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Effects of Dietary Protein and Lipid Levels on Growth Performance and Body Composition of African Catfish *Heterobranchus longifilis* (Valenciennes, 1840) Fingerlings

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Abstract: The approximate levels of dietary protein and lipid that would sustain good growth and survival of African catfish *Heterobranchus longifilis* fingerlings were determined in this study. Twelve diets formulated to contain four protein levels and three lipid levels for each protein level were arranged in a 3×4 factorial design. Diets were fed for 56 d to triplicate groups of *Heterobranchus longifilis* fingerlings with an average initial weight of 0.84±0.03 g. Survival of fish was not affected by either dietary protein or lipid level. Fish fed on diets containing 7 and 12.5% lipid had increased Specific Growth Rates (SGR) up to 35%. Daily feed intake of fish decreased with increasing dietary protein level at all the lipid levels and showed a tendency toward higher values at 7% lipid diets compared to 12.5 or 18% lipid diets at all the protein levels. Feed efficiency of fish fed on 35% protein diet with 12.5% lipid was higher than other groups. However, no significant difference was observed in the feed efficiency of fish fed diets containing 7 and 12.5% lipid with 35% protein. The Protein Efficiency Ratio (PER) of fish increased with increasing protein and lipid levels up to 35% protein with 12.5% lipid. Hepatosomatic and Viscerosomatic index (HIS and VSI) decreased significantly with increasing dietary protein. Moisture content of fish fed 7% lipid diets was higher than those with 12.5 or 18% lipid at each protein level. Lipid deposition in whole body, carcass and liver was higher in fish fed on 18% lipid diets than those fed 7 or 12.5% lipid at each protein level. Significant interaction of lipid and protein was observed in final body weight, feed efficiency, daily feed intake, PER, body protein, body crude lipid and body ash contents of *H. longifilis* fingerlings. The results of this study indicate that an increase of dietary lipid level can improve growth and PER and the diet containing 35% protein with 12.5% lipid would be suitable for optimum growth and produced protein-sparing effect in *Heterobranchus longifilis* fingerlings.

Key words: African catfish, *Heterobranchus longifilis*, dietary protein and lipid, protein-sparing effect, growth, body composition

INTRODUCTION

Protein is one of the most important nutrient categories for growth. It is an expensive macro component of fish feed because of its bulk in the feed formula. Previous studies on protein requirements in aquaculture species have focused on the determination of amount required to produce optimum growth and not be utilized for energy. The energy requirement can be provided by lipid or carbohydrate. Lipid plays an important role in fish nutrition as a source of energy and Essential Fatty Acids (EFA) to maintain biological structure and normal functions of cell membranes[1]. Within certain limits, increasing dietary lipid levels improve diet utilization[2-4]. Dietary lipid was also reported to bring protein sparing effect, replacing protein, which may otherwise be used to provide energy[5,6], to reduce organic matter and nitrogen losses[7]. Currently in salmon aquaculture, high fat diet is being used. But in many fish species, the increase of dietary lipid levels must be evaluated carefully for it may lead to increased fat deposition in fish.

Heterobranchus longifilis is an economically important food fish, cultured primarily in freshwater ponds in tropical countries. It exhibits many qualities, which makes it suitable for commercial culture. These include hardiness, high disease resistance, rapid growth, high yield potential, high fecundity, air-breathing characteristics and good market potential. This study

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was undertaken to determine the approximate levels of dietary protein and lipid to support optimum growth, feed utilization and body composition of *Heterobranchus longifilis* fingerlings.

MATERIALS AND METHODS

Experimental diets: Twelve practical diets were formulated and prepared to contain four protein levels 25, 30, 35 and 40% at three lipid levels for each protein 7, 12.5 and 18%. Diets were prepared by mixing the dry ingredients in a laboratory mixer followed by addition of oil and pregelatinized cassava starch in a 300 mL water per kg diet, mixed together to give a pelletable mixture. The wet mixture was then pelleted using 2 mm diameter die and sundried. The dry pellets were packed in polythene bags, sealed and stored at -20°C until used.

