Feeding rate of red tilapia (*Oreochromis niloticus mossambicus*) and correlation between feed intake and water quality

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Abstract

This study investigated the feeding rate and correlation between feed intake (FI) and water quality parameters of red tilapia cage culture suspended in earthen ponds. The first experiment conducted in laboratory condition to investigate the feeding rate and the results show that the feeding rates in the laboratory of fish sizes 100, 200, 300, 400, 500, 600, 700 and 800 g were 3.61±0.22, 3.22±0.43, 2.72±0.35, 2.59±0.22, 2.27±0.11, 2.24±0.05, 2.15±0.04 and 2.07±0.04% of their body weight, respectively. The second experiment was performed in outdoor cages suspended in earthen ponds conditions. There was a negative relationship between total ammonia nitrogen (TAN) level in the pond water on FI and average daily gain (ADG). Whenever TAN level was higher than 0.5 mg L^{-1}, FI and ADG would decrease.

Keywords: feeding rate, feed intake, hybrid red tilapia, water quality

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Introduction

Tilapia is currently known as 'aquatic chicken' due to their high growth rates, adaptability to a wide range of environmental conditions and ability to grow (El-Sayed, 2006). Therefore, there has been enormous development in the farming of tilapia worldwide, making it not only the second most significant farmed fish globally, next to carp, but also the most important freshwater aquaculture species of the 21st century. The main purpose of cultivating tilapia is to raise the fish to table size in the shortest possible time (Lovell, 1989), resulting in the fact that feed makes up the largest cost of fish production, which is a challenge to most tilapia farmers (Steffens, 1989).

In Thailand, tilapia farming especially 'red tilapia' is gaining popularity due to the red color of the fish, which is similar to expensive sea species. The demand in both domestic and international markets has increased for both live fish and fish meat. Producing the red tilapia in cages suspended in ponds, feeding is one of the major production costs that affect the profitability of farming. One way to help farmers to reduce production costs is by feeding effectively, and in the right quantities, so that the fish can eat food on demand. In practice, the farmers feed their fish three times a day by hand. The purpose of the feeding is to feed the fish until they do not eat, which is the point of "Satiation". This method needs an experiment but it is labor and time-intensive. Presently, many farmers rely on feeding rates, which may not be based on the fish's demand.

The growth performance of the fish is a complex process affected by many behavioral, physiological, nutritional, and water quality factors; with behavioral (feeding rate) and water quality being recognized as two of the major factors affecting growth, feed intake, and food conversion of the fish. Previous studies have shown that there is a huge variation in feeding rate and water quality that dramatically affect tilapia Example of the studies are : the study of the influence of feeding rate and diet on the growth and survival of Nile tilapia (*Oreochromis niloticus*) (Santiago, Aldaba, & Reyes, 1987), the effect of water temperature on the growth and sex ratio of juvenile Nile tilapia *Oreochromis niloticus* (Linnaeus) reared in geothermal waters in southern Tunisia (Azaza, Dhraïef, & Kraïem, 2008), water quality and Nile tilapia growth performance under different feeding schedules (Nayara, Vanessa, Davi, Rafael, & Arcelo, 2011), and the effect of ammonia on growth and survival rate of *Tilapia rendalli* in Quail Manured Tanks (Masautso, & Musuka, 2014).

Up to date, studies of feeding rate, feeding strategies on growth performance and the effect of water quality on feed intake have been mostly done on Nile tilapia juveniles under laboratory conditions (El-Sayed, 2002; Riche, 2004 ; Caldini, RebouÇas, Cavalcante, Martins, & Marcelo, 2011). However, the knowledge of the actual feeding rate and relationship between feed intake and water quality parameters of red tilapia (*Oreochromis niloticus mossambicus*) in cages suspended in ponds during cultivation is still lacking. Therefore, this study focuses on the feeding rate of hybrid red tilapia, and the correlation between feed intake and water quality.

