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Selection of a commercial feed for Nile tilapia (*Oreochromis niloticus*) broodfish breeding in a hapa-in-pond system

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Abstract

A 95-day trial was conducted on a commercial farm in Thailand to compare the performance of three locally available feeds on the seed production of Nile tilapia (*Oreochromis niloticus*). Three hundred and sixty female Nile tilapia (mean weight $\pm$ SE, 91.5 ± 2.3 g) with the same numbers of male (123.4 ± 2.1 g) were stocked in each of 12 large nylon hapas suspended in two fertilized earthen ponds. An estimated 16 million eggs and yolk-sac fry were collected from the mouths of incubating females using hand nets at 5-day intervals. Broodfish were fed near to satiation twice daily. The female groups fed with large and small catfish pellets produced 27% and 30% more ($P < 0.05$) seed, respectively, as compared to those females that were fed a herbivorous diet. Seed outputs from the catfish pellet-fed fish were 138 ± 6 and 141 ± 5 seed m^{-2} day^{-1}, respectively, while that from herbivorous feed was 108 ± 2 seed m^{-2} day^{-1}. Broodfish consumed the small catfish pellets more readily than the large catfish pellets and grew faster on this diet. These results showed that excess energy enhanced somatic growth rather than the reproductive output of the fish. The number of seed per gram of feed was significantly higher ($P < 0.05$), which resulted in the lowest production cost when the females were fed with the large catfish pellets as compared to the females that received the smaller catfish pellets and the

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herbivorous feed. Overall seed yield and the clutches started to decline after the second month of the experimental period regardless of the type of feed given, showing quadratic relations. It indicated that an appropriate feed with a sound feeding strategy is required to minimize hapa fouling and maintain good water quality, and thereby produce high seed yield for longer periods.

Keywords: Nile tilapia; Seed production; Hapa-in pond; Feed selection; Feed quality

1. Introduction

Adult Nile tilapia (*Oreochromis niloticus*) are omnivores (Philippart and Ruwet, 1982), and feed on detritus, blue green or green algae, diatoms, macrophytes and bacteria (Bowen, 1982). Selection of feed for tilapia broodfish depends mainly on the culture system used. In traditional systems, tilapia broodfish are reared in ponds with or without supplementary feed and fry are collected from the edges of the ponds. Fry productivity is usually low because of incomplete harvesting, mortality due to adverse environmental conditions, predation by other fish, cannibalism by older fry and reduction in spawning frequency due to presence of fry (Mires, 1982; Macintosh and Little, 1995).

A hatchery technique, using a hapa-in-pond system, has been developed through intensive research efforts over the last decade (AASP, 1996; Little et al., 1995, 1997; Bhujel et al., 1998). This involves spawning of broodfish in large nylon hapas suspended in fertilized ponds. There is artificial incubation of eggs and yolk-sac fry (seed) collected at 5–7-day intervals from the mouths of females. This technology has been commercialized recently and proven to be economically viable (Little et al., 1997; Bhujel, 1997). Adoption of this technology is now taking place rapidly because of its ability to deliver large quantities of good quality fry predictably (Bhujel et al., 1998).

In tilapia, quantity and quality of food affects both the frequency of spawning (Hughes and Behrends, 1983; Guerrero and Guerrero, 1985; Macintosh and Little, 1995) and the number of seed per clutch (e.g. Guerrero and Guerrero, 1985; Rana, 1986, 1988; Macintosh and Little, 1995). The availability and cost of broodstock feeds are major factors considered by commercial hatcheries but most nutritional trials to date have been conducted in clear water systems with semi-purified diets (e.g. Wee and Tuan, 1988; Gunasekera et al., 1996a,b). So far, no research has been carried out to investigate suitable types of feed for tilapia broodfish managed intensively in hapas installed in fertilized ponds where natural food provides a considerable proportion of the nutritional requirements. Commercial floating pellets have been available in Thailand for more than a decade but recently a larger range of size and formulations have been marketed. None, however, are manufactured specifically for tilapia broodfish, although good results have been obtained using floating catfish pellets (Little et al., 1993). Typically, feed manufacturers have not been interested in producing specific broodfish diets because of substantially lower demand (Springate and Bromage, 1983). However, large-scale tilapia hatcheries in Thailand use more than 60,000 working broodfish to produce 5–10 million fry per month, and the broodstock require 2–4 t of feed per month (Little et al., 1997;

Bhujel, 2000). Selection of feed is, therefore, very important as its quality is directly associated with the seed output and the production cost.

