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Effect of Dietary Lipid Level on Growth Performance and Feed Utilization by *Heterobranchus longifilis* Fingerlings

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Abstract: A study was undertaken to determine the effect of the dietary lipid level on growth and feed efficiency of *Heterobranchus longifilis* fingerlings. Three isonitrogenous diets (35% crude protein) with increasing dietary lipid levels (7, 12.5 and 18% dry matter) were fed to triplicate groups of 20 fish (initial body weight 0.83±0.01 g) for eight weeks. Final body weight and Specific Growth Rates (SGR) of fish fed the 7 and 12.5% lipid diets was significantly higher than that of fish fed the 18% lipid diet. No significant differences in feed intake and feed conversion efficiency were observed among groups. At the end of the trial, protein content was significantly higher in fish fed the 7 and 12.5% lipid diets. The result of this trial indicate that an increase of dietary lipid level from 12.5 to 18% did not improve growth performance and feed efficiency of *H. longifilis* fingerlings. The inclusion of 18% of dietary lipid significantly reduced protein and energy retention efficiencies. It may be concluded that, under the experimental conditions, the increase of dietary lipid level beyond 12.5% had no beneficial effects.

Key words: African catfish, *Heterobranchus longifilis*, lipid level, growth, feed efficiency

INTRODUCTION

The commercial culture of freshwater fish is an expanding industry. A special form is the rearing in high-density warm water systems. This has been attempted with a limited number of species, namely the tilapias, cyprinids, catfish and eels. During the last years, the channel catfish (*Ictalurus punctatus* Raf.), the African catfish (*Clarias gariepinus*; *Heterobranchus longifilis*) and European catfish (*Siliurius glanis* L.) were investigated for their suitability to intensive culture. They have a good growth potential, which, however, depends on environmental factors such as optimum temperature, water quality or nutrients.

Dietary protein is the most important factor affecting growth performance and feed cost (Lovell, 1989). Generally, increasing protein level in the diets can lead to improved fish production. Protein utilization for growth may be improved by partially replacing dietary protein with lipid to produce a protein-sparing effect. However, excessive energy in diets can lead to increased body lipid deposition and growth reduction of fish because of a lack of necessary nutrients for growth resulting from a reduction in feed consumption (Daniels and Robinson, 1986). On the contrary, insufficient non-protein energy in diets causes protein waste as the proportion of dietary protein used for energy increases and ammonia excreted after amino acids are metabolised can reduce water quality (Phillips, 1972; Shyong *et al*., 1998). Therefore, it is important to improve dietary protein utilization for body protein synthesis rather than for energy purposes. A protein-sparing effect associated with increasing dietary energy level has been reported for several species of fish (Cho and Kaushik, 1990). Higher energy levels generally come from increased dietary lipid as lipid is an energy-dense nutrient and readily metabolised by fish (NRC, 1993).

Heterobranchus longifilis is an economically important food fish. It has high yield potentials, rapid growth and high fecundity among other qualities that makes it suitable for commercial culture. Although the dietary crude protein requirement for *H. longifilis* has already been studied by Fagbenro *et al.* (1992), no information about the protein-sparing effect of dietary lipids is available for this species. The present study, therefore, was conducted to evaluate the effect of lipid levels in a practical diet on growth and body lipid deposition of *H. longifilis* fingerlings.

MATERIALS AND METHODS

Experimental diets: Three isonitrogenous (35% crude protein) diets were formulated with increasing dietary lipid levels (7, 12.5 and 18% DM) and energy levels ranging

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from17.92-20.54 kJ g^{-1} GE. 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 temperature (27±1.25), pH (7.10±0.24), dissolved oxygen (7.15±0.32mg L^{-1}), ammonia (0.08±0.075 mg L^{-1}), nitrate (0.39±.07 mg L^{-1}) and nitrite (0.02±0.01mg L^{-1}) remained within acceptable ranges recommended for *C. gariepinus* (Viveen *et al*., 1985). During the experimental period fish were reared under a 12:12-h L: D photoperiod. One hundred and eighty 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 groups of twenty per 30-l cylindrical plastic tank. Each dietary treatment had three replications and the experiment was conducted for 8 weeks. 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 gk g^{-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 and carcass lipid. In this study, visceral included liver, heart and gastrointestinal tissue and associated fat.

