Utilization of feather meal fermented *Bacillus subtilis* to replace fish meal in the diet of silver pompano, *Trachinotus blochii* (Lacepede, 1801)

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Abstract. This study aimed to evaluate the suitability of fermented feather meal as an alternative to fish meal in the diet of silver pompano, *Trachinotus blochii* (Lacepede, 1801). Five diets were formulated to contain 40-41% crude protein, with diet P0 containing 100% fish meal (control diet), and diet P1, P2, P3 and P4 were 10%, 20%, 30%, and 40% levels of fermented feather meal (FFTM) replacement of fish meal in the diet respectively. The juvenile *T. blochii* (with average in body weight 8.56±0.18 g) were stocked into 0.5 m × 0.5 m × 1 m floating net cages at a density of 20 fish cage^{-1}. The experimental diets was given three times daily at approximately 8.00 AM, 12.00 PM and 5.00 PM to apparent satiation for 63 days. The results showed that there was significant difference ($p < 0.05$) in weight gain, specific growth rate, feed efficiency, protein efficiency ratio and proximate composition of fish carcass. Nevertheless there was no significant difference ($p > 0.05$) in the survival rate of the fish in all the treatments. The implication of this study demonstrated the use of 20% fermented feather meal can replace fish meal in the diet of silver pompano.
Key Words: feather meal, *Bacillus subtilis*, feed efficiency, growth, silver pompano.

Introduction. Intensive fish culture requires continuous supply for high quality and quantity of feed. Presently, fishmeal is playing a vital role for protein source in fish diet. However, this protein sources is costly; therefore, the local feed industry substitute an amount of the fishmeal with others local products such as feather meal. This is a chicken slaughterhouse product whose continuity in supply is guaranteed and is cheaper than the imported alternatives. Feather meal has good quality, contains high protein (91%) and lipid (1%) (Okareh et al 2015). Besides, it comes from dried sources and contains 0.16% calcium, 0.04% phosphorus, 0.15% potassium, and 0.15% sodium (Chor et al 2013). However, it is a protein difficult to digest because 90% of it consists of beta-keratin and fiber (Pandian et al 2012).

Keratin is a hardening epidermal tissue composed of fiber proteins rich in sulfur and cystine amino acids mostly found in nails, hair, and feathers. Disulfide bonds formed from amino acids and cystines produce keratin proteins which are very stable, rigid, and not easily digested by proteolytic enzymes such as trypsin, pepsin, and papain. Keratin is neither soluble in water nor in the glands of the digestive tract (Vidhya & Palaniswamy 2013; Brandelli et al 2015). The low digestibility of keratin protein makes chicken feather inappropriate source for fish feed.

The microbial hydrolysis technique in fermentation is a method of keratin degradation meant to increase protein digestibility level of the chicken feather (Brandelli et al 2015). One of the keratin degrading microorganisms is *Bacillus subtilis*. Through the enzyme keratinase, this bacterium degrades keratin in chicken feather. The enzyme is produced by *B. subtilis* bacteria and is capable of hydrolyzing various soluble and insoluble proteins (Singh et al 2017; Imtiaz & Rehman 2018). Fermentation of feather meal using *B. subtilis* increased the fish meal protein digestibility rate from 39.09 to

48.75% (Adelina et al 2017). The digestibility level of dried chicken feather processed might also increase 54.20% (Zerdani et al 2004).

In this study, the chicken feather fermentation was carried out using *B. subtilis* strain, access code JX188065.1. These bacteria were isolated from the digestive tract of tiger shrimp, *Penaeus monodon* from Riau (Feliatra et al 2016). Information about the use of *B. subtilis* as a fermentor is yet to be established, though it has been tested as a probiotic in the diet of tilapia, *Oreochromis niloticus* (Feliatra et al 2016). The test fish used in this study was silver pompano, *Trachinotus blochii*. Information about the use of *B. subtilis* as a fermentor is yet to be established, though it has been tested as a probiotic in the diet of tilapia, *Oreochromis niloticus* (Feliatra et al 2018). The present study was conducted to know the effect of replacement fish meal by fermented feather meal on growth of silver pompano.

