Egypt. J. Aquat. Biol. & Fish., Vol.6, No.3 : 17 - 38 (2002) ISSN 1110 – 6131

CARBOHYDRATE TO LIPID RATIO (CHO:L) IN PRACTICAL TILAPIA DIETS: I- EFFECT OF DIETARY CARBOHYDRATE TO LIPID RATIO ON GROWTH PERFORMANCE OF HYBRID TILAPIA (*Oreochromis niloticus x O aureus*).

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Key words: Hybrid tilapia, carbohydrate to lipid ratio, growth performance, total lipid of liver.

ABSTRACT

A 160 day feeding trial was performed to determine the effects of dietary carbohydrate to lipid ratio (CHO:L) on growth and body composition of hybrid tilapia (40.6 ± 0.43 g, initial weight). Eight artificial diets were formulated, representing two protein levels (25 and 30%) , within each level four carbohydrate to lipid ratios (2,4,6 and 8 CHO:L ratio) were tested. Growth rates in fish differed ($P<0.05$) with CHO:L ratio. Weight gain (%) was significantly lower ($P<0.05$) in fish fed diets containing low crude protein. Maximum weight gain (363.5%), SGR (0.96% /day), FCE (43.4%), protein retention (24.4%) and energy retention (15.7%) were observed in fish fed a 6 CHO:L ratio. Fish fed either high protein and low protein within 2 and 8 CHO:L ratios tended to produce lower growth and feed conversion efficiency. The different CHO:L ratios had effect on percentage body lipid. HSI (%) of fish increased, however, total lipid of liver decreased ($P<0.05$) as CHO:L increased. These results indicate that hybrid tilapia efficiently utilize carbohydrate to lipid ratio for growth performance when increased up to 6.0 CHO:L ratio. Higher dietary CHO:L ratio up to 6 with low protein level in diet (25% CP) may result in sparing effect for high dietary protein (30%) with 4 CHO:L ratio.

INTRODUCTION

Maximizing the utilization of dietary protein for growth is related to both the dietary inclusion level of protein and the availability of non- protein energy sources, namely lipid and carbohydrate. Inclusion of non- protein energy has been shown to spare dietary protein from catabolism to provid and enhance its utilization for growth, a process known as " protein sparing " (Dias *et al.*, 1998).

Any imbalance with respect to non protein energy sources and /or their levels of inclusion may have a direct affect on growth, conversion efficiencies, nutrient retention and body composition (Jafri, 1998). In warm- water fish, dietary carbohydrate utilization is considerably high, and incorporation of this nutrient may add beneficial effects to the pelleting quality of the diet and to fish growth (NRC, 1993; Wilson, 1994). Cooking or gelatinization of starch has been demonstrated to increase carbohydrate utilization for fish (Catacutan and Coloso, 1995). High levels of dietary lipid may create problem in the pelleting quality of the diet (Jauncey, 1982), as well as, adversely affect the fish carcass / body composition (Hanley, 1991). It is thus imperative to determine the optimum dietary carbohydrate: lipid (CHO:L) ratio .

Earlier studies on this topic have been reported for channel catfish (Garling and Wilson, 1977), *Tilapia zilli* (El-Sayed and Garling, 1988), hybrid bass (Nematipour *et al.*, 1992) and hybrid clarias catfish (Jantrarotai *et al.*, 1994). El-Sayed and Garling (1988), found that *Tilapia zilli* fingerlings can efficiently utilize both carbohydrates and lipids as energy sources if they are substituted for one an other of 2.25:1 which commensurate with CHO:L physiological fuel values. Though, Li *et al.* (1991) reported that the lower protein diets supplemented with carbohydrate and lipids could spare 18-22% dietary protein of Nile tilapia (*Oreochromis niloticus*).

The present study was undertaken to determine the optimum dietary carbohydrate to lipid ratios and the possibility of reducing the percentage of protein in the diet that produce the best growth, feed conversion , improved nutrient retention and body composition .

MATERIALS AND METHODS

Experimental conditions:-

Hybrid tilapia (*Oreochromis niloticus X O. aureus*) 40.9± 0.43 were purchased from a local tilapia farm and held in an outdoor cement pond subdivided by netting to eight rearing units (10m^2 /unit) with 1 m depth. Fish were adapted to the new environment and fed on a commercial pelleted diet for two weeks prior to the experimental start. Eight rearing units (40 fish/unit) were supplied with fresh water from Nile River. The water was monitored twice weekly for temperature (29.8± 3.1°C); pH (7.6±0.41); Oxygen (5.44 ± 0.63 mg/l) and ammonia (0.39 ± 0.12 ppm), as described by APHA (1992).

Experimental diets:-

Eight artificial diets (Table 1) were formulated representing two protein levels (25 and 30%) within each level four carbohydrate to lipid ratios (2, 4, 6 and 8 CHO:L ratio) were tested. The CHO:L of each diet was adjusted by incorporation of biscuit industry byproduct as carbohydrate source and cotton seed oil.

Feeding trial :-

Fish were fed 3% of body weight per day. The daily ration was subdivided into two equal partion and fed at 0 900 h and 1400 h. Fish were weighed every two weeks and the daily ration was adjusted accordingly. No diet was fed on the day of the weekly measurement. The experimental period expanded for 160 days (from 27 April to 2 October, 1999).

At the beginning and end of the experiment, all fish were counted and weighed, and ten fish from each rearing unit were collected for determination of liver weight, chemical body composition according to AOAC (1995) methods and liver lipid by Folch *et al.*, (1957), and muscle gross energy was calculated after NRC (1983). Proximate analysis of dietary ingredients and diets were performed using standard method (AOAC, 1995) and gross energy of diets was calculated after NRC (1977).

