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Growth efficiency and profitability indices of African catfish (*Clarias gariepinus*) fingerlings fed with different levels of *Adansonia digitata* (Baobab) seed meal

Ajibade Akinniyi Oyetunji[1*], Adeosun Olubunmi[1], Sule Okanlawon Sakiru[2], Adedokun Mathew Adewale[3] and Adesina Babatunde Taiwo[4]

[1]Department of Fisheries Technology, Oyo State College of Agriculture and Technology, Igbo-ora, Oyo State, Nigeria.
[2]Department of Fisheries, Wildlife and Forestry, Olabisi Onabanjo University, Ogun State, Nigeria.
[3]Department of Animal health and production, Faculty of Science, Oke-Ogun Polytechnic, Oyo State, Nigeria.
[4]Department of Agriculture, Animal Science Programme, College of Agriculture Sciences, Landmark University, P. M. B. 1001, KM 4, Ipetu Road, Omu-Aran, Kwara State, Nigeria.

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The effects of diet with different inclusion levels of baobab seed meal inclusions on the growth and gross margin analysis of *Clarias gaiepinus* fingerlings was evaluated under a controlled laboratory condition. Five inclusion levels of Baobab Seed Meal (BSM) to replace soya bean meal were studied at 0, 5, 10, 15 and 20% dietary protein. The experimental diets were uniform by targeting 40% crude protein with energy level of 20 MJ/kg. Fingerlings of *C. gariepinus* with an average weight (g) of 2.91 ± 0.16 g were reared for 90 days in plastic aquaria. Feed intake, weight gain, feed efficiency ratio (FER), protein efficiency ratio (PER) and survival rates (SR %) were evaluated, using standard formula. Significantly higher growth (p<0.05) was obtained from the fish fed with Diet Two (5% BSM) and Diet Three (10% BSM) than the fish fed with control diet. The best utilized diet for *C. gariepinus* was Diet Two in relation to weight gained and total fish production. Therefore, Baobab seed meal can serve as a worthy unconventional feed ingredient in the diet of *C. gariepinus* at 10% level of inclusion for maximum profit, although 5% BSM inclusion recorded the best growth performance.

Key words: Growth parameter, *Clarias gariepinus,* Baobab seed meal, fingerlings.

INTRODUCTION

Fish has continued to be the source of hope towards solving global malnutrition due to its nutritive values above other animal sources of protein (Delgado et al., 2003; Fasakin, 2007). The expansion and intensification of aquaculture has been recommended in ensuring the increase in food fish production in order to meet global demand since capture fisheries have been declining over decades (Delgado et al., 2003; Akinrotimi et al., 2007; FAO, 2006).

The rapid growth of aquaculture faces the challenge of

*Corresponding author. E-mail: ajibadeyemi@yahoo.com.

high cost of feedstuff. This limitation is greatly expressed in the protein sources of the diet of fish. Also, nutritional diseases were highlighted as the major limiting factors in aquaculture and livestock production in Nigeria. The competition for feedstuffs because of human and livestock needs is another limitation to availability of feed resources in developing countries (Bale et al., 2013). However an alternative dietary protein is universally sought for in Africa to reduce the cost of feeding the fish which amounts to over 80% of total cost of production. The choice of replacing either the fishmeal or soya bean meal fraction of fish diet, such as *Clarias gariepinus,* is to reduce cost of production. Therefore, affordability and profitability of fish production relies on partial or total replacement with other non-conventional feedstuffs containing a high degree of crude protein.

