

## EFFECT OF DIETARY PROTEIN INGREDIENTS FROM NON-TOXIC AGRICULTURAL FIELD SOURCES ON MEAT QUALITY OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*)

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**ABSTRACT:** This research investigated the effects of dietary protein ingredients from non-toxic agricultural field sources on the production quality of the Nile tilapia. The Nile tilapia (*Oreochromis niloticus*) is a species of freshwater fish that is of significant economic value. The experiments deployed three different dietary treatments as the tilapia feeds: pure rice bran (Treatment 1 or T1); a mixed feed of fish meal, rice bran and dried corn grains (T2); and a commercial feed (T3). The measurements of growth were taken every 14 days for a total period of 120 days, while the survival rate and the meat quality parameters with respect to color values (L\*, a\* and b\*), texture and sensory preference were determined at the start and termination and compared. The findings revealed a significant difference in the growth weights ( $p \leq 0.05$ ), with T2 achieving the greatest weights ( $75.4 \pm 26.0$  g). The average daily growth (ADG) and the feed conversion ratio (FCR) were also highest for the T2 group, with an average of  $1.27 \pm 0.12$  g/day ( $p \leq 0.05$ ) and  $1.74 \pm 0.42$  ( $p > 0.05$ ), respectively. Overall, the composition of the dietary protein ingredients from non-toxic agricultural field sources significantly influences on the meat quality and sensory preference of *O. niloticus*.

**Keywords:** Dietary protein ingredients, Non-toxic agricultural field, Meat quality, Nile tilapia

### 1. INTRODUCTION

An herbivorous fish species, the Nile tilapia or tilapia (*O. niloticus*) play a significant economic role in the global aquaculture [1]. The species is extensively cultured in over 100 countries in the tropical and subtropical regions [2]. In Thailand, tilapia farming is common and also contributes substantially to the economy. According to [3], the global production and consumption of tilapia have increased exponentially. Tilapia are easily cultured and highly tolerant to the adverse environmental conditions [4], in addition to their ability to thrive on a wide variety of nutrient sources, ranging from pond algae and bacteria to high-quality feedstuffs, such as grain, oilseeds and fishmeal [5].

The commercial feeds are commonly adopted by most fish farmers as the protein source [6]. Nonetheless, the costliness of the commercial feeds has led to the deployment of many varieties of feed ingredients as the tilapia diet, in particular the plant proteins such as rice polish [1], spirulina flakes [5] and soybean products [7]. To date, the effects of dietary protein ingredients from non-toxic agricultural field sources on the growth and meat quality of fish have largely been inconclusive.

This research has thus investigated the effects of plant protein ingredients from non-toxic agricultural field sources on the growth and meat quality of tilapia. In the experiments, three different dietary treatments were deployed as the

fish feeds and the measurements relevant to the quantity and quality of the fish subsequently determined.

### 2. MATERIALS AND METHODS

#### 2.1 Fish Source

The fingerlings of the Nile tilapia (*O. niloticus*) were obtained from Thailand's Pathum Thani Aquaculture Genetic Research Institute and transported to the hatchery at the Division of Fisheries, Rajamangala University of Technology Thanyaburi. The fingerlings were of 3–5 cm in length and were acclimatized in a plastic tank containing clean freshwater for two weeks.

#### 2.2 Experimental Design

The experiments were carried out using a completely randomized design (CRD) comprising three feed treatments: pure rice bran (T1), a mixed feed of rice bran, dried corn grains and fish meal (T2), and a commercial feed (T3). T1 and T2 were obtained from non-toxic agricultural field sources. The fingerlings were allotted into nine cages with a density of 20 fish per cage prior to the individual measurements of the weight and length. The nine cages were then divided into three equal groupings, with each grouping fed with either one of the three diets twice a day, at 08:30 a.m. and 4:00 p.m., at a rate of 3–4% of their body weight

per day. One hour after feeding, uneaten diet and fecal matter were removed from the tanks.