Statistical analysis:-

Comparison among different dietary treatments were made by two – way analysis of variance according to Snedecor and Cochran (1980). Duncan's multiple range test at $P<0.05$ (Duncan's, 1955).

RESULTS AND DISCUSSION

Hybrid tilapia (*Oreochromis niloticus X O. aureus*) fed diets containing varying carbohydrate to lipid ratios (CHO:L ratios 2 to 8) and protein levels (30and 25%) exhibited different growth performance (Table 2). Weight gain percentage as well as specific groth rate were highest in fish fed w6 CHO :L ratio 30% crude protein diet as opposed to fish fed the 2 CHO:L ratio with 25% dietary protein.

As presented in Table (2) and Figures 1,2 (a ,b) weight gain and specific growth rate (SGR) progressively increased significantly ($P<0.05$) with increasing carbohydrate to lipid ratio up to 6 CHO:L in the diet. Therefore, it appears that hybrid tilapia can tolerate up to 41.06% carbohydrate in the diet (Table 1) which is in agreement with the values reported for Nile tilapia (40% carbohydrate diet) (Anderson *et al.*, 1984) and *Tilapia zilli* (40%) (El-Sayed and Garling, 1988). Also, the same authors, demonstrated that *Tilapia zillii* fingerlings can efficiently utilize both carbohydrates and lipids as energy sources if they are substituted for one another at a rate of 2.25:1 which commensurate with CHO:L physiological fuel values.

The decreasing weight gain of hybrid tilapia (Table 2) fed on diets with 8 CHO:L ratio (a low fat high and carbohydrate diets) was comparable to those fed other diets which may be related to deficient essential fatty acids and this agrees with the findings of El-Sayed and Garlin (1988), who reported that *Tilapia zillii* may have been able to utilize higher levels of dietary CHO (>37% dextrin) if adequate essential fatty acids were available.

However, reduced growth in hybrid tilapia fed diets containing either high lipid with low carbohydrate diet (2 CHO:L ratio) could be the result of reduced feed intake (Table 3) by the fish due to high dietary lipid, reducing the intake of necessary amount of protein and other nutrients required for maximum growth (Jafri, 1998).

In the present study, the differences observed in growth indicate that the ability of the hybrid tilapia to adapt to increasing levels of dietary carbohydrate up to 41.06 with CHO:L ratios 6, appeared to be more pronounced than that reported for channel catfish and tilapia (Garling and Wilson, 1977; El- Sayed and Garling, 1988). The beneficial effects of dietary carbohydrate in warm water fish is well documented (Wilson, 1994). In Nile tilapia, increased growth was observed by feed on diets containing appropriate levels of carbohydrate, fat and protein (Teshima and Kanazawa, 1986). Jafri (1998) found that reduction in dietary lipid from 19.95 to 8.07 with concomitant increase in carbohydrate level from 0.44 to 27.28, corresponding to CHO:L ratios of 0.02 to 3.38 significantly improved the growth in *Clarias batrachus*.

Also, in plaice (*Pleuronectus platessa*), weight gain was greater in fish fed diets containing both carbohydrate and lipid, than those receiving lipid as the sole dietary non- protein energy source (Cowey *et al.*, 1975). The same trend was also observed by

Jantrarotai *et al.*, (1994), who found that the optimum CHO: L in hybrid catfish (*Clarias macrocephalus X C. gariepinus*) diets which produced good growth rate ranging from 3.83 to 11.24.

On the other hand, in channel catfish, diets containing 24% crude protein and 275 K cal /100 g (ME), with CHO:L ratios ranging from 0.45 to 4.5, have been reported to produce fish with no significant differences in weight gain (Garling and Wilson, 1977). Similarly in hybrid striped bass (Nematipour *et al.*, 1992) and rainbow trout (Brauge *et al.*, 1993) feeding different CHO:L ratio diets did not affect specific growth rate.

Result of weight gain percentage (WG%) (Table 2) as affected with CHO:L ratio within the protein levels tested (30 or 25%), showed that WG% was not significantly affected with protein levels in the fish fed at 4 CHO:L ratio. These data confirm the existence of a protein – sparing effect of lipids and carbohydrates, which seems to be influenced by the non- protein energy sources. In this connection, Li *et al.*, (1991) reported that Nile tilapia (*Oreochromis niloticus*) fed the lower protein diets supplemented with carbohydrates and lipid could spare 14-22% dietary protein.

Anderson *et al.* (1984) found that *Oreochromis niloticus* fed diets containing 40% carbohydrate (which represents approximately 30% of gross dietary energy) did not retard growth. Also, Degani and Viola (1987) found that the increase in the percentage of available carbohydrate (wheat meal) reduced the amount of protein or fat used for energy, and increased the amount of carbohydrate used for energy which therefore did not reduce the growth rate of eels (*Anguilla anguilla*). On the contrary, Dias *et al.* (1998) reported that protein – sparing is influenced by the dietary digestible energy level rather than by the nature of the non- protein energy sources.

The adverse growth responses that were observed for hybrid tilapia treatment with 25% cp with 2 CHO:L ratio (Table 2) may be attributed to increased crude fiber contents (10.78%) in this treatment than reported by Anderson *et al.* (1984). They found fiber levels up to 10% were not desirable in tilapia diets. Shiau *et al*, (1988), showed that increased stomach emptying of tilapia receiving the diets containing high levels of carboxymethyl cellulose increased the passage of chyme into the small intestine and clearly contributed to the observed shortening in the overall transit times.