Furthermore, the European Commission has encouraged the import of Baobab fruit pulp as a novel food through authorization (Buchman et al., 1982). Its use was also approved in 2009 by the Food and Drug Administration as a food ingredient in the United State of America (Addy and Eteshola, 1984; Addy et al., 1995). A few countries in West Africa use the leaves, fruit pulp and seeds as ingredient in sources of porridges and beverages (Faturoti, 1989b; De Caluwe et al., 2009). Baobab fruit is now recognized as a super fruit because of its richness in vitamins, fatty acid and mineral (Grunewald and Galizia, 2009). The level of vitamin C in fruit pulp is about '2.8 to 3.0 g/kg' (Vertuani et al., 2002) while calcium content ranges between '211 g to 2160 ml/100 g' (Sena et al., 1998; Lockett et al., 2002: Brady, 2011). The seeds are rich in protein ranging from 18 to 36% crude protein (Salami and Okazie, 1994; Murray et al., 2001; Bale et al., 2013). The seed are readily and cheaply available, especially in the middle belt, far north and south western Nigeria (Nkafamoya et al., 2007a). However, the full potential of baobab seed is yet to be exploited which help in tagging as a non-conventional feedstuff of choice for poultry industry, farm animals and aquaculture. This study therefore investigated performances of BSM in the diet of *C. gariepinus* relative to growth indices and economic advantage.

MATERIALS AND METHODS

Study area

The study was carried out in the laboratory of the Department of Fisheries Technology, Oyo State College of Agriculture and Technology, Igboora, Oyo State, Nigeria. This is located on latitude 70.5 N and longitude 30.3 E at an altitude of 140 m above sea level.

Source and processing of baobab seeds and soya bean

Baobab seeds were harvested from its characterized pod from the baobab plant within the Oyo State College of Agriculture and Technology, Igboora, between the months of November and January, 2016. Seeds were soaked in water for twenty minutes and manually rinsed to remove the sugar coat. The seeds were then sundried for seven days (four hours per day). The dark brown coats of the dried seeds were then removed from the grains after partial milling using pestle and mortar. This helped to attain constant moisture content and reduce the anti-nutritional factor of the seed. The grains were finally ground by using hammer mill to obtain BSM, stored under room temperature and proximate composition.

Experimental fish and acclimation

One hundred and fifty juveniles of African catfish (*C. gariepinus*) with an average weight of 3.86 ± 0.16 g and length of 7.13 ± 0.63 cm were obtained from the Department of Aquaculture Technology, Igboora. The organisms were previously fed during fourteen days with 2.0 mm pellets with 45% of protein (5% of total body weight) (Reish and Oshida, 1986) for their acclimation in the Fisheries Technology Departmental Laboratory.

Experimental diets and feeding

Five isonitrogeneous (40% crude protein) and isoenergetic (20 Mj/Kg) experimental diets with different concentrations of baobab seed meal (0% as control treatment; 5, 10, 15 and 20%) were made (Table 1). There proximate analysis was shown in Table 2. Gross energy of feed was estimated by combustion using a bomb calorimeter (Adiabatic calorimeter) as described by Sibbald (1976). After acclimation (14 days), experimental diets were applied for 90 days (twice per day at 5%).

Digestibility involved the use of a reference diet and a test diet over a period of 28 days as a second phase of the feeding trial. Reference diet targeted 40% C.P. 70% of each ingredient of formulated reference diet was subsequently determined to achieve a 30% total reduction. The balance was then made up with already prepared baobab seed meal (BSM) as described by Cho and Slinger (1979). Diet was manually mixed with distilled water (40 g/100 g diet mix) and pressure pelleted using sieve and later dried in a current of air at room temperature for 24 h. Experimental diets with iso-nitrogenous protein were then fed to *C. gariepinus* fingerling for 28 days. Water quality was monitored through physicochemical analyses. Water acidity, dissolved oxygen and water temperature were determined using a pH-meter, titrimetric method, and mercury-in-glass thermometer, respectively, as described by Boyd (1981) in the laboratory of Oyo State College of Agriculture and Technology, Igbo-ora, Nigeria. Fingerlings of *C. gariepinus* were initially fed with a commercial diet containing 40% Crude protein for one week at 5% of their body weight (Reish and Oshida, 1986) as acclimation period. Feed left over and faecal discharge was removed by siphoning as described by Oyelese (1994).

