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Evaluation of Feather Meal as a Dietary Protein Source for African Catfish Fry, *Clarias gariepinus*

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ABSTRACT

Animal by-products including Feather Meal (FTM) have shown very promising findings when included in aquaculture feeds. However, their use is limited to a few fish species only. More studies are needed to investigate the full potential of this by-product. In the present study, a total of six diets were formulated to replace fish meal protein with FTM at levels of 0% (FTM0), 20% (FTM20), 40% (FTM40), 60% (FTM60), 80% (FTM80) and 100% (FTM100). Danish fish meal was used as a sole protein source in the control diet. All diets were isonitrogenous (40% protein), isolipidic (12% lipid) and isoenergetic (380 kcal/100 g diet). The fish growth performances and feed utilization were negatively affected with the increase inclusion levels of FTM in the diets. The feed intake dropped drastically when the FTM protein inclusion levels were increased up to 40-100%. The significantly high fish mortalities and retarded growth in FTM40-FTM100 treatments were suggested as a result of starvation, due to the extremely low feed intake. The low FCR, PER and NPU of fish from these treatments also indicated that the feather meal protein could not be digested and utilized well by the fish. Therefore, inclusion of the FTM protein in diets for the fry of *C. gariepinus* should not be more than 20% to maintain good growth and survival of the fish.

Key words: Feather meal, african catfish, *Clarias gariepinus*, diet palatability

INTRODUCTION

African catfish *Clarias gariepinus* is a globally popular aquaculture species due to its easiness in reproduction, high growth rate, tolerance to high densities culture conditions, resistance to diseases and ability to accept a wide variety of feed (Huisman and Richter, 1987). The culture techniques for the full life cycle of African catfish has been well-established and the global production of this species has been increased from 11,787 tonnes in 2000 to 517,357 tonnes in 2010 (FAO, 2010). Nevertheless, intensive culture of the fish is challenged by high operational cost, as a result of relying on the high protein commercial diets which increased feed cost. The economically feasible catfish farming can be achieved when it is based on cost-effective feed compound of locally available agricultural by-products (Degani *et al.*, 1989). Therefore, many studies have been conducted to determine the suitability of animal- and plant-based ingredients such as poultry-byproduct meal (Abdel-Warith *et al.*, 2001; Goda *et al.*, 2007), shrimp head waste meal (Nwanna, 2003; Nwanna *et al.*, 2004), soybean meal (Balogun and Ologhobo, 1989; Goda *et al.*, 2007), rice husk meal (Zaid and Ganiyat, 2009) and grasshopper meal (Alegbeleye *et al.*, 2012) to replace fishmeal in the diets for different life stages of African catfish.

Feather meal (FTM) is one of the poultry by-products which contain high protein content (80-85 percent) and commercially available. With some chemical treatments, it can be a good source of the sulphur-containing amino acids (Spinelli, 1980; Onifade *et al.*, 1998; Bertsch and Coello, 2005). Besides, the cost of feather meal is approximately two thirds the costs of other animal proteins in the market and it is readily available from many sources (Bishop *et al.*, 1995). Feeding trials to evaluate the potential of FTM to substitute fish meal in aquaculture feed have been conducted on several fish species, including the Chinook salmon *Oncorhynchus tshawytscha* (Fowler, 1990), Japanese flounder *Paralichthys olivaceus* (Kikuchi *et al.*, 1994), Indian major carp *Labeo rohita* (Hasan *et al.*, 1997) and other finfish species (Allan *et al.*, 2000; Bureau *et al.*, 2000; Lee, 2002; Wang *et al.*, 2006; Li *et al.*, 2009). The only report on the effects of dietary feather meal on the growth performances of the African catfish fingerlings was described by Serwata and Davies (2001) which recommended a dietary FTM inclusion of not more than 25%. When hydrolyzed feather meal was mixed with chicken offal meal and maggot meal, the mixture was able to replace 50% of the total fishmeal used in the diets for African catfish fingerlings without causing any adverse effect on the fish growth (Adewolu *et al.*, 2010). Apart from these, little is known about the full potential of feather meal as a dietary protein source in the diets of different life stages of African catfish.

