Int Aquat Res (2016) 8:333–341
DOI 10.1007/s40071-016-0146-x

ORIGINAL RESEARCH

Complete replacement of fish meal by other animal protein sources on growth performance of *Clarias gariepinus* fingerlings

Arnauld S. M. Djissou · Dogbè C. Adjahouinou · Shunsuke Koshio · Emile D. Fiogbe

Received: 9 August 2016 / Accepted: 3 October 2016 / Published online: 12 October 2016

Abstract To completely replace the fish meal by a mixture of earthworm and maggot meals, experimental diets were tested during 42 days on *Clarias gariepinus* fingerlings. Five isoproteic and isoenergetic diets (40 % crude protein and 17.9 ± 0.3 kJ g^{-1}) including the control diet (D1) based on fish meal, were formulated. All these diets satisfied the essential amino acids requirements of *C. gariepinus* fingerlings. These diets were tested on triplicate groups of 50 fishes (initial body weight: 3 ± 0.1 g) bred in tank (0.5 m^3). The approximate ratios 2:5; 1:4; 1:12 and 0:1 between the earthworm meal and the maggot meal were used, respectively, to formulate four diets D2, D3, D4 and D5 without fish meal. After the feeding period, significant differences ($P < 0.05$) were observed on growth, feed utilization between control diet (D1) and test diets (D2–D5). Fish fed earthworm- and maggot-based diets were grown better than those fed the control diet. Survival and feed utilization were not significantly affected by the ratio between earthworm meal and maggot meal in the test diets. Lipid content was higher in carcass and fillet of fishes fed earthworm- and maggot meals-based diets than that of those fed fish meal-based diet. This study indicates that when the ratio 2:5 between the earthworm meal and the maggot meal is used to entirely replace fish meal and the ratio lysine/arginine of the diet is inferior to 1, the growth performances and feed utilization of *Clarias gariepinus* fingerlings are improved.

Keywords Maggot · Earthworm · Growth performance · Feed utilization

Introduction

The nutrition is one of the most important factor to consider in fish farming, because it contributes up to 50 % of fish production costs (Omoruwou and Edema 2011). Nowadays, it is necessary to increase fish production for satisfying the increasingly growing demand of protein. Therefore, fish breeding has been found necessary to increase fish production in order to make fish/protein available to the population. However, one of major constraints facing aquaculture is feeding. The prominence of fish meal in the production of animal feeds cannot be disputed but constitute the highest cost, thereby making the price of the feed to rise exponentially (Olaniyi and Salau 2013). In formulating nutritive diet for fish breeding, fish meal is used as the main dietary

A. S. M. Djissou (✉) · D. C. Adjahouinou · E. D. Fiogbe
Laboratory of Research on Wetlands, LRZH/FAST/University of Abomey-Calavi, Abomey-Calavi, Benin
e-mail: arnauldb52@gmail.com

S. Koshio
Laboratory of Aquatic Animal Nutrition, Kagoshima University, Kagoshima, Japan

protein source because of its nutritional quality and palatability properties (Hardy and Tacon 2002). It is, therefore, very crucial to find an alternative to replace fish meal to reduce fish feeding cost and halieutics resources pressure (Monebi and Ugwumba 2013).

Several studies attempted to substitute fish meal with other plant protein sources such as soybean or cottonseed meals in African catfish and vundu catfish (Imorou Toko et al. 2008), *Lemna minor* in common carp (*Cyprinus carpio*) fry (Yilmaz et al. 2004), *Azolla nilotica* in *Oreochromis niloticus* (Ebrahim et al. 2007) and animal protein sources such as earthworm in *Heterobranchus longifilis* (Sogbesan et al. 2007), Heteroclarias fingerlings (Monebi and Ugwumba 2013), maggot in *Clarias anguillaris* (Madu and Ufodike 2003) and *Clarias gariepinus* (Oyelese 2007), snail, termite, tadpole (Tacon and Metian 2008). In general, these studies showed that total replacement of fish meal leads to the decrease of feed intake, feed efficiency and growth performances. According to Imorou Toko et al. (2008), these results can be generally attributed to the removal of most antinutritional factors by various diets (heating, soaking, enzymes or amino acids supplementation, etc.).

