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Influence of Replacing Fishmeal with the Black Soldier Fly (*Hermetia illucens)* Meal Supplemented with Ginger (*Zingiber officinale)* in the Diet on Some Zootechnical Characteristics of Pre-adults of the African Catfish (*Clarias gariepinus* Burchell, 1822) in Western Cameroon

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ABSTRACT

The fast growing of the aquaculture sector increases the need for natural feed substances such as insects. The present study was carried out to address the effects of replacing fish meal with black soldier fly larvae meal (BSF) supplemented with ginger powder (GP) in feed on the survival, growth performance, and muscle composition of the African catfish pre-adults. A total of 945 fish were randomly divided into 7 groups of 60 *Clarias gariepinus* (156±15g/fish) with 3 replications, and placed in 21 plastic tanks with a capacity of 0.6m^3. Seven isonitrogenous diets were formulated. Three treatments represented the group of individuals fed with diets substituted at 70%, 85%, 100% BSF, respectively, while the other three treatments followed the same levels of substitutions but with the addition of 1% GP, and the last treatment represented the control experiment with 100% fish meal. At the end of the trial, three individuals (850±50g/fish) were randomly selected per treatment and were used for the bromatological analysis. The results show that the survival rate was comparable in all treatments (P>0.05), and the fish fed with 100%BSF + 1%GP exhibited the best survival rate. The growth and nutrient utilization characteristics were not significantly influenced whatever the treatment, with the exception of the consumption index, which was higher in fish fed with 100%BSF+ 1%GP during the growth stage. The evolution of weight gain was generally comparable during the experiment (P>0.05). The condition factor K was close to 1, implying the good health of the fish during breeding. The bromatological characteristics of the flesh indicate that the fish fed with 100%BSF+ 1%GP were comparable with the control and possessed a good nutritional value without negatively affecting the nutritional profile of the fish. Consequently, the replacement of 100% *Hermetia illucens* supplemented with 1% *Zingiber officinale* is recommended for the growth of *Clarias gariepinus* pre-adults

INTRODUCTION

In Africa and Cameroon in particular, aquaculture is based on three main species **(FAO, 2020)** including *Clarias gariepinus* which is a widely used species due to its hardiness, its appreciated flesh, and its high economic value. Increased production in the aquaculture industry demands a sustainable supply of fishmeal as the latter accounts for 40–60% of total protein in traditional Silurid feed, yet it is under enormous pressure due to increased demand, despite its limited supply **(Fawole *et al.*, 2020)**. There is therefore a problem of high production costs linked to automotive power, the latter representing 50 to 70% of the total production costs in an intensive system **(Ofosu *et al.*, 2015)**. The growth of the aquaculture industry therefore depends on the reduction of fish utilization in the manufacture of fish feed since this commodity contradicts with human food and the needs of the food industries **(Trintignac & Métivier, 2019)**. This situation has directed research toward alternative protein sources, in particular toward those that are not directly usable for human consumption **(FAO, 2013)**.

Currently, few edible insect species have been proposed as feed for farmed fish **(van Huis *et al.*, 2013; Lock *et al.*, 2016; Wang *et al.*, 2017; Rukisah *et al*., 2024)**. Among these, black soldier fly (BSF) larvae were chosen as ideal candidates for alternative protein sources in animal feed due to their ability to convert organic waste into a high-value protein (37–63% DM) containing acid motifs, essential amino acids relatively similar to fish meal, their high fat content (7–39% DM) with an excellent lipid profile, their very high multiplication capacity, their ability 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; Fonseca *et al.*, 2017; Ssepuuya *et al.*, 2017; Wang & Shelomi, 2017; Nana *et al.*, 2018)**. The potential benefits of *Hermetia illucens* meals have been demonstrated in many aquaculture species as a fish meal replacer **(Li *et al.*, 2017; Liu et *al.*, 2018)**. **Belghit *et al.* (2019)** reported that *H. illucens* larvae meals can completely replace fish meal 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 feed consumption and a decline in growth yield and feed conversion ratio in the Greenland halibut (*Psetta maxima*) juveniles upon increasing the level of inclusion of BSF meal. The same effect occurred in **Fawole *et al.* (2020)** from 75% replacement of fish meal with the black soldier fly larvae meal in the the African catfish (*Clarias gariepinus*). This would be due to its strong odour linked to the processing method which can affect the palatability of the fish. The supplementation of certain phytoadditives in *Hermetia illucens* meals may show promise for a total replacement of fish meal in feed with high protein levels. These additives can strengthen the immune system, stimulate growth thanks to their antioxidant properties, enhance taste, and are also known as excellent immunomodulatory agents in humans and animals including fish **(Talpur *et al.*, 2013.)**.

It was suggested that an inclusion rate of 1% of *Zingiber officinale* in fish feed would give better growth and feed utilisation values and would contribute to improving immuno-haematological parameters as well as disease resistance **(Jahanjoo *et al.*, 2018; Ude *et al.*, 2018; Adegbesan *et al.*, 2019)**. However, according to the literature consulted, information on the combined effect of BSF larvae meal added to ginger is not yet available. Whereas, they could have made it possible to completely replace fish meal, and thus considerably reduce the production cost linked to food. In this context, the use of phyto-additives such as ginger is important thanks to its properties and the flavor it would give to the food **(Jahanjoo *et al.*, 2018; Ude *et al.*, 2018)**. The following study was conducted to evaluate the effects of different inclusion rates of BSF larvae meal supplemented with ginger on the survival, growth parameters, and muscle composition of the pre-adult of African catfish.

