

Partial replacement of fish and soyabean meal protein in mirror carp (*Cyprinus carpio*) diets by protein in hazelnut meal

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Abstract

An 80-day feeding trial was conducted as two experiments to evaluate the effects of replacement of fish meal (FM) and soyabean meal (SBM) protein with hazelnut meal (HM) protein in the diets of mirror carp (*Cyprinus carpio*) fingerlings. Growth parameters and body composition were measured in fingerlings cultured under laboratory conditions in a recirculation system aquarium at 26 ± 0.3 °C. In Experiment I four isonitrogenous, isoenergetic diets were formulated by replacing 0, 25, 35 and 45% of protein from FM by HM. Fingerlings receiving the diets in which 0, 25 and 35% of the FM protein were replaced, had similar body weights, specific growth ratios (SGR), protein efficiency ratios (PER) and feed conversion ratios (FCR). In Experiment II four isonitrogenous, isoenergetic diets were formulated by replacing 0, 20, 40 and 60% of protein in SBM with HM. Fingerlings receiving the diets where 0, 20 and 40% of the SBM protein were replaced, had similar body weights, SGR, PER and FCR. However, fingerlings consuming the highest dietary inclusion level of HM (60% replacement) had significantly lower responses for all the above parameters than fingerlings receiving the other diets. The fat content of fingerlings fed diet FM₃ where 45 % of FM protein was replaced by HM protein, was significantly lower than those on the other diets. It was concluded that HM could replace up to 35% of the protein in FM and 40% of protein supplied by SBM in fingerling carp diets without adverse effects on growth, FCR, PER, FI, BWG and body composition.

Keywords: Fish, hazelnut meal, fish meal, soyabean meal, *Cyprinus carpio*, aquaculture

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Introduction

A main objective of fish culturing is to maximize both survival and growth rates at least cost. Feed cost is the largest production cost for commercial aquaculture. Moreover, fish meal (FM) prices have risen in real terms in the past three decades and are likely to increase further with continued growth in demand. Fish meal production is also rather heavily localized in some regions of the world resulting in becoming more expensive and difficult to obtain in many countries practicing aquaculture (Tacon & Jackson, 1985; Hossain *et al.*, 2001; Adebyo *et al.*, 2004). Considerable attention has been paid to the replacement of FM with plant protein sources such as soyabean meal (SBM) (Oliva-Teles *et al.*, 1994; Refstie *et al.*, 1998), Mauna seed meal (Siddhuraju & Becker, 2001), winged bean (Fabgenro, 1999) and various legume seed (Gouveia & Davies, 1998; Hossain *et al.*, 2001; Buyukcapar & Kamalak, 2006). Research on the inclusion of plant-based ingredients in practical diets for salmonids and omnivorous fish such as channel catfish, tilapia and carp has shown that partial replacement of FM is feasible (Davies *et al.*, 1990; Webster *et al.*, 1992).

This becomes imperative as availability of unconventional protein sources used in fish diet formulation in developing countries is a prerequisite for increased fish production (Adebyo *et al.*, 2004). Particularly, soyabean products have been used to replace a significant portion of FM protein in fish diets with nutritional, environmental and economic benefits (Lim & Akiyama, 1992; Rumsey *et al.*, 1993; Kaushik *et al.*, 1995; Naylor *et al.*, 2000). However, the rapid expansion of the livestock industry in many parts of the world is absorbing almost all of the feedstuffs produced, thus increasing the cost of conventional crops including legume feedstuffs used in aquaculture feeds (Siddhuraju & Becker, 2002).

The hazelnut is cultivated for its nuts in commercial orchards in Turkey, Europe, China and Australia. Hazelnut production in Turkey was about 480.000 tons (in shell) in 2003 (SIS, 2004). Hazelnuts are extensively used in confectionery to value chocolate for chocolate truffles and products such as nutella.

Hazelnut meal (HM) resulting from the solvent extraction of hazelnut oil is readily available (Yalcin *et al.*, 2005). Although HM was evaluated for rainbow trout by Bilge (2006), so far there have been no published studies on the use of HM as a protein resource in mirror carp (*Cyprinus carpio* L) diets. The objective of the present study was to evaluate the effects of replacing the protein supplied by FM or soyabean meal with HM on the growth parameters and body composition of mirror carp fingerlings cultured under laboratory conditions.

