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The Development of Small-Scale Hapa Culture of Tilapia (*Oreochromis niloticus*) in Northeastern Thailand. II. The Feasibility of Using Low-Cost Compound Feeds

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Abstract

In two experiments, the use of two commercial feeds and six compound diets with rice bran as the bulk ingredient was evaluated for small-scale cage culture of tilapia (*Oreochromis niloticus*) in northeastern Thailand.

In the first experiment, the cost effectiveness, expressed as feed costs per kg fish produced, of a home-mixed diet (fishmeal 17%, soybean meal 30%, rice bran 53%), was better than that of the tested commercial feeds. It yielded higher returns than a commercial tilapia feed, but less or similar returns than a commercial catfish feed.

The second experiment attempted to decrease feeding costs by reducing the protein levels in the home-mixed diet. At the same time, the effect of partial fishmeal substitution by soybean meal was evaluated. At two levels of dietary protein (23 and 27%), a compound diet of fishmeal and rice bran was compared to a diet in which the fishmeal was partially substituted by soybean meal. Growth and feed conversion between all treatments were not significantly different.

Small-scale farmers in northeastern Thailand strongly preferred low-cost feeds. Development of small-scale cage or hapa culture of tilapias there should begin with such feeds, even though less profitable.

Introduction

Because of high costs of commercial feeds, small farmers in north-eastern Thailand are practically excluded from semi-intensive aquaculture. Compared to livestock feeds or to raw ingredients, complete fish feeds are very expensive. Commercial fish feeds are also poorly

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available in rural areas. Farm-made ("home-mixed") compound feeds, based on inexpensive and locally available ingredients may be a potential alternative to stimulate commercial aquaculture in rural areas (New 1987).

The Tilapia Hapa Culture Project of the Srisaket Agricultural College (Srisaket, Thailand) was set up to foster semi-intensive fish culture in northeastern Thailand. It was designed to develop an appropriate technology and management of hapa culture and to stimulate its introduction in local village ponds. In a previous study, the effect of the size and density of the fish at stocking was reported (Middendorp and Verreth, this vol.). The objective of the present study was to identify cheap alternative feed formulations and to evaluate their cost effectiveness in comparison to an earlier tested commercial diet (Middendorp and Verreth 1991, this vol. and in press). In preliminary trials, compound feeds of rice bran with chicken layer mash or pig fattening concentrate resulted in poor growth and were rejected for further study. Since the most readily available ingredients in northeastern Thailand were fishmeal, soybean meal, rice bran and a commercial cattle feed, the tested home-mixed diets were formulated on the basis of these feedstuffs.

The present study was carried out in small wire cages instead of hapas made of mosquito net. Since the objectives of this study were not assumed to be directly affected by the cage type, the experiment was regarded as meeting the objectives of the Tilapia Hapa Culture Project.

Materials and Methods

Sixteen wire cages (0.9 x 0.6 x 0.9 m; submerged in 0.65 m of water, hence: volume submerged: 0.35 m^3; mesh size: 2.5 x 2.5 cm), placed in a reservoir at Srisaket Agricultural College, were stocked with tilapia (*Oreochromis niloticus*). One corner of each cage was covered with nylon mosquito netting (60-cm wide) to prevent food wastage by the movements of the fish. The bottom was also covered. Tilapia had been obtained from the Lam Pao Fisheries Station and kept for six weeks in a pond at Srisaket Agricultural College before stocking. Stocking densities were 50 fish (initial biomass: 3,500 kg) and 35 fish (initial biomass: 3,750 kg) for experiments 1 and 2, respectively. At the end of experiment 1, the fish were collected and put together in a basin from which the fish for experiment 2 were selected.

After stocking in the cages, the fish were acclimatized for another seven days. Rearing time in both experiments was 35 days, defined as the number of days the fish were actually fed. Feeding was three times a day, at an estimated 2.5% of body weight per day (BW·day^{-1}). Feed rations were measured daily. Fish were batch-weighed at stocking and harvest. Mean initial weights ranged from 68 to 71 g and from 103 to 111 g in experiment 1 and 2, respectively.

The study was carried out in two consecutive experiments, each carried out with four replicates per treatment. In the first experiment, four different diets were compared: commercial protein-rich catfish feed, a commercial tilapia feed and two home-mixed diets, consisting respectively of a combination of rice bran with a commercial cattle feed and rice bran with fishmeal and soybean meal (diets 1-4, Table 1). Diets were approximately isocaloric (18.0 kJ·g^{-1}).

