DIETARY ENERGY REQUIREMENT OF *CLARIAS GARIEPINUS* JUVENILE AT FIXED CRUDE PROTEIN AND ITS EFFECTS ON GROWTH, NUTRIENT PERFORMANCE, HAEMATOLOGY AND BIOCHEMICAL INDICES

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ABSTRACT

This study investigated the optimum dietary energy requirement of African catfish, Clarias gariepinus juveniles fed 35 % crude protein level and the effects on growth, nutrient performance, haematology and biochemical indices. The control diet A had 2800 kcal while, treatments B, C, D and E have 3000, 3200, 3400 and 3600 kcal energy inclusion respectively. Diets were fed to triplicate groups of eight catfish (51 ± 0.56 g) per tank twice daily to satiation for 8 weeks. Significant effects of graded energy levels across diets (p<0.05) on growth and nutrient utilization were recorded relative to diet A. The optimal dietary energy was within the range (3000 – 3200 kcal/Kg) on nutrients utilization and growth parameters. The least value (1.33 ± 0.17) and the best feed conversion ratio was recorded with fish fed 3000 kcal/kg while, the protein efficiency ratio was significantly high (p<0.05) at 3200 kcal/kg (52.80 ± 3.33). There was no significant difference (p>0.05) recorded across diets in the measured blood parameters and fish organs. Some biochemical parameters like total protein, albumin, cholesterol and high density lipoprotein were not significantly affected by dietary energy inclusion levels, other stress enzyme, like superoxide dismutase was significantly different between diet with diet A and diet E respectively. Though, diet A had the best estimated investment cost (₦ 48.30), diet C had the highest values for both net profit (₦ 50.68) and benefit cost ratio (₦ 1.79). Therefore, feed at 35 % CP would require between 3000 – 3200 kcal/Kg for optimum performance.

Keywords: *Clarias gariepinus*, Energy, Protein, Growth, Nutrient, Haematology, Biochemicals

INTRODUCTION

The high costs of feed and low quality of fingerlings are the major limiting factors in the development of aquaculture in Africa (Fagbenro, 1999). Equally, Gabriel *et al.* (2007) and Aderolu and Sogbesan (2010) asserted that fish feed is a significant factor in the viability of aquaculture operations and as the sector is increasingly becoming intensive, feed accounts for at least 60 – 70 percent of the total cost of fish production. Therefore, it is expedient to know the actual nutritional requirement of catfish under varying culture conditions so that suitable diets can be formulated to maximize their growth, reproduction and maintenance of good health (Ozigbo *et al*., 2014).

Fish needs a good nutritious diet which must contain right ingredients, and of acceptable cost, must be palatable to the fish and should not contain anti-nutritional components that can inhibit the performance of the fish.

The dietary protein to energy ratio in fish diets is of great importance, since dietary protein and energy not only influence the growth and the composition of the body but they also influence plasma metabolites, digestive enzymes activities in different species of fish (Yamamoto *et al*., 2000; Okorie *et al*., 2007).Therefore, the inclusion of an adequate amount of energy from lipids and carbohydrates can minimize the use of protein as an energy source in fish feed (Mohseni *et al.,* 2013).

However, excess dietary energy inclusion has the following side effects which include reduced feed consumption (Okorie *et al*., 2007), inhibition of nutrients utilization (Winfree and Stickney, 1981), reduction in growth of farmed fish (Sweilum *et al.,* 2005), production of fatty fish (Salhi *et al*., 2004). Furthermore, it could result into generation of undesirable nitrogenous waste, which reduces water quality parameters and promotes eutrophic environment (Goodwin, 2011).

In view of the above the present study was aimed at investigating the optimum dietary energy requirement of African catfish, *Clarias gariepinus* Juveniles under known crude protein level and the attendant effect on growth, nutrient performance, haematology and biochemical indices.

MATERIALS AND METHODS

Experimental Site: The experiment was carried out at the Nutrition Unit of the Department of Marine Sciences, University of Lagos, Lagos, Nigeria for a period of 56 days.

Feed Ingredients: The feed ingredients; fish meal, soy bean meal, groundnut cake, maize, noodles waste, mineral and vitamin premix, di-calcium phosphate, methionine, salt, lysine and oil, were gotten from a feed store in Agege, Lagos and milled into homogenous powder. The dietary ingredients were analyzed for their proximate composition (AOAC, 2000) and formulated into isoproteinous (35 % CP) and non isocaloric diets using the Pearson square method (Wagner and Stanton, 2012).They were mixed together with hot water to form consistent dough for each of the experimental diet and were pelletized using 3 mm die.

Feed Formulation: Five experimental diets were formulated with varying levels of energy and a constant crude protein level of 35 percent across diets. Treatment A had 2800 kcal energy inclusion and treatments B, C, D and E have 3000, 3200, 3400 and 3600 kcal energy inclusion respectively (Table 1).