Materials and Methods

Mirror Carp (*C. carpio*) fingerlings derived from brood stock held at the State Hydraulic Works (Adana, Turkey) where artificial insemination was used in the reproduction of the fish were transferred to the Department of Fisheries, Faculty of Agriculture and University of Kahramanmaraş Sutcu, Imam and maintained in a 250-L fibreglass tank until they reached a body weight of approximately 10 g. In the preparatory phase the carp were raised at 26 ± 1 °C to the starting body mass of about 10.68 ± 0.16 g. They were kept in high quality water on a diet containing approximately 350 g protein/kg, 80 g lipid/kg, 7 g ash/kg and with an energy content of 13.54 MJ ME/kg dry matter. At the start of the experiment this diet was replaced by the experimental diets. Five days prior to the start of the experiment, carp of comparable body weights were selected from a large population, weighed and placed in the respiration aquaria. Fish fry were randomly allocated at a stocking rate of 10 fish per aquaria. Each diet was tested in two replicate aquariums. All fish were fed by hand twice a day at a fixed feeding rate of 3% body weight per day for 80 days. At the end of the trial, three fish per aquarium were sampled to determine whole body composition.

A recirculation system contained a set of aquaria, each with a capacity of ca. 80 L and maintained at 26 ± 0.3 °C. A photoperiod was set at 12 h light and 12 h dark. Water quality was monitored throughout the study (temperature and dissolved oxygen daily, pH and nitrogenous compounds every week). Mean recorded values (\pm s.e.) were: temperature 26 ± 0.1 °C, pH 7.03 ± 0.2 , dissolved oxygen 7.7 ± 0.22 mg/L, total ammonium 0.345 ± 0.02 mg/L and nitrite 0.035 ± 0.003 mg/L. Water quality was maintained using a biologic filter and electronic heater. Water was recirculated through the filter at a rate of 5 L/min. Additional aeration was provided by an inflator. During acclimatization the carp were fed the same ration at twice maintenance. The chemical compositions of FM (IFN 5-02-025), SBM (IFN 5-04-604) and HM (TS 323/T1:2004) are given in Table 1.

Table 1 Proximate compositions and estimated gross energy content of fish meal (FM), soyabean meal (SBM) and hazelnut meal (HM) used in the experimental diets

Constituents (g/kg)	FM	SBM	HM
Dry matter	900.6	890.0	880.0
Crude protein	701.6	470.0	390.0
Crude fat	113.3	10.0	20.0
Crude ash	135.0	60.0	70.0
Crude fibre	5.0	60.0	80.0
Gross energy (MJ/kg) ¹	21.3	17.5	16.9

¹ Gross energy was estimated using the following coefficients: 23.6 KJ/g for crude protein; 39.5 KJ/g for crude fat and 17.2 KJ/g for carbohydrates (NRC, 1993)

In Experiment I four isonitrogenous, isoenergetic diets were formulated to evaluate the nutritive value of HM for carp fingerlings. The control diet contained 403 g/kg FM and 150 g/kg SBM as main protein sources. Hazelnut meal was tested at three inclusion levels (25, 35 and 45% replacement of FM protein) by reducing FM levels. The composition of the experimental diets is given in Table 2. Ingredients were mixed, formed into a moist pellet about 2 mm in diameter and then dried in a forced-air oven at 45 °C.

In Experiment II four isonitrogenous, isoenergetic diets were also formulated to evaluate the nutritional value of HM replacing the protein in SBM in the diets of carp fingerlings. Details of ingredients and proximate composition of the diets used for the second trial are given in Table 3. The method of preparation of the diets was similar to that adopted in Experiment I. The control diet contained 250 g FM/kg and 390 g SBM/kg as main protein sources. Hazelnut meal was tested at three inclusion levels (20, 40 and 60% replacement of SBM protein) by reducing SBM levels (Table 3).

Table 2 Ingredients, chemical composition and estimated gross energy content of the diets used in Experiment I where fish meal protein was partially replaced by protein in hazelnut meal (as fed)