The second experiment was designed according to a two-factorial design with dietary protein content and partial substitution of fishmeal by soybean meal as treatment variables. All diets were based on diet 4 of experiment 1, i.e., composed of rice bran, fishmeal and, depending upon the treatment variable, soybean meal (diets 5-8, Table 1). The

Table 1. Diet formulation, protein content and feed costs (US$1 = 25 Baht) of the tested diets.

Diet	Diet formulation				Protein content (%)	Price (B·kg^{-1})
	FM (%)	SB (%)	RB (%)	CC (%)		
Experiment 1						
1. Catfish feed (Charoen Phokpand)					39.4	12.00
2. Tilapia feed (Saha Pattana Kaset)					24.9	7.50
3. Home-mixed diet	-	-	14	86	32.1	6.15
4. Home-mixed diet	17	30	53	-	36.3	7.67
Experiment 2						
5. Home-mixed diet	15.8	27.1	57	-	27.3	7.36
6. Home-mixed diet	15.0	12.9	72.1	-	22.8	6.42
7. Home-mixed diet	35.7	-	64.3	-	26.8	7.93
8. Home-mixed diet	25.0	-	75.0	-	22.8	6.75

The protein analysis was done by the Srisaket Agricultural College (experiment 1) and by the National Inland Fisheries Institute, Bangkok.

gross energy content of the diets was estimated to be approximately 18.0 $kJ \cdot g^{-1}$.

Two commercial feeds and six home-made diets were tested. The commercial feeds were a catfish feed of the company Charoen Phokpand (pellet diameter: + 5 mm) and a tilapia feed of Saha Pattana Kaset (pellet diameter: + 9 mm). The feed ingredients used to compose the home-made diets were: brown fishmeal; fine rice bran; commercial cattle concentrate and mechanically extracted soybean meal. The soybean meal was of a different batch in each experiment. A vitamin premix was not considered necessary as it was assumed that tilapia may obtain vitamins directly from algae and other particles floating in the water (Dickson 1987).

Compound diets were processed three times per week by forcing the mixed ingredients as a moist dough through the die (3 mm) of a meat-mincing machine. The feed strands were air-dried in the shade and crumbled. Feed particle length ranged from 3 to 8 mm. Dust was sieved out. A detailed analysis of the feed composition is given in Table 2. For experiment 1, diet composition was analyzed directly. For experiment 2, ingredients were analyzed and diet composition was calculated.

Table 2. The proximate composition (on dry-weight basis) of the diets tested and, in case of home-mixed diets, of their ingredients.

	Crude protein (%)	Ether extract (%)	NFE (%)	Ash (%)	Crude fiber (%)	Gross energy ($kJ \cdot g^{-1}$)	Price ($B \cdot kg^{-1}$)
Experiment 1							
Fish meal	57						15.0
Soybean meal	49						10.0
Rice bran	12						4.0
Cattle concentrate	29						6.5
Diet 1 (catfish feed)	39.4	2.2	44.4	14.0	-	17.8	
Diet 2 (tilapia feed)	24.9	6.1	60.7	8.3	-	18.6	
Diet 3	32.1	8.8	40.4	18.6	-	18.0	
Diet 4	36.3	6.9	40.0	16.9	-	18.1	
Experiment 2							
Fish meal	50.7	2.4	8.2	37.7	0.96		15
Soybean meal	42.5	10.7	34.2	6.2	6.40		10
Rice bran	13.5	19.1	48.5	8.9	10.00		4
Diet 5	27.3	14.2	38.3	12.7	7.6	18.5	
Diet 6	22.8	15.5	40.6	12.9	8.2	18.4	
Diet 7	26.8	13.1	34.1	19.2	6.8	17.3	
Diet 8	22.8	14.9	38.5	16.1	7.7	17.8	

The analyses were done at the Srisaket Agricultural College (experiment 1, ingredients), the National Inland Fisheries Institute, Bangkok (experiment 1, diet composition) and the Asian Institute of Technology (experiment 2). The numbers of the diets refer to the diets as mentioned in Table 1. The fat content was estimated by weighing dried ether extract; NFE = Nitrogen Free Extract. Gross energy was calculated by summing the energy content of protein, fat and NFE (protein: 23.9 $kJ \cdot g^{-1}$; NFE: 16.8 $kJ \cdot g^{-1}$; Ether extract: 39.9 $kJ \cdot g^{-1}$).

Specific growth rate (SGR), feed conversion ratio (FCR) and mean daily feeding rate (R) were computed according to procedures described by Middendorp and Verreth (this vol.). Feed costs are the calculated costs of all feed ingredients, expressed per kg compound feed. Feeding costs (per kg fish produced) were calculated as feed costs multiplied with FCR. For all ingredients, the current market price was used in the calculations.