The growth values (Table 2) indicate that hybrid tilapia (*Oreochromis niloticus X O. aureus*) are able to adapt to increased levels of carbohydrate to lipid ratios in the diet, but that levels in excess of 6 CHO:L ratio will result in a significant growth depression. These results are higher than these reported in previous works (El-Sayed & Garling 1988) for *Tilapia zillii* and for Nile tilapia by Li *et al.* (1991) which may be attributed to the use of hydrolyzed starch as biscuit industry byproduct in the present study. According to Lovell (1989), raw carbohydrate yields lower digestible energy per gram than cooked or partially hydrolysed starch. Shiau & Liang (1995) observed increased phosphofructokinase activity and decreased glucose-6- phosphatase activity in hybrid tilapia with increasing carbohydrate complexity in the diet. Subsequently, the activities of malic enzyme, glucose –6- phosphate dehydrogenase and phosphogluconate dehydrogenase also positively related to carbohydrate complexity in the diet of hybrid tilapia (Lin and Shiau, 1995).

Furthermore, tilapia has been reported to utilize starch better than glucose (Shiau and Chen, 1993; Anderson *et al.*, 1984). Pieper & Pfeffer (1980) suggested that poorer performance of simple sugar such as glucose might be due to "negative physiological effect" caused by glucose saturation. This is because that glucose as a simple sugar requires no digestion and is rapidly assimilated across the gut. However starch must undergo enzyme hydrolysis before assimilation. Thus, glucose appears at gut absorption sites more rapidly than sugar of more complex molecular structures. The implication of this is two fold. First, the rapid absorption of glucose would mean that considerable amounts of glucose enter the body before sufficient elevation of the activities of carbohydrate metabolic enzymes. This in turn would restrict the use of these highly digestible carbohydrate sources and thus cause the low availability of glucose to fish (Furuichi & Yone, 1982). Second, glucose is known to inhibit the transport of amino acids at absorption sites across the fish gut membrane (Hokazono *et al.*, 1979). Thus, glucose might have effects on the protein requirement of fish.

Though Shiau & Chen (1993); Shiau & Lin (1991) and Tung and Shiau, (1991) suggested that poor glucose utilization by tilapia can be attributed to the glucose being a) not absorbed by fish, b) absorbed but lost through the gills or c) catabolized with energy released and dissipated as heat. However, Shiau and Chen (1993), suggested that chromium supplementation improved glucose utilization by hybrid tilapia (*Oreochomis niloticu X O. aureus*) and that Cr_2O_3 supplementation facilitated the glycolysis pathway, increased lipogenesis by increasing the conversion of glucose to acetyl CO A .

In general results presented in Table (2) revealed that within each protein level, increasing the CHO:L ratio from 2 to 8 did not affect the survival rate of hybrid tilapia during the experimentle period. These results are in accordance with that reported by Jafri (1998), for walking catfish (*Clarias batrachus*), who found that no specific pattern of mortality was noticed among the treatment with respect to CHO:L ratios in the diet, the average survival rate was over 96% respectively.

The higher feed intake values were recorded for hybrid tilapia fed diet with 8 CHO:L ratio (Table 3). The same trend was also observed in walking catfish (Jafri 1998) who found that feed intake was significantly lower ($P<0.05$) in fish fed the diet containing low carbohydrate and high dietary lipid (0.02 CHO:L diet).

The results in Table (3) revealed that hybrid tilapia fed either the lowest (2) or the highest (8) CHO:L ratio diets tended to produce lower feed conversion efficiencies (FCR), however, in fish diets containing CHO:L ratio diets ranging from 4 to 6 were reported to produce higher FCR with no significant difference ($P>0.05$). Similar findinges were reported for *Tilapia zillii* by El- Sayed & Garling (1988) who found that diets containing 24.11 CHO:L ratio produced the poorest feed utilization however with 8.76 CHO:L ratio it was significantly improved ($P<0.05$). Jafri (1998) showed that fish feed conversion efficiency are affected by levels of non-protein energy source in diet. Jantraotai *et al.* (1994) reported that the optimum CHO:L ratio in hybrid catfish diets which produced good feed utilization ranged from 3.83 to 11.24.

Protein efficiency ratio (PER) of hybrid tilapia fed did 2 CHO:L ratio did not differ ($P>0.05$) from that of fish fed diet 8 CHO:L ratio but was significantly lower ($P<0.05$) than that of fish fed diets 4 and 6 CHO:L ratio (Table 3). In this connection, Jafri (1998) found that PER for walking catfish improved with dietary 3.38 CHO:L ratio respectively. Also, Hutchins *et al.* (1998), showed that protein efficiency ratio was highest in sunshine bass (*Morone chysops X M.saxatilis*) fed the 20/11 (% carbohydrate /% lipid) diets as opposed to fish fed the 40/2 diets. The same author added that PER progressively increased with increasing carbohydrate complexity in the diet, however sunshine bass fed glucose had lower values for protein efficiency ratio due possibly to the faster absorption of the monosaccharide; excess absorbed glucose may be cleared from circulation before cells can utilize it efficiently (Hilton and Atkinson, 1982). Evidence of excess blood glucose clearance, probably via excretion are reported by (Pieper and Pfeffer, 1980).