A batch total of 150 fingerlings of *C. gariepinus* were used during the digestibility test. 75 fingerlings per diet (treatment) were used which involved three replicates. Feeding was carried out twice per day (mornings and early evenings). 1% OF CHROMIC OXIDE was added to reference and test diets before feeding trial. Feed left over and faecal discharge were removed by siphoning before separating the coloured faeces due to the presence of chromate agent.

Calculation:

(i) Apparent digestibility coefficient of diet (%) is given (Cho et al., 1985; NRC, 2011):

ADCs=100 - 100 (% M diet / % M Faeces) x (% Nutrient Faeces / % Nutrient Diet)

Where, % M = Marker concentration (% dry matter); % N= Nutrient

content (% in dry matter)
(ii) Digestibility coefficient of test ingredient (ADCing) as described by Cho et al. (1985)

$$ADCing = (x + y) \times ADCN_{T.\ diet\ -}\ (x) \times ADC_{Ref.\ diet}$$

Where, $_{ADCing}$ = apparent digestibility coefficient of nutrient or energy in the test diet. ADC $_{Ref.\ diet}$ = apparent digestibility coefficient of nutrient or energy in the reference diet. ADC $_{T.\ diet\ =}$ apparent digestibility coefficient of nutrient or energy in test diet. x = Nutrient contribution of reference diet. y= Nutrient contribution of test ingredient.

Growth characteristics estimation

Weight gain (WG) was obtained using the followed formula

MWG = Final mean weight – initial mean weight
The Feed Efficiency Ratio (FER) was obtained using the followed formula by Osborne et al. (1999)

$$FER = \frac{F\ C\ R}{FI}$$

Where FI = feed intake; which was the sum of daily mean feed intake of fish in each treatment for the experimental period. FCR = Feed conversion ratio; FCR = Dry feed weight (kg) / Average weight gain; Or FCR = Wet weight of fish (kg) / Average weight gain; The protein efficiency ratio (PER) was obtained using the followed formula by Osborne et al. (1999):

PER = mean weight gain (g) / Protein consumed (g)

The Specific Growth Rate (SGR) was obtained using the following formula by Osborne et al. (1999)

SGR = log (Final weight) – log (initial weight) / (Total days of experiment) × 100

The percentage survival rate (%SR) was obtained by using the formula by Osborne et al. (1999)

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

Profit index = Total fish production / cost of feed; Incidence cost = Cost of feed / Total fish produced; Net profit = Income generated from fish production – Cost of feed; Apparent metabolizable energy (kcal/g) = (Fi × GE) / Fi where Fi = Feed intake and GE = Gross energy

Digestibility involved the use of a reference diet and a test diet over a period of 28 days as a second phase of the feeding trial. Reference diet targeted 40% C.P. 70% of each ingredient of formulated reference diet was subsequently determined to achieve a 30% total reduction. The balance was then made up with already prepared baobab seed meal (BSM) as described by Cho and Slinger (1979). Diet was manually mixed with distilled water (40 g/100 g diet mix) and pressure pelleted using sieve and later dried in a current of air at room temperature for 24 h. Experimental diets with iso-nitrogenous protein were then fed to *C. gariepinus* fingerling for 28 days. Water quality was monitored through physicochemical analyses. Water acidity, dissolved oxygen and water temperature were determined using a pH-meter, titrimetric method, and mercury-in-glass thermometer, respectively, as described by Boyd (1981) in the laboratory of Oyo State College of Agriculture and Technology, Igbo-ora, Nigeria. Fingerlings of *C. gariepinus* were initially fed with a commercial diet containing 40% Crude protein for one week at 5% of their body weight (Reish and Oshida, 1986) as acclimation period. Feed left over and faecal discharge was removed by siphoning as described by Oyelese (1994).