Experimental system and animals: The experiment was conducted in thirty-six cylindrical plastic tanks, each containing 30l of aerated water from storage reservoir. About 30% of the water in the system was replaced daily to avoid accumulation of waste products. Water quality parameters such as pH (6.55-7.20), dissolved oxygen (6.95-7.75 mg L^{-1}), ammonia (0.08-0.25 mg L^{-1}), nitrate (0.39-6.07 mg L^{-1}) and nitrite (0.02-0.24 mg L^{-1}) remained within acceptable ranges recommended for *C. gariepinus*[8,9]. During the experimental period fish were reared under a 12:12-h L: D photoperiod. Seven hundred and twenty four-week-old (average weight 0.84±0.03) *H. longifilis* fingerlings were used in the experiment. They were obtained from the hatchery of National Institute for Freshwater Fisheries Research, New Bussa Nigeria.

Experimental procedure: Fish were randomly assigned into 12 groups of twenty per 30-l cylindrical plastic tank. Each dietary treatment had three replications and the experiment was conducted for 8 weeks in a 3×4 factorial design. The fish were individually weighed at the beginning and at the end of the experiment and bulk-weighed by tank weekly in-between. Weekly bulk weights were used to adjust the daily feed ration for the following week. Fish were offered 50 g kg^{-1} of their body weight per day, sub divided into three equal feeds at 09:00, 15:00 and 21:00 h daily.

Faecal matter was collected once a day at about 8:00 am before feeding commenced during the later part of the experiment. Faeces collection was performed by siphoning materials from the bottom of tank. At the onset of the experiment, ten fish were killed for analysis of initial carcass composition. At the termination of the experiment, ten fish were taken from each replication for determination of whole body composition, organ indices, liver, visceral and carcass lipid. In this study, visceral included liver, heart and gastrointestinal tissue and associated fat and carcass included the eviscerated fish without gill and head.

Analytical methods and analysis of data: Proximate composition of diets and whole body fish were analysed following Association of Official Analytical Chemist[10] methods. Nitrogen Free Extract (NFE) was calculated by difference. Determinations of lipid contents by chloroform-methanol (2:1, v/v) extraction[11] were performed on pooled samples of whole body, liver, visceral, carcass or head for each treatment. All samples were analysed in triplicate.

Specific Growth Rates (SGR), %weight gain, feed efficiency, Protein Efficiency Ratio (PER) and % body store of lipid were calculated as follows:

SGR (%/day) = [(In final body weight-In initial body weight)/days X 100]

% Weight gain = (Final body weight-initial body weight/initial body weight) X 100

Feed efficiency = live weight gain/feed intake (dry matter) X 100

PER = live weight gain (g)/crude protein fed (g dry matter)

% of body store = (lipid weight of carcass, viscera, liver or head/lipid weight of whole body) X 100.

Organ indices [Viscerosomatic Index (VSI) and Hepatosomatic Index (HIS)] were calculated as follows:

Organ indices (OI,%) = organ weight (g)/body weight (g) X 100

Data were subjected to analysis of variance in accordance with the design of the experiment using two-way ANOVA and Duncan's multiple range test. Differences between treatment means were considered significant at $p<0.05$.

RESULTS

Growth performance, hepatosomatic and viscerosomatic indices: Final body weight, Specific Growth Rate (SGR), feed efficiency, feed intake, hepatosomatic index and viscerosomatic index of *Heterobranchus longifilis* fingerlings fed the experimental diets are given in Table 1. Increased protein and lipid levels caused significant improvement in growth performance Table 2. The best growth result (final body weight and SGR) of fish fed 35%

Table 1: Ingredients and nutrient contents of the experimental diets

	Dietary lipid levels (%)											
	7				12.5				18			
	Dietary protein levels (%)											
	25	30	35	40	25	30	35	40	25	30	35	40
Ingredients (%)												
Fish meal	20.00	24.00	29.00	35.00	20.00	24.00	29.00	35.00	20.00	24.00	29.00	35.00
Soybean meal	15.00	23.00	27.00	32.00	15.00	23.00	27.00	32.00	16.00	23.50	27.00	33.00
Cod liver oil	3.12	3.13	3.02	2.86	8.62	8.63	8.52	8.36	14.12	14.13	14.02	13.86
Corn flour (Maize)	57.68	45.67	36.78	25.94	52.18	40.17	31.28	20.44	45.68	34.17	25.78	13.94
Cassava starch	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Vitamin/mineral mixture[a]	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Salt (NaCl)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Nutrient contents (%)												
Moisture	6.71	6.77	6.33	5.61	6.23	6.88	6.69	6.33	6.31	6.45	6.31	6.59
Crude protein	24.94	30.31	35.10	40.05	25.08	30.02	35.31	39.80	25.06	29.96	34.98	40.12
Crude lipid	7.15	7.07	7.10	7.06	12.52	12.50	12.45	12.65	17.90	17.95	17.97	17.94
Ash	8.90	8.20	8.75	9.30	8.40	8.45	8.25	8.80	8.20	8.00	8.25	8.95
Crude fibre	1.52	1.48	1.42	1.44	1.41	1.38	1.39	1.40	1.45	1.35	1.37	1.32
Nitrogen free extract (NFE)[b]	50.78	46.17	41.30	36.54	46.36	40.77	35.91	31.02	41.08	36.29	31.12	25.08
Gross energy (MJ/kg)[c]	17.37	17.81	18.10	18.42	18.75	18.94	19.34	19.61	19.95	20.29	20.58	20.73