Hapa fouling is one of the major problems for the hapa-based system (Bhujel, 2000). It reduces the exchange of water (Littlewood, 1990; Paul and Davies, 1986; Claereboudt et al., 1994) affecting natural food availability (Paul and Davies, 1986; Claereboudt et al., 1994) and dissolved oxygen levels (Claereboudt et al., 1994; Dubost et al., 1996). Poor water quality has been implicated as a possible cause of low fertilization and poor viability of eggs or embryos resulting in low seed output (Ambali, 1990; Bevis, 1994). Algae, fish faeces and particulate materials suspended in water column are the major causes of the fouling (WHOI, 1952; Dubost et al., 1996) but the effects of quantity and quality of feed inputs on fouling and seed output in green water systems have not been established. This study was, therefore, conducted to compare the performance of three locally available feeds on commercial seed production by Nile tilapia in a hapa-in-pond system.

2. Materials and methods

A 95-day trial was conducted at Nam Sai Farm, a commercial tilapia hatchery, located in Prachinburi Province, Thailand. Two catfish feeds and a herbivorous fish feed (see Table 1 for feed compositions) manufactured by Chareon Pokphand (CP) (Thailand) were tested on 12 broodfish groups stocked in 12 large nylon hapas (24×5 m^2) installed in two earthen ponds (0.20 and 0.23 ha). Each type of feed was, therefore, tested on four replicate groups of broodfish (two replicate groups in each pond). A constant water depth of 0.6 m inside each hapa was maintained throughout the trial. The ponds used for the trial were fertilized weekly with NPK-fertilizer (16-20-0: N, P_2O_5, K_20,) at 4-kg nitrogen and 2-kg phosphorous ha^{-1} day^{-1}. The *Chitralada* strain of Nile tilapia (*O. niloticus* L.) used were originally obtained from the Asian Institute of Technology (AIT). The broodfish used for the trial were produced on the farm. Before use in the trial, the broodfish fry were nursed in a hapa (40 m^2) installed in a pond for

Table 1
General features of commercial feeds used in the trial conducted in a hapa-in-pond system to select a suitable commercial feed for Nile tilapia (*O. niloticus*) broodfish

Commercial feeds	Feed price[a] (Baht[b]/kg)	Physical and chemical properties of feeds[a]				
		Pellet size (mm)	Crude protein (%)	Fat (%)	Crude fiber (%)	Moisture (%)
Herbivorous feed	8.0	5–6	15.5	4	10	12
Catfish feeds						
Large pellets	13.7	5	25	4	8	12
Small pellets	15.4	3	30	4	8	12

[a] Source: Chareon Pokphand, Thailand.
[b] 1 US$ = 37 Baht.

about 4 months, and transferred to a pond fertilized with chicken manure and reared for the maturation period of about 2 months. The mature broodfish ranged in size from 80 to 150 g. They were selected, manually sexed and kept separately in hapas for 2–3 days. A total of 360 females (91.5 ± 1.0 g) and the same number of males (123.4 ± 0.9 g) were counted, batch weighed and stocked in each large hapa.

Twelve large waterproof metal cans (6 kg feed can^{-1}) were used to store the feeds. The cans were loaded on a handcart and brought to the pond site to feed fish twice daily at 0900 and 1600 h except on the morning of the day of each seed harvest, when feeding only took place in the afternoon. The broodfish were fed near to satiation for the first month. The amount of feed consumed was recorded at each feeding and calculated for each 5-day period of seed harvest intervals. The feeding rate was fixed for the remaining 2 months based on the amount consumed in the first month. Seed was harvested from the mouths of incubating females with hand nets at 5-day intervals, graded by stage of development, and batch weighed (Little et al., 1993). A sample of 200 seed from each stage was counted and weighed after each seed harvest in order to estimate total seed numbers. Two hapas were used for each replicate group of broodfish. At each seed harvest, used hapas were exchanged, sun-dried for about 3 h, folded, weighed and kept in an open shed until the following seed harvest. The difference between the initial hapa weight and the weight at each seed harvest was taken as a measure of hapa fouling. Broodfish were counted and batch-weighed monthly. A total of 36 females and 29 males were randomly sampled for initial gonado-somatic index (GSI) and four fish of each sex, from each replicate hapa were sampled for final GSI. The following parameters were considered for the comparison among the treatment feeds:

(a) Seed yield, i.e. culture system's productivity = number of eggs or yolk-sac fry m^{-2} of hapa space day^{-1}

(b) Seed output, i.e. productivity of the input used = number of eggs or yolk-sac fry g^{-1} of feed or protein

(c) Clutch, a group of eggs or yolk-sac fry collected from a female per harvest = number of spawned female

(d) Clutch size, i.e. no. of eggs or yolk-sac fry per clutch = total estimated seed total number of $clutches^{-1}$

(e) Daily weight gain = (Final weight − initial weight) number of culture $days^{-1}$

(f) Seed production cost = variable cost + fixed cost (all costs were based on the seed yield per unit area).