Earthworm (*Eisenia fetida*) and maggot (*Musca domestica*) are animal protein sources with highly nutritive values (Sogbesan et al. 2006; Sogbesan and Ugwumba 2008). Also, they have high digestibility (NRC 2011) and good essential amino acids contents (Adesina 2012). These sources of animal proteins are less expensive and easy to produce using animal manures and/or agro-alimentary wastes (Sogbesan et al. 2006; Djissou et al. 2015). Therefore, they strongly contribute to reduce the cost of feed. The African catfish (*Clarias gariepinus*) is an omnivorous species with carnivorous tendency (Akete 2014), very rustic and appreciated, with strong economic potential and fast growth (Kareem and Ogunremi 2012).

In replacement of the fish meal, the proteinic sources must bring the ten essential amino acids (EAA) required for fishes (Médale et al. 2013). To satisfy the essential amino acids requirements for *Clarias gariepinus* fingerlings, the experimental diets without fish meal based on a mixture of earthworm and maggots (proteinic sources) were tested to determine their performances of growth and feed utilization on these *Clarias gariepinus* fingerlings.

Methods

Culture of the sources of animal protein and fish origin

The production of earthworm and maggots as well as artificial reproduction of *Clarias gariepinus* has been carried out at the experimentation station of the Laboratory of Research on Wetlands (University of Abomey-Calavi, Benin). Earthworms (*Eisenia foetida*) have been produced according to the method of Vodounnou et al. (2016), during 90 days (cycle of production of the earthworms) with ping dung substrate in 18 tanks. In each tank, 4 kg of substrate and 60 g of mature earthworms were sown. Maggots (*Musca domestica*) were produced according to Djissou et al. (2015) method with a mixture of soybean cake and chicken viscera substrate. Therefore, 3 kg of this substrate were put in 12 containers protected against solar rays and rain. Seven cycles of production of 3-4 days have been carried out in order to obtain the necessary quantity for the experimentation.

Earthworm and maggot meals manufacturing: at the end of the production period, the harvested earthworms and maggots were cleanly rinsed in water. Maggots were then boiled for 20 min. These prepared earthworms and maggots were weighed and freeze-dried at 7 °C for 24 h in a lyophilisator (EYELA FDU-2110). They were again weighed after the drying operation, and then milled until to powder form using a milling apparatus. The obtained dried meals were packaged in airtight plastic bag and stored in fridge until use.

Fingerlings of *Clarias gariepinus* with initial body weight of 3 ± 0.1 g were obtained 34 days after artificial reproduction which was implemented according to the method of Ducarme and Micha (2003).

Chemical analyses

The feed ingredients were analysed following AOAC (1990) procedures: crude protein was assessed by the Kjeldahl method after an acid digestion using Kjeltec 2300 Auto Analyser (Tecator Höganas, Sweden). The amino acids of feed ingredients were analysed with a Waters HPLC system (Waters 474, Waters, Milford,

MA, USA) including two pumps (Model 515, Waters), an auto-sampler (Model 717, Waters), a fluorescence detector (Model 474, Waters) and a temperature control module. These amino acids analyses were done following the method previously described by Bosch et al. (2006). Thus, aminobutyric acid was added as an internal standard before hydrolyzation. Amino acids were derivatized with AQC (6-aminoquinolyl-*N*-hydroxysuccinimidyl carbamate) and then separated with a C-18 reverse-phase column Waters Acc. Tag (150 mm × 3.9 mm). All of these analyses were conducted twice per sample in the Laboratory of Aquatic Animal nutrition of Kagoshima University (Japan).

