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Replacement of fishmeal in cobia (*Rachycentron canadum*) diets using poultry by-product meal

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Abstract An 8-week feeding trial was conducted to evaluate the use of local poultry by-product meal (PBM) in replacement of imported fishmeal in the diets of cobia, *Rachycentron canadum.* Six isolipidic (12%) and isoproteic (45%) experimental diets were formulated using PBM to replace fishmeal at 20, 40, 60, 80 and 100% dietary protein. Eleven juvenile cobia (initial mean weight of 30.7 ± 0.78 g) were randomly stocked in 300-L circular fibreglass tanks and hand-fed based on the total biomass of each tank, twice a day at 0900 h and 1500 h. The fish were group weighed at 2-week intervals to monitor their growth performance in order to adjust the feeding ratio. At the end of the feeding trial, weight gains (WGs) ranging from 221 to 322% were obtained. The specific growth rate (SGR), WG and protein efficiency ratio (PER) for fish fed with PBM-based diets were not significantly different ($P > 0.05$) when compared to fish fed the control diet. The best SGR was recorded for fish fed with 60PBM diet, which was significantly higher ($P < 0.05$) than those fed the control diet with values at 2.40 ± 0.01 and 1.97 ± 0.26%/day, respectively. The FCR of 1.83 ± 0.05 for fish fed the 60PBM diet was not significantly different ($P > 0.05$) when compared to those fed the control diet. The PBM source and dietary level did not significantly ($P > 0.05$) affect the hepatosomatic index of the fish. The results from this study suggested that PBM could replace 100% dietary fishmeal without adversely affecting the growth performance, but an optimal replacement level at approximately 60% was recommended for better growth performance and efficient feed utilization.

Keywords Cobia · Nutrition · Fishmeal · Poultry by-product meal · Specific growth rate

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Introduction

Cobia, *Rachycentron canadum,* Linnaeus, 1766 is a marine carnivorous species commonly referred to as the ling, lemon fish, crab-eater or aruan tasek in the Malay language (Anon 2007; 2008). Cobia is widely distributed in tropical and subtropical waters (Briggs 1960). Cobia is becoming a popular species for aquaculture due to its impressive growth performance, primarily in the United States and Asia (Holt et al. 2007). The successful development of artificial propagation techniques and larval production contributed to the fast development of the cobia aquaculture industry. Besides exhibiting good growth performance and many other favourable production-related characteristics, cobia also renders a high-quality fillet that is suitable for sashimi, broiled, fried or steamed dishes (Chang 2003; Shiau 2007).

Understanding the nutritional requirement for cobia is essential to ensure profitable production and long-term sustainability of the cobia aquaculture industry. Some previous studies had looked at specific aspects of cobia nutrition such as optimum dietary protein (Chou et al. 2001; Craig et al. 2006), lipids requirement (Chou et al. 2001; Craig et al. 2006; Wang et al. 2005) and energy budget (Sun et al. 2006).

Limited fishmeal supply due to the fast development of the aquaculture industry, as well as dependence of other industries on fishmeal as a protein source has caused a marked increase in the price recently. Over the last 20 years, the total global fishmeal production has remained fairly static at around 6 million tonnes and the usage by the aquaculture sector has shown a marked increase from 45% in 2002–57% in 2006 (Jackson 2007). Based on a global survey in 2006, the aquaculture sector uses up to 68.2% of the global fishmeal production and 88.5% of the total reported fish oil production (Tacon and Metian 2008). The global trend shows increasing fishmeal and fish oil prices in the long run, thus exerting pressure on the feed Manufacturers for protein dietary substitution. In order to minimize the dependence on fishmeal, alternative protein sourcing is a priority area of study for all aquaculture species. Previous studies pertaining to the utilization of alternative protein sources to replace fishmeal are soya bean meal (Chou et al. 2004), organic protein sources such as NuPro®, soya bean meal and hemp (Lunger et al. 2007) and organically certifiable yeast-based protein source (Lunger et al. 2006) have been carried out for cobia. However, there is a general lack of information regarding replacement studies using PBM for cobia.