Material and Method

Feather meal fermentation using B. subtilis. Fermentation of feather meal took place in 4 stages: (1) chicken feather meal were prepared and sterilized in autoclave at 100^{o}C for 15 minutes then cooled; (2) Petri dishes 90 x 15 mm size prepared 3 pieces and sterilized, then put 10 g of feather meal into each; (3) pure *B. subtilis* was dropped 50 mL onto feather meal and repeated 3 times, then incubated at a temperature of 50^{o}C and pH 8 for 72 hours (Desi 2002). Feather meal fermentation is ready to be used as diet ingredients; (4) fermentation of feather meal was analyzed for protein, lipid and carbohydrate following the AOAC methods (2012).

Diet preparation and analysis. Diet ingredients such as fish meal, tofu waste, wheat flour, vitamin mix, mineral mix and fish oil were purchased from a local feedstuff supplier. Feather meal was made from mashed broiler chicken feathers, and fermented feather meal (FFTM) was obtained from chicken feather meal fermented with the bacterium *B. subtilis*. The ingredients were weighed according to the formulations in Table 1, then mixed until homogeneous, molded into pellets, then dried in an oven at 60^{o}C. Dry pellets were proximate analyzed following the AOAC methods (2012). The results of the proximate composition was shown in Table 1.

Table 1

Formulation and proximate composition of experimental diets

Ingredients (%)	*Diet P0 (FFTM 0)*	*Diet P1 (FFTM 10)*	*Diet P2 (FFTM 20)*	*Diet P3 (FFTM 30)*	*Diet P4 (FFTM 40)*
Fish meal	65	48	32	16	-
Fermented feather meal (FFTM)[1]	-	10	20	30	40
Tofu waste	23	29	34	38	41
Wheat flour	6	7	8	10	13
Vitamin mix[2]	2	2	2	2	2
Mineral mix[3]	2	2	2	2	2
Fish oil	2	2	2	2	2
Chromic oxide	1	1	1	1	1
Proximate composition (%)					
Crude protein	41.45	41.88	41.46	40.93	40.34
Crude lipids	2.08	2.27	2.21	2.33	2.46
Moisture	7.49	7.04	6.62	9.29	7.16
Ash	9.18	12.63	9.17	5.84	5.86
Crude fiber	7.51	7.66	7.88	7.34	7.78
NFE[4]	32.29	29.52	32.66	34.27	36.40
Chromic oxide	0.69	0.80	0.78	0.80	0.74
Energy (kcal DE / 100 g)[5]	318.45	312.43	320.99	325.32	330.77

[1] FFTM = fermented feather meal; [2] vitamin mix (mg/100 g diet): thiamin 5.0; riboflavin 5.0; Ca-pantothenate 10.0; niacin 2.0; pyridoxin 4.0; biotin 0.6; folic acid 1.5; cyanocobalamin 0.01; inositol 200; ρ-aminobenzoic acid 5.0; menadion 4.0; vit A palmitate 15.0; chole-calciferol 1.9; α-tocopherol 20.0; Cholin Chloride 900.0; [3] Mineral mix (mg/100 g diet): KH_2PO_4 412; $CaCO_3$ 282; Ca (H_2PO_4) 618; $FeCl_3.4H_2O$ 166; $ZnSO_4$ 9.99; $MnSO_4$ 6.3; $CuSO_4$ 2; $CuSO_4.7H_2O$) 0.05; KJ 0.15; Dextrin 450; Cellulose 553.51; [4] NFE = nitrogen-free extract; calculated = 100-(%CP+%CL+%moisture+%ash+%CF); [5] Energy = {(protein x 4.5 kcal/g)+(lipid x 9.1 kcal/g)+(NFE x 3.5 kcal/g)}/100 (NRC 1993); DE = digestible energy.