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Where, % M = Marker concentration (% dry matter); % N= Nutrient content (% in dry matter (ii) Digestibility coefficient of test ingredient (ADCing) as described by Cho et al. (1985).

$$ADCing = (x + y) \times ADCN_{T.\ diet\ -}\ (x) \times ADC_{Ref.\ diet}$$

Where, $_{ADCing}$ = apparent digestibility coefficient of nutrient or energy in the test diet. ADC $_{Ref.\ diet}$ = apparent digestibility coefficient of nutrient or energy in the reference diet. ADC $_{T.\ diet\ =}$ apparent digestibility coefficient of nutrient or energy in test diet. x = Nutrient contribution of reference diet. y= Nutrient contribution of test ingredient.

Experimental design and statistical analysis

The experimental layout was a completely randomized design with five treatments in three replicates. Each treatment was made in a plastic container (0.50 m × 0.33 m × 0.33 m) and randomly allotted organisms. Every two days temperature, dissolved oxygen and pH were measured with average values of 25.5°C, 6.7 mg / L and 7.7, respectively. The efficiency of diets was evaluated where the control diet served as basal diet for comparison. One-way analyses of variance (ANOVA) and student's t-test were used in comparing growth parameters in trial diets and control diet (Diet 1). Descriptive statistics were also used to give pictorial representation of performance in experimental fish fed the diets.

RESULTS AND DISCUSSION

The result of this feeding trial is presented in Tables 1 to 4.

Formulation of experimental diets

BSM inclusions of 0% (D1), 5% (D2), 15% (D3), 20% (D4) and 25% (D5) were utilized. These inclusion rates reduced Soyabean meal from 52.97% to 42.37% but recorded a corresponding increase of 0.00 to 10.60% in incorporated BSM during formulation. The quantities of other nutrients were kept constant to formulate complete diets as shown in Table 1. Proximate analysis of experimental feed is presented in Table 2. It showed that feed at different inclusion level of Baobab was

Table 1. Percentage composition of the experimental diet.

	Baobab Seed meal level				
Feed ingredients	**Diet 1(%)**	**Diet 2(5%)**	**Diet 3(10%)**	**Diet 4(15%)**	**Diet 5(20%)**
Maize	8.53	8.53	8.53	8.53	8.53
Soyabean	52.97	50.32	47.67	45.06	42.37
Baobab seed meal	0.00	2.65	5.30	7.91	10.60
Fishmeal	25.51	25.51	25.51	25.51	25.51
Limestone	4.00	4.00	4.00	4.00	4.00
Bone meal	6.00	6.00	6.00	6.00	6.00
Vitamin premix	0.50	0.50	0.50	0.50	0.50
Sodium chloride	0.50	0.50	0.50	0.50	0.50
Lysine	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25
Palm oil	1.25	1.25	1.25	1.25	1.25
Total	100.00	100.00	100.00	100.00	100.00
Crude protein	40.00	40.00	40.00	40.00	40.00

Table 2. Proximate composition.

Feed ingredients	Diet 1(0%)	Diet 2(5%)	Diet 3(10%)	Diet 4(15%)	Diet 5(20%)
Crude protein	39.02	39.90	39.60	39.20	39.00
M.E (MJ/kg)	20.09	20.60	20.30	20.10	20.00
Calcium	1.80	1.80	1.80	1.80	1.80
Phosphorus	0.90	0.90	0.90	0.90	0.90
Lysine	0.65	0.65	0.65	0.65	0.65
Methionine	0.80	0.80	0.80	0.80	0.80
Crude fibre	9.40	9.00	9.20	9.30	9.10

Table 3. Selected water quality parameters (±SD).

Parameter	Temperature (°C)	Dissolved oxygen (mg/L)	Water acidity (pH)
Diet 1(%BSM)	25.40 ± 0.17	6.60 ± 0.04	7.50 ± 0.07
Diet 2(5% BSM)	25.80 ± 0.01	6.60 ± 0.17	7.50 ± 0.07
Diet 3(10% BSM)	25.40 ± 0.02	6.80 ± 0.02	8.00 ± 0.02
Diet 4(15% BSM)	26.10 ± 0.08	6.70 ± 0.18	8.00 ± 0,012
Diet 5(20% BSM)	26.0 ± 0.03	6.60 ± 0.09	7.90 ± 0.02

Mean with the same superscript along the same column are not significantly different (p>0.05).

isonitrogenous containing about 39% crude protein while gross energy levels ranged from 20.0 to 20.6 Mj/kg.

