Predicted to be the most abundant vegetable oil in the future, palm oil has the potential to be a sustainable alternative to fish oil in aqua feeds. The oil is a rich source of natural pigments and antioxidants and offers many advantages for feed applications.

Malaysian Palm Oil Board

Palm Oil in Salmonid Feeds

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Farming of salmonid species is a major industry. Total salmonid production is estimated to be about 1.5 million metric tons. Atlantic salmon accounts for most of the production. A significant trend in the salmon feed industry is the increase in lipid levels in the feeds. Commercial salmon grower feeds contain up to 40% fat. Most of the fat has traditionally been from marine fish oil. It is estimated that more than 60% of the total fish oil use in aquaculture is towards salmon feed production. The aqua feed industry already uses about 70% of the global supply of fish oil and by the year 2010, this use is estimated to reach about 97% of the world supply. Such high usage is clearly unsustainable. Therefore, there is a great urgency within the salmonid feed industry to find alternatives to fish oil.

A potential replacement for fish oil in aqua feeds is palm oil. Global production of crude palm oil exceeds 24 million tons and is predicted to surpass soybean oil production within the next decade making it the most abundant vegetable oil in the world. Crude palm oil is extracted from the outer flesh of fruit from oil palm trees. When freshly extracted, palm oil is the richest known natural source of beta-carotene that gives it a characteristic deep orange-red color. Palm oil is also a rich source of vitamin E, consisting of tocopherols and tocotrienols.

Research on the use of palm oil in fish diets has shown encouraging results. Studies by the Fish Nutrition Laboratory of Universiti Sains Malaysia have shown that palm oil can replace fish oil in tilapia and catfish feeds. Research carried out in collaboration with the Institute of Aquaculture, University of Stirling (Scotland), BioMar AS (Norway) and BioMar Ltd. (U.K.) on Atlantic salmon has shown similar encouraging results. A study conducted by Gordon Bell and his team (University of Stirling) has shown that palm oil can completely replace added fish oil in Atlantic salmon feeds. In this respect, palm oil is similar to other vegetable oils that had been reported in numerous scientific studies to be able to replace a significant part of fish oil in trout and salmon diets without negatively affecting growth, feed utilization and survival. In addition to its low cost and high availability, palm oil also has many additional advantages over other vegetable oils when used in salmonid feed formulations.

Dr. Wing-Keong Ng received his Masters degree in Aquaculture from the Asian Institute of Technology (Thailand), and doctorate in Nutrition at the University of California (Davis, USA). After a post-doctoral fellowship at the Mississippi State University (USA), he returned to his native Malaysia. He is currently an Associate Professor affiliated with Universiti Sains Malaysia (Penang, Malaysia) where he started the Fish Nutrition Laboratory. He has published extensively in the area of aquaculture nutrition and is on the editorial board of several journals. His areas of interest include aquatic animal nutrition, feed technology, microbial biotechnology, aquaculture systems, shrimp culture, ornamental fish and marine coastal ecosystems.

1. Reduces Feed Rancidity and Oil Leakage

Conventional vegetable oils are highly susceptible to attack by atmospheric oxygen resulting in rancidity. The low concentrations of polyunsaturated fatty acids (PUFA) in palm oil give it exceptional resistance to oxidation. Together with the protective effects of potent natural antioxidants (carotenoids and vitamin E) present in palm oil, the incidence of feed rancidity should be substantially reduced when palm oil is used in salmon feeds. Aqua feeds containing palm oil can therefore be stored longer while maintaining freshness and palatability.

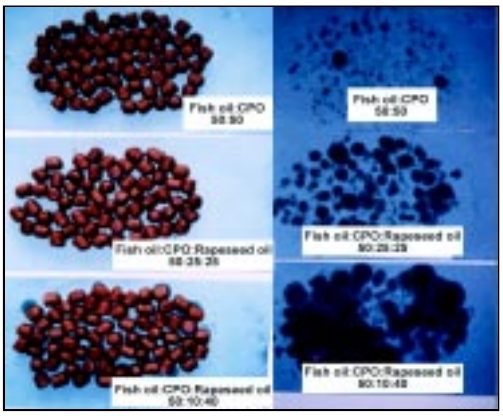
The inclusion of palm oil also reduces the incidence of oil leakage common in high lipid diets (Figure 1). This is because palm oil has a higher melting point compared to other vegetable oils and fish oils. Consequently, migration of lipids to the pellet surface that causes loss of valuable nutrients, and staining of packaging materials and feed equipment is reduced.