Dissolved oxygen (DO) and temperature were measured at a depth of 30 cm both inside and outside each hapa at 10-day intervals at 0615 and 1500 h with a portable DO meter (YSI model 58). Multi-factor ANOVA (Statgraphics ver. 7) was used to test the effects of feed type, seed harvest cycle and the pond. Effects of pond and the seed harvest cycle were separated considering them as blocks. Means of the treatment feeds were then compared using Tukey's multiple range test as well as Student's *t*-test. Cost of seed production was calculated based on the actual prices paid by the commercial hatchery located in Central Thailand.

3. Results

3.1. Seed yield and clutches

Females fed with the large and small catfish pellets produced 27% and 30% more ($P < 0.05$) seed (eggs and yolk-sac fry), respectively, than was collected from the females fed with the herbivorous feed (Table 2 and Fig. 1). The two catfish pellets yielded similar seed output ($P > 0.05$). The females fed with large and small catfish pellets had 20% and 17% more clutches, respectively, compared to the females fed with the herbivorous feed (Table 2, Fig. 2). Feed type had no effect on the individual size of harvested seed. Overall seed yield and the clutches started to decline after the second month of the experimental period regardless of feed type given showing quadratic relations (Figs. 1 and 2).

3.2. Broodfish growth

Final mean weights and the daily weight gains of both females and males fed with small catfish pellets were highest and those fed with the herbivorous diet were the lowest ($P < 0.05$, Table 2). Mean weights of females and males increased significantly ($P < 0.05$) in each month regardless of the feed treatment. Final GSI of females and males, the means of which ranged from 2.57% to 3.22% and from 0.64% to 0.81%, respectively, were not affected by the feed type ($P > 0.05$).

3.3. Feed consumption

Broodfish consumed small catfish pellets more ($P < 0.05$) than the large catfish pellets (Table 2). Seed output per gram of feed was significantly higher ($P < 0.05$) from

Table 2
Growth and reproductive performance of Nile tilapia (*O. niloticus*) broodfish from the trial conducted in a hapa-in-pond system

Broodfish growth, feed and reproductive parameters	Herbivorous feed (HF)	Catfish feeds	
		Large pellets (LCP)	Small pellets (SCP)
Female weights			
Initial	91 ± 1^a	93 ± 2^a	91 ± 2^a
Final	179 ± 6^a	215 ± 8^b	264 ± 18^c
Weight gain (g fish^{-1} day^{-1})	0.9 ± 0.1^a	1.3 ± 0.1^b	1.8 ± 0.1^c
Male weights			
Initial	123 ± 1^a	124 ± 2^a	123 ± 1^a
Final	265 ± 9^a	306 ± 4^b	350 ± 7^c
Weight gain (g fish^{-1} day^{-1})	1.5 ± 0.1^a	1.9 ± 0.1^b	2.4 ± 0.1^c
Total feed consumed (kg hapa^{-1})	124.4 ± 4.0^a	135 ± 6.1^a	167.5 ± 1.7^b
Clutch hapa^{-1} harvest^{-1}	70 ± 2^a	84 ± 3^b	82 ± 4^b
Seed yield (no. m^{-2} day^{-1})	108 ± 2^a	138 ± 6^b	141 ± 5^b
Seed output (no. g^{-1} feed)	9 ± 1^a	10 ± 1^b	9 ± 1^a
Seed output (no. g^{-1} protein)	60 ± 7^c	43 ± 4^b	30 ± 3^a

Mean values in rows with same superscripts are not significantly different ($P > 0.05$).

