Nigerian Journal of Fisheries Vol. 8 (1) 2011

PROTEIN SPARING EFFECTS OF CARBOHYDRATE IN THE PRACTICAL DIETS OF *Oreochromis niloticus*

*ORIRE, A.M. & S.O.E. SADIKU
Department of Water Resources, Aquaculture and Fisheries Technology,
Federal University of Technology, P.M.B. 65, Minna, Niger State, Nigeria
*Corresponding author: orire9@yahoo.com +234-7032552295

ABSTRACT
A feeding trial was conducted to establish protein sparing effects of various lipid sources in Oreochromis niloticus fingerlings mean weight 8.05 ± 0.05 g for eight weeks. Nine experimental diets and one commercial reference diet was used for the trial. The experimental diets consisted of three levels of carbohydrate (C) and protein (P) designated as 10C:30P, 30C:25P and 50C:20P ratios. Three carbohydrate sources used were cornfibre, cornstarch and glucose-D. The result obtained showed significant differences (P < 0.05) among the carbohydrate/protein ratios fed to O. niloticus. However, the cornstarch based diets spared protein at 30% inclusion level bringing down crude protein to 25%. While, glucose based diets could spared protein up to 50% inclusion level but had a decline in growth towards the end of the feeding trial. The cornfibre based diets least spared protein for growth.

Keywords: Fish nutrition, nutrient, aquaculture, Nile tilapia.

INTRODUCTION

Protein is the single most expensive ingredient in fish diets. The fact that high levels of dietary protein may lead to the consumption of protein for energy purposes, has led to the investigation of the use of non-protein energy sources in fish diets (El-sayed and Garling, 1988; Desilva *et al.*, 1991; Shiau and Peng, 1993 and Erfanullah and Jafri, 1995). It has been reported that fish do not have a carbohydrate requirement (NRC, 1993). However, several studies have been carried out on the carbohydrate-lipid ratio in fish diet to spare protein (Bierber-Walschny and Pfeffer, 1987; Nematipour *et al.*, 1992 and Ali *et al.*, 2001) .the recommended dietary inclusion of digestible carbohydrate is up to 20% for diets fed to salmonids and marine fish and up to 40% for warm water species (Wilson, 1994). Anderson *et al.* (1984) and Qadri and Jameel (1989) reported that the growth performance and feed utilization in young *Oreochromis .niloticus* was enhanced by progressive levels (up to 40%) of various carbohydrates in the diets. Ali *et al.* (2001) reported that *O. niloticus* utilizes carbohydrates more efficiently than lipids. On cellulose utilization, Al-Ogaily (1996) observed that 9% cellulose in diets of *O. niloticus* improves the growth, FCR, PER, and NPR values. He however, did not observe any negative effects of utilizing 12% cellulose in the diet. Anderson *et al.* (1984), however, concluded that an increase in the level of cellulose above 10% is not desirable in the diets of *O. niloticus*. It has been observed that elevated crude fibre content in fish diets may exert a negative effect on the digestibility of nutrients (Kirchgessener *et al.*, 1986). Ali *et al.* (2001) obtained best results in the diet containing 10.5% cellulose in *O. niloticus*. There is dearth of information on the protein sparing effects of carbohydrate in the practical diets of cultured fish species. The objective of this study was to investigate the protein sparing effects on carbohydrate in the diet of *O. niloticus*.

MATERIALS AND METHODS

Experimental procedure

The study was conducted in a recycling water system of the Department of Water Resources, Aquaculture and Fisheries Technology, School of Agriculture and Agricultural Technology, Federal University of Technology, Minna.

The experimental design was factorial 3 X 3 while fishes were allotted by complete randomized design where ingredients were the only variables. 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. The diets were designated as 10C:30P, 30C:25P and 50C:20P for the carbohydrate (C): protein (P) ratios. Three carbohydrate sources were used; complex (corn fibre), moderately complex (cornstarch) and Glucose-D (simple sugar) while fishmeal was the sole protein source (Table 1).