Methodology

1. The feeding rate of different sizes of red tilapia in the laboratory

1.1 Fish sample preparation

This experiment was conducted under laboratory conditions in the department of Aquaculture, Faculty of Fisheries, Kasetsart University, Bangkok, Thailand. The fish used in this experiment were obtained from a commercial Tilapia farm located 80 km from the laboratory. Prior to the start of the experiment, the fish were allowed a two-week acclimation period in two 10,000 L^{-1} rectangular tanks with a flow-through system, during which they were fed with 30% crude protein at 2% of their body weight, divided into three equal meals at 08:00 12:00 and 17:00 hours. All the pellets involved placing in the feeding ring (5 cm radius) to train the fish to become accustomed to swimming to the feed and facilitated to counting the feed left.

1.2 The experiment

The trial was divided into eight series of experiments according to the fish weight, which are 100, 200, 300, 400, 500, 600, 700 and 800 grams, respectively. In each experiment, three 800 L^{-1} rectangle tanks were used. Five fish were applied in each tank. To avoid the impact of water quality on the performance traits, sediment suction was performed, water was 50% exchanged every day and oxygen continuously supplied by using two air stones. Dissolved oxygen (DO) and water temperature were measured using a DO meter (YSI 550 A) and pH was measured with a Lutron pH meter 230 SD daily in the morning and evening. Total ammonia-nitrogen (TAN) and nitrite-nitrogen (NO_2-N) were examined in the laboratory by means of APHA, AWWA & WPCF (2005) for three days (day 1, 3 and 5) of the five days of each fish size.

1.3 Data analysis

The red tilapia feeding rate was calculated for each size of the fish and the data were demonstrated as the mean ± standard deviation (SD) and percentages.The differences of feeding rate of each fish size were analyzed using one-way analysis of variance (one-way ANOVA) followed by Duncan's new multiple range test (DMRT), if there are significant differences for the means in feeding rate. Data were tested for homogeneity of variance and normality of data prior to ANOVA.

Results were considered significant at 5% level of significance ($P < 0.05$). All statistical analyses were done with the Statistical Package for the Social Sciences (SPSS) Version 17 software (Chicago, Illinois, USA). Also, the fish were cared for in the optimal conditions set by the certified authority (license no. U1-02364-2558) from the Institute of Animal for Scientific Purposes Development (IAD), Thailand.

2. Correlation between feed intake and water quality in the outdoor pond conditions

2.1 Study site and experimental fish preparation

This experiment was conducted in 2 red tilapia earthen ponds, located at a tilapia fish farm in Nakhon Nayok Province, central Thailand, over the period of four months. Two ponds (A and B) with sized 1.5-2 acres were examined. Each pond contained 12 cages of 5×10×1.5 meters (width× length×depth) suspended in the water. An average of 250 grams of fish were stocked in each cage at stocking density of 900 fish per cage (12 fish/m^3). Six 5-hp paddlewheel aerators were installed at six points in the pond (Figure 1) and they were operated around 8 to 12 hours per day in the evening. Due to the time limitation for sample collection, only six cages were selected to collect the feeding rate and water quality data.

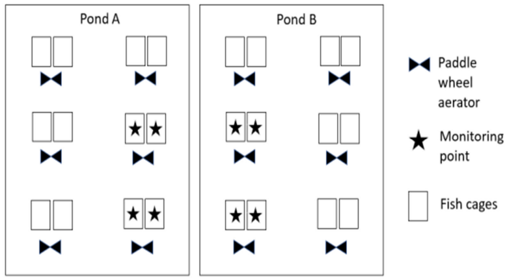

Figure 1 The distribution of cages, paddle wheel aerators, and the monitoring points of experiment.

2.2 Water quality parameters

Water sampling and water monitoring of DO, water temperature, pH, transparency, TAN, NO_2-N and chlorophyll-a (Chl a) for each sample cages were done before feeding. Altogether, 7,056 samples (2 ponds × 4 cages × 7 parameters × 3 times × 3 replicate × 14 weeks) of red tilapia pond water were checked and collected in the middle of each cage three times/day/week. DO and water temperature were measured using a DO meter (YSI 550 A). The pH of each cage was determined by using Lutron pH meter 230 SD. The transparency of the water was measured by a Secchi disc. TAN, NO_2-N and Chl a were analyzed in the laboratory at The Department of Aquaculture, Faculty of Fisheries, Kasetsart University, using standard methods (APHA, AWWA & WPCF, 2005)

2.3 Feeding management

Four fish cages in each pond were selected for feeding examination. Fish were fed with 30% protein floating pellet feed three times a day at 08:00, 12:00 and 17:00 hours by hand at the feeding rate following the result of experiment I. In the case of not enough feed for the fish, the feed was applied until satiation. The feeding time was no more than 1 hour because it was the maximum feeding time of the fish (Martins, Conceiçã, & Schrama, 2011). The amount of feed leftover was collected and calculated to find FI and the feeding rate of each fish size. This feeding rate calculation was monitored every week (one day/week) until finished the culture crop (about 4 months).