Water quality parameters

The water quality parameters selected and measured during experimental period of 90-days are shown in Table 3. These include mean water temperature, dissolved oxygen and water acidity at a range of 25 to 26%C, 6.6 to 6.8 mg/L and 7.5 to 8.0, respectively.

Growth and nutrient utilization

The growth and nutrient utilization of *C. gariepinus* fingerlings fed baobab seed meal is shown in Table 4. AVW was highest in fish fed diet 2 and 3 (10 and 15% BSM) with 22.43 and 18.70 g, respectively. Similarly, FI was highest in diet 2 and 3 that recorded 1274.91 and 1063.27 g while the least intake was associated with diet 4.(20% BSM) followed by diet 5(25% BSM) that recorded 858.52 and 922.61 g, respectively.

Proximate compositions of formulated feeds were

Table 4. Growth in experimental fish in terms of changes in body weight (g) and length (cm).

Week	Diet 1		Diet 2		Diet 3		Diet 4		Diet 5	
	TW	**AVW**	**TW**	**AVW**	**TW**	**AVW**	**TW**	**AVW**	**TW**	**AVW**
2	94.20	03.14	109.50	03.65	91.2	03.04	75.90	02.53	65.4	02.18
4	120.6	04.02	115.80	03.86	142.20	04.74	91.20	03.04	184.2	06.14
6	254.7	08.49	379 20	12.64	275.10	09.17	252.3	08.41	293.70	09.79
8	282.0	09.40	437.67	16.21	302.13	11.19	270.90	90.03	275.67	10.21
10	365.	13.54	448.20	16.60	376.11	13.93	296.64	12.36	304.08	12.67
12	448.6	18.69	471.03	22.43	448.8	18.70	334.80	15.93	296.31	14.11

Week	Feed Intake (s)				
	Diet 1	**Diet 2**	**Diet 3**	**Diet 4**	**Diet 5**
2	61.23	71.24	59.28	49.27	42.51
4	78.39	75.27	92.43	58.76	119.73
6	165.56	246.48	178.88	164.06	190.97
8	183.30	284.41	196.43	176.15	179.14
10	237.63	291.33	244.53	192.79	197.6
12	291.56	306.15	291.72	217.49	192.66
Total Intake (g)	1017.67	1274.91	1063.27	858.52	922.61

Table 5. Growth performance , feed utilization and cost benefits of *Clarias gariepinus fingerlings* fed varying levels of Baobab Seed Meal diets.