Poultry by-product meal (PBM) is a good alternative protein source to replace fishmeal. PBM has high protein content (60–80%), is highly digestible and is commercially available in the market in high volumes and controlled quality. PBM as a fishmeal replacement has been reported in various aquaculture species such as Nile tilapia (Soltan 2009), shrimp (Cruz-Suarez et al. 2007), grouper (Shapawi et al. 2007), rainbow trout (Steffens,1994), bass species (Rawles et al. 2006; Subhadra et al. 2006; Webster et al. 2000), gilthead seabream (Nengas et al. 1999) and many other species with varying inclusion levels in the diets. In terms of nutrient digestibility studies using poultry meal in cobia diets, a study by Zhou et al.*(*2004) indicated that 90% crude protein and 92% crude lipid were efficiently digested. Digestibility studies using PBM for the Atlantic cod reported poor digestibilities (Tibbetts et al. 2006).

At present, there is limited information on cobia diets using PBM. Thus, this study was attempted to determine the quality and acceptability of local poultry by-product meal in replacing FM in cobia diets. The objectives of this study are to quantify the maximum level of local PBM protein that could be incorporated into the diets of the juvenile cobia and to evaluate the fillet quality.

Materials and methods

The study was conducted at the National Shrimp Fry Production and Research Centre (NAFPRE) hatchery, Fisheries Department, Kg. Pulau Sayak, Kedah, Malaysia.

Preparation of experimental diets

Imported fishmeal and local PBM were the major protein components used in the experimental diets. The proximate (crude protein, crude lipid, ash, fibre and moisture) and amino acid composition of the fishmeal and PBM were analysed using standard methods (AOAC 1997). The PBM was purchased from the Dinding Poultry Processing Plant, Kg. Acheh, Setiawan, Perak, Malaysia.

Six experimental diets were formulated to be isonitrogenous (45% crude protein) and isolipidic (12% crude lipid). The control diet (0PBM) was formulated using imported fishmeal as the main protein source. Other diets were formulated using PBM to replace fishmeal dietary protein at 20, 40, 60, 80 and 100% and named as diet 20PBM, 40PBM, 60PBM, 80PBM and 100PBM, respectively. The formulations for the experimental diets are presented in Table 1.

The diets were prepared using a pelletizer (Hwang Yang Co., Taiwan). Each macro ingredient was weighed according to the formulation and placed in the mixer bowl for about 15 min. The mixed micro ingredients (vitamins, minerals, binder and others) were then added into the mixer bowl to be well blended. After mixing all the ingredients, fish oil and water were added into the mixture. The diets were then transferred to the pelletizer for extrusion through a 4 mm die. Finally, the diets were oven dried at 65°C and subsequently cooled to room temperature. The experimental diets were analysed for proximate analysis prior to the feeding trial to verify accuracy of the formulation. The experimental diets were hydrolysed (acid hydrolysis, performic acid and alkaline hydrolysis), and amino acid analysis was performed using high-performance liquid chromatography (Waters Corporation, Milford, Massachusetts, USA). Results from this verification are reported in Table 2.

Table 1 Ingredients composition of the experimental diets (% of dry weight)

Ingredients	0PBM	20PBM	40PBM	60PBM	80PBM	100PBM
Fishmeal	50.0	40.0	30.0	20.0	10.0	0.0
Poultry by-product meal	0.0	12.0	24.0	36.0	48.0	60.0
Soybean meal	11.5	11.5	11.5	11.5	11.5	11.5
Wheat pollard	8.3	8.7	9.1	9.5	9.9	10.3
Rice bran	9.7	8.7	7.6	6.6	5.5	4.5
Corn meal	10.2	9.3	8.4	7.5	6.6	5.7
Fish oil	5.0	4.5	4.1	3.6	3.2	2.7
Mineral premix	1.0	1.0	1.0	1.0	1.0	1.0
Vitamin premix[a]	0.1	0.1	0.1	0.1	0.1	0.1
Vitamin C[b]	1.0	1.0	1.0	1.0	1.0	1.0
Choline Chloride	1.5	1.5	1.5	1.5	1.5	1.5
Binder	1.7	1.7	1.7	1.7	1.7	1.7