Experimental diets

Based on the composition of essential amino acids and crude protein of the main ingredients used (Table 1), five experimental diets (D1–D5) were formulated varying the ratio (except control diet D1) between earthworm meal and maggot meal (2:5; 1:4; 1:12 and 0:1, respectively) used for full replacement of fish meal (Table 2). Maggots are quantitatively more used in the feed formulation, because they are richer in amino acids than earthworms (Table 1). These ratios were adjusted not only to completely replace the fish meal but also to satisfy essential amino acids requirements of *Clarias gariepinus* fingerlings. The control diet (D1) was formulated with fish meal purchased from Ghana. All the formulated diets were isonitrogenous and isoenergetic (40 % protein and 17.9 ± 0.3 kJ g^{-1}) and approximately balanced in essential amino acids for *Clarias gariepinus* fingerlings requirements. Also, brewer's yeast, collected from Beninese society of brewery of Parakou (Benin), was used as complementary protein source to achieve dietary protein requirements of African catfish fingerlings. On the other hand, local palm oil was used as dietary lipid sources. Diets were manufactured by mixing the dry ingredients as described by Imorou Toko et al. (2007) for *C. gariepinus* fingerlings. The manufactured feeds were stored at 4 °C in airtight plastic bag until distribution.

Experimental procedure

The feeding trial was conducted during 6 weeks in re-circulated system including 15 tanks containing each 0.5 m^3 of water supplied by a drilling and a compressor (FIAC, axair 100L 2CV 10B 230 V) at a flow rate of 3 L min^{-1}. Fifty fingerlings (initial mean weight, IBW: 3 ± 0.1 g) were stocked in each tank. Each dietary treatment was experimented in triplicate. To prevent fish death, each tank was covered at 50 % with a mat for protecting fingerlings against sun rays.

The water quality parameters were monitored twice per week and remained throughout the trial within the acceptable range reported for the rearing of African catfish (Akinwole and Faturoti 2007). These parameters were not significantly different among the experimental tanks and varied from 27.6 to 28.5 °C, 3.93 to 4.48 mg L^{-1} and 4.72 to 5.02 for temperature, dissolved oxygen and pH, respectively.

Table 1 Composition of essential amino acids (EAA) and crude protein (CP) of the main ingredients (g kg^{-1} dry matter)

EAA	Fish meal	Rice bran	Soybean meal	Brewer's yeast	Cottonseed meal	Maize bran	Earthworm meal	Maggot meal
Thr	23.1	0.5	7.6	24	4.5	2.0	17.6	20.9
Val	27.7	1.0	5.6	28	5.0	2.0	13.2	19.1
Mét	19.4	0.0	2.4	8	2.0	0.0	7.6	18.2
Ile	24.5	0.5	5.2	23	25	1.0	11.6	30.5
Leu	37.9	1.0	17.2	35	9.5	6.0	31.2	63.5
Phe	37.4	1.0	13.6	21	11	4.0	18.4	35.3
His	17.5	1.0	6.4	12	7	3.0	13.6	30.1
Trp	5.7	1.4	3.2	7	4	1.0	1.2	31.7
Lys	42.2	1.0	12	38	5	2.5	26.8	42.3
Arg	34.3	2.9	20.4	26.0	21.5	5.0	28.4	60.6
CP	662	48	324	500	303	103	569	584

Table 2 Formulation and composition of experimental diets (g kg^{-1} dry matter)

Ingredients	D1	D2	D3	D4	D5
Fish meal	400	0	0	0	0
Rice bran	50	50	50	50	50
Soybean meal	250	250	250	250	250
Brewer's yeast	0	50	50	50	50
Cottonseed meal	150	150	150	150	150
Maize bran	60	0	0	0	0
Earthworm meal	0	120	80	32	0
Maggot meal	0	305	343	390	421
Palm oil	30	30	30	30	30
Vitamin mix[a]	5	10	10	10	10
Mineral mix[b]	5	10	10	10	10
Starch	50	20	22	23	24
Methionine	0	5	5	5	5
Crude protein	40.0	40.0	40.0	40.0	40.0
Ratio[c]	–	2:5	1:4	1:12	0:1
Gross energy (kJ g^{-1}dry matter)[d]	18.2	18.7	17.9	18.0	17.6
Diet cost ($ kg^{-1})[e]	0.779	0.396	0.391	0.386	0.387