Maximum protein retention and energy retention (Table 3) were noted in hybrid tilapia fed 4 and 6 CHO:L ratio diets regardless of dietary protein levels, which coincided with the highest weight gain percentage (Table 2). Higher levels of dietary lipid or carbohydrate (2CHO:L or 8 CHO:L ratio diets) significantly reduced protein and energy retention in fish, indicating that hybrid tilapia fed with similar energy content, supplied by different energy sources, resulted in differential utilization of lipid and carbohydrate energy (Jafri, 1998). These results are partially agreed with those obtained by El-Sayed and Garling, (1988) for *Tilapia zilli*. They found an increase in protein production value and net energy retention with increasing dietary lipid (all diets were isocaloric and isontrogenous) which could be attributed to the relative amount of non- protein energy sources. This may indicate that *Tilapia zilli* can utilize dietary lipid more efficiently than CHO (Teshima *et al.*, 1978). They explained that theincreasing dietary lipid levels, may have led to reduction in the energy lost as heat, resulting in a more efficient utilization of dietary protein for growth (Beamish and Medland, 1986).

The significant decrease seen in the energy retention value in (Table 3) in fish 8 CHO:L ratio diet (low lipid and high carbohydrate, Table 1) may be attributed to a high energy loss as heat (heat increment) resulting from high dietary carbohydrate intake (Lovell, 1989). Similar observation has also been reported in hybrid catfish fed a low lipid and high raw carbohydrate from broken rice (Jantrarotai *et al.*, 1994).

Lipid retention tended to increase with increasing dietary CHO:L ratio regardless of dietary protein levels (Table 3). This conclusion supports the results of Brauge *et al.*, (1994), that whole body lipid gain in relation to digestible lipid intake was elevated in rainbow trout (*Oncorhynchus mykiss*) fed diets with the highest digestible carbohydrate levels.

The different CHO:L ratios of the experimental diets had no effect on moisture and protein contents of the muscle of hybrid tilapia (Table 4). However, decreasing CHO:L ratios in diets from 8 to 2 as increased dietary lipid intake (Table 3), regardless of dietary protein levels , resulted in increased muscle lipid. Similar results have been reported in Nile tiliapia (Hanley, 1991) and in *Tiliapia zillii* (El-Sayed

& Garling, 1988). They found that body moisture and protein were negativaly correlated to dietary lipid, while the positive correlation between body lipids and dietary lipids may indicate that when dietary lipids was supplied in excess, a proportion of this lipid was deposited as fat.

The inverse relationship between dietary carbohydrate levels or increased CHO:L ratios from 2 to 8 and muscle body lipid content (Table 4) appear interesting, since increased carbohydrate failed to produce undesirable fat accumulation in the body of the walking catfish (Jafri, 1998).

On the other hand Degani & Viola (1987), showed that eels (*Anguilla anguilla*) fed a highest carbohydrate level in their diet had a higher percentage of body fat. The same authors added that it is possible that European eels used less protein for protein synthesis and more as a source of energy. In this regard , Shiau and Liang (1995), found positive relationship between carbohydrate complexity and energy stores (muscle lipid). They observed increased phosphofructokinase activity and decreased glucose –6- phosphatase activity in hybrid tilapia with increasing carbohydrate complexity in the diet. Subsequently, the activities of malic enzyme, glucose –6-phosphate dehydorgenase and phosphogluconate dehydrogenase also were positively related to carbohydrate complexity in the diet of hybrid tilapia (Lin & Shiau, 1995). Glycolysis provides intermediates for synthetic pathway essential for cell division, cell proliferation has been associated with an enhanced rate of glycolysis (Greiner *et al.*, 1994). Reducing equivalents produced from the pentose phosphate pathway could be used to generate body and liver lipid from excess dietary carbohydrate energy (Likimani & Wilson, 1982).

In the present study (Table 4). the hepatosmatic index (HIS) data suggest that a high dietary CHO:L ratio enhances HIS. According to Brauge *et al.* (1994), hepatosomatic index was significantly elevated ($P<0.05$) in rainbow trout fed diets highest digestible carbohydrate levels. It is well known that liver size is directly related to hepatic glycogen level in salmonids (Kim and Kaushik, 1992). Also, Berger and Halver (1987) showed that liver enlargement may result from increased lipid or glycogen deposition or from liver protein depletion. Woods *et al.*, (1995) observed an increase in non- lipid fluid in the hepatocytes of striped bass fed diets with increasing carbohydrate energy which partially accounted for the observed increase in HIS values.

Liver lipid content of hybrid tilapia (Table 4) fed on diet with 2CHO:L ratio were significantly higher than those of fish fed 8 CHO:L ratio diets. This could be attributed to increased glycogenic processes and deposition of excess lipid (Garling & Wilson, 1977). Similar findings have been reported for catfish by Jantraroti *et al.* (1994), who found that feeding the high lipid diet tended to yield a high liver lipid contents. On the contrary, Brauge *et al.* (1994), proposed that the diet containing the highest level of lipid led to the lowest liver lipid suggesting that lipid deposition from dietary lipid does not occur in liver but probably in adipose tissue.

These data indicate that carbohydrate to lipid ratio can be effectively used by hybrid tilapia within 6 CHO:L ratio diets. Higher dietary CHO:L ratios up to 6 with low protein level in diet (25%) may result in sparing effect for high dietary protein (30%) with 4 CHO:L ratio .