The high operational cost of catfish farming was mainly due to the dependency on the expensive fish meal-based feed. Although alternative protein sources can be included in the diets for African catfish fingerlings to reduce the feed cost, the intensive culture of this species would be more profitable if such practice can be applied at a younger stage. Thus, the present study was carried out to evaluate the effects of FM protein replacement with FTM at 0-100% inclusion levels on growth performances, feed utilization and body composition of African catfish fries.

MATERIALS AND METHODS

Preparation of diets: Table 1 shows the ingredients, formulation and proximate compositions of the experimental diets. Six isonitrogeneous, isolipidic and isocaloric diets were formulated to contain

Table 1: Composition and proximate analysis of the experimental diets

Item	FTM0	FTM20	FTM40	FTM60	FTM80	FTM100
Ingredient (g per 100 g diet)						
Fish meal	56.65	45.32	33.99	22.66	11.33	0.00
Feather meal	0.00	9.86	19.71	29.57	39.42	49.28
Dietary lipid source	6.43	7.54	8.63	9.73	10.83	11.93
CMC	2.36	2.36	2.36	2.36	2.36	2.36
Vitamin premix	3.00	3.00	3.00	3.00	3.00	3.00
Chromic oxide	0.50	0.50	0.50	0.50	0.50	0.50
Mineral premix	4.00	4.00	4.00	4.00	4.00	4.00
Dicalcium phosphate	1.00	1.00	1.00	1.00	1.00	1.00
α-cellulose	5.34	6.10	6.88	7.66	8.43	9.21
Tapioca	28.25	28.39	28.53	28.67	28.81	28.94
Proximate analysis (%)						
Protein	39.82 ± 0.26^{ab}	39.51 ± 0.55^{ab}	41.25 ± 0.66^{ab}	38.95 ± 0.92^{c}	40.34 ± 0.86^{a}	40.67 ± 0.55^{bc}
Lipid	11.45 ± 0.36^{a}	11.23 ± 0.20^{ab}	11.87 ± 0.20^{a}	12.14 ± 0.10^{bc}	11.50 ± 0.39^{bc}	11.26 ± 0.06^{a}
Moisture	4.78 ± 0.08^{a}	5.12 ± 0.13^{ab}	5.03 ± 0.13^{ab}	5.89 ± 0.09^{c}	4.43 ± 0.39^{d}	5.37 ± 0.17^{b}
Ash	86.55 ± 0.08^{a}	87.43 ± 0.19^{b}	89.10 ± 0.27^{c}	89.74 ± 0.15^{d}	90.70 ± 0.41^{e}	91.27 ± 0.20^{f}
Gross energy (kcal/100 g)	380	380	380	380	380	380

Values in the same row with same superscripts are not significantly different ($p>0.05$)

40% protein, 11% lipid (Degani *et al.*, 1989) and 380 kcal/100 g diet. In the present study, Danish fish meal was used as the sole protein source in the control diet while the commercial feather meal was supplied by Fushishan Industrial Company Limited, China. Fish meal protein was replaced with 0, 20, 40, 60, 80 and 100% of FTM. These diets were labeled as FTM0, FTM20, FTM40, FTM60, FTM80 and FTM100, respectively.

Experimental setup and procedures: The fry of African catfish with average weight 2.85 ±0.01 g were obtained from the Fish Hatchery of Borneo Marine Research Institute, Universiti Malaysia Sabah (BMRI, UMS). Feeding trial with the duration of four weeks was conducted at a roofed outdoor space in the Fish Hatchery of BMRI. Before the feeding trial started, the experimental fish were acclimated in a 1000 L tank and fed with the control diet. Ten fish were also sampled from the same batch of fish and frozen at -86°C for subsequent whole-body proximate analysis. After the acclimation period, the fish were randomly distributed into eighteen 50 L fiber-glass tanks (15 fish per tank) with 45 L dechlorinated tap water. Each tank was equipped with an air-lift water recirculating system that contained coral pieces and sponge as the filter media (water flow rate 20 mL/s, 40 cycles/ day). All tanks were provided with aeration and covered with rigid mesh net on the top to prevent the fish from escaping. Handmade polyethylene mesh net shelter in a form of cylinder (each cylinder diameter 7 cm×length 15 cm) was also provided in each tank.