Experimental Fish and system

One hundred and fifty (150) fingerlings of *Oreochromis niloticus* mean weight 8.05 ± 0.05 g were obtained from the hatchery unit of National Institute of Freshwater Fisheries Research NewBussa, Niger State. The fishes were acclimatized for one week and were fed on commercial catfish diet (crude protein 40%). At the commencement of the feeding trial, a group of 15 fishes were randomly assigned to 30 tanks each group was placed in an individual 50-L cylindrical tank in triplicate. The experiment was conducted for 8 weeks. Before the commencement of the feeding trial, seven 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. Five 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 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 as stated below:

$$Mean\ weight\ gain = Mean\ final\ weight - Mean\ initial\ weight$$

$$Specific\ Growth\ Rate\ (SGR) = \left(\frac{Log_e W_2 - Log_e W_1}{T}\right) \times 100$$

Where, W_2 and W_1 represent – final and initial weight,

T – Duration of experiment in days

$$Feed\ conversion\ ratio = Feed\ dry\ matter / fish\ live\ weight\ gain$$

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

$$Protein\ intake\ (g) = Feed\ intake \times crude\ protein\ of\ feed$$

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

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 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.

Table 1: Formulated diets and Proximate analysis of different carbohydrate sources and Protein ratios fed *Oreochromis niloticus*

Formulated diets	CF10: 30P	CS10: 30P	GL10: 30P	CF30: 25P	CS30: 25P	GL30: 25P	CF50: 20P	CS50: 20P	GL50: 20P	CRD 45%
Fishmeal	27.92	33.31	36.39	20.97	26.93	30.33	14.03	20.70	24.26	
Corn fibre (CF)	67.09	0.00	0.00	74.03	0.00	0.00	80.97	0.00	0.00	
Corn starch (CS)	0.00	61.69	0.00	0.00	68.08	0.00	0.00	74.46	0.00	
Glucose D (GL)	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	
Feed proximate compositions (%)	1	2	3	4	5	6	7	8	9	
Moisture	8.42	7.54	9.52	9.2	5.88	7.23	13.58	8.58	7.16	7.62
Ash	10.94	8.78	4.38	5.94	6.98	5.44	5.41	5.97	5	9.92
Ether extract	4	7	7	3.92	7	5.94	3	5.88	6.93	12.84
Crude Protein	29.61	30.26	30.71	24.65	25.33	26.14	20.98	20.55	19.65	44.65
Crude fibre	37.45	35.36	37.43	26.70	24.33	11.14	7.44	7.33	11.14	2.43
NFE	9.58	11.06	10.96	29.59	30.12	30.80	49.59	51.69	50.12	22.54

RESULTS

The Corn fibre (CF) based diets fed at three levels of carbohydrate-protein (C/P) ratios gave significant differences ($P < 0.05$) in the growth performances measured. Diet containing 10:30 C/P ratio, gave significantly higher ($P < 0.05$) mean weight gain (MWG) (0.39), (30:25) (0.33) while diet containing 50:20 C/P ratio gave significantly ($P < 0.05$) lower MWG (0.08). However, there was no significant difference ($P > 0.05$) in the specific growth rate (SGR) values between treatments 10:30 and 30:25 (0.07) but both were significantly higher ($P < 0.05$) than diet containing 50:20 C/P ratio (Table 2). The CF based diets at 10:30 C/P and 30:25 apparently gave a significantly lower ($P < 0.05$) feed conversion ratio (FCR) values (5.00 and 5.15 respectively) than the 50:20 C/P (6.50) (Table 2).The CF based diets at 30:25 C/P ratio also exhibited significantly higher ($P < 0.05$) PER value (0.78) but with no significant difference ($P > 0.05$) to 50:20 C/P value (0.77). Moreover, diet containing 10:30 C/P gave the lowest PER value but with a significantly higher ($P < 0.05$) ANPU value followed by 50:20 and lowest value was obtained for 30:25 C/P ratio. On the body compositions, 10:30 C/P based diet gave significantly higher body protein followed by 50:20 and 30:25 C/P ratios respectively with significant difference ($P < 0.05$) between the treatments. The fat contents were significantly lower ($P < 0.05$) for diet containing 10:30 C/P ratio (4.52) than 30:25 (5.70) and 50:20 (5.69) with no significant difference ($P > 0.05$) between the treatments. There were significant differences ($P < 0.05$) in the ash values for all the treatments which was significantly higher ($P < 0.05$) for diet containing 50:20 C/P ratio. There were significant differences ($P < 0.05$) in the moisture contents for all the treatments which were significantly lower ($P < 0.05$) for 10:30 (12.95) and 50:20 (13.55) with no significant difference ($P > 0.05$) between the treatments (Table 3).

