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Effect of feeding different carbohydrate to lipid ratios on the growth performance and body composition of Nile Tilapia (*Oreochromis niloticus*) fingerlings[1]

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Abstract — In this study, we evaluated the growth performance and body composition of Nile tilapia (*Oreochromis niloticus*) fed five isonitrogenous and isoenergetic diets (A, B, C, D and E) containing varying levels of carbohydrates (18.27–40.37%) and lipids (8.14–19.53%) with carbohydrate-to-lipid (CHO/LIP) ratios ranging from 4.95 to 0.94. Significant ($P < 0.05$) differences were observed in the body weight gain, condition factor, specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio (PER), net protein retention (NPR) and apparent net energy retention (ANER) values of fish fed diets with different CHO/LIP ratios. The A, B and C diets with CHO/LIP ratios ranging from 4.95 to 2.06 did not result in any difference ($P > 0.05$) in fish performance. Decreasing the CHO/LIP ratio to 1.38 (diet D) significantly ($P < 0.05$) reduced growth rate and feed efficiency. A further decrease in the CHO/LIP ratio to 0.94 (diet E), however, did not affect ($P > 0.05$) these values any more. The hepatosomatic index (HSI) increased with a decrease in the CHO/LIP ratio and was the highest (1.81) with a CHO/LIP ratio of 0.94 and lowest (1.33) with a CHO/LIP ratio of 4.95. No significant ($P > 0.05$) differences were observed in the HSI values between the fish fed diets B, C and D with CHO/LIP ratios ranging from 3.33 to 1.38. The body compositions of the fish were significantly affected ($P < 0.05$) by different CHO/LIP ratios in the diets. Body moisture and crude protein contents decreased whereas fat and ash contents increased with decreasing CHO/LIP ratios. The CHO/LIP ratio in the diets did not, however, affect ($P > 0.05$) the gross energy content of the fish. The results of the present study indicate that the optimal dietary CHO/LIP ratio for a maximum growth performance of *Oreochromis niloticus* ranges between 2.06 and 4.95.

***Oreochromis niloticus* / carbohydrate to lipid ratio / feeding / growth / body composition**

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[1] Dedicated to Prof. Dr. Wilhelm Hartfiel on his 75th birthday.

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Résumé — Effets de divers régimes alimentaires à base de glucides et de lipides sur la croissance et la composition corporelle du Tilapia (*Oreochromis niloticus*) fingerling. Cette étude avait pour but d'évaluer les performances de croissance et la composition corporelle du Tilapia (*Oreochromis niloticus*) alimenté avec différents régimes isoazotés et isoénergétiques (A, B, C, D, et E) contenant 18,27 à 40,37 % de glucides (CHO) et 8,14 à 19,53 % de lipides (LIP), dans des proportions CHO/LIP variant de 4,95 à 0,94. Des différences significatives ($P < 0,05$) ont été observées sur les valeurs de gain de poids corporel, de coefficient de condition (k), de taux de croissance spécifique (SGR), d'indice de consommation (FCR), de coefficient d'efficacité protéique (PER), de rétention protéique nette (NPR) et de rétention en énergie nette apparente (ANER). Les performances de croissance n'ont pas été significativement différentes ($P > 0,05$) entre les régimes A, B et C (rapport CHO/LIP variant de 4,95 à 2,06). En revanche, la diminution du rapport CHO/LIP à 1,38 (régime D) a diminué le taux de croissance et l'efficacité alimentaire ; une diminution plus importante jusqu'à 0,94 (régime E) n'a pas eu d'effet plus notable ($P > 0,05$). L'indice hépatosomatique (HSI) a augmenté avec la décroissance du rapport CHO/LIP et a atteint un maximum (1,81) avec une valeur de CHO/LIP égale à 0,94 et un minimum (1,33) avec une valeur de 4,95. Aucune différence significative ($P > 0,05$) n'a été observée entre les régimes B, C et D (CHO/LIP variant de 3,33 à 1,38) pour les valeurs de HSI. Les teneurs corporelles en eau et en protéines ont été diminuées alors que celles en gras et en cendres ont augmenté avec la diminution du rapport CHO/LIP ($P < 0,05$). En revanche, la teneur en énergie brute n'a pas été affectée ($P > 0,05$). Les résultats de l'étude montrent que le rapport CHO/LIP optimal pour une croissance maximale du tilapia (*Oreochromis niloticus*) se situe entre 2,06 et 4,95.

