British Journal of Applied Science & Technology
5(6): 526-537, 2015, Article no.BJAST.2015.051
ISSN: 2231-0843

SCIENCEDOMAIN *international*
www.sciencedomain.org

Replacement of Fish Meal with Bambara Nut Waste Meal in the Diets of Larval African Catfish *Clarias gariepinus* Burchell (1822)

U. D. Enyidi[1,2*] and B. O. Mgbenka[1]

[1]*Department of Zoology, Fisheries and Hydrobiology Unit, University of Nigeria Nsukka, Enugu State, Nigeria.*
[2]*Department of Fisheries and Aquatic Resources Management, Michael Okpara University of Agriculture Umudike, Umuahia Abia State, Nigeria.*

Authors' contributions

This work was carried out in collaboration between all authors. Author BOM designed the study. Author UDE performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript and managed literature searches. Author UDE managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/BJAST/2015/12886
Editor(s):
(1) Katselis George, Dep. Aquaculture & Fishery Management, Technological Educational Instituation of Messolonghi, Greece.
(2) Antonino Nizza, Faculty of Veterinary Medicine, University of Naploli-Federico II, Via F. Delpino, Naples, Italy.
Reviewers:
(1) Anonymous, West Pomeranian University of Technology, Szczecin; Poland.
(2) Anonymous, National Institute of Oceanography and Fisheries, Gulfs of Suez, Egypt.
(3) Anonymous, Universidade Estadual de Ponta Grossa, Brazil.
(4) Anonymous, Universidad Nacional del Nordeste, (UNNE), Sargento Cabral 2139, Corrientes, Argentina.
Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=763&id=5&aid=6899

Original Research Article

Received 22nd July 2014
Accepted 16th October 2014
Published 13th November 2014

ABSTRACT

Background: High cost of fishmeal (FM) adversely affects growth performance of African catfish fingerlings. There is need for alternative ingredients from affordable and available sources like plant proteins to meet growing feed demands in the larviculture of African catfish. Bambara nut waste meal (BNWM) is a proteinous, cheap and abundant, byproduct usually discarded or used to feed domestic chicken in Africa.
Aims: To substitute fishmeal (FM) with bambara nut waste meal (BNWM) in five novel diet of larval African catfish *Clarias gariepinus* average weight 1.850±0.79 g and examine their growth and nutritional performances.
Place and Duration: The experiment was carried out at the Fisheries and Hybrobiology, research

**Corresponding author: E-mail: adoption2009e@gmail.com;*

unit department of Zoology University of Nigeria Nsukka between Nov.29 and 30 of December.
Methodology: We substituted BNWM:FM per diet as follows; feed 1, (F1), 94:0%; feed 2, (F2), 89:5%; feed 3, (F3), 74:20%; feed 4, (F4), 59:35%; and feed 5, (F5), 39:55%. Other ingredients were vitamin premix, vitamin C and palm oil. Catfish larvae of average weight 1.850±0.79, stocked at 15 larvae aquarium^{-1} were fed with the experimental diets (F1-F5) for 30d.
Results: African catfish larvae grew with optimal SGR of 8.2% day^{-1} for those fed with 39BNWM:55FM, F5 and 7.2% day^{-1} for those fed with 59BNWM:35FM, F4. The catfish fed with F1 94BNWM:0FM, and F2, 89BNWM:5FM, had lowest but similar SGR 5.0 and 5.3% day^{-1} respectively. Food conversion ratio (FCR) were similar for larvae fed with F5, F4 and F3 (P>0.05). Similarly FCR were similar for larvae fed with F1 and F2 (P>0.05). The weight gains of the larvae were best and similar for those fed 39BNWM:55FM, F5 (5.0 g) and F4 59BNWM:35FM, (4.5 g), but better than those fed 74BNWM:20FM, F3 (3.5 g). Those fed with F1 had least weight gain of (2.2 g). The protein efficiency ratio (PER) increased with FM inclusion but similar for catfish fed F5 6.78±0.02 and F4 6.33±0.05. The catfish PER was lowest for those fed all plant protein diet F1 94BNWM:0FM, PER, 3.97±0.04.3. Cost of feed increased with FM inclusion and fishmeal ratio (FMR) was highest for F5.
Conclusion: The study shows that BNWM can supplement FM up to 59% in diets of African catfish. The lack of significant differences between FCR and SGR of catfish fed 39BNWM:55FM, F5 and F4 59BNWM:35FM is indicative of cost saving and benefits of BNWM. It shows that BNWM which is discarded in mills is a valuable resource that holds profitable potential in aquafeed production.

Keywords: Specific growth rate; feed conversion ratio; bambara nut waste meal; fishmeal.

1. INTRODUCTION

African catfish is omnivorous and possesses fast growth, hardiness and high fecundity and commands good market prices [1,2]. Despite the boom in culturing African catfish, the production of fingerlings still remains a problem. Fingerling production in sub Saharan Africa is hampered by high cost of feed and cost of imported live feed like artemia. The cost of fishmeal is responsible for high cost of fish feed [3,4]. Generally growth and intensification of aquaculture production also depends on development of sustainable protein source, to replace fish meal in aqua feed like plant protein [3,5].

One of the major problems of culturing African catfish is the high cost of imported feed and lack of adequate and nutritious local fish feed due to cost of fish meal [6,7]. Poor feed production impacts negatively on fingerling production which reduces number of fish seed used for restocking. The availability of fingerlings produced under controlled conditions, making use of natural as well as high protein diet is hampered in Africa by the cost of feed and artemia [2,8].