[a] Rovimix 6288, Roche, Switzerland

[b] Roximix Stay-C35, DSM Nutritional, France

Table 2 The proximate and amino acid composition of the experimental diets

Diet	0PBM	20PBM	40PBM	60PBM	80PBM	100PBM
Proximate composition(% of dry weight)						
Crude protein	46.6	46.6	47.1	47.0	47.5	48.3
Crude lipid	11.5	12.5	11.4	11.9	12.2	11.1
Ash	11.8	12.5	12.5	13.0	13.4	13.4
Crude fibre	2.7	2.8	3.0	2.6	2.7	2.9
Energy (cal/g)	4,759	4,706	4,537	4,155	5,084	4,332
Amino acid composition (%)						
Asp	3.20	3.40	3.16	3.28	3.36	3.31
Glu	5.31	5.60	5.30	5.52	5.79	5.76
Ser	1.77	1.80	1.72	1.90	1.98	2.03
Gly	2.62	2.85	3.00	3.44	3.92	4.40
His	0.99	0.96	0.90	1.02	1.03	1.03
Arg	2.75	2.71	2.65	3.03	3.20	3.29
Thr	1.77	1.69	1.55	1.69	1.76	1.78
Ala	2.50	2.54	2.40	2.53	2.65	2.70
Pro	2.14	2.19	2.41	2.52	2.83	3.06
Tyr	0.97	0.94	0.95	1.09	1.15	1.20
Val	2.23	2.11	1.93	2.01	2.03	2.00
Met	2.38	2.14	2.06	1.91	1.85	1.83
Cys	0.38	0.32	0.34	0.38	0.45	0.49
Iso	1.98	1.83	1.67	1.74	1.75	1.73
Leu	3.29	3.06	2.84	2.94	2.97	2.92
Phe	1.90	1.75	1.62	1.70	1.72	1.72
Trp	0.41	0.38	0.37	0.36	0.41	0.30
Lys	2.51	2.56	2.31	2.35	2.34	2.27

Procurement of fish

Juvenile cobia (two to five gram) was air freighted from Taiwan and reared in a 16,000-L cement tank until they attain 30 g each. The fish were fed twice a day using commercial diets (crude protein 45%, crude lipid 16%, imported from Taiwan). A flow-through water system was deployed during the rearing stage. Fish sampling was conducted weekly to monitor their growth rates. When the fish size attained around 30 g each, they were selected and transferred into the experimental tanks (300 L) and were acclimated for 2 weeks. About 15–20 juvenile cobia were stocked in each tank. During the acclimatization period, the fish were fed on control diet.

Experimental design

Growth performance

The study was conducted in 300-L conical fibreglass tanks. A total of 18 tanks were used in this feeding trial (3 tanks per diet). The tanks were fitted with aeration, seawater and freshwater supply. The sea water supply passed through sedimentation process prior to a sand filter. Each tank was covered with a nursery net to keep the fish from jumping out of the tanks.

After the acclimatization process, the weight and total length of the fish were measured individually and randomly distributed into the experimental tanks. Fish with an initial weight ranging from 29.5 to 32.0 g were used in this study and stocked at 11 fish/tank. Three replicate tanks were randomly assigned to each diet.

The fish were hand-fed twice a day at 0900 h and 1500 h. The feeding ratio used was approximately 7% of the fish biomass in the tank. The feed were fed to satiation with the maximum feed used at 7% of the fish biomass. After the second feeding, any excess diets from each tank was weighed and recorded. Sampling was carried out at 2-week intervals by bulk weight and the fish number was counted and recorded. Based on the biomass recorded at each sampling, the daily feed amount was adjusted accordingly. At the end of 8 weeks feeding trial, the weight and total length of fish were measured and recorded individually.