Table 1: Percentage composition of dietary feed ingredients with fixed crude protein (35 %) and varying energy levels

Ingredient	Diet A	Diet B	Diet C	Diet D	Diet E
Fish meal	11.0	19.5	24.0	28.0	38.0
Soy Bean Meal	35.0	13.0	11.0	7.0	0.0
Groundnut cake	12.0	18.0	12.0	10.0	0.0
Maize	20.0	22.0	20.0	20.0	5.0
Noodles wastes	15.0	20.0	23.0	23.0	45.0
Oil	0.0	0.5	3.0	5.0	5.0
Dicalcium Phosphate	2.0	2.0	2.0	2.0	2.0
Methionine	0.5	0.5	0.5	0.5	0.5
Lysine	0.5	0.5	0.5	0.5	0.5
Fish vitamin premix	2.0	2.0	2.0	2.0	2.0
Salt	2.0	2.0	2.0	2.0	2.0

Experimental Procedure: One hundred and fifty (150) *C. gariepinus* juveniles (average weight 51.45 ± 0.18 g) were purchased from a fish farm in Lagos and transported in aerated aquaria. The fish were acclimatized for 14 days in transparent rectangular plastic holding tanks (0.55 x 0.33 x 0.31 m^3) and fed 3 mm Coppens feed. Water was changed every two days with de-chlorinated water from a borehole to maintain good water quality. The physico-chemical parameters of the water were monitored as described by previous studies (Boyd, 1979; Aderolu and Akpabio, 2009); water temperature ranged from 26 to 29 ^oC, dissolved oxygen ranged from 5.0 to 6.0 mg/l and pH ranged from 6.7 to 8.0 pH during the experimental period.

Feeding Regime: Fish were weighed and randomly stocked into the plastic tanks at the rate of 8 fish per tank with average weight of 51.45 ± 0.18 g. They were starved overnight before the commencement of the feeding trials to empty their stomachs. Fish were fed experimental diets to satiation by hand, twice daily (9.00 and 16.00 hour) for a period eight weeks. The weight of the experimental fish were measured using a digital balance (Camry EK 5055) at the beginning of the experiment and at the end of every week to determine the average weight gain while the quantity of the feed fed for each week was also recorded. These data were used to determine the growth parameters and nutrient utilization parameters of the experimental fish.

Growth and Nutrient Utilization Parameters: The following parameters were obtained from the records of feed intake and weight gain. Average Feed Intake (AFI) = Total Feed Intake ÷ Number of Days of Experiment. Mean Weight Gain (MWG) = Mean Final Body Weight (MFW) – Mean Initial Body Weight (MIW). Average Daily Gain (ADG) = Mean Final Body Weight (MFW) – Mean Initial Body Weight (MIW) ÷ Number of days of experiment. Specific Growth Rate (SGR) = $\log_e W_2 - \log_e W_1 \times 100 \div T_2 - T_1$, where, e = natural logarithm, $T_2 - T_1$ = experimental period, W_1 = initial weight and W_2 = final weight. Feed Conversion Ratio (FCR) = Feed Intake ÷ Weight Gain, and Protein Efficiency Ratio (PER) = Mean Weight Gained ÷ Protein Intake.

Haematological Analysis: Blood samples were collected from the caudal peduncle of the experimental fish, selected from each treatment in a 2 ml syringe and ethylene-diamine-tetra-acetic acid (EDTA) and to sterile plain sample bottles as described by Joshi *et al*. (2002). The specimens were taken to Lagos University Teaching Hospital, Idi-Araba, Lagos for haematological analysis. Haemoglobin (Hb), red blood cells (RBC), white blood cells (WBC), haematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean cell haemoglobin concentration (MCHC) and platelets (PLT) were analyzed using the micro-haematocrit centrifuge machine (Hawskley Haematospin 1300 Model). Samples of blood in the plain bottles were spun at 3000 rpm to collect serum for biochemistry analysis. Aspartate aminotransferase (AST) and alanine aminotransferase were analysed by the method of Reitman and Frankel (1957), alkaline phosphatase (ALP) (Otto *et al.,* 1946), total protein (Tietz, 1995), albumin, globulin (Donmas *et al*., 1971), cholesterol (Allain *et al.,* 1974), triglyceride and high density lipoprotein cholesterol (Ochei and Kolhatkar, 2000), low density lipoprotein cholesterol (Friedewald *et al.,* 1972) and catalase (Goth, 1991).

Histometry Analysis: Organs of fish which include heart, bile, spleen, liver, kidney, intestine and gills were carefully harvested from the fish and weighed using electronic digital balance (KERN 770). This analysis was performed to determine the weight of these organs in relation to the weight of the fish. The percentage relative organ weights were calculated as: Relative Organ Weight = Organ Weight × 100 ÷ Fish Weight.

Economic Analysis: The cost of feed and fish were the economic criteria under consideration in this study and were based on the current market cost of feed ingredients and market value of a kilogram of fresh fish in Nigeria at the time of the experiment. The economic evaluations in terms of gross profit (GP), net profit value (NPV), investment cost analysis (ICA) and benefit cost ratio (BCR) were calculated based on the method of New (1989) as follows: Gross profit = Net profit value (N) – Investment cost analysis (N), Net profit value = Mean weight gain of fish cropped (g) × Total no of the survival (n) x cost per kg, Estimated Investment Cost Analysis = Cost of feeding juvenile + Cost of stock, and Benefit cost ratio = Present worth of gross returns over present worth of costs.

