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Effects of Different Types of Oils on Growth Performance, Survival and Carcass Composition of Nile Tilapia (*Oreochromis niloticus*)

Mariama Sagne

Institut Universitaire de Pêche et d’Aquaculture (IUPA), Université Cheikh Anta Diop

UCAD II bâtiment pédagogique/Rez de chaussée, BP: 5005 DAKAR,

Abdoulaye Loum

Institut Universitaire de Pêche et d’Aquaculture (IUPA), Université Cheikh Anta Diop

UCAD II bâtiment pédagogique/Rez de chaussée, BP: 5005 DAKAR,

Jean Fall (Corresponding author)

Institut Universitaire de Pêche et d’Aquaculture (IUPA), Université Cheikh Anta Diop

UCAD II bâtiment pédagogique/Rez de chaussée, BP: 5005 DAKAR,

Tel: 221-77-956-4339 E-mail: kagoshima77@yahoo.com

Diegane Ndong

Agence Nationale de l’Aquaculture, Cité Comico 3 VDN Liberté 6 Extension LOT N1

BP: 1496 DAKAR

Malick Diouf

Institut Universitaire de Pêche et d’Aquaculture (IUPA), Université Cheikh Anta Diop

UCAD II bâtiment pédagogique/Rez de chaussée, BP: 5005 DAKAR,

Alassane Sarr

Institut Universitaire de Pêche et d’Aquaculture (IUPA), Université Cheikh Anta Diop

UCAD II bâtiment pédagogique/Rez de chaussée, BP: 5005 DAKAR,

Omar Thiom Thiaw

Institut Universitaire de Pêche et d'Aquaculture (IUPA), Université Cheikh Anta Diop

UCAD II bâtiment pédagogique/Rez de chaussée, BP: 5005 DAKAR,

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Abstract

The study evaluated the growth performance, survival and body composition of *Oreochromis niloticus* fed isonitrogenous (25%) and isocaloric (186 cal/kg) diets containing different types of oils (fish oil (FO) and vegetable oils (VO) (Soybean oil (SO) and Peanut oil (PO)) at 6% level for a period of 42 days. Significant difference was observed in the body weight gain (WG), specific growth rate (SGR), feed conversion ratio (FCR) values, body protein and lipid content. The diet E containing a mixture of vegetable oils in equal proportions (1:1) produced the best results WG (413.25%), SGR (3.86) and FCR (1.37), whereas the diet B (75% FO + 25% VO) showed the poorest performance WG, FCR and SGR. The survival rate ranged from 55 to 100%, being 55% for C (50% FO+ 50%VO), 65% for A (100% FO) and 100% for B (75% FO+ 25%VO), D (25% FO+ 75%VO) and E (100%VO). The type of dietary lipid significantly affected the body composition of fish. Fish fed on diets B (75% FO+ 25%VO), C (50% FO+ 50%VO), E (100%VO) presented the highest body protein content compared to initial fish. The highest body protein content was obtained in the fish fed on diet B (75% FO+ 25%VO). There was no significant difference in the body protein content of fish fed on diet C (50% FO+ 50%VO) and E (100%VO) also between the initial fish and those fed on diet D (25% FO + 75% VO). The lowest body protein content was obtained with fish fed diet with A (100% FO). Tilapia fed diet containing 100% FO, had the highest body lipid content compared to the initial fish. The lowest body lipid contain was observed in the fish fed on B (75% FO+ 25%VO). There was no significant difference in body lipid and protein content among fish fed diet with D (25% FO+ 75%VO) and initial fish. Results of the present study suggest that diet supplemented with a mixture of vegetable oils (SO and PO) could totally replace fish oil and produce the best growth response in *Oreochromis niloticus.*

Keywords: Fish oil, Soybean oil, Peanuts oil, Tilapia, *Oreochromis niloticus*

1. Introduction

Fishmeal and oils derived from wild harvested whole fish currently constitute the major aquatic protein and lipid sources available within the animal feed marketplace. Due to the expansion of aquaculture, it is expected that the total use of fishmeal and oils by the aquaculture sector will decrease in the long term. Thus, alternatives to the use of marine materials in fish feeds must be found.

