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Full Length Research Paper

Effects of carbohydrate sources on the growth and body compositions of African catfish (*Clarias gariepinus*)

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Feeding trial was conducted to examine the protein sparing effects of carbohydrate in *Clarias gariepinus*, an attempt to reduce the feed cost. *C. gariepinus* fingerlings mean weights of 8.32 ±0.04 g were randomly allotted into a group of 15 fishes per tank in triplicate of 10 treatments. They were fed on nine experimental diets and a commercial catfish reference diet (CRD). The formulated diets have three levels of carbohydrate (5, 10 and 20%) of three carbohydrate sources (corn fibre, corn starch and glucose) and three levels of crude protein (30, 25 and 20%). The results of the trial showed significant differences (P<0.05) in all the carbohydrate sources fed to *C. gariepinus* at different levels of carbohydrate/ protein ratios. However, of the three carbohydrate sources, corn fibre spared protein at 5% inclusion levels while other carbohydrate sources gave significantly same degree of performance.

Key words: Protein sparing, carbohydrate sources, *Clarias gariepinus*.

INTRODUCTION

Carbohydrate is a cheap source of dietary energy in domestic animals including fish (Shiau and Linn, 2001). Carbohydrates are important non-protein energy sources for fish and should be included in their diets at appropriate levels which maximize the use of dietary protein for growth. The amount of non-protein energy sources that can be incorporated in fish diets is not fully understood and as such no dietary requirement for dietary carbohydrate has been demonstrated in fish; however, certain fish species exhibit reduced growth rates when fed carbohydrate free diets (Wilson, 1994). Peragón et al. (1999) further reported that carbohydrates affect nutrient utilization in the muscle of Rainbow Trout (*Oncorhynchus mykiss*). Carbohydrate utilisation is much more variable and probably is related to natural feeding habits, and incorporation of this nutrient may add beneficial effects to the pelleting quality of the diet and to fish growth (Fagbenro et al., 2003; Wilson, 1994; NRC, 1993). Excessive dietary carbohydrate in fish diet may also lead to fat deposition by stimulating the activities of lipogenic enzymes (Likimani and Wilson, 1982). Thus, rainbow trout (Brauge et al., 1994), *Tilapia zilli* (El-sayed

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and Garling, 1988), and red drum, *sciaenops* (Serrano et al., 1992; Ellis and Reigh, 1991) have been reported to have poor utilization for carbohydrate than *Oreochromis niloticus* (Shimeno et al., 1993). It has been reported that carbohydrate deprivation reduces NADPH-production in fish liver but not in adipose tissue (Barroso et al., 2001). Information on nutritional studies in African catfish *Clarias gariepinus* seems limited and has been dealt mainly with dietary protein and energy requirements using semi purified diets (Degani et al., 1989; Uys 1989; Henken et al., 1986; Machiels and Henken, 1985). Until now, carbohydrate utilization is still under investigation as reported by Sánchez-Muros et al., 1996, although *C. gariepinus* is reported to be omnivorous and might utilize carbohydrate well. The objective of this study is to determine the effect of feeding various sources of carbohydrate on growth and body compositions of African catfish, *C. gariepinus*.

MATERIALS AND METHODS

Experimental system

The study was conducted in a recycling water system of the Department of Water Resources, Aquaculture and Fisheries Technology of School of Agriculture and Agricultural Technology, Federal University of Technology, Minna. Water quality parameters were monitored (Temperature- 24.5-25.60; pH-6.0-7.5; conductivity (µ/cm) × 10^{-2}-74.12-103.34; Dissolve oxygen (mg/L-5.50-6.60 ± 3.00; Ammonia nitrogen (mg/L) -0.07-0.36 ± 0.05_1; nitrate nitrogen (mg/L) - 0.39-6.07±250.00; Nitrite nitrogen (mg/L) - 0.02-0.24±0.25.

Experimental diets

The experimental design was complete randomized design (CRD). Nine experimental diets and one commercial reference diet [(CRD) - Coppens Catfish feed from Netherland)] were used for the feeding trial. The experimental diets were formulated using equational method of two unknowns. Nine experimental diets of three levels of protein (30, 25 and 20% CP) were formulated with three sources of carbohydrate; complex, moderately complex and simple sugar (corn fibre, corn starch and glucose-D) at 5, 10 and 20% inclusion levels. The formulation and its proximate analysis is shown in Table 1.