The proximate chemical composition (i.e. protein, lipid, fiber, ash, moisture, dry matter) in the experimental diets and resultant tilapia meat were analyzed according to the Association of Analytical Chemists (AOAC) [8]. The numbers of dead fish were also recorded during the experiment. The weight and length data were recorded every 14 days throughout the experiment to assess the fish growth. The average daily growth (ADG), the survival rate (SR) and the food conversion ratio (FCR) were respectively calculated using the following equations:

$$ADG = (W_e - W_s)/t,$$

where  $W_e$  is the weight at the end (termination) of the experiment,  $W_s$  is the weight at the start of the experiment, and  $t$  is the number of days.

$$SR = ((N_e - N_s)/N_s) \times 100,$$

where  $N_e$  is the number of fish alive at the end (termination) of the experiment and  $N_s$  is the number of fish alive at the start of the experiment.

$$FCR = W_f/W_t,$$

where  $W_f$  is the feed intake and  $W_t$  is the total weight of fish at the end of the experiment.

In this research, the color value analysis ( $L^*$ ,  $a^*$  and  $b^*$ ) was carried out in accordance with Pomeranz and Meloan (1994) [9] using a AMT501 Precise Color Reader Meter. The hardness value was determined according to the texture profile analysis [10]. The sensory analysis for color, texture, taste and odor was conducted using a nine-point graded hedonic scale, where 1 = extremely dislike, 2 = strongly dislike, 3 = moderately dislike, 4 = mildly dislike, 5 = indifferent (i.e. neither like nor dislike), 6 = mildly like, 7 = moderately like, 8 = strongly like, and 9 = extremely like [11].

### 2.3 Data Analysis

Analysis of variance (ANOVA) was utilized to statistically analyze the growth factors and the sensory data pertinent to each dietary treatment. The significance between the means was compared using Duncan's new multiple range test (DMRT) at the probability level of 0.05 ( $p \leq 0.05$ ).

## 3. RESULTS

Table 1 tabulates the proximate composition of the three experimental diets: T1, T2 and T3. By comparison, the mixed feed (T2) contains the highest percentage of protein (20.0%), followed by the commercial feed (T3) and the pure rice bran (T1) of 18.2% and 12.8%, respectively. Interestingly, the protein content of T3 of 18.2% is substantially below the figure advertised on the package of 35.0%, while its ash content is the highest. Meanwhile, the pure rice bran (T1)

exhibits the highest level of lipid (10.0%).

Table 1 The proximate composition (%) of the experimental diets

Parameters	Experimental diets		
	T1	T2	T3
Protein	12.8	20.0	18.2
Lipid	10.0	7.5	4.0
Fiber	5.3	7.8	8.0
Ash	8.0	8.7	11.8
Moisture	10.5	6.4	9.3
Dry matter	89.5	93.6	90.7

Table 2 compares the growth performance of the tilapia fed with either of the three dietary treatments. The average increases in weight and length of the tilapia were significantly different between the three treatments ( $p \leq 0.05$ ), with T2 achieving the highest average weight and length increases. In addition, the difference in diets had a significant impact ( $p \leq 0.05$ ) on the average daily growth (ADG). The highest ADG was observed in the T2 group, while the T3 group had the lowest ADG. Nevertheless, no significant differences in the survival rate (SR) and the food conversion ratio (FCR) were observed between the three dietary treatments. According to [1], a low food conversion ratio (FCR) is an indicator of feed utilization efficiency. In the experiments, the mixed feed (T2) exhibited the lowest FCR.

Table 2 The growth parameters (mean $\pm$ SD) of the Nile tilapia fed with the three dietary treatments