***Oreochromis niloticus* / glucide/ lipide / alimentation / performance de croissance / composition corporelle**

1. 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 nonprotein energy sources in fish diets [12–14]. Providing adequate energy from carbohydrates and lipids in fish diets can minimize the use of costly protein. The utilization of carbohydrates and lipids by fish is species specific. Although lipids are well utilized by most fish, excessive levels may reduce fish growth or produce fatty fish [11, 16, 36]. On the contrary, lipid deficient diets may result in growth retardation and other physiological symptoms [10, 36]. No specific dietary requirement for carbohydrates has been demonstrated in fish [24]. An appropriate level of carbohydrates in fish diets is, however, required to avoid any disproportionate catabolism of proteins and lipids for the supply of energy and metabolic intermediates [35, 38].

The carbohydrate to lipid (CHO/LIP) ratio in fish diets has been investigated by a number of authors. Palmer and Ryman [26] suggested that there may be an optimum carbohydrate to lipid ratio value in trout diets which could maximize the metabolism of glucose through hepatic glycolysis and the overall efficiency of glucose use. Acceptable carbohydrate to lipid ratios for channel catfish diets have been reported to be between 0.45 and 4.5 [16]. Bieber-Wlaschny and Pfeffer [5] observed a better growth rate and enhanced protein and energy retention in rainbow trout (*Salmo gairdneri* R.) when the diets consisted of both fat and starch as compared to diets containing either only fat or starch. El-Sayed and Garling [13] reported that *Tilapia zillii* can efficiently utilize both carbohydrates and lipids as energy sources and that these can be substituted at a rate of 1/2.25 commensurate with their physiological fuel values. Nematipour et al. [25] reported that hybrid stripped bass efficiently utilize both carbohydrates and lipids as energy sources but suggested that lipids be partially replaced with carbohydrates to improve fish quality and productivity. Erfanullah and Jafri [15] observed that the growth of walking catfish (*Clarias batrachus*) fed diets containing varying CHO/LIP ratios (0.02 to 43.00) differs significantly.

Limited information is available on the optimal level of CHO/LIP ratio in the diets of *Oreochromis niloticus.* Shimeno et al. [33] studied the metabolic response of dietary carbohydrate to lipid ratios in *Oreochromis niloticus.* They reported that fish growth performance and protein sparing effects are elevated with an increase in dietary carbohydrate to lipid ratios. The present study was therefore conducted to determine the optimum carbohydrate to lipid ratio in practical diets of *Oreochromis niloticus* fingerlings.

2. MATERIALS AND METHODS

Oreochromis niloticus fingerlings with an average weight of 10.29 ± 0.33 g were collected from the fish hatchery of the King Abdulaziz City for Science and Technology (KACST) Deerab, Riyadh. The fish were acclimatized to the experimental conditions for a period of two weeks before the start of the actual experiment. During this period, they were kept on the same standard diet as fed previously at the hatchery. Thirty randomly captured fish (divided into three replicates of 10 fish each) were killed immediately. After recording their body weight and length, they were stored at –30 °C until determination of their initial body composition at a later stage [3]. One hundred and fifty fish were then randomly divided into 5 different groups with 3 replicates containing 10 fish in each replicate. The fish were kept in glass tanks (100 × 42.5 × 50.0 cm) containing dechlorinated and well aerated tap water and fitted with a waste filtration facility. The water temperature was maintained at 28 ± 1 °C with the help of a thermostatically controlled heating system. Compressed air was used to maintain the oxygen supply. Regular monitoring of water quality parameters was carried out. These values ranged from 7.1–8.0 for pH , 5.6–6.7 $mg \cdot L^{-1}$ for dissolved oxygen, 0.12–0.20 $mg \cdot L^{-1}$ for ammonia nitrogen, 0.33–0.58 $mg \cdot L^{-1}$ for nitrite nitrogen and 235–350 $mg \cdot L^{-1}$ for alkalinity as $CaCO_3$.