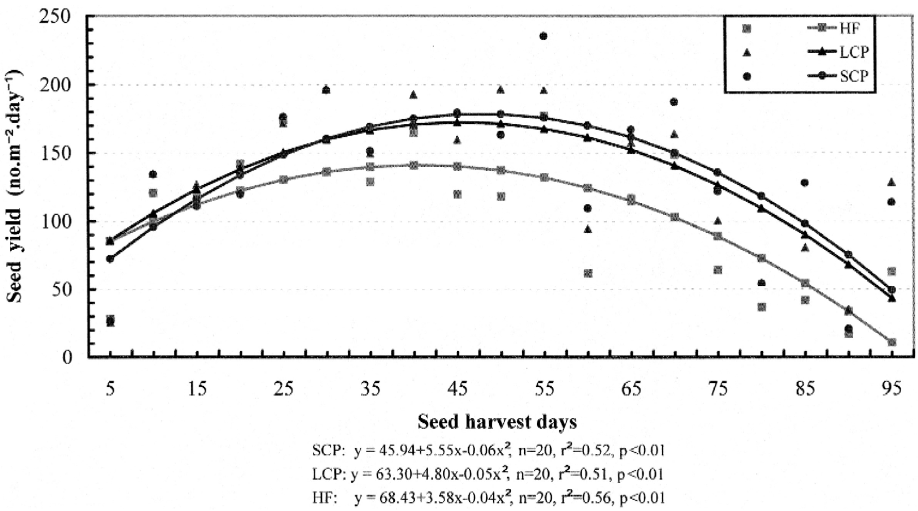

Fig. 1. Seed yield (no. m^{-2} day^{-1}) of Nile tilapia (*O. niloticus*) bred in a hapa-in-pond system fed with small catfish pellets (SCP), large catfish pellets (LCP) and a herbivorous feed (HF).

the large catfish pellet treatment than the other two feeds tested (Table 2). The seed output per gram of protein decreased ($P < 0.05$) with the increase in dietary protein.

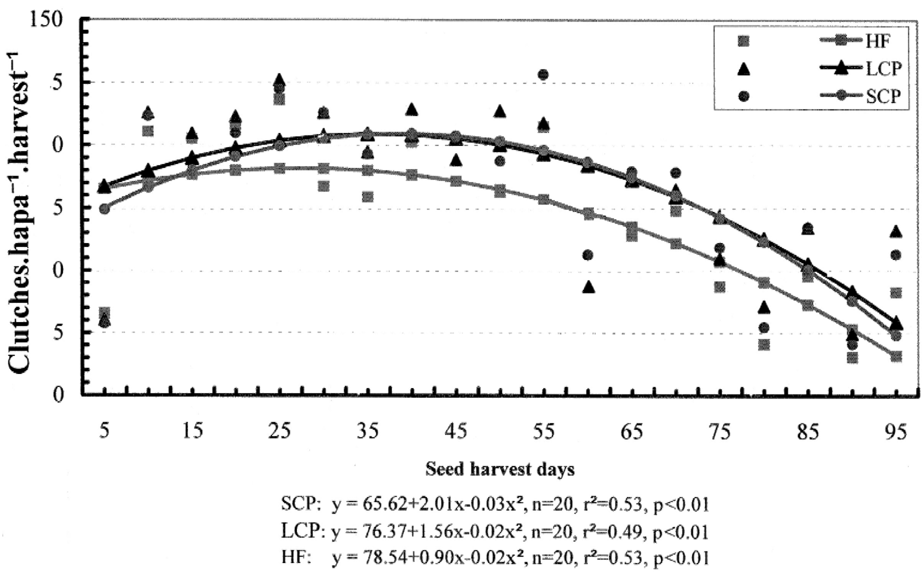

Fig. 2. Number of clutches collected per hapa per harvest from Nile tilapia (*O. niloticus*) bred in a hapa-in-pond system fed with small catfish pellets (SCP), large catfish pellets (LCP) and a herbivorous feed (HF).

3.4. Hapa fouling

Degree of hapa fouling as measured by increase in hapa weight was affected by treatment diets (Table 3). Hapas with fish fed the small catfish pellets containing 30% CP were about 11% more fouled than from the large catfish pellets ($P < 0.05$). However, fouling was similar ($P > 0.05$) in the other two treatments. A similar trend in levels of hapa fouling over time was observed for all the diets, showing a peak of up to 12.4 kg foul per hapa at around 15 days.

3.5. Water quality

Early morning dissolved oxygen (DO) levels decreased a month after fish stocking. DO levels outside the hapas were higher than inside the hapas for the first month, but this situation was reversed after this time. Morning and afternoon DO levels were lower both inside the hapas when fish were fed with the small catfish pellets compared to the other two feeds (Table 3). Both morning and afternoon temperature increased gradually over the experimental period. However, no effects were observed related to the type of feed.