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Table (1): Composition and proximate analysis of experimental diets (g/100g dry weight)

Crude protein level (%)	30				25			
CHO:L *	2	4	6	8	2	4	6	8
Ingredients (g/100g dry weight)								
Fish meal (72%cp)	14.8	28.0	21.7	28.0	28.0	22.0	21.02	18.0
Soy bean meal	38.7	15.0	25.0	13.0	-	10.0	14.15	18.68
Biscuit industry by -product [1]	26.3	48.0	49.4	54.0	39.5	51.23	57.0	60.0
Bone meal	8.68	3.0	-	3.0	20.0	8.57	3.0	-
cotton seed oil	9.25	4.0	1.9	-	10.5	5.2	2.83	1.32
Vitamin and mineral premix [2]	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Proximate analysis (%dry matter)								
Moisture	11.7	10.2	11.6	12.2	10.3	11.8	12.2	12.3
Crude protein (cp)	29.38	29.76	29.1	29.3	25.07	24.96	24.94	24.47
Ether extract (EE)	13.21	9.05	6.7	5.21	14.75	9.72	7.51	5.96
Crude fibre (CF)	9.58	7.12	7.33	5.92	10.78	7.58	5.19	5.42
Ash	8.09	6.85	4.21	4.76	9.37	5.95	5.24	4.02
Nitrogen free extract (NFE)	28.04	37.52	41.06	42.61	29.73	39.99	44.92	47.83
Gross energy [3] (Kcal /100 g diet)	405.7	404.5	397.3	390.8	403.4	398.3	398.1	393.0
CHO:L*	2.12	4.15	6.13	8.18	2.02	4.10	5.98	8.03
Protein energy x100/Gross energy (PE/GE)	40.19	40.83	40.7	41.6	34.5	34.8	34.8	34.6
CHO energy / Gross energy	29.0	39.0	43.4	45.8	31.0	42.2	47.4	51.1

*CHO:L (Carbohydrate --to --lipid ratios diet).

1-Biscuit industry by –product (6.3% Cp; 3.80% EE; 74.2% NFE; 2.0 fiber; 2.4% ash and 11.3% moisture)

2-Vitamin and mineral premix (each 1kg contains: 4.8m. I.U vit A; 0.8 m.I U vit D3; 4.09 vit. E; 0.8g vit K; 4 g vit. B12; 4.0g vit B_2 ; 0 6g vit B6; 4.0 g vit pantothenioc acid; 8.0 g vit Nicotinic acid; 400 mg vit Folic acid; 20mg vit. Biotin, 200g choline chloride; 4.0 g copper; 0.4 g Iodine; 12 g Iron; 22 g Manganese, 22g Zinc and 0.04 g Selenium.

3-Gross energy (kcal /100g diet) Calculate by NRC (1977)= 5.55 X % crude protein + 9.45 X% ether extract +4.2X % nitrogen free extract.

Table (2): Growth of hybrid tilapia fed varying protein levels and carbohydrate to lipid ratio diets. (Mean ± S.E).

Parameters	Crude protein level (%)		CHO:L				Interaction							
	30	25	2	4	6	8	30/2	30/4	30/6	30/8	25/2	25/4	25/6	25/8
Initial body weight (g)	40.9 ±2.18	41.0 ± 2.2	40.7 ±1.69	41.4 ±2.68	41.2 ±2.33	40.5 ±2.09	40.6 ±2.33	41.6 ±2.82	40.9 ±2.71	40.2 ±1.86	40.7 ±2.05	41.2 ±2.53b	41.4 1.94b	40.7 ±2.31
Final body weight (g)	181.6 ±5.9a	170.4 ±6.3b	154.0 ±6.5c	186.5 ±6.1a	190.7 ±5.9a	172.8 5.4b	161.5 ±6.2d	189.3 ±6.1b	199.6 ±5.9a	175.8 ±5.3c	146.4 ±6.7c	183.76. 6.1bc	181.7 ±5.8bc	169.8 ±5.4d
Weight gain (g)	14.07 ±4.9a	129.4 ±4.8b	113.2 ±5.1c	145.1 ±5.4a	149.5 ±4.3a	132.3 ±4.6b	120.9 ±5.7d	147.7 ±5.1b	158.7 ±4.4 a	135.6 ±4.3 c	105.7 ±5.6e	142.5 ±4.3bc	140.3 ±4.2 bc	129.1 ±4.9d
Percentage Weight gain [(1)] (WG%)	344.0 ±6.9a	315.2 ±6.2b	277.3 ±7.4c	350.5 ±6.8a	363.5 ±6.1a	327.3 ±7.1b	295.8 ±6.5d	355.0 ±7.6b	388.0 ±5.4a	337.3 ±8.2c	258.8 ±6.3c	345.9 ±5.9bc	338.9 ±6.7bc	317.2 ±6.0d
Specific growth rate[(2)] (%dry), SGR.	0.93 ±0.03	0.89 ±0.04	0.83b ±0.04	0.94a ±0.03	0.96a ±0.05	0.91ab ±0.03	0.86c ±0.03	0.94b ±0.03	0.99a ±0.05	0.92bc ±0.02	0.80d ±0.04	0.93b ±0.03	0.92bc ±0.05	0.89c ±0.04
Survival rate (%)	92.5	95.0	92.5	92.5	95.0	90.0	92.5	92.5	95.0	90.0	95.0	95.0	95.0	92.5

a, b, c, d and e means in the same yow with different superscript are significantly different ($P<0.05$).

(1)WG(%) = 100x (final body weight –initial body weight)/ initial body weight.

(2)SGR (%day) = (Ln final body weight –Ln initial body weight) x100 /days.

Table (3): Feed efficiency and nutrient retention of hybrid tilapia to varying protein levels and carbohydrate to lipid ratio diets (Mean ± S.E.)

