Songklanakarin J. Sci. Technol.
31 (1), 105-110, Jan. - Feb. 2009

Songklanakarin Journal
of Science and Technology

http://rdo.psu.ac.th/sjst

Original Article

Effects of replacing fishmeal with wastes derived from local fisheries on the growth of juvenile tilapia, *Oreochromis niloticus*

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Received 20 April 2007; Accepted 20 November 2008

Abstract

A feeding trial was conducted to investigate the effects of partially and totally replacing fishmeal with by-product derived from local fisheries on growth performances of tilapia (*Oreochromis niloticus*). Tilapia fingerlings (average initial weight 0.38±0.05 g) were fed with 5 different diet formulas composing of fish meal protein replacement levels of 0%, 25%, 50%, 75, and 100%. Tilapia were raised in 80 x 80 x 80 cm^3 hapa in an earthen pond for 8 weeks. Each treatment contained 3 replications. No feeding trial was applied as negative control. The result showed that fish by-product powder could substitute for fishmeal on a crude protein basis at a level of not more than 25%. As a result, feed cost can only be cut down approximately 3 US cents/kg. Specific growth rate, weight gain, survival rate and feed conversion ratio were not significantly different between the fish fed with the 75% and 100% fishmeal containing diets (P>0.05). The outcome would be applied to reduce the solid wastes from fish processing and partially replace the imported fishmeal. This can also be used as guideline for farmers in small communities to produce their own tilapia feed.

Keywords: Tilapia, fishmeal replacement, by-product, alternative protein source

1. Introduction

Tilapia (*Oreochromis niloticus*) is one of many economical freshwater fish cultured worldwide. In 2005, the increased export of tilapia brought in approximately 17 million US dollars for Thailand (Fisheries Foreign Affairs Division 2007). The tilapia culture business continues to increase and thereby the demand for fish feeds is expanding. The diet of fish is one of the main factors that support the success of tilapia culture, especially for juvenile fish with a high dietary protein requirement; however, the feed cost is extremely high being up to 70% of the total cost. Unfortunately, fishmeal, a major source of fish feed, appears to be in short supply and rather costly. This increases the expense of the fish diet so much that fish farmers are not able to afford the high cost in the long run and sustainable aquaculture as a consequence might not be viable. For this reason, the research for alternatives to fishmeal is one of the first international research priorities (Hardy and Kissil, 1997). Although alternative protein sources are able to cut down the feed cost, fish might not get as good growth nor utilize the nutrients in these diets. Many studies have been made to use alternative protein sources such as plant proteins (Sitjà-Bobadilla *et al.*, 2005; Tantikitti *et al.*, 2005; Cheng *et al.*, 2003), and rendered animal proteins (Millamena 2004;

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Yoshitomi *et al.*, 2006; Cavalheiro *et al.*, 2007) for reducing fishmeal in fish feeds. However, some animal proteins are restricted in fish feed because of bovine spongiform encephalopathy and avian influenza.

Thailand is one of the fast-growing countries in the small-scale agro-industrial enterprises. Fermented fish business has been recognized as one of the profitable small-scale industries. Edible parts of freshwater fishes are cut and processed into fermented fish. During this process, unused parts are thrown away as solid wastes and always generate unpleasant odor. Limited information is available on the potential of replacing fishmeal with processed fisheries by-product for tilapia diet.

The purpose of this research was to determine the feasibility of freshwater fish by-product from local fisheries fermented product as an alternative protein source to produce a fish diet to reduce the fishmeal shortage. The benefits would be a reduction in expenses and the utilization of the fish waste.

2. Materials and Methods

2.1 Experimental fish

Tilapia fingerlings (average initial weight 0.38±0.05 g) derived from a local farm in Chiang Mai, Thailand, were acclimated in hapa located in earthen pond for a week. A small commercial pellet feed was given twice a day until satiation during this period.

2.2 Experimental design and procedure

The Completely Randomized Design was applied for this experiment with 6 treatments, each in triplicate. Fish of similar sizes were distributed into 24 tanks with 45 juveniles per tank (200 fish/m^2). Each diet was randomly assigned to triplicate tanks. The feeding trial lasted for 56 days.