The cornstarch (CS) based diets exhibited significant difference ($P < 0.05$) in some cases across the treatments. There was no significant difference ($P > 0.05$) in the MWG between treatments containing 10:30 and 30:25 C/P ratios (3.87 and 4.27 respectively), which were significantly higher ($P < 0.05$) than 50:20 (0.29). However, there was no significant difference ($P > 0.05$) in the SGR values for 10:30 and 30:25 C/P ratios (0.73 and 0.73 respectively) both of which were significantly higher ($P < 0.05$) than 50:20 (0.06) (Table 2). The cornstarch based diets at C/P ratio 30:25 gave significantly lower ($P < 0.05$) FCR value (1.56) followed by 10:30 (2.29) with no significant difference ($P > 0.05$) between the treatments, while 50:20 gave the significantly higher ($P < 0.05$) FCR value (6.93) (Table 2). The CS based diets was well utilized at 30:25 C/P ratio (3.10) which was significantly higher ($P < 0.05$) in PER and ANPU values than other C/P ratios. There was no significant difference ($P > 0.05$) in the ANPU values for 10:30 and 50:20 (30.45 and 30.71 respectively). However, diet containing 50:20 gave a significantly higher ($P < 0.05$) survival percentage than other ratios. The body protein composition was significantly higher ($P < 0.05$) for 30:25 and 10:30 C/P ratios (76.78 and 77.15 respectively) with no significant difference ($P > 0.05$) between the treatments. Moreover, the 10:30 C/P ratio gave significantly low ($P < 0.05$) body fat but with no significant difference with treatment 30:25 C/P ratio. Moreover, diet containing 50:20 C/P ratio gave a significantly higher ($P < 0.05$) ash content than other ratios (Table 3).

The Glucose-D (GL-D) based diets at 10:30 C/P ratio gave a significantly higher ($P < 0.05$) MWG (5.39), and SGR (0.88), values than other C/P ratios (Table 2). The Glucose based diets 10:30 C/P ratio gave a significant lower ($P < 0.05$) FCR value (0.72) followed by 30:25 while 50:20 gave significantly higher ($P < 0.05$) FCR value (5.56) (Table 2). The Glucose-D based diets gave a significantly higher ($P < 0.05$) PER (9.16) and ANPU (53.40) values at 50:20 C/P ratios than other ratios which were significantly low ($P < 0.05$) for 30:25 C/P ratio (1.52 and 29.53 respectively). Diets containing 10:30 and 50:20 C/P ratios gave a significantly high ($P < 0.05$) body protein but with no significant difference ($P > 0.05$) between the treatments (Table 3). Figures 1 – 3 showed the growth response of different carbohydrate source fed *Oreochromis niloticus*. The glucose based diets apparently spared protein up to the 6th week of the feeding trial before it started to drop. While the corn starch based diets spared protein at 30% inclusion level at crude protein inclusion level of 25% while the corn fibre based diets did not spare protein at all levels.