Tank cleaning and partial water exchange were carried out daily to maintain water quality. The fish were hand fed twice (08:00 and 15:00 h) daily until close to apparent satiation. The uneaten feed in each tank was measured after the feeding in all tanks was completed. The fish weight was measured fortnightly and mortalities were recorded throughout the trial. After the feeding trial ended, five fish were randomly sampled from each tank, anesthetized in iced-water then frozen at -86°C for subsequent whole-body proximate analysis. The whole-body fish were then chopped, minced and dried in oven at 105°C for 24 h. The dried samples were then grinded into powder form and kept in a refrigerator until analysis.

Analytical methods: The Weight Gain (WG), Specific Growth Rate (SGR), Survival Rate (SR), Total Feed Intake (TFI), Feed Conversion Ratio (FCR), Protein Efficiency Ratio (PER) and Net Protein Utilization (NPU) of fish fed experimental diets were calculated after the feeding trial ended. The equations for calculating these parameters were listed as footnotes in Table 2.

Whole body proximate composition analysis was determined following the standard methods described by AOAC (1997). In brief, the moisture and ash contents were determined by drying the samples in oven at 108°C for 24 h and by incineration the samples at 550°C in muffle furnace, respectively. Crude protein levels were analyzed using a semi-auto Kjeldahl System (Kjeldec 8100 Distillation Unit) after the samples were digested using sulfuric acid. Crude lipid levels were evaluated with the ether-extraction method using the Soxtec TM 2043 Extraction unit (FOSS Analytical, Sweden).

Statistical analysis: The WG, SGR, SR, FCR, PER, NPU of fish and proximate analysis of all diets and fish whole-body composition were statistically analyzed using one-way ANOVA. Differences among treatments were compared by using Duncan's multiple range tests. Values were considered significant different at $p<0.05$.

RESULTS

The growth performances, survival and feed utilization of African catfish fed diets with different inclusion levels of feather meal are shown in Table 2. Fish fed control diet (FTM0) attained significantly higher ($p<0.05$) weight gain (WG, 999.62±65.03%), specific growth rate (SGR, 8.56±0.22%) and feed intake (FI, 33.18±3.16 g/fish) than those fed other diets that contained feather meal (FTM20-FTM100). Nevertheless, no significance differences ($P>0.05$) were found in the SR, FCR, PER and NPU between fish fed control and FTM20 diets.

Survival rate of the fish was affected by the inclusion of FTM in the diets. The lowest survival rate was recorded in fish group fed FTM100 (37.78%), followed by FTM80 (57.78%), FTM40 (57.78%), FTM 60 (64.44%), FTM0 (84.44%) and FTM20 (88.89%). Similar trend of result was found in the FCR where it became poorer along with the increased levels of feather meal in the diets.

For the fish whole-body proximate composition, fish fed the control and FTM20 diets contained higher level of crude protein (20.57±3.96 and 20.22±1.84%, respectively) than those from other treatments, including the initial fish (19.98±1.64%). The whole-body protein of fish fed FTM40, 60, 80 and 100 diets ranged from 16.93±0.41-18.95±0.07%. Fish fed the control diet contained the highest crude lipid level (8.11±0.40%) and this value was significantly higher than those from other treatments (Table 3). In general, the whole-body lipid content decreased along with the increased inclusion levels of feather meal into the diets. The whole-body moisture content increased along with the increasing of feather meal replacement level in the diets. No definite trend was observed in the whole-body ash contents as a result of feather meal inclusion in the diets.

Table 2: Effects of different replacement levels of fish meal with feather meal on growth and feed utilization in African catfish fry