Parameters	Experimental diets		
	T1	T2	T3
$W_s$ (g)	1.5 $\pm$ 0.3 <sup>a</sup>	1.5 $\pm$ 0.4 <sup>a</sup>	1.6 $\pm$ 0.5 <sup>a</sup>
$W_e$ (g)	47.3 $\pm$ 17.1 <sup>a</sup>	75.4 $\pm$ 26.0 <sup>b</sup>	41.1 $\pm$ 12.0 <sup>a</sup>
$L_s$ (cm)	4.5 $\pm$ 0.3 <sup>a</sup>	4.5 $\pm$ 0.3 <sup>a</sup>	4.5 $\pm$ 0.4 <sup>a</sup>
$L_e$ (cm)	13.7 $\pm$ 1.8 <sup>a</sup>	15.9 $\pm$ 1.8 <sup>b</sup>	12.8 $\pm$ 1.3 <sup>c</sup>
ADG (g/day)	0.81 $\pm$ 0.14 <sup>a</sup>	1.27 $\pm$ 0.12 <sup>b</sup>	0.69 $\pm$ 0.04 <sup>a</sup>
SR (%)	65.0 $\pm$ 20.0 <sup>a</sup>	70.0 $\pm$ 15.0 <sup>a</sup>	78.3 $\pm$ 16.1 <sup>a</sup>
FCR	2.07 $\pm$ 0.25 <sup>a</sup>	1.74 $\pm$ 0.42 <sup>a</sup>	2.01 $\pm$ 0.28 <sup>a</sup>

Note:  $W_s$  and  $W_e$  are respectively the weights at the start and end,  $L_s$  and  $L_e$  are respectively the length at the start and end, ADG is the average daily growth, SR is the survival rate, and FR is the food conversion ratio. The mean values in the same row with the same superscript letter are significantly different ( $p > 0.05$ ).

Table 3 presents the proximate composition of the tilapia meat for the three dietary treatments. The results were statistically significantly different ( $p \leq 0.05$ ). The protein percentage was highest in the tilapia fed with the commercial feed (T3), followed by those with the mixed feed (T2) and

the pure rice bran (T1). The tilapia fed with T2 exhibited the highest gain in lipid content from initially 6.29% to 28.86%.

Table 3 The proximate composition (%) of the Nile tilapia fed with the three dietary treatments

Parameters	Experimental diets			
	Initial	T1	T2	T3
Protein	58.86 <sup>a</sup>	60.09 <sup>a</sup>	60.83 <sup>a</sup>	67.46 <sup>b</sup>
Lipid	6.29 <sup>a</sup>	27.26 <sup>b</sup>	28.86 <sup>c</sup>	15.35 <sup>d</sup>
Ash	26.04 <sup>a</sup>	11.62 <sup>b</sup>	14.46 <sup>c</sup>	19.82 <sup>d</sup>
Moisture	2.95 <sup>a</sup>	2.33 <sup>b</sup>	4.49 <sup>c</sup>	2.78 <sup>d</sup>
Dry matter	97.05 <sup>a</sup>	97.67 <sup>b</sup>	95.51 <sup>c</sup>	97.22 <sup>d</sup>

Note: The mean values in the same row with different superscript letters are significantly different ( $p \leq 0.05$ ).

Table 4 tabulates the quality parameters with regard to the color value, where  $L^*$  is the lightness,  $a^*$  denotes the redness in relation to greenness (+ represents redness and - represents greenness), and  $b^*$  denotes the yellowness in relation to blueness (+ represents yellowness and - represents blueness). The results showed that  $L^*$  of both raw and boiled meat were not significantly different ( $p > 0.05$ ) between the three experimental feed groups. Meanwhile,  $a^*$  for the exterior of the boiled meat exhibited a statistical difference among the three dietary treatments ( $p \leq 0.05$ ). Moreover,  $b^*$  of both raw and boiled meat were significantly different between the groups ( $p \leq 0.05$ ).

