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Utilization of Fermented Feather Meal as a Replacement of Fish Meal in the Diet of Hybrid Clarias Catfish

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ABSTRACT

The suitability of replacing fish meal in the hybrid clarias catfish diet with fermented feather meal was evaluated. The fermentation by yeast was performed to increase efficiency of feather meal. Five diets were formulated with diet 1 containing 100 % fish meal (control diet) and diet 2, 3, 4 and 5 were 25 %, 50 %, 75 %, and 100 % of fermented feather meal replacement of fish meal in the diet formula respectively.

The results showed that average final weight (125.72±10.65 to 132.67±6.91 g), average daily weight gain (0.92±0.20 to 1.05±0.12 g/ind/day), feed conversion ratio (FCR) (2.62±0.30 to 2.97±0.62) and apparent net protein retention (ANPR) (25.43±4.51 to 29.86±2.89 %) of hybrid clarias catfish fed with diet formulas 1, 2 and 3 were not significantly different ($P>0.05$). Meanwhile, protein efficiency ratio (PER) (0.91±0.04 to1.26±0.15) and protein intakes (PI) (45.23±0.41 to 50.88±0.486.91 g/ind) were not significantly different ($P>0.05$) among hybrid clarias catfish fed with diet formulas 1, 2, 3 and 4. Survival rate (100 %) was not significantly different ($P>0.05$) among all treatments.

This study suggested that the percentage of fish meal replacement with fermented feather meal in hybrid clarias catfish diet at 25 % had a close growth and feeding efficiency to fish meal diet and was not significantly different from fish fed with the control diet. The 25 % of replacement fish meal by fermented feather meal could reduce diet cost by about 0.81 baht/kg.

Key words: feather meal, fermentation, fish meal, feed efficiency, hybrid clarias catfish

INTRODUCTION

The cost of artificial fish diet is high because a major source of protein is obtained from fish which has suitable protein quality, amino acid palatability (NRC, 1993). In present day, the increasing demand and uncertain availability of fish meal (Kikuchi, 1999; Sargent and Tacon, 1999) are reasons for nutritionists to study alternative sources of protein for supplying dietary protein in artificial fish feeds such as soybean meal, wheat gluten, corn meal etc. (Tacon, 1994; Kaushik *et al*., 1995; Watanabe *et al*.,1998; Taksin and Somsueb, 2005). Feather meal is by-product from poultry production and slaughter house. Feather is composed of a complex protein (keratin), which can be broken down by hydrolysis and to make it more digestable. Moreover, the digestibility of feather meal is directly affected by cooking time and pressure. Feather meal is rich in essential amino acids such as cystine, threonine, arginine and has high pepsin digestible protein (75-

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87%). The balance of these amino acids is does due to fish meal and soybean meal (Sarmwatanakul and Bamrongtum, 2000). Feather meal is used as a replacement of fish meal in various animal feeds such as poultry, cow, goat, pig, sheep (El Boushy and van der Poel, 1990; Andrighetto and Bailoni, 1994; Cozzi *et al*., 1995; Chiba *et al*., 1996; Kane *et al*., 2002) and fish (Fowler, 1990; Bureau *et al*., 2000; Somseueb and Boonyaratpalin, 2001). Feather meal can be easily digested by ruminant animals and when supplemented with urea it is more digestible. A high percentage of feather meal causes fish diet to be indigestible. This is due to the fact that the protein has 2 molecules of cysteine that form a sulfide bond which causes poor digestion in monogastric animals. However, Fowler (1990) reported that fish diets which contained 15% of feather meal did not affect growth and feeding efficiency of Chinook salmon. In addition, Somseueb and Boonyaratpalin (2001) also reported that the maximum feather meal replacement for hybrid clarias catfish diet was 5% of the fish meal.

The improvement of protein quality in artificial fish diet by fermentation was studied using by-products from fish and shrimp processing and non-edible part of fish (head and visceral) as a protein substitute. Protein compounds are fermented by enzymes from self-digestion and changed to poly-peptides, peptides and amino acids under optimum conditions before using as a nitrogen source (Jarernjiratrakul, 1996). Naturally, some of keratinophyllic microorganisms that are found in soil and animal skins such as bacteria: *Bacillus*, *Steptomyces* and fungi: *Mocus*, *Rhyzopus* and *Aspergillus*, can cause fermentation of feather meal (Grazziotin *et al*., 2006).

The purpose of this study was to find out if the fermented feather meal could improve the protein quality and feather meal could be used as a major source of protein for partial or total replacement of fish meal in artificial fish diets as major protein source which could reduce the cost of fish diet.