2.4 Measurement and analytical methods

During the experimental period, each month, fifty fish were randomly selected from each cage to measure total length and body weight to calculate fish weight (FW) and average daily gain (ADG) as followed:

$$\text{ADG (g/fish/day}^{-1}\text{)} = \text{weight gain (g) / time (days)}$$

This experiment was performed until the finish of the culture crop, which was over the period of four months. The experimental data were demonstrated as the mean±standard deviation (SD). The correlation between water quality, FI, and ADG was examined using the Pearson product-moment correlation coefficient. If there was a correlation, the regression analysis would be performed for estimation. All data analyses were analyzed using the Statistical Package for the Social Sciences (SPSS) 12.0 for windows (SPSS Inc., Chicago, IL, USA).

Results and discussion

1. The feeding rate of different sizes of red tilapia in the laboratory

1.1 Water quality

Averages of DO, temperature, pH, TAN and NO_2-N in the experimental tanks were 4.30±0.06 mg L^{-1}, 29.01±0.14 °C, 7.46±0.09, 0.13±0.02 mg L^{-1}, 0.05±0.01 mg L^{-1}, respectively. All water quality parameters were in the optimal range for tilapia growth. Azaza, Dhraïef, & Kraïem (2008) reported that the optimum water temperature was between 26-32 °C, and pH was in the range of 7-8 (El-Sherif, & El-Feky, 2009). DO in water of 3 mg L^{-1} should be the minimum for optimum growth of tilapia (Kolding, Haug, & Stefansson, 2008; Wang, Lefevre, Huong, Cong, & Bayley, 2009; Tran-Duy, Van dam, & Schrama, 2012). TAN concentrations should be below 0.5 mg L^{-1} for long-term exposure (Hargreaves, & Tucker, 2004; Masautso, & Musuka, 2014). Atwood, Fontenot, Tomasso, & Isely (2001) found that small-sized Nile tilapia (4.4 g) were more tolerant to NO_2-N than large fish (90.7 g). The 96 h LC_{50} of NO_2-N were 81 and 8 mg L^{-1} in small and large fish, respectively.

However, to avoid abnormal condition, nitrites should not exceed 0.25 mg L^{-1} in soft water (Lawson, 1994). The key parameters of water quality throughout the trial was shown in (Table 1).

Table 1 Mean concentration (±SD) of DO, water temperature, pH, TAN and NO_2-N in laboratory.

fish weight (g/fish)	parameter				
	DO (mg L^{-1})	water temperature (°C)	pH	TAN (mg L^{-1})	NO_2-N (mg L^{-1})
100	4.27±0.33	29.05±0.26	7.42±0.29	0.11±0.01	0.06±0.02
200	4.31±0.28	28.91±0.24	7.43±0.27	0.12±0.12	0.05±0.01
300	4.31±0.32	28.87±0.28	7.48±0.18	0.11±0.00	0.06±0.01
400	4.27±0.33	29.08±0.19	7.34±0.12	0.11±0.01	0.04±0.02
500	4.30±0.36	28.88±0.35	7.39±0.10	0.14±0.00	0.07±0.02
600	4.33±0.22	28.96±0.31	7.44±0.26	0.14±0.19	0.04±0.03
700	4.40±0.17	29.00±0.56	7.58±0.12	0.17±0.40	0.05±0.01
800	4.20±0.17	29.29±0.91	7.58±0.12	0.12±0.03	0.04±0.03
mean±SD	4.30±0.06	29.01±0.14	7.46±0.09	0.13±0.02	0.05±0.01
min.	4.20	28.87	7.34	0.11	0.04
max.	4.40	29.29	7.58	0.17	0.07

