Solid POME sludge as a new source of fish feed ingredient for Nile tilapia (Oreochromis niloticus)

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ARTICLE INFORMATION

The micro-filtration technology was employed to filter fresh palm oil mill effluent (POME) to get the solid sludge. Dead-end configured filtration system was used to recover substantial amounts of the suspended solids and oil & grease with appreciable removal efficiency for COD, TSS, TS and O&G. The dried sludge (DSO) was used as a feed major ingredient together with defatted fishmeal to formulate a diet. Three diets were tested on Nile tilapia; O. niloticus fingerlings comprising of DSO mixed with defatted fishmeal, crude palm oil (CPO) and defatted fishmeal and a third group of fingerlings fed with Fish oil (FO) mixed with defatted fishmeal as a control. The growth of all fingerlings was monitored every 2 weeks for a period of 8 weeks. The result showed that there is significant growth performance in fish fed with DSO indicating that it can be used as a fish feed ingredient to supply some proteins and lipids.

1. Introduction

Oil Palm industry is the largest agro-based industry in Malaysia, the country has grown to be the second largest producer and exporter of palm oil after Indonesia in 2009 (Palm Oil, 2010. "Market", para. 4).

During the processing of fresh fruit bunches (FFB) water is the most needed resource. It has been reported that 5 - 7.5 tons of water is required to produce 1 ton of crude palm oil, of which more than 50% of the water will end up as Palm Oil Mill Effluent (POME) (Ahmad et al., 2003). The raw POME is a colloidal suspension containing 95-96% water, 0.6-0.7% oil and 4-5% total solids including suspended solids. In year 2004, more than 40 million tons of POME was estimated to have been generated from 372 mills in Malaysia (Yacob et al., 2006).

The discharge of POME into local water courses without treatment creates serious problems of environmental pollution due to its high load chemical oxygen demand (COD), total suspended solids (TSS), protein and carbohydrate with the respective estimated values of 70,900mg/L, 25,800mg/L, 12.9g/L and 28.9g/L (Mohammad et al., 2004). In an effort to reduce the ecological and pollution hazards posed by the discharge of untreated POME into the environment, several attempts have been made by researchers to utilize this effluent for various purposes. Two of them are (a) direct use of the fermented sludge as organic fertilizer and (b) utilization of the effluent as animal feed. The methods attempted for the conversion of sludge into animal feeds include moisture reduction through dehydration, filtration, centrifugal solids recovery, biodegradation,
...and the use of effluent as substrate for the production of single-cell protein and cultivation of Chlorella algae, among others.

The conventional treatment technology of POME typically consist of biologically treated aerobic and anaerobic digestion, however, this treatment system is not capable of producing high quality treated effluent. Consequently, this partially treated wastewater still pollutes watercourses receiving it (Wong et al, 2002). Another new technology under research is the zero waste evaporation technology. A possible technological solution to produce quality effluent is through the use of membrane technology at the tertiary treatment stage (Wong et al, 2002). The principal advantage of membrane processes are low energy consumption, simplicity and environmental friendliness (Wu et al, 2006).

There are many membrane process applications on water and wastewater treatment that have proven to be efficient. Researchers such as Alfonso & B'orquez (2002), Wu et al. (2006) and Mohammad et al. (2004) have made remarkable achievements in the treatment and recovery of protein from wastewater by membrane separation processes. However, the recovered protein was seldom further elaborated in nurturing its potential use, although Jaouen et al.(1992) and Ockerman (1992), respectively suggested that the protein might be used as animal or fish feed and fertilizer.

### Table 1: Comparison of Characteristics of raw POME and the permeate with standards

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range of values</th>
<th>Standard limit</th>
<th>Raw POME</th>
<th>Permeate (from membrane)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>3.4-5.2</td>
<td>5-9</td>
<td>4.31±0.03</td>
<td>4.35±0.01</td>
</tr>
<tr>
<td>COD (mg/L)</td>
<td>15,000-100,000</td>
<td>-</td>
<td>63,750±232</td>
<td>12,100±312</td>
</tr>
<tr>
<td>SS (mg/L)</td>
<td>5,000-54,000</td>
<td>400</td>
<td>26,400±223</td>
<td>800±124</td>
</tr>
<tr>
<td>O&amp;G (mg/L)</td>
<td>150-18,000</td>
<td>50</td>
<td>4,000±197</td>
<td>150±306</td>
</tr>
<tr>
<td>TKN (mg/L)</td>
<td>180-1,400</td>
<td>200</td>
<td>800±67</td>
<td>500±87</td>
</tr>
</tbody>
</table>

*Means of triplicate determinations ±SD, *DOE- Department of Environment, Malaysia.