Analytical methods and analysis of data: Chemical analyses of the experimental diets (Table 1) and whole fish were made using the following procedures: dry matter after drying in an oven at 105°C until constant weight; ash by incineration in a muffle furnace at 450°C for 16 h; protein (N X 6.25) by the Kjeldahl method after acid digestion; Lipid by petroleum ether extraction in a Soxtec System; energy by direct combustion in an adiabatic bomb calorimeter. Liver and muscle lipid were determined by the method of Folch *et al.* (1957).

Statistical analysis of the data was done by one-way analysis of variance. The probability level for rejection of the hypotheses was 0.05. Significant differences among means were determined by the Duncan's multiple range test.

Table 1: Composition and proximate analysis of the experimental diets

	Diets		
	7 L	12.5 L	18 L
Ingredients (percentagedry weight)			
Fish meal	29.00	29.00	29.00
Soybean meal	27.00	27.00	28.00
Cod liver oil	3.02	8.52	14.02
Corn flour (Maize)	36.78	31.28	24.78
Cassava starch	2.00	2.00	2.00
Vitamin/mineral mixture [a]	2.00	2.00	2.00
Salt	0.20	0.20	0.20
Proximate analysis (percentage dry weight)			
Moisture	6.33	6.69	6.31
Crude protein	35.10	35.31	34.98
Crude lipid	7.10	11.95	17.97
Ash	9.82	9.12	8.52
Crude fibre	1.42	1.39	1.37
Nitrogen free extract [b]	40.23	35.54	30.85
Gross energy (kJ g)$^{-1}$	17.92	19.06	20.54

[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, 1mg; selenium, 0.25 mg; vitamin A, 5000IU; vitamin D, 2000IU; DL-α-tocopherol acetate, 100 mg; menadione, 15 mg; thiamine hydrochloride, 5mg; riboflavin, 10 mg; pyridoxine hydrochloride, 10mg. Panthothenic acid, 35mg; 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)

RESULTS

Fish growth and body condition indices: Growth performance, feed efficiency and protein efficiency ratio of *Heterobranchus longifilis* fingerlings fed the experimental diets are reported in Table 2. The final body

Table 2: Growth performance and feed efficiency of *Heterobranchus longifilis* fingerlings fed the experimental diets[a]

	Diets		
	7 L	12.5 L	18 L
Initial body weight (g)	0.83±0.01	0.83±0.02	0.81±0.03
Final body weight (g)	4.30±0.47[b]	4.36±0.22[b]	3.80±0.18[a]
Weight gain (g kg ABW^{-1e} day^{-1})	24.16±0.21[b]	24.22±0.32[b]	23.21±0.06[a]
Specific growth rate [b]	2.93±0.09[b]	2.95±0.01[b]	2.77±0.37[a]
Feed intake (g kg ABW^{-1} day^{-1})	25.62±1.54	25.04±1.68	24.21±0.20
Feed efficiency ratio [c]	0.96±0.06	0.98±0.08	0.95±0.01
Protein efficiency ratio [d]	2.75±0.06	2.77±0.19	2.74±0.21

[a]Figures in the same line with different superscript letters are significantly different ($p< 0.05$). Mean±standard error., [b] SGR: ((ln (final body weight)-ln (initial body weight)) / (time in days) × 100., [c] FER: wet weight gain/ dry feed intake., [d] PER: wet weight gain/ crude protein intake., [e] Average body weight: (initial body weight+final body weight)/2

Table 3: Proximate composition (percentage wet weight) of *H. longifilis* fingerlings fed the experimental diets[a]