Experimental fish

150 fingerlings of African catfish, *C. gariepinus* of mean weight 8.32±0.04 g were obtained from the hatchery unit of the Department of Water Resources, Aquaculture and Fisheries Technology, Federal University of Technology, Minna. The fishes were acclimatized for one week and fed on commercial catfish diet (crude protein 45%). At the commencement of the feeding trial, a group 15 fishes were randomly selected, weighed and assigned to 50 L cylindrical tank. The treatments were randomly assigned to a triplicate group of the tanks. The duration of the experiment was 8 weeks. Before the commencement of the feeding trial, 7 fishes from the acclimated lots were randomly sacrificed for determination of initial whole body composition. The fishes were bulked weighed fortnightly and at the end of the experiment, all fishes were weighed and counted individually. 5 fishes from each tank were collected for determination of final whole body composition. The fishes were fed twice daily between the hours 10 .00 and 16.00 to apparent satiation.

Experimental analyses and growth parameters

Proximate analysis for moisture, crude protein, crude lipid and ash of carcass, feed ingredients and experimental diets were determined according to the methods of Association of Official Analytical Chemists (AOAC, 2000). Final values for each group represent the arithmetic mean of the triplicates. Feed intake was monitored to measure average feed intake and their effects on growth. The growth and nutrient utilization parameters measured include weight gain, specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio (PER), apparent net protein utilization (ANPU). The growth parameters were computed stated as follows:

Mean weight gain = Mean final weigh – mean initial weight

$$\text{Specific Growth Rate (SGR)} = \frac{(\text{Log}_e W_2 - \text{Log}_e W_1)}{T_2 - T_1} \times 100$$

Where, W_2 and W_1 represent final and initial weight, and T_2 and T_1 represent final and initial time.

Feed conversion ratio – Feed fed on dry matter/fish live weight gain

Protein efficiency ratio (PER) = Mean weight gain per protein fed

Protein intake (g) = Feed intake x crude protein of feed

Apparent net protein utilization (ANPU %) = (P2 - P1) / Total protein consumed (g) × 100

Where, P1 is the protein in fish carcass (g) at the beginning of the study and P2 is the protein in fish carcass (g) at the end of the study.

Statistical analysis

The experimental design was factorial and the data was subjected to one way analysis of variance to test their significant levels at 5% probability. The mean were separated using Turkey's method. The regression coefficients were analyzed using Minitab Release 14 while the graphs were drawn using the Microsoft excel window 2007.

RESULTS

Table 2 showed the results of growth parameters for various carbohydrate sources fed *C. gariepinus*. The growth performance of *C. gariepinus* fed corn fibre at three levels of carbohydrate (C) and protein (P) (C/P) ratios indicated no significant differences (P<0.05) between treatment 10:25 and 20:20 C/P ratios both of were significantly lower (P<0.05) than 5 : 30 in mean weight gain (MWG) and specific growth rate (SGR). There were no significant differences (P>0.05) in the feed conversion ratios (FCR) for all the treatments. There were significant differences (P<0.05) in the protein

Table 1. Formulation and composition of the experimental diets and proximate analysis.

Feedstuffs	**Corn fibre (5 : 30)**	**Corn starch (5 : 30)**	**Glucose (5 : 30)**	**Corn fibre (10 : 25)**	**Corn starch (10 : 25)**	**Glucose (10 : 25)**	**Corn fibre (20 : 20)**	**Corn starch (20 : 20)**	**Glucose (20 : 20)**	**CRD**
Fishmeal	27.92	33.31	36.39	20.97	26.93	30.33	14.03	20.70	24.26	
Corn fibre	67.09	0.00	0.00	74.03	0.00	0.00	80.97	0.00	0.00	
Corn Starch	0.00	61.69	0.00	0.00	68.08	0.00	0.00	74.46	0.00	
Glucose	0.00	0.00	58.61	0.00	0.00	64.67	0.00	0.00	70.74	
V/M premix	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	
Total	**100.01**	**100.00**	**100.00**	**100.00**	**100.01**	**100.00**	**100.00**	**100.16**	**100.00**	
Proximate values	Diet1	Diet2	Diet3	Diet4	Diet5	Diet6	Diet7	Diet8	Diet9	Diet10
Crude protein	29.61	29.86	29.96	24.75	24.69	24.98	19.98	20.69	19.45	44.65
Crude fibre	4.00	7.00	7.00	3.92	7.00	3.00	3.00	5.88	6.93	15.84
C.Fat	10.94	8.78	4.38	5.94	5.88	5.41	5.41	5.97	5.00	12.92
Ash	40.20	41.10	44.00	40.78	40.35	42.87	41.87	32.46	35.95	5.34
NFE	5.45	3.16	5.77	14.83	12.10	13.98	20.98	25.50	24.00	11.15
Moisture	9.80	10.10	8.89	9.78	9.98	9.76	8.76	9.50	8.67	10.10
	100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100.04**	**100**

Table 2. Mean growth parameters of *Clarias gariepinus* fed various Carbohydrates : Protein ratios for 8 weeks.