Changes in aqua-feed have been characterized by an increase in dietary lipid levels to reduce nitrogen wastes and improve growth performance. This evolution combined with the strong increase in aquaculture production has led to a rise in demand for fish oils, while their availability remains limited. Alternative lipid sources to fish oil are used in greater amounts. Key alternatives include vegetable oils reducing the part of marine resources in aqua-feed

High-quality marine fish oils have been used almost exclusively as dietary lipid sources in the formulation of commercial fish feeds. However, vegetable oils used as alternative to fish oil consisted lately of an important part of the research on fish nutrition. Nevertheless, lipid digestibility was higher in diets containing vegetable oil than with animal lipid in Atlantic salmon fed diets based on flaxseed oil (Menoyo et al., 2007) and in Atlantic halibut fed diets based on vegetable oil (Martins et al., 2009).

Unlike fish oil, vegetable oils are less expensive and do not accumulate persistent organic pollutants (POPs), thus production costs can be lowered with vegetable oil-based diets, as well as contaminant exposure for fish and consumers. Additionally, these feeds will not alter organoleptic properties of the fillets and will be highly digestible for rainbow trout (*Oncorhynchus mykiss*).

Optimum dietary levels of the n-6 acids have been estimated at about 1% for red belly tilapia, *Tilapia zillii*, and 0.5% for Nile tilapia, *Oreochromis niloticus*. Other investigations evaluating the nutritional value of dietary lipid sources suggested that linolenic n-3 series fatty acids as well as n-6 fatty acids are dietary essentials for Nile; blue, *O. aureus*; and hybrid tilapia, *O. niloticus* x *O. aureus*; because fish fed diets supplemented with oils rich in n-3 fatty acids provided good growth and reproductive performance. However, it has been shown that the growth-promoting effects of n-6 fatty acids were superior to those of the n-3 series in red belly tilapia. The optimum dietary requirements of tilapia for n-3 fatty acids have not been determined. The sparing effect of dietary protein by increasing dietary lipid levels has also been reported in hybrid tilapia. However, tilapias do not tolerate as high a dietary lipid level as do salmonids. A level of 5% dietary lipid appeared sufficient to meet the minimum requirement of the so-named tilapia hybrid, but a level of about 12% was needed for maximum growth. Thus, it appears that lipid levels ranging 5 - 12% are optimum in diets for tilapia (Lim et al., 2009). Since vegetable oils such as corn, soybean, peanut, linseed, cotton seed oils contain high levels of n-6 and also significant amounts of n-3 fatty acids, they can be used in tilapia diets. Takeuchi et al., (1983) reported that 5% supplement of corn oil or olive oil resulted in better growth and feed utilization than the addition of cod liver oil.

Dietary lipids play an important role as potential supplier of energy, essential fatty acids and soluble vitamins. They also affect the quality of cultured fish because of their influence on the fatty acid composition of body tissues (Mukhopadhayay & Rout, 1996). The addition of lipids in fish diets contributes to protein sparing by increasing their digestible energy value (De Silva et al., 1991). In this line, the lipid requirement of different fish species varies.

Substitution of fish oil (FO) in fish aquafeeds has become inevitable due to the limited global supply of FO (Naylor et al., 2009; Turchini et al., 2009). Vegetable oils (VO) are common substitutes, but the main limitation with their use is the absence of n-3 long-chain (≥C20) polyunsaturated fatty acids (LC-PUFA).

The current study investigates the effects of feeding FO with high levels of vegetable oil substitution on tilapia growth, survival, and lipid deposition.