MATERIALS AND METHODS

1. Study area

The study was carried out from July 25 to December 10, 2022, within a production unit in Foto, located in Dschang sub-division, Menoua Division, and the West Region of Cameroon (Fig. 1).

Dschang is a mountainous town located between latitude 5° 10’ and 5° 38’ North, and between longitude 9°50’ and 10°26’ East, with an altitude fluctuating between 1400 and 2100m.

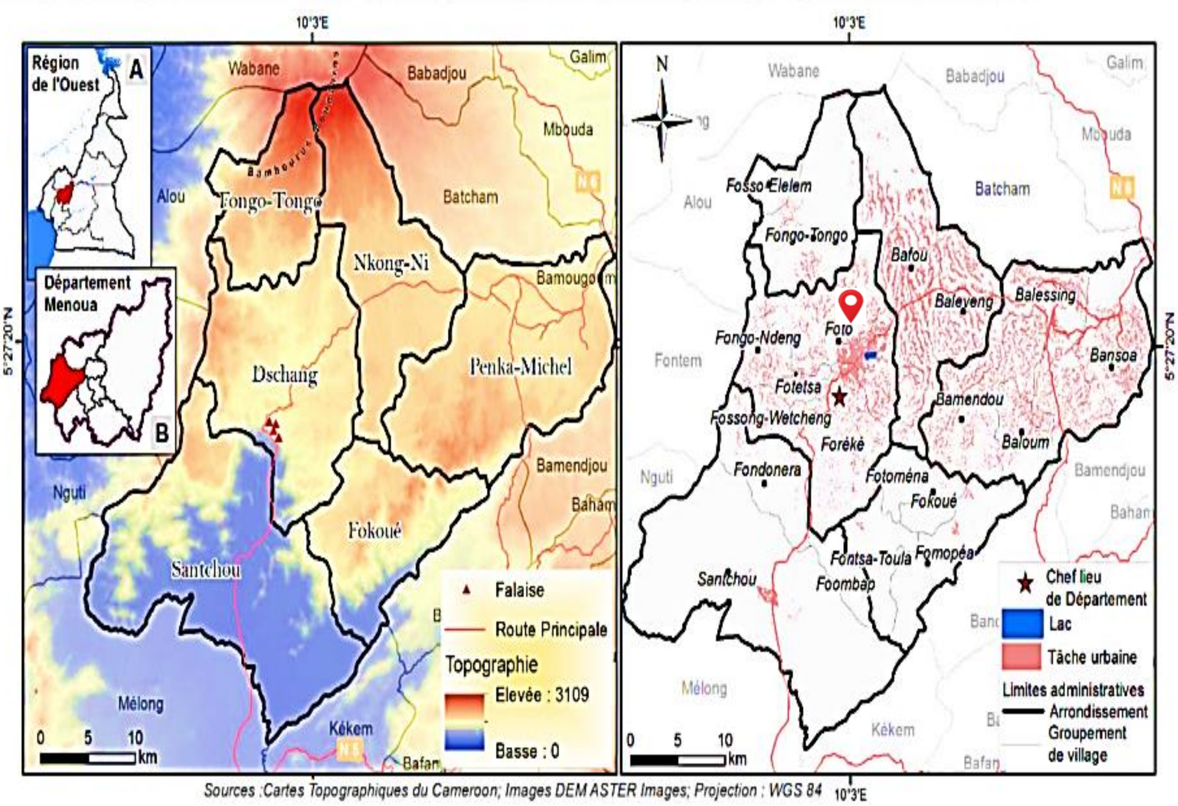

Foto locality

Fig. 1. Geographical location of the study area (**INC (2023)**.

2. Biological material

Nine hundred and forty-five (945) pre-adults of *Clarias gariepinus* with an average weight of 156 ±15 g from the pre-growings were *in situ* addressed during 70 days of rearing. They were then randomly distributed into 7 groups in 21 plastic tanks of 0.6m^3 each.

3. Experimental diets and feed manufacturing

3. a. 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 harvesting the larvae obtained between 14 and 18 days after getting 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, defatted with an oil press at 70°C, and finely ground using a mill (DESTA brand) before being incorporated into the fish diet.

3.b. 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.

3.c. Formulation of experimental diets

Apart from the BSF larvae meal and ginger powder (GP) 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, and then weighed. The experimental diets were formulated to be isonitrogenous containing 40% crude protein (Table 1) according to the nutritional needs of the fish, and analyzed according to the protocol of **AOAC (1990) (**Table 2). After weighing, the smallest ingredients in terms of quantity were gradually introduced and mixed in a container to obtain a substantial mixture before being placed in the mixer. Using a blinder, the ingredients were blended for 10 minutes for better homogenisation. Then, the mixture was evenly divided into seven groups, and the individual ingredients were gradually weighed and added to the mixture according to the different treatments. Finally, each food was individually introduced into an extruder and then dried and coated.

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**
Soya bean meal	22	22	22	22	22	22	22
Groundnut meal	12	12	12	12	12	12	12
Corn flour	15	15	15	15	15	15	15
Cassava flour	3	3	3	3	3	3	3
Additives							
Palm oil	5	5	5	5	5	5	5
Kitchen salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Complete Vita (ADEK)	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Methionine	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Lysin	0.5	0.5	0.5	0.5	0.5	0.5	0.5
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

	Constituents (%MS)					
Sample	**DM**	**CL**	**Ash**	**CP**	**CL**	**CF**
Protein constituents						
FM	92.78	88.11	11.88	60.85	9.24	2.02
LM	92.52	94.96	5.04	54.88	14.01	7.14
T0	92.46	88.72	8.27	38.45	5.92	/
T1	91.68	87.61	6.47	37.39	7.77	/
T′1	92.07	88.56	7.15	37.76	9.75	/
T2	92.32	88.57	7.93	36.77	7.21	/
T′2	91.71	88.70	7.44	37.24	8.98	/
T3	92.20	88.76	7.54	36.53	8.94	/
T′3	92.35	87.20	7.37	36.88	9.15	/

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 respectively 70%, 85% and 100% BSF LM with ginger; DM: Dry matter; CL: Crude lipid; CP: Crude protein; CF: Crude fiber; LM: Larvae meal; BSF: Black soldier fly; GP: Ginger powder.

