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Use of soybean meal as partial or total substitute of fish meal in diets for blue catfish (*Ictalurus furcatus*)

Carl D. Webster, James H. Tidwell, Laura S. Tiu and Daniel H. Yancey

Aquaculture Research Center, Kentucky State University, Frankfort, KY 40601, USA.

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Webster C. D., J. H. Tidwell, L. S. Tiu, D. H. Yancey *Aquat. Living Resour.*, 1995, **8**, 379-384.

Abstract

Two 12-week feeding experiments were conducted in aquaria with juvenile blue catfish, *Ictalurus furcatus*. In experiment 1, juvenile (6 g) blue catfish were fed one of four isonitrogenous (34% protein) and isocaloric (10.0 kJ of digestible energy/g of diet) diets containing 13, 9, 4, and 0% menhaden fish meal. Soybean meal was added in increasing percentages (48, 55, 62, and 69%) to the respective diets. Fish were fed all they would consume in 40 minutes twice daily (08:00 and 16:00). After 12 weeks, fish fed a diet with 13% fish meal had a significantly higher individual body weight than fish fed any of the other diets. There was no significant difference ($p>0.05$) in body weights of fish fed the other four diets. No significant differences were found in percentage survival, feed conversion ratio, and protein efficiency ratio among treatments. In experiment 2, blue catfish (9 g) were fed one of five isonitrogenous (35% protein) and isocaloric (10.5 kJ of digestible energy/g of fiet) diets. Diet 1 contained 15% menhaden fish meal and 42% soybean meal. Diets 2-5 contained 0% fish meal and 69% soybean meal with various (0.0, 0.3, 0.6, and 0.9%) percentages of added L-methionine. Fish were fed as in experiment 1. After 12 weeks, individual weight, weight gain, survival, specific growth rate, and feed conversion ratio were not significantly different ($p>0.05$) among treatments and averaged 36 g, 302%, 100%, 1.6%/day, and 2.4, respectively. Whole-body compositions of fish were not significantly different ($p>0.05$) among treatments and averaged 61% and 27% for percentage protein and fat, respectively. These data indicate that soybean meal can totally replace fish meal in a diet for blue catfish without supplemental L-methionine. This may allow producers to feed more economical diets without adverse effects on growth and survival.

Keywords: *Ictalurus furcatus*, soybean meal, diet, growth, food conversion.

L'utilisation du soja en remplacement partiel ou total d'aliments à base de poisson dans le régime alimentaire du poisson-chat (Ictalurus furcatus).

Résumé

Deux expériences de 12 semaines ont été conduites sur l'alimentation en aquarium de juvéniles d'*Ictalurus furcatus*. Dans la première expérience des juvéniles (6 g) ont été nourris de 25 % d'aliments azotés (34 % de protéines), régime isocalorique (2,4 kcal/g) contenant respectivement 13, 9, 4 et 0 % de poisson menhaden (clupéidé). Le soja a été ajouté avec des pourcentages croissants (48, 55, 62 et 69 %) à ces régimes respectifs. Les poissons ont été nourris 2 fois par jour (à 8 h et 16 h), les aliments ont été totalement consommés en 40 minutes. Après 12 semaines, les poissons nourris à base d'un régime à 13 % de poisson, avaient un poids vif significativement plus élevé que les poissons nourris avec les autres régimes. Il n'y avait pas de différence significative au niveau du poids pour les poissons nourris avec les quatre autres régimes alimentaires. Aucune différence significative n'a été observée dnas le taux de pourcentage de survie, de conversion alimentaire et d'efficacité en protéines, entre les différents traitements.

Dans la deuxième expérience, les poissons-chats (9 g) ont été nourris de 1/5 d'aliments azotés (35 % de protéines et régime isocalorique) (2,5 kcal/g). Le premier régime contenait 15 % de poisson menhaden et 42 % de soja. Les régimes 2 à 5 contenaient 0 % d'aliments à base de poisson et 69 % de soja avec différents pourcentages de L-méthionine (0,03 ; 0,06 et 0,09 %). Les poissons ont été nourris comme dans la première expérience. Après 12 semaines, le poids individuel, le gain en poids, le taux de survie, le

taux de croissance spécifique et le taux de conversion alimentaire n'étaient pas significativement différents entre les traitements et étaient en moyenne de 36 g, 302 %, 100 %, 1,6 %/jour et 2,4 respectivement. Les compositions corporelles des poissons n'étaient pas significativement différentes entre les traitements et étaient en moyenne de 75, 61 et 27 % pour le pourcentage d'humidité, de protéines et de graisses respectivement.