Table 4 Color values of the Nile tilapia for both raw and boiled meat, where  $L^*$ ,  $a^*$  and  $b^*$  respectively denote the lightness, redness and yellowness

Tilapia meat	Color value	Experimental Diets		
		T1	T2	T3
Raw meat				
Outer	L*	33.3±4.0 <sup>a</sup>	37.5±5.9 <sup>a</sup>	35.1±6.4 <sup>a</sup>
	a*	-0.5±0.4 <sup>a</sup>	-1.5±0.6 <sup>a</sup>	-1.3±0.5 <sup>a</sup>
	b*	1.3±1.6 <sup>a</sup>	7.5±2.0 <sup>b</sup>	3.0±1.2 <sup>a</sup>
Inner	L*	45.9±0.8 <sup>b</sup>	38.2±2.7 <sup>a</sup>	39.7±0.7 <sup>a</sup>
	a*	-2.3±1.1 <sup>a</sup>	1.6±2.7 <sup>b</sup>	-1.6±1.1 <sup>ab</sup>
	b*	1.9±1.5 <sup>a</sup>	2.4±1.9 <sup>a</sup>	3.9±0.9 <sup>a</sup>
Boiled meat				
Outer	L*	28.4±7.8 <sup>a</sup>	28.6±5.5 <sup>a</sup>	30.8±8.8 <sup>a</sup>
	a*	-0.5±0.4 <sup>a</sup>	-0.7±0.9 <sup>b</sup>	1.2±0.2 <sup>b</sup>
	b*	-0.4±0.7 <sup>a</sup>	1.6±1.3 <sup>ab</sup>	2.4±1.2 <sup>b</sup>
Inner	L*	67.5±6.8 <sup>a</sup>	66.2±6.6 <sup>a</sup>	58.5±5.2 <sup>a</sup>
	a*	1.7±0.7 <sup>a</sup>	1.7±1.1 <sup>a</sup>	3.9±1.7 <sup>a</sup>
	b*	15.1±2.3 <sup>a</sup>	14.4±1.7 <sup>a</sup>	18.5±0.6 <sup>b</sup>

Note: The mean values in the same row with different superscript letters are significantly different ( $p \leq 0.05$ ).

Table 5 compares the quality of tilapia meat texture for the three dietary treatments. The results showed that the hardness values of the outer raw and inner boiled meat were not significantly different ( $p > 0.05$ ) between the three dietary groups. By comparison, the hardness values of the inner raw meat belonging to the T2 and T3 groups were not significantly different ( $p > 0.05$ ) but statistically significant for T1 ( $p \leq 0.05$ ).

Table 5 Hardness values (kg force) of the raw and boiled Nile tilapia meat

Tilapia meat	Experimental diets		
	T1	T2	T3
Raw meat			
Outer	0.7±0.1 <sup>a</sup>	0.6±0.1 <sup>a</sup>	0.6±0.0 <sup>a</sup>
Inner	0.5±0.1 <sup>b</sup>	0.4±0.0 <sup>a</sup>	0.4±0.0 <sup>a</sup>
Boiled meat			
Inner	0.3±0.1 <sup>a</sup>	0.3±0.0 <sup>a</sup>	0.3±0.0 <sup>a</sup>

Note: The mean values in the same row with different superscript letters are significantly different ( $p \leq 0.05$ ).

In Table 6, the overall sensory preference of tilapia meat showed the highest score for the fish fed with T3 (6.4±1.4), followed by T2 (7.4±1.0) and T1 (8.1±0.9). However, the taste scores were not significantly different ( $p > 0.05$ ).

Table 6 Sensorial preference scores of the boiled Nile tilapia meat for the three dietary treatments

Sensorial preference	Experimental diets		
	T1	T2	T3
Texture	6.2±1.4 <sup>a</sup>	6.9±1.2 <sup>b</sup>	8.2±0.7 <sup>c</sup>
Color	5.2±1.4 <sup>a</sup>	6.8±1.4 <sup>b</sup>	7.3±1.8 <sup>b</sup>
Odor	3.4±1.8 <sup>a</sup>	4.4±2.3 <sup>a</sup>	6.3±1.9 <sup>b</sup>
Taste	7.1±1.4 <sup>a</sup>	7.3±1.5 <sup>a</sup>	7.1±2.5 <sup>a</sup>
Overall acceptability	6.4±1.4 <sup>a</sup>	7.4±1.0 <sup>b</sup>	8.1±0.9 <sup>c</sup>

Note: The mean values in the same row with different superscript letters are significantly different ( $p \leq 0.05$ ).