4. Experimental setup and data collection

4. a. Survival and growth characteristics

During the trial, the water in the tanks was completely renewed every two days and the fish were fed twice a day. Parameters control was made every 28 days and all the fish were caught using a dip net, then manually counted per treatment. The total weight of the fish in each tank was weighed using a professional mechanical stainless steel scale with a capacity of 20kg (accuracy 100g). Then, 10 individuals from each treatment were randomly sampled for individual weight measurement (using a 5kg capacity scale balance – accuracy 0.1g – ‘Digital scale’ brand), total and standard lengths using a locally- made ichthyometer. Proceeding this, each tank was immediately cleaned before fish were reintroduced. Dead fish were daily removed, counted, and their weights were recorded.

4.b. 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.

4.c. Bromatological characteristics of the flesh

At the end of the test, fish from each tank (MW: 850 ± 50 g) were chosen randomly for muscles analysis in the laboratory. They were immersed in an anaesthetic bath based on clove oil (100 mg/L), and the flesh was collected from each sample according to the different treatments, then weighed and dried at 60°C until a constant weight using an oven. Then, it was ground in a blender machine and packaged in an aluminum foil for analysis. The nutritional properties of the flesh were analyzed using the methods proposed by **AOAC (1990)**.

5. Calculations

5.a. Survival rate (SR)

SR (%) = $\frac{\text{Total number of fish harvested}}{\text{Total number of fish stocked}} x100$ **(Olurin *et al.*, 2012)**

5.b. Growth characteristics

- **Weight gain (WG)**
- WG (g) = final body weight – initial body weight **(Olurin *et al.*, 2012)**
- **Average weight gain (AWG)**
- AWG (g/day) = $\frac{\text{final bdy zeight} - \text{initial body weight}}{\text{number of feeding days}}$ **(Zango *et al*., 2016)**

- **Consumption index (CI)**: CI = $\frac{\text{Total quantity of feed given}}{\text{Average weight gain}}$ (Adegbesan *et al.*, 2019)

- **Specific growth rate (SGR)**

- SGR (%) = $\frac{\ln \text{final body weight} - \ln \text{initial body weight}}{\text{number of feeding days}} x100$

Where, ln = neperian logarithm **(Brown, 1977)**

- **Condition factor (K)**

- K = (TW/TL^3) X 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.

- **Feed efficiency (FE)**: FE = $\frac{\text{Average weight gain}}{\text{Feed quantity consumed}}$

- **Protein efficiency ratio** (PER): PER = $\frac{\text{Average weight gain}}{\text{Protein diet fed}}$ **(Adegbesan *et al*., 2019)**

Where, protein diet fed = $\frac{\text{Final quantity of feed consumed X protein content in diet}}{100}$

6. Statistical analyses

Data were analyzed using the SPSS (20.0) statistical program, with significance predetermined at $P< 0.05$. Individual and total tank metrics were analyzed using the one-way analysis of variance. If treatments were determined to be significantly different; a post hoc means separation test was performed using the Tukey HSD test. The graphs were drawn using MicroSoft Office Excel, 2020 version.

RESULTS

1. Effects of black soldier fly larvae meal supplemented with ginger on the survival performance of the pre-adults of *Clarias gariepinus*

Figure 2 shows the survival rate of pre-adults of *Clarias gariepinus* fed on black soldier fly larvae meal supplemented with ginger after 20 weeks of rearing. It appears that the survival rate of preadults was not significantly (*P*>0.05) influenced by the effect of the treatments. However, the smallest value was recorded in individuals fed with the control diet T0 (76.30±3.39), and the largest value was recorded in individuals fed 100% BSF larvae meal supplemented with T′3 ginger powder (87.41±2.57).

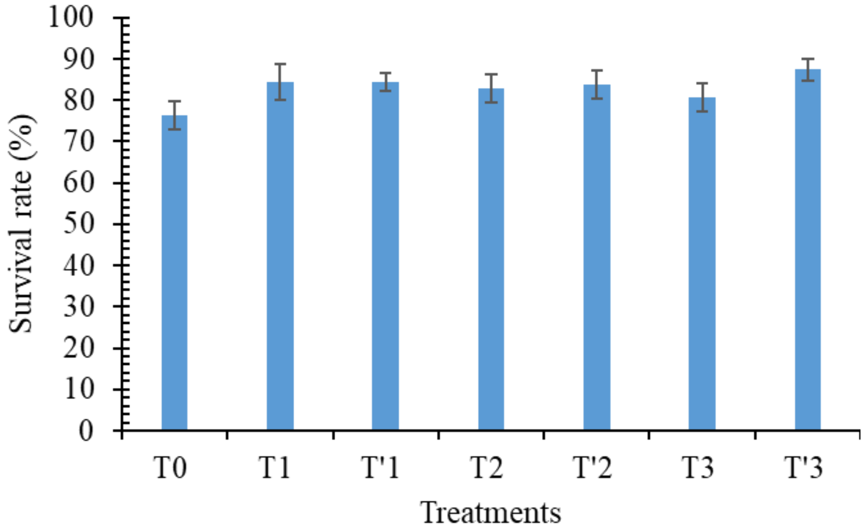

Fig. 2. Survival rate of *C. gariepinus* pre-adults fed at different substitution levels of BSF larvae meal