Parameter	5CF : 30P	10CF : 25P	20CF:20P	5CS : 30P	10CS : 25P	20CS:20P	5GL: 30P	10GL : 25P	20GL:20P	CRD	SD ±
Initial Body Wt. (g)	$1.72^{a}\pm0.08$	$1.80^{a}\pm0.11$	$1.87^{a}\pm0.33$	$1.72^{a}\pm0.06$	$1.72^{a}\pm0.21$	$1.72^{a}\pm0.30$	$1.68^{a}\pm0.16$	$1.83^{a}\pm0.05$	$1.53^{a}\pm0.06$	$1.68^{a}\pm0.17$	0.18
Final Body Wt. (g)	$3.17^{b}\pm1.75$	$2.02^{c}\pm0.11$	$2.14^{c}\pm0.37$	$2.25^{c}\pm0.52$	$2.61^{b}\pm0.56$	$2.04^{c}\pm0.16$	$1.89^{c}\pm0.29$	$2.00^{c}\pm0.09$	$1.83^{c}\pm0.35$	$6.55^{a}\pm1.34$	0.76
Weight gain (g)	$1.46^{b}\pm1.74$	$0.37^{bc}\pm0.31$	$0.27^{bc}\pm0.10$	$0.54^{c}\pm0.51$	$0.90^{c}\pm0.58$	$0.32^{bc}\pm0.31$	$0.21^{bc}\pm0.31$	$0.18^{bc}\pm0.05$	$0.30^{bc}\pm0.39$	$4.87^{a}\pm1.18$	0.74
SGR(%)	$1.09^{b}\pm0.90$	$0.21^{cd}\pm0.48$	$0.24^{cd}\pm0.08$	$0.48^{d}\pm0.40$	$0.75^{c}\pm0.40$	$0.31^{cd}\pm0.33$	$0.21^{cd}\pm0.14$	$0.16^{cd}\pm0.04$	$0.32^{cd}\pm0.38$	$2.42^{a}\pm0.21$	0.41
FCR	$3.06^{c}\pm2.32$	$3.29^{c}\pm1.89$	$3.24^{c}\pm2.55$	$4.02^{b}\pm3.22$	$2.67^{c}\pm1.26$	$4.45^{a}\pm1.70$	$4.32^{b}\pm0.00$	$4.95^{a}\pm0.00$	$2.59^{c}\pm0.00$	$0.41^{d}\pm0.09$	1.99
PER	$2.86^{b}\pm3.40$	$0.91^{d}\pm0.76$	$0.73^{d}\pm0.28$	$0.92^{d}\pm0.88$	$1.87^{c}\pm1.21$	$2.94^{b}\pm2.74$	$0.36^{e}\pm0.39$	$0.38^{e}\pm0.10$	$0.81^{d}\pm1.04$	$5.19^{a}\pm1.25$	1.57
ANPU(%)	$43.43^{f}\pm0.01$	$75.91^{c}\pm0.01$	$91.49^{b}\pm0.01$	$1.60^{j}\pm0.01$	$66.26^{d}\pm0.01$	$59.19^{e}\pm0.01$	$13.03^{i}\pm0.01$	$38.51^{g}\pm0.01$	$95.53^{a}\pm0.01$	$30.88^{fg}\pm0.01$	0.01
Survival (%)	$53.34^{d}\pm23.09$	$60.00^{c}\pm6.67$	$62.22^{c}\pm7.70$	$68.89^{b}\pm36.71$	$46.67^{bc}\pm24.04$	$71.11^{b}\pm10.18$	$40.00^{e}\pm0.00$	$44.44^{bc}\pm15.39$	$40.00^{e}\pm24.04$	$75.55^{a}\pm16.78$	19.40

Mean data on the same row carrying letters with different superscripts are significantly different (P<0.05) from each other.

efficiency ratios (PER) of treatments 15:25 and 20:20 C/P ratios which were significantly higher (P<0.05) than 5:30 C/P ratio. There were significant differences (P<0.05) in the apparent net protein utilization (ANPU) for all the treatments which was highest for diet 20:20 C/P ratio. The survival percentages also indicated significant differences (P<0.05) between diets 15:25 and 20:20 both of which were significantly higher (P<0.05) than 5:30 C/P ratio.

