Recent Developments In The Use Of Palm Oil In Aquaculture Feeds: A Review

Christian Larbi Ayisi, Jin-Liang Zhao

SUMMARY: The continuous and rapid growth of aquaculture in terms of size and annual total production has resulted in the need to seek for pragmatic measures to reduce the cost of production which feeding covers approximately 60%. This present work reviews the advances made in the use of palm oil as an alternative lipid source in aquafeeds. In this review it is documented that with respect to price, availability and cost effective wise palm oil is the best choice as compared to other vegetable oils as well as fish oil. Also it is made clear that the use of palm oil in aquafeeds partially or exclusively does not compromise the growth, feed utilization as well as body composition of fish. It is also made clear based on existing information that palm oil impacts on the quality of aquafeeds positively. We therefore suggest that the use of palm oil in aquafeeds should be well embraced and much work should be done concerning its effects on non-specific immunity as well as effects on the expression of genes responsible for growth promoting and lipid metabolism.

Key words: Aquaculture, Developments, Feed, Palm oil, Recent,

————————◆————————

1.0 INTRODUCTION

Aquaculture with reference to definition is the farming of aquatic organisms including the shell fish, fin fish and even plants. This mode of culturing system may be employed to both species of marine and fresh water species and can range from land-based to open ocean production. Aquaculture as a system of farming is normally practiced in coastal mates and has existed since the 1800s (1). Aquaculture in 1990 contributed about 10% of the total world fish production in 1990 and continues to play important role in the world fish production (20). In 1997, FAO reported that aquaculture happens to be one the fastest growing food production activities in the world. According to reports by FAO 2009, production of aquaculture with respect to weight has risen from about 3.6% in 1970 to 36% of world production in 2006. Average wise, aquaculture with an annual growth rate of 7.2% has outpaced the world population growth rate (19). As the aquaculture sector grows, the problem of cost of production keeps re-occurring. In any aquaculture venture, the protein component of feed is responsible for its high cost (18) specifically fishmeal and fish oil (13). The priority of the fish farmer or commercial feed producer is to ensure that protein is efficiently transformed into tissue protein for growth (23). Also metabolization of protein by fish should be directed towards body protein synthesis and not to serve as source of energy (3). The growth rate of fish vary significantly and most often appear to be limited by availability of food as well as the quality and quantity of dietary non-protein to protein nutrients. Due to this fact the focus of most researchers have been to cut the cost of feed by producing practical diets that are available at cheaper cost all year round (10; 12). Although dietary energy present in diets plays an important role in determining body lipid deposition, the dietary lipid content is regarded as the most important factor affecting carcass lipid in fish (8). Fish oil is solely depended upon for the production of feeds for fish cultured in captivity. Fish such as herring, sardine, anchovy and capelin, among others which are of low or no economic value for human consumption (24) are used to produce fish oil. Aquaculture is mostly relying on fish meal (FM) and fish oil (FO) of which (22) reported that aquaculture sector alone consumed approximately 835,000 tonnes making up about 88.5% of the total fish oil produced in 2006. It was projected that the supply from wild feed grade fisheries will remain static in the next decade hence the viability, growth and profitability of aquaculture could be negatively impacted (21). Some work has been done to assess different types of oils as possible use in aquafeeds in place or with fish oil to cut down the cost of feeding and the cost of aquaculture production at large. In this current paper we review the use of palm oil in aquaculture feeds taking into consideration its availability and price relating it to fish oil and other vegetable oils, its effects of feed quality, growth performance, fatty acid and body composition as well as suggestions on future research that could be undertaken.