2. Materials and Methods

2.1 Culture Conditions

Male sex-reversed tilapia fries (*Oreochromis niloticus*) of initial weight 1.43 ±0.22g were collected from the tilapia hatchery in Richard Toll, Saint Louis, Senegal. Fish were acclimated to the experimental conditions for a period of two weeks. During this period, they were fed with a commercial diet as previously occurred at the above mentioned hatchery. To determine the initial body composition, 20 selected fish on a random basis were killed, filleted and stored at -18C for proximate analysis at a later AOAC stage, 1984. At the beginning of the experiment, one hundred tilapia fry were randomly divided into five different groups with two replicates containing 10 fish/each. Fish were kept in 10 glass tank (50 x 40 x 30) containers (50 L). Each aquarium was put in a re-circulating system maintained at 30 ± 1°C. An air stone continuously aerated each of both aquariums. All of such aquaria were cleaned up every day in the morning and the afternoon by siphoning off accumulated waste materials. Fish were then fed with 10% of body weight per day and gradually decreased to 4% per day. Each diet was fed twice a day at 08:00 (a.m.) and 17:00 (p.m.) for 42 days to duplicate groups of fish. On the other hand, each group of fish was weighed in the beginning and every two weeks and the amount of diet fed was adjusted, accordingly. A photoperiod of 12 h light, 12 h dark (08:00-20:00h) was used, while fluorescent ceiling lights supplied the illumination. After 6 weeks of feeding, fish were taken out from each treatment; the dorsal muscle tissue of each was dissected and used for carcass composition analysis purposes.

2.2 Diet Preparation

Five diets were formulated to contain approximately equal amounts of digestible protein (25%) and digestible energy (186 cal/kg). Main protein sources (fishmeal, millet meal and maize meal) already grounded into mill was passed as particles through n^{o}. 40 (425µm) mesh sieve. Mineral mix and vitamin mix were purchased from Aquavet Company, Thiès, Senegal. After all, ingredients were thoroughly mixed, and appropriate quantity of water provided (30% for 100 g of mixed ingredients). Diets were supplemented with 6% of mixture of fish oil (FO) and vegetable oil (VO) (75% FO + 25% VO; 50% FO + 50% VO; 25% FO + 75% VO) or fish oil (100% FO) and vegetable oil (100% VO) at (PO-SO 1:1) (Table 1). Dough was passed through an extruder to produce spaghetti and dried at 37°C for two days. So, the concerned dried diet was packaged into plastic bag and stored frozen until its usage.

Table 1. Composition of experimental diets for tilapia *(Oreochromis niloticus)*.

Treatments					
Ingredients	A	B	C	D	E
Fishmeal	334	334	334	334	334
Maize meal	311	311	311	311	311
Millet meal	191	191	191	191	191
Cellulose	100	100	100	100	100
Fish oil (FO)	48	32	24	16	0
Vegetable oil (PO + SO)*	0	16	24	32	48
Vit mix[a]	8	8	8	8	8
Min mix[b]	8	8	8	8	8

[a]= vit A 250000 UI; vit D3 250000UI; vit E 5000mg ; vit B1 100mg ; vit B2 400mg ; vit B3(pp) 1000mg ; vit B5 pantode Ca2000mg ; vit B6 300mg ; vit K3 1000g ; vit C 5000mg ; H biotin 15mg ; choline 100g ; anti-oxydant (BHT), crushed and calcined attapulgite qs 1000mg;;

[b]= phosphorus 7% ; calcium 17% ; sodium 1,5% ; potassium 4,6% ; magnesium 7,5% ; manganese 738mg ; zinc 3000mg ; iron 4000mg ; copper 750mg ; iodine 5mg ; cobalt 208mg ; calcined and ground attapulgite qs 1000g; fluorine 1.5% (approximately),

***PO:** peanut oil

***SO:** soybean oil

The proximate composition of the experimental diets and samples of the dorsal muscle were analyzed according to AOAC standard methods (1984).