Replacement of FM protein (%)	Experimental diets			
	0	25	35	45
	Control	FM ₁	FM ₂	FM ₃
Ingredients (g/kg)				
Fish meal	400	306	260	220
Soyabean meal	150	150	150	150
Hazelnut meal	-	180	280	380
Maize flour	350	240	170	95
Sunflower oil	89	110	125	138
Dicalcium phosphate	1	2	2	3
Vit.-Min. ¹	5	5	5	5
Limestone	1	1.5	1.5	2
Kavilamisin ²	1	1	1	1
Salt	1	1.5	1.5	2
Methionine	1	1.5	2	2.5
Lysine	1	1.5	2	2.5
Total	1000	1000	1000	1000
Composition (g/kg)				
Dry matter	891.2	887.0	885.3	890.0
Crude protein	371.0	370.2	369.6	373.2
Crude fat	165.5	170.0	168.8	173.3
Crude ash	72.0	75.0	73.9	73.6
Crude fibre	28.3	29.0	31.3	37.4
Gross energy (MJ/kg) ³	20.3	20.4	20.6	20.7

¹ Per 5 kg vitamin-mineral premix: 20.000.000 IU vitamin A; 2.00.000 IU vitamin D₃; 200.000 mg vitamin E; 12.000 mg vitamin K₃; 20.000 mg vitamin B₁; 30.000 mg vitamin B₂; 200.000 mg niacin; 50.000 mg Ca-panthothenate; 20.000 mg vitamin B₆; 50 mg vitamin B₁₂; 500 mg D-biotin; 1.200 mg folic acid; 200.000 mg vit C and 300.000 mg inositol; 1.200.000 mg cholin chloride; 40.000 mg Mn; 30.000 mg Zn; 800 mg Co; 1.000 mg I; 150 mg Se; 40.000 mg Mg

² Kavilamisin ® containing Avilamicin 10.000 mg/kg

³ Gross energy was estimated using the following coefficients: 23.6 KJ/g for crude protein; 39.5 KJ/g for crude fat and 17.2 KJ/g for carbohydrates (NRC, 1993)

Growth performances were evaluated as body weight gain (BWG), feed conversion ratio (FCR) and specific growth rate (SGR):

Body weight gain (BWG) (g) = Fi W (g) – in W (g)

Feed conversion ratio (FCR) = (dry feed consumed (g)/live body weight (g))

Specific growth rate (SGR) = $100 \times (\ln(\text{Fi W}) - \ln(\text{in W}))$

Feed intake (g) per fish = (Total feed consumption (g) per aquaria) / (number of fish per aquaria).

Table 3 Ingredients, chemical composition and estimated gross energy content of the diets used in Experiment II where soyabean meal (SBM) protein was partially replaced by protein in hazelnut meal (as fed)

Replacement of SBM protein (%)	Experimental diets			
	0	20	40	60
	Control	SBM ₁	SBM ₂	SBM ₃
Ingredients (g/kg)				
Fish meal	250	250	250	250
Soyabean meal	390	310	230	150
Hazelnut meal	-	100	200	300
Maize flour	233.5	210	178.5	152.5
Sunflower oil	115	118	129	135
Dicalcium phosphate	1	1	1	1
Vit.-Min. ¹	5	5	5	5
Limestone	1	1	1	1
Kavilaminin ²	1	1	1	1
Salt	2	2	2	2
Methionine	1	1.5	2	2
Lysine	0.5	0.5	0.5	0.5
Total	1000	1000	1000	1000
Composition (g/kg)				
Dry matter	891.2	889.6	892.3	879.9
Crude protein	371.0	372.4	371.1	370.0
Crude fat	159.5	161.4	168.0	174.7
Crude ash	65.0	66.1	68.0	69.7
Crude fibre	37.1	36.5	38.9	40.4
Gross energy (MJ/kg) ³	20.5	20.5	20.7	20.8

¹ Per 5 kg vitamin-mineral premix: 20.000.000 IU vitamin A; 2.00.000 IU vitamin D3; 200.000 mg vitamin E; 12.000 mg vitamin K₃; 20.000 mg vitamin B₁; 30.000 mg vitamin B₂; 200.000 mg niacin; 50.000 mg Ca-panthothenate; 20.000 mg vitamin B₆; 50 mg vitamin B₁₂; 500 mg D-biotin; 1.200 mg folic acid; 200.000 mg vit C and 300.000 mg inositol; 1.200.000 mg cholin chloride; 40.000 mg Mn; 30.000 mg Zn; 800 mg Co; 1.000 mg I; 150 mg Se; 40.000 mg Mg

² Kavilaminin ® containing Avilaminin 10.000 mg/kg

³ Gross energy was estimated using the following coefficients: 23.6 KJ/g for crude protein; 39.5 KJ/g for crude fat and 17.2 KJ/g for carbohydrates (NRC, 1993)

Experimental diet ingredients and fish samples were analyzed for their proximate composition according to the methods of AOAC (1990). A completely randomized design was adopted with two replicates per diets. Each replicate had 10 fish. Fish in each replicate were group fed. Fish were individually weighed at the start of the experiment (0 day) and at 20 day intervals (20, 40, 60 and 80 days). One-way analysis of variance (ANOVA) was carried out to determine the effect of diets on growth parameters using General Linear Model (GLM) of Statistica for Windows (1993). Significant differences between individual means were identified using the Duncan's multiple comparison test. Mean differences were considered significant at $P < 0.05$.