The Completely Randomized Design (CRD) with three replications were used in this study. Five diets were formulated to contain 40-41% protein and 293.05-330.77 kcal/100 g diet of energy. The diet of treatments were: diet P0 (FFTM 0) containing 100% fish meal, and diet P1 (FFTM 10), P2 (FFTM 20), P3 (FFTM 30) and P4 (FFTM 40) were 10%, 20%, 30%, and 40% levels of FFTM replacement of fish meal in the diet respectively.

Feeding trial. Silver pompano fish with an initial mean weight of 8.56±0.18 g were fed with a commercial diet about 7 days before starting the feeding trial. A total of 300 fish were randomly stocked into 0.5 m × 0.5 m × 1 m floating net cages at a density of 20 fish per cage. The experimental diets were given three times daily at approximately 8.00 AM, 12.00 PM and 5.00 PM to apparent satiation for 63 days. At the start and end of the experiment, five fish of each cage were randomly sampled for carcass composition analysis.

Measurement of water quality parameters. Measurement of water quality in the floating net cages was conducted. The parameters measured were temperature, pH, dissolved oxygen (DO), and ammonia. The pH measurements, DO, and ammonia were carried out at the beginning, middle, and end of the study at 12.00 pm, while temperature measurements were taken every day at 08.00 am, 12.00 am and 05.00 pm. Temperature was measured using mercury-in-glass thermometer; pH was measured by a pH metre; dissolved oxygen was measured by a DO metre and ammonia were obtained by titration.

Digestibility study. The ten juvenile silver pompano fish with mean weight of 8.56±0.18 g were placed in a 100-L round plastic containers. The fish were fed three times a day, at 8.00 am, 12.00 am, and 5.00 pm till satiation. All uneaten feed were collected an h after feeding and subsequently, after 4-5 h of feeding and fresh feces were collected by siphoning. Feces were also collected every morning before feeding time. All fecal samples were collected and pooled until sufficient for chemical analysis. The fecal samples were completely dried in the oven at temperature of 60^{o}C, ground using a laboratory grinder and kept in a freezer until further analysis. Analyses of protein, lipid, carbohydrate and chromic oxide content of the feed and feces following the AOAC methods (2012).

Data calculation. At the end of the experimental period, fish growth and feed utilization of all treatments were calculated by the following formulas:

a. Weight gain (g) = final fish weight – initial fish weight;

b. Specific growth rate (SGR) (%) = (Ln mean final fish weight – Ln mean initial fish weight)/ culture period (day) x 100;

c. Survival rate (%) = (final number of fish/initial number of fish) × 100;

d. Diet and nutrient digestibility (protein, lipid and carbohydrate):

Diet digestibility (%) = $(1 - \frac{a}{a'})$ x 100;

Nutrient digestibility (%) = 1 – $(\frac{a}{a'} \times \frac{b'}{b})$ x 100

where: a = % chromic oxide in diets; a' = % chromic oxide in feces; b = % nutrient in diets; b' = % nutrient in feces;

e. Feed efficiency (FE) (%) = increased fish mass/total feed consumed;

f. Protein intake = quantity of diet consumption x % protein in diet;

g. Protein efficiency ratio (PER) = increasing weight in fish mass/protein intake in diet

h. Apparent net protein retention (ANPR) = {[(W1x% P1)-(W0x% P2)]/P} x 100

where: W1 = mean final fish weight (g); W0 = mean initial fish weight (g); P = protein intake in diet; P1 = final percentage of protein in fish; P2 = initial percentage of protein in fish;

i. Carcass composition at the end of experiment were observed for crude protein, crude lipid and carbohydrate.

