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Growth and body composition of channel catfish (*Ictalurus punctatus*) fed diets containing various percentages of canola meal

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Abstract

A 12-week feeding trial was conducted in aquaria with juvenile (10 g) channel catfish to examine the effects of partially substituting canola meal for soybean meal in prepared diets. Six isonitrogenous (32% protein) and isocaloric (2.7 kcal digestible energy g^{-1}) diets were formulated to contain 0, 12, 24, 36, and 48% canola meal (CM). There were two diets with 0% CM; one with 8% fish meal (FM) and one with 4% FM. All diets with CM had 4% FM. Fish were fed twice daily all they could consume in 20 min. After 12 weeks, fish fed a diet with 8% FM and 0% CM had significantly higher ($P < 0.05$) percentage weight gains than fish fed all other diets. Fish fed diets containing 12 and 36% CM had significantly higher ($P < 0.05$) percentage weight gains (average 604%) than fish fed a diet containing 48% CM. Feed conversion ratio (FCR) of fish fed a diet containing 48% CM was significantly ($P \leq 0.05$) higher (2.25) than values for fish fed 12, 24, and 36% CM. There were no histological differences in the thyroid of fish fed any of the diets. These data suggest that channel catfish can be fed diets containing up to 36% CM without adverse effects on growth or body composition. Fish fed a diet with 48% CM had a lower percentage weight gain compared with fish fed diets containing between 12 and 36% CM, possibly due to reduced palatability of the diet. Use of canola meal in practical diets for channel catfish may allow producers and feed mills to formulate more economical diets by adding another plant protein source to ingredients used in commercial catfish diets. © 1997 Elsevier Science B.V.

Keywords: Channel catfish; Canola meal; Diets; Growth

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1. 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. Soybean meal is considered to be one of the most nutritious of all plant protein feedstuffs (Lovell, 1988). However, growth has tended to be reduced in fish fed diets with soybean meal replacing all the fish meal (Lovell et al., 1974; Webster et al., 1992a).

Other plant protein sources, such as cottonseed meal (CSM) and distillers' grains with solubles (DGS) can be used in fish diets; however, both ingredients are low in lysine. It has been reported that the addition of up to 30% cottonseed meal in diets for channel catfish has no adverse effects on growth (Robinson and Brent, 1989; Robinson, 1991). Use of 35% DGS in diets for channel catfish has been reported to give acceptable growth (Webster et al., 1991, 1992b). However, as ingredient prices fluctuate, there is a need for additional plant protein sources to be used in diets for channel catfish.

Canola is the name given to selected varieties of rapeseed (*Brassica napus* and *Brassica campestris*) that are low in both glucosinolates (antithyroid factors) and erucic acid (Higgs et al., 1983). Higgs et al. (1988, 1990) reported that the protein quality of canola is equivalent to that of herring meal and higher than for soybean meal and cottonseed meal based on essential amino acid index. Canola meal, like other oilseed meals, contain high levels of fiber, phytic acid, and phenolic compounds (such as sinapine and tannins) (Fenwick et al., 1986; Vermorel et al., 1986). Glucosinolates are a unique antinutritional factor to canola/rapeseed meals (Higgs et al., 1995).

Owing to the antinutritional factors present, use of rapeseed/canola meal has been limited. Rapeseed meal (RM) can be included at levels of up to 20% of the diet for salmonids (Higgs et al., 1982; Hardy and Sullivan, 1983). Davies et al. (1990) stated that RM could be added at a level of 15% of the diet for tilapia. The purpose of the present study was to evaluate various percentages of canola meal as a potential ingredient to be included in practical diets for channel catfish.

2. Materials and methods

2.1. Experimental diets

Six experimental diets were formulated to contain various percentages of canola meal (CM) as partial replacement for soybean meal. Diet 1 (with 8% fish meal, FM, and 0% CM) was formulated to be similar to a high-quality commercial channel catfish diet. Diet 2 (4% FM and 0% CM) was formulated to be similar to commercial diets currently used to feed channel catfish. The other four diets (diets 3–6) contained 4% FM, soybean meal, and various percentages (12, 24, 36, and 48%) of CM partially replacing soybean meal (Table 1). All diets were formulated isonitrogenous (32% protein) and isocaloric (2.7 kcal digestible energy g^{-1} of diet).