Ces données indiquent que le soja peut remplacer totalement l'aliment à base de poisson pour le poisson-chat sans ajout supplémentaire de L-méthionine. Ceci permettrait aux producteurs d'utiliser un aliment plus économique sans effets contraires sur la croissance et le taux de survie.

Mots-clés : Nutrition, alimentation azotée, croissance, *Ictalurus furcatus*.

INTRODUCTION

Fish meal is one of the most expensive ingredients in prepared fish diets. Fish nutritionists have tried to use less expensive plant protein sources to partially or totally replace fish meal. Of all the plant protein feedstuffs, soybean meal is considered to be the most nutritious and is used as the major protein source in many fish diets (Lovell, 1988). However, growth has tended to be reduced in fish fed diets with soybean meal replacing all the fish meal (Cowey *et al.*, 1971; Lovell *et al.*, 1974; Jackson *et al.*, 1982). One possible reason for this decreased growth is activity of protease (trypsin) inhibitors in crude or inadequately heated soybean meal (Dabrowski and Kozak, 1979; Wilson and Poe, 1985). A second possible reason may be suboptimal amino acid balance of soybean meal. Murai *et al.* (1986) reported that the nutritional value of soy flour for carp, *Cyprinus carpio*, was improved by the addition of essential amino acids, especially methionine. A third possible explanation may be that the energy content of soybean meal is lower than that of fish mela in diets for fish (Viola *et al.*, 1983; Hilton and Slinger, 1986).

Heat treated full-fat soybean meal has been included in fish diets at high percentages with positive results (Reinitz *et al.*, 1978; Viola *et al.*, 1983; Wee and Shu, 1989). Viola *et al.* (1983) reported that heating soybean meal at 105°C for 30-90 min destroyed most of the trypsin inhibitors present. However, excessive heating may cause loss of essential amino acids (Plakas *et al.*, 1985).

Blue catfish, *Ictalurus furcatus*, possess several attributes that could make it a desirable culture species in temperate regions of the United States. They have a higher dressing percentage than white or channel catfish (Dunham *et al.*, 1983) and a lower optimum growing temperature (24°C) than channel catfish (30°C). Moreover, blue catfish are easier to seine (Chappell, 1979) and have higher individual weight gains in temperature regions than channel catfish (Tidwell and Mims, 1990). At present, little data on the nutritional requirements of blue catfish have been reported. The purpose of these studies was to evaluate commercially available soybean meal as a partial or total substitute for fish meal in a diet for blue catfish.

MATERIALS AND METHODS

Experiment 1

Five experimental diets were formulated to contain various percentages of soybean meal (SBM) in partial or total replacement of fish meal. Diet 1, with 48% SBM and 13% fish meal, which is similar to a high-quality commercial channel catfish diet, served as the control. Diets 2, 3, and 4 contained 55, 62, and 69% SBM, and 9, 4, and 0% fish meal, respectively (Webster *et al.*, 1992*a*). A fifth diet was otherwise identical to diet 4 except that the SBM had been heated (105°C for 60 min) in a drying oven prior to addition. Percentage protein of the diets was determined by macro-Kjeldahl, fat by the acid-hydrolysis method, and moisture by drying (100°C) until constant weight (AOAC, 1990). Digestible energy (DE) was estimated from the diet ingredients as established for channel catfish (NRC, 1993). Amino acid compositions of the fiets were determined from tabular values provided for diet ingredients (NRC, 1983). All diets were isonitrogenous (34% protein) and isocaloric (10.0 kJ digestible energy/g).

The feeding trial was conducted in twenty 37.5-1 glass aquaria. Water was recirculated through biological and mechanical filters. Illumination was supplied by fluorescent ceiling lights with an 18:6 per day light:dark cycle. Ten juvenile blue catfish (average weight = 7.9 g; Danbury Fish Farms, Danbury, Texas) were randomly stocked into each aquarium and fed twice daily (08:00 and 16:00) for 12 weeks. There were four replicates per diet. Growth performance, feed conversion, and body composition were measured as described in Webster *et al.* (1992*b*). Data were analyzed by analysis of variance using the SAS ANOVA procedure (Statistical Analysis Systems, 1988).

Experiment 2

Five experimental diets were formulated. Diet 1, with 42% SBM and 15% fish meal, was formulated to be similar to a high-quality commercial channel catfish diet (NRC, 1977). The other four diets (diets 2-5) contained 0% fish meal, 65% SBM, and various percentages (0.0, 0.3, 0.6, 0.9%) of supplemental crystalline L-methionine (Sigma

Table 1. – Composition of a diet similar to a high-quality commercial catfish diet (with fish meal) and experimental diets (without fish meal) fed to juvenile blue catfish. All diets without fish meal contained various percentages of supplemental L-methionine (experiment 2).

	Diet No.				
	1	2	3	4	5
Ingredient					
Menhaden Fish meal (67%)	15.00	0	0	0	0
Soybean meal (47%)	42.00	65.00	64.70	64.40	64.10
Ground corn	35.50	23.00	23.00	23.00	23.00
Cod liver oil [1]	2.00	5.00	5.00	5.00	5.00
Premix [2]	3.00	3.00	3.00	3.00	3.00
Dicalcium phosphate	0.50	2.00	2.00	2.00	2.00
CMC [3]	2.00	2.00	2.00	2.00	2.00
L-methionine	0	0	0.30	0.60	0.90
Nutrient composition					
Moisture (%)	11.39	7.75	7.91	10.90	9.19
Protein (%) [4]	34.76	34.83	35.02	34.92	34.93
Fat (%) [4]	7.16	8.79	8.87	8.62	8.43
DE [5]	10.2	10.8	10.8	10.7	10.7
P:E [6]	34.1	32.3	32.4	32.6	32.6

[1] Ethoxyquin was added at 0.02% of lipid.

[2] Premix supplied the following vitamins and minerals (mg or IU/kg of diet): A, 5280 IU; D_3, 2640 IU; E, 660 IU; cyanocobalamine (B_{12}), 0.011 mg; K, 13.2 mg; riboflavin, 15.8 mg; panthothenic acid, 42.2 mg; thiamine, 13.2 mg; niacin, 105.6 mg; pyrodoxine (B_6), 13.2 mg; folic acid, 2.6 mg; choline, 580 mg; ascorbic acid, 935 mg; zinc, 207 mg; iron, 72 mg; manganese, 216 mg; copper, 9 mg; iodine, 4.5 mg; cobalt, 1.8 mg; selenium, 0.3 mg; KCl, 3474 mg; NaH_2PO_4, 1932 mg.

[3] CMC = Carboxymethylcellulose.

[4] Moisture-free basis.

[5] DE = Digestible energy in kJ/g of diet; based on estimated values of diet ingredients for channel catfish (NRC, 1993).

[6] P:E = Protein to energy ratio (as mg protein/kJ of DE).

Chemical Co., St. Louis, MO) (*tabl.* 1). Amino acid compositions of the diets were calculated from tabular values provided for diet ingredients (NRC, 1983). All diets were formulated isonitrogenous (35% protein) and isoenergetic (10.5 kJ digestible energy/g of diet).

The feeding trial was conducted in fifteen 37.5-l acrylic aquaria. Water was recirculated through biological and mechanical filters. Continuous illumination was supplied by fluorescent ceiling lights.

Juvenile blue catfish were obtained from a single spawn at the Aquaculture Research Center, Kentucky State University, Frankfort, KY, USA. Juvenile blue catfish (average weight 8.9 ± 1.2 g) were used for the feeding trial. Six fish were randomly stocked into each aquarium with three replications per treatment. All fish were fed all they could consume in 40 min twice daily (08.00 and 16.00 h) for 12 weeks. Growth performance and feed conversion were measured as described in Webster *et al.* (1992*b*). Data were analyzed by analysis of variance (ANOVA) using the SAS ANOVA procedure (Statistical Analysis Systems, 1988). Duncan's multiple-range test was used to compare differences among individual means.