#### 4. DISCUSSION

In the Food and Agriculture Organization (FAO)'s [12] comprehensive reviews on tilapia nutrition requirements, early juvenile fish (0.02-10.0 g) require a diet high in protein, lipids, vitamins and minerals but low in carbohydrates. On the other hand, sub-adult fish (10-25 g) require more energy from lipids and carbohydrates for metabolism but less protein for growth. In addition, several factors, including fish size and

age, dietary protein source, energy content, water quality and culture condition, influence the protein requirements of tilapia [2].

The research findings revealed that the protein ingredients from non-toxic agricultural field sources influence the growth of *O. niloticus*. In [5], the authors experimented with five dietary concoctions for tilapia feeds and noted that the protein and lipid levels of the concoctions were similar to those of commercial feeds. Specifically, dietary protein is mostly responsible for the tilapia growth [13]. In general, the protein requirement for tilapia growth was estimated between 25% and 40% of the total requirement, depending on the species, age/size of fish, ingredient digestibility and the extent of foraging for natural ingredients [3],[4]. The results of this research indicates that a mere 20.0% protein is required for tilapia growth.

The experimental results also showed that the whole body protein and lipid contents increased at termination (i.e. the end of the experiment). It was found that the fish fed with T3 had the highest percentage of protein and that those fed with T2 exhibited the highest percentage of lipid. According to [1], different feed intakes contributed to differences in the chemical composition of tilapia meat. In addition, the source of feed materials directly influences both quality and quantity of the fish meat [14].

On the quality parameters, the redness ( $a^*$ ) of raw tilapia meat belonging to the T2 dietary group was similar to that of T3 but was significantly different from T1's ( $p \leq 0.05$ ). In addition, the inner raw meat of tilapia fed with pure rice bran (T1) possessed more brightness ( $L^*$ ) but less redness ( $a^*$ ) and yellowness ( $b^*$ ) in comparison with that of T2 and T3. The inner boiled meat for the three dietary groups exhibited no significant differences in the color values. Furthermore, the hardness values of the raw and boiled meat were not significantly different ( $p > 0.05$ ) among the three diet groups.

According to [15], the adoption and the willingness to change the consumption habit with regard to meat products are influenced by the levels of consumer's familiarity with and sensory appeal of the meat products. In this research, the fish fed with the commercial feed (T3) received the overall highest score on the sensory preference, followed by those fed with the mixed feed (T2) and the pure rice bran (T1). Lin [16] documented that supplementation the diet with manganese, iron, vitamin A and selenium has been observed to improve meat quality; and that selenium supplementation in the diet could enhance the meat texture characteristics but not the meat color of juvenile groupers. Sultana [5] reported that the mixture supplemented with commercial feed can

improve both the growth and meat quality. Nevertheless, it was documented that when plants were used as the primary source of protein in tilapia feeds, higher supplementary mineral levels would be required [2].

It could also be inferred from the research findings that the plant protein ingredients from non-toxic agricultural field sources could be used as the tilapia feeds with no significant difference ( $p > 0.05$ ) among the dietary treatments. Khan [1] reported that a partial replacement of fish meal with rice polish (up to 20%) and mustard oil cake (up to 22%) was economically efficient, reducing the feed formulation cost by 24% without significantly lowering the nutritional quality. Thus, the plant protein ingredients from non-toxic agricultural field sources could be utilized as an economically and nutritionally viable dietary protein substitute for fish meal.

## 5. CONCLUSION

This research has investigated the effects of the dietary protein ingredients from non-toxic agricultural field sources on the production quality of the Nile tilapia. The study utilized three dietary treatments as the tilapia feeds: pure rice bran (T1), a mixed feed of fish meal, rice bran and dried corn grains (T2), and a commercial feed (T3). The research findings showed that the best growth performances with respect to weight, length, ADG and FCR were achieved for the tilapia fed with the mixed feed (T2). In addition, it was found that the different dietary treatments contributed differently to the meat quality. The experiments have confirmed the applicability of the plant protein ingredients from non-toxic agricultural field sources as an alternative protein ingredient in the formulation of tilapia feeds.

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