On carbohydrate sources-protein ratios, glucose based diets at 10:30 carbohydrate/protein ratio gave a significantly higher ($P < 0.05$) mean weight gain, SGR, PER and low FCR however, it was significantly low ($P < 0.05$) in survival rate followed by cornstarch while corn fibre gave significantly lower ($P < 0.05$) growth parameter values. At 30:25 carbohydrate/protein ratio, corn starch exhibited significantly high ($P < 0.05$) mean weigh gain, SGR, PER, ANPU and low FCR, while there was no significant difference ($P > 0.05$) difference between the mean survival rate with glucose based diets. At 50:20 carbohydrate/protein ratios, corn starch and glucose although with no significant difference ($P > 0.05$) between them, gave a significantly higher ($P < 0.05$) mean weight gain, and SGR than corn fibre based diets. However, corn fibre and glucose based diets gave significantly higher ($P < 0.05$) FCR values despite the significantly high ($P < 0.05$) PER and ANPU values (Table 2).

The regression co-efficient indicated a significantly ($P < 0.05$) weak relationship between the levels of carbohydrate and protein in the diets. There was a significantly negative relationship between the weight gain and the glucose level ($x = 10.8 - 0.0228y$; $r^2 = 0.04$; $P < 0.05$) while the relationship with the protein levels was significantly positive ($x = 8.35 + 0.0.71y$; $r^2 = 0.30$; $P < 0.05$) respectively. The corn starch also indicated similar relationship. The weight gain and corn starch exhibited significantly negative relationship ($x = 11.5 - 0.043y$; $r^2 = 0.17$; $P < 0.05$) while it was significantly positive for the crude protein levels ($x = 5.93 + 0.169y$; $r^2 = 0.15$; $P < 0.05$) respectively.

Table 2: Mean growth parameters/nutrient efficiency of *Oreochromis niloticus* fed various Carbohydrate Sources/Protein ratio for eight weeks

Growth Parameters	CF10: 30P	CF30: 25P	CF50: 20P	CS10: 30P	CS30: 25P	CS50: 20P	GL10: 30P	GL30: 25P	GL50: 20P	CRD 40%	SD ±
Initial Body Wt. (g)	8.52^{a} ±0.08	8.68^{a} ±0.13	8.61^{a} ±0.03	8.59^{a} ±0.02	8.56^{a} ±0.12	8.61^{a} ±0.06	8.48^{a} ±0.04	8.53^{a} ±0.07	8.52^{a} ±0.03	8.54^{a} ±0.03	0.07
Final Body Wt. (g)	8.90^{d} ±0.86	9.00^{d} ±0.74	8.69^{d} ±0.76	12.92^{b} ±2.92	12.84^{b} ±5.29	8.90^{d} ±0.22	13.87^{a} ±5.90	10.77^{c} ±2.60	8.81^{d} ±9.67	14.32^{a} ±2.10	4.22
Weight gain (g)	0.39^{d} ±0.82	0.33^{d} ±0.73	0.08^{e} ±0.74	3.87^{b} ±2.90	4.27^{b} ±5.18	0.29^{d} ±0.18	5.39^{a} ±5.94	2.24^{c} ±2.54	0.29^{d} ±9.65	5.78^{a} ±2.04	4.19
SGR(%)	0.07^{c} ±0.13	0.07^{c} ±0.00	0.02^{c} ±0.00	0.73^{a} ±0.40	0.73^{a} ±0.68	0.06^{c} ±0.04	0.88^{a} ±0.25	0.42^{b} ±0.70	0.06^{c} ±0.00	0.92^{a} ±0.25	0.45
FCR	5.00^{b} ±11.11	5.15^{b} ±0.00	6.50^{a} ±0.00	2.29^{c} ±1.64	$1.56d^{c}$ ±1.39	6.93^{a} ±3.03	0.72^{d} ±0.20	2.83^{e} ±2.36	5.56^{a} ±0.00	1.29^{c} ±0.49	4.03
PER	0.44^{e} ±0.38	0.78^{e} ±0.00	0.77^{e} ±0.00	2.17^{d} ±1.63	3.10^{c} ±3.76	0.25^{de} ±0.16	4.82^{b} ±1.32	1.52^{ac} ±1.75	9.16^{a} ±0.00	2.23^{d} ±0.79	1.89
ANPU(%)	24.81^{e} ±0.01	6.56^{g} ±0.01	16.24^{f} ±0.02	30.45^{d} ±0.01	38.46^{b} ±0.01	30.71^{d} ±0.01	33.14^{c} ±0.06	29.53^{d} ±0.01	53.40^{a} ±0.06	34.97^{c} ±0.01	0.01
Survival (%)	83.33^{b} ±5.77	90.00^{a} ±10.00	93.00^{a} ±5.77	43.33^{f} ±30.55	43.33^{f} ±35.12	76.67^{c} ±5.77	30.00^{g} ±34.64	43.33^{f} ±30.55	50.00^{e} ±56.57	66.67^{d} ±20.82	26.22