2.3 Growth Parameters

Growth response parameters were calculated as follows: Weight gain (%) = 100* ((final mean body weight - initial mean body weight)/ initial mean body weight); Specific Growth Rate (SGR, % /day) = 100* ((In Wt- In Wi) /T), where Wt is the weight of fish at time t, Wi is the weight of fish at time 0 and T is the rearing period in days; Feed Conversion Rate (FCR) = total dry feed fed g/ fish / total wet weight gain g/ fish. Survival rate (%) = 100* (number of fish which survived/initial number of fish).

2.4 Water Quality Measurement

Water temperature and dissolved oxygen were measured each following day using YSI Model 58 oxygen meter (Yellow Springs Instrument, Yellow Springs, OH, USA).

2.5 Statistical Analysis

Data were analyzed using the following statistic system (SAS-PC) (Joyner., 1985) and subjected to one-way analysis of variance (ANOVA). Treatment effects were considered significant at $P < 0.05$; Duncan's test was used to compare significant difference among treatments.

3. Results

During the feeding trial, water-quality parameters averaged (±SD) water temperature 29 ± 1ºC; dissolved oxygen, 6 ± 1 mgL^{-1}. The proximate composition of the experimental Feeds is shown in Table 2. The related results show statistically similar composition (P>0.05) of the experimental feeds with respect to protein, lipid, fiber and Ash.

Table 2. Proximate analysis of experimental diets fed tilapia (*Oreochromis.niloticus)*

	Treatments				
Composition	A	B	C	D	E
Dry matter*	89.26	90.58	90.35	89.60	87.70
Crude protein*	25.14	25.69	24.69	24.95	26.72
Crude lipid*	8.32	8.71	8.02	8.84	8.63
Crude fiber *	2.3	1.65	1.93	2.02	1.90
Ash*,	2.14	2.52	2.54	2.40	2.41
Energy (Cal/kg)	183.96	187.75	178.66	187.44	192.15

* Presented in percentage of dry weight.

Data related to the growth performance of *Orechromis niloticus* fed on different types of dietary lipids are presented in the Table 3. Significant P<0.05 difference was observed in the body weight gain of fish fed. The highest growth performance (P<0.05) was observed in fish fed on diet E containing only the mixture of vegetable oil (peanut oil and soybean oil) in equal proportion as compared to the control diet A; intermediate in the fish fed on diets A, C and D. Fish fed on diet B showed the poorest performance. Similar results were observed for the SGR. Fish fed on diet A, C and E showed the best FCR values. Its survival ranged from 55 to 100%, be 55% for fish fed on diet C, 65% for fish fed on diet A, 100% for fish fed on diet B, D and E.

Table 3. Initial, final weight, weight gain, SGR, FCR and survival of Tilapia (*Oreochromis niloticus)*

	Treatments				
Parameters	A	B	C	D	E
Initial weight g/fish	1.42	1.44	1.46	1.42	1.36
Final weight g/fish	4.97	4.12	6.48	5.36	7.13
Weight gain g/fish	3.55^{ab}	2.68^{b}	5.02^{ab}	3.94^{ab}	5.74^{a}
Weight gain (%)	250.89^{ab}	185.79^{b}	343.84^{ab}	278.24^{ab}	413.25^{a}
SGR	2.99^{ab}	3.01^{b}	3.53^{a}	3.44^{ab}	4.27^{a}
FCR	1.77^{a}	2.67^{b}	1.45^{a}	1.98^{ab}	1.37^{a}
Survival (%)	65	100	55	100	100

^{ab} Means in the same column with the different letter are significantly different

(P＜0.05).

Table 4 displays initial and final body compositions of whole fish. Significant P<0.05 difference was observed in the body composition of fish fed different types of dietary lipids. The body protein content was significantly high in fish fed diet B compared to the body protein content of initial fish. The lowest body protein was obtained in fish fed on diet A. Diet D did not show any significant difference in the body protein and lipid content as compared to initial fish. Fish fed on diet C and E did not show any significant difference in their body crude protein. The body fat content was significantly high in fish fed diet E followed by fish fed diets C and A, respectively. Fish fed on diet B showed the lowest body fat content as compared to initial fish. No significant difference was observed in the body fat content of fish fed on diet D as compared to initial fish.

