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Nutrient utilization, haematological indices and carcass compositions of *heteroclarias* fingerlings fed *Hermetia illucens* (Linnaeus, 1758) larvae meal

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Abstract
A feeding trial was conducted in 18 (34 litres) plastic bowls for 56 days to evaluate the nutrient utilization, haematological indices and carcass compositions of *Heteroclarias* fingerlings fed *Hermetia illucens* (Linnaeus, 1758) larvae meal. Six 40 % experimental diets were formulated with different replacement levels of *Hermetia illucens* larvae meal (HILM) and designated as T1 (0 % HILM: control), T2, T3, T4, T5 and T6 containing 20 %, 40 %, 60 %, 80 %, and 100 % respectively. 10 fingerlings (2.54 g – 2.57 g) were stocked into each 18 plastic bowl and fed thrice daily to satiation. At the end of the experimental duration, the fish fed T2 had the highest weight gain. However, significant differences ($P>0.05$) were recorded among treatment means in weight gain. There was no significant difference ($P<0.05$) in feed conversion ratio between T1 and T2, however, significant differences were recorded between T5 and T6. No significant differences were recorded among treatment means in their survival rate. In the haematological indices of the experimental fish fed *Hermetia illucens* larvae meal, there were no significant differences ($P<0.05$) among the fish fed T3 – T5 in packed cell volume, though there was a significant difference ($P>0.05$) between T1, T2 and T6. No significant difference recorded among treatment means in the red blood cell, however, a significant difference was recorded in white blood cell between fish fed T1, T3 and T2, T5, T6. The proximate compositions (wet basis) profile of the experimental fish fed *Hermetia illucens* larvae meal showed that there was a significant difference ($P<0.05$) among treatment means in moisture content. However, no significant difference ($P>0.05$) was recorded among the treatment means in crude fibre. *Hermetia illucens* larvae meal can be included in the diet of *Heteroclarias* fingerlings without negatively affecting their health condition and survival.

Keywords: *Hermetial illucens*, *Heteroclarias*, haematological indices, growth parameters

1. Introduction

The significant increases in annual production of fish in sub-Saharan Africa from around 2000 onwards can be partially ascribed to the concerted efforts on the nutritional requirements of the species during all life history stages, feed formulation, optimization of feeding and feed management practices and the development of high-density tank farming practices (Hetch, 2013) [24]. Sufficient consumption of feed is essential for increased growth and profitability in aquaculture (Sogbesan and Ugwumba, 2008) [47]. Therefore, fish needs a good nutritious diet which must contain right ingredients, and of acceptable cost, must be palatable to the fish and should not contain anti-nutritional components that can inhibit the growth performance of the fish (Sanchez-Muros *et al*., 2014; Aderolu *et al*., 2018) [41, 6].

Fish meal, as a conventional source of animal protein in fish diet which has been measured by its balanced amino acids, mineral and vitamin content, palatability and growth factors (Tacon, 1993) [52]. Due to the wide range utilization of fish meal by man, livestock and poultry industries has resulted in a geometrical increase in the price. Reducing protein cost in fish diet formulation has necessitated the quest for cheaper and locally available animal's protein to replace high-cost fishmeal that has other competing uses by man and other sectors (Abdelghany, 2003; El-Saidy and Gaber, 2003; Fasakin *et al*., 2006) [2, 19, 21].

Black soldier fly (*Hermetia illucens*) is a fly of the Stratiomyidae family, where the larvae can grow up to 2.70 cm in length, 0.6 cm in width and weigh up to 220 mg in their last larval stage (Diclaro and Kaufman, 2009) [16]. The larvae feed on fresh matter and with a minimal disturbance on a wide range of decaying organic materials and particularly animal manure and human excreta (Hardouin and Mahoux, 2003; Diener *et al*., 2011) [23, 17]. *Hermetia illucens* has been proposed as an efficient way to dispose of organic waste, by converting them into a protein-rich and fat-rich biomass suitable for animal feeding for all livestock species (Van-Huis *et al*., 2013) [54]. The larvae are sold for pets and fish bait, and it can be easily dried for longer storage (Leclercq, 1997; Veldkamp *et al*., 2012) [30, 55]. *Hermetia illucens* larvae are readily available and have been accredited for its high protein with amino acid profile (Adejinmi, 2000; Arango-Gutierrez *et al*., 2004; St-Hilaire *et al*., 2007) [4, 10, 49]. Therefore, using feeds based on *Hermetia illucens* larvae in aquaculture opens additional marketing opportunities for fish farmers (Tiu, 2012) [53].