T0: diet containing fish meal; T1-T2-T3: diets containing respectively 70%, 85% and 100% of BSF LM; T'1-T'2-T'3: diets containing, respectively, 70%, 85% and 100% BSF LM with ginger

2. Evolution of the average weight of the pre-adults of *C. gariepinus* fed on *H. illucens* supplemented with ginger depending on the different treatments

Fig. (3) represents the evolution of the average weight of the pre-adults of *C. gariepinus* subjected to BSF larvae meal within 140 days of study. From this, it appears that in general, the evolution of the average weight presented no significant difference between the treatments and was increasing throughout the trial regardless of the treatment (*P*>0.05). However, some significant differences were observed between the periods of 28, 112 and 140 days (*P*<0.05) respectively. At the end of the experiment, the smallest value was obtained in T0 (884.9± 13.3), and the largest in the treatment T′3 (1022.8± 15.1).

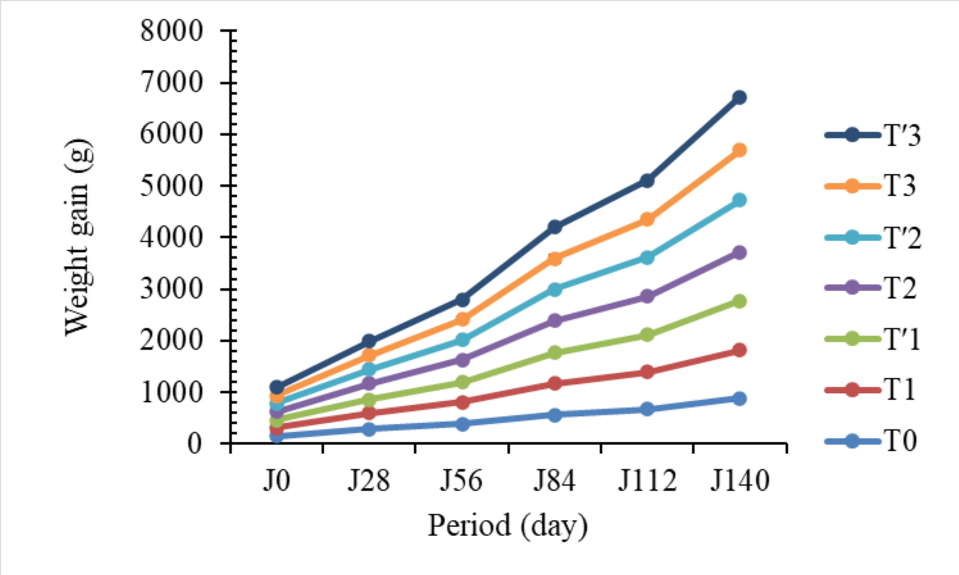

Fig. 3. Evolution of the average weight of pre-adults of *C. gariepinus* fed on fly larvae meal, supplemented with ginger according to the different treatments

T0: diet containing fish meal; T1-T2-T3: diets containing respectively 70%, 85% and 100% of BSF LM; T'1-T'2-T'3: diets containing respectively 70%, 85% and 100% BSF LM with ginger

3. Growth performance of pre-adults of *Clarias gariepinus* fed with black soldier fly larvae meal supplemented with ginger

Table (3) presents the effect of BSF larvae meal supplemented with ginger on the growth performance of pre-adults of *Clarias gariepinus* after 140 days. It appears that whatever the treatment, no significant difference (P>0.05) was observed between the characteristics studied, with the exception of the consumption index (P<0.05). The best characteristic values were obtained for the most part in pre-adults who fed on the 100% diet of BSF larvae meal added to ginger powder, while the opposite effect was observed in the pre-adults who fed on 100% fish meal. This concerns the weight gain (T′3 = 866.2 ±16.2; T0 = 728.3 ±12.1), the average daily gain (T′3 = 6.2 ±0.1; T0 =5.2 ±0.1), the consumption index (T′3 = 1.0 ±0.1; T0 =1.2 ±0.0) and the protein efficiency coefficient (T′3 = 2.6 ±0. 3). For the other characteristics, they were more or less comparable between the treatments.

Table 3. Growth characteristics of pre-adults of *C. gariepinus* fed larvae meal supplemented with ginger