MATERIALS AND METHODS

Fermented feather meal replacement for fish meal in the fish diet was investigated on fish diet production process, feed quality, growth and feed utilization efficiency. The research was conducted at the experimental unit of Feed Quality Control and Development Division, Department of Fisheries at Pranakornsri Ayutthaya province. Blood samples were sent to Blood Research Unit of Ramathibodi Hospital for triiodothyonine (T3) and thyroxine hormone (T4) analysis.

Experimental planing

The hybrid clarias catfish was used and the 5 treatments were based on the different diet formulas as 0, 25, 50, 75 and 100% (w/w) replacement of fish meal with fermented feather meal. The diets contained 30% of crude protein and 400 kcal GE/100g diet of gross energy. Experimental fish were placed in 120 liters glass aquarium under close flow through systems with aeration. The fish were fed with diet formulas as shown in Table 1 and then experimental diets and fish samples were collected for analysis.

Production of experimental diet using fermented feather meal for protein source

The experimental diet was conducted as followed :

1. Feather meal was fermented with bakery yeast and cassava powder [x%:0.5%:10% (x = percentage of feather meal in feed formula)] and then add 30% water (by weight), stirred every 4 hours for aeration and fermented for 48 hours.

2. All experimental diets were formulated that contained 30% protein and 400 kcal/100 g diet gross energy.

Formula 1 100% fish meal : 0% fermented feather meal as control feed

Formula 2 75% fish meal : 25% fermented feather meal

Formula 3 50% fish meal : 50% fermented feather meal

Table 1 Experimental diet formulas.

Raw material	Diet formula and percentage of fermented feather meal replacement of fish meal				
	Formula 1 (0%)	Formula 2 (25%)	Formula 3 (50%)	Formula 4 (75%)	Formula 5 (100%)
Fish meal	25	18.75	12.5	6.25	-
Feather meal	-	4.4	8.8	13.3	17.7
Soybean meal	30	30	30	30	30
Rice bran	15	15	15	15	15
Cassava powder	10	10	10	10	10
Alpha starch	6	6	6	6	6
Vegetable oil	1.3	1.3	1.3	1.3	1.3
Fish oil	1.0	1.4	1.9	2.3	2.7
Lard	-	0.4	0.6	0.9	1.6
Di-calcium phosphate	0.92	0.78	1.11	1.34	1.63
Vitamins & minerals	2	2	2	2	2
Ground husk	8.28	9.47	10.29	11.11	11.57
Bakery yeast	0.5	0.5	0.5	0.5	0.5

Note: Five diets were formulated to contain 30% crude protein and 400 kcal/100g diet gross energy. Average composition of crude protein of fish meal and feather meal were 60% and 80%, respectively.

Formula 4 25% fish meal : 75% fermented feather meal

Formula 5 0% fish meal : 100% fermented feather meal

Raw materials were mixed to form a homogenous mixture, and then oil was added. Subsequently, 30% of water was added to dry mixture and blended until it became dough like paste.

3. Moist feed mixture was passed through a meat grinder with diet size of 3 mm. and dried in open air and then crumbled into small pieces. Dried pellets were stored in airtight plastic bags at -4°C.

Experimental fish culture

1. Hybrid clarias catfish (*Clarias macrocephalus* x *Clarias gariepinus*) with an initial mean weight 70.0 ± 5.0 g were fed with the experimental diets about 7 days before starting the feeding trial.

2. Twenty fish were randomly sampled, stocked individually in 120 liters glass aquaria with close flow through systems with aeration. Fish were fed twice a day at 9.00 a.m. and 4.00 p.m. and gradually fed until fish were full. The unused diet was collected, dried and weighed and then deducted from the consumed diet weight every 2 weeks.

3. Fish were counted and weighed every 2 weeks and were not fed on morning period of weighing day.

4. Measurement of water quality in the tank was conducted. Temperature was measured every day at 9.00 a.m., other parameters were measured as dissolved oxygen (DO) by titration method, pH by pH meter, alkalinity by titration method, hardness by EDTA titration method and ammonia by indophel blue colorimetry method (APHA AWWA WPCF, 1995).

5. At the end of the experiment (8 weeks), 3 fish of each treatment were randomly sampled for carcass composition analysis. In order to obtain thyroid activity, 3 ml blood samples were collected and measured for level of triiodothyonine (T3) and thyroxine (T4) hormone.

Nutrition analysis of experimental diets

Experimental diets were randomly sampled then dried and blended to a size that passed through a 200 micron mesh sieve, then homogenized and stored in airtight containers at -18 °C until analyzed (AOAC, 1990). The nutritive values were as following.