The clariid catfishes (*Heterobranchus* species and *Clarias* species) command an excellent food of high commercial value in Nigeria and some other countries of the world (Huda *et al*., 2002; Adebayo and Popoola, 2008) [26, 3]. This is because of their fast growth and good taste (Oladosun *et al*., 1994) [37]. The hybrid clariid (*Heteroclarias*) is a product from the crossbreed between *Heterobranchus* species and *Clarias* species and could be gotten in commercial quantity (Nwadukwe *et al*., 1993) [36]. It grows fast with a high survival rate, resistance to disease, better taste, tolerance to unfavourable environmental conditions and has high market demand (Sogbesan *et al*., 2005) [45]. Therefore the study was conducted to evaluate the nutrient utilization, haematological indices and carcass compositions of *Heteroclarias* fingerlings fed *Hermetia illucens* (Linnaeus, 1758) larvae meal.

2. Materials and Methods

2.1 Experimental site

The experiment was conducted at Fisheries Laboratory of Department of Forestry and Fisheries, Kebbi State University of Science and Technology Aliero. Aliero is located in Southeast of Kebbi State at approximate longitudes 3°6'W 4°27'E and 11°03'S 12°47'N (Singh, 2013) [43].

2.2 Collection of *Hermetia illucens* Larvae Meal (HILM)

The larvae were collected from Labana Farms Limited in Aliero Local Government Area of Kebbi State. The collection was done by mixing manure with water (floating method), and float out larvae was collected with a sieve (0.5 mm). The collected larvae were oven dry at 100 °C for 4 hours, ground in powder form and packed in an airtight polyethylene bag until needed.

2.3 Experimental Fish

A total of one hundred and eighty (180) pieces of *Heteroclarias* fingerlings (2.87±0.28 – 3.75±0.43) was purchased from a reputable farm in New Bussa, Borgu Local Government Area of Niger State and transported to the experimental site. The fingerlings were acclimatized for 14 days and fed commercial diets.

2.4 Experimental ingredients and diets formulation

The ingredients such as maize meal, fish meal, vitamin and mineral premix, vegetable oil were purchased from Jega market in Jega Local Government Area of Kebbi State. Maize meal, fish meal and *Hermetia illucens* larvae meal were taken to Agric. Chemical Laboratory, Usmanu Danfodio University Sokoto for proximate analysis (Table 1). Six (6) experimental diets were formulated at 40 % crude protein and designated as T1 (0 % HILM: control), T2, T3, T4, T5 and T6 containing 20 %, 40 %, 60 %, 80, and 100 % replacement levels of HILM respectively (Table 2).

Table 1: Proximate composition of feed ingredients

Parameters (%)	Fishmeal	HILM	Maize meal
Crude protein	60.17	30.10	11.17
Ether extract	8.84	15.86	4.33
Crude fibre	6.28	9.47	1.17
Ash content	16.65	20.42	4.56
Moisture content	4.45	6.23	6.80
Nitrogen free extract	3.61	17.92	71.97

Key: HILM = *Hermetia illucens* larvae meal

Table 2: Gross composition of experimental diets

Ingredients (g)	Replacement levels (%)					
	0	20	40	60	80	100
Fishmeal	552.20	510.40	445.60	304.30	166.50	0.00
Hermetia illucens larvae meal	0.00	122.90	293.40	531.00	664.40	704.00
Maize meal	388.10	310.50	206.40	110.60	115.70	242.80
Vegetable oil	9.70	6.20	4.60	4.10	3.40	3.20
Vitamin/Mineral premix	50.00	50.00	50.00	50.00	50.00	50.00
Total	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
Proximate composition (%)						
Crude protein	40.30	40.01	40.10	41.38	40.62	40.07
Ether extract	9.58	10.11	10.33	10.92	11.04	11.61
Crude fibre	2.16	2.81	2.09	2.30	3.43	3.57
Ash content	9.51	9.77	10.82	10.66	9.96	10.90
Moisture content	4.89	5.63	5.02	5.72	5.44	5.18
Nitrogen free extract	33.56	31.67	31.64	29.02	29.51	28.67
Gross energy (kcal)	452.47	448.28	450.74	453.07	451.87	450.79

2.5 Experimental procedures

The experiment was conducted using 18 plastic bowls (34 litres) and stocked at 10 fingerlings per bowl. The fingerlings were fed HILM based diets thrice to satiation for 8 weeks. Faecal materials and uneaten feed were siphoned every morning from the bowls using a rubber hose. Random sampling was carried out bi-weekly to determine the new body length and weight, using a sensitive weighing balance (Model: CS-200) and a graduated plastic ruler.