Fig 1. *Extruded Atlantic salmon feeds placed on absorbent tissue paper (left) and the resultant oil stains after 10 minutes (right). A = fish oil/palm oil, 50:50; B = fish oil/palm oil/rapeseed oil, 50:25:25; C = fish oil/palm oil/rapeseed oil, 50:10:40.*

(A)

(B)

(C)



2. Superior Energy Source

Palm oil is a superior source of dietary energy. *In vitro* studies done in fish suggest that saturated and monounsaturated fatty acids are preferred over PUFA as a substrate for mitochondrial β-oxidation. Palm oil contains an abundant supply of saturates (48%) and monoenes (42%). Studies done in our lab have shown the protein sparing effect of palm oil in catfish diets and a similar situation probably exists for salmonids.

3. Improved Fillet Quality

While most vegetable oils contain almost exclusively tocopherols, palm oil is unique because tocotrienols represent about 80% of the vitamin E content. We have recently shown that the deposition of palm vitamin E in the fillets of tilapia fed a tocotrienol-rich fraction extracted from palm oil imparts higher oxidative stability compared to the fillets of fish fed diets supplemented with equivalent levels of dietary synthetic α-tocopherol acetate. This would translate to longer shelf life for seafood products. The deposition of tocotrienols in fish fillets also adds value to the product, especially if eaten raw as sashimi, since the potential health benefits of tocotrienols in the human diet may include beneficial effects on the prevention of cardiovascular diseases and cancer. It may also increase the market value and consumer acceptance of salmon steaks in which pigmentation is a quality parameter. The potential accumulation of palm vitamin E in salmon flesh would slow down the oxidation of these pigments thereby maintaining coloration for longer periods. Further research is being planned along these lines.

4. Beneficial to Fish and Consumers' Health

It is speculated that feeding high levels of PUFA-rich oils leads to increased oxidative stress for the fish and result in pathological conditions. Palm oil which is low in PUFA and high in antioxidants, therefore, offers opportunities to produce high-energy diets without the damaging side effects of increased lipid radicals.

A major dietary change that has caused significant concern to human nutritionists is the increase in the intake of omega-6 fatty acids relative to the omega-3 fatty acids. Omega-3 to omega-6 ratio varies from 1:2.5 for Eskimos on a fish-based diet to 1:20 for modern diets rich in vegetable oils. Eskimos who rely on their traditional diets are relatively free of degenerative diseases common to urban dwellers. Since human diets already have too much omega-6 PUFA, a good fish oil substitute should limit the deposition of these fatty acids in fish fillets. Palm oil is superior to most conventional vegetable oils in this respect as it has low levels of omega-6 PUFA.

Constraints in the Use of Palm Oil in Feeds for Salmonids

1. Low level of Omega-3 Fatty Acids

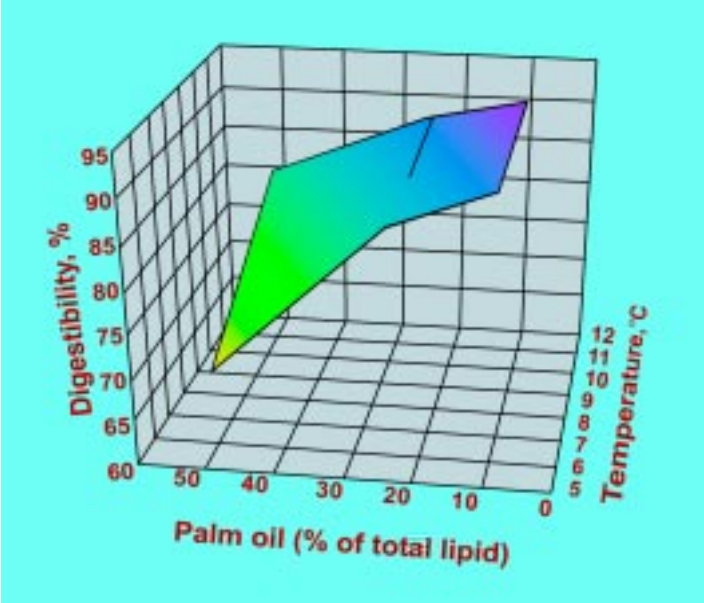
Palm oil does not contain omega-3 highly unsaturated fatty acids (HUFA), which are required by salmonids and known to be beneficial to human health. Consequently, palm oil in salmonid diets should be formulated in conjunction with HUFA sources such as fish oil and fishmeal to assure that minimal HUFA requirements are met.

The use of high levels of palm oil in salmonid diets will decrease the concentrations of beneficial omega-3 HUFA in fish fillets destined for the human consumer. One strategy that can be used to normalize the flesh levels of beneficial omega-3 HUFA is to revert back to a fish oil-based diet at an appropriate time before harvest. This feeding strategy will allow the use of higher levels of palm oil in salmonid diets for the major part of the grow-out phase thus providing cost savings without significantly altering the health benefits of the resultant fish fillet in the human diet.