Statistical Analysis: Data obtained throughout the experiment period were subjected to one-way analysis of variance (ANOVA),comparisons among treatment means were carried out by Duncan multiple range test (Duncan, 1955) at a significance level of (P<0.05). All computations were done using the statistical package SPSS 16.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

The growth performance and feed utilization of juvenile *C. gariepinus* fed diets containing different levels of digestible energy and constant protein (35 %) over the 56-day feeding trial is presented in Table 2. The varying energy levels had significant impact (p<0.05) on final weight (FNW), MWG and SGR when compared with control diet A. However, no significant difference (p>0.05) was recorded among diets B, C and D. The energy effect at constant crude protein peaked at 3200 kcal/Kg while, the energy effect outside the range (3000 – 3200 kcal/Kg) was significantly poor (p<0.05) on growth and nutrient utilization parameters (Figure 1).

FCR of 1.33 ± 0.17 and 1.35 ± 0.07 were recorded with fish fed 3000 kcal/Kg and the group fed 3200 kcal/kg respectively and no significant effect was recorded in FCR record up to the highest energy level (3600 kcal/Kg) used in the study. Additionally, the PER was significantly high (P<0.05) at 3200 kcal/Kg (52.80 ± 3.33) to further confirmed the effectiveness of Diet C.

The effect of varying energy levels on haematological parameters is recorded in Table 3. There was no significant difference (p>0.05) recorded across diets in the measured parameters except, MCHC which differed significantly from diets A and C.

The effect of the experimental diets on plasma enzymes is recorded in Table 4.. Of all the parameters evaluated, there was no significant effect (p>0.05) of the experimental diets on total protein, albumin, cholesterol and high density lipoprotein. Globulin, alanine aminotransferase and triglyceride are both only significantly different between diet C (2800 kcal) and diet E (3600 kcal). While SOD is significantly lowest on diet C (3200 kcal) compared to other experimental diets, catalase level on the other hand in diet c is equally significantly different from other experimental diets all the plasma enzymes.

The result of the histometry analysis is recorded in Table 5. The level of dietary energy in the experimental diets did not have significant effect (p>0.05) on any of the organs examined.
The cost implications of feeding *C. gariepinus* juveniles on different energy levels at 35 % protein content is presented in Table 6.

Diet A (₦ 48.30) had the least estimated investment cost across all diets, while diet E (₦ 72.02) had the highest investment cost compared to other experimental diets. However, diet C (₦ 50.68) had the highest net profit compared to all other diets and diet A (₦ 6.54) recorded the lowest net profit in the terms of economic estimate of this study. Also, the Benefit cost ratio was highest with diet C (₦ 1.79) while, the lowest value was recorded with diet A (₦ 1.14).

DISCUSSION

The quality, quantity, the balance of dietary energy and the requirements of protein for growth are considered as the key to obtaining the nutritional requirements of a specific farmed species at a specific life stage (Rosas *et al.,* 2001). These nutrient requirements, however, are not absolute but rather, they should be present in the correct proportions (Wilson, 1994).

Table 2: Growth and nutrient utilization parameters of *C. gariepinus* juveniles fed different energy levels at 35 % protein content

Parameter	Diet A	Diet B	Diet C	Diet D	Diet E
MFW	81.63 ± 0.18^{c}	157.50 ± 20.15^{a}	163.16 ± 0.58^{a}	146.19 ± 0.62^{ab}	127.32 ± 0.09^{b}
MIW	51.38 ± 0.18	51.51 ± 0.18	51.50 ± 0.35	51.57 ± 0.09	51.38 ± 0.18
AFI	119.45 ± 11.05^{b}	139.76 ± 8.49^{ab}	150.85 ± 9.50^{a}	134.02 ± 7.06^{ab}	134.63 ± 6.19^{ab}
MWG	30.25 ± 0.00^{c}	106.00 ± 19.98^{a}	111.66 ± 0.93^{a}	94.63 ± 0.53^{ab}	75.94 ± 0.27^{b}
ADG	0.54 ± 0.00^{c}	1.89 ± 0.36^{a}	1.99 ± 0.02^{a}	1.69 ± 0.01^{ab}	1.36 ± 0.00^{b}
SGR	0.83 ± 0.00^{c}	1.99 ± 0.22^{a}	2.06 ± 0.02^{a}	1.86 ± 0.00^{a}	1.62 ± 0.01^{b}
FCR	3.95 ± 0.37^{a}	1.33 ± 0.17^{b}	1.35 ± 0.07^{b}	1.42 ± 0.07^{b}	1.77 ± 0.08^{b}
PER	41.81 ± 3.87^{b}	48.92 ± 2.97^{ab}	52.80 ± 3.33^{a}	46.91 ± 2.47^{ab}	47.12 ± 2.17^{ab}

MIW-mean initial weight, MFW-mean final weight, FWG- final weight gain, MWG- mean weight gain, AFI- average feed intake, SGR- specific growth rate, FCR- feed conversion ratio, PER-protein efficiency ratio, ADG- average daily gain, Figures in each row with different superscript are significantly different (p <0.05) from each other