3.6. Cost of seed production

Production cost per seed was 22–23% higher from the fish fed with the herbivorous diet as compared to the two catfish pellets (Table 4). Variable and fixed costs constituted two-thirds and one-third of the total seed production costs in hapa-based seed production, respectively. Labor was the major cost, accounting for one-third of the total cost of

Table 3
Hapa fouling and water quality parameters during the trial conducted in a hapa-in-pond system to select a suitable commercial feed for Nile tilapia (*O. niloticus*) broodfish

Broodfish growth, feed and reproductive parameters	Herbivorous feed (HF)	Catfish feeds	
		Large pellets (LCP)	Small pellets (SCP)
Hapa fouling (kg hapa^{-1} cycle^{-1})			
Mean	6.8 ± 0.6^{ab}	6.6 ± 0.6^{a}	7.3 ± 0.8^{b}
Range	5.1–10.2	5.3–10.5	5.5–12.4
Mean temperature (°C) range			
at 0615 h	25.6–30.9	25.7–30.8	25.6–30.8
at 1500 h	29.8–34.5	29.6–34.4	29.6–34.5
Mean dissolved oxygen (mg^{-1} l) range			
at 0615 h	0.6–3.9	0.7–3.7	0.3–3.6
at 1500 h	9.4–14.1	10.1–15.9	7.7–13.0

Mean values in rows with same superscripts are not significantly different ($P > 0.05$).

Table 4
Production cost of eggs or yolk-sac fry of Nile tilapia (*O. niloticus*) spawned in a hapa-in-pond system using three commercial feeds (calculation based on the local conditions of Central Thailand)

Items	Production costs (Baht rai^{-1} month^{-1})		
	Herbivorous feed (HF)	Catfish feeds	
		Large pellet (LCP)	Small pellet (SCP)
(A) Fixed cost			
(1) Land rent	313	313	313
(2) Electricity and water	86	86	86
(3) Office supplies	165	165	165
(4) Management	551	551	551
(5) Depreciation	909	909	909
Total fixed cost	2024	2024	2024
(B) Variable cost			
(6) Broodfish	249	231	210
(7) Feed	763	828	1027
(8) Fertilizer and lime	474	474	474
(9) Fuel, test kits, etc.	49	49	50
(10) Labor	1781	1970	1974
(11) Miscellaneous	500	500	500
Total variable costs	3816	4052	4235
(C) Total cost	5840	6076	6259
(D) Total seed production (million rai^{-1} month^{-1})	894,240	1,142,640	1,167,480
(E) Production cost (Baht 100,000 seed^{-1})	653	532	536

1 rai land = 1600 m^2 and 37 Baht = 1 US$.

seed production in this system. Other major costs involved were depreciation of equipment and machines, and the costs of feed and management.

4. Discussion

The present study showed that females fed with the large and small catfish pellets produced 20% and 17% more clutches, respectively, yielding 27% and 30% more seed per unit area of culture system compared with the herbivorous feed. The higher increments in the seed output compared with the number of clutches showed that the females fed with the catfish pellets produced larger clutch sizes as seed output is a function of number of clutches and the clutch size. The increase in clutch size was most probably due to the increase in female weight (e.g. Guerrero and Guerrero, 1985; Rana, 1986, 1988; Macintosh and Little, 1995), which probably resulted from higher feed or energy intake. The increment in the clutches or the number of females spawned was probably due to the closeness of the crude protein level of the catfish pellets to the optimum level required for broodfish compared with that of herbivorous feed (De Silva and Anderson, 1995).

Greater consumption of small catfish pellets than both the large catfish pellets and the herbivorous diet could have been due either to the difference in pellet size or dietary protein level. Results indicated that pellet size had considerable effects on feed consumption. Smaller pellets might be relatively easier to eat and may have been preferred by the broodfish. However, no systematic study has been carried out so far on this aspect. The results also indicated that dietary protein level might have been associated with feed consumption. Higher protein diet might be more palatable, resulting in greater consumption that affected reproductive performance. Several authors have found that dietary protein level affect reproductive performance in tilapia. Gunasekera et al. (1996a) found that brooders fed with 10% crude protein diet produced less seed due to prolonged spawning intervals. Wee and Tuan (1988) found that broodfish that were fed with 20% CP diet produced less seed compared to fish fed medium protein (27.6% and 35% CP) diets. Santiago et al. (1985) found that a 20% crude protein diet was resulted in lower seed production, compared with a 40% CP diet.