Five isonitrogenous and isoenergetic diets containing different levels of carbohydrates and lipids were prepared using a pellet press with a 2 mm die (Tab. I). The maize grain was used as a source of carbohydrate. It was replaced gradually with equal amounts of corn oil and cod-liver oil on an energy equivalent basis. α-cellulose was added to balance the diet composition. The diets were dried at 60 °C and then stored at –18 °C throughout the experimental period. The proximate chemical compositions of the diets are given in Table II. The gross energy contents of the diets were calculated on the basis of their protein, fat and carbohydrate (NFE) contents using the equivalents of 23.64, 39.54, and 17.15 $MJ \cdot kg^{-1}$ respectively [21]. Each diet was fed ad libitum to 3 replicates in a completely randomized design, twice daily for a period of 63 days. Daily feed intake and fortnightly weight gains were recorded. In order to quantify the exact amount of feed intake any feed refusal was siphoned out immediately, dried and weighed. The experiment was conducted under artificial light with a light and dark cycle of 12:12 hours. At the end of the experimental period all the fish were killed and their body weights and lengths were recorded. Five fish from each tank were dissected and their livers were removed and weighed. To determine the whole body composition, the rest of the fish from each tank were cut into pieces, minced, homogenized and immediately frozen at –30 °C for further analysis. The proximate chemical composition was determined according to AOAC methods [3]. The gross energy (GE) contents of the fish were calculated from the fat and protein contents using the equivalents of 39.54 $MJ \cdot kg^{-1}$ crude fat and 23.64 $MJ \cdot kg^{-1}$ crude protein [21].

Table I. Composition of the experimental diets (%).

Ingredients	Diets				
	A	B	C	D	E
Fish meal	45.00	45.50	46.00	46.50	47.00
Wheat bran	13.00	13.00	13.00	13.00	13.00
Maize grain	35.00	28.00	21.00	14.00	7.00
Cod liver oil	1.50	3.00	4.50	6.00	7.50
Corn oil	1.50	3.00	4.50	6.00	7.50
Gelatin	1.00	1.00	1.00	1.00	1.00
α-Cellulose	0.00	3.50	7.00	10.50	14.00
Mineral mixture[1]	2.00	2.00	2.00	2.00	2.00
Vitamin mixture[2]	1.00	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00	100.00

[1] One kg of the premix contained: $CaHPO_4$, 530 g; K_2HPO_4, 80 g; Na_2HPO_4, 90 g; $MgCl_2 . 6H_2O$, 100 g; KCl, 67.5 g; K_2SO_4, 80 g; NaCl, 30 g; KI, 0.05 g; $ZnSO_4.7H_2O$, 2.5 g; SeO_2, 0.03 g; $CuSO_4.5H_2O$, 0.15 g; $FeSO_4.7H_2O$, 18 g; $(NH_4)_6Mo_7O_{24}.4H_2O$, 0.01 g; $MnSO_4.H_2O$, 0.5 g; NaF, 1.2 g; $CoCl_2.6H_2O$, 0.01 g.
[2] One kg of the premix contained: Vitamin A, 400 000 IU; D_3, 200 000 IU; E, 5 000 IU; K_3, 1 g; B_1, 1 g; B_2, 1.5 g; B_6, 1 g; Pantothenic acid, 5 g; Niacin, 3 g; Folic acid, 0.5 g; B_{12}, 2 mg; Biotin, 100 mg; Vitamin C, 20 g.

