

FARMED FISH AS BIOLOGICAL AGENTS FOR EXTRACTING RESIDUAL PALM OIL IN DISCARDED SPENT BLEACHING CLAYS FROM THE PALM OIL REFINING INDUSTRY

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ABSTRACT

Spent bleaching clays (SBC) from palm oil refining contain 20% to 30% adsorbed oil that cannot be recovered economically. This article highlights research conducted to evaluate the potential use of this waste product in the feeds of farmed fish. The impact of graded dietary levels of SBC on growth, feed utilization, body composition, fish health and water quality parameters in feeding trials conducted are discussed. High dietary levels of SBC can be incorporated into catfish and tilapia feeds without any significant negative impact on their growth and health. Nevertheless, total solids and total suspended solids concentration in tank culture water increased significantly concomitant to the increasing dietary levels of SBC fed to the fish. The issue of heavy metal accumulation in fish tissues will also be discussed in the context of current global legislation in regards to feed and food safety. The potential advantages and challenges in using palm oil-based SBC in aquafeeds will be highlighted. It is concluded that farmed fish can be effectively used as low-technology biological agents for the economical extraction of the adsorbed oil in SBC from palm oil refining. Application of this concept will bring benefits to the palm oil, aquaculture and waste disposal sectors.

Keywords: spent bleaching clay, palm oil, lipid, aquaculture, waste utilization.

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INTRODUCTION

Spent bleaching clays (SBC) are waste products from the refining of vegetable oils and animal fats. During the refining process, bleaching is carried out to remove impurities and pigments to produce the desired colour and flavour acceptable to the refined oil buyer. The bleaching process is carried out under vacuum at high temperatures by bringing the oil into contact with activated bleaching clay. Bleaching is achieved when pigment molecules and other impurities in the oil are adsorbed onto the large surfaces of the bleaching clay. Bleaching clays

used in edible oil refining are mainly bentonites, which are complex alumino-silicates belonging to the montmorillonite group of clays. The physical and chemical properties of these bentonites have been described by Hertrampf and Piedad-Pascual (2000) and the bleaching process described by Gunstone and Norris (1983). Depending on its activity and particle size, the oil retention in SBC ranges from 20% to 75% of the spent clay weight (Gunstone and Norris, 1983; Wong, 1983).

About forty-two million tonnes of crude palm oil (CPO) were produced in 2008 (Gunstone, 2010). In palm oil refining, the quantity of bleaching clay used is usually 0.5% to 2.0% of the weight of CPO (Young, 1987). This would give rise to an estimated annual generation of 215 000 to 860 000 t of SBC globally. After use, these SBC may contain 20% to 30% adsorbed oil that cannot be recovered economically. SBC is currently regarded as a waste product and usually discarded in landfills (Wong, 1983) or burnt in incinerators to produce energy.

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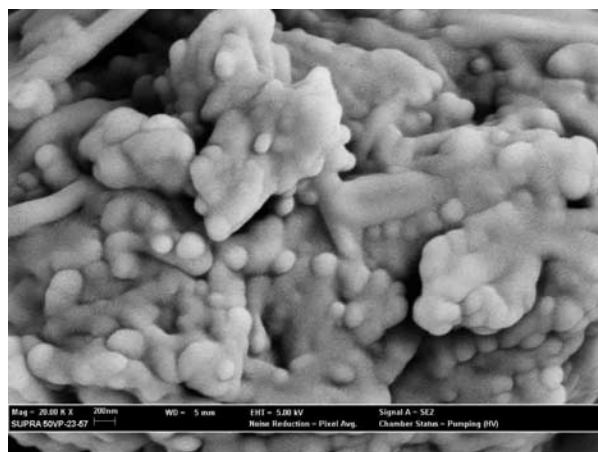
USE OF SPENT BLEACHING CLAY IN AQUAFEEDS

Marine fish oils are traditionally used as the main dietary lipid source in many commercial fish feeds. The demand for marine fish oils in aquaculture feeds has increased in recent years due to the rapid development of the global aquaculture industry and the technological advances in fish feed manufacturing that allows the incorporation of high levels of dietary oils to produce energy-dense diets. Aquaculture is currently the fastest-growing food production sector in the world. Aquafeeds currently use about 70% of the global supply of fish oil, and by the year 2010, fish oil used in aquaculture is estimated to reach about 97% of the world supply (Tacon, 2003). Fish oil is produced from small marine pelagic fish and represents a finite fishery resource. Over the past decade, global fish oil production has reached a plateau and is not expected to increase beyond current levels. In order to sustain its rapid development, the aquaculture industry cannot continue to rely on finite stocks of marine pelagic fish for fish oil supply, and fish oil alternatives must be found (Turchini *et al.*, 2009).