Growth characteristics	Treatments							P – value
	T0	T1	T′1	T2	T′2	T3	T′3	
BWi (g)	156.7 ±1.3	155.7 ±0.3	156.7 ±0.7	156.9 ±0.3	157.3 ±0.8	156.6 ±1.1	156.6 ±1.3	/
BWf (g)	884.9 ±13.3	925.8 ±32.6	959.3 ±18.6	951.4 ±20.0	1001.5 ±18.2	972.1 ±23.0	1022.8 ±15.1	/
SLi (mm)	253.0 ±3.9	253.8 ±3.6	249.9 ±0.7	248.6 ±5.3	248.0 ±4.4	248.7 ±3.8	249.5 ± 4.4	/
SLf (mm)	442.5 ±1.7	446.7 ±12.0	464.5 ±9.1	464.0 ±6.1	484.3 ±12.0	478.5 ±13.9	488.5 ±2.2	/
TLi (mm)	281.8 ±4.7	284.8 ±1.0	278.0 ±1.0	278.2 ±6.6	277.8 ±6.1	278.4 ±2.7	280.7 ±4.0	/
TLf (mm)	496.3 ±2.3	504.3 ±12.9	514.9 ±11.8	520.3 ±15.1	541.9± 12.0	535.8 ±17.3	547.2 ±3.1	/
WG (g)	728.3 ±12.1	770.1 ±32.7	802.6± 17.9	794.5 ± 20.1	844.2 ±18.7	815.5 ±23.9	866.2 ±16.2	0.819
AWG (g/J)	5.2 ±0.1	5.5 ±0.2	5.7 ±0.1	5.7 ±0.1	6.0 ±0.1	5.8 ±0.2	6.2 ±0.1	0.824
SGR (%)	1.2 ±0.0	1.3 ±0.0	1.3 ±0.0	1.3 ±0.0	1.3 ±0.0	1.3 ±0.0	1.3 ±0.0	0.998
CI	1.2±0.0^{a}	1.2 ±0.2^{b}	1.1±0.1^{bc}	1.1±0.1^{bc}	1.1±0.0^{bc}	1.2±0.1^{bc}	1.0 ±0.1^{c}	
FE	0.9 ±0.0	0.9 ±0.1	0.9 ±0.1	0.9 ±0.0	1.0 ±0.1	0.9 ±0.0	1.0 ±0.1	0.947
K	1.0 ±0.0	1.0 ±0.1	1.0 ±0.0	1.0 ±0.0	0.9 ± 0.1	0.9 ±0.1	0.9 ±0.0	0.771
PER	2.2 ±0.1	2.2 ± 0.3	2.4 ±0.1	2.3 ±0.1	2.4 ±0.1	2.2 ±0.1	2.6 ±03	0.865

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; BWi:initial body weight; bwf: final body weight; TLi: initial total length; TLf: final total length; WG: weight gain; AWG: average weight gain; SGR: specific growth rate, K: condition factor; CI: consumption index; FE: feed efficiency; PER: protein efficiency ratio; a, b, bc, c: significant difference between the values (p <0,05).

4. Weight-length relationship in pre-adults of *C. gariepinus* fed with larvae meal supplemented with ginger depending on the treatments

From Table (4), showing the weight-length relationship in pre-adults of *Clarias gariepinus* fed on BSF larvae meal supplemented with ginger after 140 days of rearing, it appears that the coefficient of determination R^2 varied from 0.9570 (T3) to 0.9778 (T0). The allometry coefficient b varied from 2.6828 (T3) to 3.001 (T1) and growth was negative allometric in all treatments, except for T0 and T1 where it was isometric. Growth was negative allometric in the total population.

Table 4. Weight-length relationship in pre-adults of *C. gariepinus* fed with fly meal supplemented with ginger

Treatment	Length-weight relationship parameters					Type of growth
	N	Equation	R^2	A	b	
T0	135	PT = 7E-06LT$^{2.9967}$	0.9778	7E-06	2.9967	I
T1	135	PT = 7E-06LT$^{3.001}$	0.9634	7E-06	3.0010	I
T′1	135	PT = 2E-056LT$^{2.8392}$	0.9690	2E-05	2.8392	A-
T2	135	PT = 3E-05LT$^{2.7784}$	0.9616	3E-05	2.7784	A-
T′2	135	PT = 4E-05LT$^{2.7096}$	0.9641	4E-05	2.7096	A-
T3	135	PT = 5E-05LT$^{2.6828}$	0.9570	5E-05	2.6828	A-
T′3	135	PT = 4E-05LT$^{2.7039}$	0.9640	4E-05	2.7039	A-
Total	945	PT = 2E-05 LT$^{2.7995}$	0.9627	2E-05	2.7995	A-

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, R2= etrmination coefficient, a= constant, b= allometric oefficient, A- = negative allometric, I = isometric

5. Bromatological characteristics of the flesh of pre-adults of *C. gariepinus* fed with *H. illucens* larvae meal supplemented with ginger

Table (5) presents the bromatological characteristics of the flesh of pre-adults of *C. gariepinus* fed on BSF larvae meal supplemented with ginger. It appears that significant differences (P>0.05) were observed with the values of the crude protein and dry matter (dry constituent).

Table 5. Bromatological characteristics of pre-adults of *C. gariepinus* fed on *H. illucens* larvae meal supplemented with ginger according to the different treatments

Treatment	Components (%dry weight)							Components (%fresh weight)					
	FW	DW	DM	Ash	OM	CP	Lipids	H20	DM	Ash	OM	CP	Lipids
T0	53.74	11.53	92.59 [b]	5.12	94.88	76.22 [e]	8.58	78.54	19.86	1.18	20.27	17.66	1.99
T1	51.97	12.00	92.17 [c]	4.93	95.07	69.99 [b]	10.30	76.91	21.28	1.23	21.85	17.53	2.58
T′1	58.74	13.63	93.59 [a]	5.71	94.28	71.26 [c]	10.74	76.80	21.72	1.41	21.78	17.67	2.66
T2	43.02	10.25	93.09 [b]	4.22	95.77	71.58 [d]	10.56	76.17	22.18	1.08	22.74	18.32	2.70
T′2	52.20	12.76	92.98 [b]	4.13	95.86	70.90 [c]	13.87	75.56	22.73	1.08	23.35	18.64	3.65
T3	61.44	14.63	93.87 [a]	4.08	95.92	68.69 [a]	16.25	76.19	22.35	1.04	22.78	17.42	4.12
T′3	89.69	20.18	93.34 [b]	4.36	95.63	72.07 [d]	10.39	77.50	21.01	1.05	21.44	17.37	2.50