[a]supplied the following (per kg of diet): calcium, 4500 mg; phosphorus, 4200 mg; potassium, 1700 mg; magnesium, 400 mg; iron, 30 mg; zinc, 30 mg; manganese, 20 mg; copper, 5 mg; iodine, 1 mg; selenium, 0.25 mg; vitamin A, 5000IU; vitamin D, 2000IU; DL-α-tocopherol acetate, 100 mg; menadione, 15 mg; thiamine hydrochloride, 5 mg; riboflavin, 10 mg; pyridoxine hydrochloride, 10 mg. Panthothenic acid, 35 mg; nicotinic acid, 50 mg; biotin, 0.5 mg; folic cid, 2 mg; ascorbic acid, 200 mg; inositol, 250 mg; choline, 400 mg; vitamin B_{12}, 0.1 mg and ethoxyquin, 60 mg.
[b] calculated by difference (100-crude protein-crude lipid-ash-crude fibre).
[c]Based on 23.4 MJ kg^{-1} protein, 39.2 MJ kg^{-1} lipid and 17.2 MJ kg^{-1} NFE

Table 2: Growth performance, feed efficiency, feed intake hepatosomatic and viscerosomatic index of *Heterobranchus longifilis* (Valencienns 1840) fingerlings (average initial weight of 0.84±0.03g) fed diets containing various protein and lipid levels for 8 weeks[1]

Dietary protein (%)	Dietary lipid (%)	Final body weight (g/fish)	SGR (%/day)	Feed efficiency (%)	Daily feed intake (%)	PER	HSI	VSI
25	7.0	3.21±0.09^{a}	2.23±0.03^{a}	75.64±2.34^{a}	2.70±0.02^{h}	2.58±0.47^{a}	0.86±0.09^{bc}	5.38±0.49^{b}
	12.5	3.53±0.10^{b}	2.51±0.02^{b}	85.08±4.41^{ab}	2.32±0.03^{f}	2.81±0.27^{ab}	0.95±0.11^{c}	5.57±0.57^{b}
	18.0	3.79±0.13^{b}	2.54±0.10^{b}	91.73±2.30^{b}	2.29±0.01^{e}	2.48±0.27^{a}	1.04±0.16^{c}	5.75±0.97^{b}
30	7.0	3.62±0.28^{b}	2.55±0.34^{b}	89.38±9.48^{b}	2.54±0.02^{g}	2.84±0.38^{ab}	1.02±0.12^{c}	4.62±0.72^{ab}
	12.5	3.70±0.10^{b}	2.56±0.09^{b}	92.14±3.90^{b}	2.28±0.02^{e}	2.92±0.71^{abc}	0.86±0.07^{bc}	4.88±0.46^{ab}
	18.0	3.79±0.08^{b}	2.58±0.03^{b}	93.71±4.21^{b}	2.13±0.02^{b}	2.41±0.11^{a}	0.70±0.02^{a}	4.14±0.23^{b}
35	7.0	4.38±0.08^{cd}	3.10±0.04^{d}	120.40±3.56^{d}	2.17±0.02^{c}	3.16±0.32^{bc}	0.76±0.16^{ab}	4.81±0.21^{ab}
	12.5	4.47±0.12^{cd}	3.12±0.03^{d}	128.25±4.44^{e}	2.12±0.02^{b}	3.32±0.36^{c}	0.76±0.11^{ab}	4.74±0.13^{ab}
	18.0	4.20±0.19^{c}	2.59±0.12^{b}	109.31±8.86^{cd}	2.11±0.01^{b}	2.80±0.03^{ab}	0.75±0.10^{ab}	4.68±0.32^{ab}
40	7.0	4.78±0.06^{d}	3.11±0.03^{d}	130.23±2.49^{e}	2.13±0.003^{b}	2.78±0.07^{ab}	0.68±0.02^{a}	4.48±0.21^{ab}
	12.5	4.51±0.19^{d}	3.04±0.01^{cd}	117.15±5.42^{c}	2.20±0.02^{d}	3.14±0.40^{bc}	0.72±0.06^{a}	4.36±0.22^{a}
	18.0	4.22±0.26^{cd}	2.89±0.12^{c}	108.44±8.59^{c}	2.07±0.02^{a}	2.82±0.27^{ab}	0.76±0.11^{ab}	4.23±0.30^{a}
Two-way ANOVA								
Dietary protein		p<0.0008	p<0.00004	p<0.00001	p<0.0001	p<0.05	*P*<0.046	p<0.032
Dietary lipid		p<0.0005	p<0.00864	p<0.0001	p<0.0004	p<0.03	*P*<0.970	p<0.930
Interaction		p<0.0412	p<0.46221	p<0.027	p<0.008	p<0.01	*P*<0.381	p<0.985