2.6 Water quality management

The water quality parameters monitored (Table 3) include temperature (°C), pH, dissolved oxygen, ammonia and nitrite. The temperature was determined using a mercury thermometer, pH was determined using a pH meter (Model: Metrohm-800), dissolved oxygen (DO) was determined using a DO meter (Model: JPB-70A), while ammonia and nitrite were determined using a titrimetric method as described in AOAC (2000) [9].

Table 3: Mean±SE Water quality parameters monitored during the experiment

Parameters	Treatments					
	T1	T2	T3	T4	T5	T6
DO (mg/l)	5.41±0.05	4.96±0.76	5.44±0.23	5.04±0.53	5.44±0.12	5.30±0.22
T (°C)	27.67±0.33	28.33±0.33	28.00±0.00	27.67±0.67	28.00±0.00	28.33±0.33
pH	7.05±0.03	7.06±0.06	7.73±0.10	7.21±0.48	7.33±0.36	7.06±0.10
Amm (mg/l)	0.13±0.00	0.15±0.00	0.15±0.02	0.16±0.00	0.14±0.01	0.17±0.00
Ntr (mg/l)	2.48±0.03	2.44±0.05	2.20±0.17	2.18±0.07	2.53±0.28	2.22±0.22

Keys: DO = Dissolved oxygen, T = temperature, Amm = ammonia, Ntr = nitrite.

2.7 Growth Parameters

The growth parameters for each treatment were estimated using the following formulae:

i. Weight gain = Wf – Wi, where: Wf = final weight of the fish at the end of the experiment, Wi = initial weight at the beginning of the experiment.
ii. Specific growth rate = In wf – In wi/t × 100, where: In wf = logarithm of final weight, In wi = logarithm of initial weight, t = experimental duration.
iii. Feed efficiency = weight gained/feed intake
iv. Feed conversion ratio = feed fed/weight gain
v. Protein efficiency ratio = weight gain/protein fed × 100
vi. Protein retention = protein gain/protein fed × 100
vii. Relative growth rate = Wf – Wi/Wi × 100, where: Wf = final weight at the end of the experiment, Wi = initial weight at the beginning of the experiment.
viii. Survival rate = Nf/Ni × 100, where: Nf = number alive at the end of the experiment, Ni = number stocked at the beginning of the experiment.
ix. Gross feed conversion efficiency = 1 × 100/FCR, where: FCR = food conversion ratio.
x. Protein productive value = PR2 – PR1/Pi × 100, where: Pi = protein intake during the whole experimental period, PR1 = total fish body protein at the start of the experiment, PR2 = total fish body protein at the end of the experiment.
xi. Average daily gain = Mean final body weight – Mean initial body weight/Number of days of the experiment

2.8 Haematological Indices

The blood sample from each was collected by bleeding the fish from the caudal fin using a dissecting blade. The blood sample was collected immediately into sample bottles containing ethylene diamine tetra-acetic acid as anticoagulant and taken to the laboratory for the analysis. The white blood cell (WBC) and red blood cell (RBC) were estimated as described by Stoskoph (1993) [50]. Packed cell volume (PVC) was determined using the micro-haematocrit method as described by Snieszko (1960) [48], haemoglobin (Hb) was estimated as described by Nicholls (1990) [33], while platelet count (PC) was determined as described by Lamb (1981) [29]. Mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) were calculated as described by Abalaka (2013) [1].

2.9 Proximate Analysis

The proximate composition such as crude protein, ether extract, moisture content, ash content and fibre were determined using the standard procedure described in AOAC (2000) [9]. The Nitrogen Free Extract (NFE) was calculated as: 100 – (Crude protein + ether extract + moisture content + ash content + fibre).

2.10 Statistical Analysis

All the collected data were subjected to one-way analysis of variance (ANOVA). Differences between the means were separated using Duncan Multiple Range Test (DMRT) at 5 % (P<0.05) with the aid of MINITAB (V14) statistical package for Windows.