The formulation of the experimental diets is shown in Table 2. Crude protein (Kjeldahl method), total lipid (ether extraction by Soxhlet method), ash (550^{o}C, 18 h) and moisture (105^{o}C, 24 h), contents were analyzed by standard methods (AOAC, 1995). The by-product derived from local fisheries processing was dried, ground, and incorporated to replace fishmeal protein at 0%, 25%, 50%, 75%, and 100% (treatment diet 1, 2, 3, 4, and 5, respectively). The experimental diets were stored at -20^{o}C until used.

Table 1. Proximate composition of fish processing by-product

Constituent	%
Moisture	11.82±0.95
Protein	40.73±0.98
Lipid	22.59±0.42
Ash	26.03±0.54
Fiber	5.41±0.35
Carbohydrates (by difference)	15.81±0.65

Diets were hand-fed at 10% of body weight twice daily. The formulation of the experimental diets is shown in Table 2. The feeding rate was adjusted every 14 days.

2.3 Statistical analysis

All data from the feeding trial and chemical analysis were tested using one-way analysis of variance (SPSS 11.5 for windows). Percentage survival data were arcsin-square-root transformed before statistical analysis. If a significant difference was identified, differences among means were compared by Tukey's multiple range tests (SPSS 11.5 for windows).

3. Results

The proximate analysis of fish processing by-product is shown in Table 1. The protein content of the by-product was 40.73%. The formulation of the experimental diets was set by fish meal protein replacement levels of 0%, 25%, 50%, 75, and 100% (Table 2). The proximate composition

Table 2. Ingredient compositions of the experimental diets on a dry matter basis

Treatment (% replacement)	Ingredient composition (% kg of feed)				
	fish meal	soybean meal	rice bran	fish processing by-product	Premix*
1 (0%)	25.27	24.58	49.15	0	1
2 (25%)	21.58	23.41	46.82	7.19	1
3 (50%)	16.70	21.87	43.73	16.70	1
4 (75%)	9.95	19.74	39.47	29.84	1
5 (100%)	0	16.59	33.19	49.22	1

*1 kg of Premix (C.N.P. animal nutrition) contains: Manganese 5.4 g, Iron 14.2 g, Copper 1.0 g, Zinc 2.9 g, Sodium 3.9 g, Iodine 19.0 mg, Potassium 0.9 mg, and Cobalt 1.1 mg.

Table 3. Proximate analysis of the ingredient composition experimental diets

Treatment (% replacement)	Feed composition (%)						
	Gross energy (kJ/kg)	moisture	protein	fat	ash	fiber	carbohydrate
1 (0%)	1.60±0.23 [a]	9.90±0.05[a]	30.66±0.14[a]	18.52±0.35[e]	12.27±0.49[c]	4.60±0.22[c]	24.05±0.25[a]
2 (25%)	1.59±0.29 [a]	9.38±0.21[a]	29.85±0.27[b]	22.42±0.48[d]	14.23±0.28[b]	9.70±0.26[a]	14.42±0.30[b]
3 (50%)	1.69±0.32 [a]	8.93±0.19[b]	29.16±0.12[b]	26.36±0.36[c]	14.59±0.94[b]	8.35±0.09[b]	12.61±0.34[b]
4 (75%)	1.74±0.20 [a]	8.04±0.05[b]	29.13±0.17[b]	28.00±0.26[b]	14.65±0.21[b]	8.48±0.42[b]	11.70±0.22[b]
5 (100%)	1.79±0.32 [a]	6.09±0.11[c]	28.83±0.14[c]	29.68±0.28[a]	15.99±0.85[a]	7.93±0.33[b]	11.48±0.34[b]

Table 4. Feed cost and growth performances of tilapia fed with six different diets for 56 days (Mean ± standard deviation of three replications). Means within each column not sharing a common superscript are significantly different (p<0.05).