Table 4. Proximate analysis of dorsal muscle of tilapia (*Oreochromis niloticus)*

	Treatments					
Composition	Initial fish	A	B	C	D	E
Protein (N*6.25) (%)	17.5[c]	10.50[d]	19.25[a]	18.37[b]	17.5[c]	18.38[b]
Lipid (%)	6.1[d]	9.0[c]	4.0[e]	10.8[b]	5.7[d]	12.7[a]

[abcde] Means in the same column with the different letter are significantly different

($P < 0.05$).

4. Discussion

Under the experimental conditions, the results of the present study indicated that the type of dietary lipid significantly affected the growth performance of *O. niloticus*. The best growth rate, FCR and SGR were observed in fish fed on diet E containing a mixture of vegetable oils in equal proportions. This may be attributed to the fact that peanut oil and soybean oil are rich in linoleic acid (n-6) (13-43% and 51.5%, respectively). Similarly, it has been reported that plant oils rich in 18:2n-6, such as soybean oil, corn oil, sunflower oil, canola/rapeseed oil and various palm oil products constitute equally good lipid sources for tilapia (Lim et al., 2009). Moreover, it has been noticed that growth-promoting effects of n-6 fatty acids were superior to those of the n-3 series in red belly tilapia (Lim et al., 2009). Generally, n-3 fatty acids are not required by warm water fishes but for proper membrane structure and at least small quantity of these acids may be required (Stickney & Hardy, 1989). Different Tilapia species however require approximately 1% of n-6 fatty acids in their diets (Teshima et al., 1985). Since vegetable oils contain high levels of n-6 and also huge quantities of n-3 fatty acids, they can be efficiently used in Tilapia diets. Chou & Shiau (1996) reported that the growth performance of juvenile hybrid tilapia (*O. niloticus x O. aureus)* was better on diets containing lipids as compared to those fed lipid free diets.

Takeuchi et al., (1983) reported that Nile tilapia fingerling fed diets containing corn oil or soybean oil, attained the best weight gain and feed efficiencies as compared to those given beef tallow or cod liver oil. Moreover, Yingst & Stickney (1979) reported that the channel catfish fry showed the best growth rate when reared on practical diets containing menhaden oil followed by soybean oil and the poorest on beef tallow. These results are in line with our findings indicating that diet E containing only VO produced the highest growth rate. In contrast, Santiago & Reyes (1993) observed the highest weight gains in *O. niloticus* (L) brood stock fed cod liver oil.

Many authors obtained conflicting results from their studies on the replacement of FO by VO. Guillou et al., (1995) reported that soya and canola oils can replace fish oils in the diets of brook charr (*Salvelinus fontinalis*). Wing-Keong et al., (2006) showed that in fishmeal-based diets for Nile tilapia, palm oil-laden SBC can totally replace added fish oil. Wing-Keong et al., (2011) reported that a novel dietary vegetable oil blend was able to totally replace fish oil in tilapia diets without negative impact on growth performance. Such results are in accordance with the present study findings which showed that mixture of vegetable oil (diet E) in an equal proportion (ratio 1:1) can totally replace fish oil in tilapia diet. In contrast, studies have reported partial replacement (at least 50 % up to 80 %) of dietary fish oil by vegetable oil (Caballero et al, 2002). Vegetable oil inclusion significantly reduced EPA and DHA concentrations in both muscle and liver of fish juvenile Malaysian mahseer, *Tor tambroides* except for fish on 50% palm oil diet that had similar liver DHA content with those on control diet (fish oil) (Kamarudin et al., 2012). Mourente et al., (2005) found that 60% of fish oil could be replaced by rapeseed, linseed and olive oils without reduction on the growth rates in European sea bass *Dicentrarchus labrax*. Likewise, only 50% of fish oils were substituted by vegetable oils with no adverse effects on the growth or increased mortality in Atlantic salmon *Salmo salar* (Storebakken, 2002). Furthermore, total substitution of fish oil with vegetable oils (rapeseed, lin) or a mixture of vegetable oils (55% rapeseed / palm 30% / 15% linen) does not change into the ingestion voluntary growth performance and feed efficiency (Médale & Kaushik 2008). The incorporation of vegetable oils in fish feed, replacing fish oil does not alter growth performance since the needs of essential fatty acids (EFAs) are covered (Corraze & Kaushik, 2009). Largemouth bass may be able to use diets containing vegetable and animal-source lipids, which are less expensive than fish oil previously recommended (Tidwell et al., 2007).

