.1 and 0.17 ± 0.07 g/day was obtained by Ude *et al.* (2018) with a 0, 0.5, 1.0, 1.5 and 2.0% ginger powder supplementation levels respectively.

As regards the SGR, the values of 1.94±0.15 to 2.24±0.14% were obtained. These values are comparable to those (2.01 to 2.66%) recorded by Fawole *et al.* (2020) with *Clarias gariepinus* fingerlings fed 75% FL of MSN for 60 days. They are however lower than those (2.32; 2.79; 2.38 and 3.04%) obtained by Agbebi *et al.* (2012) with *Clarias gariepinus* fed with a food supplemented with 0, 1, 2 and 3 % of *Allium sativum* respectively, but higher than those (1.40 ± 0.05; 1.54 ± 0.09; 1.78 ± 0.35 and 1.46 ± 0.16%) respectively obtained by Jahanjoo *et al* (2018) at Sparidentex hasta with an incorporation of 0% phyto-biotics, 1% *Z. officinale*, 1% *Allium sativum* and 1% *Thymus vulgaris*. They are however higher than those (1.29 to 1.46) obtained by Adeoye *et al.* (2020) in fingerlings of *C. gariepinus* fed 75% BSF LM for 60 days. The values obtained are better compared to those of Zango *et al.* (2016) who

recorded 3.74 and 4.5 in *Clarias jaensis* as well as those of Mehrim *et al.* (2014) who with inclusion levels of 0, 1, 2 and 3% garlic respectively in *Oreochromis niloticus* obtain values of 1.68; 1.36; 1.66 and 1.7. The condition factor recorded values close to 1, showing that the fish were in good health during the experimental period. These values are higher than those (0.62±0.03; 0.45±0.06; 0.72±0.08; 0.64±0.09 and 0.54±0.13%) of Ude *et al.*, (2018) recorded in *C. gariepinus* juveniles fed a diet supplemented at 0; 0.5, 1.0; 1.5 and 2.0% *Zingiber officinale* powder respectively.

Concerning the protein efficiency ratio, the values obtained vary from 1.31±0.6 to 1.73±2.1. Adegbesan *et al.* (2019) after 84 days of feeding in *Clarias gariepinus* obtained comparable values of 1.80 ± 0.09; 1.65 ± 0.04; 1.60 ± 0.02 and 1.61 ± 0.03 respectively, with an incorporation rate of 0, 1, 2, and 3% of *Zingiber officinale*, while lower values of 0.91 ± 0, 03; 0.57 ± 0.13; 1.31 ± 0.08; 0.58 ± 0.19 and 0.32 ± 0.14 were obtained by Ude *et al.* (2018) with *C. gariepinus* juveniles fed for 70 days with a diet supplemented with 0, 0.5, 1.0, 1.5 and 2.0% ginger powder respectively. Also, the work of Nyadjeu *et al.* (2020) recorded lower values of 1.13 ± 0.06; 0.98 ± 0.03; 1.18 ± 0.01 and 1.39 ± 0.05 respectively following their previous work on incorporating a mixture of ginger-garlic in equal proportion (1 :1) at rates of 0.5, 1 and 1.5% in the diet of post-larvae of *Clarias gariepinus* .

The analysis of haematological characteristics was aimed to evaluate the effect of replacing fish meal with black soldier fly meal supplemented with ginger on fish health as stated by Shamna *et al.* (2017) and Fawole *et al.* (2017). The fact that hemoglobin, erythrocyte count, total leukocyte count, differential leukocyte proportions, body volume, mean Corpuscular Concentration (MCV), Mean Corpuscular Hemoglobin (MCH) and Mean Corpuscular Hemoglobin Concentration (MCHC) did not show any significant difference, indicates the fish's ability to effectively utilize BSF larvae meal supplemented with ginger powder without compromising his well-being. These results are similar to those of Fawole *et al.* (2020) and Adeoye *et al.* (2020) who fed *C. gariepinus* juveniles with 75% and 100% black soldier fly larvae meal respectively.

As for the bromatological characteristics of the flesh, crude protein, fat, ash, organic matter and dry matter contents showed no significant difference and correspond to the normative values. The values obtained were higher than those obtained by Abraha *et al.* (2018), when they evaluated the proximate composition of three species of fish according to four processing methods. However, they were comparable to those obtained by Holma and Maalekuu (2013) and Ogbonnaya and Shaba (2019) when they evaluated the effect of traditional goldfish processing methods and the effect of drying methods on the proximate compositions of catfish *(Clarias gariepinus*) respectively. These results justify the ability of BSF larvae meal supplemented with ginger to replace fish meal in the diet of *C. gariepinus* juveniles without its flesh being affected.

Conclusion

This study showed that black soldier flies larvae meal with or without ginger powder can effectively replace fish meal in the diet of *Clarias gariepinus* juveniles. However, it is good to note that at the beginning of the experiment, the individuals fed with black soldier flies larvae meal at 100% and those receiving ginger faced some difficulties in adapting to the new diets. The performances of the Individuals concerned improved gradually till the fourth week in which a net amelioration of the values obtained was observed.

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