	Diets		
	7 L	12.5 L	18 L
Whole body			
Moisture	69.75±0.19[b]	66.65±0.82[a]	67.26±1.50[a]
Protein	20.10±0.34[b]	19.96±0.21[b]	17.07±0.54[a]
Lipids	2.14±0.04[a]	2.74±0.09[b]	3.28±0.18[c]
Ash	3.15±0.32	3.10±0.28	3.29±0.10
VSI [b]	4.83±0.16[a]	5.46±0.12[b]	5.83±0.18[b]
HIS [c]	0.81±0.03[a]	0.99±0.17[b]	1.08±0.12[b]
Liver			
Lipid	11.17±0.30[a]	11.39±0.07[a]	13.68±1.11[b]
Muscle			
Lipid	5.20±0.10[a]	6.03±0.11[b]	7.70±0.02[c]

[a]Figures in the same line with different superscript letters are significantly different ($p < 0.05$). Mean±standard error., [b] Viscerosomatic index: (gut weight / body weight) X 100., [c] Hepatosomatic index: (liver weight / body weight) × 100

weight, weight gain and specific growth rates of the fish were significantly higher with the 7 and 12.5% lipid diets than with the 18% lipid diet. However, no significant differences in feed intake and feed efficiency were observed among the experimental groups, but feed intake tended to decrease with increasing lipid levels in the diets. Dietary lipid levels did not significantly affect the protein efficiency ratio. Viscerosomatic and hepatosomatic indexes were both significantly higher in fish fed the 18% lipid diet than in the other groups (Table 3).

Body composition: The whole body protein content was significantly higher in fish fed the 7 and 12.5% lipid diets and lipid content was significantly lower in fish fed the 7% lipid diet than in the other groups (Table 3). There was a trend of higher lipid deposition in the body tissue as dietary lipid level increases; resulting in significantly higher lipid in whole body and liver of fish fed the 18% dietary lipid. No significant differences were observed in the ash content of *H. longifilis* fingerlings.

Nitrogen, energy and lipid utilization of *H. longifilis* fingerlings fed the experimental diets are reported in Table 4. Nitrogen intake (g kg ABW^{-1} day^{-1}) was significantly higher with 18% lipid diet than with the other diets. There were no significant differences in N intake, N retention (g kg ABW^{-1} day^{-1} and percentage nitrogen intake) between fish fed 7 and 12.5% lipid diets. However, N retention (g kg ABW^{-1} day^{-1} and percentage nitrogen intake) was significantly lower in fish fed 18% lipid diet than in the other groups. There were no significant differences in energy intake (kJ kg ABW^{-1} day^{-1}) between groups of fish fed 7 and 12.5% lipid diets. Energy retention kJ kg ABW^{-1} day^{-1} and percentage energy intake) significantly improved with dietary lipid level. Lipid intake (g kg ABW^{-1} day^{-1}) and lipid retention g kg ABW^{-1} day^{-1}) significantly increased as dietary lipid

Table 4: Nitrogen, energy and lipid utilization by *Heterobranchus longifilis* fingerlings fed the experimental diets[a]

	Diets		
	7 L	12.5 L	18 L
Nitrogen			
Intake (g kg ABW^{-1} [b] day^{-1})	0.97±0.13 [a]	1.01±0.08[a]	1.12±0.04[b]
Retention (g kg ABW^{-1} [b] day^{-1})	0.29±0.06[b]	0.25±0.05[b]	0.13±0.02[a]
Retention (percentage NI)	30.87±10.56[b]	25.31±6.37[b]	11.99±2.21[a]
Energy			
Intake (kJ kg ABW^{-1} [b] day^{-1})	310.80±39.59[a]	341.77±25.26[a]	406.71±18.11[b]
Retention (kJ kg ABW^{-1} [b] day^{-1})	58.77±6.11[a]	61.69±6.59[a]	201±14.41[b]
Retention (percentage EI)	18.92±0.45[a]	18.18±3.14[a]	49.66±5.54[b]
Lipid			
Intake (g kg ABW^{-1} [b] day^{-1})	1.23±0.16[a]	2.14±0.16[b]	3.59±0.12[c]
Retention (g kg ABW^{-1} [b] day^{-1})	0.71±0.03[a]	1.27±0.05[b]	2.14±0.04[c]
Retention (percentage LI)	58.92±10.68	59.45±2.20	59.65±2.20