Water quality (temperature, salinity and dissolved oxygen) was monitored twice a day before feeding time by using thermometer, refractometer and dissolved oxygen meter YSI 500, respectively.

Fillet study

At the beginning of the feeding trial, ten fish were killed for fillet proximate analysis. At the end of the feeding trial, three fish from each tank were killed for fillet proximate analysis and hepatosomatic index (HSI).

Statistical analysis

Several formulae were used to quantify various ratios and indices in the study:

(a) Weight gain (WG) (%) = (final weight − initial weight) × 100/initial weight
(b) Protein efficiency ratio (PER) = Body WG (g)/(feed intake × crude protein content of the feed) (g)
(c) Hepatosomatic index (HSI) = (Liver weight/body weight) × 100
(d) Specific growth rate = (Ln Wf − Ln Wi/$t_2 - t_1$) × 100

where: Ln = Natural logaritma; Wi = Mean initial weight; Wf = Mean final weight; t_2 = day of termination and t_1 = day of stocking

(e) Feed conversion ratio (FCR) = Total feed consumed/biomass gain
(f) Survival (%) = final count at harvest/initial count × 100

Data were analysed using one-way ANOVA (Statistical SPSS version 11.5 for Windows) to compare significant differences between treatments, whereas the Duncan's multiple range test was used to compare treatment means.

Results

Nutrient composition of the experimental diets

The proximate and amino acid composition of the imported fishmeal and poultry by-product meal are shown in Table 3. Both protein sources contained high protein levels in the range of 61–73% and moderate levels of crude lipid at 10–14%. The amino acid

Table 3 Nutrients composition of dietary protein ingredients (% dry matter)

Ingredients	Imported fishmeal (IFM)	Poultry by-product meal (PBM)
Proximate composition (% dry weight)		
Moisture	8.6	5.7
Crude protein	73.9	61.9
Crude lipid	10.4	14.6
Ash	14.8	17.0
Crude fibre	0.7	0.5
Amino acid composition (%)		
Aspartic acid (asp)	5.37	4.53
Glutamic acid (glu)	7.94	7.36
Serine	2.59	2.78
Glycine	3.83	6.50
Histidine	1.51	1.45
Arginine	3.90	4.67
Threonine	2.69	2.47
Alanine	3.84	3.90
Proline	2.60	4.15
Tyrosine	1.88	1.71
Valine	3.08	2.76
Methionine	4.18	2.55
Cystine	0.48	0.67
Isoleusine	2.73	2.35
Leusine	4.50	3.95
Phenylalanine	2.49	2.30
Trptophan	0.76	0.30
Lysine	4.70	3.28

compositions in PBM particularly for methionine and lysine have limited essential amino acid when compared to FM. Methionine content in FM was higher (4.18%) when compared to PBM (2.55%). Lysine content in PBM was lower (3.28%) when compared to FM (4.70%).

Meanwhile, Table 2 shows the proximate and amino acid composition of the experimental diets. The calculated crude protein values for all diets were around 45% and the results from analysed values were in range of 47.2–48.2%. The analysed result for crude protein was slightly higher than the computed value; however, the difference was still in the acceptable range. The lipid contents for all diets were formulated to be around 12% and the analysed values ranged from 11.1 to 12.5%. The crude fibre and ash contents were in the range of 2.6–3.0 and 11.8–13.4%, respectively. The amino acid composition in diets reflected the composition of the protein sources used. Methionine and lysine contents of the experimental diets were reduced as the inclusion level of PBM was increased.

Growth performance and biometric parameters

The parameters for water quality throughout feeding trial period recorded for temperature were in the range of 24–30°C, salinity 28–30 ppt and dissolved oxygen 4–6 mg/L.