In preparing the diets, dry ingredients were first ground to a small particle size (approximately 250 μm) in a Wiley mill. Ingredients were thoroughly mixed and water

Table 1
Composition of diets fed to juvenile channel catfish containing various percentages of canola meal (CM). Values are means ± SE of three replications

	Diet (% CM)					
	1 (0)	2 (0)	3 (12)	4 (24)	5 (36)	6 (48)
Ingredient						
Menhaden fish meal (67%)	8.0	4.0	4.0	4.0	4.0	4.0
Soybean meal (49%)	50.75	57.0	47.0	37.0	26.75	16.75
Canola meal (41%)	0.0	0.0	12.0	24.0	36.0	48.0
Corn	32.0	29.0	27.0	25.0	23.25	21.25
Oil [a]	1.5	2.0	2.0	2.0	2.0	2.0
Premix [b]	4.0	4.0	4.0	4.0	4.0	4.0
CMC [c]	3.0	3.0	3.0	3.0	3.0	3.0
Dicalcium phosphate	0.75	1.0	1.0	1.0	1.0	1.0
Chemical analysis						
Moisture (%)	8.95	7.84	8.42	8.17	7.35	6.74
Protein (%) [d]	32.70	33.37	32.13	31.86	31.67	31.15
Lipid (%) [d]	5.26	5.23	5.92	6.31	7.06	7.74
Fiber (%) [d]	4.55	4.92	5.72	6.18	6.59	7.84
Ash (%) [d]	7.33	7.03	7.36	7.77	8.12	8.34
Energy (kcal g^{-1} diet) [e]	2.69	2.70	2.69	2.70	2.71	2.71
Arginine	2.07	2.14	2.04	1.93	1.84	1.82
Cystine	0.36	0.38	0.41	0.41	0.49	0.45
Lysine	1.81	1.85	1.77	1.71	1.67	1.57
Methionine	0.49	0.50	0.55	0.52	0.58	0.53
Pellet stability [f]	91.62 ± 0.16a	87.52 ± 0.34b	91.92 ± 0.60a	91.57 ± 0.30a	91.84 ± 0.20a	92.72 ± 0.26a

[a] Cod liver oil:soybean oil blend (70:30).
[b] Premix supplied the following (in mg or IU kg^{-1} of diet): vitamin A acetate, 7040 IU; vitamin D_3, 3520 IU; E, 88 IU; K (menadione dimethylpyrimidinol bisulfite), 4.2 mg; ascorbic acid, 1246 mg; B_{12}, 0.014 mg; riboflavin, 21.2 mg; pantothenic acid, 56.4 mg; thiamin, 17.6 mg; niacin, 141 mg; pyridoxine, 17.6 mg; folic acid, 3.5 mg; choline chloride, 776 mg; zinc, 276 mg; iron, 96 mg; manganese, 288 mg; copper, 12.0 mg; iodine, 6.0 mg; cobalt, 2.4 mg; selenium, 0.03 mg.
[c] Carboxymethylcellulose.
[d] Dry matter basis.
[e] Energy was calculated from ingredients based on National Research Council (1993) values for channel catfish except for canola meal, which was based on the value for rainbow trout.
[f] Percentage of dry solids retained after 10 min in static water.
Values followed by different letters are significantly ($P < 0.05$) different.

added to obtain a 25% moisture level. Diets were passed through a mincer with a die into 0.4-mm diameter 'spaghetti-like' strands and dried (20°C) for 16 h using a convection oven. After drying, the diets were broken up and sieved into appropriate pellet sizes. Lipid was added to the dried pellets immediately prior to storage (−20°C).

A cod liver oil/soybean oil blend (70:30) was used as the lipid source. Marine fish oil was used to supply essential *n*-3 fatty acids. All diets were frozen (−15°C) until immediately prior to being used. Percentage protein of the diets was determined by macro-Kjeldahl, percentage fat was determined by the acid-hydrolysis method, and moisture was determined by drying (100°C) until constant weight (AOAC, 1990). Digestible energy (DE) was estimated from the diet ingredients as established for channel catfish, except for canola meal, which has no DE value for channel catfish. A DE value for rainbow trout was used (National Research Council, 1993). Diets were also analyzed for amino acid composition by a commercial laboratory (Woodson-Tenent Lab, Dayton, OH) (Table 1).

Pellet stability of the diets was determined as follows. A 10 g sample of diet was placed on a 2-mm mesh wire screen and lowered into static water to a depth of 10 cm. After 10 min, the screen was removed and the sample placed in a convection oven (50°C) for 14 h until constant weight was achieved. The sample was cooled and reweighed. There were three replications per diet.