1.2 The feeding rates

The prevalence of the feed consumed by different sizes of the fish in the laboratory was statistically different ($P<0.05$) (Table 2). The feeding rates of fish weight 100 and 200 g/fish were 3.61±0.22% and 3.22±0.43% which were significantly greater than those of the other fish sizes ($P<0.05$). The feeding rate of fish weight 300 and 400 g/fish were not significantly different between each other at 2.72±0.35% and 2.59±0.22% ($P>0.05$). The feeding rate of fish weight 400, 500 and 600 g/fish were not significantly different between fish sizes at 2.59±0.22%, 2.27±0.11% and 2.24±0.05%, respectively ($P>0.05$). Also, the feeding rate of fish weight 500, 600, 700 and 800 g/fish were not significantly different between these fish sizes at 2.27±0.11%, 2.24±0.05%, 2.15±0.04% and 2.07±0.04%, respectively ($P>0.05$). The results are consistent with Riche, & Garling (2003), which reported that feeding rate will vary depending on the size. As the fish weight increases, the percentage of feeding decreases. However, Riche, & Garling (2003) reported feeding rate of 30-10, 10-6, 6-4, 4-3 and 3-1.5% for 0-1, 1-5, 5-20, 20-100 and more than 100 g of fish weights, respectively. Especially in the weight range of more than 100g, the feeding rate of 3-1.5% may not be suitable to use in the real farming conditions because ~~it~~ the range is too broad to apply for the fish sizes starting from 100 g to harvest sizes (500 g to 1,000 g).

Table 2 Means and standard deviations (SD) of red tilapia feeding rate in laboratory.

fish weight (g/fish)	feeding rate (%)
100	3.61±0.22[a]
200	3.22±0.43[a]
300	2.72±0.35[b]
400	2.59±0.22[bc]
500	2.27±0.11[cd]
600	2.24±0.05[cd]
700	2.15±0.04[d]
800	2.07±0.04[d]

Note: [a,b,c,d] Mean±SD with different superscripts differ at $p<0.05$.

2. Correlation between feed intake and water quality in the outdoor pond conditions

2.1 water quality

During the experimental period of 14 weeks, the average DO was 5.65±0.61 mg L^{-1}, temperature was 302.0±0.88 °C, pH was 7.50±0.40, TAN was 0.42± 0.16 mg L^{-1}, NO_2-N was 0.08± 0.04 mg L^{-1}, Chl a was 92.95±50.56 µg L^{-1} and transparency was 33.67±3.59 cm. All parameters were in a suitable range of tilapia culture, except the TAN of weeks between 7-10 were greater than the optimal range at 0.5 mg L^{-1}. However, the farmer started to exchange water in the ponds in the following week, the TAN concentrations were decreased to the normal ranges.

2.2 Feeding and growth performances

The average FI at the first week was 7.54±1.16 g/fish/day^{-1} and average ADG at week 2 was 6.15 ±1.13 g/fish/day^{-1}, which both FI and ADG values increased every week to week 6. Averages FI in weeks 2 to 6 were 9.07±0.16, 10.17±1.18, 11.50±1.10, 12.07±1.14 and 12.44±0.62 g/fish/day^{-1}. While, average ADG in weeks 3 to 6 were 6.10±1.04, 5.81±0.94, 5.87±0.90 and 5.77±0.83 g/fish/day^{-1}, respectively. After that in week 7 to 10, both FI and ADG values decreased since the average TAN concentrations were greater than 0.5 mg/L^{-1}. After water exchange in week 11, both FI and ADG values in week 11 to 14 increased again. The averages FI were 12.18±1.28, 12.83±1.88, 13.09±1.65 and 13.93±1.57 g/fish/day^{-1} and the average ADG were 6.16±0.59, 6.20±0.55, 5.87±0.43 and 5.63±0.40 g/fish/day^{-1}, respectively as shown in (Table 3).

2.3 Correlations between water quality, FI and ADG

Only the DO, TAN and Chl a have correlations with FI and ADG (Table 4).