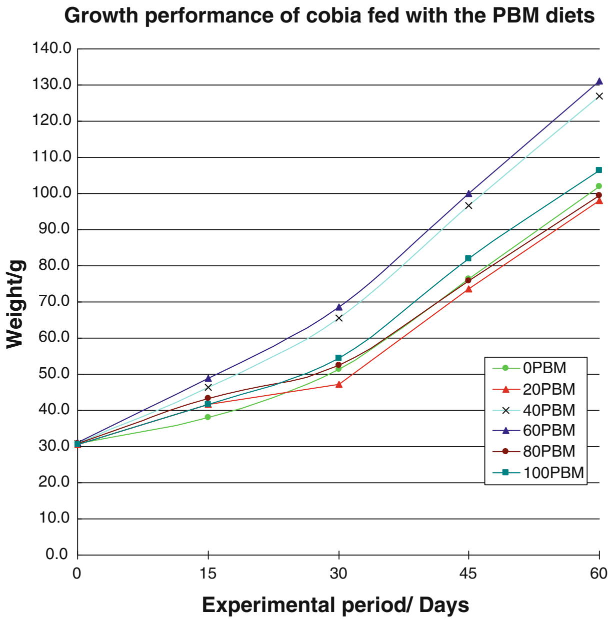

Fig. 1 The growth performance of cobia fed with diets containing various level of PBM

The growth performances of the fish during the experimental period are presented in Fig. 1. After 2 weeks, the fish fed on 60PBM diet showed the highest mean weight (48.96 ± 2.81 g) when compared to others (38.02 ± 9.66, 41.61 ± 2.96; 46.29 ± 4.18, 43.26 ± 7.06 and 41.60 ± 4.74 g). At the second sampling (day 30), the highest mean weight was obtained for fish fed the 60PBM diet (68.66 ± 5.73 g) followed by the 40PBM diet (65.62 ± 11.4 g). The same trend was observed during sampling period (day 45 and 60) where the highest mean weights were recorded for fish fed the 60PBM diet (99.96 ± 2.40 and 131.09 ± 0.66 g, respectively). The mean weights obtained for fish fed the 60PBM and 40PBM diets were not significantly different ($P > 0.05$), whereas the mean weights for fish fed the 0PBM, 20PBM, 80PBM and 100PBM diets were not significantly ($P > 0.05$) different from each other. The growth of fish fed the 40PBM and 60PBM diets were better than those fed the other diets beginning at the first sampling (14 days) through the fourth sampling (60 days).

Growth performance, feed utilization and body indices of cobia juvenile fed poultry by-product meal-based diets are shown in Table 4. The survival rate was recorded at 100% throughout the feeding trial for all tanks. The mean final weight for fish fed the 40PBM and 60PBM was not significantly ($P > 0.05$) different between these two diets with values at 127.1 ± 13.81 and 131.1 ± 0.66 g, respectively. However, the mean final weight for fish fed the 0PBM, 20PBM, 80PBM and 100PBM was significantly lower ($P < 0.05$) than fish fed the 40PBM and 60PBM (Table 4). The highest mean WG was obtained for fish fed the 60PBM diet, which was 323.0 ± 1.81% and which was significantly higher ($P < 0.05$) than fish fed the control diet (0PBM).

The mean WG for fish fed diets containing 40 and 60% of PBM protein source returned over 300% increase from the initial weight (30.7 g), which was significantly higher ($P < 0.05$) than the control diet (229.2%). The mean WG for fish fed the 40PBM, 60PBM and 100PBM diets showed no significant difference ($P > 0.05$) among the group at values 313.2 ± 46.64, 323.0 ± 1.81 and 248.0 ± 28.95, respectively. The best specific growth

Table 4 Growth performances, feed efficiency and body indices of cobia juvenile fed poultry by-product meal-based diets