Parameters	0%	5%	10%	15%	20%
Initial weight (g)	3.14 ± 0.41[a]	3.65 ± 0.13[a]	3.04 ± 0.76[a]	2.53 ± 0.04[b]	2.18 ± 0.21[b]
Average length gained (cm)	5.22 ± 0.11[a]	5.30 ± 0.13[a]	5.10 ± 0.18[a]	4.60 ± 0.32[b]	3.43 ± 0.51[b]
Final weight (g)	18.69 ± 0.11[a]	22.43 ± 0.33[b]	18.70 ± 0.48[a]	15.93 ± 0.31[c]	14.11 ± 0.42[d]
Average weight gained (g)	15.55 ± 0.05[b]	18.78 ± 0.10[a]	15.66 ± 0.02[ab]	13.40 ± 0.01[c]	11.93 ± 0.43[d]
Average feed intake (g)	12.72 ± 0.22[c]	18.17 ± 0.43[a]	14.35 ± 0.15[b]	12.27 ± 0.05[c]	10.14 ± 0.06[d]
Specific growth rate (%/day)	1.27 ± 0.01[b]	1.35 ± 0.10[a]	1.27 ± 0.11[b]	1.19 ± 0.04[c]	1.15 ± 0.02[d]
Feed efficiency ratio	0.06 ± 0.01[b]	0.05 ± 0.05[c]	0.06 ± 0.03[b]	0.08 ± 0.01[a]	0.08 ± 0.11[a]
Feed conversion ratio	0.81 ± 0.01[ab]	0.97 ± 0.03[a]	0.92 ± 0.04[a]	0.91 ± 0.02[a]	0.85 ± 0.04[ab]
Protein efficiency ratio	2.55 ± 0.02[a]	2.58 ± 0.01[a]	2.73 ± 0.04a[b]	2.73 ± 0.03[ab]	2.98 ± 0.01[b]
Survival rate (%)	80.00 ± 3.0[a]	70.00 ±5.0[b]	80.00 ± 2.0[a]	70.00 ± 2.0[b]	70.00 ±1.0[b]
Total feed intake (g)	1,017.67[b]	1,271.91[a]	1,063.27[b]	858.52[c]	922.61[d]
Total fish production (g)	448.56 [b]	471.03[a]	448.8.40[b]	334.53[c]	296.31[d]
Cost of feed (Naira)	255.93[a]	251.77[b]	247.61[c]	243.51[d]	239.29[e]
Profit index	1.69[a]	1.48[c]	1.69[a]	1.62[b]	1.34[d]
Net profit	183.97[a]	153.09[b]	182.98[a]	128.48[c]	74.88[d]
Incidence cost	0.57[c]	0.54[d]	0.55[d]	0.73[b]	0.81[a]

Means with the same superscript along the same column are not significantly different ($p>0.05$).

generally higher in values in the two diets (reference and test diets) than those in the faecal discharge. Reference diet recorded higher values in moisture, ash and crude protein content at a difference of 0.7, 4.3 and 4.05, respectively, compared to reference diet. However, lower values in dry matter and crude fibre at a difference of 0.70 and 12.07, respectively, were observed in reference diet compared to the test diet as shown in Table 5.

Similarly, proximate compositions of faecal discharge in fish fed reference diet were higher in moisture (2.10), and ash content (2.60) but lower in crude fibre (16.00), ether extract (4.48), crude protein (10.00), dry matter (2.10) compared to fish fed test diets (Table 6). A decreasing trend was observed in apparent digestibility of reference diet (94.14%), test diet (81.59%) and test ingredient (62.33%) as shown in Table 6.

Table 6. Proximate analysis of formulated feed and faeces of *C. gariepinus* fingerlings involving *Adansonia digitata* seed meal during digestibility test.

Sample	Marker (%)	Moisture content (%)	Crude fibre (%)	Ash (%)	Ether extract (%)	Crude protein (%)	Dry matter (%)
Composition of formulated feeds							
Test diet	0.54	8.90	21.00	15.00	24.60	34.65	91.10
Ref. diet	0.54	9.60	8.93	19.30	18.00	38.70	90.40
Composition of faecal discharge							
Test diet	0.65	8.10	25.00	16.00	22.2	33.5	91.90
Ref. diet	0.65	10.20	9.00	18.61	17.72	23.5	89.80

Table 7. The apparent digestibility co-efficient of the test diet, reference diet and test ingredient fed to *C. gariepinus* fingerlings in the laboratory.