Treatment (% replacement)	feed cost (baht/kg)	SGR (%/day)	Weight gain (g)	FCR	% Survival
1 (0%)	27.34	4.18±0.13a	4.40±0.32a	0.94±0.02a	83.00±3.12a
2 (25%)	26.99	3.82±0.11ab	3.71±0.13ab	1.03±0.05a	81.50±2.64a
3 (50%)	26.39	3.74±0.06b	3.47±0.06bc	1.01±0.02a	81.33±1.53a
4 (75%)	25.53	3.53±0.22bc	3.17±0.21bc	1.11±0.12a	78.67±2.02b
5 (100%)	24.29	3.34±0.14c	3.04±0.18bc	1.08±0.14a	77.33±2.75b
6*	0.00	0.58±0.12d	1.39±0.28d	-	30.50±5.27c

*no feeding
SGR, [ln(final weight) - ln(initial weight) /56 days]×100
FCR, weight gain (g)/dry feed intake (g)

of the experimental feeds is shown in Table 3. The results show statistically different composition of the experimental feeds with respect to moisture, ash, protein, lipids, fiber, and carbohydrates. The amounts of protein in fishmeal were much higher than those in fish processing by-product. On the other hand, fat and energy contents increased with inclusion level of fish by-product in the diets.

Data on growth performance are presented in Table 4. At the end of the 56-day feeding trial, the specific growth rate (SGR) of the fish fed the diets with 25% replacement did not significantly differ from those of fish fed the control diet containing 100% fishmeal. However, fish fed diets with 50%, 75%, and 100% replacement showed significantly ($P< 0.05$) lower growth in terms of weight gain (WG) and SGR compared to the fish fed the control diet. The WG and SGR of fish fed diets 2 were not significantly different from those fed diets 3 and 4, respectively. The average weight gain of tilapia was 4.40, 3.71, 3.47, 3.17, and 3.04 g for diets with 0%, 25%, 50%, 75%, and 100% replacement, respectively, and 1.39 g for the no feeding. Furthermore, feed conversion ratio (FCR) slightly increased due to the substitution of fishmeal but there was no significant difference, and the best FCR was obtained from the fish fed the diet containing 100% of fishmeal.

Survival of fish ranged from 30.5% to 83% and there was no significant difference among the dietary treatments supplemental with 0-50% fish by-product. However, incorporation of fish by-product to replace fishmeal protein tended to decrease the survival of tilapia although feed cost seems to be reduced.

4. Discussions

One important challenge concerning aquaculture in near future is to establish and maintain sustainable and profitable production. As the demand for fishmeal for aquaculture increases while their availability decreases, the feed cost is expected to rise. A dependable supply of cost-effective alternative sources of protein must be provided for fish farming. The present study demonstrated that freshwater fisheries by-product could be an alternative protein source for fishmeal in aquafeeds although there is a limited inclusion level (not more than 25%).

The growth performance and survival of tilapia decreased gradually with increasing dietary fish by-product, even at the minimum level of 25% substitution of by-product for fishmeal. This observation is consistent with that of Deng *et al.* (2006), who reported that the specific growth rate of Japanese flounder significantly decreased with increasing dietary soy protein concentrate ($P<0.05$). Yoshitomi *et al.*

(2006) also reported that 30% krill meal included in the rainbow trout diets adversely affected growth performance. In contrast, shrimp head silage could substitute for fish meal in tilapia fish feed without affecting its nutritional quality of the feed and being economical (Cavalheiro *et al.*, 2007). In addition, up to 80% of fish meal protein can be replaced by processed meat meal and blood meal coming from terrestrial animals with no adverse effects on growth, survival, and feed conversion ratio of juvenile grouper (Millamena, 2004). This conforms to other studies where diets with inclusion levels of feather meal up to 15% as substitute for fish meal was possible without affecting growth, feed efficiency, nitrogen or energy gains of rainbow trout (Bureau *et al.*, 2000).