[a]Figures in the same line with different superscript letters are significantly different ($p<0.05$). Mean±standard error., [b]Average body weight: (initial body weight+final body weight)/2

level increased. No significant difference was found in the lipid retention (percentage lipid intake) among the experimental diets.

DISCUSSION

When fish are fed a diet containing excess energy, growth may be reduced due to reduced feed consumption (Lovell, 1989). On the other hand, when fish are fed a diet deficient in energy, dietary protein is used as an energy source and this elevates the production costs. Weight gain of *H. longifilis* fed the 7% and 12.5% lipid diets were significantly higher than that of fish fed 18% lipid diets, similarly, SGR of fish fed 7% and 12.5% lipid diets were higher than those of fish fed the 18% lipid diets in this study, these trends indicate that increasing the dietary energy level by lipid will provide a more efficient utilization of dietary protein for the growth of fish. This protein-sparing effect has been reported in several fish species fed high-energy diets containing lipid as a major source (Page and Andrews, 1973; Watanabe 1982; Beamish and Medland 1986; De Silva *et al*., 1991; Dias *et al*., 1998).

The best growth performance and feed utilization was gained in the group fed 12.5% lipid diet and the decline in growth and feed utilization with increasing dietary lipid above this level was observed in present study. Similar results have been reported in turbot (Cacerez-Martinez *et al*., 1984; Regost *et al*., 2001), salmon (Silverstein *et al*., 1999), rainbow trout (Weatherup *et al*., 1997) carp (Murai *et al*., 1985), grass carp (Du *et al*., 2005).

Martino *et al*. (2002) reported in surubim, a carnivorous freshwater fish in Brazil, that fish weight gain increased with dietary lipid from 60 to 180 g kg^{-1}).

It has been suggested that feed intake is regulated by the dietary available energy (Lee and Putnam, 1973; Jobling and Wandsvik, 1983), probably because fish eat to satisfy their energy requirements. The lower feed intake of high-energy diets (18%) in this study agrees with findings in other species of fish (Lee and Putnam, 1973; Page and Andrews, 1973).

The increase of the dietary lipid level significantly improved energy utilization, which was similar to previous results on sea bass (Morales and Oliva-Teles, 1995; Dias *et al*., 1998), European sea bass (Peres and Oliva-Teles, 1999). Lipid retention (g kg ABW^{-1} day^{-1}) significantly increased as dietary lipid level increased, suggesting that excess lipid was deposited in the body tissue after the energy need has been met.

The lipid contents of liver and whole body in *H. longifilis* fed the high lipid diet were significantly higher than that of fish fed low lipid diets. These trends seem to be closely related to 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 diet (Lie *et al*., 1988; Hillestad and Johnsen, 1994; Catacutan and Coloso, 1995; Cho. 1982). An increase in liver lipid content of cod result in an increase in the HIS (Hemre *et al*., 1989).

The increase of dietary lipid levels should be carefully considered as it may affect carcass quality, mainly due to an increase of lipid deposition (Cowey, 1993; Hillestad and Johnsen, 1994). However, the muscle lipid c ontent observed In this study was lower than those reported for juvenile rockfish (*Scbastes schlegeli*) (Lee *et al*., 2002). Despite the increase in liver and whole body lipid content in the high lipid diets and considering the improvement of growth performance in 12.5% lipid diets in the present study, high (12.5%) lipid diets seems to have more beneficial effects for fish production, feed conversion ratio and protein-sparing compared to low lipid diets. Moreover, the decrease of feed and protein intake and protein utilization in high lipid diets in this study appears to have an effect of reduction of ammonia production as described by McGoogan and Gatlin (1999).