Diet	0PBM	20PBM	40PBM	60PBM	80PBM	100PBM
% of PBM protein	0	20	40	60	80	100
Mean final wt/g	101.8 ± 16.98^{a}	98.2 ± 11.59^{a}	127.1 ± 13.81^{bc}	131.1 ± 0.66^{c}	99.4 ± 18.06^{a}	106.3 ± 5.08^{ab}
Mean weight gain/%	229.2 ± 53.75^{a}	221.6 ± 36.50^{a}	313.2 ± 46.64^{b}	323.0 ± 1.81^{b}	224.0 ± 59.54^{a}	248.0 ± 28.95^{ab}
SGR(%/day)	1.97 ± 0.26^{ab}	1.94 ± 0.19^{a}	2.36 ± 0.18^{bc}	2.40 ± 0.01^{c}	1.94 ± 0.32^{a}	2.07 ± 0.14^{abc}
FCR	1.85 ± 0.04^{a}	1.86 ± 0.06^{a}	1.89 ± 0.08^{ab}	1.83 ± 0.05^{a}	2.00 ± 0.11^{bc}	2.05 ± 0.04^{c}
PER	1.20 ± 0.03^{c}	1.20 ± 0.04^{c}	1.18 ± 0.05^{bc}	1.22 ± 0.04^{c}	1.11 ± 0.06^{ab}	1.09 ± 0.02^{a}
HSI	1.97 ± 0.19	1.89 ± 0.38	1.90 ± 0.18	1.86 ± 0.26	2.04 ± 0.29	1.77 ± 0.34
Survival (%)	100	100	100	100	100	100

Values are means ± SD

Means within a given row with different superscripts are significantly different ($P < 0.05$)

Table 5 Fillet proximate composition (% wet weight basis) of cobia fingerling fed experimental diets

Diet	0PBM	20PBM	40PBM	60PBM	80PBM	100PBM
Moisture	74.0 ± 1.18	72.8 ± 2.48	73.7 ± 1.46	73.2 ± 0.95	74.2 ± 0.85	73.5 ± 0.70
Crude protein	19.6 ± 1.07	21.1 ± 2.71	19.8 ± 0.58	20.2 ± 0.60	20.0 ± 0.10	20.1 ± 0.77
Crude lipid	4.7 ± 0.89	4.7 ± 0.60	5.3 ± 1.66	5.5 ± 1.44	4.1 ± 0.34	4.9 ± 0.17
Ash	1.7 ± 0.37	1.7 ± 0.27	1.6 ± 0.18	1.8 ± 0.36	1.6 ± 0.19	1.5 ± 0.14

No significant difference for all parameters tested ($P > 0.05$)

The initial fillet composition of fish was 82.6% moisture, 16% crude protein, 1.6% crude lipid and 0.8% ash

rate (SGR) obtained for fish fed the 60PBM diet (2.40 ± 0.01%/day) was significantly higher ($P < 0.05$) than the 0PBM and 100PBM diets at values 1.97 ± 0.26 and 2.07 ± 0.14%/day, respectively. However, the SGR for fish fed the 60PBM, 40PBM and 100PBM diets showed no significant differences ($P > 0.05$). The mean final weight, mean WG and SGR for fish fed the control diet were significantly lower ($P < 0.05$) than fish fed the 40PBM, 60PBM and 100PBM diets.

Feed utilization in terms of FCR and PER shows that the 60PBM diet exhibited better FCR as well as PER when compared to other diets at values 1.83 ± 0.05 and 1.22 ± 0.04, respectively (Table 4). The FCR for the 100PBM diet was significantly higher ($P < 0.05$) than the 0PBM and 60PBM diets at 2.05 ± 0.04. The best FCR obtained for fish fed the 60PBM diet at 1.83 ± 0.05, which showed no significant difference ($P > 0.05$) when compared to 0PBM, 20PBM and 40PBM diets. The highest PER of 1.22 ± 0.04 was obtained from fish fed the 60PBM diet. There were no significant differences ($P > 0.05$) in PER among the 0, 20, 40 and 60PBM diets. The PER for the 100PBM diet was significantly lower ($P < 0.05$) when compared to the 0PBM and 60PBM diets. The HSI values showed no significant differences ($P > 0.05$) among the experimental diets.

Fillet quality

The final fillet proximate composition is shown in Table 5. The initial sample of cobia juvenile fillet was 16% crude protein and 1.6% crude lipid. After the feeding experiment, the values were higher for all treatments. The proximate compositions of fillet for all treatments were in the range of 19.6–21.1% for crude protein and 4.1–5.5% for crude lipid. There was no significant difference ($P > 0.05$) in the fillet composition among all treatments for all parameters tested.