Table 3 Mean concentration (± SD) of FW, FI, ADG and some water quality parameters.

week	parameters									
	FW (g/fish)	FI (g/fish/day^{-1})	ADG (g/fish/day^{-1})	DO (mg L^{-1})	water temperature (°C)	pH	TAN (mg L^{-1})	NO_2^--N (mg L^{-1})	Chl a (µg L^{-1})	transparency (cm)
1	278.14±54.12	7.54±1.16	-	6.55±1.90	28.58±0.25	8.30±0.55	0.35±0.14	0.12±0.02	40.26±26.74	28.08±4.13
2	321.19±56.84	9.07±0.16	6.15±1.13	6.54±0.45	30.48±0.18	7.42±0.53	0.42±0.08	0.09±0.02	41.01±16.49	35.99±2.13
3	363.89±60.83	10.17±1.18	6.10±1.04	5.82±0.98	31.62±0.15	6.96±0.52	0.42±0.04	0.05±0.01	41.05±3.32	38.80±1.70
4	404.56±63.79	11.50±1.10	5.81±0.94	5.04±1.23	31.42±0.31	7.00±0.51	0.38±0.06	0.04±0.01	44.13±13.53	39.17±4.48
5	445.65±66.75	12.07±1.14	5.87±0.90	4.93±1.29	31.47±0.14	6.89±0.08	0.37±0.06	0.05±0.03	38.54±20.38	36.16±5.57
6	486.04±66.54	12.44±0.62	5.77±0.83	5.22±1.39	31.03±0.20	7.06±0.16	0.43±0.04	0.06±0.01	72.24±3.14	33.56±5.03
7	516.35±65.07	11.02±1.77	4.33±0.57	5.39±0.60	29.85±0.59	7.85±0.07	0.50±0.33	0.06±0.01	108.84±117.01	29.42±6.48
8	545.12±63.60	10.09±1.79	4.11±0.50	5.54±0.22	29.84±0.57	7.79±0.07	0.56±0.21	0.10±0.02	85.98±51.39	31.95±4.00
9	570.81±62.12	9.07±1.28	3.67±0.41	5.89±0.05	29.83±0.54	7.73±0.08	0.68±0.17	0.12±0.01	97.72±31.12	34.47±1.53
10	594.96±60.65	7.94±0.29	3.45±0.36	6.36±0.10	29.81±0.51	7.67±0.08	0.74±0.11	0.14±0.00	103.69±16.99	37.00±0.95
11	638.08±59.18	12.18±1.28	6.16±0.59	4.79±0.78	29.63±0.14	7.65±0.16	0.20±0.06	0.05±0.03	118.89±23.39	34.00±1.41
12	681.19±57.70	12.83±1.88	6.20±0.55	6.40±0.08	29.72±0.07	7.51±0.23	0.22±0.02	0.06±0.03	166.21±2.83	28.00±1.88
13	722.29±57.44	13.09±1.65	5.87±0.43	5.36±0.66	29.64±0.37	7.52±0.25	0.32±0.08	0.11±0.01	187.37±14.23	32.51±2.65
14	761.69±60.29	13.93±1.57	5.63±0.40	5.24±0.59	29.93±0.14	7.63±0.11	0.27±0.05	0.16±0.02	155.39±56.60	32.22±3.42
mean± SD			5.38±1.01	5.65±0.61	30.20±0.88	7.50±0.40	0.42±0.16	0.08±0.04	92.95±50.56	33.67±3.59
minimum			3.45	4.79	28.58	6.89	0.20	0.04	38.54	28.00
maximum			6.21	6.55	31.62	8.30	0.74	0.16	187.37	39.17

Table 4 Pearson's correlation coefficients between FW, FI, ADG and some water quality parameters.

variable	factor analysis	
	FI (g/fish/day^{-1})	ADG (g/fish/day^{-1})
FI		0.41
ADG	0.41	
DO	**-0.67****	-0.11
water temperature	-0.42	-0.18
pH	-0.41	-0.33
TAN	**-0.66***	**-0.88****
NO_2-N	-0.26	-0.42
Chl a	**0.55***	-0.10
transparency	-0.11	-0.04

* Values larger than 0.5 are in bold.