[a] Vitamin premix contains (g 100 g^{-1} of premix): ascorbic acid, 50.0; D-calcium pantothenate, 5.0; choline chloride, 100.0; inositol, 5.0; menadione, 2.0; niacin, 5.0; pyridoxine HCl, 1.0; riboflavin, 3.0; thiamin HCl, 0.5; DL-alpha-tocopherol acetate (250 IU g^{-1}), 8.0; vitamin A acetate (20,000 IU g^{-1}), 5.0; vitamin micro-mix, 10.0; cellulose, 805.5. Vitamin micro-mix contains (g kg^{-1} of micro-mix): biotin, 0.5; cholecalciferol (1 μg = 40 IU), 0.02; folic acid, 1.8; vitamin B_{12}, 0.02; cellulose, 97.66

[b] Mineral premix contains (g kg^{-1} of premix): calcium phosphate (monobasic) monohydrate, 136.0; calcium lactate pentahydrate, 348.49; ferrous sulfate heptahydrate, 5.0; magnesium sulfate heptahydrate, 132.0; potassium phosphate (dibasic), 240.0; sodium phosphate (monobasic) monohydrate, 88.0; sodium chloride, 45.0; aluminum chloride hexahydrate, 0.15; potassium iodide, 0.15; cupric sulfate pentahydrate, 0.50; manganese sulfate monohydrate, 0.70; cobalt chloride hexahydrate, 1.0; zinc sulfate heptahydrate, 3.0; sodium selenite, 0.011

[c] Ratio earthworm meal:maggot meal

[d] Gross energy was calculated on the basis of 23.7 kJ $g^{-1}_{protein}$, 39.5 kJ g^{-1}_{lipid} and 17.2 kJ $g^{-1}_{carbohydrate}$

[e] Prices in $ (USD); 1$ (USD) = 583.54 FCFA (UEMOA), based on 2016 (September) exchange prices. Labour and processing costs were included by adding 20 % of the ingredients costs (Azaza et al. 2006)

Fish were hand-fed three times daily (08.00 AM, 01.00 and 06.00 PM) and during 6 days per week. The daily ration was fixed at 5 % according to reports of Fiogbé and Kestemont (2003). At the seventh day of each week, the total number of surviving fishes in each tank was counted and fish biomass was determined to adjust the daily ration.

Growth performance and feed efficiency

Growth performances and diet nutrient utilization were analysed using the feed conversion ratio (FCR), specific growth rate (SGR), protein efficiency ratio (PER), percentage weight gain (PWG), survival rate (SR) and protein productive value (PPV). These parameters were calculated using the following formulae:

$$\mathrm{FCR} = \frac{\text{Dry matter feed intake (g)}}{\text{Body mass gain (g)}}$$

$$\mathrm{SGR}\ (\%) = 100 \times \frac{(\ln[\mathrm{FBW}] - \ln[\mathrm{IBW}])}{\text{Number of days}},$$

where IBW and FBW are initial body weight and final body weight.

$$\text{PER} = \frac{\text{Wet body mass gain}}{\text{Protein intake}}$$

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

$$\text{PWG}\ (\%) = 100 \times \frac{\text{Mean weight gain}\ (\text{g})}{\text{Initial mean weight}\ (\text{g})}$$

$$\text{PPV} = \frac{\text{Body protein gain}}{\text{Protein intake}}$$

Taking into account that the feed cost depends on the maggots and earthworms meals' content, we calculated the cost of feed required to produce 1 kg of biomass. The economic conversion ratio (ECR) was calculated with the following equation:

$$\text{ECR} = \text{Feed cost} \times \text{FCR}$$

The cost of each experimental feed was determined on the basis of the cost of the ingredients used for its manufacturing.