The corn starch based diets did not exhibit significant differences (P>0.05) for all the

Table 3. Body composition of *Clarias gariepinus* fed different carbohydrate sources to different protein ratio.

Proximate analysis (%)	Initial	Corn fibre			Corn starch			Glucose-D			CRD	SD±
		C5:P30	C10:P25	C20:P20	C5:P30	C10:P25	C20:P20	C5:P30	C10:P25	C20:P20		
Crude protein	$52.95^{de}\pm0.01$	$63.55^{c}\pm0.00$	$66.78^{b}\pm0.01$	$66.33^{b}\pm0.01$	$53.37^{de}\pm0.01$	$67.15^{b}\pm0.01$	$63.47^{c}\pm0.01$	$55.34^{e}\pm1.72$	$61.04^{d}\pm0.01$	$68.99^{a}\pm0.01$	$66.06^{b}\pm0.01$	0.52
Crude fat	$5.39^{bc}\pm0.01$	$9.52^{a}\pm0.01$	$3.78^{c}\pm0.02$	$4.45^{cd}\pm0.01$	$5.72^{d}\pm0.01$	$5.26^{cd}\pm0.01$	$2.98^{b}\pm0.01$	$2.70^{b}\pm0.01$	$7.04^{ac}\pm0.01$	$5.44^{cd}\pm0.01$	$6.17^{d}\pm0.01$	0.01
Crude fibre	$1.23^{e}\pm0.01$	$6.20^{b}\pm0.01$	$7.17^{a}\pm0.04$	$6.12^{b}\pm0.01$	$5.71^{b}\pm0.01$	$7.02^{a}\pm0.01$	$5.97^{b}\pm0.02$	$3.71^{d}\pm0.01$	$3.99^{d}\pm0.01$	$4.65^{c}\pm0.01$	$3.56^{d}\pm0.01$	0.02
Ash	$5.60^{de}\pm0.06$	$10.13^{c}\pm0.01$	$5.31^{f}\pm0.01$	$3.91^{ef}\pm0.01$	$6.63^{e}\pm0.06$	$4.88^{f}\pm0.01$	$15.95^{b}\pm0.01$	$18.20^{a}\pm0.01$	$7.65^{d}\pm0.01$	$10.93^{c}\pm0.06$	$5.31^{f}\pm0.01$	0.02
NFE	$8.66^{a}\pm0.01$	$0.36^{e}\pm0.01$	$2.01^{c}\pm0.01$	$3.11^{b}\pm0.01$	$1.10^{d}\pm0.01$	$1.99^{c}\pm0.01$	$0.99^{d}\pm0.01$	$0.49^{d}\pm0.01$	$1.00^{d}\pm0.01$	$0.17^{e}\pm0.01$	$1.90^{c}\pm0.01$	0.01
Moisture	$26.15^{b}\pm0.01$	$10.25d^{f}\pm0.01$	$14.91^{e}\pm0.01$	$16.08^{d}\pm0.01$	$27.47^{a}\pm0.01$	$13.68^{e}\pm0.01$	$10.57^{f}\pm0.01$	$18.55^{c}\pm0.01$	$19.25^{c}\pm0.01$	$9.87^{f}\pm0.01$	$16.99^{d}\pm0.01$	0.01

Mean data on the same row carrying letter(s) with different superscripts are significantly different (P<0.05).

treatments, however, diet 20:20 C/P ratio gave the lowest mean weight gain (MWG). There were significant differences (P<0.05) in the SGR for all the treatments which was highest in 10:25 C/P ratio. The FCR values also indicated significant differences (P<0.05) for all the treatment but diet 10:25 gave the lowest FCR value. There were significant differences (P<0.05) in the PER values for all the treatments which was highest for 20:20 C/P ratio. However, the ANPU values also showed significant differences (P<0.05) for all the treatments but diet containing 10:25 C/P ratio gave the highest value.

The corn starch based diets exhibited insignificant differences (P>0.05) in the MWG for treatments 5:35 and 10:25 C/P ratios both of which were significantly higher (P<0.05) than 20:20 C/P ratio. There were significant differences (P<0.05) for the treatments in the SGR values which was highest with 10:25 C/P ratio. The FCR values also were significant (P<0.05) for all the treatments which was lowest for 10:25 C/P ratio. There were significant differences (P<0.05) in the PER and ANPU values for all the treatments which were highest for 20:20 and 10:25 C/P ratios respectively. The survival percentage was significant (P<0.05) for all the treatments but was lowest for 15:25 C/P ratio.