Parameters	Crude protein level (%)		CHO:L				Interaction							
	30	25	2	4	6	8	30/2	30/4	30/6	30/8	25/2	25/4	25/6	25/8
Feed intake (g)	343.7	344.9	318.6	350.9	345.1	363.0	323.5	344.1	349.2	358.0	313.6	357.7	340.9	367.9
Feed conversion ratio (1)	2.46±.2b	2.69±.2a	2.83±.3a	2.42±.1b	2.32±9.2b	2.75±.3a	2.68±.3b	2.33±.1d	2.20d	2.46±.3c	2.97±.2a	2.51±.2bc	2.43±.1cd	2.85±.3a
Feed conversion efficiency %(2)	40.9±3.2	37.5±7.8	35.6±2.8b	41.4±2.6a	43.4±3.1a	36.5±2.3b	37.4±3.7c	42.9±3.1b	45.5±4.9a	37.9±3.5c	33.7±3.1d	39.8±4.1bc	41.2±2.8b	35.1±2.6d
Protein intake (g)	101.6	85.7	86.8	95.9	93.3	97.5	95.0	102.4	101.6	104.9	78.6	89.3	85.0	90.0
Protein efficiency ratio (3)	1.39±.12b	1.51±.2a	1.31±0.11b	1.52±.16a	1.61±0.14a	1.36±0.14b	1.27±.17d	1.44±.15bc	1.56±.13ab	1.29±.19d	1.34±0.12cd	1.60±.17a	1.65±.21a	1.43±.18bc
Protein retained % (4)	21.5±2.1	22.7±2.0	19.4±1.8b	23.5±2.2a	24.4±1.6a	21.1±2.3ab	18.6±2.1c	22.9±2.3b	24.3±1.9a	20.1±2.0bc	20.3±1.8bc	24.1±2.3ab	24.5±1.9ab	22.0±1.8b
Energy intake (kcal)	1365.6	1373.2	1275.2	1407.6	1372.3	1422.5	1285.3	1390.5	1387.4	1399.1	1265.1	1424.7	1357.1	1445.8
Engery retained % (5)	15.2±1.8	13.9±1.7	13.6±1.4b	15.7±1.7a	15.7±1.3a	13.2±1.2b	14.1±1.3b	16.1±1.9a	16.7±1.8a	13.8±1.4bc	13.0±1.6c	15.2±1.4ab	14.6±1.3b	12.6±1.1c
Lipid intake (g)	28.98	32.14	44.5	18.0	24.5	20.29	42.73	31.14	23.40	18.65	46.26	34.77	25.69	21.93
Lipid retention % (6)	33.1±4.2a	27.8±3.b	18.4±1.9c	29.2±b	37.0±3.5a	37.3±3.1a	19.91±2.4d	30.1±2.7bc	41.3±3.9a	41.11±4.0a	16.8±1.9d	28.3±2.2c	32.8±2.8b	33.5±3.1b

a, b, c and d means in the same row with different superscript are significantly different (P<0.05).

(1) Feed conversion ratio (FCR) = feed consumption (g)/ weight gain (g)

(2) Feed conversion efficiency % (FCE) = (weight gain (g)/ feed consumption (g))x100.

(3) Protein efficiency ratio (PER) =weight gain (g)/ protein intake (g).

(4) Protein retained % (Pr)= fish protein gain x100 /protein intake (g).

(5) Energy retained % (Er) =fish energy gain (Kcal) x100/Energy intake (kcal).

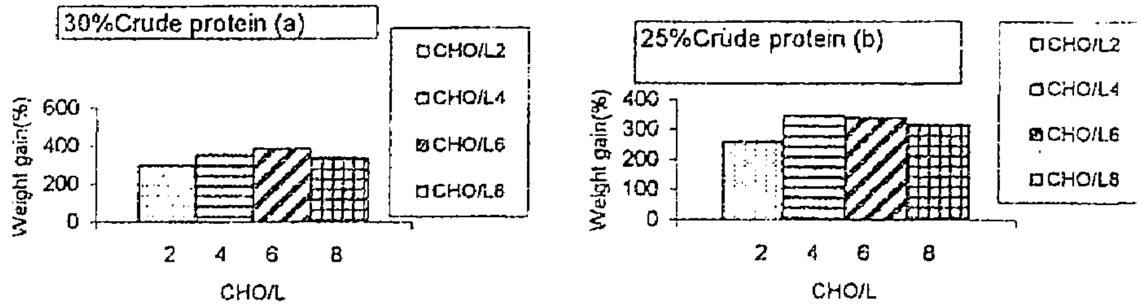
(6) Lipid retained %(Lr) = fish lipid gain (g) x100/ lipid intake (g).

Table (4) Proximate composition of muscle, hepatosomatic index and total lipid of liver of hybrid tilapia fed different protein level and total lipid of liver of hybrid tilapia fed different protein level and carbohydrate to lipid ratio diets (Mean ± S.E)