2.4 Correlation between DO and FI

DO has a negative correlation to the FI. When DO means decreased, the FI increased over the culture period. The reduction of DO is caused by sediment respiration, bacterial degradation process, and the oxygen consumption of plankton that increased with the culture period (Avnimelech, & Ritvo, 2003). However, the lowest mean of DO in this study was 4.79 mg L^{-1}, which is still higher than the DO standard suitable for raising tilapia at 3 mg L^{-1} (Kolding, Haug, & Stefansson, 2008; Tran-Duy, Van dam, & Schrama, 2012). Hence, this does not affect the feeding of fish (Figure 2).

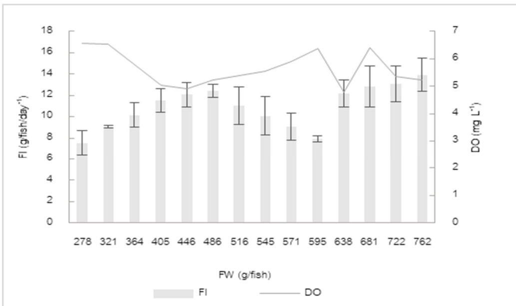

Figure 2 Correlation between DO and FI in 14 weeks of the experiment.

2.5 Correlation between TAN on FI and ADG

The results showed negative relationships between TAN and FI and ADG, When TAN is higher than 0.5 mg L^{-1}, the average FI and ADG of the fish is reduced (Figure 3 and 4). This result is consistent with other authors who also observed that high level of ammonia causes stress and produces harmful physiological responses such as osmoregulatory disturbance, kidney and branchial epithelium damage (Soderberg, 1994), retarded growth, an inefficient immune response (Cheng, Hsiao, & Chen, 2004; Pinto, Aragão, Soares, Dinis, & Conceição, 2007) and reduced survival (Jobling, 1994). Average TAN concentration of all culture systems should be lower than the proposed threshold toxicity levels for tilapia (less than 0.5 mg L^{-1}) (Hargreaves, & Tucker, 2004) because TAN concentration of above 0.5 mg L^{-1} had a tendency to harm the fish that can affect food intake, their growth and the survival of the fish (Masautso, & Musuka, 2014), which is consistent with this study's results. From these results, TAN levels tend to increase, especially after week 7 (516.35 g/fish) which may be caused by high levels of waste in the pond and no water exchange. However, it greatly reduced after week 10 (594.96 g/fish) because the farmer exchanged 40-50% of the water volume to recover water quality. During the week (week 7 to 10), it was found that the FI had decrease affecting ADG, which in week 2-6, average of ADG was 5.94±0.12, but decreased in week 7 to 10 (average TAN was higher than 0.5 mg L^{-1}) because the FI has decreased, where fish had an average ADG of 3.89±0.09 g/day, then rose again in week 11-14. The overall ADG average was 5.97±0.09 g/day.

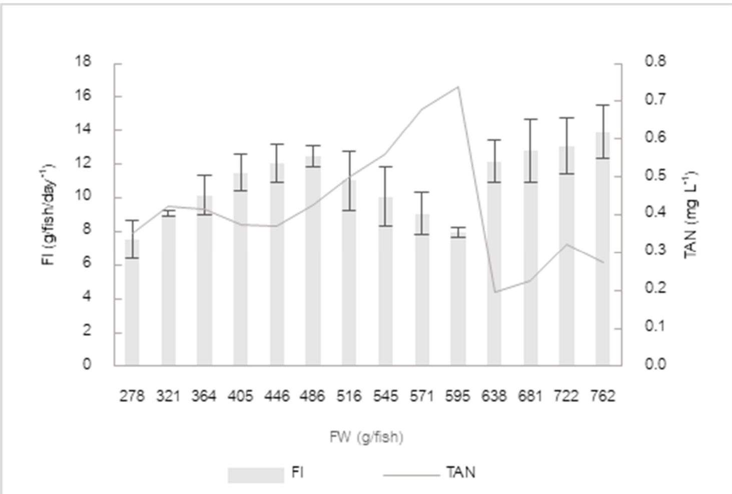

Figure 3 Correlation between TAN and FI in 14 weeks of the experiment.