Artemia is the most commonly used live feed for African catfish larvae but artemia is relatively costly in developing countries [9,10]. The requirement for live feed for *C. gariepinus* appears to have a short duration. Species can be weaned unto dry feed at a relatively early stage [11,12]. The inability of *C. gariepnus* to utilize dry feed effectively has been attributed to lack of functional stomach at start of exogenous feeding [11,13,14]. The age of the catfish larvae is determinant of its ability to utilize exogenous diets. However, [13] noted that in ontogeny *C. gariepinus*, the connection between the esophagus, the intestine and the anus opened at 144 hours post fertilization (h-PF). Complete eye differentiations took place 164 h-PF. Eye differentiation was concomitant with first feeding suggesting a key role of visual senses in feeding behavior of African catfish [13]. The first feeding period is also critical period marked with mortalities [15].

Larviculture of African catfish therefore needs live food at least for the first four days of exogenous feeding after which they can be weaned to dry diets [10]. The dry feed must then be nutritious and acceptable to African catfish [16,17]. The organoleptic qualities of the feeds must be enhanced through inclusion of ingredients like fishmeal to enhance acceptability.

The cost of fishmeal makes sourcing of alternative proteins imperative to sustain the increasing culture of African catfish [16,18]. There had been many alternatives like Soybean meal [19], Palm fruit and bambara nut [4], groundnut cake [20], sesame seed meal [21], and cotton seed meal, [18]. Most of these analyses on alternative feeds ingredients were tested on fingerling stages of African catfish and not larval or post larval. There is paucity of articles on the effects of fishmeal supplementation on the growth and survival of larval African catfish example [20,14,22].

High protein diet is very essential for growth and survival of early juveniles of *C. gariepinus*. Live feed like artemia and fish meal component of dry diets are both costly to the average fish farmer in Sub-Saharan Africa. There is need for the use of agro by products in fish feed production. This will reduce cost of production and enhance availability of feeds. Bambara nut waste meal (BNWM) is a byproduct of bambara nut flour production. Nigeria is a major producer of bambara nut which is also produced abundantly across the tropical world. Bambara nut is cheap, easily obtainable and the waste meal is either thrown away or sold at cheap prices. The protein content was reported to be about 24.14% [17,23] and carbohydrate content was estimated at 60% [22]. Bambara nut seed is also richer in essential dietary amino acids like lysine and methionine that is lacking in other known legumes.

This paper examines the effects of addition of varying inclusion levels of bambara nut meal and fish meal in feeding *C. gariepinus* larvae.

2. MATERIALS AND METHODS

2.1 Eperimental Design and Set Up

Complete randomized design (CRD) was used in this experiment. There were three replicate aquaria for each treatment feeds. Five treatment feed were made and feed 1 (F1) which had no fish meal was used as control. The catfish were stocked at density of 15 fish aquaria^{-1} which was also the observational units. This experiment was conducted in rectangular glass aquaria, of dimensions; length, 84cm, width, 40cm and depth 40cm. Aquaria were randomly arranged to receive similar treatment and be homogenous.

2.2 Aquarium and Water Quality Management

Aquaria were washed and half filled with water and aerated for 24 hrs before the introduction of fish. There was constant changing of water on a daily basis to remove uneaten food and to maintain hygiene. Rubber siphon was used in removal and introduction of the water. Water was supplied by University of Nigeria Nsukka water works. The supplied water was allowed to settle in a basin and exposed to the air for at least one hour. This was to make sure that harmful anions or cations like iron oxides that may be in are oxidized.

2.3 *Clarias gariepinus* Larvae

Larvae of *C. gariepinus* used for the experiments were obtained from African regional aquaculture center Aluu in Port Harcourt. The larvae were transported in oxygen bags and cold water bath, from Port Harcourt to our wet lab at Nsukka. The journey was done in the evening to avoid stress of hot weather. On arrival at Nsukka the larvae were allowed to rest for an hour and there was serial mixing of the aquaria water and water from oxygen bags. Approximately quarter liter of water from the aquaria was mixed with the oxygen bag water at intervals of 30 min. Then the larvae were allowed to swim freely, on their own into the aquaria. The stocking density of the larvae was 15 larvae per aquaria.

2.4 Weighing and Measurement of Larvae

The larvae were collectively weighed and average weight was taken on a weekly basis. Weight measurements of the catfish were taken per treatment replicate. There were three replicate per treatment feed in this research. Weighing balance sensitive to 0.01 g was used. Weighing of fish were done in the morning hour from 06-07 hours GMT.

2.5 Feed Preparation

Bambara nut were obtained from the open market at Nsukka Enugu state milled and sieved. The initial endosperm was removed and the remaining used for feed production. Feed composition was calculated using square method [24,25,26]. Specific weight of ingredients as shown in Table 1 were measured and mixed with a Kenwood chef mixer for 30 minutes. In the process of mixing, 150 mls of water was added to each of the feed type. Mixed dough was condition by pressure cooking for 35 min.

Vitamin C and vitamin premixes were added and the dough was pulverized using 3 mm Kenwood meat mincer. The pellets were dried at 40ºC for 24 h in an oven and then refrigerated till needed.

The proximate analyses of the diets and of BNWM were done according to methods in [27].

2.6 Experimental Feeding of Larvae

The feed was ground to powder and a little water was added to the feed to make a paste. This was due to the size of fry. Feeding was done at 5% of fish body weight. Larvae were fed twice daily in the mornings 08-09 hours and evenings, 17.00-1800 hours. Feeding was usually in the morning immediately after cleaning up the aquaria.

2.7 Fish Growth and Nutritional Parameters

Specific Growth rate (SGR) was calculated as follows:

SGR % day^{-1} = 100* (Ln final weight (g)– initial weight (g)) * Period in $days^{-1}$
Weight gain (g) (AWG) = Final body weight - Initial body weight $*3^{-1}$
Feed conversion ratio (FCR) = Feed fed (g) (dry weight)* Live weight gain $(g)^{-1}$
Protein efficiency ratio (PER) = Final wt –initial wt/fed protein
Fishmeal ratio (FMR) = FCR*(%FM in diet/100) [28].