Data analysis. Experimental data were collected and statistically analyzed by ANOVA (Analysis of Variance) with five treatments and three replications in each treatment. The DMRT (Duncan's Multiple Range Test) was used to determine the differences among the treatment means. The alphabetical notations (a, b, c, d) were used to mark the differences at a significant level of $p < 0.05$. Diet and nutrient (protein, lipid, and carbohydrate) digestibility data, while the water quality of fish culture media were analyzed descriptively.

Results and Discussion

Effect of fermented feather meal on growth and survival of silver pompano. The growth performance and survival of silver pompano diet FFTM over a 63 days period of culturing are showed in Table 2.

Table 2

Effects of experimental diets on growth and survival of silver pompano

Parameter	*Diet P0 (FFTM 0)*	*Diet P1 (FFTM 10)*	*Diet P2 (FFTM 20)*	*Diet P3 (FFTM 30)*	*Diet P4 (FFTM 40)*
Initial weight (g)	8.55 ± 0.24^{a}	8.52 ± 0.24^{a}	8.64 ± 0.14^{a}	8.58 ± 0.12^{a}	$8.47\pm0.19^{a*}$
Final weight (g)	13.96 ± 1.03^{a}	15.03 ± 1.33^{ab}	15.78 ± 0.62^{b}	13.40 ± 0.29^{a}	12.63 ± 0.48^{a}
Weight gain (g)	5.41 ± 1.25^{ab}	6.50 ± 1.23^{bc}	7.14 ± 0.84^{c}	4.81 ± 0.41^{ab}	4.15 ± 0.47^{a}
Specific growth rate (%)	0.40 ± 0.15^{a}	0.76 ± 0.14^{bc}	0.91 ± 0.24^{c}	0.62 ± 0.11^{abc}	0.59 ± 0.09^{ab}
Survival rate (%)	81.67 ± 7.64^{a}	81.67 ± 10.41^{a}	78.33 ± 14.43^{a}	83.33 ± 5.77^{a}	81.67 ± 2.89^{a}

Description: * Data values are the mean and standard deviation. Means with different superscripts (a, b, c) in the same row were significantly different ($p < 0.05$).

At the beginning of the study, the average initial weight of the silver pompano body ranged from 8.47 to 8.64 g, there was no significant difference ($p > 0.05$) in all the experimental diets. After 63 days of experimental feeding, final weight of fish increased from 12.63 to 15.78 g, there were significantly ($p < 0.05$) different form each other.

Fish fed diet containing 20% fermented feather meal (P2, FFTM 20) produced the best mean weight gain in silver pompano (7.14±0.84 g). This was significantly higher than those of other test diets. This performance was followed by that obtained from fish diet (P1, FFTM 10) which has a mean weight gain of (6.50±1.23 g). The lowest average weight gain was observed in the diet P4, FFTM 40 (4.15±0.47 g) but not significantly different ($p > 0.05$) from diet P0 (FFTM 0), and diet P3 (FFTM 30) could be ascribed the presence of anti-nutritional factors in the feather meal may have constrained the proper assimilation of nutrients by the fish and its conversion to tissue. SGR was significantly different amongst the dietary treatments ($p < 0.05$). Fish fed diet containing 20% fermented feather meal (FFTM 20) exhibited significantly higher SGR (0.91±0.24%) compared with the other fed diets, while diet P0, (FFTM 0) had the least SGR (0.40±0.15%). However, in this study we found out that inclusion of up to 20% of FFTM did not give any detrimental effects on the growth performance of the silver pompano, suggesting that it was possible to include feather meal at that percentage in silver pompano diet. Adelina et al (2017) reported that fish fed diet containing 10% FFTM produced the best mean a specific growth rate of in *Lates calcarifer*, Bloch. Campos et al (2015) found that replacement fishmeal by feather meal hydrolysate up to 12.5% in European seabass (*Dicentrarchus labrax*) diets without impairing growth. Abwao et al (2017) incorporated up to 10% of FFTM in *Oreochromis mossambicus* diets and concluded that there was no detrimental effect affecting the growth performance of the fish.