1. Crude protein by Kjeldahl nitrogen
2. Crude lipid by ether extraction
3. Total ash by muffle furnace combustion
4. Crude fiber by Weede method
5. Carbohydrate by % NFE equation

% NFE = 100 – (% protein +% lipid +% fiber+% ash + moisture)

6. Gross Energy (GE)

GE = (% NFE × 4.11) + (% protein × 5.64) + (% lipid × 9.44)

Analysis of experimental fish

Fish growth and feed utilization of all treatments were measured every two weeks until the end of the experiments (Jantrarotai *et al*., 1996; Chuapoehuk, 1999; Tinnungwatana and Viputhanumas, 2000; Somsueb and Boonyaratpalin, 2001). The following parameters were investigated.

1. Percentage of weight gain (%)

$$= \frac{\text{(Mean final fish weight – Mean initial fish weight)}}{\text{Mean initial fish weight}} \times 100$$

2. Daily mean weight gain or average daily gain (g/ind/day)

= (Mean final fish weight – Mean initial fish weight) / culture period (day)

3. Survival rate (%) = (Final number of fish / Initial number of fish) × 100

4. Feed conversion ratio (FCR) = Total feed consumed / Increased fish mass

5. Protein efficiency ratio (PER) = Increasing weight in fish mass / Protein intake in diet

6. Apparent net protein retention (ANPN) = $\{[(W_1 \times \% P_1)-(W_0 \times \% P_2)] / P\} \times 100$

W_1 = Mean final fish weight (g)

W_0 = Mean initial fish weight (g)

P = Protein intake in diet

P_1 = Final percentage of protein in fish

P_2 = Initial percentage of protein in fish

7. Protein intake = Quantity of diet consumption ×% Protein in diet

8. Carcass composition at the beginning and end of experiment were observed for crude protein, crude lipid and crude fiber content as following :

1. Crude protein by Kjeldahl nitrogen
2. Crude lipid by ether extraction
3. Crude fiber by Weede method

9. The level of triiodothyonine (T3) and thyroxine hormone (T4) were evaluated at the end of all experiments by collecting 3 ml of blood from the caudal vein of three fish from each treatment and sent to Blood Research Unit of Ramathibodi Hospital for triiodothyonine and thyroxine hormone analysis to search for unusual thyroid activity that affected growth and metabolism.

Data collection and analysis

Experimental data were collected and statistically analyzed by ANOVA (Analysis of Variance) with 5 treatments and 3 replications in each treatment. The DMRT (Duncan's New Multiple Range Test) was used to determine the differences among the treatment means. The alphabetical notations (a, b, c, d, e, f) were used to mark the differences at a significant level of $P \leq 0.05$.

RESULTS

Quality of experimental diets

All experimental diets revealed the same physical characteristics that were cylindrical shape, 3 mm. in diameter, 5 – 10 mm. in length, light- brown color, breakable by fingers, sank easily in aquarium and stood in water about 5 – 8 minutes. Approximate composition of

experimental diets containing fermented feather meal replaced for fish meal in hybrid clarias catfish diets are presented in Table 2.

According to Table 2, the crude protein contents in the experimental diets were similar. The crude lipid and gross energy in the experimental diets increased with increasing percentage of fermented feather meal replacement. Comparing the approximate percentage of protein, lipid, fiber and moisture in experimental diets, they were similar to the commercial feed for catfish.

Growth and feed utilization efficiency

1) Average weight of hybrid clarias catfish throughout the experiment

At the beginning, the average initial weight ranged from 73.73 to 74.09 g. A significant difference in average weight occurred at the 2nd week of the experiment. The fish fed with diet formulas 1, 2 and 3 were significantly higher than the other experiments ($P<0.05$) and diet formula 2 showed the highest average weight and decreased orderly from formulas 1, 3, 4 and 5. At the 8th week, the average final weight ranged from 96.56 to 132.67 g. The weight of fish fed with diet formulas 1 and 2 were significantly higher than the other experiments and diet formula 2 showed the highest average weight of hybrid clarias catfish during the experimental period of 8 weeks. (Table 3)

2) Percentage of weight gain

Percentage of weight gain in fish fed with diet formulas 1, 2, 3, 4 and 5 were significantly different ($P<0.05$) among treatment groups. According to Table 4, the results showed that the highest percentage of weight gain was in fish fed with diet formula 1 (79.08±9.54%) and the lowest in diet formula 5 (30.13±8.48%). There were not significantly different ($P>0.05$) among fish fed with diet formula 1 (79.08±9.54%), formula 2 (79.07±9.00%) and formula 3 (69.97±15.08%), no

Table 2 Approximate composition of hybrid clarias catfish experimental diet with different ratios of fermented feather meal replacement of fish meal and commercial feed for catfish.