Table II. Proximate chemical composition of fish diets (on % dry matter basis).

Parameters	Diets				
	A	B	C	D	E
Dry matter (%)	91.68	91.83	92.01	91.82	92.19
Crude protein	38.02	37.96	38.12	37.83	37.24
Crude fibre	2.19	4.78	8.05	11.23	14.12
Total fat	8.14	10.56	14.01	16.84	19.53
Ash	11.38	11.51	10.90	10.84	10.74
Nitrogen free extract (NFE)	40.27	35.19	28.92	23.26	18.37
Gross energy ($MJ \cdot kg^{-1}$)	19.12	19.18	19.50	19.58	19.66
CP/CHO/LIP ratio[1]	47/36/17	47/31/22	47/25/28	46/20/34	46/15/39
CHO/LIP ratio[2]	4.95	3.33	2.06	1.38	0.94
P / E ratio (g protein$\cdot MJ^{-1}$)[3]	19.88	19.79	19.55	19.32	18.94

[1] Proportionate gross energy ratio from crude protein, carbohydrates and lipids.
[2] Carbohydrate to lipid ratio on a weight basis.
[3] Crude protein to gross energy ratio.

Feed conversion ratio (FCR), specific growth rate (SGR), protein efficiency ratio (PER), net protein retention (NPR), apparent net energy retention (ANER) and hepatosomatic index (HSI) were calculated as follows:

– Feed conversion ratio = kg dry feed consumed per kg wet weight gain.

– Specific growth rate (as percentage of body weight gain per day) = 100 [ln final wt. (g) – ln initial weight (g)] / time (days).

– Protein efficiency ratio = liveweight gain (g) / protein consumed (g).

– Net protein retention = [increase in carcass protein / protein fed] × 100.

– Apparent net energy retention (ANER = [(final body GE $KJ \cdot g^{-1}$) – (initial body GE $KJ \cdot g^{-1}$) / KJ GE fed] × 100).

– Hepatosomatic index = (liver weight / fish weight) × 100.

The condition factor (k) was calculated according to the equation $k = [W(g) / L(cm)^3] \times 100$, where W is the wet weight of fish in grams and L is the length in centimeters. The results were subjected to statistical analysis using the analysis of variance technique and the means were compared by the Fisher LSD test according to Snedecor and Cochran [34]. A second order polynomial model (quadratic-linear model) was used to determine the optimal CHO/LIP ratio for the maximum growth of the fish [7]. The model used was:

$$Y_i = \alpha + \beta_1 x_i + \beta_2 x_i^2 + \varepsilon_i, \quad i = 1, 2, 3 \ldots\ldots, n$$

where $\varepsilon_i \sim N(0, \sigma^2)$.

3. RESULTS

Significant differences ($P < 0.05$) were observed for the body weight gain of fish fed different CHO/LIP ratios (Tab. III). No significant differences ($P > 0.05$) were observed for the body weight gain of fish fed diets A, B and C with CHO/LIP ratios ranging from 4.95 to 2.06. Decreasing the carbohydrate to lipid ratio to 1.38 (diet D) significantly reduced ($P < 0.05$) the body weight gain in fish. A further decrease in the CHO/LIP ratio to 0.94 (diet E), however, did not reduce ($P > 0.05$) the body weight gain any more. Similar trends were observed for the specific growth rate and condition factor. The relationship between body weight gain and carbohydrate to lipid ratios, determined using the second order polynomial model, is shown in Figure 1. Although the optimal dietary CHO/LIP ratio for the maximum growth performance of fish ranged from 2.06 to 4.95, the maximum weight gain appeared to be at a dietary CHO/LIP ratio of 3.4. No fish mortality was observed during the whole experimental period. Similarly, no visual abnormalities were seen in fish livers.