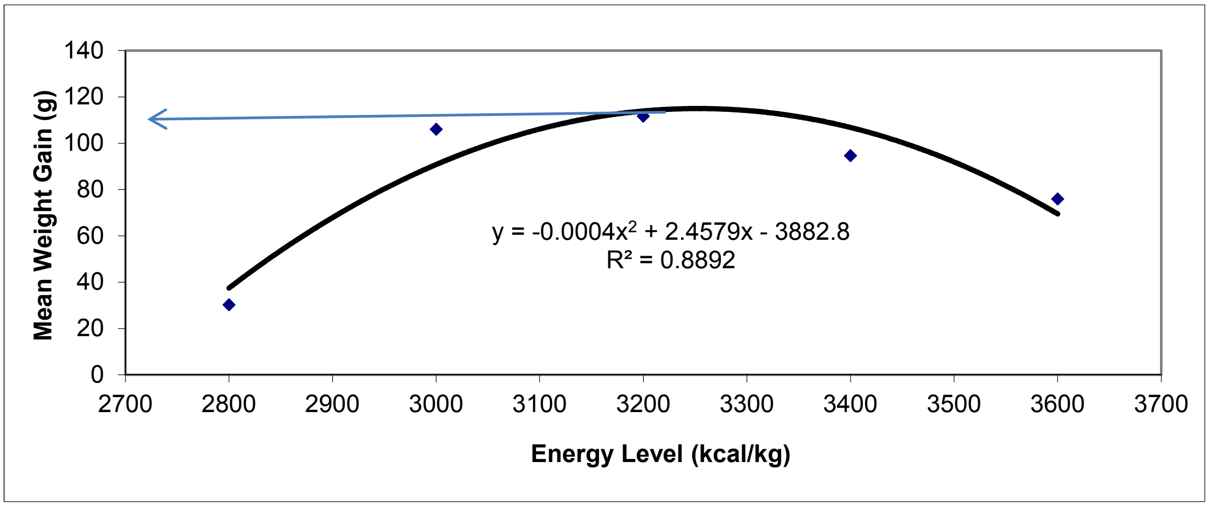

Figure 1: The second-order polynomial regression of MWG with varying dietary energy in African catfish, *C. gariepinus*

Table 3: Haematological parameters of *C. gariepinus* juveniles fed different energy levels at 35 % protein content

Parameter	Diet A	Diet B	Diet C	Diet D	Diet E
WBC ($x10^9$/L)	30.96 ± 7.07	27.86 ± 4.12	27.7 ± 4.18	27.63 ± 6.41	27.46 ± 6.11
HGB (g/dL)	8.76 ± 2.7	9.33 ± 0.90	9.20 ± 0.85	9.70 ± 2.64	10.13 ± 1.91
RBC ($x10^{12}$/L)	3.48 ± 0.86	3.55 ± 0.21	3.36 ± 0.11	3.69 ± 0.83	3.75 ± 0.73
HCT (%)	26.33 ± 8.08	28.00 ± 2.64	27.66 ± 2.51	29.00 ± 7.79	30.33 ± 5.68
MCV (fl)	74.96 ± 5.73	79.34 ± 11.77	82.10 ± 5.51	77.98 ± 6.74	80.83 ± 3.04
MCH (pg)	24.93 ± 2.00	26.45 ± 4.00	27.30 ± 1.87	26.09 ± 2.23	27.05 ± 1.11
MCHC (g/L)	33.26 ± 0.14^{a}	33.32 ± 0.12^{ab}	33.24 ± 0.07^{a}	33.45 ± 0.03^{b}	33.40 ± 0.06^{ab}
PLT (10^9/L)	29.66 ± 0.14	30.33 ± 0.57	29.66 ± 0.57	30.83 ± 3.25	31.33 ± 2.75

***PCV** - Packed Cell Volume, **HGB**- Hemoglobin, **RBC** - Red Blood Cell, **WBC** - White Blood Cell, **MCV** mean corpuscular volume, **MCHC** – mean corpuscular hemoglobin concentration, **MCH** – mean corpuscular hemoglobin, **PLT** – platelet, Figures in each row with different superscript are significantly different (p<0.05) from each other*

Table 4: Serum biochemical parameters of *C. gariepinus* juveniles fed different energy levels at 35 % protein content