2.0 QUALITIES OF PALM OIL

The oil palm (Elaeis guineensis) is an ancient tropical plant from the West African tropical rainforest region. Palm oil (PO) is obtained from the oil palm (Elaeis guineensis family: Arecaceae). Palm oil is fruit flesh oil; however, it also produces seed oil (palm kernel oil) (9). Palm oil also contains a higher proportion of vitamin E. Some of the carotenoids produced by plants also present some vitamin A activity. Among them, β-carotene exhibits the highest vitamin A activity. As documented by (5; 11; 17) carotenoids specifically ß-carotene plays essential roles which are known to include serving as pro- vitamin A as well as antioxidants. In addition to these functions they serve as immune-regulators as well as being mobilized from muscle to ovaries which depicts that it plays essential functions in reproduction. They also help fish to resist to bacterial and fungal infections (17) Palm oil as reported by (4) is also the only vegetable oil available in the world market, which is rich in tocotrienols. The aliphatic tail shows the difference between tocopherols and tocotrienols. Whiles the tail of tocotrienols is an unsaturated isoprenoid chain with three bonds embedded at 3', 7', and 11'that of tocopherols have a saturate phytyl chain which has three chiral centers with configuration position at 2, 4' and 8',. The tocopherols and tocotrienols in vitamin E serve as a potent antioxidant to protect cellular membranes from free radical-catalyzed lipid peroxidation (7). According to (13), a greater proportion of crude palm oil is made up of 16:0 and 18:1n-9 (43.5% and 36.6% of total lipid fatty acid composition, respectively). It also possesses relatively low levels of 18:2n-6 (9.1%). Palm oil is made up of a high proportion of palmitic acid with considerable quantities of oleic and linoleic acids (15). The fatty acid (FA) composition of palm oil therefore makes it a good potential candidate to replace FO in diets for O. niloticus to provide sufficient energy for maximum growth.

3.0 AVAILABILITY OF PALM OIL

Global production of vegetable oil such as palm oil is projected to increase by over 30% by 2020 due to the continuous supply by developing countries. In Malaysia and Indonesia, where land restrictions and environmental regulations have become more binding, combined palm oil output will expand by almost 45%, raising their share in global output to 36%. On the average there are approximately 17 major oils produced globally. Out of this palm oil and its related oil is produced in large quantities (Oil world, 2013). Palm oil happens to be the largest oil produced with the cheapest price in the world vegetable oil market. Along with soybean oil, palm oil provides one of the largest vegetable oil tonnages in the world hence it has a high availability (U.S.Department for Agriculture, 2007). The total percentages for various oils produced globally in 2013 as reported by oil world are presented in figure 1 According to this report by oil world 2013, palm oil with its related oils was the largest produced oil which made up about 32% of the total oil produced in the year 2013. This was followed by soybean oil with a percentage of about 22.4%.

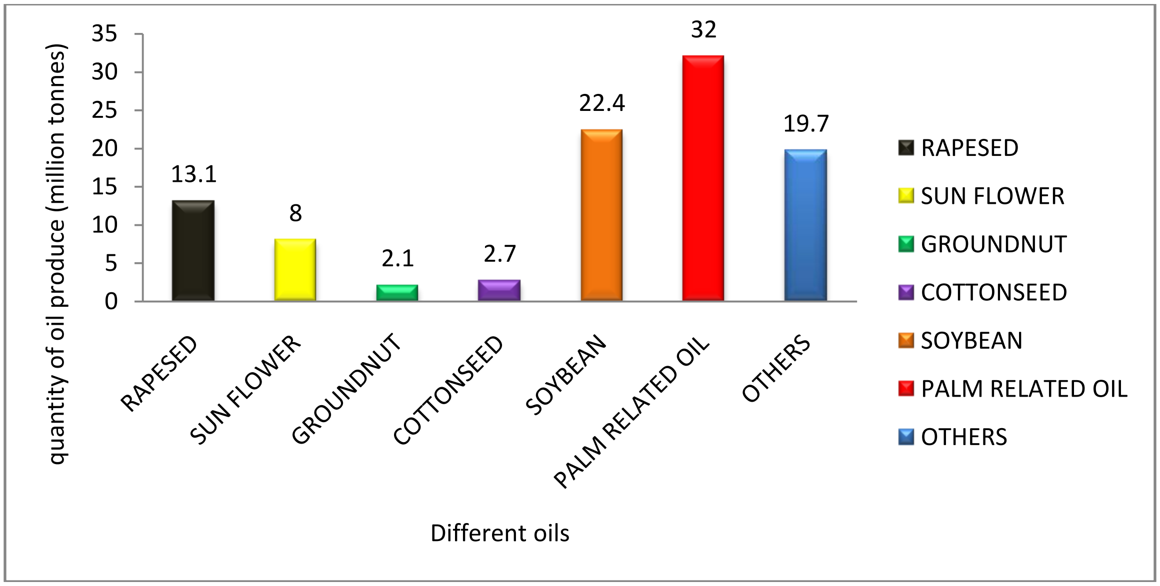

Fig.1 Production of palm oil vs. other vegetable oils 2013 (source: oil world 2013).