The glucose based diets indicated insignificant differences (P>0.05) for all the treatments in the MWG and SGR values. There were significant differences (P<0.05) in the FCR for all the treatments but was lowest for 20:20 C/P ratio. The PER values indicated no significant differences (P>0.05) between diets 5:30 and 10:25 both of which were significantly lower (P<0.05) than 20:20 C/P ratio. The ANPU values were significant for all the treatments but highest for 20:20. The survival percentages indicated no significant differences (P>0.05) between diets 5:25 and 20:20 but were significantly high (P<0.05) for 10:25.

Table 3 showed the results of the nutrient utilization. There were no significant differences (P>0.05) between diets 15:25 and 20:20 in the body protein and significantly higher (P<0.05) than 5:30. The body fat showed significant difference (P<0.05) for all the treatments which was highest for 5:30 C/P ratio. The body ash indicated significant differences (P<0.05) for all the treatments but was lowest for 20:20 C/P ratio. There were significant differences (P<0.05) in the moisture content but lowest for 10:30 C/P ratio.

The corn starch based diets exhibited significant differences (P<0.05) in the body protein for all the treatments which was highest for 15:25 C/P ratio. Similarly, the body fat indicated significant differences (P<0.05) for all treatments but was lowest for 20:20 C/P ratio. The body ash also expressed significant differences (P<0.05) for all the treatments, however, diet 10:25 gave the lowest body ash. There was also significant differences (P<0.05) in the body moisture contents which was lowest for diet 20:20 C/P ratio.

The glucose based diets indicated significant differences (P<0.05) in the body protein for all the treatments but was highest for 20:20. The body fat also showed significant differences (P<0.05) for all treatments but was lowest for 5:30 C/P ratio. Similarly, there were significant differences (P<0.05) in the body ash and body moisture which are lowest for 10:25 and 20:20 C/P ratios respectively.

However, the growth responses for corn fibre and glucose shown in Figure 1 indicated a growth curve with apparently similar trend while, the corn fibre appeared to have a better protein sparing toward the end of the feeding trial at 5:30 C/P