Means on the same row carrying letter (s) with different superscript (s) are significantly different from each other ($P<0.05$)

Table 3: Body composition of *Oreochromis niloticus* fed various Carbohydrate sources/Protein ratios for eight weeks

Proximate composition (%)	Initial	CF10: P30	CF30: P25	CF50: P20	CS10: P30	CS30: P25	CS50: P20	GL10: P30	GL30: P15	GL50: P20	CRD	SD ±
Crude protein	60.44^{f} ±0.01	73.55^{e} ±0.01	63.37^{fe} ±0.01	66.33^{cd} ±0.01	76.78^{b} ±0.01	77.15^{b} ±0.01	71.04^{d} ±0.01	78.33^{a} ±0.01	73.57^{c} ±0.17	78.99^{a} ±0.01	76.06^{b} ±0.01	0.05
Crude fat	3.40^{g} ±0.01	4.52^{e} ±0.01	5.70^{b} ±0.01	5.69^{b} ±0.01	3.78^{cd} ±0.01	4.26^{cd} ±0.01	7.05^{a} ±0.01	4.45^{e} ±0.01	2.98^{e} ±0.01	5.43^{c} ±0.01	6.17^{b} ±0.01	0.01
Crude fibre	1.23^{g} ±0.06	3.17^{e} ±0.06	5.71^{b} ±0.01	6.71^{a} ±0.01	2.20^{fg} ±0.06	3.02^{de} ±0.06	4.00^{f} ±0.06	4.12^{f} ±0.01	5.97^{b} ±0.01	4.65^{c} ±0.06	3.55^{ef} ±0.01	0.02
Ash	5.60^{b} ±0.01	5.43^{c} ±0.01	6.62^{b} ±0.01	10.20^{a} ±0.01	5.31^{c} ±0.01	4.88^{c} ±0.01	6.65^{b} ±0.01	3.91^{d} ±0.01	9.99^{a} ±0.01	5.90^{b} ±0.01	5.31^{c} ±0.01	0.01
NFE	9.27^{a} ±0.01	0.31^{cd} ±i0.01	1.09^{c} ±0.06	3.48^{b} ±0.01	1.01^{c} ±0.00	1.99^{c} ±0.01	2.66^{b} ±0.57	0.11^{cd} ±0.01	0.99^{d} ±0.01	0.17^{cd} ±0.01	0.99^{d} ±0.01	0.17
Moisture	20.05^{a} ±0.01	12.95^{c} ±0.01	17.47^{b} ±0.01	13.55^{c} ±0.01	10.91^{d} ±0.01	6.68^{e} ±0.01	9.25^{cd} ±0.01	9.07^{cd} ±0.01	6.37^{f} ±0.01	4.85^{ef} ±0.01	6.90^{e} ±0.01	0.01

Means on the same row carrying letter (s) with different superscript (s) are significantly different from each other (P<0.05)