According to Malaysian palm oil board report 2008, the production of palm oil has seen increases in terms of quantity whereas the production of fish oil has kept on decreasing since the year 2000. Whereas the total production of palm oil increased from 21.9 million tones in 2000 to 37.1 million tones in 2006, the total fish fish oil produced in 2000 reduced drastically from 1.3 million tones to 0.9 million tones in 2006.

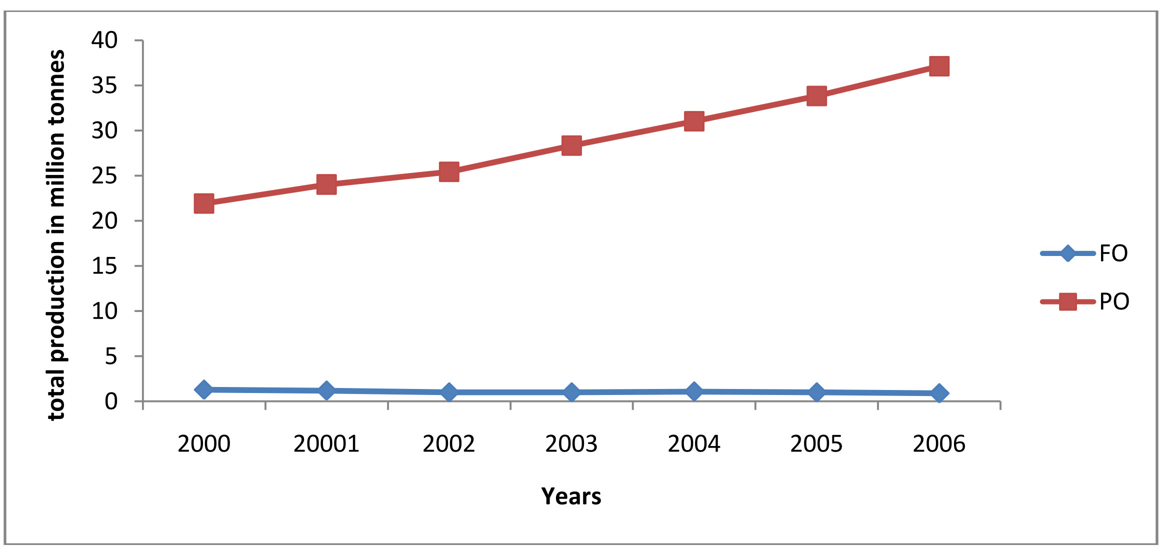

Fig.2 Production of palm oil vs. fish oils 2006 (source: Malaysian Palm oil board, 2008).

3.0 PRICES OF PALM OIL

Palm oil over the years has been a force to reckon with in terms of its low prices on the international market. As shown in fig. 1, the prices of palm oil as compare to other vegetable oils have been very stable.

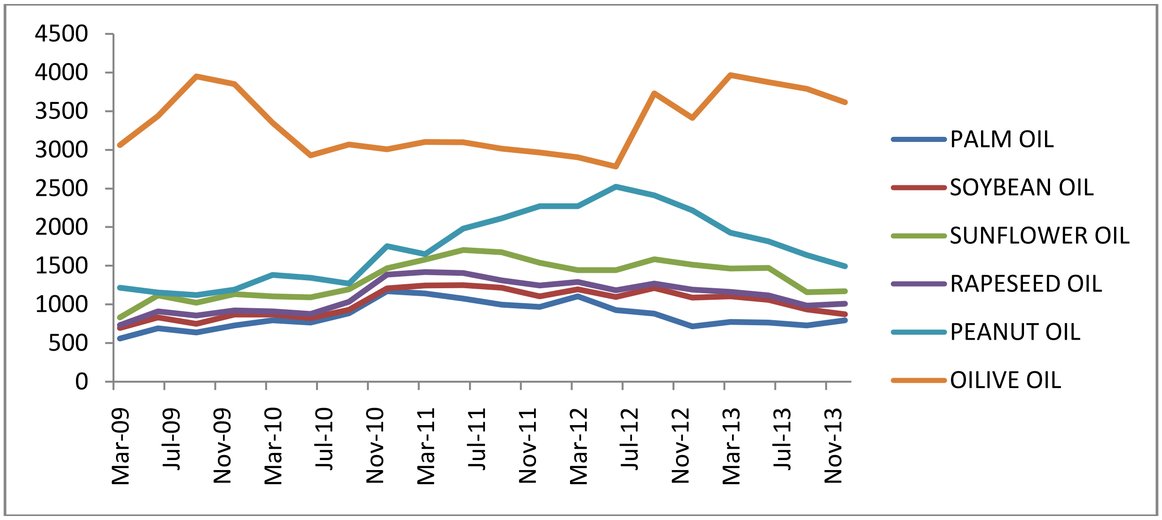

Fig.3 Quarterly prices of vegetable oils from March, 2009 to December 2013. (Source: mundus index)