Parameter	Diet A	Diet B	Diet C	Diet D	Diet E
AST (U/L)	57.66 ± 35.85[c]	37.33 ± 16.1[b]	61.00 ± 41.86[d]	32.33 ± 7.02[a]	32.33 ± 9.23[a]
ALT (U/L)	17.00 ± 1.73[b]	15.33 ± 4.50[ab]	14.33 ± 3.78[ab]	14.00 ± 2.64[ab]	12.66 ± 2.88[a]
Total protein (g/dl)	34.66 ± 3.21	37.66 ± 1.15	35.00 ± 3.00	36.00 ± 2.00	38.00 ± 9.64
Albumin (g/dl)	15.00 ± 2.00	15.00 ± 0.00	14.00 ± 1.00	13.00 ± 0.00	13.66 ± 2.30
Globulin (g/dl)	19.66 ± 2.00[a]	22.66 ± 2.30[ab]	21 ± 0.30[ab]	23 ± 0.72[ab]	24.34 ± 2.00[b]
CHOL (g/dl)	2.93 ± 0.72	3.39 ± 0.55	3.70 ± 0.50	3.76 ± 0.30	4.50 ± 1.969
TG (mmol/l)	3.400 ± 1.17[a]	3.36 ± 0.40[a]	3.10 ± 0.26[a]	3.33 ± 0.56[a]	6.03 ± 4.86[b]
HDL(mmol/l)	1.56 ± 0.40	1.86 ± 0.20	1.83 ± 0.11	2.00 ± 0.00	2.13 ± 1.00
LDL(mmol/l)	0.20 ± 0.00a	0.56 ± 0.25[cd]	0.8 ± 0.14[d]	0.50 ± 0.56[bc]	0.30 ± 0.28[ab]
Catalase umol/(ml/min)	716.29 ± 50.36[b]	682.55 ± 100.11[b]	662.03 ± 73.43[a]	719.65 ± 39.41[b]	756.52 ± 27.05[b]
SOD (mol/ml/min/gpr)	1.53 ± 1.24[b]	0.68 ± 0.29[a]	0.94 ± 0.72[a]	0.69 ± 0.26[a]	0.77 ± 0.09[a]

Figures in each row with different superscript are significantly different (p<0.05) from each other. ALT = Alanine Transaminase, AST = Aspartate Aminotransferase, HDL = High Density Lipoprotein, LDL = Low Density Lipoprotein, TG = Triglycerides, Chol = Cholesterol, SOD = Super Oxide Dismutase

Table 5: Histometry parameters of selected organs of *C. gariepinus* juveniles fed different energy levels at 35 % protein content

Organs weight (g)	Diet A	Diet B	Diet C	Diet D	Diet E
Heart	0.72 ± 0.45	0.73 ± 0.13	0.35 ± 0.29	0.28 ± 0.19	0.31 ± 0.11
Bile	0.78 ± 0.16	0.69 ± 0.93	0.15 ± 0.08	0.20 ± 0.04	0.24 ± 0.11
Spleen	0.37 ± 0.17[b]	0.22 ± 0.13[ab]	0.11 ± 0.02[a]	0.11 ± 0.02[a]	0.19 ± 0.05[ab]
Liver	1.8 ± 0.60	1.46 ± 0.48	1.46 ± 0.48	1.68 ± 0.20	2.16 ± 0.39
Kidney	0.74 ± 0.60	0.53 ± 0.15	0.63 ± 0.64	0.50 ± 0.10	0.43 ± 0.35
Intestine	1.44 ± 0.13	1.58 ± 0.83	1.62 ± 0.37	1.74 ± 0.46	2.22 ± 0.48
Gills	4.30 ± 1.33[b]	2.73 ± 0.46[a]	4.11 ± 0.51[b]	3.44 ± 0.29[ab]	3.51 ± 0.25[ab]

Figures in each row with different superscript are significantly different (p<0.05) from each other

Table 6: Cost implications of feeding *C. gariepinus* juveniles fed different energy levels at 35 % protein content

Parameter	Diet A	Diet B	Diet C	Diet D	Diet E
Cost of feeding (N per fish)	18.30	28.30	34.05	34.22	42.02
Cost of juvenile (N per fish)	30.00	30.00	30.00	30.00	30.00
Estimated investment cost (N per fish)	48.30	58.30	64.05	64.22	72.02
Net profit (N per fish)	6.54	41.99	50.68	34.42	16.57
Benefit cost ratio (BCR)	1.14	1.72	1.79	1.54	1.24

The results of the present study demonstrated that the level of dietary energy (3000 – 3200 kcal/Kg) influenced growth performance of juvenile *C. gariepinus*. It has been established that optimal energy/protein ratio enhance growth, pond water quality management, survival rate, size uniformity and eventually low cost of production (Isyagi *et al.*, 2009), but beyond this point we either have a non-significant increase in growth or a total poor performance. This is similar to what was reported by Lemos *et al.* (2014), where they determined the effect of digestible protein to energy ratios on growth of Siamese fighting fish (*Betta splendens*) and established optimum dietary protein and energy for the experimental fish to be 35 % CP and 3200 kcal/Kg. Though fish consume food to satisfy their energy requirement, excess dietary energy may limit intake of essential nutrients like protein and amino acids and thus, excesses of energy can lead to growth reduction, hinder digestion and absorption of other nutrients by the fish and increase fat deposition in fish (Salhi *et al.,* 2004; Sweilum *et al.,* 2005). Growth potential differs across fish species and is highly dependent on feed composition, nutrient uptake and on how well the feed has been adjusted to meet the nutritional needs of the fish. The above reasons could probably explained the variation in growth performance across the different energy level fed and thus the effect of low energy (> 3000 kcal/Kg) content of the feed was significantly obvious. Although at low dietary energy levels protein may be used for energy, as has been demonstrated in *C. gariepinus* (Ali and Jauncey, 2005) and other fishes (Yamamoto *et al.,* 2000) but in the present study we maintained constant protein level in other to actually feel the inclusion effect of graded energy level.

Specific growth rate and FCR were clearly improved at dietary energy level range 3000 – 3200 kcal/Kg, this same trend was earlier recorded in a number of farmed fish species (El-Mowafi *et al.,* 2010), including gilthead sea bream (Lupatsch *et al.,* 2001; 2003) but in these previous studies, growth was not limited by dietary protein content as recorded in the present study.