### Table 2: Growth performance and feed utilization results of Nile tilapia, O. niloticus fingerlings fed different experimental diets for 8 weeks.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Parameter measured</th>
<th>FO</th>
<th>PMO</th>
<th>DSO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Mean initial weight (g)</td>
<td>5.48±0.26</td>
<td>6.13±0.18</td>
<td>5.79±0.15</td>
</tr>
<tr>
<td>2.</td>
<td>Mean Final weight (g)</td>
<td>28.56±0.11</td>
<td>26.06±0.20</td>
<td>25.41±0.09</td>
</tr>
<tr>
<td>3.</td>
<td>WG (%)</td>
<td>421.17±0.2</td>
<td>325.12±0.1</td>
<td>338.86±0.2</td>
</tr>
<tr>
<td>4.</td>
<td>FCR</td>
<td>2.21±0.31</td>
<td>2.35±0.26</td>
<td>2.48±0.17</td>
</tr>
<tr>
<td>5.</td>
<td>PER</td>
<td>1.35±0.04</td>
<td>1.19±0.02</td>
<td>1.13±0.05</td>
</tr>
</tbody>
</table>

*Results are means ± standard deviation; values are means of triplicate determinations. *a, b Values in the same column with different superscript letters differ (P<0.05)

...The effective use of palm oil sludge as fish feed will be of economic significance, especially in view of the rising cost of imported fish feedstuffs as occasioned by the unsustainable depletion of fish meal and oil as aquaculture feed ingredient and at the same time the reduction of pollutants in the environment.

Nile tilapia (Oreochromis niloticus) is currently the 2nd most cultured finfish species in the world after carp and by 2005, its total production had surpassed 500,000 metric tons with an average compound growth rate of about 12% per annum since 1986 (FAO, 2006). The most positive aquacultural characteristics of tilapia are its tolerance to poor water quality and the ability to utilize a wide range of natural food sources. Several researches have attempted to use waste materials as fish feedstuff or feed ingredients with relative success. Most common among these ingredients include beer hops, brewers dry yeast among others (Oliva-Teles & Goncalves, 2001). With increasing growth of aquaculture and growing concerns over the availability of feedstuff and feed ingredients (especially fishmeal and fish oil) for fish culture, research into possible alternatives are on the increase (Hardy, 1996) and dried sludge from POME may as well be a possible candidate, as suggested by Jaouen et al.(1990) and Ockerman(1992)

This study was designed to use the principle of micro-filtration membrane technology for the bio-resource recovery and evaluate its use as fish feed ingredient for rearing tilapia fingerlings.

### 2. Material and Methods

#### 2.1 POME collection and screening

Adequate quantity of fresh POME sample was collected from a Palm oil mill, MALPOME industry at Jawi-Penang, Malaysia and transported to the

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laboratory in aseptic polyethylene sample containers. The POME sample was stored at -4°C in the laboratory until used subsequently for experiment and/or physico-chemical analysis. Prior to the recovery experiment, raw POME was sieved (screening) using conventional sieve with average pore size of 245 µm in order to remove coarse debris and stones in the suspension.

2.2. Bio-resource recovery process

A laboratory scale, dead-end configured microfiltration membrane (DEMM) technology was used to recover sludge. The set-up and operation of the DEMM was similar to that described in a previous study (Modise et al., 2006), but with minor amendments. Raw POME was pushed through the membrane by pressurizing at vacuum pressure with a vacuum pressure pump. A magnetic stirrer provided moderate but undefined shear force and fluid velocity across the membrane surface, which was needed to reduce sludge (solid-cake) build-up on the membrane surface. The DEMM technology which is usually operated as batch operation (Ho & Sirkar, 1992) was used to recover the macromolecules in the POME.

The permeate was collected in a measuring cylinder and stored at -4°C until subsequently analyzed for physico-chemical properties, while the residual sludge or retentate was removed from the surface of the membrane, dried in an oven maintained at 80°C and finally stored at -4°C until processed for use as fish feed ingredient.

2.3. Characteristics of POME, retenate, diets and feed ingredients

Selected parameters such as chemical oxygen demand (COD), suspended solids (SS), oil and grease (O&G), total Kjeldahl nitrogen (TKN), Ammonical nitrogen (AN) and pH were chosen to characterize both raw POME and the permeate collected after the micro-filtration experiment (treatment). These parameters were measured according to the analytical procedure described in the Standard Methods for water and wastewater examination (20th edition, 1998) to evaluate how they meet the level of statutory discharge limit in the Environmental Quality Act (Prevailing Effluent Discharge Standards for crude palm oil mills,1984) before being discharged into watercourse (Wong et al,2002). See Table 1.

The dry POME sludge, other feed ingredients used and prepared experimental diets were analyzed for their proximate compositions according to the standard AOAC methods (1997). Results of these analyses are presented in Table 2.