2.8 Data Analysis

One way ANOVA was used in calculating treatment and block effects and Fishers least. Significant difference ($FLSD_{0.05}$) was used in separating treatment means. Analysis were done with Spss statistical package v.14.

3. RESULTS

A summary of the result of the experiment is presented in Table 2.

3.1 *Clarias gariepinus*

The larvae of *C. gariepinus* readily accepted prepared feed. There was no observed preference in larval acceptance of feed irrespective of treatment feed. The catfish larvae were affected by temperature drop Table 3 which was as a result of the harmattan season. Low temperature resulted in late and reduced feeding and lower growth rate. There was no case of mortality throughout the period of the experiment.

Table 1. Composition and proximate composition of experimental diets varying in FM and BNWM, used in feeding larval African catfish for 30d

Ingredient	Feed 1	Feed 2	Feed 3	Feed 4	Feed 5
Fishmeal	0	5	20	35	55
Bambara nut meal	94	89	74	59	39
Vit & Min premix	3.8	3.8	3.8	3.8	3.8
Vit. C	0.2	0.2	0.2	0.2	0.2
Palm oil	2	2	2	2	2
Total	100	100	100	100	100
Proximate analyses					
Crude protein	17.9	19.9	26.1	31.5	40.4
Crude fat	4.0	4.3	6.1	6.3	8.4
Crude fiber	7.0	6.9	6.2	6.4	5
Moisture	10.2	10.5	11	10.1	12
Ash	4	4	4.7	4.3	6.4

Proximate analyses of bambara nut waste meal BNWM	
Crude protein	21.92
Lipid	7.16
Crude fiber	3.78
Dry matter	90.76
Moisture	9.24
Ash	4.54
Phytate	0.84

Vit. A, 4800, 000 I.U.D, vit. D, 800,000 I.U, vit.E, 12,000 I.U.D, vit. E, 12,000 I.U.D, vit. K, 0.80g, vit. B1, 0.04g, vit. B2, 1.20g, vit. B12, 8.0g, vit.C, 100g, Folic acid, 0.80g, Biotin, 0.06g, Choline Chloride,80.0g, manganese,10.0g, Iron, 50.0g, Copper, 10.0g, Iodine, 0.30g, Cobalt, 0.3g,Selenium 0.4g

3.2 Water Quality

The average dissolved oxygen content of the water was 6.8±03 mgl^{-1}. Temperature fluctuations were within 21 to 30 degrees. Temperature reading is recorded in Table 3, water exchange was regularly maintained to ensure good water quality. Aquaria were aerated regularly maintaining the dissolved oxygen level.

3.3 Specific Growth Rate (SGR)

The catfish larvae grew with increasing inclusion level of FM. However there was negative correlation between increasing percentage inclusion of BNWM and SGR of the fish R^2=0.98, P=0.009 Fig. 1. The larvae fed with feed five (F5, 39BNWM:55FM) had the highest SGR of 8.2 % day^{-1} followed by those fed with feed four (F4, 59BNWM:35FM) with SGR of 7.2% day^{-1}. There was 1% difference in the SGR of catfish fed with F4 and F5, although this was very close it statistically showed some significant difference (P,<0.05). FLSD $_{0.05}$ 0.71. The SGR of larvae fed with F3, (74BNWM:20FM) was 6.0% day^{-1}, and this was significantly different from those of F5 and F4 (P<0.05). The lowest catfish SGRs, was recorded for the larvae fed with feeds 1 (F1, 94BNWM:0FM) 5.0±0.4% day^{-1}, and feed 2 (F2, 89BNWM:5FM)), 5.3±0.5% day^{-1} respectively. There was however no significant difference (P>0.05) in the SGR of F1 and F2 larvae. The SGR of the larvae are presented in Table 2.

3.4 Feed Conversion Ratio (FCR)

The FCR of larval catfish did significantly reduce with increase in inclusion of FM. There was however a positive correlation between the feed conversion ratio and the percentage inclusion of BNWM $R^2$0.85, P=0.007 Fig. 2. Catfish FCR increased with increasing BNWM inclusion from 1.1±0.2 at F5 (39BNWM:55FM) to 4.6±0.3 at F1 (94BNWM:0FM). The FCR of catfish fed with F5 were not significantly different from those fed with feed 4, F4. (59BNWM:35FM) (1.4±0.6) P>0.05. Feed 3 F3, (74BNWM:20FM) produced FCR that was similar to that of F5 and F4 but better than F1 (94BNWM:FM) and F2 (89BNWM:5FM) P<0.05 Table 2. The larval FCR seems to be affected more by high inclusion levels of BNWM than FM. The larval feed conversion ratios were also adversely affected by change in water temperature. By observation we noted during the experimental period that catfish larvae accepted less feed and therefore had lower feed intake during low temperature periods (early morning hours of week two) of experiment Table 3. In week two of the experiment water temperature fell as low as 21±0.01º, due to harmattan period in Nsukka around December period of the experiment.