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, H2O: water

DISCUSSION

The values of the survival rate of the pre-adults obtained after 20 weeks of rearing, which were generally greater than 76% whatever the treatment applied, show that BSF larvae meal supplemented with ginger or not, did not affect survival of pre-adults of *C. gariepinus*. The mortalities observed overall would be due to handling during controlled fishing, because the more the fish grows, the more it is exposed during handling. The greater value of the survival rate obtained in the T′3 treatment would be due to the combined properties of BSF larvae meal and ginger powder which would give the catfish more hardiness. The values obtained are lower than those obtained by **Hu *et al.* (2017)** upon evaluating the effect of BSF larvae meal in the diet of the yellow catfish fry after 8 weeks of rearing. However, they were comparable to those held by **Azri *et al.* (2022)** in *C. gariepinus* fry fed 0, 33 and 50% BSF larvae meals for 6 weeks.

The majority of growth characteristics studied in the pre-adults of *C. gariepinus* were comparable to each other; this would show that BSF larvae meal added to ginger or not can effectively replace fish meal in fish feed. However, the better values that were observed in individuals fed 100% BSF larvae meal supplemented with ginger would confirm the positive effect of the addition of ginger powder as an additive to BSF larvae meals in the palatability and digestibility of the pre-adult of African catfish. This phenomenon was most observed at the level of the consumption index; the best value of which was obtained with the T′3 treatment. The consumption index values (1.0 to 1.2) are higher than those of **Raphael (2016)**, who obtained values between 1.49 and 1.63 when evaluating the effect of BSF larvae meal on body composition, growth and food utilization characteristics of the African catfish fry.

The values of the average daily gain obtained during the study (5.2±0.1g/D - 6.2±0.1g/D) are higher than those of **Raphael (2016)** and **Belghit *et al.* (2019)**, who recorded values between 3.13 and 3.19 & 3.7 and 3.8g/D, respectively. The best values obtained in pre-adults fed on foods containing ginger powder would prove the capacity of ginger to increase the palatability of the fish thanks to the taste that it would bring to the food from its properties.

The specific growth rate (1.2 to 1.3%) is lower compared to the values obtained by **Rawski *et al.* (2021)** who registered values between 1.91% and 2.20% in *Siberian sturgeon* fed with a food containing BSF larvae meal at different substitution levels. Additionally, the current values are lower than those of **Adeoye *et al.* (2020)** who determined values between 2.39 and 5.48%. However, the SGR values are higher than those observed by **Stenberg *et al.* (2019)** in the Atlantic salmon (*Salmo salar*) fed a diet with an increasing replacement of fish meal with insect meals for 8 weeks (1.08 ± 0.01% to 1.11 ± 0.06%).

The condition factor K varying from 0.9 ±0.0 to 1.0 ±0.1 at the end of the test reflects the good condition of the fish throughout the breeding process. These results are lower than those of **Renna *et al.* (2017)** (1.18 to 1.23) and **Belghit *et al.* (2019)** (1.4 ±

0.1); however, they are superior to those obtained by **Adeoye *et al.* (2020)** (0.80 ± 0.07 to 0.90 ± 0.09),

The protein efficiency coefficient values recorded at the end of the grow-out stage were between 2.2 ±0.1 and 2.6 ±0.3, which would prove a better quality of the nutrients contained in the experimental diets according to the estimation of the crude protein rate during formulation. These values are comparable to those obtained by **Renna *et al.* (2017)** (2.46 to 2.52) in the rainbow trout fed food substituted with 0, 25 and 50% BSF larvae meal. However, the values are higher than those of **Xiao *et al.* (2018)** (1.39 ± 0.13 - 2.59 ±0.09)and **Adeoye *et al.* (2020)** (0.41 ± 0.08 - 1.55 ± 0.20) though lower than those of **Rawski *et al.* (2021)** (2.34 ± 2.92).

The values of the bromatological characteristics of the pre-adults flesh obtained at the end of rearing, made it possible to generally affirm that whatever the characteristics studied, the values are close to those of the control treatment, although some differences were observed. However, the values are all within the range of normative values for fishmeal. The greater value of crude protein (dry constituent) obtained in the T0 treatment would be due to the fish meal containing fewer lipids than the BSF larvae meal since the opposite effect occurred at the level of the lipids contained in the flesh of the different samples. The protein values are higher compared to those obtained by **Fawole *et al.* (2020)** and **Njoroge (2020)** but lower than those obtained by **Azri *et al.* (2022)**. Regarding lipids and ash, the values obtained are lower than those of **Hu *et al.* (2017)**, **Muin *et al.* (2017)**, **Xiao *et al.* (2018)**, **Fawole *et al.* (2020)**, **Hu *et al.* (2020)** and **Azri *et al.* (2022)**.

CONCLUSION

At the end of this study, with the aim of evaluating the effect of the black soldier fly larvae meals (*Hermetia illucens*) supplemented with ginger powder (*Zingiber officinale*) on the survival, growth performance and nutritional quality of the flesh of the African Catfish *Clarias gariepinus* (Burcell, 1822), it was mainly deduced that the larvae meal of *H. illucens* supplemented with *Z. officinale* powder can effectively replace fish meal in the diet of *C. gariepinus* pre-adults.

REFERENCES

Adegbesan, S.I.; Obasa, S.O.; Akintokun, A.K. and Abdulraheem, I. (2019). Effects of Dietary Supplementation of *Zingiber officinale* Root-Powder on Growth, Nutrient Utilisation and Intestinal Microbes of African Mud Catfish (*Clarias gariepinus*) Fingerlings. J. Aquac. Fish., 3:1-17.