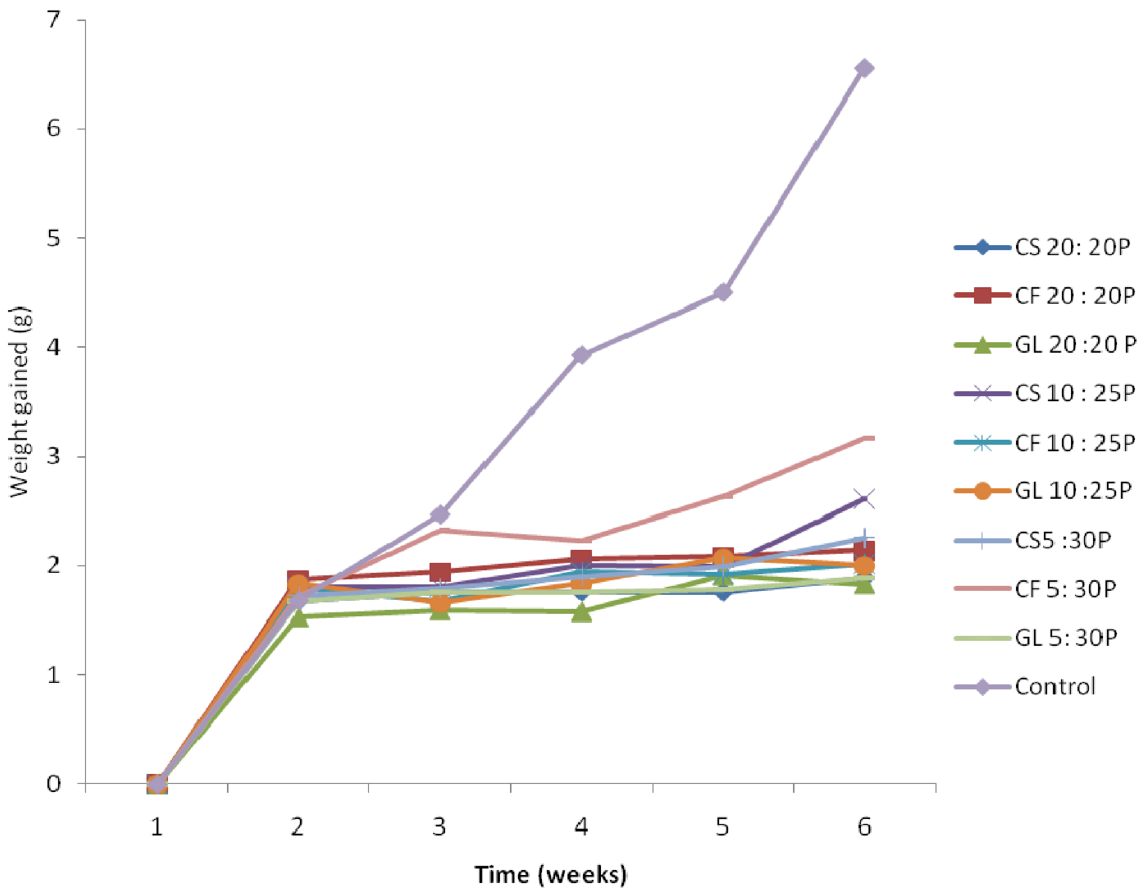

Figure 1. Clarias gariepius fe various sources of carbohydrate at varying levels of inclusion for 56 days.

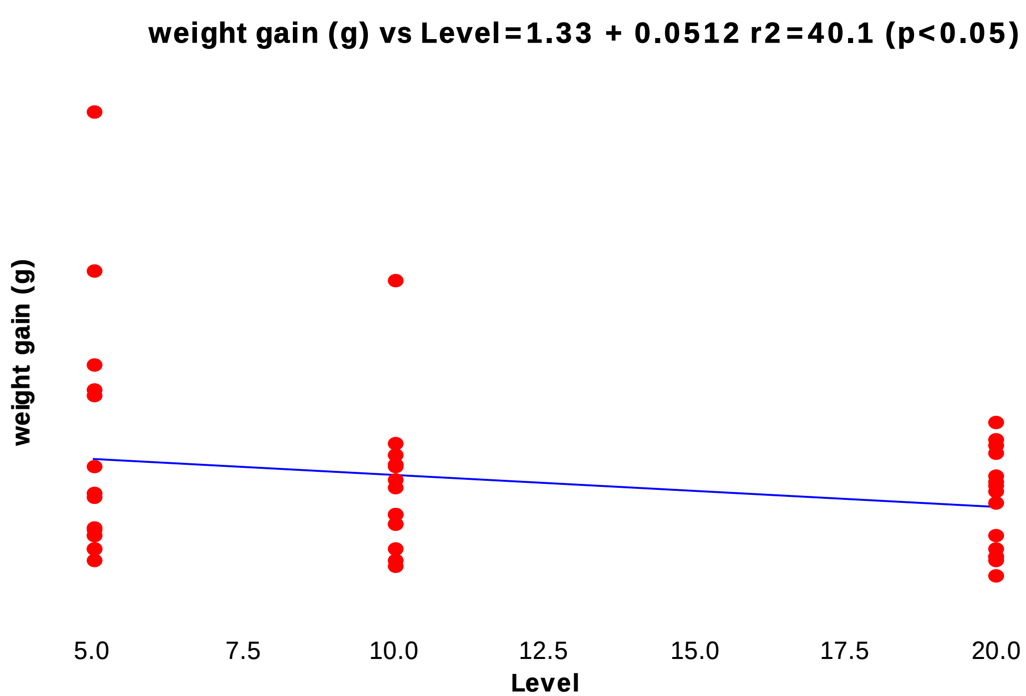

Figure 2. Regression of Clarias gariepinus fed varying inclusion levels of corn starch, corn fibre and glucose for 8 weeks.

ratio. The regression co-efficient in Figure 2 showed positive relationships between weight gain and the glucose levels and negative relationship with protein levels. The corn starch also showed a negative relationship in its weight gain and the inclusion levels of corn starch and a positive relationship with protein levels the corn fibre based diets indicated a negative relationship between the weight gain and the corn fibre levels and positive relationship with protein levels.