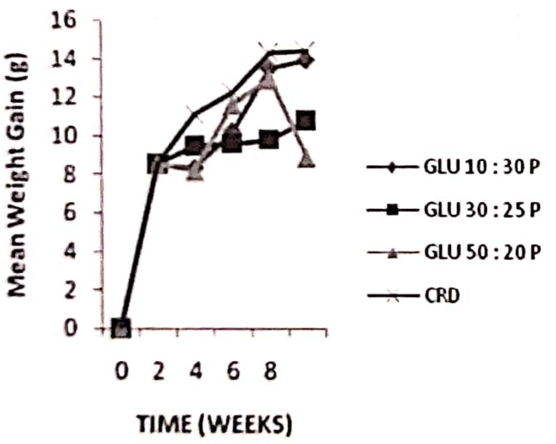

Fig. 1: Growth response of *O.niloticus* fed various glucose/protein ratios for 8 weeks

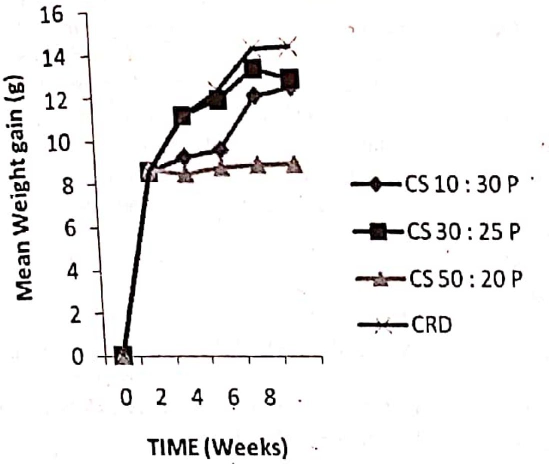

Fig. 2: Growth response of *Oreochromis niloticus* fed varous corn starch/protein ratios for eight weeks

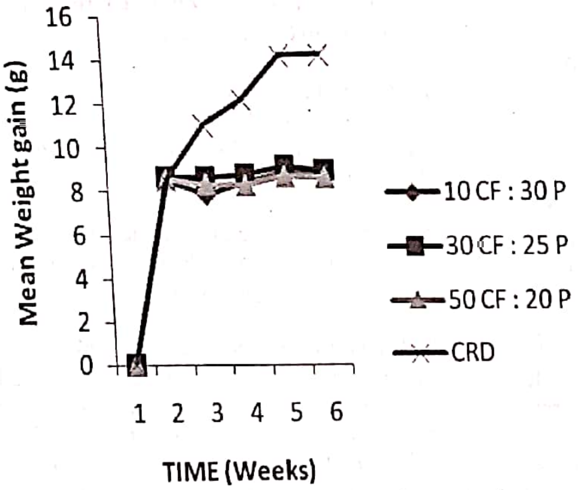

Fig. 3 : Growth response of *Oreochromis niloticus* fed various corn fibre/protein ratios for eight weeks

DISCUSSION

The results showed that Corn fibre (CF) based diets least spared protein for growth since the best growth performance was obtained at the highest inclusion level of protein. This trend indicated the limitation of *Oreochromis niloticus* to digest complex carbohydrate (Anderson *et al*., 1984; Ali *et al*., 2001) which resulted from poor feed intake and unavailability of nutrients (Jacquelyn, 2000).

The Cornstarch (CS) based diets exhibited protein sparing at 30:25 C/P ratio whose growth parameters were better than other ratios. However, there was decline in growth when inclusion level went beyond 30% that resulted in significant poor growth. This could be attributed to inadequate crude protein in the diet and subsequent withdrawal of same from the less vital parts of the body to maintain the functions of more vital ones (Wilson, 1984; Lovell, 1980). When the crude protein was 30%, there was a poor utilization of the diet, a reflection of nutrient wastage and possible use of excess amino acids for energy (Bureau *et al*., 2002; Lovell, 1988). The Cornstarch a less complex in structure could be utilized efficiently by *O. niloticus* up to 30% but not up to 50% (Fig. 2). It was evident from the result that the corn starch spared protein for growth up to 30% inclusion level, thereby minimizing the use of protein for energy (Shiua and Lan, 1996; Fu *et al*., 2001). The nutrients utilization as measured by PER and ANPU were significantly higher for diet 30:25 C/P ratio, which is in agreement with Shiau and Lin (1993) who reported for *Paneaus monodon* utilization of starch from 20% to 30% in the diets. The strong relationship shown in the regression co-efficient values revealed protein sparing of glucose in *O. nilotcus*. However, relationship was stronger in strength than that of glucose which indicated that, *O. niloticus* could utilize cornstarch to spare protein better than other carbohydrate sources.