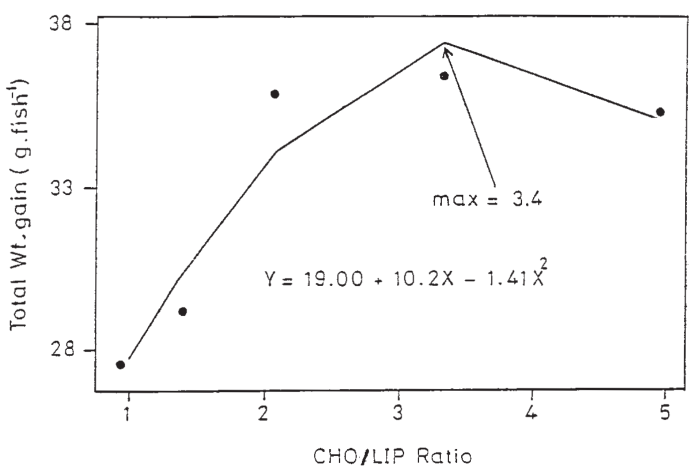

Figure 1. Relationship between CHO/LIP ratio and body weight gain.

The hepatosomatic index value increased with the decrease in the CHO/LIP ratios and was the highest (1.81) with a CHO/LIP ratio of 0.94 and lowest (1.33) with a CHO/LIP ratio of 4.95 (Tab. III). The fish fed diets B, C and D with CHO/LIP ratios ranging from 3.33 to 1.38 did not show any difference ($P > 0.05$) in the HSI values. No significant differences ($P > 0.05$) were observed in the feed consumption of fish fed different CHO/LIP ratios (Tab. III). The diets A, B and C with CHO/LIP ratios ranging from 4.95 to 2.06 did not result in any difference ($P > 0.05$) in their feed efficiency, protein and energy retention. Decreasing the CHO/LIP ratios to 1.38 and 0.94 (diets D and E) significantly depressed these values. Fish fed diets A, B and C did not show any difference ($P > 0.05$) in their PER, NPR and ANER values. Similarly the differences between diets D and E with CHO/LIP ratios of 1.38 and 0.94 respectively were not significant ($P > 0.05$).

The body composition of the fish was significantly affected ($P < 0.05$) by dietary CHO/LIP ratios (Tab. IV). The differences among diets A, B and C were, however, non significant ($P > 0.05$). Similarly, the diets D and E did not lead to any difference ($P > 0.05$) in the proximate composition of fish. Body moisture and crude protein contents decreased whereas fat and ash contents increased with a decrease in dietary CHO/LIP ratios. No significant ($P > 0.05$) differences were observed for gross energy retention.

4. DISCUSSION

The overall total feed consumption by *Oreochromis niloticus* was not affected by the variability in CHO/LIP ratios. This indicated that both carbohydrates and lipids were equally acceptable by fish within the levels used on an energy equivalent basis in this experiment. As far as the carbohydrate and lipid levels in fish diets are concerned, our results were in close agreement with the findings of Teshima et al. [37] who concluded that *Tilapia nilotica* fingerlings grew optimally with diets containing 30–40% proteins, 12–15% lipids and 30–40% digestible

Table III. Growth performance of *Oreochromis niloticus* fed different levels of carbohydrates and lipids.