Statistical analysis

Data obtained from the experiment were subjected to one-way analysis of variance after verifying the normality and the homogeneity of variance using the statistical software Statviews (version 5.01). Least-significant-difference test of Fisher was used to compare differences among individual means. Treatment effects were considered significant at $P < 0.05$

Results

The composition (crude protein and amino acids profile) of ingredients is shown in Table 1. All the experimental diets satisfied the requirements of essential amino acids for African catfish fingerlings except valine in D2 (Table 3). The ratio lysine/arginine was lower than 1 in all the formulated diets except the control diet D1.

The data on growth, survival and feed utilization are presented in Table 4. It is generally noteworthy that earthworm- and maggot-based diets increased, significantly, growth performances of *C. gariepinus* much

Table 3 Calculated amino acid composition of the diets used in the trial (g kg^{-1} of diet)

Essential amino acids	D1	D2	D3	D4	D5	Requirement*
Threonine	17	8	12	13	13	5–5.6
Valine	19	7	11	11	12	7.1–8.4
Methionine	12	9	13	14	14	6–6.4
Isoleucine	18	11	18	18	19	6–7.3
Leucine	29	19	32	33	34	8–9.8
Phenylalanine	25	13	20	21	21	12–14
Histidine	14	9	15	15	16	4–4.2
Tryptophan	5	6	13	14	15	1.2–14
Lysine	34	14	22	23	24	12–14.3
Arginine	30	20	33	34	35	10–12

* Essential amino acid requirements of *Clarias gariepinus* according to NRC (1993, 2011)

Table 4 Growth performance and feed utilization of *C. gariepinus* fingerlings fed with the experimental diets

Parameters	D1	D2	D3	D4	D5
IBW (g)	3.01 ± 0.01	3.01 ± 0.012	3.01 ± 0.01	3.01 ± 0.01	3.01 ± 0.04
FBW (g)	12.49 ± 2.88^{a}	24.66 ± 1.78^{b}	22.02 ± 2.16^{b}	22.12 ± 1.27^{b}	21.03 ± 1.14^{b}
FCR	2.03 ± 0.43^{b}	1.06 ± 0.02^{a}	1.18 ± 0.06^{a}	1.08 ± 0.03^{a}	1.01 ± 0.03^{a}
SGR	3.25 ± 0.53^{a}	4.97 ± 0.17^{b}	4.69 ± 0.23^{b}	4.72 ± 0.14^{b}	4.59 ± 0.13^{b}
PER	1.16 ± 0.16^{a}	2.35 ± 0.03^{b}	2.13 ± 0.11^{b}	2.31 ± 0.06^{b}	2.47 ± 0.06^{b}
SR (%)	93 ± 0.0	95.83 ± 5.46	94.16 ± 8.82	91.66 ± 7.41	97.67 ± 0.83
PWG	413.82 ± 95.22^{a}	819.05 ± 63.04^{b}	731.51 ± 74.59^{b}	732.98 ± 39.78^{b}	696.91 ± 37.31^{b}
PPV	0.32 ± 0.11	0.39 ± 0.06	0.35 ± 0.03	0.34 ± 0.02	0.38 ± 0.05
ECR	1.58 ± 0.04^{b}	0.42 ± 0.03^{a}	0.46 ± 0.01^{a}	0.42 ± 0.02^{a}	0.39 ± 0.03^{a}

Mean ± SD values in the same line followed by the same superscript are not significantly different ($P > 0.05$)

more than control diet. However, it is suitable to notice that the highest earthworm/maggot ratio in the test diet (D2) produced the best fingerlings SGR (4.97 % day^{-1}), and this growth factor decreased proportionally, but not significantly, with the highest ones (D3–D5) until 4.59 % day^{-1} while the diet D1-based fish meal has the lowest SGR (3.25 %). Furthermore, the final mean body weight (FBW) of fishes fed earthworm- and maggot-based diets started to deviate significantly after the third week of rearing from that of fish fed fish meal based diet D1 (Fig. 1).