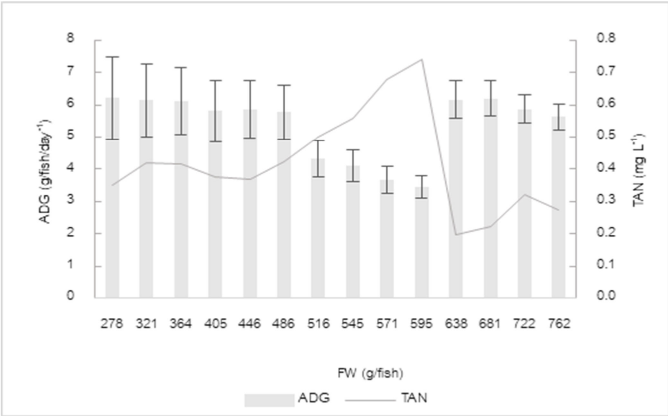

Figure 4 Correlation between TAN and ADG in 14 weeks of the experiment.

2.6 Correlation between Chl a on FI

The result showed a positive relationship between Chl a and FI. As a general rule of thumb, the amount of Chl a in the outdoor pond condition tend to increase over the culture period, which resulted from phytoplankton biomass increase (Figure 5). The result is also consistent with other researchers showing high load of nutrient from commercial feed between the crops caused phytoplankton blooms and commercial fish farming ponds, are expected to have higher Chl a concentration compared to low input ponds (extensive fish farming) due to their higher nutrient loads. (Szyper, & Lin, 1990; Little & Edwards, 2004; Kunlasak, Chitmanat, Whangchai, Promya, & Lebel, 2013).

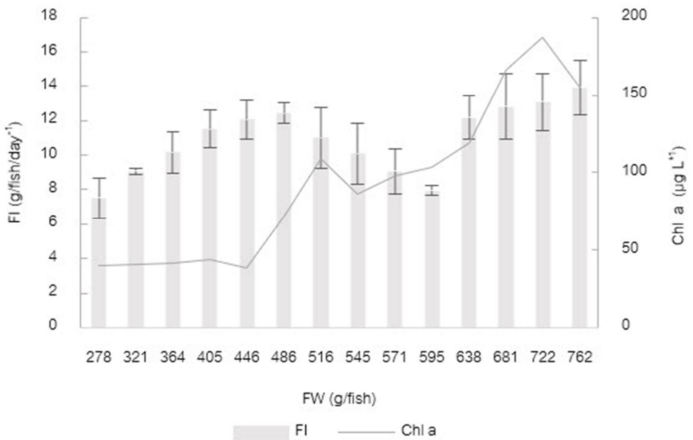

Figure 5 Correlation between Chl a and FI in 14 weeks of the experiment.

2.7 Regression analyses

The analyses indicated that DO, TAN, FW and Chl a affected FI at 45%, 43%, 38% and 30%, respectively. While TAN affected ADG at 78% (Table 5 and Figure 6).

Table 5 Factors analysis and regression model of FI and ADG.

variable	factor analysis			regression model			
	FI	ADG	model r^2	source	F	Sig.	equation
FW	0.61		0.38	significance *	7.37	0.19	FI= 0.0082 FW+6.6211
Chl a	0.55		0.30	significance *	5.28	0.04	FI = 0.0218 Chl a +8.9007
DO	-0.67		0.45	significance **	9.86	0.09	FI = -2.1735 DO+23.196
TAN	-0.66		0.43	significance *	9.23	0.01	FI = -8.2803 TAN+14.385
TAN		-0.88	0.78	significance **	42.82	0.00	ADG = -5.6854 TAN+7.756

Significance level: * Correlation is significant at the 0.05 level and ** is significant at the 0.01 level.