One potential substitute for fish oil in aquafeeds is palm oil, which is currently the most produced vegetable oil in the world. We have previously reported on the potential and advantages that palm oil has over other vegetable oils when used in diets for Atlantic salmon (*Salmo salar*), tilapia (*Oreochromis* spp.) and various catfishes (Ng, 2002; Ng *et al.*, 2003; 2004; 2007; Bahurmiz and Ng, 2007; Ng and Gibon, 2010). We have shown that the use of various palm oil products such as CPO, refined palm olein or palm fatty acid distillates in the diets of these fish elicited growth and feed utilization efficiency comparable to fish fed equivalent levels of dietary marine fish oils. Another potential source of palm oil for use in fish diets is the residual oil adsorbed onto SBC (Figure 1). This would represent the most economical way of incorporating palm oil into the diets of farmed fish given the current high price of vegetable oils, including palm oil. As far as we know, no previous nutritional evaluation of the potential of using this oil-laden SBC from palm oil refining in fish diets has been reported, and we are the first researchers to publish our findings in mainstream international journals.

Fish Growth and Health

When fed isonitrogenous and isolipidic fish meal-based practical diets, Nile tilapia fed up to 30% SBC (at the expense of marine fish oil and α -cellulose) grew equally well compared to fish fed the control diet without SBC (Ng *et al.*, 2006b). African catfish and red hybrid tilapia were shown



Source: Ng *et al.* (2006b).

Figure 1. Scanning electron micrograph of the spent bleaching clay showing the presence of adsorbed residual palm oil which essentially filled up most of the latticed pore spaces on the clay. Bars = 200 nm.

to be able to tolerate up to 30% and 40% inclusion of SBC in their feeds, respectively (Ng and Low, 2005; Ng *et al.*, 2006a). Feed utilization efficiency was also not significantly affected by the inclusion of high levels of SBC. Survival, whole body composition, body-organ indices and hematocrit of tilapia were not affected by the dietary treatments. Preliminary evaluation of liver histology under the light microscope did not reveal any obvious structural abnormalities, with hepatocytes in fish fed SBC-added diets being well-organized and compartmented similar to that observed in fish fed the control diet.

Fillet Quality

It is generally known that the fatty acid composition of fish fillets is directly influenced by the fatty acid composition of the dietary oils used. The fillet fatty acid profile of fish fed SBC-added diets will therefore depend on the source of SBC. The use of SBC from vegetable oil refining (such as palm oil) will decrease the concentrations of beneficial n-3 long-chain polyunsaturated fatty acids (LC-PUFA) in the fillet of fish fed such SBC-added diets. The fatty acid composition of SBC from palm oil refining was consistent with that of palm oil with 48% saturates, 35% monoenes and 7% polyunsaturates (Ng *et al.*, 2006b). Palmitic acid (16:0) and oleic acid (18:1) are the main fatty acids found in the residual palm oil adsorbed onto SBC. On the plus side, the low content of 18:2n-6 found in SBC from palm oil refining as compared to in soyabean or rapeseed oils will avoid excessive deposition of this undesirable fatty acid in fish fillets (Ng *et al.*, 2003; 2006b). As oils with high

PUFA content are highly susceptible to oxidation and rancidity, the oxidative stability of both the feed pellets and fish fillets can be substantially improved with the use of palm oil-laden SBC.

The high levels of saturates and monoenes found in palm oil-laden SBC make it an excellent source of dietary energy for fish. Despite a general trend of lowered n-3 fatty acid concentrations in the muscle lipid of tilapia fed increasing levels of SBC, the drop in 22:6n-3 (DHA, docosahexaenoic acid) was not significant even when added dietary fish oil was completely substituted by SBC from palm oil refining (Ng *et al.*, 2006b). It would seem that Nile tilapia fed fishmeal-based diets were able to selectively retain DHA in their muscle lipid. Due to its higher oxidative stability, spent palm oil bleaching clay might be a more suitable diet ingredient for fish compared to SBC from the refining of marine oils or other vegetable oils which are more unsaturated.