Discussion

PBM has a very good nutritional quality and acceptability at high inclusion levels for many fish species including cobia. The experimental diets were formulated to contain almost the same nutrient content which was around 45% crude protein and 12% crude lipid based on previous studies (Chou et al. 2001; Lunger et al. 2006, 2007; Zhou et al. 2007; Wang et al. 2005). The amino acid composition of the PBM used in the present study conformed to the published values for this ingredient (Shapawi et al. 2007; Yu 2006). The methionine content in all experimental diets was in the range of 1.83–2.38%, which was higher than the suggested value of 1.05–1.19% for juvenile cobia (Zhou et al. 2006). The lysine content in all experimental diets was in the acceptable range of 2.27–2.56% when compared to suggested values of 2.33% (Zhou et al. 2007). There was no amino acid supplementation used in these experimental diets. Amino acid profile analyses for experimental diets showed no significant differences among the diets particularly for methionine and lysine content. Therefore, the juvenile cobia were expected to grow well although without amino acid supplementation since all amino acids requirement were supplied in the range of suggested values.

Growth performance shown by juvenile cobia was very good and indicated that diets containing high inclusion level up to 100% protein dietary of PBM were well accepted by cobia. These findings suggested that it is possible to use FM free diets for cobia without negative effect on growth performance. This finding conforms to the previous studies reported by several researchers for other species using PBM in replacing FM. The humpack grouper grew well on a diet with 75% local grade PBM and 100% imported grade PBM (Shapawi et al. 2007), the gilthead seabream (PBM replaced 75% FM) and red seabream (100%PBM) as reported by Nengas et al. (1999) and Takagi et al.(2000), respectively. Hu et al. (2008) had also reported that a combination of PBM and meat and bone meal could be used up to 66.7% FM protein (with lysine and methionine supplementation) for gibel carp. The white shrimp can accept a diet containing 31% PBM-Pet Food Grade protein (Cruz-Suarez et al. 2007). Usman et al. (2007) also reported that poultry offal silage meal was able to substitute 37% of fishmeal protein in the diets of tiger grouper and the largemouth bass (75 and 100% PBM) which exhibited growth no significant difference as compared to the control diet (Tidwell et al. 2005).

The fishmeal replacement studies on cobia using other protein sources have shown positive results as reported by some researchers. Chou et al. (2004) reported that the substitution of fishmeal with soybean meal at 40% was acceptable in diets for juvenile cobia. In addition, Lunger et al. (2006) reported that there was no effect on the growth and feed conversion of juvenile cobia fed with diet containing organic protein supplementation at certain level. Many researchers have reported that cobia are efficient in digesting protein and lipid in almost all of the ingredients tested to date. The present results obtained are similar to previous findings and suggestions with other ingredients used.

Based on this finding, the amount of PBM usage in cobia diets can be increased up to 60% of dry weight basis in the formulation (100% PBM protein replacing FM protein), hence the amount of FM usage can be proportionally decreased. The results from this study showed that the local PBM can be used to replace up to 100% fishmeal dietary protein in the juvenile cobia diets without adverse effects on growth performance. However, the 60PBM diet gave better growth performance than the control and 100PBM diets. Similar patterns are reported for seabass, *Lates calcarifer* where the diet containing 50% poultry offal meal and 50% FM protein gave better growth performance than the control diet (Che Utama and Saadiah 1999).

The final fillet analyses for lipid and protein content were similar for all treatments. These values are comparable to those previously reported for cobia (Chou et al. 2004; Zhou et al. 2007; Lunger et al. 2007).

In conclusion, the results from this study suggest that juvenile cobia can be fed using 100% PBM protein without negative effect on growth and fillet qualities based on parameters tested. However, 60% PBM protein is recommended for better growth and efficient feed utilization. Further study needed to investigate why the replacement of 100% PBM protein diet gave better growth compared to the control diet.

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