2.2. Experimental system and animals

The feeding trial was conducted in 24 110-l glass aquaria. Water was recirculated through biological and mechanical filters. The recirculating system consisted of a 3375-l vertical screen filter system utilizing high-density polyester screens (Red Ewald, Inc., Karnes City, TX) and a drum filter system comprised of plastic 'bio-balls' and fibrous polyester material. These two filter systems removed particulate material and provided substrate for *Nitrosomonas* and *Nitrobacter* bacteria. Continuous aeration was provided by a blower and air stones. Water exchange rate for the system was approximately 2% of total volume per day. Chloride levels were maintained at approximately 200 mg l^{-1}, by addition of food grade NaCl, to minimize potential adverse effects of nitrite to fish health. Each aquarium was supplied with water at a rate of 5.0 l min^{-1} and cleaned daily to remove uneaten feed and feces. Black plastic covered the back and sides of all aquaria to minimize disturbances resulting when personnel were present in the laboratory. Continuous illumination was supplied by fluorescent ceiling lights.

Water temperature and dissolved oxygen were measured every other day using a YSI Model 58 oxygen meter (YSI Industries, Yellow Springs, OH). Total ammonia and nitrite were measured every other day using a DREL 2000 spectrophotometer (Hach Co., Loveland, CO). Total alkalinity and chloride were monitored twice weekly using the titration method of the DREL 2000; pH was monitored three times weekly using an electronic pH meter (pH pen; Fisher Scientific, Cincinnati, OH). Over the duration of the study, mean ± SD values for these water quality variables were: water temperature, 25.4 ± 0.9°C; dissolved oxygen, 6.3 ± 0.5 mg l^{-1}; total ammonia, 0.64 ± 0.62 mg l^{-1}; nitrite, 1.84 ± 2.66 mg l^{-1}; total alkalinity, 90.1 ± 19.0 mg l^{-1}; chlorides, 248 ± 45 mg l^{-1}; pH, 8.8 ± 0.1.

Juvenile channel catfish (*Ictalurus punctatus*) were obtained from a commercial supplier (Davis Catfish Farm, Leesburg, AL) and had an average weight (±SE) of 10.0 ± 0.5 g. Fifteen fish were randomly stocked into each aquarium with four replications per treatment. After stocking, to minimize stress of handling, fish were not weighed for the duration of the feeding trial. All fish were fed all they could consume in

20 min twice daily (07:30 and 16:00 h) for 12 weeks. At the start and conclusion of the feeding trial, a number of fish were sacrificed by decapitation (15 at stocking and six fish per aquarium at conclusion), homogenized in a blender, stored in polyethylene bags, and frozen for subsequent protein, fat, and moisture analysis. Protein was determined by macro-Kjeldahl, fat was determined by ether extraction, and moisture was determined by placing a 10-g sample in an oven (100°C for 24 h) to be dried until constant weight (AOAC, 1990).

Growth performance and feed conversion were measured in terms of final individual fish weight (g), survival (%), feed conversion ratio (FCR), protein efficiency ratio (PER), and protein retention value (PRV). Growth response parameters were calculated as follows: PER = wet weight gain (g)/protein fed (g; dry-matter basis); PRV = [(100)(protein gain, g)(% dry matter of fish)]/[(diet fed, g)(% dry matter of diet)(% dietary protein)]; FCR = total dry feed fed (g)/total wet weight gain (g).

Since dietary incorporation of RM and CM is considered to lead to histopathological changes of the thyroid follicles in fish, two fish were randomly sampled from each aquarium for histopathological examination. Fish were anesthetized in tricaine and killed by decapitation. The lower half of the head was removed from each fish to obtain the thyroid, and placed into Bouin's fixative for 2 weeks and then transferred to 70% ethyl alcohol. A sample of the ventral pharynx, between the second and third gill arches was cut from each fish and embedded in paraffin. Transverse sections, 6 μm thick, were stained with hematoxylin and eosin and thyroid follicles examined with a light microscope.

2.3. Statistical analysis

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. All percentage and ratio data were transformed to arc sin values prior to analysis (Zar, 1984).

3. Results

Final average weight of channel catfish fed diet 1 (8% FM and 0% CM) was significantly higher ($P < 0.05$) than that of fish fed diet 2 (0% CM), diet 4 (24% CM), and diet 6 (48% CM), but not significantly different ($P > 0.05$) from fish fed diet 3 (12% CM) and diet 5 (36% CM) (Table 2). However, percentage weight gain of channel catfish fed diet 1 was significantly higher ($P < 0.05$) compared with fish fed all other diets. Fish fed diets 3 and 5 had significantly ($P < 0.05$) higher percentage weight gains than fish fed diets 2 and 6, but were lower than fish fed diet 1. Fish fed diet 6 (48% CM) had a lower ($P < 0.05$) percentage weight gain than fish fed diets 3 and 5. Survival was 98% or better for each treatment and did not differ among treatments.