Parameters	Diets					
	A	B	C	D	E	S.E.[1]
Initial weight ($g \cdot fish^{-1}$)	10.26	10.43	10.19	10.38	10.21	0.33
Final weight ($g \cdot fish^{-1}$)	45.55^a	46.81^a	46.04^a	39.55^b	38.74^b	1.07
Total weight gain ($g \cdot fish^{-1}$)	35.29^a	36.38^a	35.85^a	29.17^b	28.53^b	1.17
Specific growth rate (SGR)	2.37^a	2.38^a	2.39^a	2.13^b	2.13^b	0.10
Condition factor (k)	2.98^a	3.06^a	2.95^a	2.70^b	2.60^b	0.21
Consumed feed dry matter ($g \cdot fish^{-1}$)	41.72	41.12	41.50	41.80	42.56	1.19
Feed conversion ratio (FCR)	1.18^a	1.13^a	1.16^a	1.43^b	1.49^b	0.11
Protein efficiency ration (PER)	2.23^a	2.33^a	2.26^a	1.85^b	1.80^b	0.13
Net protein retention (NPR)	34.99^a	36.45^a	35.15^a	27.26^b	26.56^b	1.31
ANER[2]	24.60^a	25.71^a	24.29^a	19.67^b	18.91^b	0.96
Hepatosomatic Index (HSI)	1.33^c	1.59^b	1.69^b	1.62^b	1.81^a	0.18

[1] Pooled standard error.
[2] Apparent net energy retention value.
[a,b,c,d] Different superscripts in the same row mean significant differences between the values at 5%.

Table IV. Body composition of *Oreochromis niloticus* fed different levels of carbohydrates and lipids (on % wet basis)[1].

Parameters	Diets					
	A	B	C	D	E	S.E.[2]
Moisture (%)	74.57[a]	74.72[a]	74.39[a]	73.95[b]	73.53[b]	0.66
Crude protein	15.69[a]	15.64[a]	15.52[a]	14.99[b]	14.96[b]	0.28
Total fat	4.70[b]	4.76[b]	4.65[b]	5.04[a]	5.11[a]	0.14
Ash	4.65[b]	4.73[b]	4.70[b]	5.01[a]	5.13[a]	0.16
Gross energy ($MJ \cdot kg^{-1}$)	5.56	5.57	5.50	5.53	5.55	0.11

[1] Composition of fish slaughtered at the beginning of the experiment (moisture, 73.25%; crude protein, 15.62%; fat, 4.75%; ash, 5.13% and gross energy, 5.56 $MJ \cdot kg^{-1}$).
[2] Pooled standard error.
[a,b,c,d] Different superscripts in the same row mean significant differences between the values at 5%.

carbohydrates. El-Sayed and Garling [13] did not observe any significant difference in the performance of *T. zillii* over a wide range of CHO/LIP ratios (8.76–0.81). They suggested that *T. zillii* can possibly utilize dietary lipids as an energy source more efficiently than carbohydrates. Our results neither support such a wide range of CHO/LIP ratios in the diets for *O. niloticus* nor confirm their hypothesis that dietary lipids are more efficiently utilized as an energy source than carbohydrates. The levels of dietary carbohydrates and lipids used by El-Sayed and Garling [13] in their experiment ranged from 12.0–36.8% and 4.2–14.8% respectively. The results of the present study indicate that the performance of *O. niloticus* was only significantly affected when the level of lipids in the diets increased beyond 14%. Nematipour et al. [25] did not also observe any significant difference in the performance of hybrid stripped bass over a much wider range of carbohydrate to lipid ratios (2.5 to 16.8). The reason may be the dietary levels of carbohydrates and lipids that ranges from 25–42% and 2.5–10% respectively.

The increase in FCR values with the decrease in the CHO/LIP ratio indicates the poor utilization of diets when the dietary lipid level increases over 14%. Similarly, the efficiency of protein and energy utilization decreased when the CHO/LIP ratio in the diets dropped to 1.38 and 0.94. These results indicate that *O. niloticus* is capable of best utilizing lipids up to a level of 14% with a minimum level of carbohydrates (29%) in their diets. Lowering the carbohydrate level beyond this limit with a simultaneous increase in lipid level, even on an energy equivalent basis, not only affected their growth performance but also the overall efficiency of energy and protein utilization. Fish fed low lipid high carbohydrate diets might metabolize less protein to meet their energy needs than fish fed high lipid low carbohydrate diets, resulting in higher dietary protein retention in tissues. The effect of cellulose, used as a filler to balance the energy content of the diets, cannot be ignored. Al-Ogaily [1] observed that 9% cellulose in the diets of *O. niloticus* improves the growth, and FCR, PER and NPR values. He, however, did not observe any negative effects of utilizing 12% cellulose in the diet. Anderson et al. [2], 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 the elevated crude fiber content in fish diets may exert a negative effect on the digestibility of nutrients [20]. Our results are in line with these findings since the diet that produced the best results in the present study contained 10.5% cellulose.

The negative effect of larger amounts of dietary lipids (at low levels of carbohydrate supply) could be explained in relation to a higher metabolic demand for glucose that necessitates increased gluconeogenesis. Shimeno et al. [33] suggested that carbohydrates accelerate glycolysis and lipogenesis and decrease gluconeogenesis and amino acid degradation in the liver. This metabolic response seems to explain the high ability of *O. niloticus* to utilize dietary carbohydrates and their protein sparing effect. These results are in line with the earlier findings of Anderson et al. [2] and Qadri and Jameel [27] who 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. The results of the present study indicate that *O. niloticus* can utilize carbohydrates more efficiently than lipids. Chou and Shiau [11] reported that the optimal dietary lipid for the maximum growth of hybrid Tilapia (*O. niloticus* × *O. aureus*) is about 12%. They suggested that *Tilapia* do not utilize the additional energy provided by the supplementary dietary lipid (over 5%) for growth. Similar observations were made by Seenapa and Devaraj [30] who reported that fingerlings of *Catla catla* (Ham.) which is another herbivorous fish, efficiently utilize carbohydrates up to 35% but show poor growth on diets with dietary fat contents up to 12%. The protein sparing effect was only observed with carbohydrates. Our results are also in line with the findings of Erfanullah and Jafri [15] who observed that the growth of walking catfish (*Clarias batrachus*) fed diets containing varying CHO/LIP ratios (0.02 to 43.00) differed significantly. They reported that the highest weight gain, SGR, FCR, PER, NPR and energy retention values were observed in fish fed 27% dietary carbohydrates and 8% lipids corresponding to a CHO/LIP ratio of 3.38.

The hepatosomatic index (HSI) varies as a function of dietary protein, carbohydrate and lipid level [16, 19, 22, 31]. The present results indicate that the HSI values are only affected when the carbohydrate and lipid levels in the diets are increased over 35.19% and 16.84% respectively. Nematipour et al. [25] reported that the HSI values in hybrid stripped bass did not change when fed diets high in carbohydrates or lipids. On the contrary to our findings in *O. niloticus*, the HSI values in rainbow trout have been reported to increase with the rise in carbohydrate level (reflecting an increasing glycogen storage in the liver) whereas no change of a similar kind was observed in response to high dietary fat content [5, 6]. This may be linked to the species difference, since warm water fish have been reported to utilize carbohydrates better than cold water fish [23].

The results on the body composition of fish appear to have a good correlation with growth performance. Both the endogenous and exogenous factors operate simultaneously to influence the body composition of fish [9, 17, 32]. Although the available dietary energy plays an important role in determining body lipid deposition, the dietary lipid content is regarded as the most important factor influencing carcass lipid in fish [8, 18, 29]. An increase in dietary lipid level elevates the body lipid level in *O. niloticus*. The increase in carcass lipids with increasing dietary lipids and the consequent reduction in carcass proteins have been reported for most species investigated [12]. The results of the present study indicate that the body moisture and crude protein contents decrease whereas the lipid and ash contents increase with a decrease in CHO/LIP ratio. The use of lipids as a source of dietary energy frequently contributes to the formation of higher fat reserves [4, 28]. The results of the present study suggest that the optimum dietary CHO/LIP ratio for the maximum growth performance of *Oreochromis niloticus* is between 2.06 and 4.95.

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