Chemical analysis at the end of the experiment is frequently used to determine the influence of feed on fish composition. According to Hepher (1990), endogenous and exogenous factors affect the body composition of fish. It should be noted that, the composition of the feed is the only factor, which could have influenced the difference chemical composition of fish, as other endogenous factors were maintained uniform during the study work.

Data on the body composition of fish allows assessing the efficiency of transfer of nutrients from feed to fish and also helps predict the overall nutritional status. The n-3/n-6 fatty acid ratio can also alter lipid and protein contents in fish muscle (Robaina et al., 1998). In a similar way, the results of the present study indicated that the type of dietary lipid significantly affected the body composition of fish. Fish fed diet B showed higher body crude protein and higher body fat was observed in fish fed on diet E containing only VO (ratio 1:1) compared to initial fish. This differs from the results of Tidwell et al., (2007) who showed that fatty acid composition of the diet had no effect on the proximate composition of the test fish. Richard et al., (2006) revealed that total replacement of dietary fish oil by the blend of vegetable oils did not modify muscle lipid content of rainbow trout. Substantial portion of dietary lipid is incorporated into the depot fat that mainly goes to visceral fat as compared to the rest of the body (Sheridan, 1994). Vegetable oils are cheaper, available in large quantities and less subjected to oxidation (Dosanjh et al., 1984). They enable growth and feed conversion which is as efficient as fish oils without significantly affecting the flesh’s organoleptic qualities (Guillou et al., 1995).

The use of VO as a replacement for FO 0–100% levels showed that the proximate composition of feeds did not differ statistically, except for Dry matter content. Nutritional evaluation of these feeds did show significant statistical difference among treatments, in terms of WG, FCR and SGR. The mortality rate noticed during the feeding trial did not present any conclusive trend. Chemical analysis of body composition of tilapia fed on the diets for a period of six weeks also differs statistically in terms of protein and lipid content. Results of this study show that VO could be used as a complete substitute for FO in a practical diet for tilapia fry.

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Reference

AOAC (Association of Official Analysis Chemists). (1984). Official Methods of Analysis, 14 the edition, AOAC Arlington, VA, 1141pp.

Caballero, M. J., Obach, G., Rosenlund, G., Montero, D., Gisvold, M., & Izquierdo, M. S. (2002). Impact of different dietary lipid sources on growth, lipid digestibility, tissue fatty acid composition and histology of rainbow trout, *Oncorhynchus mykiss*. *Aquaculture*, *214*, 253-271. http://dx.doi.org/10.1016/S0044-8486(01)00852-3

Chou, B. S., & Shiau, S. Y. (1996). Optimal dietary lipid level for growth of juvenile hybrid tilapia, *Oreochromis niloticus x Oreochromis aureus. Aquaculture*. *143*, 185-95. http://dx.doi.org/10.1016/0044-8486(96)01266-5

Corraze, G., & Kaushik, S. (2009). Alimentation lipidique et remplacement des huiles de poisson par des huiles végétales en pisciculture. *Cahiers Agricultures*. *18*, 112-118.