The survival rate of the silver pompano during the feeding trial was relatively high. In all the treatments, survival was above 75%. Survival rate was not significantly affected by the dietary treatments ($p > 0.05$). The highest survival rate was noted in fish fed diet P3 (FFTM 30). The lowest survival rate was obtained from fish fed diet P2 (FFTM 20). According to Abwao et al (2017) the use of fermented feather meal results in the increase in survival of *O. mossambicus* by 77-94%.

Digestibility values of experimental diets and nutrient digestibility in silver pompano*.* Digestibility of fish feed and nutrient (protein, lipid and carbohydrate) digestibility are showed in Table 3.

Table 3

Effects of experimental diets on feed digestibility, nutrient digestibility, and feed efficiency of silver pompano

Parameter	*Diet P0 (FFTM 0)*	*Diet P1 (FFTM 10)*	*Diet P2 (FFTM 20)*	*Diet P3 (FFTM 30)*	*Diet P4 (FFTM 40)*
Feed digestibility (%)	21.74	31.19	37.05	35.19	29.72
Protein digestibility (%)	52.45	63.11	67.24	62.30	60.15
Lipid digestibility (%)	42.59	44.13	44.89	41.86	41.43
Carbohydrate digestibility (%)	45.34	54.03	54.83	54.38	53.51
Total feed intake (g)	207.50 ± 3.75^{c}	204.03 ± 0.75^{c}	202.70 ± 4.52^{c}	187.70 ± 2.72^{b}	$182.00 \pm 2.42^{a*}$
Feed efficiency (%)	34.64 ± 8.58^{a}	41.75 ± 4.37^{ab}	54.03 ± 9.72^{b}	37.29 ± 6.68^{a}	34.28 ± 6.33^{a}
Protein intake (g ind^{-1})	61.69 ± 1.66^{a}	85.45 ± 0.31^{c}	84.04 ± 1.88^{c}	76.82 ± 1.11^{b}	$66.90 \pm 4{,}97^{a}$
Protein efficiency ratio (%)	0.42 ± 0.23^{a}	0.63 ± 0.18^{a}	0.77 ± 0.09^{a}	0.52 ± 0.08^{a}	0.45 ± 0.19^{a}
Apparent net protein retention (%)	35.77 ± 5.73^{a}	42.59 ± 4.55^{ab}	51.79 ± 8.65^{b}	45.64 ± 4.62^{ab}	38.53 ± 5.15^{a}

Description: * Data values are the mean and standard deviation. Means with different superscripts (a, b, c) in the same row were significantly different ($p < 0.05$).

The digestibility of feed was that diet P2, FFTM 20 (37.05%) had a significantly higher value than the other diets, whereas the lowest was observed in diet P0, FFTM 0 (21.74%). Adelina et al (2017) found that the highest feed digestibility in *Lates calcarifer* was 65.16%. Digestibility of protein and carbohydrate was the highest in fish fed with diet P2, FFTM 20 (67.24% and 54.835 respectively) and the lowest in diet P0, FFTM 0 (52.45% and 45.34% respectively). The digestibility of lipid was the highest in fish fed with diet P2, FFTM 20 (44.89%), while the lowest in diet P4, FFTM 40 (41.43%). An increase of fermented feather meal (FFTM 30 and FFTM 40) in the diets results in lower nutrient (protein, lipid and carbohydrate) digestibility. The digestibility of protein in silver pompano is higher (67.24%) than in snapper (48.75%) (Adelina et al 2017). According to Brandelli et al (2015) and Mazotto et al (2011), *B. subtilis* increase digestibility and improve the quality of protein in chicken feather. The bacteria produce keratinase, protease, lipase, and amylase enzyme which are useful in simplifying complex molecules in fish fed to increase its digestibility. Zerdani et al (2004) stated that chicken feather processing with *B. licheniformis* microbes increases the digestibility of its protein by 54.20%. The high digestibility values of FFTM indicated that it could be a good protein source for silver pompano.