Diet	FTM0	FTM20	FTM40	FTM60	FTM80	FTM100
WG	999.62±65.03^{a}	788.46±86.04^{b}	79.06±1.27^{c}	87.98±18.18^{c}	36.05±14.15^{c}	14.04±14.88^{c}
SGR	8.56±0.22^{a}	7.79±0.34^{b}	2.08±0.03^{c}	2.24±0.35^{c}	1.09±0.39^{d}	0.47±0.44^{e}
SR	84.44±21.43^{a}	88.89±3.85^{a}	57.78±38.49^{ab}	64.44±10.18^{ab}	57.78±15.40^{ab}	37.78.±10.18^{b}
FI	33.18±3.16^{a}	27.88±4.01^{b}	6.37±1.22^{c}	6.25±0.25^{c}	2.36±1.40^{cd}	2.02±0.44^{d}
FCR	1.24±0.16^{a}	1.34±0.12^{a}	2.90±0.91^{a}	3.08±0.45^{a}	2.85±0.55^{a}	19.91±17.39^{b}
PER	2.16±0.88^{a}	2.04±0.07^{a}	0.88±0.19^{bc}	1.03±0.17^{bc}	1.22±0.35^{b}	0.79±0.08^{c}
NPU	44.50±1.61	41.41±1.4	15.52±3.46	14.85±3.14	8.14±5.08	8.33*

Values in the same row with same superscripts are not significantly different ($p>0.05$), WG (%): [(Final weight- Initial weight)/Initial weight]×100, SGR (%): [(ln final weight-ln initial weight)/t]×100, SR (%): (Final number of fish/ Initial number of fish)×100, FI: Total feed consumed/(Initial number of animal+ Final number of animal)/^{2}, FCR: (Dry weight of feed/Wet weight gain), PER: (Wet weight gain/Total protein intake), NPU: [(Final fish body protein-initial fish body protein)/ Total protein intake]×100, No replication was done as a result of high mortality

Table 3: Whole-body composition of experimental fish

Parameter	Initial	FTM0	FTM20	FTM40	FTM60	FTM80	FTM100
Crude protein	19.98±1.64^{ab}	20.57±3.96^{a}	20.22±1.84^{a}	18.95±0.07^{ab}	17.42±0.43^{b}	16.93±0.41^{b}	18.32±0.45^{ab}
Crude lipid	2.23±0.05^{a}	8.11±0.40^{b}	7.25±0.29^{c}	6.42±0.22^{d}	5.99±0.20^{e}	5.66±0.30^{f}	5.41±0.11^{f}
Moisture	75.83 ±1.70^{b}	73.38±0.92^{a}	74.13±1.36^{a}	75.93±2.41^{b}	76.67±0.84^{b}	77.23±1.91^{b}	75.47±1.12^{b}
Ash	20.31±1.19^{c}	23.80±0.25^{a}	26.10±0.41^{b}	19.79±0.72^{c}	19.97±0.40^{c}	18.78±0.34^{d}	19.78±0.60^{c}

Values in the same row with same superscripts are not significantly different ($p>0.05$)

DISCUSSION

To our knowledge, this is the first report on the use of feather meal as a dietary protein source in the diets formulated for the fry (2.85 g) of African catfish. Generally, the growth performances and feed utilization of African catfish fry were negatively affected by the increased level of feather meal in the diets. Similar results were also observed in the larger size of African catfish fingerlings with initial weight of 17.1 g (Serwata and Davies, 2001). Such outcome appeared to be related to the reduced palatability of diets as a result of high inclusion levels of feather meal which is reflected by the low feed intake, especially on the FTM40-FTM100 diets. Yu (2008) recommended that the substitution of feather meal into fish feeds should be limited to less than 40%, except in the diets for trout and tilapia.

The drastically decreased in the feed intake of FTM40-FTM100 diets which led to starvation was identified to be the main reason for the extremely low WG, SGR and SR in these treatments. For whole-body compositions, fish fed with diets that contained higher inclusion levels of feather meal attained significantly lower crude lipid content. Besides, the crude protein levels in fish fed FTM40, FTM60, FTM80 and FTM100 diets were averagely lower than the initial value. Such results indicated that the fish were utilizing their body protein and lipid as the energy source to survive from starvation (Savitz, 1971; Niimi, 1972; Jobling, 1980). The whole-body protein in fish fed diet FTM20 showed no significant different but whole-body lipid level was significantly lower than the fish in the control treatment, indicating the fish firstly catabolized the body lipid then hydrolyzed the protein as the source of energy during starvation. This result is in agreement with the findings on the effects of starvation on the body composition of juvenile African catfish by Zamal and Ollevier (1995). Increase in the level of feather meal in the diet resulted in increased whole-body moisture content and did not show definite trend in whole-body ash content. Similar results were also reported by Hasan *et al.* (1997) on the fry of Indian major carp, *Labeo rohita* which fed on increasing level of poultry-feather meal in the diets. The increase of whole-body moisture content of fish in the present study may also resulted by the prolonged starvation due to the low feed intake. The whole-body moisture contents of white sturgeon, *Acipenser transmontanus* and Bunnyi, *Barbus sharpeyi* were observed to increased inversely to whole-body lipid when they were exposed to starvation (Hung *et al.*, 1997; Mahdi, 2006).