Approximate analysis		Formula 1 (0%)	Formula 2 (25%)	Formula 3 (50%)	Formula 4 (75%)	Formula 5 (100%)	Commercial feed (30% protein)
Protein	(%)	31.17	30.40	31.35	31.36	31.18	30
Lipid	(%)	2.86	4.70	5.18	5.59	6.23	≧ 4
Fiber	(%)	6.51	5.80	6.35	6.89	6.92	≤ 6
Ash	(%)	11.38	9.41	8.65	7.35	6.29	-
Moisture	(%)	9.61	11.44	9.78	8.61	8.32	≤ 12
Gross Energy (kcal/100gdiet)		365	373	385	395	403	-

Source: experimental diet analysis

Table 3 Average weight of hybrid clarias catfish fed with different diets every 2 weeks.

Time (week)	Average weight (g)				
	Formula 1 (0%)	Formula 2 (25%)	Formula 3 (50%)	Formula 4 (75%)	Formula 5 (100%)
Initial weight	74.04±0.26^{a}	74.09±0.18^{a}	73.98±0.30^{a}	73.73±0.46^{a}	74.09±0.26^{a}
2	80.64±1.33^{b}	82.25±1.28^{b}	81.89±1.79^{b}	79.55±1.59^{ab}	77.41±1.50^{a}
4	89.62±3.64^{b}	91.69±1.58^{b}	90.96±3.71^{b}	86.67±1.60^{ab}	81.95±1.31^{a}
6	106.39±5.92^{b}	108.71±3.83^{b}	107.02±8.54^{b}	101.05±2.11^{b}	89.76±2.84^{a}
8	132.58±6.65^{c}	132.67±6.91^{c}	125.72±10.65^{bc}	114.43±1.79^{b}	96.56±6.81^{a}

Note: Means with different superscripts (a,b,c,d) in the same row were significantly different (P<0.05)

significant difference between fish fed with diet formula 3 (69.97±15.08%) and formula 4 (55.21±2.63%) and no significant difference between fish fed with diet formula 4 (55.21±2.63%) and formula 5 (30.13±8.48%).

3) Average daily weight gain

Average daily weight gain in fish fed with diet formulas 1, 2, 3, 4 and 5 were significantly different (*P<0.05*) among treatment groups. The results showed that daily weight gain was the highest in fish fed with diet formulas 1 and 2 (1.05±0.12 g/ind/day) and the lowest in diet formula 5 (0.40±0.11 g/ind/day). There were no significant differences (*P>0.05*) between fish fed with diet formula 1 (1.05±0.12 g/ind/day), formula 2 (1.05±0.12 g/ind/day) and formula 3 (0.92±0.20 g/ind/day), no significant difference between fish fed with diet formula 3 (0.92±0.20 g/ind/day), formula 4 (0.73±0.03 g/ind/day) and no significant difference between fish fed with diet formula 4 (0.73±0.03 g/ind/day) and formula 5 (0.40±0.11 g/ind/day).

4) Survival rate

Survival rate showed the same values (100%) on all treatment groups.

5) Feed conversion ratio

Feed conversion ratios in fish fed with diet formulas 1, 2, 3, 4 and 5 were significantly different (*P<0.05*) among treatment groups. The results showed that feed conversion ratio was the lowest in fish fed with diet formula 2 (2.62±0.30) and the highest in diet formula 5 (4.03±0.32). There were no significant differences (*P>0.05*) among fish fed with diet formula 1 (2.77±0.33), formula 2 (2.62±0.30) and formula 3 (2.97±0.62), no significant difference between fish fed with diet formula 3 (2.97±0.62), formula 4 (3.55±0.19) and significant difference from formula 5 (4.03±0.32).

Table 4 Growth and feed efficiency of hybrid clarias catfish during 8 weeks.

	Fermented feather meal replaced for fish meal in hybrid clarias catfish diets				
	Formula 1 (0%)	Formula 2 (25%)	Formula 3 (50%)	Formula 4 (75%)	Formula 5 (100%)
Average initial weight (g)	74.04±0.26^{a}	74.09±0.18^{a}	73.98±0.30^{a}	73.73±0.45^{a}	74.09±0.26^{a}
Average final weight (g)	132.58±6.65^{c}	132.67±6.91^{c}	125.72±10.65^{bc}	114.43±1.79^{b}	96.56±6.81^{a}
Percentage of weight gain (%)	79.08±9.54^{c}	79.07±9.00^{c}	69.97±15.08^{bc}	55.21±2.63^{ab}	30.13±8.48^{a}
Average daily weight gain (g/ind/day)	1.05±0.12^{c}	1.05±0.12^{c}	0.92±0.20^{bc}	0.73±0.03^{b}	0.40±0.11^{a}
Survival rate (%)	100±0^{a}	100±0^{a}	100±0^{a}	100±0^{a}	100±0^{a}
Feed conversion ratio	2.77±0.33^{a}	2.62±0.30^{a}	2.97±0.62^{ab}	3.55±0.19^{bc}	4.03±0.32^{c}
Protein efficiency ratio	1.15±0.12^{bc}	1.26±0.15^{c}	1.11±0.24^{bc}	0.91±0.04^{ab}	0.79±0.01^{a}
Apparent net protein retention (%)	28.65±2.56^{b}	29.86±2.89^{b}	25.43±4.51^{b}	18.12±6.21^{a}	14.82±1.20^{a}
Protein intake (g/ind)	50.88±0.48^{b}	46.32±0.07^{b}	46.75±0.29^{b}	45.23±0.41^{b}	28.14±8.26^{a}