The Glucose based diets showed protein sparing at 50:20 C/P ratio. This performance showed that *O. niloticus* could utilize glucose at higher inclusion level in its diet. Several authors have reported limited ability of fish to utilize glucose as energy source to spare protein for growth (Furunchi and Yone, 1981, 1982; Wilson, 1994; Lovell, 1984). These authors established that due to quick absorption of glucose in the blood stream as noticed in the rise in the blood glucose concentration following ingestion of carbohydrate, the fish oxidizes deaminated amino acids for energy more efficiently and preferably to glucose (Lovell, 1988). From the result obtained, it was obvious that inclusion of glucose at lower level of 10%, there was efficient utilization of glucose for growth. However, increasing it to 30% inclusion level gave a low weight gain, SGR, high FCR, lowest PER and ANPU values. This showed that the increment in glucose content was poorly utilized and as such lowering the protein content to 25% was inadequate to meet the requirement, as part of which was deaminated for the supply of energy (Stone *et al.* 2003; Furunchi *et al.*, 1986). However, increasing the glucose content to 50% gave improved SGR, FCR, PER and ANPU values than other levels of inclusion. The result showed that when there is adequate supply of energy in the diet, the fish will be able to meet its energy budget thereby utilizing available protein for tissue development. Therefore, at 50:20 C/P ratio, there was a strong indication of protein sparing of glucose which has reduced the inclusion level of protein to 20% (Fig. 1). This is contrary to the submission of Chow and Halver (2009) who established that glucose does not appear to be energy source for fish over protein, although they agreed that digestible carbohydrate could spare protein for tissue building. Moreover, limited tolerance of glucose by *O. niloticus* can be observed in the weak negative relationship between the weight gain and glucose levels indicated limited tolerance of glucose by *O. niloticus* which was corroborated by the weak but positive relationship between the weight gain and protein levels (Table 2).

CONCLUSION

The results obtained showed protein sparing effects of various carbohydrate sources fed to *Oreochromis niloticus*. Of the three carbohydrate sources, corn starch spared protein best followed by glucose and the least was corn fibre. The result obtained would cut down on nutrient cost which would cut down on production cost without impacting negatively on the growth and health of fish.

REFERENCES

Al-Ogaily S.M., (1996) Effect of feeding levels of cellulose on the growth performance and body composition of *Oreochromis niloticus* Arab Gulf J. Scient. Res. 14:731-745

Ali Amanat, Nasser A. and Al-Asgah (2001). Effect of feeding different carbohydrate to lipid ratios on the growth performance and body composition of Nile Tilapia (*Oreochromis niloticus)* fingerlings. *Animal Research.* 50 (2001) 91-100.

Anderson J., Jackson A.J., Matty A.J. and Capper B.S. (1984). Effects of dietary carbohydrate and fibre on the tilapia *Oreochromis niloticus* (Linn.) *Aquaculture* 37, 303-314.

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

Bieber-Walschny M. and Pfeffer E. (1987). Gelatinized maize starch versus sunflower oil or beef tallow as sources of non-protein energy in diets for rainbow trout (Salmon gairdneri R.). I. Growth rate and utilization of dietary energy and protein. *J. Anim. Physiol. Animal Nutrition*. 57: 150-156.

Bureau, D.P., Kaushik, S.J. and Cho, C.Y. (2002) Bioenergetics. In: Fish Nutrition, 3rd edn. (Halver, J.E., Hardy, R.W, eds) pp.1-59. Academic Press California.

Chow K.W.and J.E. Halver (2009).Aquaculture Development and Coordination Progrmme, Fish feed Technology. www.fao.org/docrep downloaded2009

De-Silva S.S., Guansekera R.M and Shim K.F. (1991). Interactions of varying dietary protein and lipidlevels in young red tilapia : evidence of protein sparing, *Aquaculture* 95: 305-318.