Feed and Food Safety

Bentonite and montmorillonite clays are currently used as feed additives in feedstuffs as binders, anti-caking agents or coagulants. They are considered industrial minerals, and are allowed as feed additives according to Annex 1 of Directive 70/524/EEC of the European Union (EU) authorities. SBC are bentonites with residual vegetable oil or animal fat from edible oil refining, and would therefore be considered as materials generally regarded as safe (GRAS). With the recent emphasis by the EU to tighten control of all types of feed additives for safety reasons, we felt that it was essential to investigate the content of selected heavy metals in SBC-based diets, and whether these elements were accumulated in tilapia tissues fed such diets, among other safety considerations. The quantities of arsenic (As), cadmium (Cd) and lead (Pb) found in SBC from palm oil refining were below the maximum allowable levels permitted by EU for feed materials (Directive 2003/100/EC) (Ng *et al.*, 2006b). Even at the highest level of SBC tested, the experimental diets did not exceed the maximum allowable content for total As, Cd and Pb in complete feedstuffs for fish or animals, which was set at 6, 0.5 and 5 mg kg⁻¹, respectively. Of the three heavy metals determined in SBC, it would seem that Pb would be the first limiting element in terms of the level of SBC that can be incorporated in fish diets and still meet the EU regulations as regards to undesirable substances in animal feeds. Nevertheless, even when expressed on a dry weight basis, As, Cd and Pb concentrations found in the whole body and bones of tilapia fed SBC-based diets were well below permissible maximum levels in food and no increase in the accumulation of these

heavy metals were observed in fish tissues with increasing dietary SBC. Being a by-product, SBC has a wide range of quality, and further research on the safety aspects of SBC from various types of edible oil refining is needed.

Other Potential Benefits and Challenges

Unused bentonite clays are routinely incorporated at 1%-2% as a binding and lubricating agent in the production of pelleted poultry diets. SBC seems to have a similar binding effect, and a trend of improved pellet stability in water as the level of SBC in the diet increased was observed (Ng and Low, 2005). Improvements in the pellet stability of fish diets will be advantageous, especially in fish species that have less aggressive feeding behaviour.

The beneficial effects of fish feed containing clay in sequestering aflatoxins, a carcinogen, have been documented by several researchers (Winfree and Allred, 1992; Ellis *et al.*, 2000). For example, in one study using tritium (³H) labelled aflatoxin B₁, it was demonstrated that the inclusion of 2% bentonite clay in trout diets contaminated with aflatoxin can significantly reduce the amount of aflatoxin absorbed from the digestive system (Ellis *et al.*, 2000). Whether SBC has the same effect as natural clay in adsorbing mycotoxins in fish diets is currently not known. Further research is necessary to determine if SBC from edible oil refining can be used as a cost-effective ingredient in sequestering mycotoxin-contaminated fish feeds.

The use of SBC may be limited by its high ash content because it will take up much of the non-nutritive bulk space in diet pellets. Silica, the main mineral in bleaching clay (about 69% SiO₂), is indigestible to fish. The level of SBC that can be incorporated into fish feeds might not be restricted only by nutritional or safety considerations but also by environmental issues. We have shown that the high levels of indigestible silica that is discarded into the culture water through fecal matter will increase total suspended solids (Ng *et al.*, 2006a). It is currently not known how this biological discharge of clay particles into the water will affect the pond environment under the conditions of commercial fish production. The use of SBC in fish feeds might be limited in countries that have strict standards in allowable limits for aquaculture effluents. Nevertheless, it should be noted that bentonites and related aluminosilicate minerals such as zeolites have been used in the industrial clarification of water, and that they enhance the removal of heavy metals from culture water thereby decreasing their toxicity to fish. The potential benefits of defecated SBC to improvements in water quality cannot be discounted. Whether bleaching

clay maintains its layered microstructure which allows it to bind other molecules onto its surfaces after passing through a fish digestive system remains to be investigated.

CONCLUSION

SBC from palm oil refining usually contains about 20%-30% adsorbed oil and this constitutes a major loss in oil. The disposal of SBC is becoming a potential problem in many palm oil producing countries due to the rapid growth of the industry and the concomitant increase in the generation of this waste material. As SBC is considered non-toxic, it is frequently disposed off in landfills which can create environmental problems due to the leaching of the fatty materials and the possibility of fire hazards. Incorporating SBC in fish feeds will not only help alleviate these problems but will also lower the operating costs of fish production by reducing feed costs. The use of farmed fish as biological agents to extract residual palm oil adsorbed onto SBC is a novel way of converting waste into wealth. It is anticipated that with proper application of this concept, financial benefits to the palm oil-refining and aquaculture industries can be obtained, as well as ensuring a sustainable environmental-friendly way of disposing this waste product from the palm oil refining industry, and possibly from other oil and fat refining industries as well.

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ERRATUM

Please note that on p. 892 of the *Journal of Oil Palm Research Vol. 22 December 2010*:

(a) Table 2 line 3 should read:

N fertilizer use	kg N ha⁻¹ yr⁻¹	50	73	120	*Survey
	instead of				
N fertilizer use	t N ha ⁻¹ yr ⁻¹	50	73	120	*Survey

The error is regretted.