Note**:** Means with different superscripts (a,b,c,d) in the same row were significantly different (P<0.05)

6) Protein efficiency ratio

Protein efficiency ratios in fish fed with diet formulas 1, 2, 3, 4 and 5 were significantly different ($P<0.05$) among treatment groups. The results showed that protein efficiency ratio was the highest in fish fed with diet formula 2 (1.26±0.15) and the lowest in diet formula 5 (0.79±0.01). There were no significant difference ($P>0.05$) among fish fed with diet formula 1 (1.15±0.12), formula 2 (1.26±0.15) and formula 3 (1.11±0.24) and no significant difference between fish fed with diet formula 3 (1.11±0.24) and formula 4 (0.91±0.04) but they were significantly different from fish fed with diet formula 5 (0.79±0.01).

7) Apparent net protein retention

Apparent net protein retention in fish fed with diet formulas 1, 2, 3, 4 and 5 were significantly different ($P<0.05$) among treatment groups. The apparent net protein retention was the highest in fish fed with diet formula 2 (29.89±2.89%) and the lowest in diet formula 5 (14.82±1.20%). There were no significant differences ($P>0.05$) among fish fed with diet formula 1 (28.65±2.56%), formula 2 (29.89±2.89%) and formula 3 (25.43±4.51%) and no significant difference between fish fed with formula 4 (18.12±6.21%) and formula 5 (14.28±1.20%). The apparent net protein retention was reduced by increasing fermented feather meal

8) Protein intake

Protein intake in fish fed with diet formulas 1, 2, 3, 4 and 5 were significantly different ($P<0.05$) among treatment groups. The results showed that protein intake was the highest in diet formula 1 (50.88±0.48 g/ind) and the lowest in fish fed with diet formula 5 (28.14±8.26 g/ind). There were no significant differences ($P>0.05$) among fish fed with diet formula 1 (50.88±0.48 g/ind), formula 2 (46.32±0.07 g/ind), formula 3 (46.75±0.29 g/ind) and formula 4 (45.23±0.41 g/ind) but they were significantly different from fish fed with formula 5 (28.14±8.26 g/ind). The protein intake was reduced by increasing fermented feather meal.

9) Carcass composition of fish

The approximate compositions of experimental fish at the beginning and the end of experiment are presented in Table 5. The carcass composition (dry matter basis) of initial fish was observed on crude protein, crude lipid and fiber content (81.00%, 7.25% and 2.01%). At the end of experiment, the carcass compositions of fish fed with diet formulas 1, 2, 3, 4 and 5 were composed of crude protein content (84.71%, 84.14%, 82.12%, 86.30% and 82.13%), crude lipid content (4.33%, 4.79%, 4.48%, 4.80% and 4.96%) and fiber content (1.63%, 1.70%, 1.28%, 1.19% and 1.13%), respectively.

10) Level of triiodothyonine (T3) and thyroxine hormone (T4)

The level of triiodothyonine and thyroxine hormone in blood of fish at the end of experiment are presented in Table 6. The T3 in

Table 5 Composition of the carcass of hybrid clarias catfish fed the experimental diets for 8 weeks.

Composition	Initial fish	Fermented feather meal replaced for fish meal in hybrid clarias catfish diets				
		Formula 1 (0%)	Formula 2 (25%)	Formula 3 (50%)	Formula 4 (75%)	Formula 5 (100%)
Protein (g/ind)	59.83±0.23^{a}	62.73±0.22^{c}	62.34±0.15^{c}	60.75±0.25^{b}	63.63±0.40^{d}	60.85±0.22^{b}
Protein (%)	81.00	84.71	84.14	82.12	86.30	82.13
Lipid (g/ind)	5.36±0.02^{f}	3.21±0.01^{b}	3.55±0.01^{d}	3.3 1±0.01^{c}	3.56±0.01^{a}	3.67±0.01^{e}
Lipid (%)	7.25	4.33	4.79	4.48	4.80	4.96
Fiber (g/ind)	1.48±0.01^{f}	1.21±0.06^{d}	1.26±0.00^{e}	0.95±0.00^{c}	0.88±0.01^{b}	0.84±0.00^{a}
Fiber (%)	2.01	1.63	1.70	1.28	1.19	1.13

Note: Means with different superscripts (a,b,c,d) in the same row were significantly different ($P<0.05$)

fish blood fed with diet formulas 1, 2, 3, 4 and 5 were equal to 1.93, 1.72, 2.69, 1.96 and 2.21 μg/g whereas the levels of T4 were 7.56, 9.82, 9.59, 8.74 and 10.4 μg/g, respectively.