Adeoye, A.A.; Akegbejo-Samsons, Y.; Fawole, F.J. and Davies, S.J. (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 haematological parameters. (4), J. Wor. Aquac. Soc., 51:1024–1033.

AOAC (Association of Official Analytical Chemist). (1990). Official methods of analysis association of official analytical chemists. 15th ed. Washington, DC, Association of Analytical Chemists. Link: https://bit.ly/3uovcLo. 1298

Azri, N.A.M.; Chun, L.K.; Hasan, H.A.; Jaya-Ram, A.; Kari, Z.A. and Hamid, N.K. A. (2022). The effects of partial replacement of fishmeal with *hermetia meal* on the growth and fatty acid profile of African catfish fry. Agric. Re., 1 (1) : 17–27.

Bazinet, L. and Castaigne, F. (2011) «Déminéralisation, enrichissement et stabilisation par procédés électromembranaires. Concept de génie alimentaire: Procédés associés et applications à la conservation des aliments,» 1: 527-568.

Belghit, I.; Liland, N.S.; Gjesdal P.; Biancarosa, I.; Menchetti, E.; Li,Y.; Waagbø, R.; Krogdahl, A. and Lock, E. (2019). Black soldier fl y larvae meal can replace fishmeal in diets of sea-water phase Atlantic salmon (*Salmo salar*). Aquac., 503: 609–619.

FAO. (2013). Forestry paper. Edible insects: Future prospects for food and feed security. Rome., 171: 224.

FAO. (2020) «ACTION, SUSTAINABILITY IN. World Fisheries and Aquaculture,» Food and Agriculture Organization, United State., 244: 978-92-5-132692-3

Fawole, F. J.; Adeoye, A.A.; Tiamiyu, L.O.; Ajala, K. I.; Obadara, S.O. and Ganiyu, I.O. (2020). Substituting fishmeal with *Hermetia illucens* in the diets of African catfish (*Clarias gariepinus*): Effects on growth, nutrient utilisation, haemato-physiological response, and oxidative stress biomarkers. Aquac., 518: 734-849.

Fonseca, K.B.; Dicke, M. and van Loon, J. (2017). Nutritional value of the black soldier fly (*Hermetia illucens L.*) and its suitability as animal feed. J. Ins. Fo. Fe., 3 (2): 105–120.

Henry, M.; Gasco, L.; Piccolo, G. and Fountoulaki, E. (2015). Review on the use of insects in the diet of farmed fish: past and future. An. Fe. Sci.Tech., 203: 1–22.

Hu, J.; Wang, G.; Huang, Y.; Sun, Y.; He, F.; Zhao, H. and Li, N. (2017). Effects of substitution of fish meal with black soldier fly (*Hermetia illucens*) larvae meal, in yellow catfish (*Pelteobagrus fulvidraco*) diets. Isr. J. Aquac-Bami., 69 (1): 1-9.

Hu, Y.; Huang, Y.; Tang, T.; Zhong, L.; Chu, W.; Dai, Z.; ... and Hu, Y. (2020). Effect of partial black soldier fly (*Hermetia illucens* L.) larvae meal replacement of fish meal in practical diets on the growth, digestive enzyme and related gene expression for rice field eel (*Monopterus albus*). A. R., 17:100345.

Jahanjoo, V.; Yahyavi, M.; Akrami, R. and Bahri, A.H. (2018). Influence of adding garlic (*Allium sativum*), Ginger (*Zingiber officinale*), thyme (*Thymus vulgaris*) and their combination on the growth performance, haematoimmunological parameters and disease resistance to Photobacterium damselae in sobaity sea bream (Sparidentex hasta) Fry. Turk. J. Fish. Aquac. Sci., 18 (4): 633–645.

Kroeckel, S.; Harjes, A.G.; Roth, I.; Katz, H.; Wuertz, S.; Susenbeth, A. and Schulz, C. (2012). When a turbot catches a fly: Evaluation of a pre-pupa meal of the black soldier fly (*Hermetia illucens*) as fish meal substitute – Growth performance and chitin degradation in juvenile turbot (*Psetta maxima*). Aquac., 364: 345–352.

Le Cren, E.D. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). The J. Ani. Ecol., 20: 201–219.

Li, S.; Ji, H.; Zhang, B.; Zhou, J. and 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, intestines and hepatopancreas histological structure. Aquac., 477: 62–70.

Liu Z.; Minor, M.; Morel, P.C.H. and Najar-Rodriguew, A.J. (2018). Bioconversion of three organic wastes by black soldier fly (Diptera: *Stratiomydae*) larvae. En. Ento.., 47 (6): 1609 - 1617.

Lock, E.R.; Arsiwalla, T. and Waagbø, R. (2016). Insect larvae meal as an alternative source of nutrients in the diet of Atlantic salmon (*Salmo salar*) posts molt. Aquac. Nutr. 22: 1202-1213.

Muin, H.; Taufek, N.M.; Kamarudin, M.S. and Razak, S.A. (2017). Growth performance, feed utilisation and body composition of Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) fed with different levels of black soldier fly, *Hermetia illucens* (Linnaeus, 1758) maggot meal diet. Ira. J. of Fish. Sci., 16 (2): 567–577.

Nana, P.; Kimpara, J.M.; Tiambo, C.K.; Tiogue, C.T.; Youmbi, J.; Choundong, B. and Fonkou, T. (2018). Black soldier flies (*Hermetia illucens Linnaeus*) as recyclers of organic waste and possible livestock feed. Int. J. Biol. Chem. Sci., 12 (5): 2004–2015.