Total feed intake in fish fed with diet P0-P4 (FFTM 0 – FFTM 40) were significantly different ($p < 0.05$) but not in all the treatment diets (Table 3). The lowest total feed intake of (182.00 ± 2.42%) was observed in the diet P4 (FFTM 40). Feed efficiency in fish fed was significantly different ($p < 0.05$) but not in all the treatment diets. There were no significant differences ($p > 0.05$) between fish fed with diet P0, FFTM 0 (34.64 ± 8.58%), P3, FFTM 30 (37.29 ± 6.68%), and P4, FFTM 40 (34.28 ± 6.33%). This study is showing that the higher the inclusion of the FFTM in the diet, the lesser was the intake and efficiency of feed. This could be related to the low digestibility in fish feed diet containing 40% FFTM. This result was probably related to the palatability of the diets. As the amount of FFTM increased in the diets, there was a decrease in food consumption. Perhaps the smell of diet containing 100% FFTM affected the palatability of fish (Somsueb & Boonyaratpalin 2001). The highest of total feed intake was found in fish feed P0 (FFTM 0), but no significant differences ($p > 0.05$) among diet P1, FFTM 10 and P2, FFTM 20. The highest feed efficiency was found in fish fed P2 (FFTM 20). Yong et al (2018) reported that feather meal could be included up to 15% in tilapia diet, replacing 100% of fishmeal in the formulation and was better when compared to the control without feather meal inclusion. Higher inclusion of feather meal was suspected to be possible without compromising the growth performance (Yong et al 2018).

Protein intake showed that all the diets (P0-P4) were significantly different ($p < 0.05$) but not in all the treatment diets. There were no significant differences ($p > 0.05$)

between fish fed with diet P0, FFTM 0 (61.90±1.66 g ind^{-1}) and diet P4, FFTM 40 (66.90±4.97 g ind^{-1}), and there were no significant differences ($p > 0.05$) between fish fed diet P1, FFTM 10 (85.45±0.31 g ind^{-1}) and diet P2, FFTM 20 (84.04±1.88 g ind^{-1}). Protein efficiency ratio in fish fed were no significant differences ($p > 0.05$) among all diet. The protein efficiency ratio of the diet slightly decreased when the fermented feather meal increased 30-40%. Somsueb & Boonyaratpalin (2001) showed that increasing feather meal in fish diet resulted in decreasing with protein efficiency ratio and similar to Arunlertaree & Rakyuttithamkul (2006) presented data on the hybrid *Clarias* catfish which reported protein efficiency ratio of fish decreased with increased of feather meal in the diets.

ANPR fish fed were significant ($p < 0.05$) but not in all the treatment diets. There were no significant differences ($p > 0.05$) between fish fed with diet P0, FFTM 0 (35.77±5.73%) and P4, FFTM 40 (38.53±5.15%). The ANPR was the highest in fish fed with a diet containing 20% FFTM replacement and showed no significant difference ($p > 0.05$) from diets containing 10% and 30% FFTM but higher than diets containing 0% and 40% FFTM. The difference in ANPR might be caused by differences in the quality of protein obtained from the diet. Somsueb & Boonyaratpalin (2001) and Arunlertaree & Rakyuttithamkul (2006) also showed that increasing the feather meal in fish diet, decreased the ANPR.

Proximate composition of the fish carcass. The proximate composition of the experimental fish carcass in the initial and the final of the feeding trials is presented in the Table 4.