In northeastern Thailand, tilapia market prices ranged from 20 to 25 $B \cdot kg^{-1}$ live fish (US$1 = 25 Thai Baht). The gross margin per kg fish produced was defined as "market price minus feeding costs." Daily returns were computed from the gross margin, divided by the number of days (t) needed to double the initial stocking weight. Daily returns were expressed in $B \cdot day^{-1} kg^{-1}$ fish produced.

Means and coefficients of variation (CV) were computed per treatment. The effect of diet type on production and economic data was analyzed by one-way analysis of variance for the results of the first experiment. The results of the second experiment were analyzed by a two-way analysis of variance according to the model:

$$Y_{ijk} = \mu + (\text{Protein})_i + (\text{Substitution level})_j + e_{ijk} \qquad \ldots 1$$

where Y_{ijk}=dependent variable; μ=overall mean; $(\text{Protein})_i$=effect of protein level (i=1,2); (Substitution level)=effect of fishmeal substitution (j=1,2); and e_{ijk}=error term.

Differences between means were tested by Tukey's multiple range test ($P<0.05$). Linear regression were calculated between dietary protein content and SGR, FCR and feeding rate.

Results

Experiment 1

Mean final weights varied from 111 g (diet 3) to 155 g (diet 1). Diet 1 was significantly (Tukey, $P<0.05$) superior to diet 4 and both were better than diets 2 and 3. Coefficients of variation were less than 10% per treatment. Overall calculated feeding rate was 2.3% $BW \cdot day^{-1}$. Overall mortality was 0.5%.

Mean SGR, FCR and feeding rate differed significantly between treatments ($P<0.01$). The best growth and FCR was obtained with diet 1 followed by diet 4. The regression analysis showed a significant relation between all dependent variables (SGR, FCR and mean daily feeding rate) and dietary protein content (P<0.01).

Feed prices varied from 6.15 (diet 3) to 12 (diet 1) $B{\cdot}kg^{-1}$. Mean feeding costs (per kg fish produced) however, were less variable at around 11.3 B. Only for diet 4 (home-mixed diet made from rice bran, fishmeal and soybean meal) were the feeding costs lower (9.24 $B{\cdot}kg^{-1}$). The feeding costs of diet 4 were significantly lower than for diet 1, but other treatments were not significantly different.

The number of days needed to double any given initial weight was calculated from the SGR and was respectively, 30, 45, 53 and 38 days for diets 1 to 4. At a market price of 20 $B{\cdot}kg^{-1}$, the daily returns were estimated at 0.28 $B{\cdot}day^{-1}kg^{-1}$ fish produced for both diets 1 and 4, which were significantly higher than the daily returns for diets 2 and 3 (0.20 and 0.17 $B{\cdot}day^{-1}kg^{-1}$ fish produced). If the fish would fetch a higher market price (25 $B{\cdot}kg^{-1}$), daily returns would increase considerably to 0.45 and 0.41 $B{\cdot}day^{-1}kg^{-1}$ fish for diets 1 and 4, respectively.

Experiment 2

Mean final weights ranged from 159 to 168 g. Differences between treatments were not significant (P>0.05). Coefficients of variation were less than 10% per treatment. Overall calculated feeding rate was 2.78% $BW{\cdot}day^{-1}$. Overall mortality was 0.5%.

SGR ranged between 1.11 and 1.21% $BW{\cdot}day^{-1}$. Differences between treatment groups were not significant (Tukey's test, P=0.05). There were no significant differences between FCR values for the four diets.

Costs per kg of feed varied from 6.42 B (diet 6) to 7.93 B (diet 7). The mean feeding costs per kg of fish produced were considerably higher than in experiment 1 at 15-20 B. Differences were not significant.

The time to double the initial weights ranged from 57 to 62 days. At a market price of 20 $B{\cdot}kg^{-1}$, daily returns vary between 0 and 0.1 $B{\cdot}kg^{-1}$ (Table 3). If fish would be sold at 25 $B{\cdot}kg^{-1}$, daily returns would increase considerably (from 0.1 $B{\cdot}day^{-1}{\cdot}kg^{-1}$ per diet 7 to 0.2 $B{\cdot}day^{-1}{\cdot}kg^{-1}$ for diet 8).