In the present study, the control diet was based on high quality fishmeal as a sole protein source which explains the excellent growth and feed utilization of the fish in this treatment. SGR (SGR 1.90%/d) of African catfish fed with commercial trout diets (Degani *et al.*, 1989) were lower than the growth of fish fed the control diet (SGR 8.56%/d) and diet FTM20 (SGR 7.79%/d). The present study was aimed to investigate the amount of fishmeal protein that can be replaced with feather meal protein and apparently low replacement level of 20% seemed to be acceptable by the fish. Although their growth performances (WG and SGR) were significantly lower than those in the control diet treatment, FCR (1.34), PER (2.04) and NPU (41.41) values were very promising. Furthermore, reduced palatability of FTM20 diet can be manipulated through inclusion of suitable feeding stimulants (De Oliveira and Cyrino, 2004; Hirt-Chabbert *et al.*, 2012). The fish growth may increase and or at least comparable to that of the control diet treatment. Subsequently, low inclusion level of feather meal in diet for the fry of African catfish can be implemented to reduce feed cost. Suitable feeding stimulants for the fry of African catfish should be identified and included into the experimental diets in order to determine the true effects of feather meal-based diets on the fish growth performances and feed utilization.

The poor digestibility of feather meal could be another factor that contributed to the slow growth of fish fed with FTM40-FTM100 diets. The FCR, PER and NPU of fish fed on these high feather meal content-diets were lower than those fed on the FTM20 and control diet. These results indicated that the feather meal protein could not be digested and utilized well by the fry of African catfish. Although digestibility coefficient of the diets was not measured in the present study, reduced performance of fish as a result of poor digestibility of poultry by-product-based diets was reported in the past. Lee (2002) reported that feather meal attained the lowest apparent digestibility coefficient of crude protein compared to other tested protein sources in the test diets for grower rockfish *Sebastes schlegeli*. In humpback grouper, *Chromileptes altivelis* the dry matter and protein apparent digestibility coefficients of poultry by-product meal-based diets were significantly lower than the control diets (Shapawi *et al*., 2007). Nevertheless, contradict result was reported on Australian silver perch, *Bidyanus bidyanus* where no significant difference was detected on the apparent digestibility coefficient of the feather meal-based diets with other tested protein sources (Allan *et al*., 2000). Such variations could be due to the species-specific of tolerance to dietary feather meal among different fish species.

In general, feather meal was reported to contain lack of certain essential amino acids, including lysine, methionine and histidine (Hertrampf and Piedad-Pascual, 2000) which are required for fish growth and health. Supplementation of essential amino acids in the feather meal based-diets has proven to improve the growth performances of rainbow trout, *Oncorhynchus mykiss* (Pfeffer *et al*., 1994). Meanwhile, the estimated optimum lysine, methionine and histidine requirements by the fingerlings and fry of the African catfish have been reported to be 57 g kg^{-1}, 30.7-32 g kg^{-1} and 1-1.05% of dietary protein, respectively (Fagbenro *et al.*, 1998,1999; Khan and Abidi, 2009; Ovie and Eze, 2010). Unfortunately, amino acids analysis was not carried out in the present study. Supplementation of amino acids based on the suggested optimum level in formulating the diet of African catfish in future should be considered to improve the diet quality.

In conclusion, low level of feather meal inclusion in diets for the fry of African catfish is practicable with substitution level of not more than 20% of the total fishmeal protein, to avoid impaired palatability and reduced digestibility of the formulated diets. Further study on the amino acids composition of the tested feather meal and supplementation in the diets, digestibility coefficient of the diets and effects of the substitution on the health status of the target species should be considered to determine the full potential of feather meal as a protein source in African catfish.

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