DISCUSSION

The results on growth performance indicated utilization of carbohydrate irrespective of sources by *C. gariepinus* which was an expression of carbohydrate sparing effects of protein. Examining the carbohydrate sources at the three levels of carbohydrate/protein ratios, the corn fibre based diets was well utilized for growth at the lowest inclusion level of carbohydrate and highest crude protein inclusion level (C5:30P). However, this performance may not be seen as true protein sparing since protein was still at its maximum level of inclusion. On the contrary, the corn starch based diets at a higher inclusion level (15:25), performed better than other carbohydrate sources. While at the highest level of ratio (20:20), glucose exhibited same level of growth with other ratios. The similar in trend of growth for the glucose based diets signified that *C. gariepinus* can tolerate up to 20% glucose level in its diet without adverse effects. Utilization of up to 20% glucose level is an indication of protein sparing effects of glucose in *C. gariepinus* as evident in the regression equation that was positive which was corroborated with strong positive correlation between the mean weight gain, specific growth rate and protein efficiency ratio. This is contrary to the report of Machiels and Van Dam (1987) who reported that *C. gariepinus* has a low ability to metabolize glucose. The corn fibre did not spare protein at all while corn starch spared protein at 15:25 C/P ratio. Moreover, Balogun and Ologhobo (1989), Heinsbroek et al. (1990), and Fagbenro et al. (1993) reported that carbohydrate levels in *C. gariepinus* diets often can be substantial, and reportedly range from 15 to 35%. This is in agreement with the finding in this study; however, the ability of *C. gariepinus* to handle complex carbohydrate is very limited as observed in the growth response of various carbohydrate based diets (Adeparusi and Jimoh, 2002). The negative relationship between the weight gain and corn starch inclusion level and negative correlation between the mean weight gain and feed conversion ratio confirmed further the limited ability of *C. gariepinus* to utilize carbohydrate of a complex nature. Dietary carbohydrate levels beyond a certain point have been reported to depress feed efficiency and growth, and even cause eventual mortality (Hilton and Atkinson, 1982; Kaushik et al., 1989).

However, corn fibre has proven the need for provision of adequate energy to fish which remains essential (Abu et al., 2009). Therefore, in this study corn fibre were found to spare protein as energy source for growth at 5% inclusion level.

Conclusion

The results obtained indicated protein sparing by complex carbohydrate (corn fibre). This has further established the ability of *C. gariepinus* to utilize carbohydrate in its diets sparing expensive protein for growth.

Conflict of Interests

The authors have not declared any conflict of interests.

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REFERENCES

Abu OMG, Sanni OL, Tarawali G, Akoroda M, Dixon A (2009). The Effect of Replacing Maize with Whole Cassava Root Meal on the Nutrient Utilization of Hybrid Cat Fish. J. Aquac. Feed Sci. Nutr. 1(3): 61-67.

Adeparusi EO, Jimoh WA (2002). Digestibility coefficient of raw and processed lima bean-diet for Nile tilapia. J. Appl. Aquac. 12(3): 89-98. http://dx.doi.org/10.1300/J028v12n03_09

Association of Official Analytical Chemists (AOAC) (2000). Official Methods of Analysis. (17th edn., AOAC), Gaithersburg, MD.

Balogun MA, Ologhobo AD (1989). Growth performance and nutrient utilization of fingerling Clarias gariepinus (Burchell) fed raw and cooked soybean diets. Aquaculture 76:119-126. http://dx.doi.org/10.1016/0044-8486(89)90256-1

Barroso JB, Peragón J, García-Salguero L, Aranda F, de la Higuera M, Lupiá-ez JA (2001). Int. J. Biochem. Cell Biol. 33:785-796. http://dx.doi.org/10.1016/S1357-2725(01)00050-4

Brauge C, Médale F, Corraze G (1994). Effect of dietary carbohydrate levels on growth, body composition and glycaemia in rainbow trout, Oncorhynchus myliss, reared in seawater. Aquaculture 131:125-133.

Ellis SC, Reigh RC (1991). Effect of dietary lipid and carbohydrate levels on growth and body composition of juvenile red drum, Sciaenops ocellatus. Aquaculture 97:387-394. http://dx.doi.org/10.1016/0044-8486(91)90330-A

El-Sayed AM, Garling DL Jr (1988). Carbohydrate-to-lipid ratio in diets for Tilapia zilli fingerlings. Aquaculture 73:157-163. http://dx.doi.org/10.1016/0044-8486(88)90050-6

Degani G, Ben-Zvi Y, Levanon D (1989). The effect of different protein levels and temperatures on feed utilization, growth and body composition of Clarias gariepinus (Burchell 1822). Aquaculture 76: 293-301. http://dx.doi.org/10.1016/0044-8486(89)90082-3

Fagbenro OA, Adeparusi E, Fapohunda O (2003). Feed stuffs and dietary substitutions for farmed fish in Nigeria. Proceedings of the National Workshop on Fish Feed Development and Feeding Practices in Aquaculture, (NWFFDFPA'03), National Fresh Water Fisheries Research Institute, pp. 60-65.