Water quality in the experimental period

During the experimental period, the water temperature was monitored everyday. The average temperature ranged from 24.04-24.45 °C. Dissolved oxygen, pH, hardness, alkalinity and ammonia concentrations of water were weekly monitored. The values of dissolved oxygen, pH, hardness, alkalinity and ammonia concentrations of water ranged from 5.30-5.70 mg/l, 7.67-8.03, 132.33-134.67 mg/l as $CaCO_3$, 357.67-424.33 mg/l as $CaCO_3$ and 0.24-0.48 mg/l, respectively (Table 7).

Cost of experimental diets

Total raw material cost of diet formula 1-5 ranged from 19.18-16.59 baht/kg as presented in Table 8. Replacement of fermented feather meal at 25, 50, 75 and 100% of fish meal reduced costs about 0.81, 1.38, 2.09 and 2.59 baht/kg, respectively. In addition, when compared with commercial feed (containing 30% crude protein with price at 22 baht/kg) reduced costs about 2.82, 3.62, 4.20, 4.91 and 5.41 baht/kg, respectively.

DISCUSSION

The results of diet analysis showed that the high percentage replacement of fermented feather meal in fish diet were not significantly different (*P>0.05*) among treatment and higher than the standard for registered commercial catfish feed (1.5-3 month olds required 28% protein in diet) and protein requirement of juvenile hybrid clarias catfish (required 25-30% protein in diet) (Chuapoehuk, 1999). In this study, fish fed with diets containing a high percentage (≥ 75%) of fermented feather meal had less lower growth and feed utilization than fish fed with diets containing a low percentage (≤ 50% of fermented feather meal). The results showed that the most effective was obtained when fermented feather meal was used as a partial replacement for fish meal (≤ 50%) or used in combination with other materials such

Table 6 Level of triiodothyonine (T3) and thyroxine hormone (T4) in blood of hybrid clarias cat fish.

Hormone	Fermented feather meal replaced for fish meal in hybrid clarias catfish diets				
	Formula 1 (0%)	Formula 2 (25%)	Formula 3 (50%)	Formula 4 (75%)	Formula 5 (100%)
Total T3 (μg/g fish)	1.93±0.10 [a]	1.72±0.09 [a]	2.69±0.23 [c]	1.96±0.03 [a]	2.21±0.14 [b]
Total T4 (μg/g fish)	7.56±0.39 [a]	9.82±0.51[b]	9.59±0.80[bc]	8.74±0.14 [c]	10.4±0.68 [b]

Note: Means with different superscripts (a,b,c,d) in the same row were significantly different (*P<0.05*)

Table 7 Water quality in each treatment of hybrid clarias catfish during 8 weeks of experimental periods.

Treatment	Mean					
	Temperature (°C)	Dissloved oxygen (mg/l)	pH	Hardness (mg/l as $CaCO_3$)	Alkalinity (mg/l as $CaCO_3$)	Ammonia (mg/l)
Formula 1	24.42±0.70	5.53±0.21	7.67±0.11	132.33±0.58	357.67±18.15	0.48±0.04
Formula 2	24.07±0.55	5.30±0.10	7.73±0.27	134.00±1.00	389.00±17.58	0.24±0.08
Formula 3	24.45±1.08	5.70±0.17	7.68±0.27	132.33±1.53	392.67±12.50	0.35±0.28
Formula 4	24.04±0.79	5.53±0.21	7.70±0.14	134.67±0.58	392.33±8.74	0.26±0.01
Formula 5	24.36±0.48	5.37±0.06	8.03±0.14	134.33±0.58	424.33±26.63	0.24±0.07

as fish meal, blood meal and poultry by-product meal (non edible parts + blood).

The average final weight, percent weight gain and average daily weight gain of fish fed with diet containing 25% fermented feather meal was the highest. The growth rate of fish fed with diet a containing 25% fermented feather meal was higher when fed with diet containing 0% and 50% fermented feather meal but showed no significant difference. The results showed a similar trend as in the study by Hardy *et al*. (1984) on rainbow trout (*Salmo gairdneri*) fed with the combination of 33.8% fermented feather meal and fish silage (white Pacific liquid-fish) that had the better growth rate than the control (fish meal). In addition, the results of this study showed a higher average daily weight gain than the results published by Kosutarak (1999), who studied the hybrid catfish (*Clarias* sp.) that was fed with 25% chicken head silage with fish oil (0% and 1.3%) in diet. It was reported that the average daily weight gains were 0.2 and 0.23 g/ind/day, respectively. Boonyaratparin *et al*. (1982) working with the hybrid clarias catfish (*Clarias batrachus*) fed with a diet containing fermented trash fish with 5% salt (30% crude protein) showed an average daily weight gain of 0.92 g/ind/day, which was lower than this study. The result also agreed with the study of Somsueb and Boonyaratpalin (2001) on hybrid catfish fed with 35% of feather meal in fish meal had lower final weight gain.