Table 4

Proximate composition of the carcass of silver pompano fed the experimental diets at the start and end of the experiment

Composition	*Initial body composition (%)*	*Final body composition (%)*				
		Diet P0 (FFTM 0)	*Diet P1 (FFTM 10)*	*Diet P2 (FFTM 20)*	*Diet P3 (FFTM 30)*	*Diet P4 (FFTM 40)*
Crude protein	40.73	50.42±2.64^{a}	50.18±3.32^{a}	51.58±3.87^{a}	54.57±1.92^{a}	53.56±2.48^{a}
Lipid	3.37	3.66±0.32^{b}	3.33±0.25^{ab}	3.03±0.10^{a}	3.49±0.11^{b}	4.10±0.04^{c}
NFE	4.45	1.16±0.28^{a}	1.67±0.17^{b}	2.52±0.49^{c}	0.82±0.22^{ab}	1.52±0.71^{ab}
Crude fibre	5.56	0.58±0.24^{a}	0.91±0.49^{a}	1.00±0.06^{a}	1.05±0.26^{a}	0.67±0.14^{a}
Moisture	4.76	6.98±1.87^{c}	4.23±0.50^{ab}	4.93±0.35^{abc}	3.58±1.14^{a}	5.78±1.22^{bc}
Ash	25.36	24.98±4.79^{a}	25.50±3.30^{a}	25.31±2.39^{a}	23.12±1.84^{a}	23.40±1.28^{a}

Description: * Data values are the mean and standard deviation. Means with different superscripts (a, b, c) in the same row were significantly different ($p < 0.05$).

All fish displayed a change in the whole body composition compared with the initial composition. The crude protein, lipid and moisture content in the initial fish flesh was 40.73%, 3.37% and 4.76% respectively, and were lower when compared to the treatments, but the NFE (nitrogen-free extract), crude fibre and ash content was 4.45%, 5.56%, and 25.36% respectively, and were higher in the initial fish. The highest protein content of (54.57±1.92%) was in the fish fed with diet P3 (FFTM 30), while the lowest protein content of (50.18±3.32%) was observed in the diet P1 (FFTM 10). However, statistical analysis indicated that there was no significant difference ($p > 0.05$) in the protein content of the fish carcass. These indicated that body protein was not affected by fermented feather meal. This result agreed with Arunlertaree & Rakyuttithamkul (2006) on hybrid *Clarias* catfish that partial replacement of feather meal diet had similar carcass composition with fish meal diet. Farahiyah et al (2018) obtained that protein composition of carcass red hybrid tilapia was found to be lowest in treatment with 10% FFTM, while the highest protein percentage was in the control (100% fish meal). The highest lipid content of carcass was observed in the fish fed with diet P4 (FFTM 40), while the lowest lipid content was found in the diet P2 (FFTM 20). There was however, no significant difference ($p > 0.05$) amongst diet P0 (FFTM 0) and P3 (FFTM 30). The energy of diet was highest in 20% FFTM which could be associated with the high lipid content in the fish. These results are similar to Farahiyah et al (2018) who showed that the inclusion of the puffed feather meal increased in the diet, the content of lipid carcass also increased.

The NFE content was highest (2.52±0.49%) in diet P2 (FFTM 20) and lowest (0.82±0.22%) in the diet P3 (FFTM 30). There were significant differences ($p < 0.05$) in the NFE content of the fish carcass. The crude fiber had no significant differences ($p > 0.05$) among all diets. The percentage of moisture content was highest (6.98±1.87%) in diet P0 (FFTM 0) and lowest (3.58±1.14%) in diet P3 (FFTM 30), of which is significantly ($p < 0.05$) different from other experimental diets. Similarly to Arunlertaree & Rakyuttithamkul (2006) who obtained that the initial fiber composition on hybrid *Clarias* catfish carcass was higher than fish at the end of the experiment. Farahiyah et al (2018) obtained that the crude fiber was highest in the control group (100% fish meal) and the percentage decreased when the inclusion of puffed feather meal was increased. The ash content was highest (25.50±3.30%) in the diet P1 (FFTM 10) and lowest (23.12±1.84%) in diet P3 (FFTM 30). There were no significant differences ($p > 0.05$) in ash content amongst the fish fed the five experimental diets. Farahiyah et al (2018) showed that the ash of carcass red hybrid tilapia was highest in the initial fillet and was significantly different ($p < 0.05$) compared to the treatments.