Fagbenro OA, Balogun B, Ibironke N, Fasina F (1993). Nutritional values of some amphibian in diets for Clarias gariepinus (Burchell, 1822) (Siluroformes: Clariidae). J. Aquac. Trop. 8:95-101.

Heinsbroek LTN, Thoor RMH, Elizondo LJ (1990). The effect of feeding level on the apparent digestibilities of nutrients and energy of a reference diet for European eel, Anguilla anguilla L. and the African catfish, Clarias gariepinus (Burchell). In: The Current Status of Fish Nutrition in Aquaculture. Proceedings of Third International Symposium on Feeding and Nutrition in Fish. Takeda, M. and Watanabe, T. (eds.). Toba, Japan. pp. 175-188.

Henken AM, Machiels MAM, Dekker W, Hogendoorn H (1986). The effect of dietary protein and energy content on growth rate and feed utilization of the African catfish, Clariasgariepinus (Burchell 1822). Aquaculture 58:55-74. http://dx.doi.org/10.1016/0044-8486(86)90156-0

Kaushik SJ, Médale F, Fauconneau B, Blanc D (1989). Effect of digestible carbohydrates on protein/energy utilization and glucose metabolism in rainbow trout. Aquaculture 50:89-101. http://dx.doi.org/10.1016/0044-8486(85)90155-3

Likimani TA, Wilson RP (1982). Effects of diet on lipogenic enzyme activities in channel catfish hepatic and adipose tissue. J. Nutr. 112:112-117. PMid:7054459

Machiels MAM, Henken AM (1985). Growth rate, feed utilization and energy metabolism of the African catfish, Clarias gariepinus (Burchell, 1822), as affected by dietary protein and energy content. Aquaculture 44:271-284. http://dx.doi.org/10.1016/0044-8486(85)90226-1

Machiels MAM, Van Dam AA (1987). A dynamic simulation model for growth of the African catfish, Clarias gariepinus (Burchell, 1822) III. The effect of body composition on growth and feed intake. Aquaculture 60:55-71. http://dx.doi.org/10.1016/0044-8486(87)90357-7

National Research Council (NRC) (1993). Nutrent requirement of fish. Committee on Animal Nutrition. Board on Agriculture.National Academy of Sciences. National Academy Press. Washington DC., USA. P. 114.

Peragón J, Barroso JB, García-Salguero L, de la Higuera M, José AL (1999). Carbohydrates affect Protein-Turnover Rates, Growth, and Nucleic-Acid Content in White Muscle of Rainbow Trout (Oncorhynchus mykiss). Aquaculture 179:425-437. http://dx.doi.org/10.1016/S0044-8486(99)00176-3

Sánchez-Muros MJ, García-rejón L, Lupiá-ez JA, De La Higuera M (1996). Long-term nutritional effects on the primary liver and kidney metabolism in rainbow trout (Oncorhynchus mykiss). II. Adaptive response of glucose 6-phosphate dehydrogenase activity to high-carbohydrate/low-protein and high-fat/non-carbohydrate diets. Aquac. Nutr. 2:193-200. http://dx.doi.org/10.1111/j.1365-2095.1996.tb00059.x

Serrano JA, Nematipour GR, Gatlin DM III (1992). Dietary protein requirement of the red drum (Sciaenops ocellatus) and relative use of dietary carbohydrate and lipid. Aquaculture 101:283-291. http://dx.doi.org/10.1016/0044-8486(92)90031-F

Shiau SY, Lin YH (2001). Carbohydrate utilization and its protein-sparing effect in diets for grouper (Epinephelus malabaricus). Anim. Sci. 73:299-304.

Shimeno S, Ming DC, Takeda M (1993). Regulation of carbohydrate metabolism in fish. XVI. Metabolism of coho salmon, Oncorhynchus kistuch. Gen. Comp. Endocrinol. 81:473-483.

Uys W (1989). Aspects of the nutritional physiology and dietary requirements of juvenile and adult sharptooth catfish, Clarias gariepinus (Pisces; Clariidae). Ph.D Thesis, Rhodes University, Grahamstown, South Africa. 190 p.

Wilson RP (1994). Utilization of dietary carbohydrate by fish. Aquaculture 124:67-80. http://dx.doi.org/10.1016/0044-8486(94)90363-8