The protein intake of fish fed with diet containing 100% fermented feather meal was the lowest. This result was probably related to the palatability of the diets. As the amount of fermented feather meal increased in the diets, there was a decrease in food consumption. Perhaps the smell of diet containing 100% fermented feather meal affected the palatability of fish (Somsueb and Boonyaratpalin, 2001).

Fish growth increased when percentage of fermented feather meal in the diet decreased and this was probably due to the amino acid balance of fermented feather meal, which was not suitable for the fish when compared with fish meal. The high percentage of fermented feather meal in fish feed reduced the percentage of weight gain and daily weight gain. These results are similar to Somsueb and Boonyaratpalin (2001), who studied hybrid clarias catfish fed with a diet

Table 8 Cost of hybrid clarias catfish experimental diets

Raw material	Price	Diet formula				
	(bath/kg)	Formula 1	Formula 2	Formula 3	Formula 4	Formula 5
Fish meal	22	0.25	0.1875	0.125	0.0625	-
Feather meal	7	-	0.044	0.088	0.133	0.177
Soybean meal	14	0.30	0.30	0.30	0.30	0.30
Rice bran	8	0.15	0.15	0.15	0.15	0.15
Cassava powder	4	0.10	0.10	0.10	0.10	0.10
Alpha starch	25	0.06	0.06	0.06	0.06	0.06
Vegetable oil	32	0.013	0.013	0.013	0.013	0.013
Fish oil	40	0.01	0.014	0.019	0.023	0.027
Lard	40	-	0.004	0.006	0.009	0.016
Di-calcium phosphate	40	0.0092	0.0078	0.0111	0.0134	0.0163
Vitamins & minerals	80	0.02	0.02	0.02	0.02	0.02
Ground husk	4	0.0828	0.0947	0.1029	0.1111	0.1157
Bakery yeast	600	0.005	0.005	0.005	0.005	0.005
Total (bath/kg)	-	19.18	18.37	17.80	17.09	16.59

containing 0-5% feather meal had higher weight gain and daily weight gain than fish fed with a diet containing 35% feather meal.

Feed conversion ratio in fish fed a diet containing 25% fermented feather meal was the lowest ($P<0.05$) among the treatments but was not significantly different ($P>0.05$) from diets containing 0% and 50% fermented feather meal replacement of fish meal. However, the result showed significantly higher than diets containing 75% and 100% fermented feather meal. Feed conversion ratio in diet containing fermented feather meal slightly increased by increasing fermented feather meal in diets. The results were similar to those of Hardy *et al*. (1984) on rainbow trout (*Salmo gairdneri*) fed with the combination of 33.8% fermented feather meal with fish silage (white Pacific liquid-fish) which had higher feed conversion ratio than control group (fish meal diet). Similarly, Hasan *et al*. (1997) reported that feed conversion ratio of Indian major carp (*Labeo rohita*) were increased by increasing percentage of feather meal in fish diet.

Protein efficiency ratio of fish fed with a diet containing 25% fermented feather meal was the highest and showed no significant difference ($P>0.05$) from fish fed with diets containing 0% and 50% fermented feather meal. The results indicated significant differences ($P<0.05$) from fish fed with diets containing 75% and 100% fermented feather meal. The protein efficiency ratio of the diet slightly decreased when the fermented feather meal increased. Somsueb and Boonyaratpalin (2001) showed that increasing feather meal in fish diet resulted in decreasing with protein efficiency ratio and Fasakin *et al*. (2005) presented data on the hybrid tilapia which reported protein efficiency ratio of fish decreased with feather meal partial replacement of fish meal. Tacon *et al*. (1983) reported that the 30% feather meal replacement of fish meal in sub-adult nile tilapia diet with the addition L-methionine or L-histidine or L-lysine or all 3 amino acid together had a higher protein efficiency ratio than a diet without amino acid addition.

The apparent net protein retention was the highest in fish fed with a diet containing 25% fermented feather meal replacement and showed no significant difference ($P>0.05$) from diets containing 0% and 50% fermented feather meal but higher than diets containing 75% and 100% fermented feather meal. The difference in apparent net protein retention might be caused by differences in the quality of protein obtained from the diet. Somsueb and Boonyaratpalin (2001) also showed that increasing the feather meal in fish diet, decreased the apparent net protein retention.

The protein intakes of fish fed with diets containing 0-75% replacement of fish meal with fermented feather meal were not significantly different which indicated the fermentation of feather meal, result in small peptides and free amino acids which slowly affected the rate of amino acid absorption in intestines (Hardy *et al*., 1984).