2.4. Fish diets formulations and preparation

Three iso-lipidic, iso-nitrogenous and iso-energetic experimental diets were each formulated to contain 100 g kg⁻¹ (or 10%) lipids, 350 g kg⁻¹ (or 35%) proteins and 440 kcal of (gross energy, GE) respectively, from a mixture of fishmeal & fish oil (FO diet), fishmeal & palm oil (CPO diet) and fishmeal & dried POME slime (DSO diet) accordingly. Energy was adjusted to the same level in all diets with corn starch according to the method described by Kim & Lee, 2005.

Feed ingredients were mixed in a feed mixer (Tyrone, model TR 202 UK) and made into pellets of 3 mm in diameter with a pellets making machine (Model MH 237, Miao Hsien ltd, Taiwan), dried in an oven maintained at 65 °C and stored at -4°C until used to feed the fish in a feeding trial. Ingredients used and proximate composition values of diets are presented in Table 2.

2.5. Fish husbandry conditions and feeding trial procedure

Nile tilapia (Oreochromis niloticus) fingerlings were acclimatized to laboratory conditions in a 500 L capacity fiber glass tank and fed a maintenance diet, containing 25% crude protein for one week. Two hundred and seventy fish were randomly distributed at 30 fish per tank, into triplicates of 50 L capacity aquarium tanks per diet each (making a total of nine tanks containing 270 fish). Each tank was supplied with tap water and aerated continuously throughout the experiment. Feeding was carried out to satiation twice daily at 0900 and 1700 hrs for 8 weeks. Fecal matter was siphoned out every day before feeding. Fish growth results and quantity of feed consumed were monitored and used to calculate weight gain and feed utilization parameters accordingly at the end of the experiment. The results are as presented in Table 2.

Growth performance and feed utilization were compared by 1-way ANOVA using SPSS program, version 12. Tukey’s test was used to compare the data and P values of <0.05 were considered significant.

The parameters measured and formulae used in calculation are given by the following mathematical equations:

\[
\text{Weight gain } \% (\text{WG} \%) = \frac{100 \times (w_2 - w_1)}{w_1},
\]

\[
\text{Feed conversion ratio (FCR)} = \frac{\text{Total feed given}}{(w_2 - w_1)(g)}
\]

\[
\text{Protein efficiency ratio (PER)} = \frac{(w_2 - w_1)(g)}{\text{Total protein intake} (g)}
\]

where; \(w_1\) refers to mean initial weight, \(w_2\) is the mean final weight, (g) is unit of quantity, in grams, \(\text{total feed given}\) and \(\text{total protein intake}\) refer to total feed consumption and total quantity of proteins in the feed consumed respectively over the 8 weeks experimental period.
3. Results and Discussion
The characteristics of raw POME and permeate obtained after the filtration are presented in Table 1. In this study about 97% O&G, 55.6% carbohydrates and 43.8% of proteins were recovered and utilized effectively as fish feed ingredients. This observation is similar to the conclusion of Wu et al. 2007 where 45.3% proteins and 41.5% carbohydrates were recovered from POME using membrane ultrafiltration procedure. The results of the growth performance (Final body weight, FBW and % weight gain, WG) and feed nutrients utilization parameters (Feed conversion efficiency, FCR and protein efficiency ratio, PER) are summarized in Table 2. Both growth performance and nutrient utilization parameters suggest that the control diet, FO was better for fish growth and nutrient utilization.

The growth performance for fingerling on the DSO diet was quite similar to those fed CPO diet, even though the FO treatment was significantly higher. This suggested that the nutrient utilization in both treatments (DSO and CPO) were very similar. The trend of observation could likely be because the lipids from the dried POME sludge was essentially palm oil. This observation agrees with the conclusions of Ng et al, 2003. In an experiment with African catfish, they were able to show that dietary sources of palm oil do not affect growth performance of fish. However, the effect of the supplemental protein from the dried sludge on weight gain may not have shown due to the high fiber content in the DSO diet or probably because of the fatty acids profile of the diet fed to the fish.

Conclusion
In conclusion, the preliminary study has successfully shown that micro-filtration is efficient in removing substantial quantities of suspended solids like carbohydrates, proteins and also oil and grease. The dried POME sludge so recovered is suitable for use as a fish feed ingredient. Its utilization will provide a cheap source for ingredient of fish feed, more-so it will be a more environment friendly way of managing the enormous waste from palm oil mills. When used to formulate feeds for tilapia fingerlings, comparable growth and nutrient utilization to a diet made from crude palm oil can be achieved. However, there is a need for further intensive studies, to determine the digestibility of fish when fed a diet made from the sludge, as well as the fatty acids profile of the fish muscle, to evaluate storage properties of the fish.

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References


Solid POME sludge as fish feed ingredient:


