Pakistan J. Zool., vol. 40(5), pp. 341-346, 2008.

Replacement of Fishmeal with Soybean Meal in Diets for Channel Catfish, *Ictalurus punctatus* Fry Introduced in Pakistan

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Abstract.- Feeding trials were conducted to determine the extent fish meal (FM) that could be replaced with soybean meal (SBM) and its possible effect on growth and body composition of channel catfish (*Ictalurus punctatus*) fry. Four isonitrogenous (30% crude protein) diets were formulated, containing 30%, 20%, 10% and 0% FM. SBM was incorporated in increasing percentages 10%, 20%, 30% and 40% to the respective diets. Imported floating diet (30% protein) was used as control. Fish were fed daily @ 3% of wet body weight, which was recorded biweekly. Body weight gain, specific growth rate, food conversion ratio, net protein utilization, feed efficiency ratio and protein efficiency ratio were calculated to determine the growth performance in different treatments. At the end of trial fish was subjected to proximate analysis. In aquaria fish fed with 10% FM and 30% SBM (diet$_3$) showed significantly higher ($P<0.05$) weight gain (1.96g) than other diets but non-significant ($P>0.05$) to control diet (diet$_5$) i.e. 1.78g. In circular tanks, weight gain (1.08g) with same diet (diet$_3$) was significantly higher ($P<0.05$) than other diets but less than diet$_5$ (1.47g). The physicochemical properties of water recorded were found to be normal for channel catfish culture. Results indicated that in a diet (30% CP) for channel catfish fry, fish meal could be reduced up to 10% without compromising growth.

Key words: Channel catfish, fish meal, growth performance, soybean meal.

INTRODUCTION

Fish meal (FM) is a widely used expensive protein component of aquaculture diets because of highly available energy, excellent amino acid profiles and digestibility (New and Wijkstrom, 2002). However, the scarcity and rising cost of FM has stimulated research on alternative protein sources particularly plant proteins without compromising fish growth (Peres *et al.*, 2003). Among all plant protein sources, soybean meal (SBM) is the most extensively evaluated and commonly used ingredient in commercial aquaculture diets. The feasibility of FM replacement by plant protein sources is highly variable among fish species. A large number of studies were conducted on various fishes such as tilapia (*Oreochromis niloticus*), common carp (*Cyprinus carpio*), grass carp (*Hypophthalmichthys molitrix*), blue catfish (*Ictalurus furcatus*) and Pacific salmons (*Oncorhynchus* spp.). These studies showed reduce growth in majority of fishes due to total replacement of FM; however, partial replacement was much successful (Lim *et al.*, 2004). Several studies conducted with young channel catfish in aquaria have shown that a complete replacement of menhaden FM with SBM in diet caused some growth reduction (Mohsen and Lovell, 1990). So to counter these negative effects different strategies were adopted by researchers such as use of SBM in combination with distillers' grains (Webster *et al.*, 1992) and heat treatment (Evans *et al.*, 2005) allowed complete replacement of FM without causing growth reduction in channel catfish. However Evans *et al.* (2005) also reported that feeding channel catfish fingerling, a diet containing 45% non-heat-treated raw soybean did not cause severe histological changes associated with SBM anti-nutritional factors.

The aim of the present study was to evaluate

0030-9923/2008/0005-0341 $ 8.00/0

the prospect of extent of the FM that could be replaced with SBM without compromising the growth of channel catfish fry, which were introduced from cold-water research station Chiang Mai province Thailand to Pakistan for the first time (Rab *et al*., 2007) and to quantify the maximum level of the SBM that could be incorporated in diets without affecting growth and body composition.

MATERIALS AND METHODS

The study was conducted at the Aquaculture and Fisheries Programme, National Agriculture Research Center (NARC), Islamabad, Pakistan, for a period of six week (Sep-Oct, 2004).The experiment was conducted to evaluate the possible effects of FM replacement with SBM, on the growth performance of juvenile channel catfish. Experimental design was 2×5 factorial with three replications. Different diets were tested in glass aquaria and circular fiber glass tanks.

Table I.- Ingredients and proximate composition of experimental diets used in aquaria and circular tanks (on dry weight basis).

Ingredients	Diets			
	1	2	3	4
Fish meal	30	20	10	0
Soybean meal	10	20	30	40
Sunflower meal	10	10	10	10
Canola seed meal	10	10	10	10
Rice polishing	25	23	21	18
Gluten 30%	6	8	10	13
Wheat bran	5	5	5	5
Vitamin-C	0.5	0.5	0.5	0.5
Vitamin premixes	1.5	1.5	1.5	1.5
Soybean oil	2	2	2	2
Total (g)	100	100	100	100
Proximate composition (%)				
Dry Matter	89.3	89.8	89.4	90
Moisture	10.7	10.2	10.6	10
Crude Protein *	28.36	29.58	28.45	30.12
Crude Fat *	17.6	19.3	19.3	19.6
Crude Fiber *	3.5	2.5	3.5	2
Total Mineral (Ash)*	8.5	10	11	11.5

*Percentage of dry matter.

To meet all known nutritional requirement of channel catfish (NRC, 1993) four isonitrogenous (30% crude protein) diets were formulated from locally available feed ingredients that contained decreasing percentages of FM and increasing percentages of SBM (Table I). A floating diet (30% CP), which was imported along with channel catfish from Thailand, was used as control. Proximate compositions of diets were determined according to the Association of Official Analytical Chemists (AOAC, 1990) are also given in Table 1. Fish were fed twice daily on one of the experimental diets randomly assigned to each aquarium and fiberglass tanks.

The experimental system contained fifteen 40 l glass aquaria (erected on the iron stands) and fifteen 2000 l circular fiberglass tanks (with a flow through water system of 8 l min^{-1}). Aquaria were consistently supplied aeration through aerator (Hiblow air pump model SPP-40GJ-L Japan). Individual weight of the channel catfish juveniles was determined using an electronic scale (Sartorious balance model: BL 150 S, Sartorious AG Gottingen, Germany) at the start of experiment and biweekly thereafter. Fish with a mean weight of 2.01g and 3.02g were distributed among aquaria (10 fish/aquarium each) and circular fiberglass tanks (50 fish/tank each) respectively. Two weeks prior to the start of experiment, all the fish were acclimated to the experimental condition. Feed was adjusted @ 3% of wet body weight based on uneaten diet. Individual fish weight in each aquarium and tanks was measured fortnightly and the amount of diet was adjusted accordingly.

Physico-chemical parameters of water *i.e.*, temperature, dissolve oxygen (DO), alkalinity, hardness, electrical conductivity (EC) and pH were recorded weekly.

At the end of the feeding trial, the final weight of the fish was recorded and on the basis of it body weight gain (WG), percent weight gain (PWG), feed efficiency ratio (FER), specific growth rate (SGR), protein efficiency ratio (PER), food conversion ratio (FCR) and net protein utilization (NPU) were calculated by using the following formulae:

WG = Weight final (WF) – Weight initial (Wi)
PWG = (Wf – Wi) × 100/ initial weight.
FER = (wet weight gain/dry feed intake) × 100.

SGR = [(ln Wf – ln WI) × 100]/days.
PER = (wet weight gain/ Protein intake).
FCR = (total dry feed fed / total wet weight gain).
NPU= (body protein gain/ protein fed).

Then from each treatment, five fish were randomly sampled for whole-body proximate analysis which was carried out by Animal Nutrition Program, NARC according to AOAC (1990).

Data was analyzed using Analysis of Variance (ANOVA). Means with significant difference were compared with least significant difference (LSD).

RESULTS

Growth of channel catfish fry fed on different diets in aquaria and circular tanks is shown in Figures 1 and 2. The control diet ($diet_5$) had significantly higher growth followed by the 10/30% FM/SBM diet ($diet_3$), 30/10% FM/SBM diet ($diet_1$) and 20/20% FM/SBM diet ($diet_2$), while 0/40% FM/SBM diet ($diet_4$) has minimum growth in both aquaria and circular tanks. An increased trend of growth was observed in diets both in aquaria and circular tanks except the $diet_4$ in aquaria, where growth declined after 6 weeks (Fig. 1).

Fish in circular tanks has gained more weight than aquaria. The channel catfish fed on $Diet_5$ had significantly higher ($P<0.05$) weight gain in tanks followed by $diet_3$, $diet_1$ and $diet_2$, while fish fed on $diet_4$ had minimum weight gain. Similar trend of weight gain was also observed in glass aquaria. Overall mean values of specific growth rate (SGR) and percentage weight gain (PWG) for channel catfish when fed on $diet_5$ in both treatments differed significantly ($P<0.05$) from other locally prepared experimental diets. Among the locally prepared experimental diets, $diet_3$ had showed best results followed by $diet_1$, $diet_2$ and $diet_4$. Minimum values of FCR was recorded in $diet_5$ and $diet_{3,}$ which were non significant with each other followed by $diet_2$, $diet_1$ and $diet_4$ (Table II).

The proximate composition of whole body channel catfish juveniles *i.e.*, dry matter, percentage moisture, crude protein, ether extract and ash (when expressed on % dry matter basis) are given in Table III. No significant difference was observed between body composition of fishes kept in aquaria and circular tanks. However difference was observed among fishes fed on different diets *i.e.*, a fish fed on $diet_4$ had a significantly lower ($P<0.05$) ratio of crude protein compared to the other diets.

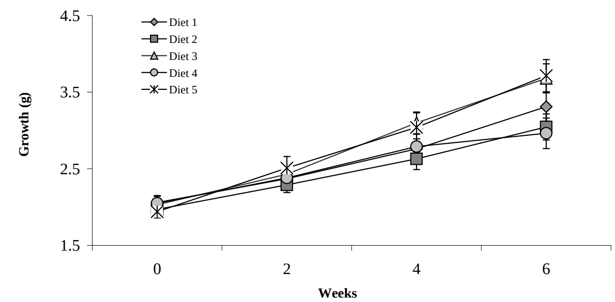

Fig. 1. Growth of channel catfish fry fed diets containing different levels of fish meal and soybean meal in aquaria

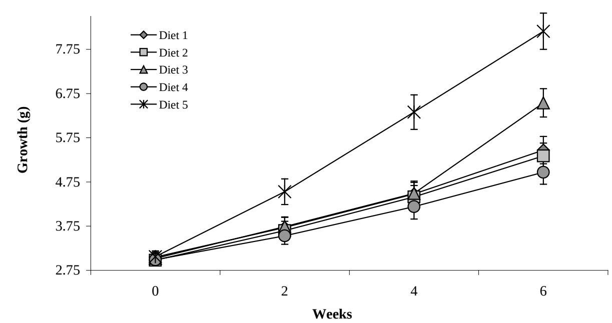

Fig. 2. Growth of channel catfish fry fed diets containing different levels of fish meal and soybean meal in circular tanks.

The mean of each of the measured water quality variables such as electrical conductivity (EC), pH, temperature, dissolved oxygen (DO), alkalinity and hardness recorded for all the diets in the aquaria and tanks are shown in Table IV. Results indicate that FM level in a diet of 30% CP made for channel catfish fry could be reduced to 10%, however, adding 30% SBM in such a diet would not compromise the growth of channel catfish.

DISCUSSION

Our results showed that beside control diet ($diet_5$), $diet_3$ was better in terms of growth and feed efficiency among experimental diets in both aquaria and circular tanks. It indicates that SBM can be

Table II.- Total weight gain (WG), percent weight gain (PWG), specific growth rate (SGR), food conversion ratio (FCR), feed efficiency ratio (FER), protein efficiency ratio (PER) and net protein utilization (NPU) of channel catfish fry fed on different diets in aquaria and tanks.

Diets	1	2	3	4	Control	Mean
Average weight gain (g)						
Aquaria	1.250^{fgh}	1.077^{gh}	1.650^{efg}	0.913^{h}	1.777^{def}	1.333^{B}
Tanks	2.440^{c}	2.320^{cd}	3.520^{b}	1.950^{cde}	5.227^{a}	3.091^{A}
Mean	1.845^{C}	1.698^{CD}	2.585^{B}	1.432^{D}	3.502^{A}	
Percent weight gain (%)						
Aquaria	62.190^{de}	53.480^{e}	82.087^{cd}	45.397^{e}	88.310^{c}	66.293^{B}
Tanks	80.793^{cd}	76.820^{cd}	116.557^{b}	64.570^{de}	173.070^{a}	102.362^{A}
Mean	71.492^{C}	65.150^{CD}	99.322^{B}	54.983^{C}	130.690^{A}	
Specific growth rate (g)						
Aquaria	1.150^{fg}	1.017^{g}	1.427^{ef}	0.887^{g}	1.500^{de}	1.196^{B}
Tanks	1.793^{c}	1.727^{cd}	2.333^{b}	1.500^{de}	3.040^{a}	2.079^{A}
Mean	1.472^{C}	1.372^{CD}	1.880^{B}	1.193^{D}	2.270^{A}	
Food conversion ratio						
Aquaria	2.580^{b}	2.913^{b}	2.060^{c}	3.387^{a}	1.930^{cd}	2.574^{A}
Tanks	2.080^{c}	2.147^{c}	1.543^{de}	2.587^{b}	1.197^{e}	1.911^{B}
Mean	2.330^{B}	2.530^{B}	1.802^{C}	2.987^{A}	1.563^{C}	
Feed efficiency ratio						
Aquaria	39.070^{ef}	34.350^{fg}	48.643^{cd}	29.667^{g}	52.100^{c}	40.766^{B}
Tanks	48.233^{cde}	46.620^{cde}	65.567^{b}	39.827^{def}	83.697^{a}	56.789^{A}
Mean	43.652^{C}	40.485^{CD}	57.105^{B}	34.747^{D}	67.898^{A}	
Protein efficiency ratio						
Aquaria	1.393^{de}	1.147^{ef}	1.733^{c}	0.990^{f}	1.737^{c}	1.4^{B}
Tanks	1.723^{c}	1.557^{cd}	2.343^{b}	1.327^{de}	2.787^{a}	1.947^{A}
Mean	1.558^{C}	1.352^{D}	2.038^{B}	1.158^{D}	2.262^{A}	
Net protein utilization						
Aquaria	0.533^{f}	0.507^{e}	0.560^{c}	0.440^{h}	0.587^{d}	0.525^{A}
Tanks	0.563^{e}	0.553^{e}	0.633^{a}	0.467^{g}	0.697^{b}	0.583^{A}
Mean	0.548^{D}	0.530^{D}	0.597^{B}	0.453^{C}	0.642^{A}	

*Values are means from triplicate group of fish where the means in each row with different letters are significantly different ($P \leq 0.05$).

replaced with FM in channel catfish diets formulated from locally available feed ingredients, but total replacement is not successful as less growth and higher FCR was recorded in Diet$_3$. This is in agreement with (Li *et al*., 2000) who reported that when a fish fed on all plant diet (30% CP), it resulted in a significantly higher FCR than the fish fed on animal protein (30% CP). Similarly several studies conducted with young channel catfish in aquaria, also reported that a complete replacement of menhaden FM with SBM in a diet formulation caused growth reduction (Andrews and Page, 1974; Twibell and Wilson, 2004).

Several nutritional parameters such as PER and NPU in current trial reflected the negative effects of SBM above dietary inclusions of 30%. FCR was noticeably affected in both glass aquaria and circular fiberglass tanks, indicating a progressive reduction in dietary protein utilization when SBM meal was more than 30% of a diet. This would be due to an amino acid imbalance, either resulted due to reduced digestibility of protein or presence of anti nutritional factors (Storebakken *et al.,* 2000; Li *et al*., 2000; Hendricks, 2002). However, these factors were not evaluated in the present trial. Similarly WG and FER were significantly reduced, with the increase of SBM in the diets except in $Diet_3$. The reason might be the difference in dietary palatability as reported by Lim *et al*. (2004).

Table III.- Proximate composition of whole-body channel catfish fry fed five experimental diets containing different levels of soybean meal and fishmeal in aquaria and tanks.

Parameters	Diet-1	Diet-2	Diet-3	Diet-4	Control	Mean
Dry matter						
Aquaria	27.51[a]	25.97[b]	25.30[b]	26.09[b]	27.610[a]	26.50
Tanks	25.97[b]	27.61[a]	26.09[b]	25.30[b]	27.51[a]	26.50
Mean	26.74[B]	26.79[B]	25.70[C]	25.69[C]	27.56[A]	
Moisture						
Aquaria	72.49[b]	74.03[a]	74.70[a]	73.91[a]	72.39[b]	73.50
Tanks	74.03[a]	72.39[b]	73.91[a]	74.70[a]	72.49[b]	73.50
Mean	73.26[B]	73.21[B]	74.30[A]	74.305[A]	72.44[B]	
Crude proteins						
Aquaria	56.48c	56.46	56.43c	54.98[f]	56.88[b]	56.25
Tanks	56.25[cd]	55.97d[e]	55.86[e]	54.88[f]	57.42[a]	56.075
Mean	56.36[B]	56.22[B]	56.15[B]	54.93[C]	57.15[A]	
Ether extract						
Aquaria	33.44[f]	34.00[e]	34.88[c]	35.33[ab]	35.01[bc]	34.52
Tanks	34.44[d]	34.77[cd]	34.88[c]	35.45[a]	33.18[f]	34.54
Mean	33.94[D]	34.38[C]	34.88[B]	35.39[A]	34.09[A]	
Ash						
Aquaria	9.38[ab]	9.690	9.57[a]	9.64[a]	8.11[b]	9.28
Tanks	9.24[ab]	9.21[ab]	9.89[a]	9.58[a]	9.38[ab]	9.46
Mean	9.31[A]	9.45[A]	9.73[A]	9.61[A]	8.75[A]	

*Values are means from triplicate group of fish where the means in each row with different letters are significantly different ($P \leq 0.05$)

Table IV.- Physico-chemical parameters of water during the experiment.*

Factors	Diets									
	1		2		3		4		Control	
	Aquaria	Tanks	Aquaria	Tanks	Aquaria	Tanks	Aquaria	Tanks	Aquaria	Tanks
Temp. (^{o}C)	26.66 ±0.00	22.06 ±0.52	26.59 ±0.01	21.43 ± 0.40	26.5 ±0.03	22.73 ± 0.37	26.38 ±0.03	22.1 ±0.24	26.54 ±0.02	21.43 ±0.80
Alkalinity (ppm)	210.24 ±0.93	228 ±21.73	205.41 ±0.11	174 ±19.74	215.66 ±0.04	191 ±24.18	213.16 ±1.16	218 ±22.56	208.66 ±0.17	203.5 ±17.36
Hardness (ppm)	191.75 ±2.13	223 ±1.44	217.58 ±6.48	223.66 ±2.69	231.49 ±5.00	245.33 ±3.37	226.49 ±1.20	230.66 ±4.02	204.08 ±1.53	232.33 ±3.41
EC µs/cm	413.33 ±0.08	389.66 ±7.08	416.91 ±2.65	387 ±6.52	432.33 ±0.21	382.33 ±5.72	422.91 ±0.71	382.66 ±6.38	421.65 ±0.17	389.33 ±7.12
DO (ppm)	5.80 ±0.04	5.27 ±0.59	5.46 ±0.10	6.59 ±0.50	5.8 ±0.04	6.78 ±0.42	5.56 ±0.01	6.26 ±0.42	5.54 ±0.03	5.88 ±0.56
pH	7.95 ±0.01	8.00 ±0.00	8.04 ±0.01	8± 0.00	7.95 ±0.01	8 ±0.00	8.08 ±0.00	8 ±0.00	8.04 ±0.01	8± 0.00

*Values are mean ± SD

The relationship among the whole body catfish protein, lipid and moisture with different diets was observed in present study. Whole body protein and lipid varies significantly among different treatment in both glass aquaria and circular tanks as reported by Zeitler *et al*. (1984) that whole body proximate composition correlated with fish species, feeding and diet formulation. However in terms of crude protein, no significant difference was observed between $Diet_3$, $Diet_1$ and $Diet_2$ in aquaria and circular tanks suggesting that $Diet_3$ (having 30% SBM) could be used for channel catfish fry without compromising its growth and body composition like $Diet_1$ and $Diet_2$ having higher ratio of FM.

The water quality parameters such as EC, pH, temperature, DO, alkalinity and hardness were almost similar for the all the treatments. These water quality means are almost optimum for channel catfish culture (Durborow, 2000; Tucker, 2001).

From these results it can be concluded that $Diet_3$ (10% FM and 30% SBM) can also result in better growth and feed efficiency in channel catfish fry raised in both aquaria and flow-through fiberglass circular tanks. SBM used in the present study could be used to reduce FM level up to 10%, without compromising growth of channel catfish juveniles. This may allow for a decrease in diet costs for growers and potentially increase profits, as well as reducing the reliance on FM as an ingredient in diets for channel catfish. However, when channel catfish juveniles fed a whole SBM diet it resulted into reduced growth. Further investigations should examine possibilities of amino acid supplementation in diets with a high percentage of SBM and low percentage of FM in longer term feeding trials to observe its effects on growth and body composition of channel catfish juveniles, as well as to cope with anti-nutritional factors present in the SBM.

ACKNOWLEDGEMENTS

This study is a part of Agriculture Linkages Programs (ALP) funded project, sponsored by United States Department of Agriculture (USDA) and Pakistan Agriculture Research Council (PARC). The authors would like to thank Animal Nutrition Program (NARC) and Poultry Research Institute (PRI) for their cooperation in fish and feed analysis.

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(Received 7 July 2007, revised 4 June 2008)