The results of the experiments showed that the growth responses of fish fed with diets containing 0, 25, 50, 75 and 100% fermented feather meal in terms of percentage of weight gain, daily weight gain, survival rate and feed utilization efficiency such as feed conversion ratio, protein efficiency ratio and apparent net protein retention were reduced by increasing the fermented feather meal in diets. The hybrid clarias catfish fed with diet containing 25% fermented feather meal showed the best growth rate and feed utilization efficiency but were not significantly different from hybrid clarias catfish fed with diets containing 0 and 50% fermented feather meal. For the results of growth and feed utilization efficiency, 25% of fermented feather meal replacement for fish meal in hybrid clarias catfish diet was suitable because it closely resembled the growth and feed efficiency to fish fed with a diet containing only fish meal. Charles *et al*. (1995) reported that the growth of *Oreochromis niloticus* was not compromised by replacement of 33-66% of feather meal diet and a 20% replacement with feather meal in the fish diet

for *Labeo rohita* also showed the same result (Hasan *et al.*, 1997).

The initial fish carcass showed little different protein composition from final fish carcass at the end of the experiment. The percentage of protein in experimental fish carcasses was not significantly different. These indicated that body lipid was not affected by fermented feather meal. This result agreed with Hilge (1984) who reported that the raw fat level of European catfish (*Silurus glanis*) fed with diet containing 50% of a fish meal – feather meal – poultry by product meal mixture replaced by field bean/corn gluten meal or by whey was lower than 10% by weight and also agreed with Fasakin *et al*. (2005) on hybrid tilapia that partial replacement of feather meal diet had similar carcass composition with fish meal diet.

Triiodothyonine (T3) and thyroxine (T4) hormone level in blood at the end of experiment appeared showed that T3 level was not clearly related to the percentage that of replacement but the level of T4 in blood leaves fed with a diet containing fermented feather meal was higher than fish fed with diet containing fish meal. In this study, the results showed that percentage of protein and level of gross energy of all fermented feather meal replaced fish meal diets were suitable for hybrid clarias catfish diet and could increase high thyroid activity in fish fed with a diet containing fermented feather meal. Becuase the thyroid activity depressed by low protein and low calories diet, thyroid activity could be indicated by levels of T3 and T4 hormone in blood of fish and both hormones could increase the basal metabolism rate (Fowler, 1990).

The 25% replacement with fermented feather meal could reduce experimental diet cost 0.81 baht/kg (compare with control diet) and when compared with commercial feed (containing 30% crude protein as 22 baht/kg) could reduce cost about 3.62 baht/kg. Meanwhile, the 50% replacement of fish meal could reduce the experimental diet cost 1.38 baht/kg (compare with control diet) and 4.20 baht/kg with commercial feed. Considering the cost of diet, the 50% fermented feather meal replaced fish meal in the experimental diet was as effective as the control diet and diet containing 25% fermented feather diet since they were not significantly different with fermented feather meal replaced fish meal. In addition, the cost of diet reduced more than 25% fermented feather meal replaced fish meal. But the growth and feed utilization efficiency tended to be lower than 0% (control diet) and 25% fermented feather meal replaced fish meal in the experimental diet. In prolong culture period, it might affect growth and feed utilization efficiency. It should be recommended with caution because farm maintenance expenses due to prolonged growth of the fish must be taken into account.

Water temperature generally did not greatly fluctuate during the experimental periods. The temperature ranged from 23°- 26°C. The dissolved oxygen ranged from 5.27-5.68 mg/l, pH 7.79-7.88, hardness 132.50-133.75 mg/l as $CaCO_3$, alkalinity 368.75-390.25 mg/l as $CaCO_3$ and ammonia concentration 0.56-0.79 mg./l. The water quality was in the desirable ranges for fish culture in this study.

CONCLUSION

A replacement study of fish meal with different percentages of fermented feather meal was conducted on hybrid clarias catfish. Based on the results obtained from this study, it could be concluded that the efficiency of feather meal which underwent the fermentation process by bakery yeast increased. The hybrid clarias catfish experimental diets had a crude protein ranging from 30.40 to 31.36% and a gross energy ranging from 365 to 403 kcal/100g diet. Growth and feed utilization efficiency of hybrid clarias catfish fed with diets containing 0, 25 and 50% fermented feather meal in diet were not significantly different. Fish fed with 25% fermented feather meal had a growth performance close to fish fed with the

control diet (100% fish meal). The cost of hybrid clarias catfish diet supplemented with 25 and 50% of fermented feather meal could reduce costs about 0.81 and 1.38 baht/kg compared with commercial feed, which reduced cost of diets about 2.82 and 3.62 baht/kg.

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