3. Results

The growth parameters of the experimental fish fed *Hermetia illucens* larvae meal is presented in Table 4. There was a significant difference (P>0.05) among treatment means in weight gain. There is no significant difference (P<0.05) in feed conversion ratio between T1 and T2, however, significant differences were recorded between T5 and T6. No significant differences amongst T3 – T6 in feed efficiency, though significant differences were recorded amongst treatment means in specific growth rate. There is no significant difference between T1 and T2, and also among T3 – T6 in gross feed conversion efficiency. Among treatment means, significant differences were recorded for average daily gain and relative growth rate. However, no significant differences was recorded among treatment means in their survival rate.

The haematological indices of the experimental fish fed *Hermetia illucens* larvae meal are presented in Table 5. There were no significant differences (P<0.05) among the fish fed T3 – T5 in packed cell volume, though there was a significant difference (P>0.05) between T1, T2 and T6. No significant difference recorded among treatment means in the red blood cell, however, a significant difference was recorded in white blood cell between fish fed T1, T3 and T2, T5, T6. A significant difference was recorded between T2 and T5 in platelet count and also between T1 and T3 in haemoglobin.

The proximate compositions (wet basis) profile of the experimental fish fed *Hermetia illucens* larvae meal for 56 days are presented in Table 6. The whole body composition of the fish fed experimental diets revealed that there was a significant difference (P<0.05) among treatment means in moisture content. However, no significant difference (P>0.05) was recorded among the treatment means in crude fibre.

Table 4: Mean±SE Growth parameters of *Heteroclarias* fingerlings fed HILM

Parameters	Treatments					
	1	2	3	4	5	6
IW (g)	2.55±0.01^a	2.54±0.02^a	2.54±0.02^a	2.55±0.03^a	2.50±0.05^a	2.57±0.01^a
FW (g)	21.52±0.09^b	26.84±0.02^a	17.99±0.01^c	17.34±0.04^d	15.75±0.03^e	14.78±0.08^f
WG (g)	18.96±0.10^b	24.30±0.04^a	15.45±0.01^c	14.79±0.06^d	13.20±0.03^e	12.21±0.07^f
FCR	2.34±0.09^d	2.49±0.12^d	3.04±0.04^{ab}	2.86±0.05^{ab}	2.78±0.06^c	3.11±0.09^a
PER	0.47±0.00^b	0.61±0.00^a	0.39±0.00^c	0.37±0.00^d	0.33±0.00^e	0.31±0.00^f
FE	0.43±0.02^a	0.40±0.02^a	0.33±0.01^b	0.35±0.01^b	0.36±0.01^b	0.32±0.01^b
SGR (%)	3.81±0.02^b	4.21±0.02^a	3.50±0.01^c	3.42±0.03^d	3.24±0.01^e	3.13±0.00^f
GFCE	42.93±1.69^a	40.35±1.96^a	32.91±0.47^b	39.41±0.58^b	35.96±0.82^b	32.21±0.96^b
PR (%)	39.90±0.04^c	41.04±0.39^b	41.36±0.24^{ab}	39.71±0.06^c	41.78±0.09^a	41.77±0.11^a
ADG (g)	0.34±0.00^b	0.43±0.00^a	0.28±0.00^c	0.27±0.00^d	0.24±0.00^e	0.22±0.00^f
PPV (%)	3.81±0.61^a	4.94±0.35^a	5.27±0.78^a	3.69±0.65^a	5.69±0.68^a	5.68±0.66^a
RGR (%)	742.78±8.15^b	956.84±9.19^a	609.26±4.77^c	579.42±8.55^d	518.48±2.85^e	475.84±0.98^f
SR (%)	96.67±3.33^a	93.33±6.67^a	93.33±6.67^a	100.00±0.00^a	93.33±3.33^a	100.00±0.00^a

ABCDEF = Means in the same row with the same superscript are not significantly different (P<0.05)

Keys: IW = initial weight, FW = final weight, WG = weight gain, FCR = feed conversion ratio, PER = protein efficiency ratio, FE = feed efficiency, SGR = specific growth rate, GFCE = gross feed conversion efficiency, PR = protein retention, ADG = average daily gain, PPV = protein productive value, RGR = relative growth rate, SR = survival rate.