RESULTS AND DISCUSSION

Experiment 1

Blue catfish fed the control (48% soybean meal and 13% fish meal) diet were significantly longer (total length) than those fed diets 4 and 5 (69% soybean meal and 0% fish meal) ($p < 0.05$), but not relative to fish fed diet 2 (55% soybean meal and 9% fish meal) and diet 3 (62% soybean meal and 4% fish meal) (*tabl.* 2). Final weights of blue catfish fed the control diet were significantly higher ($p < 0.05$) than noted for fish fed any of the experimental diets. Specific growth

Table 2. – Effects of increasing percentage of soybean meal and decreasing percentage of fish meal in prepared diets on growth of blue catfish (experiment 1). [1]

	Diet No.				
	1	2	3	4	5
Length (mm)	165.5 ± 4.1 ^{a}	156.3 ± 2.3 ^{ab}	155.6 ± 2.0 ^{ab}	154.3 ± 0.9 ^{b}	150.4 ± 5.5 ^{b}
Final wt (g)	37.45 ± 2.16 ^{a}	31.20 ± 1.66 ^{b}	29.73 ± 1.93 ^{b}	28.25 ± 0.76 ^{b}	27.45 ± 3.02 ^{b}
Survival (%)	100	100	100	100	100
FCR [2]	2.13 ± 0.10	2.46 ± 0.09	2.34 ± 0.25	2.37 ± 0.06	2.49 ± 0.22
Food intake [3]	4.71 ± 0.35	5.17 ± 0.17	4.48 ± 0.39	4.88 ± 0.16	5.08 ± 0.48
SGR [4]	2.18 ± 0.07 ^{a}	1.96 ± 0.07 ^{ab}	1.84 ± 0.07 ^{b}	1.85 ± 0.03 ^{b}	1.76 ± 0.13 ^{b}
PER [5]	1.39 ± 0.06 ^{a}	1.20 ± 0.05 ^{a}	1.30 ± 0.13 ^{a}	1.24 ± 0.03 ^{a}	1.21 ± 0.10 ^{a}

[1] Values are means ± SE of four replications. Means within a row having different superscripts were significantly different ($p < 0.05$).

[2] FCR = food conversion ratio; total dry diet fed (g)/total wet weight gain (g).

[3] Food intake (% body weight) = (DFI × 100)/($W_{t+1} + W_t$)/2 where DFI is mean daily dry food intake per fish (t, $t+1$) and W_t, W_{t+1} are the averaged wet weights at the start (t) and conclusion ($t+1$) of the study period.

[4] SGR = specific growth rate (%/day); $(\ln W_t - \ln W_i / T) \times 100$, where W_t is weight of fish at time t, W_i is weight of fish at time 0, and T is the culture period in days.

[5] PER = protein efficiency ratio; wet weight gain (g)/amount of protein fed (g).

rate (SGR) for blue catfish fed the control diet was significantly higher ($p<0.05$) than obtained for fish fed diets 3, 4, and 5, but not significantly different from that of fish fed diet 2 ($p>0.05$).

Feed conversion ratio (FCR), food intake, and protein efficiency ratio (PER) were not significantly different among treatments ($p>0.05$) (*tabl.* 2). Feed conversion values are somewhat higher than literature values (Robinson *et al.*, 1985; Gatlin and Phillips, 1989) because of the small aquaria used in the present study. Fish tend to agitate the water during feeding and may break apart diet pellets rapidly. Small particles of diet could then be removed through the standpipe, skewing the FCR values upward. However, FCR were consistent with other studies (Andrews and Stickney, 1972; Tidwell *et al.*, 1990).

No significant differences in percentage body protein and moisture were found among treatments ($p>0.05$) (*tabl.* 3). However, whole-body lipid percentages for fish fed diets 1, 3, and 4 were significantly higher than those for fish fed diet 2 ($p>0.05$). Body lipid content did not seem to be related to growth rate, food intake, or percentage lipid and energy content of the diet.