Discussion

In experiment 2, SGRs were higher than predicted from the mean stocking weights according to the procedure of Middendorp and Verreth (this vol.). They were comparable to those reported by Viola and Arieli

(1982, 1983) for cage-reared tilapia of similar stocking weights. However, feed conversion ratios were less favorable than in experiment 1 and hapa culture trials conducted in village ponds (Middendorp and Verreth, in press). In experiment 2, heavy rains caused ground water upwelling in the reservoir where the cages were placed. During that period (about 10 days), the tilapia were observed gulping for air until about 1000 hours, indicating low oxygen levels. This may have caused the relatively higher feed conversion ratios obtained in experiment 2. Compared to experiment 2 and to the mentioned literature data, the SGR, FCR and daily returns were rather favorable in experiment 1. The smaller fish size in experiment 1 may partly explain the differences in SGR between both experiments. However, it cannot account entirely for the differences in FCR, feeding costs and daily returns. Given the oxygen problems during the course of experiment 2, it is hypothesized that the quality of the surrounding water may be related to these differences.

Rice bran was an appropriate cheap bulk ingredient and binder. The water stability of the air-dried pellets based on rice bran was generally less than five minutes, and they sank quickly. However, this did not pose any problem, because the tilapia fed voraciously, leaving no time for the pellets to crumble or to pass through the cage mesh. The commercial pellets remained intact and floating for three or more hours.

Many soybean varieties are limiting in methionine and the vitamin B complex, and some also contain toxic factors such as a trypsin inhibitor or hemaglutins (Jauncey and Ross 1982). The origin of the soybean meal used in our experiments is not known. Nevertheless, partial fishmeal substitution by soybean meal (56% of the fishmeal was replaced by soybean meal in diet 5; 40% in diet 6) did not inhibit growth or feed conversion. Small differences between treatments may have been masked by the higher FCRs obtained or by the 15% fish meal still present in the feeds. Jackson et al. (1982), Viola and Arieli (1983) and Tacon et al. (1983) could not detect growth inhibition in tilapia cage cultures due to soybean-containing diets. However, in tank cultures, replacing 30% of the fishmeal by soybean meal did depress SGR and FCR at a dietary protein content of 32% but at a protein level of 24%, the growth inhibiting effect of fishmeal substitution by soybean meal could not be detected (Shiau et al. 1987). Therefore, it is concluded that the results of the present study corroborate those reported in the literature.

In cage culture of tilapia, there is increasing evidence that natural feeds may contribute considerably to tilapia growth. In cages, tilapia graze the aufwuchs off the sides (Middendorp and Verreth, this vol.).

Protein, vitamins and minerals may be obtained by the tilapia from the "green water" full of algae and organic particles (Edwards 1980 in Schroeder 1983a; Schroeder 1983b; Edwards et al. 1985; Dicskson 1987; Middendorp and Verreth, in press). According to Guerrero (1980) and Wannigama et al. (1982), for tilapia cage culture, a dietary protein content of 20% would be sufficient, while from laboratory studies usually protein levels of 30% or more are recommended (Mazid et al. 1979; Jauncey 1982; Siddiqui et al. 1988). In the present study, in experiment 2, natural feeds may well have contributed to the absence of significant differences between diets with a 23 and 27% protein content. In the same experiment, methionine, which is often limiting in diets with soybean meal, may have been obtained directly from the water surrounding the cages or from the aufwuchs growing on them.

Nevertheless, the significant linear relation between dietary protein content and SGR, as found in the first experiment, demonstrates that also in small-scale cage cultures, tilapia respond to dietary protein as in the mentioned laboratory studies. Obviously, from a production point of view, protein-rich diets are preferable, also for small-scale tilapia culture in cages.

Catfish feed was the most expensive feed ($B \cdot kg^{-1}$) while the cost of tilapia feed fell in the same range as the home-mixed diets. Nevertheless, when expressed in $B \cdot kg^{-1}$ of protein, there was no difference between the catfish and the tilapia feed. Cattle concentrate, fishmeal and soybean meal were considerably cheaper sources of crude protein.

Diet 1 (catfish feed) gave the highest SGR and the best FCR. However, when compared on the basis of feeding costs per kg fish produced, the home-mixed diet 4 (17% fishmeal + 30% soybean meal) was significantly cheaper than diet 1. Feeding costs of diet 4 were also considerably lower than of diets 2 and 3. At high market prices (25 $B \cdot kg^{-1}$), the daily returns (which are a function of feeding costs, production time and market price) were slightly higher for diet 1 than for diet 4. At less favorable market prices, the difference was virtually nil (Table 3).

Encouraged by the results obtained with diet 4, the effects of partial substitution of fishmeal by soybean meal were further studied in experiment 2. Expressed per kg protein, soybean meal is 22% cheaper than fishmeal, making substitution economically interesting. Unfortunately, the results with regard to soybean substitution were inconclusive.