El-Sayed, A.M. and Garling, D.L.Jr (1988). Carbohydrate-to-lipid ratio in diets for Tilapia zilli fingerlings. *Aquaculture*, 73, 157-163

Erfanulla and Jafri A.K., (1995). Protein-sparing effect of dietary carbohydrate in diets for fingerling (Labeo rohita) *Aquaculture*, 136, 331-339.

Fu, S.J., Xie, X.J., Zhang, W.B. and Cao, Z.D. (2001). Replacement of protein by fat and carbohydrate in diet for Atlantic salmon (salmo salar) at the end of the freshwater stage. *Aquaculture*, 152, 167-180.

Furuichi, M., Taira, H. and Yone, T. (1986). Availability of carbohydrate in nutrition of yellowtail. Bull. Jpn. Soc. Sci. fish., 52, 99-102.

Furuichi, M. and Yone, Y. (1982). Availability of carbohydrate in nutrition of carp and red sea bream. Bull. *Japan Social Science and fisheries*., 48, 945-948.

Furuichi M. and Yone Y. (1981). Change of blood sugar and plasma insulin levels of fishes in glucose tolerant test. Bulletin of the Japanese Society of Scientifc Fisheries 47, 761- 764. FAO/UNDP, 1978

Jacquelyn, E (2000). Energy yielding nutreints. University of Arkansas Cooperative Extension Service Publications UACES: Publications : ETB256-Nutrition and Feeding of Baitfish: Energy-Yielding Nutrients.

Kirchgessener, M. Hurzinger H. Schwartz, F.J. (1986). Digestibility of crude nutrients in different feeds and estimation of their energy content for carp (*Cyprinus carpio* L.), *Aquaculture* 58:185-194.

Lovell, R.T (1980). practical fish diet. In: fish feed technology. ADCP/REP80/11.

Lovell, T. (1988). Digestion and metabolism. In: *Nutrition and Feeding of fish* (ed. By Lovell, T.) Van Nostrand Reinhold, New York.

Lovell, (1984). In: Fish Nutrition. NRC (1993). National Research Council (NRC) (1993). Nutrient requirement of fish. Committee on Animal Nutrition. Board on Agriculture. National Academy of Sciences. National AcademyPress. Washington DC., USA. P. 114.

Nematipour, G.R., Brown, M.L. & Gatlin, D.M.I. (1992). Effects of dietary energy: protein ratio on growth characteristics and body composition of hybrid striped bass, Morone chrysops (female) × M. saxatilis (male). *Aquaculture*, 107, 359– 368.

Qadri N.N. and Jameel K. (1989). Effect of dietary carbohydrate of different molecular complexity on tilapia (Sarotherodon mossanbicus), *Pakistan Journal of Science*. Ind. Res. 32: 382-386.

Shiau, S.Y. and Lan, C.W. (1996). Optimum dietary level and protein to energy ratio for growth of grouper (*Epinephelus malabaricus*). *Aquaculture,* 145, 259-266.

Shiau, S.Y. and Lin, S.F., (1993). Effect of supplementary dietary chromium and vanadium on the utilization of different carbohydrates in tilapia, *Oreochromis niloticus* x *O. aureus*. *Aquaculture* 110: 321-330.

Shiau, S.Y. and Peng, C.Y. (1993). Protein-sparing effect by carbohydrates in diets for tilapia, *Oreochromis niloticus x O. aureus. Aquaculture*, 117, 327-334.

Stone D.A, G. I. Allan and A.J. Anderson (2003). Carbohydrate utilization by juvenile silver perch, Bidyanus bidyanus (Mitchell) III. The protein-sparing effect of wheat starch-based carbohydrates. *Aquaculture Research,* 34, 123-134.

Wilson, R.P. (1984) Utilization of dietary carbohydrate by fish. *Aquaculture,* 124,67-80.