Parameters	Initial	Crude protein level (%)		CHO:L				Interaction							
		30	25	2	4	6	8	30/2	30/4	30/6	30/8	25/2	25/4	25/6	25/8
Moisture %	74.9	73.8	74.2	73.3	73.7	74.2	75.0	73.7	73.2	74.1	74.8	72.8	74.2	74.3	75.2
	±1.3	±1.8	±1.7	±1.6	±1.5	±1.4	±1.6	±1.9	±1.5	±2.1	±1.8	±2.3	±1.8	±1.7	±1.9
Crude protein (% of wet weight)	13.6	15.00	14.7	14.5	15.1	14.9	15.0	14.4	15.4	15.2	15.1	14.7	14.8	14.6	14.9
	±0.71	±0.42	±0.39	±0.43	±0.40	±0.53	±0.72	±0.58	±0.42	±0.49	±0.35	±0.39	±0.42	±0.46	±0.65
Ether extract (% of wet weight)	5.9	6.2	6.3	6.9a	6.5a	6.0ab	5.7b	6.8a	6.3ab	6.1bc	5.7c	7.0a	6.9a	6.0bc	5.7c
	±0.87	±0.55	±0.62	±0.38	±0.44	±0.79	±0.69	±0.99	±0.68	±0.85	±0.64	±0.48	±0.61	±0.42	±0.38
Ash (% of wet weight)	5.6	4.9	4.8	5.4a	4.8a	5.0a	4.3b	5.2a	5.2a	4.7b	4.4b	5.6a	4.4b	5.2a	4.2b
	±0.81	±0.57	±0.44	±0.37	±0.60	±0.75	±0.51	±0.67	±0.43	±0.52	±0.37	±0.40	±0.35	±0.51	±0.43
Gross energy (Kcal)	133.6	144.3	144.0	147.7a	147.4a	141.7ab	140.0b	145.9ab	147.2a	143.8b	140.4b	149.5a	147.5a	139.6b	139.5b
	±4.2	±7.6	±6.2	±5.2	±6.4	±6.8	±5.6	±5.3	±4.9	±5.9	±5.7	±7.2	±7.5	±5.9	±6.3
Hepatosomatic index (%) (HIS)[(1)]	1.95	2.08	2.81	1.96b	2.15ab	2.15ab	2.27a	1.87d	2.09c	2.13bc	2.24a	2.04cd	2.21ab	2.16b	2.30a
	±0.21	±0.18	±0.22	±0.24	±0.20	±0.25	±0.27	±0.21	±0.39	±0.19	±0.28	±0.20	±0.24	±0.31	±0.27
Total lipid of liver (%)	17.3	19.4b	21.6a	27.0a	23.9ab	17.8b	13.4c	24.8b	23.5b	16.9c	12.5d	19.2a	24.3b	18.7c	14.3d
	±2.5	±2.3	±2.1	±2.5	±2.2	±2.0	±1.6	±2.5	±2.8	±1.8	±1.9	±2.5	±2.0	±2.3	±1.5

a, b, c and d means in the same row with different superscript are significantly different ($P<0.05$).

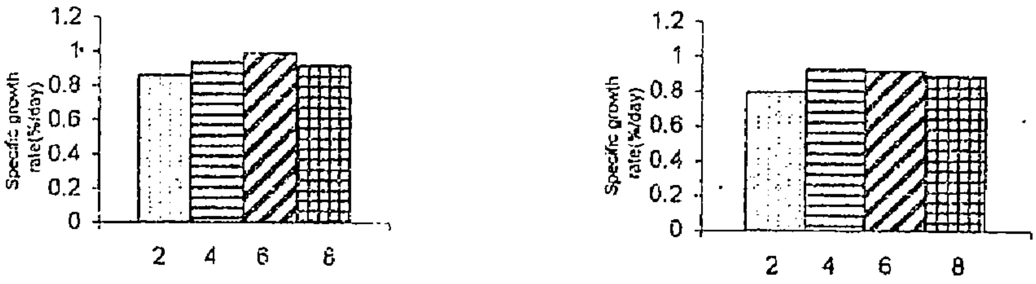
(1)HIS= liver weight (g) x100 /body weight (g).



Fig(1)a

Fig(1)b

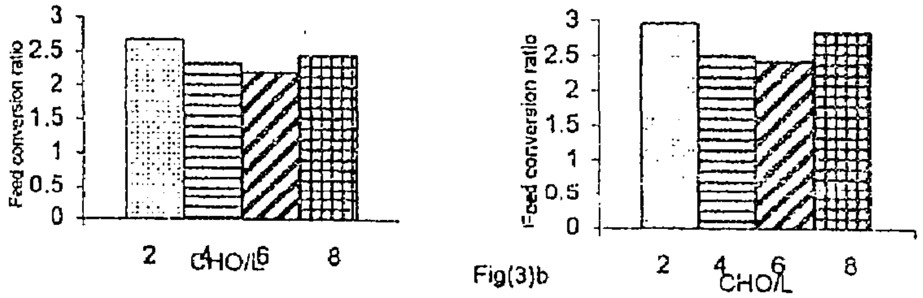
Fig(1): Effect of CHO/L ratio on percentage weight gain.



Fig(2)a

Fig(2)b

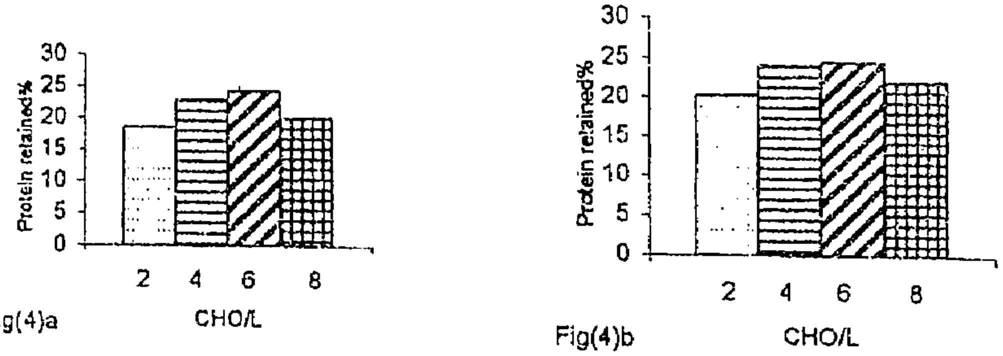
Fig(2): Effect of CHO/L ratio on specific growth rate.