Sound farm management should aim to optimize the farm's rentability. As such, the returns per unit of time are a major criterion

Table 3. Mean weights at stocking and at harvest, mean specific growth rate (SGR), feed conversion ratios (FCR), feeding rate (R) and feeding costs obtained in small cage culture of tilapia (*Oreochromis niloticus*) using different diets. Numbers between brackets refer to the corresponding coefficients of variation (%). The F-values were obtained through analyses of variance. Daily returns were estimated at selling price of 20 B·kg^{-1}.

	Initial weight (g)	Final weight (g)	SGR (%BW·day^{-1})	FCR	Feeding rate (%BW·day^{-1})	Feeding costs (B·kg^{-1} fish)	Daily return (B·kg^{-1}day^{-1})
Experiment 1							
1	69.0^{a} (7.3)	155.3^{a} (4.4)	2.32^{a} (4.4)	0.96^{a} (6.2)	2.23^{ab} (4.6)	11.52^{a} (6.2)	0.28
2	67.7^{a} (4.0)	116.9^{c} (2.3)	1.56^{c} (7.8)	1.51^{b} (7.3)	2.36^{ab} (1.0)	11.34^{ab} (7.3)	0.20
3	69.7^{a} (8.3)	110.5^{c} (3.7)	1.32^{d} (13.1)	1.83^{c} (14.9)	2.40^{a} (3.6)	11.30^{ab} (14.9)	0.17
4	70.5^{a} (2.7)	133.5^{b} (2.6)	1.82^{b} (3.6)	1.20^{ab} (2.5)	2.20^{b} (2.9)	9.24^{b} (2.5)	0.28
F-values	0.33	77.72**	49.02**	25.26**	6.69**	4.53*	
Experiment 2							
5	110.7 (7.8)	168.3 (6.7)	1.17 (7.6)	2.38 (18.0)	2.75 (9.2)	17.53 (18.1)	0.04
6	110.8 (5.2)	165.7 (9.7)	1.11 (12.2)	2.68 (16.5)	2.94 (10.7)	17.20 (16.5)	0.05
7	110.7 (6.0)	165.8 (5.2)	1.12 (14.0)	2.49 (12.9)	2.76 (1.1)	19.73 (13.0)	0.00
8	103.1 (7.7)	159.1 (6.7)	1.21 (7.6)	2.22 (9.2)	2.67 (3.3)	14.99 (9.1)	0.09
F-values:							
Protein (A)	1.03	0.62	0.06	0.00	0.21	3.96	
Soybean (B)	1.12	0.58	0.24	0.06	1.63	0.00	
A * B	1.12	0.13	1.23	2.39	1.88	2.89	

* $P<0.05$; ** $P<0.01$;
means with different superscripts are significantly different (Tukey, $P<0.05$).

to develop sound management strategies. According to this criterion, the present study reveals that in northeastern Thailand, small-scale cage culture of tilapia would better use commercial catfish feeds or a protein-rich diet. It assures excellent growth and production results and maintains the fish in good condition. The daily returns with diet 1 were always the highest, although not always better than with home-mixed diets.

Nevertheless, this strategy may prove to be unsuitable to develop commercial aquaculture among small-scale farmers. This social target group has a strong attitude towards minimizing risks instead of optimizing farm rentability. For them, lower feeding costs per kg fish produced are likely more important than higher daily returns. A slightly longer rearing period is not perceived as a loss. While introducing tilapia cage culture into villages, extension workers learned that farmers strongly preferred low feed costs, even when this implied lower growth rates because of the inferior feed quality. Apparently, farmers confused "feed costs" with "feeding costs per kg fish produced" in their attempt to minimize their (cash) risks. The price of the feed was an important asset for the successful introduction of cage culture, even after the profitability and the ease of use of commercial floating pellets had been demonstrated to the farmers in their own hapas (Middendorp and Verreth, in press). Other disadvantages, such as the limited shelf life (2-3 days) of the home-mixed feeds and the labor requirements to prepare them, are thereby easily accepted.

For a successful introduction of cage culture of tilapia among small-scale rural farmers in northeastern Thailand, a development strategy based on the use of inexpensive, home-mixed diets is recommended. In a later phase, if cage culture becomes a more important farm activity, farmers may change their attitude and opt for the use of commercial feeds. The present study demonstrated that compound feeds based on rice bran and fishmeal can be applied for a first introduction of commercial aquaculture among small-scale farmers. Feeding costs per kg fish produced are similar to those of commercial feeds. Farmers may obtain the bulk ingredient (rice bran) at little or no cost, making a home-mixed diet even more competitive than calculated in this study (in our calculations its market price has been used). Further, a compound feed based on rice bran with one or two ingredients is simple to prepare and above all, attractive to the farmers because of its low price.

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