Ingestion of dietary components has measurable effects on blood composition and may be considered as appropriate measure of a long term nutritional status (Togun and Oseni, 2005; Olabanji *et al.,* 2007). Adamu *et al.* (2006) observed that nutrition has significant effect on haematology values like PCV, Hb and RBC parameters except the MCHC. However, all the parameters still failed within the established range for healthy catfish as reported by Akinrotimi *et al.* (2011). Togun *et al*. (2007) reported that when the haematological values fall within the normal range reported for the animal, it is an indication that the diets had no adverse effect on haematological parameters as observed during the experimental period.

According to Maita (2007) and Peres *et al.* (2013) changes in the following parameters; adequacy of feed, feeding practices, water quality and the presence of acute or chronic stressors and diseases will bring about a variation in the plasma biochemistry profile of fish. Plasma enzymes activities also provide important information on nutritional status of fish and the functional state of different organs, as intracellular and plasma enzymatic concentrations are usually proportional (McCue, 2010; Coeurdacier *et al.,* 2011; Peres *et al.,* 2013). Plasma protein level is usually very stable in well-nourished animals but decreases under fasting condition and according to Pond *et al.* (1980), the total protein is as a sensitive indicator of protein status of a diet.

This could probably be that under malnutrition or stress condition altered or lower plasma total protein levels often result from consequence of amino acid oxidation or peripheral proteolysis (Di Marco *et al.,* 2008). The present study did not record significant difference in the biochemical parameters tested and the values obtained in the present study are still within a healthy range as reported by Peres *et al.* (2014), thus it can be stated that the experimental diet did not negatively impact the health status of the fish.

Fish could be stressed as a result of in-sufficient energy content (but constant protein), this probably explained why the super oxide dismutase (SOD) in diet A is significantly different among the other experimental diets and catalase on the other hand recorded the lowest value at the diet C (recommended energy requirement of the experimental fish). According to Du *et al*. (2005), both triglyceride and cholesterol increased with increasing dietary lipid content, we got similar result to this but only between the diet 2800 kcal (diet A) and diet E when the dietary energy level was increased.

In addition, the non-significant difference observed in the histometry of the fish across graded levels of dietary energy showed a clear case of no hyperplasia of organs studied.

Estimated investment cost and mean cost of feeding increased across graded energy levels in the experimental feed probably because of the increase in cost of feed associated with every increase in the energy level of feed. On the other hand however, net profit and benefit cost ratio only improved up to 3200 kcal (diet C) after which we recorded a loss of profit and this could be related to the poor feed conversion and growth rate of fish fed those higher energy content feed.

Conclusion: In conclusion, formulating feed at 35 % CP for African catfish to achieve optimum growth will require energy levels between 3000 – 3200 kcal/Kg.

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REFERENCES

ADAMU, S., THOMAS, A., ISEH, N. M., FATIHUMI M. Y. and ESIENO K. A. N. (2006). Normal values of haematology of Nigeria adopted albino rats (*Rattus norvegicus*) in Zaria. *Proceeding of 31st Annual Conference of the Nigeria Society for Animal Production,* 12th – 15th March, 2006. Bayero University Kano, Nigeria.

ADEROLU, A. Z. and AKPABIO, V. M. (2009). Growth and economic performance of Clarias gariepinus juveniles fed diets containing velvet bean, *Mucuna pruriens* seed meal. *African Journal of Aquatic Science*, 34(2): 131 – 135.

ADEROLU, A. Z. and SOGBESAN, O. A. (2010). Evaluation and potential of cocoyam as carbohydrate source in catfish,(*Clarias gariepinus* [Burchell, 1822]) juvenile diets. *African Journal of Agricultural Research*, 5(6): 453 – 457.

AKINROTIMI, O. A., ABU, O. M. G. and ARANYO, A. A. (2011). Environmental friendly aquaculture: key to sustainable fish farming development in Nigeria. *Continental Journal of Fisheries and Aquatic Science*, 5(2): 17 – 31.

ALI, M. Z. and JAUNCEY, K. (2005). Approaches to optimizing dietary protein to energy ratio for African catfish *Clarias gariepinus* (Burchell, 1822). *Aquaculture Nutrition*, 11(2): 95 – 101.

ALLAIN, C. C., POON, L. S., CHAN, C. S., RICHMOND, W. F. P. C. and FU, P. C. (1974). Enzymatic determination of total serum cholesterol. *Clinical Chemistry*, 20(4): 470 – 475.

AOAC (2000). *Official Methods of Analysis*. 18th Edition, Association of Official Analytical Chemists (AOAC), Washington DC, USA.

BOYD, C. E. (1979). *Water Quality in Warm Water Fish Ponds.* Auburn University Agricultural Experiment Station, Auburn, Alabama, USA.

COEURDACIER, J. L., DUTTO, G., GASSET, E. and BLANCHETON, J. P. (2011). Is total serum protein a good indicator for welfare in reared sea bass (*Dicentrarchus labrax*)? *Aquatic Living Resources*, 24(2): 121 – 127.