Overall, the best results were obtained with the 12.5% lipid diet which correspond to a DP / DE ratio of 19 -20 mg DP/kJ DE. This value is similar to that suggested by Dias *et al.* (1988) for juvenile European seabass (*Dicentrarchus labrax*) (19-20 DP /DE).

The results of this study indicate that an increase of dietary lipid level from 7% to 12.5% can improve growth performance and protein utilization of *H. longifilis* fingerlings. On the basis of this study, 12.5% lipid is recommended for practical diets for *H. longifilis* fingerlings.

REFERENCES

Beamish, F.W.H. and Medland, T.E., 1986. Protein sparing effects in large rainbow trout, Salmo Gairdneri. Aquaculture, 55: 35-42.

Cacerez-Martinez, C., M. Cadena-Roa and R. Metailler, 1984. Nutritional requirements of turbot (Scophthalmus maximus): I. A preliminary study of protein and lipid utilization. J. World Maric. Soc., 15: 191-202.

Catacutan, M.R. and T.M.T. Coloso, 1995. Effect of dietary protein to energy ratios on growth, survival and body composition of juvenile Asian seabass, Lates Calcarifer. Aquaculture, 131:125-133.

Cho, C.Y., S.J. Slinger and H.S. ayley, 1982. Bioenergetics of salmonid fishes: Energy intake, expenditure and productivity. Comp. Biochem. Physiol. 73B: 25- 41.

Cho, C.Y. and S.J. Kaushik, 1990. Nutritional energetic in fish: Energy and protein utilization in rainbow trout (*Salmo gairdneri*). World Rev. Nutr. Diet., 61: 132-172.

Cowey, C.B., 1993. Some Effects of Nutrition on Flesh Quality of Cultured Fish. In: Fish Nutrition in Practice (Kaushik, S.J. and Luquet, P. Eds), Proceedings of the IV International Symposium on Fish Nutrition and Feeding, INRA, Paris, France, pp: 227-236.

Daniels, W.H. and E.H. Robinson, 1986. Protein and energy requirements of juvenile red drum (*Sciaenops ocellatus*). Aquaculture, 53: 243- 252.

De Silva, S.S., R.M. Gunasekera and K.F. Shim, 1991. Interactions of varying dietary protein and lipid levels in young red tilapia: Evidence of protein sparing. Aquaculture, 95: 305-318.

Dias, J., M.J. Alvarez, A. Diez, J. Arzel, G. Corraze, J.M. Bautista and S.J. Kaushik, 1998. Regulation of hepatic lipogenesis by dietary protein/energy in juvenile European Seabass (*Dicentrarchus labrax*). Aquaculture, 161: 169-186.

Du, Z.Y., Y.J. Liu, L.X. Tian, J.T. Wang, Y. Wang and G.Y. Liang, 2005. Effect of dietary lipid level on growth, feed utilization and body composition by juvenile grass carp (*Ctenopharyngodon idella*) Aqu. Nutr., 11: 139-146.

Fagbenro, O.A., A.M. Balogun and C.N. Anyanwu, 1992. Optimal dietary protein level for *Heterobranchus bidorsalis* fingerlings fed compounded diets. The Israeli J. Aquac. Bamid., 44: 87-92.

Folch, J., M. Lees and G.H.S. Stanley, 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem., 226: 497-509.

Hemre, G.I., O. Lie, E. Lied and G. Lambertsen, 1989. Starch as an energy source in feed for cod (*Gadus morhua*): Digestibility and Retention. Aqu., 80: 261-270.

Hillestad, M. and F. Johnsen, 1994. High-energy/low-protein diets for Atlantic salmon: Effect on growth, nutrient retention and slaughter quality. Aqu., 124: 109-116.

Jobling, M. and A. Wandsvik, 1983. An investigation of factors controlling food intake in Arctic charr, *Salvelinus alpinus*. L. J. Fish Biol., 23: 391- 404.