Growth performances and feed utilization parameters such as SGR, FCR, PER and PPV were not significantly affected ($P > 0.05$) by ratio level among earthworm and maggot meals. But these parameters' values were significantly different ($P < 0.05$) between control diet and test diets except PPV. The proximate composition of the whole fish body is given in Table 5. Protein and lipid contents of the fishes increased significantly for all dietary treatments. However, the highest protein gain was noticed for fishes fed diet 2 while that of lipid gain was produced by diets 2 and 4.

Feed costs decreased significantly with total replacement of fish meal in diets (Table 2). ECR followed the same trend as feed costs, but it did not change significantly with the variation of ratio earthworm/maggot (Table 4).

Discussion

The crude protein percentage of diets tested in this study (40 %) is close to the range of the optimum protein requirement of catfishes (*Clarias gariepinus*, *Heterobranchus bidorsalis* and *Heteroclarias*) which fluctuate among 40 and 42.5 % (Fagbenro et al. 1992; Eyo 1996; Monebi and Ugwumba 2013). Several studies showed that the total replacement of fish meal by maggot or earthworm meal solely results in the reducing growth performances of some catfishes such as *Heterobranchus longifilis* (Sogbesan et al. 2007), Heteroclarias fingerlings (Monebi and Ugwumba 2013), *Clarias anguillaris* (Madu and Ufodike 2003), and *Clarias gariepinus* (Oyelese 2007). Collins et al. (2013) reported that a mixture of the proteic sources in the replacement of fish meal improves the growth performances of fishes. The combination of unconventional animal protein sources as earthworm and maggot with different ratios was used in this study to satisfy in diets, the protein and amino acid requirements of reared *Clarias gariepinus* fingerlings. Furthermore, when the feed

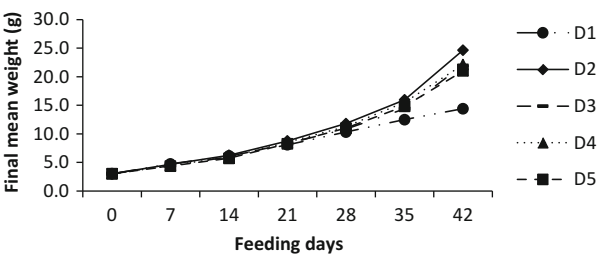

Fig. 1 Growth performance of fish *C. gariepinus* fingerlings fed experimental diets

Table 5 Proximate composition of *C. gariepinus* fingerlings fed experimental diets

Composition (% dry weight)	Initial	D1	D2	D3	D4	D5
Dry matter	23.4 ± 0.3	26.6 ± 0.25	29.7 ± 0.22	28.5 ± 0.77	29 ± 0.83	28.7 ± 0.28
Protein	13.1 ± 0.1	15.2 ± 0.55^{a}	15.9 ± 0.04^{b}	15.3 ± 0.31^{ab}	15.6 ± 0.27^{ab}	15.5 ± 0.09^{ab}
Lipid	4.3 ± 0.13	7.5 ± 0.40^{a}	9.2 ± 0.25^{b}	8.3 ± 0.36^{ab}	9.3 ± 0.5^{b}	7.4 ± 0.16^{a}
Ash	2.9 ± 0.31	3.5 ± 0.23	3.5 ± 0.28	3.1 ± 0.17	3.1 ± 0.07	4 ± 0.15

Mean ± SD values in the same line followed by the same superscript are not significantly different ($P > 0.05$)

contribution in amino acids does not meet perfectly the needs for the animal, nitrogenized catabolism increases contributing to the aquatic environment pollution, the proteinic retention is consequently reduced, and thus, the growth is slowed down (Médale and Kaushik 2009).