Diet	Reference diet	Test diet	Test ingredient
Digestibility (%)	94.14	81.59	62.33
Comment	A better feed	A good alternative	A potential substitute

DISCUSSION

The current study showed that the inclusion of the baobab seed meal (BSM) above 10% in the diet of the African mud catfish (*C. gariepinus*) resulted in a lower body weight gain. The inverse relationship seems to be an indication of the presence of an inhibitory substance in the seed that served as a depressant (Table 1) which tends to suppress palatability or intake. This is evident through the average weight gain and specific growth rate values obtained at the end of the 12-week feeding trial. The recognition was similar to the observation of Omitoyin and Faturoti (2000) and Hassan et al. (2015) in a bid to quantity productivity of diets fed to *C. gariepinus*. Adequate supply of protein and energy from formulated diets led to an overall increase in weight gain in all the treatments in the present study. The increase in body mass was a good indicator of muscle developments in fish as similarly reported by Hassan et al. (2015) that incorporated boiled and sun dried Baobab seed into the diet of *C. gariepinus* fingerlings using 0, 10, 20 and 30% inclusion rates. However, the present study observed a substantial decrease in weight gain and specific growth rate at 25% inclusion level; which could not be observed until 30% level of inclusion used by Hassan et al. (2015) for fingerlings of *C. gariepinus* due to a wide spacing of incorporated percentiles. Anene et al. (2012) reported a similar pattern in weight reducing in juveniles of *C. gariepinus* as the inclusion level of baobab seed meal increased in diet. A similar finding was reported by Chimvuramhwe et al. (2011) where a general decrease in feed intake of the diets occurred with the higher inclusions of baobab seed cake in broiler diet. Therefore, feed intake is a major factor that influences both the body weight gain and feed conversion rate in meat type animals (Faturoti, 1989a; Nkafamiya et al., 2007).

Diet two (5% BSM) and diet three (10% BSM) performed favorably well in this study, compared to the diet (Diet one). However, the control diet was most consumed in the first five weeks of feeding trial which could be due to fish adaptation to the feed from fry to fingerlings, palatability or nutrient composition. Above five weeks of feeding trial, diet two (5% BSM) and diet three (10% BSM) performed better in average feed intake than the control diet and other diets containing higher BSM inclusions. This trend could be as a result of coping adaptation of the African mud catfish to the baobab seed meal inclusion, and richness in terms of vitamins, fatty acid, calcium and other minerals (Grunewald and Galizia, 2009; Brady, 2011).The best specific growth rate (SGR%) in this study were associated with diet two (5% BSM) and diet three (10% BSM) that recorded 1.35 and 1.27, respectively (Table 5). These rates disagreed with the report of Hassan et al. (2015) that recorded higher specific growth rate for 10% BSM inclusion rather than 5% BSM inclusion for *C. gariepinus*. This could be associated with higher intake (1271.91 g) at 5% BSM inclusion than that consumed by the fish (1063.27 g) at 10% inclusion rate. However, there was no significant difference in the two rates in the present study. Furthermore, feed conversion ratio ranged between 0.81 and 0.92. In this study unlike the report of Hassan et al. (2015) that recorded a range of 1.0 to 1.26. Comparatively, at 0, 10 and 20% BSM inclusion the current study recorded 0.81, 0.92 and 0.85, respectively while Hassan et al. (2015) observed 1.26, 1.00 and 1.16. Although, there were no significant differences in the values in the two studies which indicated a similar degree of feed utilization by C. *gariepinus* fingerlings. These differences could be attributed to the superiority of processing methods in suppressing the anti-nutritional factors in baobab seed or better availability of nutrients. This is because the lower the value of FCR the better the feed utilization by the fish (Jabeen et al., 2004; Hassan et al., 2015). Hence, soaking of seed in water, removal of seed coat and drying before milling could be a better method than parboiling and drying used by Hassan et al. (2015). Furthermore, the protein sparing ability of energy sources (lipid and carbohydrate) of fish feed rated by the protein efficiency ratio (PER) (Tibbets et al., 2005). The higher the value of PER the lesser the protein consumed or the higher the mean weight gained. Hence, diet 3 (10% BSM), diet 4 (15% BSM) and diet 5 (20% BSM) with protein efficiency ratio of 2.73, 2.73 and 2.98, respectively, utilized little protein to obtain better average weights tan other diets (control diet and diet 1) in this study. The protein efficiency ratio in all the diets after comparison using the student t-test was insignificantly different from one another (Table 5). Protein was similarly utilized at similar degree (Table 5) by diet 3 and 4 because each recorded PER-value of 2.73; indicating similar feed intake to gain similar body weights.