[1]Values (means±S.E. of three replications) in the same column not sharing a common superscript letter are significantly different (p<0.05). PER = Protein efficiency ratio; HIS = Hepatosomatic index; VSI = Viscerosomatic index

protein diet with 12.5% lipid were not significantly different from those of fish fed 40% protein diet with 7% lipid. Final body weight of fish exhibited significant interaction of dietary protein and lipid levels. SGR of fish fed the 40% protein diet with 12.5 and 18% lipid were significantly lower than those fed either 40% protein diet with 7% lipid or 35% protein diet with 12.5% lipid.

Daily feed intake was affected by dietary protein level (p<0.0001) and lipid level (p<0.0004) and tended to decrease with increasing dietary protein and lipid levels. The highest value was observed at 7% lipid diets compared to 12.5 or 18% lipid at each protein level. Feed efficiency was improved as dietary protein level increased up to 40 and 35% protein with 7 and 12.5% lipid, respectively. Significant interaction was also observed.

Hepatosomatic index and viscerosomatic index were significantly affected by dietary protein level and reduced as protein level increased. No significant effect of dietary lipid levels was observed in HIS and VSI.

Protein efficiency ratio was significantly influenced by dietary lipid level and increased with increasing dietary lipid and protein levels up to 35% protein with 12.5% lipid.

Table 3: Proximate composition (%) for whole body in *Heterobranchus longifilis* fingerlings fed diets containing various protein and lipid levels for 8 weeks[1]

Dietary protein (%)	Dietary lipid (%)	Moisture	Crude protein	Crude lipid	Ash
Initial		72.34	17.47	5.67	3.66
25	7.0	73.92±4.87^{f}	16.17±0.10^{b}	6.47±0.08^{e}	3.51±0.14^{ef}
	12.5	71.81±1.83^{e}	15.57±0.23^{a}	8.04±0.09^{h}	3.34±0.25^{d}
	18.0	70.09±1.64^{de}	15.33±0.07^{a}	9.57±0.47^{i}	3.30±0.13^{bcde}
30	7.0	71.44±1.66^{de}	17.40±0.08^{c}	5.77±0.27^{c}	3.62±0.24^{fg}
	12.5	69.34±1.08^{d}	16.69±0.32^{b}	7.57±0.12^{g}	3.77±0.34^{g}
	18.0	68.41±0.3^{cd}	16.24±0.32^{bc}	8.06±0.13^{h}	3.09±0.05^{b}
35	7.0	69.75±0.19^{cde}	20.10±0.34^{e}	5.34±0.11^{b}	2.75±0.32^{a}
	12.5	66.65±0.82^{ab}	19.69±0.21^{e}	6.03±0.11^{d}	3.10±0.28^{bc}
	18.0	67.26±1.50^{ab}	17.07±0.54^{c}	7.70±0.02^{g}	3.29±0.10^{bcde}
40	7.0	67.98±1.45^{bc}	19.65±0.22^{e}	4.74±0.28^{a}	3.39±0.24^{de}
	12.5	65.99±0.81^{a}	18.07±0.44^{d}	5.20±0.10^{b}	3.33±0.12^{cde}
	18.0	65.66±2.56^{a}	17.28±0.27^{c}	6.80±0.20^{f}	3.19±0.07^{bcd}
Two-way ANOVA					
Dietary protein		p<0.001	p<0.0002	p<0.0000003	p<0.001
Dietary lipid		p<0.006	p<0.025	p<0.0000003	p<0.18
Interaction		p<0.32	p<0.002	p<0.0001	p<0.004