DIMARCO, P., PRIORI, A., FINOIA, G., MASSARI, A., MANDICH, A. and MARINO, G. (2008). Physiological responses of European sea bass *Dicentrarchus labrax* to different stocking densities and acute stress challenge. *Aquaculture*, 275: 319 – 328.

DOUMAS, B. T., WATSON, W. A. and BIGGS, H. G. (1971). Albumin standards and the measurement of serum albumin with bromcresol green. *Clinica Chimica Acta*, 31(1): 87 – 96.

DU, Z. Y., LIU, Y. J., TIAN, L. X., WANG, J. T., WANG, Y. and LIANG, G. Y. (2005). Effect of dietary lipid level on growth, feed utilization and body composition by juvenile grass carp (*Ctenopharyngodon idella*). *Aquaculture Nutrition*, 11: 139 – 146.

DUNCAN, D. B. (1955). Multiple ranges and multiple F-test. *Biometrics,* 11: 1 – 42.

EL-MOWAFI, A., RUOHONEN, K., HEVRØY, E. M. and ESPE, M. (2010). Impact of digestible energy levels at three different dietary amino acid levels on growth performance and protein accretion in Atlantic salmon. *Aquaculture Research*, 41(3): 373 – 384.

FAGBENRO, O. A. (1999). Comparative evaluation of heat-processed winged bean (*Psophocarpus tetragonolobus*) meals as partial replacement for fish meal in diets for the African catfish (*Clarias gariepinus*). *Aquaculture*, 170(3-4): 297 – 305.

FRIEDEWALD, W. T., LEVY, R. I. and FREDRICKSON, D. S. (1972). Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clinical Chemistry*, 18(6): 499 – 502.

GABRIEL, U. U., AKINROTIMI, O. A., BEKIBELE, D. O., ONUNKWO, D. N. and ANYANWU, P. E. (2007). Locally produced fish feed: potentials for aquaculture development in sub-Saharan Africa. *African Journal of Agricultural Research*, 2(7): 287 – 295.

GOODWIN, S. A. (2011). *Excess Nutrients and Cultural Eutrophication of the Cache La Poudre River: A Study of the Occurrence and Transport of Phosphorus*. M.Sc Thesis Colorado State University, Fort Collins, Colorado.

GOTH, L. (1991). A simple method for determination of serum catalase activity and revision of reference range. *Clinica Chimica Acta*, 196(2-3): 143 – 151.

ISYAGI, N., ATUKUNDA, G., ALIGUMA, L., SEBISUBI, M., JOHN, W., KUBIRIZA, G. and MBULAMERI, E. (2009). *Assessment of National Aquaculture Policies and Programmes in Uganda*. SARNISSA EC FP7 Project, University of Stirling, Stirling, United Kingdom.

JOSHI, P. K., BOSE, M. and HARISH, D. (2002). Changes in certain haematological parameters in Siluroid catfish, *Clarias batrachus* (Linn) exposed to cadbium chloride. *Pollution Resources,* 21(2): 129 – 131.

LEMOS, M. V. A. D., ARANTES, T. Q., SOUTO, C. N., MARTINS, G. P., ARAÚJO, J. G. and GUIMARÃES, I. G. (2014). Effects of digestible protein to energy ratios on growth and carcass chemical composition of siamese fighting fish (*Betta splendens*). *Ciência e Agrotecnologia*, 38(1): 76 – 84.

LUPATSCH, I., KISSIL, G. W. and SKLAN, D. (2003). Defining energy and protein requirements of gilthead seabream (*Sparus aurata*) to optimize feeds and feeding regimes. *The Israeli Journal of Aquaculture – Bamidgeh,* 55(4): 243 – 257.

LUPATSCH, I., KISSIL, G. W., SKLAN, D. and PFEFFER, E. (2001). Effects of varying dietary protein and energy supply on growth, body composition and protein utilization in gilthead seabream (*Sparus aurata* L.). *Aquaculture Nutrition*, 7(2): 71 – 80.

MAITA, M. (2007).Fish health assessment Pages 10 – 34. *In:* NAKAGAWA, H., SATO, M. and GATLIN, D. M. (Eds.). *Dietary Supplements for the Health and Quality of Cultured Fish.* CAB International, Washington DC, USA.

MCCUE, M. D. (2010). Starvation physiology: reviewing the different strategies animals use to survive a common challenge. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*, 156(1): 1 – 18.

MOHSENI, M., POURKAZEMI, M., HOSSENI, M. R., HASSANI, M. H. S. and BAI, S. C. (2013). Effects of the dietary protein levels and the protein to energy ratio in sub-yearling Persian sturgeon, *Acipenser persicus* (Borodin). *Aquaculture Research*, 44(3): 378 – 387.

NEW, M. B. (1989). Formulated aquaculture feeds in Asia: some thoughts on comparative economics, industrial potential, problems and research needs in relation to the small-scale farmer. *In*: *Workshop on Shrimp and Finfish Feed Development,* JohoreBahru (Malaysia), 25 – 29 October, 1988.

OCHEI, J. and KOLHATKAR, A. (2000). *Medical Laboratory Science, Theory and Practice.* 1st Edition. Tata McGraw-Hill Publishing Company Limited, New Delhi.