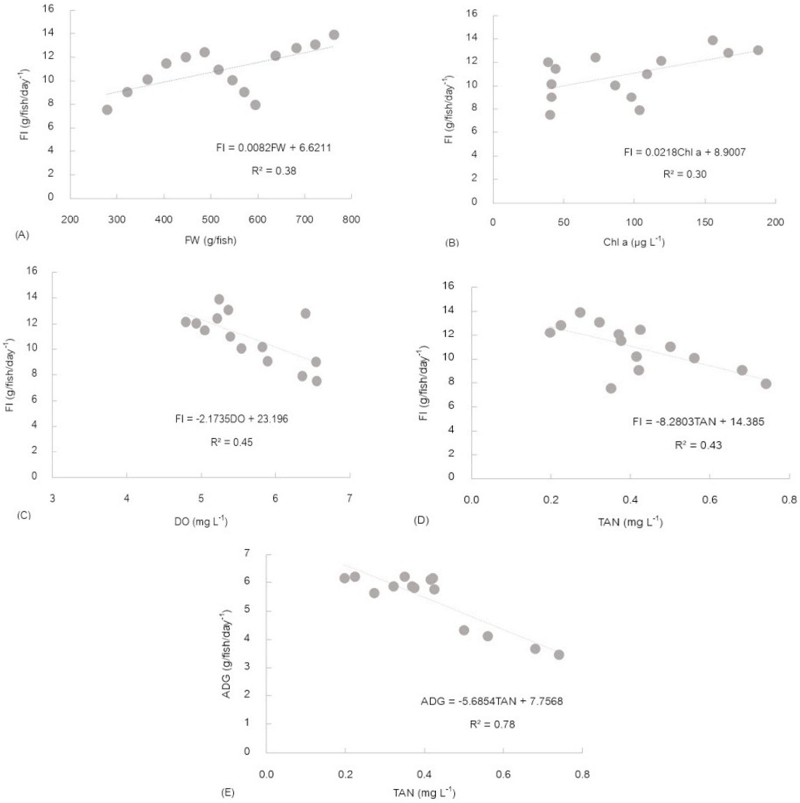

Figure 6 (A) The linear regression model of FW on FI, (B) Chl a on FI, (C) DO on FI, (D) TAN on FI and (E) TAN on ADG.

The comparison between the average FI of the fish calculated from the laboratory results and from the outdoor pond condition, reveals that in the outdoor pond condition has a higher average of 1.06 g/fish/day^{-1} in week 29-6. This is probably due to the different environments. The outdoor ponds had greater turbidity from plankton and soil particles compared with the indoor ponds or in the laboratory, so the fish were less stressed and could eat more food. This is consistent with the Hecht, & Van der Lingen (1992); Gregory, & Northcote (1993); Benfield, & Minello (1996) reports that the turbidity caused by sediment, plankton, mud, dust and organic chemicals in fish ponds should be in the range of 30-60 cm as the turbidity of the water affects the eating behavior of the fish. However, in week 7-10, fish were affected by increasing TAN concentration at more than 0.5 mg L^{-1}, resulted in the reduction of FI, which was less than the amount of feed calculated from the laboratory result. Although, the farmer exchanged the water in week 10, resulted in increasing of FI, however, it was still not at the level that should be (Table 6).

Table 6 The differences between FI in the laboratory and in the outdoor pond conditions.

week	FW (g/fish/day^{-1})	FI (g/fish/day^{-1})		
		laboratory condition	outdoor ponds conditions	differences (lab-outdoor)
week 1	278.14±54.12	7.53	7.54±1.16	0.00
week 2	321.19±56.84	8.30	9.07±0.16	-0.76
week 3	363.89±60.83	9.07	10.17±1.18	-1.10
week 4	404.56±63.79	9.79	11.50±1.10	-1.71
week 5	445.65±66.75	10.53	12.07±1.14	-1.54
week 6	486.04±66.54	11.25	12.44±0.62	-1.19
week 7	516.35±65.07	11.79	11.02±1.77	0.78
week 8	545.12±63.60	12.31	10.09±1.79	2.22
week 9	570.81±62.12	12.77	9.07±1.28	3.70
week 10	594.96±60.65	13.20	7.94±0.29	5.26
week 11	638.08±59.18	13.97	12.18±1.28	1.79
week 12	681.19±57.70	14.75	12.83±1.88	1.92
week 13	722.29±57.44	15.48	13.09±1.65	2.39
week 14	761.69±60.29	16.19	13.93±1.57	2.25

Conclusion

The results show that the feeding rate of hybrid red tilapia decreased as body weight increased. Moreover, the feeding rate of the fish in the farm was higher than in the laboratory due to environmental differences, especially with more turbidity in the farm ponds. TAN was negatively related to FI and ADG, when the TAN level was greater than 0.5 mg L^{-1}, it would affect FI and ADG.

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