[1]Values (means±S.E. of three replications) in the same column not sharing a common superscript letter are significantly different (p<0.05)

Table 4: Concentrations of lipids in carcass, head and tissue of *Heterobranchus longifilis* fingerlings fed diets containing various protein and lipid levels for 8 weeks[1]

Dietary protein (%)	Dietary lipid (%)	Carcass	Head	Liver	Visceral
25	7.0	2.46±0.08^{c}	6.80±0.23^{f}	13.84±0.18^{e}	4.00±0.18^{cd}
	12.5	2.93±0.18^{f}	6.94±0.06^{fg}	13.78±0.14^{e}	4.53±0.45^{e}
	18.0	3.59±0.15^{i}	7.08±0.04^{g}	18.26±1.92^{g}	6.36±0.01^{f}
30	7.0	2.24±0.08^{b}	6.53±0.37^{d}	12.53±0.41^{cd}	3.18±0.35^{b}
	12.5	2.84±0.11^{ef}	6.64±0.21^{de}	13.13±0.18^{de}	3.78±0.14^{c}
	18.0	3.44±0.11^{h}	6.95±0.11^{fg}	15.43±2.74^{f}	4.48±0.40^{e}
35	7.0	2.14±0.04^{ab}	5.72±0.25^{b}	11.17±0.30^{bc}	2.89±0.49^{b}
	12.5	2.74±0.09^{de}	6.09±0.03^{c}	11.39±0.07^{bc}	3.17±0.47^{b}
	18.0	3.28±0.18^{g}	6.88±0.12^{f}	13.68±1.11^{e}	4.25±0.40^{de}
40	7.0	2.05±0.05^{a}	5.23±0.20^{a}	9.49±0.37^{a}	2.45±0.40^{a}
	12.5	2.64±0.10^{d}	5.72±0.25^{b}	10.36±0.56^{ab}	2.49±0.38^{a}
	18.0	3.17±0.10^{g}	6.62±0.14^{de}	11.53±0.65^{bc}	2.74±0.27^{ab}
Two-way ANOVA					
Dietary protein		p<0.002	p<0.000001	p<0.000001	p<0.00001
Dietary lipid		p<0.0001	p<0.00001	p<0.00001	p<0.0001
Interaction		p<0.90	p<0.005	p<0.26	p<0.002

[1]Values (means±S.E. of three replications) in the same column not sharing a common superscript letter are significantly different (p<0.05)

Significant interaction of dietary protein and lipid levels was observed in the PER of *H. longifilis* fingerlings.

Survival of fish was above 90% at the end of the feeding trial in all groups and was not affected by either dietary protein level or dietary lipid level.

Body composition: The proximate composition of whole body lipid concentrations of carcass, head, liver and visceral of *H. longifilis* fingerlings are shown in Table 3 and 4, respectively. The moisture, crude protein, lipid and ash contents of whole body Table 3 were affected by dietary levels of protein and lipid. There was a trend towards higher whole body lipid content and lower moisture content with increasing dietary lipid level at each protein level. The significant effect of interaction for the crude protein content of whole body was recognized (p<0. 002).

Carcass lipid was significantly affected by dietary level of protein (p<0.002) and lipid (p<0.0001) and decreased with increasing protein level. The trend was similar to those of head, liver and visceral Table 4. Significant interaction of dietary protein and lipid levels was observed in whole body crude protein, crude lipid and ash contents, also lipid concentrations of head and visceral showed significant interaction.

DISCUSSION

The improvement in growth performance at 35% protein and 12.5% lipid could be ascribed to better utilization of dietary protein for growth rather than for energy metabolism. Increasing dietary lipid above 12.5% at the high protein level did not further improve fish growth in terms of SGR. This could be attributed to increased energy content of the diet with the resultant effect of reduced feed consumption. Similar trends have been obtained with previous studies in *Clarias gariepinus*[12,13]. Poorest Growth (SGR) was recorded for the lowest lipid diet at lower dietary protein levels. At low dietary energy levels, protein may be used

for energetic purposes rather than for protein synthesis, causing reduced growth even with high dietary protein content and hence resulted in lower feed efficiency. This has been demonstrated in *Clarias* species[12-14] and other fishes[15,16].