OKORIE, O. E., KIM, Y. C., LEE, S., BAE, J. Y., YOO, J. H., HAN, K., BAI, S. C., PARK, G. J. and CHOI, S. M. (2007). Reevaluation of the dietary protein requirements and optimum dietary protein to energy ratios in Japanese eel, *Anguilla japonica. Journal of the World Aquaculture Society*, 38(3): 418 – 426.

OLABANJI, R. O., FARINU, G. O., AKINLADE, J. A. and OJEBIYI, O. O. (2007). Growth performance and haematological characteristics of weaner rabbits fed different levels of wild sunflower (*Tithonia diversifolia* Hemsl A. Gray) leaf blood meal mixture. Pages 207 – 209. *In: Proceeding of 32nd Annual Conference of the Nigeria Society for Animal Production*, March 18 – 21, 2007, Calabar.

OTTO, A., OLIVER, H. and JANE, M. (1946). A method for the rapid determination of alkaline phosphatase with five cubic millimeters of serum. *Journal of Biological Chemistry*, 164: 321 – 329.

OZIGBO, E., ANYADIKE, C., ADEGBITE, O. S. and KOLAWOLE, P. (2014). Review of aquaculture production and management in Nigeria. *American Journal of Experimental Agriculture*, 4(10): 1137 – 1151.

PERES, H., SANTOS, S. and OLIVA-TELES, A. (2013). Selected plasma biochemistry parameters in gilthead seabream (*Sparus aurata*) juveniles. *Journal of Applied Ichthyology*, 29(3): 630 – 636.

PERES, H., SANTOS, S. and OLIVA-TELES, A. (2014). Blood chemistry profile as indicator of nutritional status in European seabass (*Dicentrarchus labrax*). *Fish Physiology and Biochemistry*, 40(5): 1339 – 1347.

POND, W. G., YEN, J. T. and LINDVALL, R. N. (1980). Early protein deficiency: effects on later growth and carcass composition of lean or obese swine. *Journal of Nutrition,* 110: 2506 – 2513.

REITMAN, S. and FRANKEL, S. (1957). Glutamic–pyruvate transaminase assay by colorimetric method. *American Journal of Clinical Pathology*, 28(1): 56 – 63.

ROSAS, C., CUZON, G., TABOADA, G., PASCUAL, C., GAXIOLA, G. and VAN WORMHOUDT, A. (2001). Effect of dietary protein and energy levels on growth, oxygen consumption, haemolymph and digestive gland carbohydrates, nitrogen excretion and osmotic pressure of *Litopenaeus vannamei* (Boone) and *L. setiferus* (Linne) juveniles (Crustacea, Decapoda; Penaeidae). *Aquaculture Research*, 32(7): 531 – 547.

SALHI, M., BESSONART, M., CHEDIAK, G., BELLAGAMBA, M. and CARNEVIA, D. (2004). Growth, feed utilization and body composition of black catfish, *Rhamdia quelen*, fry fed diets containing different protein and energy levels. *Aquaculture*, 231(1-4): 435 – 444.

SWEILUM, M. A., ABDELLA, M. M. and SALAH EL-DIN, S. A. (2005). Effect of dietary protein-energy levels and fish initial sizes on growth rate, development and production of Nile tilapia, *Oreochromis niloticus* L. *Aquaculture Research*, 36(14): 1414 – 1421.

TIETZ, N. W. (1995). *Clinical Guide to Laboratory Tests*. Third Edition, WB Saunders, Philadelphia, USA.

TOGUN, V. A. and OSENI, B. S. A. (2005). Effect of low level inclusion of biscuit dust in broiler finisher diet on pre-pubertal growth and some haematological parameters of unsexed broilers. *Research Communication Animal Science*, 1(2):10 – 14.

TOGUN, V. A., FARINU, G. O., OYEBIYI, O. O., AKINLADE, J. A., AJIBOK, H. O. and OLANIYONU, B. I. (2007). Comparative study of the effect of dietary replacement of 15 % maize offal with pigeon pea (*Cajanus cajan*) grain or leaf meal on performance of weaners rabbits. Pages 217 – 219. *In: Proceeding of 32nd Annual Conference of the Nigeria Society for Animal Production*, March 18 – 21, 2007, Calabar.

WAGNER, J. and STANTON, T. L. (2012). *Formulating Rations with the Pearson Square*. Fact Sheet No. 1.618. Department of Agriculture and Colorado Counties Cooperation, CSU Extension Programs, Colorado State University, USA. https://dspace.library.colostate.edu/bitstream/handle/10217/182546/AEXT_ucsu_206221618 2012.pdf?sequence=1 Accessed May 31, 2018.

WILSON, R. P. (1994). Utilization of dietary carbohydrate by fish. *Aquaculture*, 124(1-4): 67 –80.

WINFREE, R. A. and STICKNEY, R. R. (1981). Effects of dietary protein and energy on growth, feed conversion efficiency and body composition of *Tilapia aurea*. *The Journal of Nutrition*, 111(6): 1001 – 1012.

YAMAMOTO, T., UNUMA, T. and AKIYAMA, T. (2000). The influence of dietary protein and fat levels on tissue free amino acid levels of fingerling rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, 182(3-4): 353 – 372.