Experiment 2

Fish fed diet 5 were significantly ($p>0.05$) longer (174 mm) than those fed diet 1 (155 mm); however, fish fed diets 2-4 were not significantly different ($p>0.05$) compared to fish fed diet 1 or diet 5 (*tabl.* 4). No significant difference ($p>0.05$) in final weight of blue catfish fed diet 1 (42% SBM and 15% fish meal) and fish fed diets containing 0% fish meal (diets 2-5) was found and averaged 35.8 g among treatments (*tabl.* 4). Percentage weight gain, survival, and specific growth rate (SGR) were not significantly different ($p>0.05$) among treatments and averaged 302%, 100%, and 1.6%/day, respectively. Feed conversion ratio (FCR) was not significantly different ($p>0.05$) among treatments and averaged 2.4.

Whole-body proximate composition at the conclusion of the feeding trial resulted in no significant differences ($p>0.05$) in percentage moisture, protein, and fat among fish fed the five diets and averaged 74.5, 60.7, and 27.3%, respectively (*tabl.* 4). All diets were formulated to be similar in percentage protein and energy content.

These data indicate that growth of blue catfish may not be adversely affected by feeding a diet containing a high percentage of soybean meal (65%) and 0% fish meal. This is in contrast to some studies on carp, *Cyprinus carpio* (Nandeesha *et al.*, 1989); tilapia, *Oreochromis niloticus* X *O. aureus* (Shiau *et al.*, 1990); channel catfish, *Ictalurus punctatus* (Mohsen and Lovell, 1990); and blue catfish (Webster *et al.*, 1992*a*).

Table 3. – Whole body moisture, protein, and lipid percentages of juvenile blue catfish fed diets containing increasing percentages of soybean meal and decreasing percentages of fish meal (experiment 1). [1]

Diet No.	Moisture (%)	Protein [2] (%)	Fat [2] (%)
1	71.11 ± 0.92	47.17 ± 6.15	37.21 ± 0.78 ^{ab}
2	71.27 ± 0.22	48.10 ± 1.28	29.31 ± 1.47 ^{c}
3	70.10 ± 0.21	46.46 ± 2.12	34.48 ± 1.14 ^{ab}
4	71.19 ± 0.40	44.67 ± 1.14	38.40 ± 1.51 ^{a}
5	71.22 ± 1.32	48.06 ± 2.49	31.01 ± 3.05 ^{bc}

[1] Values are means ± SE of four replications. Means within a column having different superscripts were significantly different ($p<0.05$).
[2] Moisture-free basis.

Results of the two studies are in agreement with other studies (Davis and Stickney, 1978; E.H. Robinson, Delta Branch Experiment Station, Stoneville, MS, pers. comm.). It has been stated that channel catfish fed diets containing 0% fish meal and 60-70% SBM had similar growth rates compared to fish fed commercial catfish diets containing fish meal (E.H. Robinson, pers. com.). No differences in weight gains were reported in tilapia, *Oreochromis aureus*, fed diets containing 0% fish meal and 74% SBM (36% protein) compared to fish fed a 36% protein diet containing fish meal (Davis and Stockney, 1978). When protein level was below 30%, fish fed diets containing fish meal had higher weight gains compared to fish fed diets without fish meal.

Replacement of fish meal with soybean meal has had variable success. In those studies in which growth is reduced, several hypotheses have attempted to explain the results: 1. suboptimal amino acid balance; 2. inadequate levels of phosphorus in soybean meal; 3. presence of antinutritional factors (including trypsin inhibitors); and 4. inadequate levels of energy in soybean meal. Soybean meal has one of the best amino acid profiles of any plant protein feedstuff and the composition meets the essential amino acid requirements of channel catfish (Lovell, 1988). Amino acid analyses indicated that all diets met the amino acid requirements of channel catfish (NRC, 1983). However, the biological value of amino acids from soybean meal may be less than indicated. Dabrowski *et al.* (1989) stated that methionine availability may be reduced when soybean meal comprises a large percentage (>50) of the diet. The increase in growth in fish fed diets containing fish meal may be caused by higher amounts of biologically available sulfur amino acids (Cowey *et al.*, 1971; Jackson *et al.*, 1982); however, other studies, feeding practical diets to channel catfish, have used percentages of SBM higher than 50% and have reported no differences in growth (Reis *et al.*, 1989; Li and Lovell, 1992; Robinson and Robinette, 1993).