De Silva, S. S., Guansekera, R. M., & Shim, K. F. (1991). Interactions of varying dietary protein and lipid levels in young red tilapia: evidence of protein sparing. *Aquaculture. 95*, 305-318. http://dx.doi.org/10.1016/0044-8486(91)90096-P

Dosanjh, B. S., Higgs, D. A., Plotnikoff, M. D., McBride, J. R., Markert, J. R., & Buckley, J. T. (1984). Efficacy of canola oil, pork lard and marine oil singly and in combination as supplemental dietary lipid sources for juvenile Coho salmon (*Onchorhynchus kissutch*). *Aquaculture*. *36*, 333-345. http://dx.doi.org/10.1016/0044-8486(84)90326-0

Folch, J., Lees, M., & Sloane-Stanley, G. H. (1957). A simple method for the isolation and purification of total lipid from animal tissues. *Journal of Biological Chemistry*. *226*, 497-509.

Guillou, A., Soucy, P., Khalil, M., & Adambounou, L. (1995). Effects of dietary vegetable and marine lipid on growth, muscle fatty *acid composition and organoleptic quality of flesh of Brook charr {Sahelinus fontinalis). Aquaculture*. *136*, 351-362.

http://dx.doi.org/10.1016/0044-8486(95)00053-4

Hepher, B. (1990). Nutrition of pond fish, Cambridge. *Cambridge University Press*. 388 pp.

Joyner, S. P., 1985. SAS/STAT Guide for Personal Computer, Statistical Analysis System Institute, Cary, NC, USA.

Kamarudin, M. S., Ramezani-Fard, E., Saad, C. R., & Harmin, S. A. (2012). Effects of dietary fish oil replacement by various vegetable oils on growth performance, body composition and fatty acid profile of juvenile Malaysian mahseer, *Tor tambroides. Aquaculture Nutrition*. *18*, 532–543. http://dx.doi.org/10.1111/j.1365-2095.2011.00907.x

Lim, C., Aksoy, M., & Klesius, P. (2009). Lipids and fatty acid requirements of tilapia - Dietary supplementation essential for health, reproduction. *Global Aquaculture Advocate*, *12*(5), 86-87.

Martins, D. A., Valente, L. M. P., & Lall, S. P. (2009). Apparent digestibility of lipid and fatty acids in fish oil, poultry fat and vegetable oil diets by Atlantic halibut, *Hippoglossus hippoglossus* L. *Aquacultu*re, *294,* 132-137. http://dx.doi.org/10.1016/j.aquaculture.2009.05.016

Medale, F., Kaushik, S. (2008). Evolution des recherches en nutrition piscicole à l'INRA : substitution des produits d'origine marine dans l'alimentation des poissons d'élevage. *Nutrition, Aquaculture et Génomique INRA Prod. Anim, 21*(1), 87-94.

Menoyo, D., Lopez-Bote, C. J., Diez, A., Obach, A., & Bautista, J. M. (2007). Impact of n-3 fatty acid chain length and n3/n6 ratio in Atlantic salmon (*Salmo salar*) diets. *Aquaculture*, *267*, 248-259. http://dx.doi.org/10.1016/j.aquaculture.2007.02.031

Mourente, G., Good, J. E., & Bell, J. G. (2005). Partial substitution of fish oil with rapeseed, linseed and olive oils in diets for European sea bass (*Dicentrarchus labrax*): effects on flesh fatty acid composition, plasma postaglandins E2 and E2α, immune function and effectiveness of a fish oil finishing diet. *Aquaculture Nutrition*, *11*, 25-40. http://dx.doi.org/10.1111/j.1365-2095.2004.00320.x

Mukhopadhayay, P. K., & Rout, S. K. (1996). Effects of different dietary lipids on growth and tissue fatty acid changes in fry of carp *Catla catla* (Hamilton). *Aquaculture research*, *27*, 623-630. http://dx.doi.org/10.1111/j.1365-2109.1996.tb01295.x

Naylor, R. L., Hardy, R. W., Bureau, D. P., Chiu, A., Elliott, M., Farrell, A. P., Forster, I., Gatlin, D. M., Goldburg, R. J., Hua, K., & Nichols, P. D. (2009). Feeding aquaculture in an era of finite resources. *Proceedings of the National Academy of Sciences of the United States of America, 106*, 15103-15110. http://dx.doi.org/10.1073/pnas.0905235106