Feed conversion ratio (FCR) of fish fed diet 2 (0% CM) and diet 6 (48% CM) was significantly higher (2.25) than values for fish fed the other diets ($P < 0.05$) (Table 2). Channel catfish fed diets 1, 3, and 4 had significantly higher protein efficiency ratio (PER) than fish fed diets 2 and 6. Protein retention values (PRV) for fish fed diet 1 (8%

Table 2
Final average individual weight, percentage weight gain, percentage survival, feed conversion ratio, protein efficiency ratio, and protein retention value for channel catfish fed diets containing various percentages of canola meal (CM). Values are means ± SE of four replications

	Diet (% CM)					
	1 (0)	2 (0)	3 (12)	4 (24)	5 (36)	6 (48)
Final wt. (g)	92.95 ± 4.85a	53.10 ± 5.06d	84.75 ± 4.13ab	74.12 ± 5.25bc	79.03 ± 5.34ab	60.70 ± 1.32cd
Wt. gain (%)	743 ± 27a	379 ± 25d	599 ± 21b	542 ± 41bc	608 ± 47b	442 ± 20cd
Survival (%)	100.0 ± 0.0	98.3 ± 1.8	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0
FCR [a]	1.57 ± 0.07c	2.25 ± 0.16a	1.75 ± 0.06bc	1.82 ± 0.04bc	1.89 ± 0.06b	2.24 ± 0.11a
PER [b]	1.96 ± 0.09a	1.36 ± 0.09c	1.78 ± 0.07ab	1.73 ± 0.04ab	1.68 ± 0.05b	1.45 ± 0.08c
PRV (%) [c]	31.86 ± 1.16a	21.47 ± 1.36c	28.75 ± 1.44ab	27.74 ± 0.87b	26.80 ± 1.02b	22.72 ± 1.08c

[a] Feed conversion ratio.
[b] Protein efficiency ratio.
[c] Protein retention value.
Means in the same row followed by different letters are significantly ($P < 0.05$) different.

Table 3
Body composition (% dry matter) of juvenile channel catfish fed diets containing various percentages of canola meal (CM) in 1995. Values are means ± SE of four replications

Diet (% CM)	% Moisture	% Protein	% Lipid
1 (0)	71.79 ± 0.46ab	52.59 ± 0.81a	35.19 ± 0.75ab
2 (0)	72.81 ± 0.49a	53.64 ± 0.60a	32.89 ± 0.40b
3 (12)	71.76 ± 0.57ab	52.14 ± 0.90a	36.97 ± 0.75a
4 (24)	71.89 ± 0.27ab	52.36 ± 0.82a	35.76 ± 0.81a
5 (36)	71.11 ± 0.20bc	51.19 ± 0.54ab	36.33 ± 0.80a
6 (48)	70.18 ± 0.79c	49.28 ± 1.47b	34.76 ± 1.08ab

Means in the same row followed by different letters are significantly ($P < 0.05$) different.

FM and 0% CM) and diet 3 (4% FM and 12% CM) were significantly higher than for fish fed diets 2 and 6; however, there was no difference ($P > 0.05$) in FCR among fish fed diets 3, 4, and 5.

Whole-body proximate composition of fish fed diet 6 (4% FM and 48% CM) had a significantly lower ($P < 0.05$) percentage of moisture (70.2%) than for fish fed diets 1–4, but not significantly different ($P > 0.05$) than for fish fed diet 5 (4% and 36% CM) (Table 3). Percentage protein in fish fed diet 6 was significantly lower (49.3%) than for fish fed diets 1–4 (average of 52.7%), but not different from fish fed diet 5 (51.2%). Percentage body lipid was significantly lower in fish fed diet 2 (4% FM and 0% CM) than for fish fed diets 3–5, but not different than fish fed diet 1 (8% FM and 0% CM) and diet 6 (4% FM and 48% CM).

Water stability of the diets was very good. Diet 2 (4% FM and 0% CM) had a significantly lower ($P < 0.05$) percentage of dry solids after 10 min in water compared with the other diets (Table 1).

There were no histological differences in the thyroid of fish fed the test diets. Thyroid follicles were spherical and filled with eosinophilic colloid; abnormally shaped follicles were uncommon. Height of the follicular epithelium in most fish ranged from 1 to 6 μm, but some fish had follicular epithelium as thick as 10 μm. The density and amount of interstitial tissue between follicles varied among fish; however, there was no relationship between thyroid structure and treatments.