When alternative protein sources are applied, fish growth performance and quality of final product must be examined. Like some nutritional problems found in plant-derived protein, Table 5 shows the limiting amino acids of various plant protein sources (Hardy and Tacon, 2002). In addition, fish is not able to digest the storage form of phosphorus in seeds, phytate. Possible reasons for the reduced growth of tilapia at partial replacement with fish by-product meals in this study may be due to deficiencies in decreased protein composition and essential nutrients in the diets. Table 6 shows the amino acid profile of sardine fish meal and fish-processing waste from Alaska. It indicates that the variation in quality of products as well as amino acids is one of drawbacks that limits their use in fish feed. As a result, the amino acid pattern of whole tilapia should be determined and used as a basis for comparing the effectiveness of the protein sources used in the experimental diets. The diets containing high level of fishmeal replacement probably contained less individual essential nutrients which might reflect the lower palatability of the diets. In addition, the high fiber and ash contents of diets in which fishmeal was replaced by with fisheries by-product result in the formation of weak pellets with poor stability in water. Diet could be loosed before fish taken. Fagbenro and Bello-Olusoji (1997) claimed that fiber and ash content could be reduced by transformation of shrimp head waste into silage by the process of fermentation. A similar observation on the reduction of ash and fiber in silage by the use of formic acid was also made by Fox (1994). Consequently, the pellets made of shrimp head silage possessed better structural stability in water. However, fisheries by-products are usually left at room temperature for a certain period. As a result, the protein might be degraded due to bacterial activities and that leads to a lower quality diet. For this reason, the raw materials must be kept frozen until use. Moreover, insufficient availability of

Table 5. Nutritional problems in rainbow trout associated with various plant protein sources

Feed ingredient	Limiting amino acid	Phosphorus digestibility (%)	Fiber(%)	References
Corn gluten meal	Lysine	8.57	4.4	Sugira *et al.*, 2000
Wheat gluten meal	Arginine	4.52	6.7	Sugira *et al.*, 2000
Soybean meal	Methionine	2.0	3.4	Sugira *et al.*, 2000

Table 6. Proximate composition and amino acid profile of sardine fish meal (FM) and a fish-processing waste [red salmon head meal (RSHM)] from Alaska.

Amino acid (%AA /100 g of protein)	FM (Hernández *et al.*, 2008)	RSHM (Li *et al.*, 2004)
Alanine	7.5	4.09
Arginine	6.6	4.7
Aspartic acid	9.2	6.04
Glutamic acid	16.6	8.32
Glycine	11.5	4.47
Histidine	3.5	1.39
Isoleucine	5.7	2.88
Leucine	8.0	4.55
Lysine	6.5	3.76
Methionine	2.2	1.73
Phenylalanine	4.9	2.6
Serine	4.6	2.71
Threonine	2.3	2.99
Tyrosine	3.1	2.28
Valine	6.8	2.98

raw materials is one of the challenges associated with using freshwater fisheries by-products. In contrast, supplies of marine fish are more abundant.

Apparent fish survival rates decreased with increasing dietary fish by-product powder although there was no any fish diseases detected during the experimental period. Therefore, the reason for the lower survival was probably due to the experimental diets which might affect the innate immunity of fish. Moreover, the reduced feed intake due to lower palatability of diets in which high levels of dietary fish meal were replaced with animal protein ingredients (Xue and Cui, 2001). This indicates that protein from fisheries by-product could not effectively replace fishmeal protein in diets of tilapia possibly because of lower feed intake, amino acid imbalance and poor utilization of nutrients. Further studies include diet supplementation to improve feed intake, survival rate, immunity, and growth of tilapia.

In conclusion, only 25% of the dietary fishmeal protein can be replaced by by-product protein derived from local fisheries processing. As a result, fish wastes are no longer classified as waste since we can recycle them and use as fish feed. In terms of fish growth, the presence of high levels of fat seems to be a limiting factor for using high levels of fish by-product in diets for tilapia juveniles. Further studies to determine the long-term effect on the performance of fish fed the fish meal replacement diet under on-farm conditions is suggested. This might be used as a guideline for farmers in small communities to produce their own tilapia feed; however, the variation of raw materials for fish diets should be of concern.

Acknowlegements

We would like to thank Dr. Ralph Cooper for his helpful suggestions throughout this paper writing. Thanks to the NCE-EHWM Fund for partially PhD education financial assistance.

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