Richard, N., Kaushik, S., Larroquet, L., Panserat, S., & Corraze, G. (2006). Replacing dietary fish oil by vegetable oils has little effect on lipogenesis, lipid transport and tissue lipid uptake in rainbow trout (*Oncorhynchus mykiss*). *British Journal of Nutrition, 96*, 299- 309. http://dx.doi.org/10.1079/BJN20061821

Robaina, L., Izquierdo, M. S., Moyano, F. J., Socorro, J., Vergara , J. M., & Montero, D. (1998). Increase of the dietary n-3/n-6 fatty acid ratio and addition of phosphorous improves liver histological alterations induced by feeding diets containing soybean meal to gilthead seabream, *Sparus aurata. Aquaculture, 161*, 281–293. http://dx.doi.org/10.1016/S0044-8486(97)00276-7

Santiago, C. B., & Reyes O. S., (1993). Effects of dietary lipid source on reproductive performance and tissue lipid levels in Nile Tilapia *Oreochromis niloticus* (Linnaeus) broodstock. *Journal of Applied Ichthyology*, *9,* 33-40. http://dx.doi.org/10.1111/j.1439-0426.1993.tb00385.x

Sheridan, M. A. (1994). Regulation of lipid metabolism in piokilothermic vertebrates. *Comparative Biochemistry and Physiology*, *107*, 495-508. http://dx.doi.org/10.1016/0305-0491(94)90176-7

Stickney, R. R., & Hardy, R. W. (1989). Lipid requirements of some warm water species. Aquaculture, *79*,145-156. http://dx.doi.org/10.1016/0044-8486(89)90455-9

Storebakken, T. (2002). Nutrient requirements and feeding of finfish for aquaculture Atlantic salmon. Pages 79–102 in C. D. Webster and C. Lim, editors. CABI Publishing,Wallingford, UK.

Takeuchi, T., Satoh, S., & Watanabe, T. (1983). Requirement of Tilapia nilotica for essential fatty acids. *Bulletin of the Japanese Society for the Science of Fish*, *49*(7), 1127-1134.

Teshima, S., Kanazawa, A., & Uchiyama, Y. (1985). Effect of dietary protein, lipid and digestible carbohydrate levels on the weight gain, feed conversion efficiency and protein efficiency ratio of *Tilapia nilotica. Memorial Kagoshima University Research Center South. Pacific*, *6*, 56-71.

Tidwell, J. H., Coyle, S., & Anne, L. B. (2007). Effects of Different Types of Dietary Lipids on Growth and Fatty Acid Composition of Largemouth Bass. North American Journal of Aquaculture, *69*(3), 257-264. http://dx.doi.org /10.1577/A06-040.1

Turchini, G. M., Torstensen, B. E., & Ng, W. K. (2009). Fish oil replacement in finfish nutrition. *Reviews in Aquaculture*, *1*, 10-57. http://dx.doi.org/10.1111/j.1753-5131.2008.01001.x

Wing-Keong, Ng., KOH, C.-B., & DIN, Z. B. (2006). Palm oil-laden spent bleaching clay as a substitute for marine fish oil in the diets of Nile tilapia, *Oreochromis niloticus. Aquaculture Nutrition*, *1*, 459-468. http://dx.doi.org/10.1111/j.1365-2095.2006.00449.x

Wing-Keong, Ng., Teoh, C. Y., & Turchini, G. M, (2011). Farmed Tilapia Net Producers Of Long-Chain Omega Fatty Acids. *Global aquaculture advocate*, p 22-24.

Yingst III, W. L., & Stickney, R. R. (1979). Effects of dietary lipids on fatty acid composition of channel catfish fry. *Transactions of the American Fisheries Society, 108*, 620-625. http://dx.doi.org/10.1577/1548-8659(1979)108<620:EODLOF>2.0.CO;2

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