4. Discussion

The present study may be the first to evaluate the addition of various percentages of canola meal (CM) in a diet for channel catfish. Li and Robinson (1994) reported that addition of 25% CM to a diet did not affect growth compared with fish fed a commercial diet in ponds; however, no other levels of CM were evaluated. Data from the present study indicate that while fish fed diets containing between 24 and 36% CM had reduced growth compared with fish fed a diet with 8% FM and 0% CM (diet 1), growth rates were nonetheless high (with weight gains of approximately 600%). This is in contrast to growth of fish fed a diet with 4% FM and 0% CM (diet 2), which met all amino acid requirements of channel catfish, but which resulted in the lowest growth rate.

The lower growth rate of channel catfish fed diet 2, compared with fish fed most other diets is unexpected and unexplained. These findings may be due to use of small fish (10 g) in a controlled environment finding the diet unpalatable. While larger (70–100 g) channel catfish readily consume diets with high percentages of SBM and low percentages of FM (E.H. Robinson, personal communication, 1996), small fish in aquaria may not. The higher FCR for fish in the present study fed diet 2 indicate that palatability may have been reduced. Mohsen and Lovell (1990) reported that channel catfish fed a diet containing 20% FM had higher weight gains than fish fed diets containing 0, 5, and 10% FM. Webster et al. (1992a) reported that blue catfish fed a diet containing 13% FM had higher growth rates than fish fed diets containing 0, 4, 9% FM. However, Webster et al. (1995) reported that growth in blue catfish was not adversely affected when fed a soybean meal-based diet containing 0% FM.

Davies et al. (1990) reported that PER and net protein utilization (NPU) in tilapia were not different in fish fed a diet with 30% rapeseed meal from fish fed a control diet, although growth was reduced. This may indicate that reduced growth was due to an imbalance in amino acid composition of rapeseed meal, or reduced protein (amino acid) digestibility in rapeseed meal. In the present study, protein efficiency ratio (PER) and protein retention value (PRV) were similar among fish fed diet 1 and diets containing between 12 and 36% CM, indicating that protein value of diets with up to 36% CM were similar to a control diet.

Addition of CM to aquaculture diets has generally resulted in reduced growth in fish. Possible explanations for reduced growth of fish fed rapeseed and canola meal include:

1. inferior amino acid balance (Leslie and Summers, 1975), presence of tannins (Sosulski, 1979), and reduced metabolizable energy content;
2. high fiber content which can decrease transit time of intestinal contents and reduces protein and energy digestibility (Higgs et al., 1983);
3. increased level of glucosinolates (Higgs et al., 1983).

Energy content of CM is lower than for FM or soybean meal; however, additional energy from lipid should offset any deficiencies. Tannins may reduce protein digestibility (Krogdahl, 1989), while sinapine and glucosinolates may reduce the palatability of CM (Higgs et al., 1983; McCurdy and March, 1992). In the present study, fish fed a diet containing 48% CM had higher FCR than fish fed diets containing between 12 and 36% CM, suggesting reduced palatability of the diet since fish were fed carefully. Higgs et al. (1983) reported that growth and feed consumption were reduced in chinook salmon fed diets where CM partially replaced herring meal, but amino acid composition of diets was similar. Hilton and Slinger (1986) stated that reduced growth of rainbow trout fed CM-based diets was due to reduced diet intake. Others have reported that rapeseed and canola protein concentrates could not totally replace fish meal in diets for rainbow trout unless a feed attractant was added (Higgs et al., 1995).

Thyroid tissue appeared normal in channel catfish fed diets containing up to 48% CM. This is in contrast to studies on salmonids where compensatory increases in thyroid activity have been noted to offset reduced thyroid hormone synthesis (Higgs et al., 1982). Higgs et al. (1983) reported that the thyroid gland had follicular hyperplasia and epithelial hypertrophy, but these lesions were not observed in the present study. These differences may be due to canola meal affecting species differently, or that levels of glucosinolates in diets fed in the present study were not high enough to adversely affect the thyroid gland of channel catfish.

With the cost of fish meal increasing, it is important to evaluate less expensive protein sources for use in aquaculture diets. Results of the present study indicate that a diet with 4% FM and up to 36% CM may be acceptable, under favorable economic conditions, for use in channel catfish diets. But it appears that addition of 48% CM causes reduced growth in juvenile channel catfish.

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