Fish offal meal as an alternative protein source of fish meal for Tilapia, *Oreochromis sp.*

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Abstract

The use of local feedstuffs to substitute conventional feedstuffs in fish nutrition has been widely studied. However, there is no report to date on the use of by-products from fish processing plants as feed for fish. The lack of locally available feedstuff for aquaculture feeds has encouraged the use of by-products from local sources, such as fish offal meal (FOM),a feedstuff derived from the discarded parts of fish obtained from the fish processing industry that are unfit for human consumption and can be a valuable protein source in aquaculture diets. This study was conducted to evaluate the effectiveness of using FOM as a protein substitute of fishmeal (FM) in tilapia diets. FOM was prepared from discarded fish parts collected from a wet market in Serdang Selangor through the process of drying and grinding. A total of 480 red hybrid tilapia juveniles, *Oreochromis spp.* were allotted equally to four treatment groups: 50, 80 and 100% replacement of FM with FOM in the diet and a control diet of commercial feed. The data collected consists of weight gain, feed intake, feed conversion ratio (FCR), specific growth rate (SGR), protein efficiency ratio (PER), survival rate and water quality parameters. At 26 wk of culture, fish fed with 100% substitution of FM with FOM showed the best performance with highest body weight gain ($p<0.05$), feed intake, SGR, PER and lowest FCR. This study shows that substitution of 100% FM with FOM has no negative or detrimental effect on the growth performance of tilapia while producing the best result in term of body weight gain.

Key words: Fish offal meal, tilapia, growth performance, feed conversion ratio

Introduction

According to FAO, in 2012 aquaculture was the fastest growing food producing sector with global production of 90.4 million tonnes, valued at USD 144.1 billion (FAO, 2014). World food fish production alone had doubled from 32.4 million tonnes in 2000 to 66.6 million tonnes in 2012 (FAO, 2014). Farmed food fish in Asia had recorded an annual growth of 8.2% from 2000 to 2012 and was higher than the decade prior to 2000. Asia accounts for 88% by volume of the world aquaculture production. FAO has reported that Asia produces more cultured than wild catch food fish since 2008 with cultured fish contributing 52% of the total aquaculture production in 2012 with an average annual growth rate registered at 8.6% from 1980 to 2012.

In Malaysia, the impressive expansion of the aquaculture industry has started in the early 1980's (Liong *et al.*, 1988). The increasing production of aquaculture from 354,427 metric tonnes in 2008 to 530,205 metric tonnes in 2013 (DOF, 2013) has shown that this industry is sustainable. As the national population increases, there is a great challenge for the nation to produce sufficient food to feed the growing population. In order to ensure that the production of food is sufficiently secured for the nation, the government has prioritized the aquaculture industry as one of the key components in the national key economic areas (NKEA). However, the constraint in this industry is the ever increasing feed cost. Feed is the most crucial cost factor in aquaculture, accounting for up to 70% of the production cost with protein being the most expensive dietary source. Fish feed production relies on the use of many imported feedstuffs and hence subject to global price fluctuations and availability.

It is therefore imperative to explore locally available feed substitutes and enhance food security. Many studies have been conducted using by-products from poultry (Mardhati *et al.,* 2010*;* Farahiyah *et al.*, 2014) and agro-industrial by products (Ng and Chong, 2002; Thongprajukaew *et al.*, 2015) in aquaculture feeding. El- Sayed (1998) substituted 100% of fishmeal with shrimp meal in red and Nile tilapias without any adverse effect on weight gain and feed efficiency of both fishes. Use of fisheries by-products including fish protein concentrate and hydrolysates, shrimp meal, krill meal and squid meal as partial or total replacement in tilapia diet has been reported earlier (El-Sayed, 1999). However, limited studies have been conducted on the use of fish by-products namely discarded parts of fish (USDA, 2010) as aquaculture feed.

In certain parts of the world the fish processing plant by-products are used and transformed into low-market value products such as animal feed, fishmeal and fertilizer Chalamaiah *et al.,* (2012),. However, in recent years, more studies have been done on transforming the by-products into more valuable products known as fish protein hydrolysates. This finding has created more attention to develop this product into human health supplements due to its high protein content with good amino acid balance and bioactive peptides (Chalamaiah *et al.,* 2012; He *et al.*, 2013).

In certain European countries such as Norway, 97% of by-products from Norwegian aquaculture are being utilized. Fish offal meal (FOM) is a by-product from the fish processing industry, consisting of discarded parts (head, bones and internal organs) which are not fit for human consumption. This by-product, instead of being wasted and dumped, can be utilized to produce fish feed and indirectly helps towards a greener environment.