In the present study, all diets tested were well accepted by the fish (Table 2), with daily feed intake value ranging from 2.07-2.70 g $100g^{-1}$ fish. The voluntary feed intake of *H. longifilis* fingerlings tended to be depressed for the diet containing highest lipid level, as observed in other studies with different species[17-19].

The feed efficiency in the present study improved with the higher protein diets. At the lower protein level feed efficiency improved little with increased lipid level in the diet. At higher protein level feed efficiency was best at 12.5% lipid and 35% protein diet. Earlier workers[14-16] have also reported improved feed efficiency, up to a certain level of dietary lipid inclusion. The reduced feed efficiency exhibited by *H. longifilis* fed the high protein with the highest lipid diet could be attributed to lower feed intake by fish. The high-energy content of the diet, resulted in low protein intake[13,20], or to the hindrance of digestion and absorption of other nutrients by the high-energy content in the diet[21].

The growth performance and feed conversion results also showed that the protein requirement of *H. longifilis* fingerling (as percentage of the diet) could be reduced by increasing dietary lipid. This fact has been demonstrated in a number of freshwater fish and marine teleosts[22,28]. Increasing dietary lipid from 7% to 12.5% allowed the protein level to be decreased from 40 to 35% without affecting the SGR and feed efficiency. Likewise, when comparing diets with the same protein content, the increase in dietary lipid led to an improvement in growth performance and feed efficiency, suggesting that protein may be utilized for growth rather than for energy and, therefore, energy from lipid spares protein in *H. longifilis* fingerlings. A significant improvement in growth performance due to the sparing effect of lipid on dietary protein has been reported for *C. gariepinus* and in gilthead seabream[26-28]. The PER indexes show the same trend observed for growth and feed efficiency. The highest value of this index also corresponds to the diet containing 35% protein with 12.5% lipid.

The interaction of dietary protein and lipid for final body weight, feed intake, feed efficiency and PER perhaps is an indicative of the lipid level that gives optimal growth at a particular protein level. It also indicates that with the increasing dietary protein level the permissible lipid level that enhances growth is higher.

The whole body lipid contents of *H. longifilis* fingerlings fed the medium and high lipid diets were significantly higher than that of fish fed the low lipid diets at the same protein level. This trend seems to be closely related to the dietary lipid levels. The lipid content of fish in this study was positively correlated with the dietary lipid level ($r = 0.72$, $p<0.0001$). This is in agreement with other studies showing that lipid content of fish fed high-energy diets is higher than that of fish fed low energy diets[4,29-32]. Feeding trout *ad libitum* with a non-protein energy source and restricted protein led to increasing level of fat in the carcass[33], this findings compares favourably with our results in which the fish tend to increase their lipid deposition with increasing lipid levels in the diets in conjunction with decreasing protein intake.

The lipid contents of liver, carcass, head and visceral in *H. longifilis* fingerlings increased with increasing dietary lipid levels at all protein levels. These trends seem to be closely related to the dietary energy level. This is in agreement with other studies showing that lipid content of fish fed high-energy diets is higher than that of fish fed low energy diets[7,29-31,34]. As with whole-body lipid, increasing dietary lipid at each protein level also resulted in greater accumulation of liver lipid, with the lower protein diets having the highest value. The same trend has been noted in *C. gariepinus* fed higher lipid diets[13,35]. Despite of increase of body and liver lipid contents in the medium (12.5%) and high (18%) lipid diets, considering the decrease of lipid contents with increasing dietary protein level and improvement of growth performance in 35% protein with 12.5% lipid diet in the present study, medium lipid diets seem to have more beneficial effects for fish performance and feed utilization compared to low and high lipid diets. Moreover, the decrease of feed intake in high lipid diets in this study appears to have an effect of reduction of ammonia production as described by McGoogan and Gattlin[36].

The results of this study indicate that an increase of dietary lipid level has a protein-sparing effect, in the diet containing 35% protein with 12.5% lipid and would support optimum growth and minimal lipid deposition in vital organs of *H. longifilis* fingerlings.

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