Some fish, such as red drum, *Sciaenops ocellatus*, find SBM unpalatable and will not consume diets that have 0% fish meal (reigh and Ellis, 1992). Mohsen

Table 4. – Length, weight, percentage weight gain, survival, specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio (PER), food intake, and whole-body composition of juvenile blue catfish fed a diet containing fishmeal and for diets without fish meal and various percentages of supplemental L-methionine (experiment 2). [1]

	Diet No.				
	1	2	3	4	5
Total length (mm)	155.2 ± 2.2 [b]	170.9 ± 2.8 [ab]	171.0 ± 6.9 [ab]	169.3 ± 7.9 [ab]	173.7 ± 4.7 [a]
Final indiv. wt. (g)	28.89 ± 1.44 [a]	36.06 ± 1.26 [a]	37.74 ± 3.71 [a]	36.83 ± 5.07 [a]	39.16 ± 3.12 [a]
Weight gain (%)	257.3 ± 13.7 [a]	302.0 ± 10.9 [a]	319.3 ± 31.3 [a]	308.8 ± 32.3 [a]	324.4 ± 18.4 [a]
Survival (%)	100 [a]	100 [a]	100 [a]	100 [a]	100 [a]
SGR (%/day)	1.46 ± 0.10 [a]	1.65 ± 0.03 [a]	1.70 ± 0.09 [a]	1.67 ± 0.09 [a]	1.72 ± 0.05 [a]
FCR	2.79 ± 0.25 [a]	2.34 ± 0.08 [a]	2.19 ± 0.22 [a]	2.29 ± 0.27 [a]	2.21 ± 0.20 [a]
PER	1.05 ± 0.09 [a]	1.24 ± 0.03 [a]	1.33 ± 0.12 [a]	1.29 ± 0.17 [a]	1.32 ± 0.13 [a]
Food intake (% body wt.)	3.88 ± 0.31 [a]	3.30 ± 0.04 [a]	3.15 ± 0.17 [a]	3.26 ± 0.29 [a]	3.21 ± 0.23 [a]
Whole-body composition					
Moisture (%)	76.09 ± 0.34 [a]	74.43 ± 0.85 [a]	74.00 ± 0.52 [a]	74.50 ± 0.47 [a]	73.51 ± 1.25 [a]
Protein (%) [2]	62.23 ± 0.99 [a]	59.73 ± 0.80 [a]	58.77 ± 0.44 [a]	62.39 ± 1.94 [a]	60.39 ± 1.33 [a]
Fat (%) [2]	25.53 ± 1.20 [a]	28.89 ± 0.17 [a]	28.04 ± 1.27 [a]	26.77 ± 1.30 [a]	27.52 ± 0.18 [a]

[1] Values are means ± SE of three replications. Means in the same row with different superscripts were signifiantly different ($p < 0.05$).

[2] Moisture-free basis.

and Lovell (1990) reported that addition of animal by-products to a soybean meal-based diet improved palatability. However, fish adapted to a SBM diet may have similar growth rates and consumption rates as fish fed diets containing animal protein sources. In the two studies, blue catfish appeared to consume diets containing 0% fish meal and did not find them unpalatable. Diets without fish meal did have a higher percentage (5%) of cod liver oil top-dressed onto the diets compared to the diet containing fish meal (diet 1; 2%) which may have increased palatability.

The variable success of researchers in using SBM as a total replacement for fish meal indicates the wide variation possible in the nutritive value of SBM for various fish species and the influence of diet formulation on growth. These data from the present studies indicate that a diet in which SBM totally replaces fish meal can be fed to juvenile blue catfish without adverse effects on growth and body composition when the diet contains 35% protein, cod liver oil, and 2% supplemental dicalcium phosphate. Further evaluation of an all-plant protein diet on growth of blue catfish in production trials should be conducted.

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