Feed intake increases with increasing age of fish in the present study which agreed with the report of Faturoti (1989a), Anene et al. (2012), and Hassan et al. (2015); as shown in Table 4. However, at higher inclusion level of BSM in the diet of *C. gariepinus* juveniles; feed intake and average weight gain decreased (Table 5). This decreasing trend was similarly reported by Fagbenro et al. (2010) at higher incorporation of alternative feed ingredient in the diet of (*C. gariepinus*) juveniles. Hence lower feed efficiency ratios recorded in diet 2 and 3 could be attributed to higher intakes of feed which resulted in a higher delivery of total fish production (Table 5). The lower the values of FER the better the efficient use of feed by the fish. Therefore, acceptability and digestibility of feeds decreased with increase inclusion levels of BSM which may be caused by a reduced palatability and increased accumulation of anti-nutritional factors, respectively. This result agrees with the findings of Alatise et al. (2014) and Adedokun et al. (2016) who reported significant reductions in growth performances and feed utilization of *C. gariepinus* fingerlings fed boiled Jatropha kernel meal and smoked fish waste meal based diets, respectively. The gross marginal analysis of the fish diet showed that the inclusion rate of 5, 10, 15 and 20% of BSM reduced the total feed cost by N4.16, N8.32, N12.42 and N16.46 per kg, respectively, compared to the control diet (0% BSM).

The economic analysis reveals reduction in the production cost of the experimental diets as BSM inclusion increased. The current study therefore evaluated the degree of profitability in relation to profit index, incident cost and net profit.

The incident cost helped in ranking the unit cost of feed but the lower its numerical value the better because it measures the cost of feed in relation to total fish produced. In the current trial, the increasing order of profit index recorded diet 2(0.54), diet 3(0.55), control diet (0.57), diet 4(0.73) and diet 5(0.81). This ranking supported diet 2 and 3 as economically preferred diets because of higher returns in body mass at a reduced price; with no significant difference among the numerical values. The profit index, however, showed that diet 3 with an equitable value (1.69) with the control diet was economically better than diet 2 and other diets. This implies that the higher the numerical value of profit index the better the gain because it measures the overall fish produced relative to price of feed. Similar trend was observed in the values of net profit for using each diet such that, in ascending order, 74.88 (diet 5), 128.48 (diet 4), 153.09 (diet 2), 182.98 (diet 3), and 183.97 (control diet). Diet 3 and control diet with the highest and similar profit values served as the most profitable diets for chosen fish.

A decreasing order in apparent digestibility was observed in the control diet with Soyabean as protein source, test diet with incorporated baobab, and test ingredient itself (Table 7).

This confirmed the superiority of reference diet (control diet) in the current study, and a need to improve the test ingredient through a better processing method in reducing the anti-nutritional factors.

Conclusion

Diet 2 (5% BSM) and diet 3 (10% BSM) would be preferred in relation average weight and specific growth rate because there were no significant differences in their efficiency. Financially, diet 3 (10% BSM) would be chosen because it maximizes the financial benefit of the fish farmer. The digestibility of the test diet is lower than that of reference diet.

Recommendations

Baobab seed meal could be used to partially replace soybean meal in the diet of African catfish as a means of increasing the profit margin of a fish farmer without compromising yield. A better processing method, such as high heat treatment, may help in reducing further the anti-nutritive components of baobab seed in future studies.

ABBREVIATION

BSM, Baobab seed meal; **SBM,** Soya bean meal; **PER,** Profit efficiency ratio; **FER,** Feed efficiency ratio; **SR%,** Percentage of survival rates; **FCR,** Feed conversion ratio; **SGR,** Specific growth rates; **BCR,** Benefit cost ratio.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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