4.0 EFFECT ON FEED QUALITY.

The use of palm oil in aquafeeds adds a great value to the feed produced. It possesses different properties which makes it a better source of oil in respect to its effect on the quality of feed. Rancidity which is the chemical decomposition of fats, oils and other lipids (this degradation also occurs in mechanical cutting fluids) is a normal phenomenon found in aquafeeds. Most oils specifically vegetable oils are prone to attack by atmospheric oxygen, a phenomenon which leads to rancidity. This phenomenon normally leads to poor quality of aquafeeds which usually forms a greater portion of the cost involved in aquaculture. Palm oil however, has the ability to withstand rancidity due to the presence of its low levels of polyunsaturated fatty acids. The level of feed rancidity in aquafeeds made of palm oil is substantially lower in aquafeeds made of palm oils as compared to other vegetables. This is an advantage of the use of palm oil in aquafeeds over the use of other oils with fish oil inclusive. This is basically due to the fact that palm oil contains vitamins E and carotenoids which are potent antioxidants in the natural states which have protective values against rancidity. Palm oil again possesses one quality over other oils which help to retain much of the oil used in the preparation of aquafeeds. This was confirmed by (14) who documented that the increase of crude palm oil in feed for salmonids resulted in the reduction of oil leakage with respect to high levels of levels of lipids (approximately 40%). Unlike most oils including fish oil, palm oil has a higher melting point (95 F) due to its semi-solid state. This characteristic of palm oil therefore reduces drain of other lipids used in preparation of aquafeeds. It also ensures that packaging of aquafeeds is kept as neat as possible.