Fig(3)a

Fig(3)b

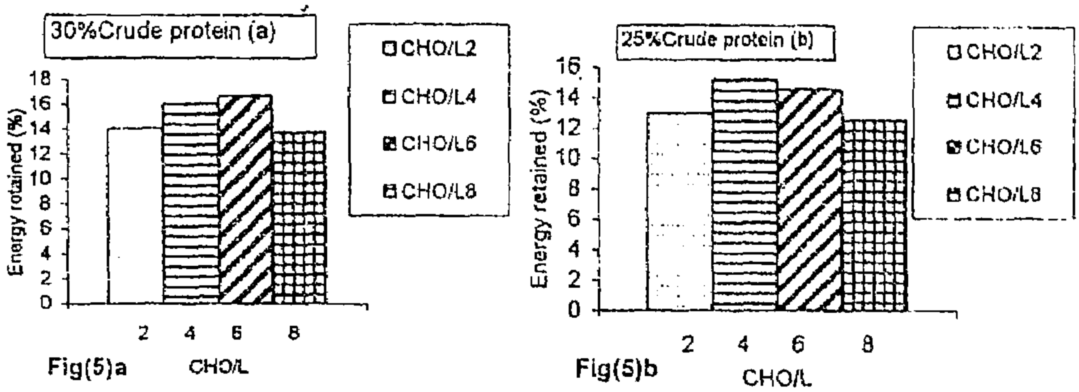
Fig(3): Effect of CHO/L ratio on feed conversion ratio.



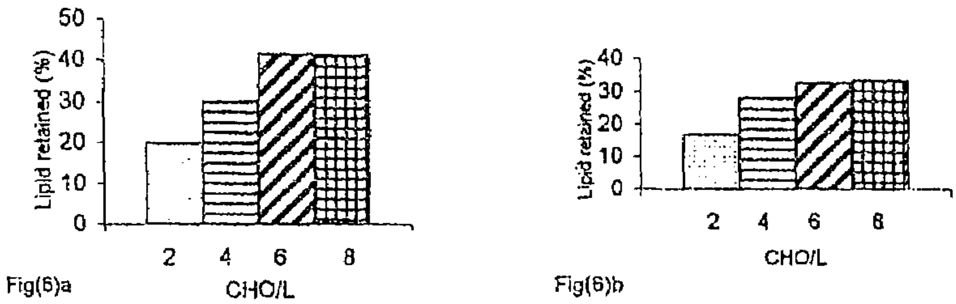
Fig(4)a

Fig(4)b

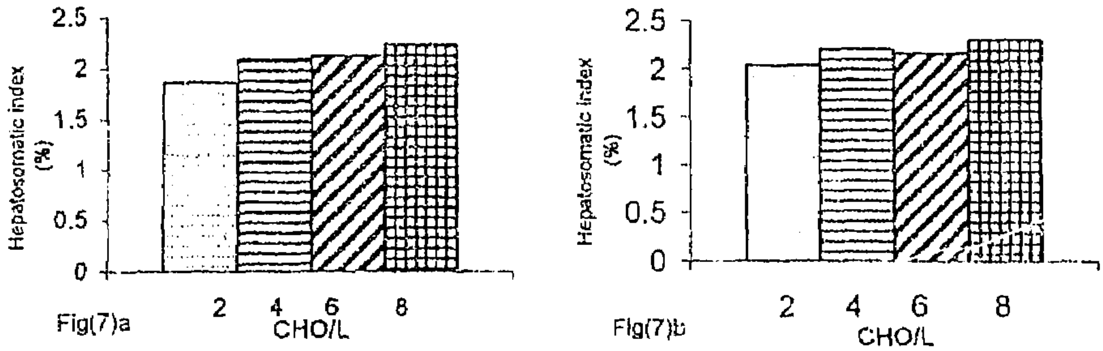
Fig(4): Effect of CHO/L ratio on protein retained.



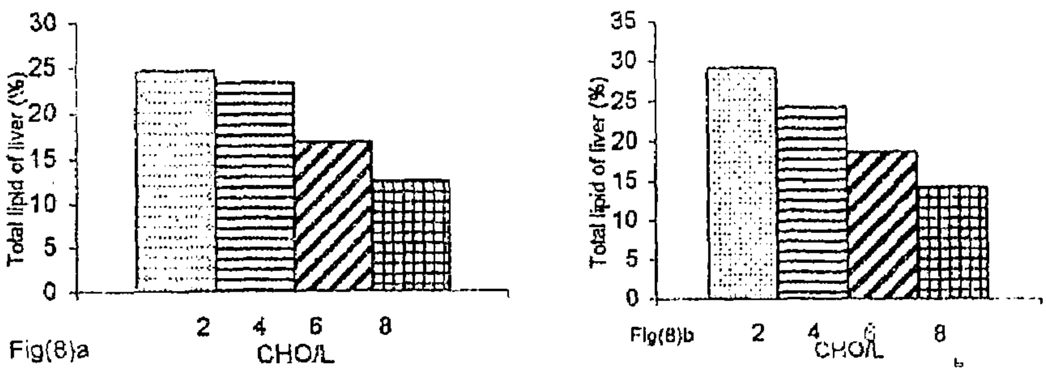
Fig(5): Effect of CHO/L ratio on energy retained.



Fig(6): Effect of CHO/L ratio on lipid retained.



Fig(7): Effect of CHO/L ratio on hepatosomatic index.



Fig(8): Effect of CHO/L ratio on total lipid of liver.