3.5 Weight Gain

From the initial average weight of 1.85±0.79 g the catfish had optimal weight gain of 5.00±0.4 g when fed with diets F5 (39BNWM:55FM). The AWG was reduced to 4.54±0.2 when the amount of BNWM in the diet was increased to 59BNWM:35FM) Feed 4. There was however no significant difference between the AWG of catfish fed with F5 and those fed F4 (P>0.05). Further percentage increment of BNWM in the catfish diet to 74BNWM:20FM, (F3) significantly reduced AWG to 3.53±0.3 g. There was significant difference (P<0.05) in the AWG of F3, F4 and F5. Increasing inclusion of the BNM from 74% (F3) to 89% (89BNWM:5FM) (F2) and 94% (94BNWM:0FM) (F1) led to further reduction in weight gain of the larval catfish from 3.53 g (F3), to 2.83 g (F2) and 2.23 g (F1). There was no significant difference in the AWG of F2 fed catfish and those on F1 (P>0.05) Table 2. We noted a negative correlation between the percentage inclusion of BNWM and AWG of the fish, R^2 0.91, P=0.008, Fig. 3.

Table 2. Average weight gain (g),(AWG), Specific growth rate % day-1(SGR),Feed conversion ratio (FCR), Protein efficiency ratio (PER) and Fishmeal ratio (FMR) of African catfish frys average weight 1.85±0.79 g fed with diets varying BNWM and FM for 30d

FEED	AWG	SGR	FCR	PER	FMR
F 1 (94:0)	2.23±0.5^{c}	5.0±0.4^{d}	4.6±0.3^{b}	3.97±0.4^{a}	0.00±0.4^{d}
F 2 (89:5)	2.83±0.1^{bc}	5.3±0.5 ^{d}	4.5±0.1^{b}	4.58±0.03^{b}	0.23±0.3^{c}
F3 (74:20)	3.53±0.3^{b}	6.0±0.3^{c}	1.6±0.6^{a}	5.31±0.07^{c}	0.32±0.1^{b}
F4 (59:35)	4.54±0.2^{a}	7.2±0.2^{b}	1.4±0.3^{a}	6.33±0.05^{a}	0.49±0.5^{b}
F5 (39:55)	5.00±0.4^{a}	8.2±0.5^{a}	1.1±0.2^{a}	6.78±0.02^{a}	0.61±0.6^{a}
FLSD$_{-0.05}$	0.77	0.71	1.87	0.54	0.09

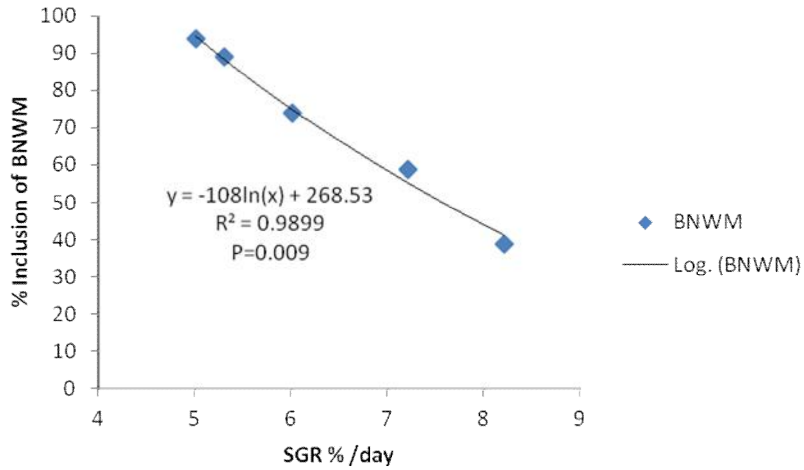

Fig. 1. Relationship of percentage inclusion of bambaranut waste meal with specific growth rate of African catfish fry fed with diets varying in inclusion of BNWM and fishmeal (FM) for 30d

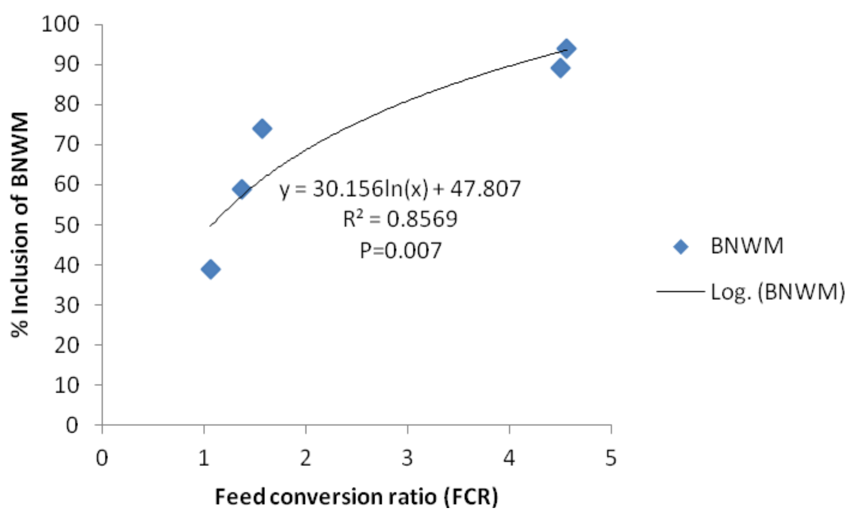

Fig. 2. Relationships between percentage inclusion of bambaranut waste meal (BNWM) and feed conversion ratio (FCR) of African catfish fed with diets varying in inclusion of BNWM and fishmeal for 30d

Table 3. Average weekly water temperature variations during harmattan season of catfish culture. Catfish were fed FM /BNWM diets for 30d

	Period	F1	F2	F3	F4	F5
Week 1	Morning	25±0.2	25±0.5	24±0.4	26±0.1	29±0.4
	Afternoon	27±0.6	27±0.7	29±0.4	29±0.4	31±0.6
Week 2	Morning	23±0.8	21±0.4	22±0.9	23±0.5	23±0.3
	Afternoon	22±0.6	22±0.9	24±0.5	23±0.2	24±0.6
Week 3	Morning	22±0.5	23±0.7	23±0.6	24±0.1	25±0.8
	Afternoon	22±0.8	22±0.6	23±0.4	23±0.4	24±0.6
Week 4	Morning	26±0.3	26±0.3	25±0.6	27±0.6	28±0.5
	Afternoon	28±0.6	28±0.4	30±0.7	31±0.3	32±0.7