5.0 EFFECT ON GROWTH PERFORMANCE AND BODY COMPOSITION

The effect of palm oil on growth performance, fatty acids and body composition of fish has been reported by some scientists (2; 16; 24; 25; 26; 27) with different results. In an experiment by (2) to investigate the Effect of dietary palm oil on growth and carcass composition of Heterobranchus longifilis fingerlings**.** They aimed at replacing dietary fish oil with palm oil. In their study triplicate groups of H. longifilis fingerlings were fed the experimental diets for 8 weeks using isonitrogenous (45% crude protein), isoenergetic (20 KJg-1) experimental diets containing either 6.0% FO and 0% PO, 4.5% FO and 1.5% PO; 3.0% FO and 3.0% PO; 1.5% FO and 4.5% PO; or 0% FO and 6.0%PO. They used soybean and fish meal as the protein source. They documented that dietary palm oil had no significant effect on growth rate or feed conversion ratio. Similarly, No significant differences were observed between dietary treatments for moisture, protein and ash content in H. longifilis fingerlings. They again documented that fillet saturated, monounsaturated fatty acids and liver lipid deposition were significantly ($P<0.05$) higher in fish fed 6.0% PO diet. In a similar work by (16) on the Growth Performance, Body Composition, Hematology and Product Quality of the African Catfish (Clarias gariepinus) Fed Diets with Palm Oil. They assessed the replacement value of palm oil for cod liver oil in diets for juvenile African catfish with initial weight of 24.04 g for an 8 week period. Fish were fed experimental diets in which there was either 9% cod liver oil (Diet 1), 6% cod liver oil, 3% palm oil (Diet 2), 3% cod liver oil, 6% palm oil (Diet 3), or 9% palm oil (Diet 4).There were significant differences in body weight gain among all treatments, with fish fed diets 2 and 3 performing better. Fishes fed diets 3 and 4 had significantly higher survival than fish fed diets 1 and 2. Significant differences were recorded in carcass parameters of fish at the end of the feeding trial, with fish fed diets 3 and 4 having higher values. Fish fed diet 2 had higher blood parameters which decreased with increasing level of palm oil in the diet. There was no significant difference in the organoleptic properties of fish fed different dietary treatments and the end of the trial. The results of this study shows that diet containing 3% cod liver oil and 6% palm oil is nutritionally suitable for feeding the African catfish. In a 60-day feeding trial to establish the effects of palm oil blended with oxidized and non-oxidized fish oil on growth performances, hematology, and non-specific immune response in juvenile Japanese sea bass, Lateolabrax japonicas, seven experimental diets containing 100 g/kg of dietary lipid in forms of palm oil (10P), fish oil (10F), fish oil blended with palm oil at different ratios, 6:4 (6F4P) and 4:6 (4F6P), oxidized fish oil (10OF), and oxidized fish oil blended with palm oil at different ratios, 6:4 (6OF4P) and 4:6 (4OF6P) were fed to Japanese sea bass (1.73±0.01 g). After the feeding trial, (24), documented that the experimental diet did not affect survival, feed conversion ratio, condition factor, and hematocrit significantly. Also they reported that, the relatively higher specific growth rate and hematology were observed in 6F4P and again documented that both palm oil as well as oxidized fish oil acted negatively on serum lysozyme activity (P<0.05). They therefore suggested a ration of 6F4P as an innocuous ratio for Japanese sea bass. With a similar objective as those reported above, (25) researched to evaluate the effects of dietary lipid sources on the reproductive performance of tilapia brood fish. These researchers used four isonitrogenous (35% protein) and isolipidic (10%) casein-based diets consisting of fish oil (FO), FO and crude palm oil (FO +CPO; 1:1), CPO or linseed oil (LSO) as the lipid source, respectively. They used pre-spawning female Nile tilapia (Oreochromis niloticus, GIFT strain) which were individually color-tagged, and six females and two males were stocked into a one-tonne breeding tank. The researchers studied the reproductive performance of 12 individual females for 25 weeks after feeding each diet to two tanks of brood fish. As documented by (25) female brood fish fed the two CPO-based diets showed significantly (Pb0.05) larger gonad sizes and lower intraperitoneal fat compared to fish fed the FO or LSO diets. They again documented that, the first spawning of fish fed diets consisting FO+CPO, FO or LSO occurred at 44.1, 45.5, and 76.3 days respectively of which they occurred later than that of the fish fed CPO diets which occurred at 30.8 9.9 days. In this very work, the highest number of actively spawning tilapia was observed in fish fed the FO +CPO diet, followed by fish fed the CPO, FO or LSO diet, respectively. With respect to the assessment of total number of eggs per fish based on the shorter inter spawning internal and higher spawning frequency, (25) documented that the fish subjected to two CPO-based diets produced the highest after the 25 week feeding trial. The mean diameter, volume as well as weight of eggs reported in this very work did not vary among dietary treatments. However, egg hatchability for brood fish subjected to CPO-based diets was significantly higher than all other treatments. Dietary lipid source used in the research influenced the fatty acid composition of the muscle, gonad, egg as well as newly hatched larvae. The highest relative concentration of saturates, monoenes, arachidonic acid as well as n-6/n-3 ratio reported in the gonads, eggs and larvae of tilapia occurred in fish subjected to the CPO diet. Comparatively, the fish subjected to LSO based diets recorded the highest total n-3 PUFA concentration in the gonads whiles those fed the FO based diets recorded the lesser concentration of total n-3 PUFA. Interestingly, (25) concluded that based on the results, the addition of CPO in tilapia brood stock diets has the ability to reduce the cost of producing tilapia fry hence maximizing profit. In addition, (26) have studied Dietary fish oil replacement with palm or poultry oil increases fillet oxidative stability and decreases liver glutathione peroxidase activity in barramundi (Lates calcarifer). This study demonstrated that complete dietary fish oil replacement with either palm or poultry oil in barramundi (Lates calcarifer) did not have negative effects on growth or hepatosomatic index of juvenile fish up to an average size of 50 g. This notwithstanding, the authors found that dietary fish oil replacement with either palm or poultry oil in barramundi significantly decreased the omega-3(n-3) long-chain PUFA content as far as the fish muscle (fillet) lipids was concerned with specific reference to eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Due to the fact that EPA and DHA content decreased, the peroxidation index of the muscle lipids was also decreased. Unlike glutathione peroxidase (GPx) activity, glutathione S-transferase (GST) activity or reduced glutathione concentration in the liver of barramundi subjected to either palm or poultry oil-based diets glutathione peroxidase (GPx) activity were not affected significantly as compared to those subjected to fish oil-based diet. Comparatively, lower levels of GPx as well as GST activity were recorded in the muscle than that recorded in the gastrointestinal tract, liver or swim bladder. The authors suggest that liver GPx activity may be considered as a good predictor of fillet shelf life in barramundi as well as other fish species. Recently, (27) also studied the effect of the replacing dietary fish oil with vegetable oils on the growth and flesh quality of large yellow croaker (Larmichthys crocea). In current research, they employed a basal diet of (FO) containing 66.5% fish meal as well as 6.4% menhaden fish oil and 3 other experimental diets. They also prepared three other experimental diets by replacing the fish oil with 50% soybean oil (SO50), 100% soybean oil (SO100) and 100% palm oil (PO100), respectively. They randomly assigned the four diets to 4 floating sea cages with each cage being stocked at 250 fish individuals with an initial average weight of 245.29 g ± 7.45 g. The results reported by Duan et al. 2014, after the trial depicted that the specific growth rate of fish fed SO50 or PO100 were significantly higher than that of fish fed FO or SO100 (P<0.05). The different diets they employed in this very study affected the crude lipid contents of ventral muscle and viscera significantly. In each case lower crude lipid contents were recorded in fish fed FO than in those fed the other 3 diets (P<0.05). The condition factor, viscerosomatic index, hepatosomatic index, gutted yield as well as colorimetric values of fish among the dietary treatments were not affected significantly (P>0.05). Compared to FO diet, SO50, SO100 and PO100 diets led to substantial decreases in the liquid loss and water loss from fresh fillets (1d, 4 ℃) (P<0.05). They therefore documented that growth performance as well as selected flesh quality properties were substantially improved when dietary fish oil was replaced with vegetable oils in large yellow croaker.