Lee, D.J. and G.B. Putnam, 1973. The response of rainbow trout to varying protein/energy ratios in a test diet. J. Nutr., 103: 916-922.

Lee, S.M., I.G. Jeon and J.Y. Lee, 2002. Effects of digestible protein and lipid levels in practical diets on growth, protein utilization and body composition of juvenile rockfish (*Sebastes schlegeli*). Aqu., 211: 227-239.

Lie, O., E. Lied and G. Lambertsen, 1988. Feed optimization in Atlantic cod (*Gadus morhua*): Fat versus protein content in the feed. Aqu., 69: 33-341.

Lovell, R.T., 1989. Nutrition and Feeding of Fish. Van Nostrand-Reinhold, New York, USA,pp: 260.

Martino, R.C., J.E.P. Cyrino, L. Portz and L.C. Trugo, 2002. Effect of dietary lipid level on nutritional performance of the surubim, *Pseudoplatystoma coruscans*. Aqu., 209: 209-218.

McGoogan, B.B. and D.M. Gatlin, 1999. Dietary manipulations affecting growth and nitrogenous waste production of red drum, Sciaenops ocellatus: I. Effects of dietary protein and energy levels. Aqu., 178: 333- 348.

Morales, A.E. and A. Oliva-Teles, 1995. Resultados Preliminares Sobre La Utilização Metab?lica De Dietas Con Dos Niveles Lipidicos En Lubina *Dicantrarchus labrax* . In: Orvay, F.C., Reig, A.C. Eds., Proc. V National Congress on Aquaculture, Sant Carles de la Rapita, Spain, pp: 570-575.

Murai, T., T. Takeuchi, T. Watanabe and T. Nose, 1985. Effects of dietary protein and lipid levels on performance and carcass composition of fingerling carp. Bull. Jpn. Soc. Sci. Fish., 51: 605-608.

National Research Council (NRC), 1993. Nutrient requirements fishes. National Academy Press, Washington, DC, pp: 114.

Page, J.W. and J.W. Andrews, 1973. Interaction of dietary levels of protein and energy on channel catfish (*Ictalurus punctatus*). J. Nutr., 103: 1339- 1346.

Peres, H. and A. Oliva-Teles, 1999 Effect of dietary lipid level on growth performance and feed utilization by European sea bass juvenile (*Dicentrarchus labrax*). Aqu., 179: 325-334.

Phillips, A.M., 1972. Calorie and Energy Requirements. In: Halver, J.E. (Ed.), Fish Nutrition, Academic Press, New York, pp: 2- 29.

Regost, C., J. Arzel, M. Cardinal, J. Robin, M. Laroche and S.J. Kaushik, 2001. Dietary lipid level, hepatic lipogenesis and flesh quality in turbot (*Psetta maxima*). Aqu., 193: 291-309.

Shyong, W.J., C.H. Huang and H.C. Chen, 1998. Effects of dietary protein concentration on growth and muscle composition of juvenile Zacco barbata. Aqu., 167: 35- 42.

Silverstein, J.T., K.S. Shearer, W.W. Dickhoff and E.M. Plisetskaya, 1999. Regulation and nutrient intake and energy balance in salmon. Aqu.. 177: 161-169.

Viveen, W.J., C.J.J. Richter, Van P.G.W.J. Oordt, J.A.L. Janseen and E.A. Huisman, 1985. Practical Manual for the Culture of the African Catfish (*Clarias gariepinus*), Purdoc, The Hague, the Netherlands, pp: 121.

Watanabe, T., 1982. Lipid nutrition in fish. Comp. Biochem. Physiol., 73: 3-15.

Weatherup, R.N., K.J. McCracken, R. Foy, D. Ride, J. McKendry, R.J. Maris and R. Hoey, 1997. The effects of dietary fat content on performance and body composition of farmed rainbow trout Oncorhynchus mykiss. Aqu., 15: 173-184.