Water quality. The results of water quality measurements during the experimental period are showed in Table 5.

Table 5

Water quality parameters recorded during the feeding trial

Mean	*Diet P0 (FTM 0)*	*Diet P1 (FFTM 10)*	*Diet P2 (FFTM 20)*	*Diet P3 (FFTM 30)*	*Diet P4 (FFTM 40)*
Temperature (^{0}C)	28.4 ± 0.6^a	28.8 ± 0.8^a	28.4 ± 0.5^a	28.7 ± 0.5^a	$28.6 \pm 0.7^{a*}$
pH	7.8 ± 0.2^a	7.8 ± 0.2^a	7.9 ± 0.1^a	7.8 ± 0.3^a	7.8 ± 0.4^a
Salinity (ppt)	29.0 ± 1.0^a	30.0 ± 0.5^a	29.0 ± 1.0^a	29.0 ± 1.0^a	30.0 ± 0.5^a
Dissolved oxygen (mg L^{-1})	6.8 ± 0.4^a	7.0 ± 0.2^a	6.9 ± 0.5^a	6.8 ± 0.5^a	7.0 ± 0.3^a
Ammonia (mg L^{-1})	0.04 ± 0.02^a	0.03 ± 0.02^a	0.04 ± 0.02^a	0.05 ± 0.01^a	0.05 ± 0.02^a

Description: * Data values are the mean and standard deviation. Means with different superscripts (a, b, c) in the same row were significantly different ($p < 0.05$).

Water temperature during the maintenance of silver pompano in generally did not greatly fluctuate during the experimental periods. The temperature ranged from 28.4 to 28.8°C, pH ranged from 7.8 to 7.9, salinity ranged from 29.0 to 30.0 ppt, DO ranged from 6.8 to 7.0 mg L^{-1} and ammonia concentrations ranged from 0.03 to 0.05 mg L^{-1}. The water quality was in the desirable ranges for silver pompano culture in this study.

Cost of experimental diets. Total raw material cost of diet P0-P5 ranged from 24,345 to 38,725 Rp/kg as presented in Table 6.

Table 6

Cost of silver pompano experimental diets

Raw material	*Price (Rp/kg)*	*Diet P0 (FTM 0)*	*Diet P1 (FFTM 10)*	*Diet P2 (FFTM 20)*	*Diet P3 (FFTM 30)*	*Diet P4 (FFTM 40)*
Fish meal	30,000	19,500	14,400	9,600	4,800	-
Feather meal	10,000	-	1,000	2,000	3,000	4,000
Tofu waste	3,500	805	1,015	1,190	1,330	1,435
Wheat flour	7,000	420	490	560	700	910
Vitamin mix	400,000	8,000	8,000	8,000	8,000	8,000
Mineral mix	400,000	8,000	8,000	8,000	8,000	8,000
Fish oil	100,000	2,000	2,000	2,000	2,000	2,000
Total (Rp/kg)		38,725	34,905	31,350	27,830	24,345

Note: Official exchange rate: P0-P4 14,198 per US$.

Table 6 shows that the more the amount of FFTM in the diets, the lower the cost of diet. Cost of control feed (FFTM 0) is Rp. 38,725 / kg. Replacement of fermented feather meal at 10, 20, 30 and 40% of fish meal reduced costs about 3,820, 7,375, 10,895 and 14,380 Rp/kg, respectively. The growth and feed utilization tended to be higher in feed containing 20% FFTM in the experimental diet. The composition of the use of 20% FFTM to replace fish meal needs to be recommended as silver pompano diet to reduce costs of diet.

Conclusions. This study obtained that inclusion up to 20% of fermented feather meal might replace fish meal in the diet of silver pompano, and resulted in improving the growth performance and feed efficiency. The composition of protein, fiber and ash content in the final carcass of fish was similar in all treatment diets, but the lipid content was the lowest in FFTM 20 diet.

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