FUTURE RESEARCH

To achieve the goal of reducing the cost of feeding in aquaculture, much is expected to be done with respect to both on and off-field research. Although some work has been done on the use of palm oil in aquaculture feeds much can still be done. The research on the use of palm oil in aquaculture feeds could be geared towards the effects of this resource on non-specific immunity as well as effects on the expression of genes responsible for growth promoting and lipid metabolism.

CONCLUSION AND RECOMMENDATION

In conclusion, we document that palm oil with respect to availability, cost effective as well as sustainability is a good choice in relation to other vegetable oils as well as fish oil. Also it can be concluded that fish oil, to some extent can be replaced either partially or totally in aquafeeds with palm oil without compromising growth, feed utilization as well body composition. We therefore recommend based on this review that in developing countries where palm oil is in abundance as against the scarce and expensive fish oil, palm oil could be used in place of fish oil or other vegetable oils to cut down the cost of feeding captivated fish species.

REFERENCES

[1]. J.E. Bardach, J.H. Ryther, and W.O. McLarney, The farming and husbandry of fresh and marine organisms. Aquaculture, 868–875, 1972.

[2]. T. O. Babalola and D. F. Apata, "Effect of dietary palm oil on growth and carcass composition of Heterobranchus longifilis fingerlings". Journal of Central European Agriculture, 13(4), 782-791, 2012.

[3]. D.M. Borba, I.E. Francalossi, and L.E. Pezzato Dietary Energy Requirement of Piracanjuba fingerlings, Brycon orbigynanus, and Relative Utilization of Dietary Carbohydrate and Lipid. Aqu. Nutr. 12(3): 183-191, 2006.

[4]. R.C. Cottrell, Nutritional aspects of palm oil. American Journal of Clinical Nutrition 53, 989–1009, 1991.

[5]. B.H. Davis Carotenoid metabolism in animals: a biochemist's view, Pue Appl Chem, 57, 679-684, 1985.

[6]. FAO, Food and Agriculture Organization ' Aquaculture Production Statistics, 1986-1995. FAO Fish .Cire No. 815 Rev .Rome, Italy. 1997.

[7]. A.B. Gapor, A.S.H. Ong, A. Kato, H. Watanabe, and T. Kawada, "Antioxodant activities of palm vitamin E with special reference to tocotrienols." The International Journal of Oil Palm Research and Development 1, 63–67, 1989.

[8]. F. Hanley, "Effects of feeding supplementary diets containing varying levels of lipid on growth, food conversion, and body composition of Nile tilapia, Oreochomis niloticus (L.)". Aquaculture 93:323–334, 1991.

[9]. J.W. Hertrampf and F. Piedad-Pascual, "Soya protein products. In: Handbook on Ingredients for Aquaculture Feeds. (Hertrampf, J. W. & Piedad-Pascual, F. eds)",
a. pp. 396, 2000.

[10]. D.M. Jamu and O.A. Ayinla Potential for the Development of Aquaculture In Africa. NAGA, World Fish Center Quart. 26(3): 9-13, 2003.

[11]. E.A. Johnson and G.H. An, "Astaxanthin from microbial sources", Crit Rev Biotechnol, 11, 297-326, 1991.

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

[13]. National Research Council (NRC), Nutrent requirement of fish. Committee on Animal Nutrition. Board on Agriculture.National Academy of Sciences. National Academy Press. Washington DC., USA. P. 114 (1993).

[14]. W.K. Ng, Palm oil in salmonids feeds. Aquafeeds: Formulation and Beyond.1: 7-9, 2004.

[15]. W.K. Ng, V. Gibon, Palm oil and saturated fatty acid-rich vegetable oils. In: Turchini, G.M., Ng, W.K., Tocher, D.R. (Eds.), Fish Oil Replacement and Alternative lipid Sources in Aquaculture Feeds. CRC Press, pp. 99–132, 2010.

[16]. S.N. Ochang, A.O. Fagbenro and T.O. Adebayo, "Growth Performance, Body Composition, Haematology and Product Quality of the African Catfish (Clarias gariepinus) Fed Diets with Palm Oil", 2007.

[17]. F. Shahidi, B. Metusalach and J.A. Brown, "Carotenoid pigments in seafoods and aquaculture." Crit Rev Food Sci Nutr, 38, 1-67, 1998.

[18]. S.Y. Shiau, and S.F. Lin, "Effect of supplementary dietary chromium and vanadium on the utilization of different carbohydrates in tilapia, Oreochromis niloticus x O. aureus". Aquaculture. 110: 321-330, 1993.

[19]. R. P. Subasinghe, "Epidemiological approach to aquatic animal health management: Opportunities and challenges for developing countries to increase aquatic production through aquaculture". 2005

[20]. A.G. J. Tacon, “Feed ingredients for warm water fish. Fish meal and other processed feed stuffs” .FAO Fish Cir., 856, FAO, Rome, Italy, 64 pp, 1993.

[21]. A.G. Tacon, “Use of fish meal and fish oil a global perspective”. Aquatic Resources, Culture and Development 1: 14, 2004.

[22]. A.G.J. Tacon and M Metian, “Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: trends and future prospects”. Aquaculture 285:146- 158, 2008.

[23]. A.H. Weatherley, and H.S. Gill, “Recovery growth following periods of restricted rations and starvation in rainbow trout, Salmo gairdneri Richardson”. J. Fish Bio. 18(2): 195-207, 1987.

[24]. H. Yu-Zhe, R.Tong-Jun, J. Zhi-Qiang, J. Bai-Qiao, G. Jian, K. Shunsuke, and K. Connie-Fay, “Effects of palm oil blended with oxidized fish oil on growth performances, hematology, and several immune parameters in juvenile Japanese sea bass, Lateolabrax japonicas”. Fish Physiology and Biochemistry **38 (6)**: 1785-1794, 2012.

[25]. W.-K. Ng and Y. Wang, “Inclusion of crude palm oil in the broodstock diets of female Nile tilapia, Oreochromis niloticus, resulted in enhanced reproductive performance compared to broodfish feddiets with addedfish oil or linseed oil”. Aquaculture **314** 122–13, 2011.

[26]. A.R. Wan, A. Wan, A.J.S. David, and A.S. Kathryn,. Dietary fish oil replacement with palm or poultry oil increases fillet oxidative stability and decreases liver glutathione peroxidase activity in barramundi (Lates calcarifer) Fish Physiol Biochem **39**:1631–1640, 2013

[27]. Q. Duan, K. Mai, J. Shentu, Q. Ai, H. Zhong, Y. Jiang, L. Zhang, C. Zhang, and S. Guo, “Replacement of Dietary Fish Oil with Vegetable Oils Improves the Growth and Flesh Quality of Large Yellow Croaker (Larmichthys crocea)” J. Ocean Univ. China (Oceanic and Coastal Sea Research) **13**: 445-452, 2014.