A preliminary study was done in MARDI to identify the proximate composition of the fish offal meal. The nutrient content of FOM as used in this study, nevertheless, was high and comparable to the conventional local fish meal. Its protein content was 54.59%, lipid 13.56%, fibre 0.76%, with a gross energy value of 18.5 MJ/kg (Farahiyah *et al.*, 2015). FOM may be variable in its nutritional quality depending on the source of its raw materials and also the processing method employed. The digestibility value of FOM was also high where protein and amino acid digestibility's were above 95% with a digestible energy (DE) value of 17.69 MJ/kg. Measurement of digestibility is important in order to evaluate the nutritive value of a feed or an ingredient for formulating the diets (Bureau and Cho, 1999). However the nutritional value of the FOM may vary from batch to batch depending on the source of material and its quality. This study was conducted to determine the effects of substituting fishmeal with fish offal meal in the aquaculture feed on the growth performance of tilapia.

Materials and Methods

Fish offal collection and preparation

Discarded fish samples weighing 80 kg were collected from a wet market in Serdang, Selangor over a period of 14 d and transported to the laboratory in MARDI, Serdang to be prepared as FOM. The discarded fish parts consisted of all parts of fish including the head and internal parts not sold as they were deemed unfit for human consumption. The collected samples were screened for any impurities such as crab shells and legs. Samples were washed with clean water and sterilized using an autoclave at 120˚C for 20 min and dried in the oven at 60˚C for 4-5 d until the sample was fully dried at around 10% moisture. The dried samples were then ground and pulverized into very fine form, less than 1 mm in particle size, to produce FOM which was kept in plastic sample bags and stored in a cool dry storage room at 4^0C until use. Samples were analysed for proximate composition (dry matter, crude protein, crude fibre, ash, gross energy and lipid) following the method of AOAC (AOAC International, 2002) . Crude protein was analysed for its N content (as g N x 6.25) using the Kjedahl method (Gerhardt protein analyzer, United Kingdom) and amino acids concentration was determined using Amino Acid Analyzer (Biochrom, United Kingdom) .

Digestibility study

The reference diet was formulated to meet the nutrient requirement of tilapia (NRC, 1993) where fishmeal was used as the sole protein supply. The experimental diet consisted of 70% of the reference diet and 30% of the test ingredient (FOM) by weight (Lim *et al.,* 2005). Digestibility of FOM was performed using an indirect method where chromic oxide was used as an inert marker and was incorporated at 0.5% in the experimental diet. Ten tilapia fish (mean weight of 20 g) were placed in a 70-L aquarium glass tank. The experiment consisted of two treatments (reference diet and experimental diet) with 3 replicates of each treatment conducted using 6 tanks. The fish were fed once a day till satiation in the morning at 0900. All uneaten feed were collected an hour after feeding. After 4-5 h feeding, fresh feces were collected. Feces were also collected every morning before feeding time. The collection of feces was done through siphoning the feces into a plankton net and samples were collected gently to avoid any damage or break off of the fecal strand which could cause leaching of nutrients. Samples of the feces were pooled for the 10 d of the fecal collection and dried in the oven. Analyses of chromium, protein, amino acids and energy content of the feed and feces were performed to determine the digestibility values. The digestibility calculation followed the formulae of Lim *et al., (*2005):

ADC of nutrient (%) = 100- 100 x [(% Cr diet/ Cr feces) x (% fecal nutrient/ % diet nutrient)

ADC of test ingredient (%)
= ADC of test diet + [(0.7/0.3) x (% nutrient in reference diet / % nutrient in test ingredient) x (ADC of test diet- ADC of reference diet)]

where ADC: Apparent Digestibility Coefficient

Feeding trial

Six hundred red hybrid tilapia juveniles, *Oreochromis spp.,* (mean initial weight of 8.5 g) were obtained from a hatchery located in

Kuantan, Pahang. The juveniles were fed a commercial pellet preparation (Dindings starter, 32% CP) throughout the 2-wk acclimatization period. The fish were randomly and equally assigned to 5 treatments with 3 replicates per treatment. The treatments were A: control diet with no FOM, B: substitution of 50% of fish meal in the control diet with FOM, C: substitution of 80% of fish meal in the control diet with FOM, D: substitution of 100% of fish meal in the control diet with FOM and E: commercial diet. Treatment E was intended as a positive control. The experimental feed was formulated to be isocaloric and isonitrogenous using the digestible values of protein, amino acids and digestible energy obtained from the digestibility study. Duration of the feeding trial was 182 d.