3.6 Protein Efficiency Ratio (PER)

There was negative correlation between percentage inclusion of BNWM and the protein efficiency ratio (PER) of the catfish R^2=0.93, P=0.009 Fig. 4. The consistent increase in PER with reduced inclusion of BNWM and higher FM is similar to results of AWG. However the best PER were for the catfish fed with F5, 39% BNWM (39BNWM:55FM) PER, 6.78±0.02 and those fed 59% BNWM (59BNWM:35FM) F4 PER, 6.33±0.05. There was no significant difference (P>0.05) between PER of catfish fed with either F5 or F4. Increasing the amount of BNWM in the diet from 59% of F4 to 74% BNWM (74BNWM:20FM) F3, reduced the PER to 5.31±0.07. The PER of catfish fed with F3 was significantly lower those fed with F5 and F4. (P<,0.05) but better than F2 (89BNWM:5FM) (P<0.05). Feeding the catfish with 100% plant protein diet F1 (BNWM94:FM0) gave the lowest PER of 3.97±0.4.

3.7 Fishmeal Ratio (FMR)

Fishmeal ratio measures the quantity of fishmeal in diet needed to produce 1kg of the fish. There was steady increase in FMR with increasing inclusion of FM in the diets. However for the catfish fed with F5, 39% BNWM (39BNWM:55FM) results showed that 0.61±0.6 kg of FM will be needed to produce 1kg of fish flesh. The catfish fed with F4 59% BNWM (59BNWM:35FM) would require 0.49±0.5 kg to produce 1 kg of the fish flesh, which was significantly lower than F5 (P<0.05). The FMR increased with increasing inclusion of FM. The catfish fed with F3, 74% BNWM (74BNWM:20FM), required almost 50% of the FM requirement of those fed with F5, 0.32 kg to produce 1kg of the fish Table 2. Feed 2 89% BNWM:5%FM had the lowest FMR 0.23±0.3 kg.

3.8 Temperature

The diurnal temperature variations in the experiment were measured with minimum and maximum thermometer inserted into the aquaria. There were notable temperature fluctuations during the second and third week of the experiment. Catfish was adversely affected in the second and; part of third week of experiment. The lowest temperature range measured was 21º-23ºC in week 2 and 22º-25ºC recorded in week 3 of the experiment Table 3. The temperature effects were noted especially in the early hours of the morning. The fish were observed not very active in feeding during feeding hours however as the day went on temperature usually increased during afternoon time marked with increased activities like feeding. This research was carried out during harmattan period in Nigeria marked with cold morning hour temperature. Moreover the experimental set up was under a roofed house without walls within the fish farm. This exposed the set up to environmental changes in temperature and not room temperature.

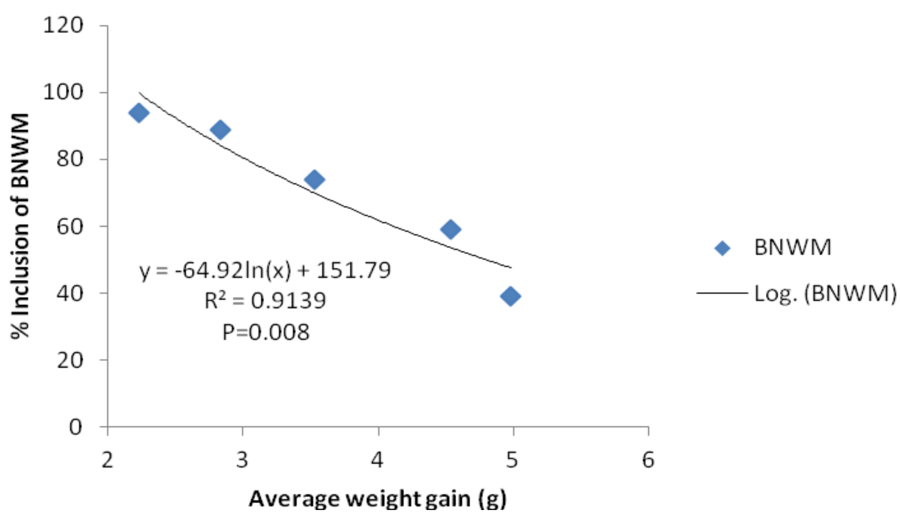

Fig. 3. Relationship of percentage inclusion of bambara nut waste meal (BNWM) with average weight gain of African catfish fry, fed with diets varying in inclusion levels of BNWM and fishmeal (FM) for 30d