Table 5: Mean±SE Haematological indices of *Heteroclarias* fingerlings fed HILM

Parameters	Replacement levels					
	0 %	20 %	40 %	60 %	80 %	100 %
PCV (%)	22.33±1.86^d	25.00±1.15^{cd}	31.33±0.88^a	29.00±0.58^{ab}	30.00±0.58^a	26.00±0.58^{bc}
RBC (×10^{12}l)	2.33±0.33^a	2.67±0.67^a	3.33±0.33^a	2.70±0.35^a	3.60±0.31^a	2.43±0.30^a
WBC (×10^{9}l)	5.93±0.07^b	8.60±1.14^a	6.27±0.37^b	7.33±0.33^{ab}	8.57±0.30^a	8.77±0.39^a
PLT (×10^{9}l)	1.98±0.06^{ab}	2.01±0.02^a	1.51±0.25^{bc}	1.61±0.13^{abc}	8.57±0.14^c	1.57±0.12^{abc}
Hb (fl)	7.45±0.62^c	8.33±0.38^{bc}	11.11±0.95^a	9.67±0.19^{ab}	10.00±0.19^{ab}	8.67±0.19^{bc}
MCV (fl)	100.56±18.42^a	104.17±21.62^a	95.83±9.61^a	111.18±14.52^a	84.92±9.38^a	109.57±11.55^a
MCH (pg)	33.53±6.14^a	34.73±7.21^a	34.16±5.07^a	37.06±4.83^a	28.31±3.12^a	36.53±3.86^a
MCHC (g/dl)	33.34±0.01^a	33.33±0.01^a	35.35±2.02^a	33.33±0.01^a	33.33±0.01^a	33.33±0.01^a

ABCD = Means in the same row with different superscripts are significantly different (P>0.05).

Keys: HILM = *Hermetia illucens* larvae meal, PCV = Packed cell volume, RBC = Red blood cell, WBC = White blood cell, PLT = Platelet count, Hb = Haemoglobin, MCV = Mean corpuscular volume, MCH = Mean corpuscular haemoglobin, MCHC = Mean corpuscular haemoglobin concentration.

Table 6: Mean±SE Carcass composition (wet) of *Heteroclarias* fingerlings fed *Hermetia illucens* larvae meal.

Parameters (%)	Initial	Treatments					
		1	2	3	4	5	6
MC	76.21±0.89^a	70.39±0.19^c	65.28±0.14^d	70.22±0.13^c	71.32±0.17^c	65.53±0.27^d	73.68±0.29^b
CP	14.44±0.25^b	15.96±0.02^b	16.41±0.16^a	16.54±0.10^a	15.88±0.02^b	16.71±0.04^a	16.71±0.04^a
EE	1.03±0.04^d	1.18±0.04^d	1.59±0.05^c	1.67±0.06^c	1.78±0.12^c	2.38±0.19^b	2.68±0.08^a
CF	0.09±0.05^a	0.18±0.10^a	0.14±0.04^a	0.17±0.07^a	0.10±0.05^a	0.13±0.01^a	0.11±0.05^a
AC	2.54±0.54^c	4.56±0.03^a	4.13±0.08^{ab}	4.70±0.10^a	3.45±0.20^b	4.33±0.18^a	4.07±0.10^{ab}
NFE	5.70±1.32^c	7.72±0.37^b	12.44±0.32^a	6.71±0.26^{bc}	7.47±0.37^{bc}	10.91±0.41^a	2.75±0.09^d

ABCD = Means in the same row with different superscripts are significantly different (P>0.05).
Keys: MC = moisture content, CP = crude protein, EE = ether extract, CF = crude fibre, ash content, NFE = nitrogen free extract.

4. Discussion

The crude protein (30.10) of *Hermetia illucens* larvae meal (HILM) is an indication of the protein-rich and the potential of its use in the reduction of overdependence on fishmeal and soyabean meal in aquaculture feed industry (Table 1). The growth performance of *Heteroclarias* fingerlings in this present study showed good utilization of *Hermetia illucens* larvae meal at replacement level of 20% (T2) in terms of weight gain, however, beyond this, a decline in weight gain was recorded. This finding is in line with the report of Sogbesan and Ugwumba (2008) [47], they recorded a decline as the inclusion level of termite meal increases. This may be attributed to diet palatability. When alternative sources of food are used in fish diets, the common problem encountered is the acceptability of the feed by fish, which is frequently related to the palatability of the diet (Rodriguez *et al*., 1996) [39]. The feed conversion ratio obtained in this study was lower compared to that recorded by De-Silver and Anderson (1995) [15]. Sogbesan *et al*. (2007) [46] reported that high feed conversion ratio is an indication that the lower quantity of the feed consumed was utilized by the fish which could have been as a result of a bitter taste. However, lower feed conversion ratio indicates better utilization of feed by the fish (Mary *et al*., 2015; Shah *et al*., 2018) [31, 42]. The recorded specific growth was similar to that of Shah *et al*. (2018) [42] in Table 3 while evaluating the specific growth rate in rainbow trout.