The fishes were reared in 15 1-tonne polyethylene tanks with re-circulating aquaculture system. Aeration was supplied continuously throughout the experiment. The fish were fed twice daily (0830 and 1600) with the feeding rate of 3-4% of body weight. The fish were weighed fortnightly and feeding portion was adjusted depending on the fish weight. Water parameters (dissolved oxygen, temperature, ph and ammonia level) were monitored weekly using a multiprobe meter (YSI Proplus model, Yellow Springs) throughout the feeding trial to ensure their consistency were within the range of cultured freshwater fish requirement. To maintain water quality, fifty percent of the water was exchanged weekly.

Data on body weight gain, feed conversion ratio (FCR), specific growth rate (SGR), protein efficiency ratio (PER), and survival rate were collected and analysed using Analysis of Variance (ANOVA) with significant differences between means separated by Tukey test using the SAS Version 9.3 (ref).

Results and Discussion

The nutrient content of FOM was found to be high and comparable to the conventional local fishmeal. Its protein content was 54.59 % with lipid 13.56%, fibre 0.76%, ash 19.88% and gross energy value of 18.5 MJ/kg. FOM may be variable in its nutritional quality depending on the source of its raw materials and also the processing method employed. The digestibility value of FOM was high at 50.5% with protein digestibility coefficient of 0.925 and amino acid digestibility's of more than 95%. The digestible energy coefficient was 0.96 with the digestible energy value of 17.76 MJ/kg. Table 1 shows the digestible values of the FOM prepared.

Table 1. Proximate value and digestible values of fish offal meal (FOM)

Nutrient	Total value	Digestible coefficient	Digestible value
Dry matter (%)	93.33	na	na
Lipid (%)	13.56	na	na
Ash (%)	19.88	na	na
Fibre (%)	0.76	na	na
Crude Protein (%)	54.59	0.93	50.50
Amino acids (%)			
Thr	1.70	0.91	1.55
Cys	0.22	1.00	0.22
Val	2.53	0.91	2.31
Met	1.18	0.91	1.08
Ile	1.52	0.91	1.38
Leu	3.56	0.94	3.34
Phe	1.76	0.80	1.40
His	1.02	0.95	0.97
Trp	0.12	1.00	0.12
Lys	0.14	0.93	0.13
Arg	4.11	0.95	3.91
Energy (MJ/kg)	18.50	0.96	17.76

na – not available

The mean weight gain, feed intake, FCR, SGR and PER of fish fed with 100% substitution of FOM was found to be the highest among treatments with FOM inclusion and the control diet (Table 2). The control diet with no FOM inclusion however showed the lowest performance in terms of weight gain, feed intake and SGR but did not differ significantly with treatments B and C. Fish fed with 100% substitution of FOM (Treatment D) showed the highest weight gain of 316.25 g which was higher ($p<0.05$) than the other treatments. The lowest weight gain was observed in the control treatment A with 249.75 g but was not significantly different than those fed with 50% and 80% of FOM substitution.

The highest feed intake was shown in treatment D with 427.31 g which was different ($p<0.05$) compared with treatments A and B but did not differ significantly with treatment C. The lowest feed intake was observed in treatment A with 353.61 g. Feed conversion ratio for fish fed with 0, 50 and 80% of FOM however did not show any significant difference when compared among these treatments with the FCR of 1.41, 1.40 and 1.43, respectively. It was however observed that the lowest FCR (1.43) was recorded in treatment C, and there was no significant difference found ($p>0.05$) among treatments A, B and D. High feed intake in treatment C with low contribution in terms of weight gain had contributed to the high value of of FCR.

Table 2. Growth performance of tilapia fed with FOM substitution at 4 different levels and a commercial diet

Treatment	Weight gain (g)	Feed intake (g)	FCR	SGR	PER
A	249.75[c]	353.61[d]	1.41[ab]	3.07[c]	2.21[b]
B	267.75[c]	375.51[cd]	1.40[ab]	3.09[c]	2.23[b]
C	279.17[c]	397.04[bc]	1.43[a]	3.11[c]	2.20[b]
D	316.25[b]	427.31[b]	1.35[bc]	3.25[b]	2.31[ab]
E	380.83[a]	503.13[a]	1.32[c]	3.38[a]	2.37[a]

[abc]Means with different superscripts within the same column differ significantly($p<0.05$).
*Treatment: A - control diet with no FOM, B- substitution of 50% of fish meal in the control diet with FOM, C- substitution of 80% of fish meal in the control diet with FOM, D- substitution of 100% of fish meal in the control diet with FOM and Treatment E - commercial diet, FCR – Feed conversion ratio, SGR – Specific Growth Rate, PER – Protein Efficiency Ratio