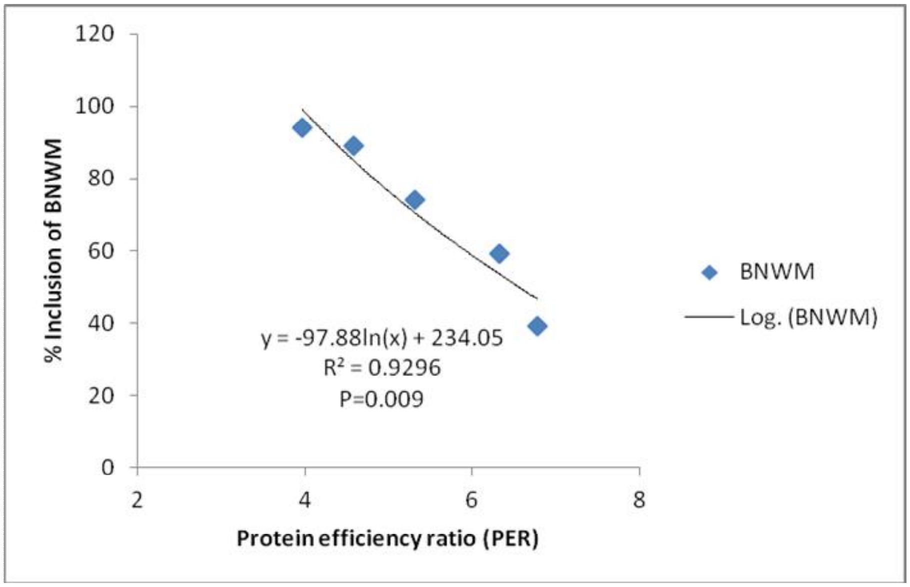

Fig. 4. Relationship of percentage inclusion of bambara nut waste meal (BNWM) with protein efficiency ratio (PER) of African catfish fry, fed with diets varying in inclusion levels of BNWM and fishmeal (FM) for 30d

The highest temperature ranges were 25ºC-29ºC for week 1 and 26ºC -28ºC for the 4th week of the experiment. Temperature fluctuation affected fish welfare and feeding period of the catfish larvae. During the low temperature fluctuations of second and third week larvae were not accepting feed during early morning hours 08 hr, as they were doing in previous week. Feeding rate was reduced with reduction in temperature.

4. DISCUSSION

Larval African catfish growth rate was affected more by increasing inclusion levels of the BNWM than FM. Although the catfish grew with good SGR there was negative correlation noted between SGR and percentage inclusion of BNWM. This could be due to several factors like reduced amino and fatty acid. Reduction in dietary Lc-3 PUFA had been noted in aqua diets where FM was substituted with plant proteins. The fatty acid of African catfish is based on the dietary fatty acids [29]. There could be reduced growth rate of fish if fish oil or other essential oil are not included in diet formulation. However our experimental diets contained palm oil which has been noted good for African catfish [29]. Palm oil has some linoleic acid and also linolenic acid [27,29]. Fish generally needs some linolenic acid in their diets [30,27]. African catfish is known to naturally feed on palm fruits [20,22]. Bambara nut waste meal is not an oil source and needs fortification with oil due to its low oil content Table 1.

Although the combination of F5 (55FM:39BNWM) seems optimal in terms of SGR (8.2% day^{-1}), the SGR of catfish fed with F4, (59BNWM:35FM) (7.2% day^{-1}) was comparably close with 1% day^{-1} tradeoff. Growth reduction was not up to 5% when BNWM was increased from 39% to 59%, but was about 10% at 74% BNWM inclusion F3. The performance of the catfish fed with F4 suggests that African catfish larvae may not need up to 55% FM in their diets. More so there were no significant differences in the weight gains and length gains of the catfish irrespective of whether they were fed with F5, F4 or F3.

The increase in FCR of the catfish larvae fed with higher than 39% BNWM inclusion levels suggests effects of reduced amino acids from FM. It could as well be due to higher amount of Anti nutritional factors like phytic acid. Proximate analyses in this research showed that BNWM has Phytate content of 0.84 kg^{-1}. Increasing BNWM increased carbohydrate content of the ingredient. However there was no significant difference in the FCR of catfish fed F5, F4 and F3. This seems to also show that the catfish larvae utilized the BNWM efficiently well. African catfish is known to utilize carbohydrates in feeds [1,24]. Bambara nut meal has 50%

carbohydrates [17] and 30% neutral sugar majorly glucose and galactose [24].

Although the catfish utilize BNWM effectively it was evident that inclusion level more than 74% reduced growth rate considerably. The poor performances of the fish fed with F2 and F1 were evident that BNWM should not be used alone in the diets of larval African catfish. Complete substitution of FM with BNWM reduced larval growth rate from 8.2% day^{-1} of F5, to 5% day^{-1} of F1. The inclusion of 5% FM in F2 could not significantly increase growth rate. This suggests that catfish larvae assimilated more nutrients from BNWM due to its higher inclusion level than FM. This was earlier reported by [16] for first feeding African catfish fed with diets substituting FM with BNM and corn meal. Although BNM contained essential amino acids like methionine and cystine, complete substitution of FM causes lack of other amino acids which could have been supplied by FM. Evidently, poor growth of fish fed with F1 and F2 could be as result of the poor amino acid profile of the diets. The poor growth could also be as result of nutritional poor amino acid profile of the diets. Nevertheless, poor array of essential amino in diets could lead to proteins catabolic processes and hence poor growth. Amino acids had been noted to be catabolic substrate in first feeding fish larvae [31].

The result of this experiment is in line with [2], who noted high SGR and weight gain in *C. gariepinus* fish fed 50% FM diets It is also in line with earlier works of [32,31] who found 50% inclusion of fish meal optimal in fish feed of swim up fry's of channel catfish.

It may not be economical to produce 55% FM diet in sub- Sahara Africa due to the cost. The fed cost 0.26USD $kg^{-1}$for F5 will be costly for fish farmers especially in the sub-Saharan Africa. The cost of production of feed F3, 74% BNWM and F4, 59% BNWM diet feed 4 was cheaper than F5. The difference could attract farmer's patronage and could provide alternative to F5. The growth and nutritional effects of F3 is also in line with earlier work of [33], who found 20% fishmeal inclusion with soybean producing optimal weight gain in catfish. The result on the FMR shows that the catfish production was driven by the inclusions of the FM than by BNWM. Consequently the cost of producing 1kg of the fish was consistently higher with FM inclusion. This underscores the need for the substitution with BNWM. There was almost 20% reduction in the FMR of the fish when F4 was used in feeding the fish instead of F5. This could have serious economic impact in industrial production. The fact that there were no significant differences in the SGR of the fish fed F5 and F4 shows that it was not necessary to feed with 55% FM. A look at the cost of F5 and F4 Table 4 shows that about 0.06USD is saved per kg diet produced. This could be of some economic importance in producing fish feed industrially.

Table 4. Cost of producing experimental diets kg^{-1} used in feeding larval catfish

Feed	Cost USD	Cost nigeria naira
F1	0.12 USD	20.90^{d}
F2	0.13 USD	23.15^{d}
F3	0.17 USD	29.90^{c}
F4	0.21 USD	36.65^{b}
F5	0.26 USD	45.65^{a}

The results on temperature effects highlights' importance of temperature in African catfish larviculture. The experiment was carried out in research facility that was partially outdoor since there were no wall round the house canopy and experiment was carried out under real environmental temperature and pressure. The exposure of the aquaria to direct environmental contact made the fish directly vulnerable to direct weather changes. Most catfish experiments in Nigeria are done in indoor facilities; this does not reflect the true effect of temperature in natural settings in the farms. This research gives a true picture of conditions and welfare of the catfish under normal Nigerian rearing settings. Since most of the farms are neither indoor or recirculatory systems, catfish larvae are usually stocked in ponds outside under natural weather conditions, therefore facing vagaries of the climate. Since the replicates tanks were randomly distributed the effects was similar for all treatment. However, low temperature ranges of the aquarium water in week 2, of the experiment were 21±0.01ºC to 23±0.01ºC (due to the harmattan season). Low temperature ranges <23ºC reduces growth rate of African catfish. Optimal temperature range for raising of African catfish larvae is 30ºC [34]. Catfish larvae that were reared entirely at 22ºC showed more size variation than those on higher temperatures. Size variation results from differential feed intake as a result of the low temperature regime. This is in line with findings in this research. The temperature effects in the feeding of catfish noted in this experiment could explain poor harvest of fingerlings of African catfish reared during the harmattan periods in Nigeria and other sub Saharan regions. There are not much work on the environmental effects of larviculture of African catfish. The increase in rearing temperature from week 3 to 4 of the experiment however increased growth rate. This is in line with [11], who noted that temperature is most important abiotic variable affecting growth and early juvenile of siluroides, and also [22] who noted similar temperature effects on hybrids of *C. gariepinus* and *H. bidorsalis.* For most siluroide species the optimal culture temperature range for larvae and early juveniles was 26ºC-30ºC [11].

5. CONCLUSION

BNWM can supplement up to 59% of FM in the diets of larval African catfish. The lack of significant differences between FCR and SGR of catfish fed with F5 and F4 shows that BNWM supported catfish high growth rate even at almost 50% reduction in amount of fishmeal. BNWM which is discarded in mills is a valuable resource that holds profitable potential aquafeed production. BNWM is a plausible alternative to FM in larval diets but should not be used alone. The cost of production and protein conversion ratio and fish meal ratio favors production of F4 and F3 diets more than F5. The results on phytic acid content and low lipid level of the BNWM shows that BNWM should not be used all alone. More researches are also needed on the adults or grow out stages to elucidate its effects on the grow out stage and brooder.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ali MZ, Jauncey K. Approaches to optimizing dietary protein to energy ratio for African catfish *Clarias gariepinus* (Burchell, 1822). Aquaculture Nutrition. 2005;11:95-101. DOI:10.1111/j.1365-2095.2004.00325.
2. Nyina-Wamwiza L, Wathelet B, Kestemont P. Potential of local agricultural by-product for the rearing of African catfish *Clarias gariepinus* in Rwanda. Effects on growth feed utilization and body composition. Aquaculture Research. 2007;38:206-214. DOI: 10.1111/j.1365-2109.2007.01658.x.
3. Hardy RW. Utilization of plant proteins in fish diet: Effects of global demand and supplies of fishmeal. Aquaculture Research. 2010;41:770-776.
4. Viola S, Mokady U, Rappaport U, Arieh Y. Partial and complete replacement of fish meal by soybean meal in fish feed for intensive culture of carp. Aquaculture. 1982;26:223-236.
   Available: http://dx.doi.org/10.1016/0044-8486(82)90158-2.
5. Gatlin DM, Frederic TB, Brown P, Dabrowski K, Hardy RW, Wurtele E. Expanding utilization of sustainable plant products in aqua feed: A review. Aquaculture Research. 2007;38:551-579. DOI: 10.1111/j.1365-2109.2007.01704.x
6. Hecht T. Review of feeds and fertilizers for sustainable aquaculture development in sub-Saharan Africa. In M.R. Hasan, T. Hecht, S.S. De Silva & A.G.J. Tacon, eds. Study and analysis of feeds and fertilizers for sustainable aquaculture development. FAO Fisheries Technical Paper No. 497, Rome, FAO. 2007;77–110.
7. Ayinla OA. Analysis of feeds and fertilizers for sustainable aquaculture development in Nigeria. In M.R. Hasan, T. Hecht, S.S. De Silva & A.G.J. Tacon, eds. Study and analysis of feeds and fertilizers for sustainable aquaculture development, FAO Fisheries Technical Paper No. 497, Rome, FAO. 2007;453–470.
8. Nwadukwe FO, Nawa IG. Effects of rearing period on the production of hybrid catfish (*Clarias gariepinus* X *Heterobranchus longifillis*) fingerlings. Journal of Aquatic Sciences. 2000;15:23-26.
9. Santiago CB, Gonzal AC, Ricci M, Harpaz S. Response of bighead carp *Aristichthys nobilis* and Asian catfish *Clarias macrocephalus* larvae to free-living nematode *Panagrellus redivivus* as alternative feed. Journal of Applied Ichthyology. 2003;19:239-243. DOI: 10.1046/j.1439-0426.2003.00454.x
10. Evangelista AD, Fortes NR, Santiago CB. Composition of some live organisms and artificial diet as feed for Asian catfish *Clarias macrocephalus* (Gunther) larvae. Journal of Applied Ichthyology. 2005;21:437-443. DOI:10.1111/j.1439-0426.2005.00643.x.
11. Hecht T. An alternative life history approach to the nutrition and feeding of

Siluroidae larvae and early juvenile. Aquatic Living Resources. 1996;9:121-133.

12. Faruque MM, Ahmed KMD, Quddus MMA. Use of live food and artificial diet supply for the growth and survival of African catfish (*Clarias gariepinus*) larvae. World Journal of Zoology. 2010;5:82-89.
13. Dabrowski K, Culver D. The physiology of larval fish. Aquaculture Magazine. 1991;17:49-61.
14. Osman AGM, Wuertz S, Mekkawy AI, Verreth J, Kirschbaum K. Early development of African catfish *Clarias gariepinus* (Burchell 1822), focusing on the ontogeny of selected organs. Journal of Applied Ichthyology. 2008;24:187-195. DOI: 10.1111/j.1439-0426.2007.01018.x.
15. Ronnestad I, Thorsen A, Finn RN. Fish larval nutrition: A review of recent advances in the role of amino acids. Aquaculture. 1999;177:201-216.
16. Enyidi U, Kiljunen M, Jones R, Vielma J, Pirhonen J. Nutrient assimilation by first-feeding African catfish (*Clarias gariepinus*) assessed using stable isotope analysis. Journal of the World Aquaculture Society, 2013;44:161-172. DOI:10:1111/jwas.12016.
17. Enyidi UD. Production of feeds for African catfish *Clarias gariepinus* using plant proteins. Jyvaskyla Studies in Biological Sciences. 2012;251. ISBN: 978-951-39-4925-9, ISSN: 1456-9701.
18. Francis G, Harinder P, Makkar S, Becker K. Anti nutritional factors present in plant derived alternate fish feed ingredients and their effects in fish. Aquaculture. 2001;199:197-227. Available:http://dx.org/10.1016/S0044-8486(01)00526-9.
19. Imorou Toko I, Fiogbe ED, Kestemont P. Mineral status of African catfish *Clarias gariepinus* fed diet containing graded levels of soybean or cotton seed meal. Aquaculture. 2008;275:298-305. Available: http://dx.doi.org/10.1016/j.aquaculture.2007.11.038
20. Mgbenka BO, Orji RCA. Use of fresh palm fruit extract as feed ingredient in the diet of larval African catfish *Clarias gariepinus*. Journal of Applied Aquaculture. 1997;7 (4):79-91. DOI:10:1300/j028v07n04_06
21. Davies OA, Ezenwa NC. Groundnut cake as alternative protein source in the diet of *Clarias gariepinus* fry. International Journal of Science and Nature. 2010;1:73-76. ISSN: 0973-3140.
22. Enyidi, Mgbenka BO. Substitution of fishmeal with bambara nut waste meal in diets of first feeding (*Clarias gariepinus* X *Heterobranchus bidorsalis*) "Heteroclarias". International Journal of Fisheries and aquatic Studies, 2014;1(3):118-122.
23. Dakora FD, Muofhe LM. Nitrogen fixation and nitrogen nutrition in symbiotic bambara ground nut (*Vigna subterranean* (L) verdc.) and kersting beans (*Macrotyloma geocarpum* (harms) marech.et Baud.) In Herkler J., Begemann F., and Mushonga, J.(Eds.). Proceedings on the workshop on conservation and improvement of Bambara groundnut (*Vigna subterranean* (L.) verdc.) 14-16 November 1995 Harare Zimbabwe. 1995;72-78.
24. Hardy R. Fish feed formulation. In Fish feed technology ADCP Rep./80/11. 1980;550.
25. Ali MZ, Jauncey K. Evaluation of mixed feeding schedules with respect to compensatory growth and body composition in African catfish *Clarias gariepinus*. Aquaculture Nutrition. 2004;10:39-45.
26. Britz PJ, Hecht T. Temperature preferences and optimum temperature for growth African sharptooth catfish (*Clarias gariepinus*) larvae and post larvae. Aquaculture. 1987;63:205-214.
27. NRC. National Research Council). Nutritional requirement of fish. National Academy press, Washington DC. 1993;114.
28. Boyd CE, Tucker C, MCnevin A, Bostick K, Clay J. Indicators of resource use efficiency and environmental performance in fish and crustaceans aquaculture. Reviews in Fisheries Sciences. 2007;15:327-360.
29. Ng WK, Lim PK, Boey PL. Dietary lipid and palm oil sources affects growth, fatty acids composition and muscle α-tocopherol concentration of African catfish, *Clarias gariepinus*. Aquaculture. 2003;229-243.
30. Mohsen AA, Lovell RT. Partial substitution of soybean meal with animal protein sources in diets for channel catfish. Aquaculture. 1990;90:303–311.
31. Rønnestad I, Thorsen A, Finn RN. Fish larval nutrition: A review of recent

advances in the role of amino acids. Aquaculture. 1999;177:201-216.
Available: http://dx.doi.org/10.1016/S0044-8486 (99)00082-4.

32. Minka SR, Bruneteau M. Partial chemical composition of bambara pea (*Vigna subterranea* (L) Verde). Food Chem. 2000;68:273-276.
33. Winfree RA, Stickney RR. Starter diets for channel catfish: Effects of dietary protein on growth and carcass composition. Progressive Fish-Culturist. 1984;46(2):79-86.
34. Lovell RT. Nutrition and feeding of fish Van Nostrand Reinhold Chapman and Hall, IT Pub. Co., New York. 1989;253.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=763&id=5&aid=6899