The results showed that the total replacement of fish meal by combination of earthworm and maggot meals in *Clarias gariepinus* fingerlings feeding improved their growth performances and feed utilization. The highest growth performances and feed utilization were obtained with the diet 2 containing the highest earthworm/maggot ratio (2:5). Progressive increment in PWG was observed with increasing ratio between earthworm and maggot meals. The fish meal-based diet (D1) produced the lowest growth rate which may be attributed to its low feed efficiency. Moreover, this low growth could be due not only to the quality of the fish meal used but also to the high ratio between lysine and arginine in control diet (D1).

According to Massumotu et al. (1996) and Sogbesan et al. (2006), the biological value of protein source depends on its amino acid profile as well as its digestibility. The good FCR and PER values obtained for *C. gariepinus* fingerlings fed diets devoid of fish meal (D2–D5) are enabled by the unconventional animal protein sources used (earthworms and maggots) which are rich in essential amino acids (Adesina 2012). PER and FCR are also generally related to digestibility of nutrients (Jabir et al. 2012).

Fish survival was not affected by experimental diets. The high survival rates recorded indicate that feeding *C. gariepinus* fingerlings with earthworm- and maggot-based diets could enhance their survivorship. This is made possible because *C. gariepinus* is an omnivorous fish species which used efficiently animal protein source to cover energy requirements (NRC 2011). Moreover, these results indicate that the protein quality of feed formulated with unconventional animal protein source ingredient was well accepted by the fish.

An optimal EAA profile is a requisite for fish growth and nitrogen retention (Luo et al. 2006; Peres and Oliva-Teles 2009). All the experimental diets in the current trial are of high protein quality (Oyelese 2007), because each of them contains all the EAA with values higher than the requirement except valine in diet 2. The difference of growth observed among the dietary treatments can be due to the lysine and methionine rates (1.4 and 0.9, respectively) which were more close to the *C. gariepinus* fingerlings requirements in the diet 2 than in the other diets. As a matter of fact, lysine and methionine are the first limiting EAA in many fish diets (Mai et al. 2006) mainly in those based on unconventional of proteins sources (Médale and Kaushik 2009). Also, lysine is one of the amino acids involved in growth processes (Li et al. 2009) and known to interact antagonistically with arginine (Cabral et al. 2013) by increasing the activity of the arginase and, consequently, arginine requirement (Kestemont 2007). Its low rate in diet 2 (inferior 1) comparatively to the other diets explains, therefore, clearly the best growth performance registered. Likewise, the best growth recorded with diet 2 can also be justified by the rate perfectly within the requirement range of phenylalanine (NRC 1993), an amino acid able to enhance channel catfish growth performance (Garg 2007).

On the other hand, the lowering effect noticed for the earthworm meal/maggot meal ratio of the diets, may be due to the EAA composition of maggot meal which is higher than that of earthworm meal. The increasing incorporation of maggot meal in experimental diets raised, progressively, its EAA composition exceeding the fingerlings requirements.

The results indicate that *C. gariepinus* fingerlings, can effectively utilize diets with combination of earthworm and maggot meals used for the entirely replacement of fish meal, without affected their survivability. The best growth performances and feed utilization were recorded with diets manufactured without fish meal which lysine/arginine ratio was inferior to 1. On the other hand, these diets enabled the reduction of ECR from 70 % (D3) to 75 % (D5) approximately (*versus* control diet D1). This is due to the low production cost of earthworm and maggot meals which is about 61 and 76 % of the cost of fish meal, respectively. Although no

significant difference was noticed among the growth performances and ECR induced by experimental diets (D2–D5), the diet D2 with a ratio 2:5 between earthworm and maggot may be considered the most efficient.

The use of unconventional sources of proteins such as earthworm and maggot reduces the diets cost and improves the production of *C. gariepinus*.

Acknowledgments Financial support was provided by Japan International Cooperation Agency (JICA) through Laboratory of Aquatic Animal Nutrition, Kagoshima University, Japan.

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