Table 3. Water quality parameters of tilapia tank culture

Treatment	Initial				Final			
	Temp	pH	DO2	NH_3	Temp	pH	DO2	NH_3
A	27.03	6.90	5.29	0.01	26.63	6.98	4.56	0.03
B	26.97	6.87	5.17	0.01	26.40	6.99	4.23	0.02
C	26.97	6.95	4.62	0.01	26.27	7.01	4.06	0.03
D	26.93	7.09	5.02	0.01	26.30	7.06	4.20	0.03
E	26.97	6.93	4.26	0.01	26.13	7.04	3.88	0.03

Highest SGR was recorded in tilapia fed treatment D with 3.25% day^{-1} and differed significantly with the other treatments. Treatments A, B and C however showed no significant difference among the treatments. In terms of the efficiency of utilizing protein, there were no significant differences found among all treatments ($p>0.05$), however, treatment D recorded the highest percentage of PER with 2.31, followed by treatments B, A and C with 2.23, 2.21 and 2.20, respectively (Table 2).

In the present study, a commercial diet (Treatment E) was used to compare the growth performance of the fish fed the commercial diet with fish fed FOM inclusion. Fish fed the commercial diet had higher weight gain, feed intake and SGR, but not significantly different ($p>0.05$) with treatment D in terms of FCR and PER. Commercial feed might contain compounds such as attractants to lure fish to consume more of the feed thus gaining weight, however the efficiency in converting the feed to meat and the efficiency of utilizing the protein content in the feed was not significantly different with fish fed with diet based on 100% FOM inclusion. The cost of production to produce a kg of fish meat using commercial feed was RM 4.60, whereas using 100% FOM the production cost was RM 2.60, a reduction of 43.5% in feed cost. Even though the FCR of using 100% FOM was slightly higher than the commercial feed, the reduction in cost using FOM was more cost saving and economical.

The nutrient content of FOM used in this study, nevertheless, was high and comparable to the conventional local fishmeal. Its protein content was 54.59%, lipid 13.56%, fibre 0.76%, with a gross energy value of 18.5 MJ/kg. The local fishmeal used in the control diet and also for other treatments was obtained from a local supplier. The protein value of the fishmeal was high, around 60%, however the quality of the fishmeal itself was in doubt, as there were many impurities in the fishmeal such as rice straw and some unidentified particles. Adulteration of the fishmeal might be the reason for the poor growth performance of the tilapia when fed with the control diet using 100% fishmeal.

In contrast, FOM was produced manually in our laboratory and all the impurities had been discarded and screened before preparation of FOM. The protein content was solely obtained from the FOM. The FOM however might be variable in its nutritional quality depending on the source of its raw materials and also the processing method used. From the study it was found that the digestibility value of FOM was also high where protein and amino acid digestibility percentage were above 95% with a digestible energy value of 17.69 MJ/kg.

From the present study, it was observed that FOM could fully substitute fishmeal in tilapia feed with no adverse effect on growth and feed intake. At 26 wk of growth, fish fed with 100% substitution of fishmeal with FOM showed the highest weight gain, feed intake, SGR, PER and the lowest FCR. The fish were able to utilize efficiently the nutrient from FOM as it was palatable.

Mardhati *et al.* (2010) reported that inclusion of 40% poultry offal meal was acceptable in tilapia diets. During the feeding trial period, no mortality was recorded in all treatments, indicating that the FOM was safe and did not induce any disease or negative effect towards the growth of tilapia. Water quality was also in good condition with ammonia levels below 0.03 mg/L (Table 2). At the initial stage, ammonia was around 0.01 mg/L, however as the fish aged and gained weight, more ammonia was released through feed and feces.

The east coast region of peninsular Malaysia is well known for its fish-based products, such as fish sausage (keropok lekor), fish cake (satar) and fish crackers. Apart from these down-stream products, fishing is an occupation and income generator for most people in the region. The use of FOM in fish diets could be an advantage for them to produce their own feed by maximising the utilization of by-products of the fish processing industry. Small scale local farmers may fully utilize the by-products of fish and transform them into FOM to be incorporated in fish feed. Furthermore, the utilisation of by-products from fish based industry may help to increase the income of the fishermen and the small product entrepreneurs.

Conclusion

The use of fish offal meal as a substitute or protein alternative for fishmeal in aquaculture feeds has shown promising results, with better performance than the control diet and is much cheaper in terms of production cost. The fish offal meal can be produced locally, thus encouraging the use of locally available feedstuffs rather than the conventional imported feedstuffs. This could also contribute in lowering the import value of the country and encourage small entrepreneurs to venture in this industry.

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