2. Lowered Digestibility in Cold Weather

Low water temperatures during the winter season appear to reduce lipid and fatty acid digestibility in rainbow trout and Atlantic salmon fed high levels of dietary palm oil (Figure 2). Nevertheless, growth performance was not compromised even at 100% replacement of fish oil. The reduced lipid digestibility was due in part to the increasing resistance of dietary triglycerides to digestion with decreasing water temperatures. Future research plans include the testing of emulsifiers and palm free fatty acids to facilitate absorption of the oil at low water temperatures.

Fig2. *Changes in apparent lipid digestibility in Atlantic salmon at various water temperatures and fed diets supplemented with different levels of crude palm oil.*



Conclusion

The expansion of oil palm cultivation in Malaysia and other tropical countries offers the possibility of a cost effective and sustainable alternative to fish oil in salmonid feeds. Palm oil offers several advantages that outweigh a few disadvantages in its application as a lipid source in aqua feeds. Further laboratory and commercial-scale studies are planned to fully exploit palm oil as a dietary lipid source in aqua feeds.

References

Available from the author upon request.

Table. *Fatty acids, vitamin E and carotenoids of Malaysian crude palm oil*

Chemical characteristics	Range of values
Fatty acid composition (%)	
12:0	0.1 – 1.0
14:0	0.9 - 1.5
16:0	41.8 – 46.8
16:1	0.1 – 0.3
18:0	4.2 – 5.1
18:1	37.3 – 40.8
18:2*w*6	9.1 – 11.0
18:3*w*3	0.05 – 0.6
20:0	0.2 – 0.7
Vitamin E (mg/kg)	600 – 1000
Tocopherols	20%
Tocotrienols	80%
Carotenoids (mg/kg)	500 – 700
a-carotene	36%
b-carotene	54%

Recent Research Publications on Fish Oil Alternatives

Total replacement of fish oil by soybean or linseed oil with a return to fish oil in turbot (Psetta maxima) - 1. Growth performance, flesh fatty acid profile, and lipid metabolism. C. Regost, J. Arzel, et al. 2003. *Aquaculture* 217:465-482.
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The study investigated the replacement of fish oil by vegetable oils and the effects of a washout with a return to fish oil on growth performances and lipid metabolism. Three diets with identical protein and lipid levels were formulated containing either 9% of added fish oil (FO), soybean oil (SO), or linseed oil (LO). Each diet was fed to marketable size turbot for 13 weeks. After that all groups were fed with FO diet for 8 weeks. The inclusion of vegetable oils in the diets resulted in a slight decrease in growth compared to those fed with fish oil-based diet. Feed conversion and body composition were not affected by dietary lipid sources. Fatty acid composition of liver and muscles reflected the dietary fatty acid composition. Fish fed SO diet were rich in 18:2w6 (linoleic acid). Fish fed LO diet were rich in 18:3w3 (linolenic acid). Fish fed the vegetable oils had lower levels of 20:5w3 (EPA) and 22:6w3 (DHA) when compared to those fed with FO. The fatty acid composition of fish fed previously with SO and LO diets was still different to that of fish fed with FO diet even after being on FO-based diets for 8 weeks. The levels of 18:2w6 and 18:3w3 declined after the transfer, but still higher than those of fish fed with FO diet. The study demonstrated that replacement of fish oil by vegetable oils is possible with negligible impact on growth performance of turbot, however, a duration of 8 weeks of feeding with fish oil is not sufficient to restore the fatty acid profile of turbot back to that of fish fed with fish oil for 19 weeks.

Total replacement of fish oil by soybean or linseed oil with a return to fish oil in Turbot (Psetta maxima) - 2. Flesh quality properties. C. Regost, J. Arzel, et al. 2003. **Aquaculture** 220:737-747.
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This study evaluated the flesh quality of fish produced from the previous study (see above). It found that the inclusion of vegetable oils did not affect the gutted and fillet yields. However, the sensory qualities, notably odor, color and texture were influenced by the oils. The dorsal fillet of the turbot fed soy oil had a more pronounced potatoes odor and a lower fat texture. However, these differences disappeared after the washout period, demonstrating that sensory properties due to the intake of vegetable oils can be reduced with a return to a fish-oil-based diet.

Continued on page.15

Questions on fish oil replacement?

EXPERTS ANSWER

A New Section to be Launched

We will shortly be launching a section to answer technical questions from the readers. Questions sent by readers will be directed to experts in the appropriate area and answers will be published in the section. Please send your questions to victor@feedware.com.

Editor