However, the specific growth rate is considered to vary depending on the size of fish; though smaller fish grow faster than larger ones (Sumpter, 1992) [51]. The protein productive value recorded was higher than that reported by (Ikram *et al*., 2019) [27]. The variation may be attributed to different fish species. The ability of an organism to utilize nutrients especially protein will positively influence its growth rate (Sogbesan and Ugwumba, 2008) [47]. The feed efficiency and protein efficiency ratio varies among the treatment means but comparable to the control diet. Cho and Watanabe (1988) [12] reported that feed efficiency and protein efficiency ratio of fingerlings are usually a reliable exponent of nutritional adequacy of the diet. The survival rate obtained in this study concur with the finding of Hu *et al*. (2007) [25] while investigating the effects of substitution of fishmeal with black soldier fly (*Hermetia illucens*) larvae meal, in yellow catfish diet. Sabina *et al*. (2018) [40] reported that handling of carp fishes by providing supplementary feed boosted the growth along with survival rate in-tank condition.

Dietary constituents of fish feed, as well as their response to stress, can influence the typical physiological regime, nutrition and health condition of the fish body (Aderemi, 2004; Doyle, 2006) [5, 18]. The packed cell volume recorded in this study is not in consistent with the findings of Gana and Ndako (2019) [22]. Reduction in the concentration of packed cell volume in the blood usually suggested the presence of toxic factors which has an adverse effect on the blood formation (Oyawoye and Ogunkunle, 1998) [38]. Packed cell volume is an important haematological parameter which is used in the diagnosis and follows up of anaemia and polycythaemia (Clauss *et al*., 2008) [13]. The red blood cell, white blood cell and platelet count are comparable with the control diet. As reported by Merck (2012) [32] red blood cell, white blood cell and platelet count are used in the monitoring and diagnosis of diseases. Red blood cell is involved in the transport of oxygen and carbon dioxide in the body (Isaac *et al*., 2013) [28]. Soetan *et al*. (2013) [44] reported that animals with low white blood cells are exposed to high risk of disease infection, while those with high counts are capable of generating antibodies in the process of phagocytosis and have high degree of resistance to diseases. However, low platelet count suggests that the process of blood clotting will be prolonged resulting in excessive loss of blood in the case of infection or injury (Nse-Abasi *et al*., 2014) [34]. The mean corpuscular haemoglobin and mean corpuscular haemoglobin concentration estimated were similar to the findings of Akinrotimi *et al*. (2010) [8] while investigating the haematological characteristics of *Tilapia guineensis* from Baguma creek, Niger Delta Nigeria.

The determination of the proximate composition of fishes is essential to ensure that they meet the requirement of food regulations and commercial specification (Emmanuel *et al*., 2011) [20]. Adebayo and Popoola (2008) [3] recorded high and low carcass protein and moisture content respectively. This is not in agreement with the recorded value in this study. The differences may be attributed to different tested diets and methods of chemical analysis. Protein considerably varies with rearing environment, water quality, genetic composition and as well as the feeding rates of the fish. The quantitative determination of fish moisture content is absolutely paramount in any quality control programme for such products (Nurullah *et al*., 2007) [35]. The lipid content recorded is not in conformity with the value recorded by Gana and Ndako (2019) [22] while haematological indices and proximate composition of *Clarias gariepinus* fingerlings fed different inclusion levels of tadpole meal. The differences may be attributed to different diet compositions, culture medium and environment. Begum *et al*. (2012) [11] reported that lipid content is directly related to the nutrition of the fish. Therefore, lipids serve as transporters for fat-soluble vitamins (Craig and Helfrich, 2017) [14].

5. Conclusion

From the present study, it was concluded that *Hermetia illucens* larvae meal might substitute fish meal up to 20 % without losses in body weight gain. The growth performance of *Heteroclarias* fingerlings fed the highest level of *Hermetia illucens* larvae meal was the poorest, however, neither signs of nutrient deficiencies, disease symptoms nor higher mortalities were recorded.

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