Njoroge, M.A. (2020). Growth performance and carcass characteristics of the african catfish (*Clarias gariepinus*) reared on diets containing black soldier fly (*Hermetia illucens*) larvae meal (Doctoral dissertation). Agriculture and Enterprise Development of Kenyatta University, 1: 1-102

Ofosu, I.W.; Awudzi, M.Y. and Dadson, J.K. (2015). Formulation et analyse protéique d'aliments pour poissons incorporés aux graines de rocou. Rev. int. rech. l'innov. Agric., 1 (1): 20-25.

Olurin, K.B.; Iwuchukwu, P.O. and Oladapo, O. (2012). Larval rearing of African catfish, *Clarias gariepinus* fed decapulated Artemia, wild copepods or commercial diet. *African Journal of food science and technology,* 3 (8):182-185.

Raphael, T. (2016). Comparisons of Growth Performance of African Catfish (*Clarias gariepinus* Burchell, 1822) Fingerlings Fed Different Inclusion Levels of Black Soldier Fly *(Hermetia illucens)* Larvae Meal Diets. Chapter 3: The effects of black soldier fly (*Hermetia illucens*) larvae meal on growth performance and feed utilisation of African catfish (*Clarias gariepinus*) fingerlings. Thesis of Msc. in Agriculture (Aquaculture). Department of Animal Sciences, Faculty of AgriSciences, Stellenbosch University. 57:50–53

Rawski, M.; Mazurkiewicz, J.; Kierończyk, B. and Józefiak, D. (2021). Black soldier fly full-fat larvae meal is more profitable than fish meal and fish oil in *Siberian sturgeon* farming: the effects on aquaculture sustainability, economy and fish GIT development. Ani., 11 (3): 604-619.

Renna, M.; Schiavone, A.; Gai, F.; Dabbou, S.; Lussiana, C.; Malfatto, V.; Prearo, M.; Capucchio, M.T.; Biasato, I.; Biasibetti, E.; De Marco, M.; Brugiapaglia, A.; Zoccarato, I. and Gasco, L. (2017). Evaluation of the suitability of a partially defatted black soldier fly (*Hermetia illucens L.*) larvae meal as ingredient for rainbow trout (*Oncorhynchus mykiss Walbaum*) diets. J. Anim. Sci. Biotec.., 8 (57):1-13

Ricker, W.E. (1975). Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Bd. Can., 191:1–382.

Rukisah; Sumarlin; Lembang M. S.; Gaffar, S.; Patabo, M.; Sevannia, P. and Susianty (2024). Assessing the Growth Potential of Clarias sp. (Catfish) on a Hybrid Diet of Pellets and Fresh *Hermetia illucens* Maggot Inputs. Egyptian Journal of Aquatic Biology & Fisheries, 28(1): 1351 – 1360

Ssepuuya, G.; Namulawa, V.; Mbabazi, D.; Mugerwa, S.; Funa, P.; Nampijja, Z. and Nakimbugwe, D. (2017). Use of insects for fish and poultry compound feed in sub-Saharan Africa – A systematic review. J. Ins. Fo. Feed., 3: 289-302.

Stenberg, O.K.; Holen, E.; Piemontese, L.; Liland, N.S.; Lock, E.J.M. and Belghit, I. (2019). Effect of dietary replacement of fish meal with insect meal on in vitro bacterial and viral induced gene response in Atlantic salmon (*Salmo salar*) head kidney leukocytes. Fish & shellfish immunology, 91 : 223-232.

Trintignac, P. and Métivier, R. (2019). Pré étude régionale sur l'utilisation d'insectes dans l'alimentation des poissons d'élevage, Smidap., 1 : 8-40.

Ude, E.; Iheanacho, S.C.; Ogbu, M.; Ayotunde, E. and Ogueji, E. (2018). Growth, Haematology and Immuno-Modulatory Potential of Ginger (*Zingiber officinale*) Supplemented Diets in *Clarias gariepinus* Juvenile (Burchell, 1822). Aquac. Stu., 18 (1): 41–49.

Van Huis, A.; Van Itterbeeck, J.; Klunder, H.; Mertens, E.; Halloran, A.; Muir, G. and Vantomme, P. (2013). *Edible insects: future prospects for food and feed security*. Food and agriculture organisation of the United Nations., 171: 0258-6150

Wang, Y.S. and Shelomi, M. (2017). Review of black soldier fly (*Hermetia illucens*) as animal feed and human food. *Fo.*, *6* (10): 91-107.

Wang, L.; Li, J.; Jin, J.N.; Zhu, F.; Roffeis, M. and Zhang, X.Z. (2017). A comprehensive evaluation of replacing fishmeal with housefly (*Musca domestica*) maggot meal in the diet of Nile tilapia (*Oreochromis niloticus*): growth performance, flesh quality, innate immunity and water environment. Aquac. Nutr., 23 (5): 983–993.

Xiao, X.; Jin, P.; Zheng, L.; Cai, M.; Yu, Z.; Yu, J. and Zhang, J. (2018). Effects of black soldier fly (*Hermetia illucens*) larvae meal protein as a fishmeal replacement on the growth and immune index of yellow catfish (*Pelteobagrus fulvidraco).* Aquac. Res., 49 (4):1569-1577.

Zango, P.; Tomedi, M.T.E.; Efole, T.E.; Tiogue, C.T.; Nguenga, D.; Kamanke, S.M.K.; ... and Tchoumboue, J. (2016). Performances de reproduction du poisson chat endogène du Cameroun *Clarias jaensis* (Boulenger, 1909) en milieu contrôlé. *International Journal of Biological and Chemical Sciences*, 10 (2) : 533-542.