In the present study, there was no difference between the two catfish pellets (25% and 30% CP) in terms of seed output although smaller pellets were consumed more and resulted in bigger females. Gunasekera et al. (1996a) also did not find any difference between 20% and 35% crude protein diets for broodfish. However, our study showed that the higher protein diet was lower in terms of protein conversion efficiency into reproductive output indicating that neither more feed nor higher protein diet increased number of egg clutches or the clutch size. This was also supported by Wee and Tuan (1988) who found that 42.6% and 50.1% protein diets were less seed productive compared with 27.5% and 35% CP diet. A negative trend in total number of spawnings per female with the dietary protein level (20–50% CP) was also reported by De Silva and Radampola (1990). The present study clearly showed that excess energy accumulates in the form of somatic growth resulting in bigger females. Normally, commercial tilapia hatcheries in Thailand discard females larger than 250 g as they are difficult to handle during seed collection, occupy more space, consume more feed, and are more susceptible to diseases and adverse environmental conditions. High feeding rates and high protein diets are, therefore, unnecessary for Nile tilapia (Santiago et al., 1985).

In addition to the dietary level of protein, its quality or the amino acid balance might be more important for reproduction. Santiago et al. (1988) have reported that inclusion of *Leucaena leucocephala* leaf meal at more than 40% to replace fish meal decreased weight of female Nile tilapia resulting in low fry production. The underlying reason might be an imbalance of amino acids in the vegetable protein. Similarly, Cumaratunga and Thabrew (1989) have also found that Nile tilapia females fed with a diet containing fishmeal, instead of legume meal, had better ovarian growth and larger oocytes. Cuttlefish meal has been found to be more beneficial for egg viability, hatchability and condition of larvae (Watanabe et al., 1984). Chang et al. (1988) have also collected more seed from red tilapia when fed with eel diet (44% CP) as compared to tilapia diet (24% CP) and trash fish (21.7% CP). These studies clearly indicate that quality of protein is also very important in broodfish performance. The protein quality or the assumed low level of fishmeal of the herbivorous diet in our study might be the main reason for the low seed output. As no systematic work has been carried out, so far, to determine the optimal level of amino acids for reproduction, the levels optimal for growth are considered to be optimal for reproduction as well (De Silva and Anderson, 1995).

The other aspects of this study were to investigate the effects of feed type on hapa fouling and water quality. The highest level of hapa fouling, as measured by the increments in the weight of hapa, was obtained with the small catfish pellets (30% CP). Relatively lower levels of dissolved oxygen inside and outside the hapa fed with this feed indicated that quantity and the quality of feed had effects on hapa fouling. It also showed that higher nutrient inputs increased hapa fouling and negatively affected the water quality. The decreasing trends of seed yields and clutches after reaching the peak might be due to the effect of hapa fouling and the deteriorating water quality. It indicated that an appropriate feed with sound feeding strategy is necessary in order to minimize hapa fouling and maintain good water quality for the continuous achievement of high seed yield for longer period.

Comparison of seed production cost among the diets tested was the ultimate purpose of this trial. The difference in the cost of seed production was mainly due to the price and the amount of feed used and the total seed output. Feed cost was lower for herbivorous feed but low seed output resulted in higher production cost per seed. Although, seed output from small catfish pellet was higher, the production cost per seed was relatively higher than for the large catfish pellet due to higher feed price and greater feed consumption. Nevertheless, Nile tilapia fed with catfish pellets, though they were about twofold costlier in price, produced seed at lower cost than the fish fed the herbivorous feed.

It is clear from this study that the herbivorous diet resulted in lower seed production and was less profitable compared to the two catfish pellets in terms of seed output of Nile tilapia in a green water system. It also indicated that neither high protein diets nor the higher feeding levels were beneficial in terms of seed output in tilapia, which was also concluded by Mironova (1978). At present, most of the hapa-based commercial tilapia hatcheries in Thailand use 25–30% crude protein diets; however, this study showed that 25% crude protein diet is nutritionally adequate and cost effective as well. Further study may be done with the similar size of pellets with 20% CP or with higher crude protein but providing a similar amount of protein or energy by adjusting the amount of feed. Moreover, research may be done to investigate the suitability of several other types of commercial feeds available on the market.

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