Results

Fish in all dietary groups fed actively on the experimental diets. There was no rejection of feed until the end of the experiment. The acceptability of the diets was more or less similar. No mortality or any signs of disease were observed in any of the dietary groups during the study period. The body weight of fish increased with increasing age.

At the end of Experiment I there were no differences ($P > 0.05$) in the body weight between the FM₁, FM₂ and Control diets. However, fish fed diet FM₃ showed reduced ($P < 0.05$) growth performance compared with fish on the other diets (Table 4). Body weights of the fish ranged from $29.7.6 \pm 0.2$ to 45.7 ± 0.2 g. The feed intake (FI) and growth parameters such as BWG, FCR, SGR and PER are presented in Table 4. The FI of the fish fed on the FM₃ diet was lower ($P < 0.05$) than in the others. Fish fed on the Control, FM₁ and FM₂ diets had similar BWG values while fish fed the FM₃ diet had lower ($P < 0.05$) BWG values than those on the other diets. Fish fed the control, FM₁ and FM₂ diets had similar FCR, SGR and PER values whereas fish fed on the FM₃ diet had lower ($P < 0.05$) FCR, SGR and PER values than those on the other diets. Fingerlings fed the diet with 45% replacement had the lowest and poorest results.

Table 4 Growth parameters of mirror carp obtained in Experiment I where fish meal protein was partially replaced by protein in hazelnut meal (n = 20)

Replacement (%)	Experimental diets			
	0	25	35	45
Parameters	Control	FM ₁	FM ₂	FM ₃
In W (g)	10.9 ^a ± 0.2	10.4 ^a ± 0.1	10.6 ^a ± 0.1	10.9 ^a ± 0.2
Fi W (g)	45.7 ^a ± 0.2	45.5 ^a ± 0.2	43.6 ^a ± 0.1	29.7 ^b ± 0.2
BWG (g)	34.8 ^a ± 0.9	35.1 ^a ± 0.8	33.0 ^a ± 0.9	18.8 ^b ± 1.0
FCR	1.4 ^a ± 0.1	1.4 ^a ± 0.1	1.5 ^b ± 0.1	2.0 ^c ± 0.4
FI (g/fish)	47.2 ^a ± 2.3	46.3 ^a ± 2.2	47.6 ^a ± 2.1	36.1 ^b ± 2.3
SGR	2.2 ^a ± 0.1	2.3 ^a ± 0.1	2.2 ^a ± 0.2	1.5 ^b ± 0.1
PER	2.1 ^a ± 0.1	2.1 ^a ± 0.1	2.2 ^a ± 0.1	1.2 ^b ± 0.1

^{abc} Row means with common superscript do not differ ($P > 0.05$)

Diets FM₁, FM₂, FM₃ contain 180, 280, 380 g hazelnut meal/kg, respectively

In W - initial body weight; Fi W - final body weight; FI - feed intake; BWG - body weight gain; FCR - feed conversion ratio; SGR - specific growth rate; PER - protein efficiency ratio

The effect of diets on whole body composition of mirror carp fingerlings at the end of the feeding Experiment I is given in Table 5. Fish fed on the Control and FM₁ diets had a similar fat content. However, fish fed on diets FM₂ and FM₃ had a significantly lower fat content than those on the other diets.

At the end of Experiment II there were no significant ($P > 0.05$) differences in the body weight between the Control, SBM₁ and SBM₂ treatments. However, fish fed diet SBM₃ showed a reduced ($P < 0.05$)

growth performance compared with those on the other diets. The body weights of the fish ranged from 37.8 ± 0.1 and 45.0 ± 0.1 g (Table 6). The FI and growth parameters, BWG, FCR, SGR and PER, are presented in Table 6. Feed intake of fish fed the SBM₃ diet was lower ($P < 0.05$) than the others. Fish in the Control, SBM₁ and SBM₂ treatments had similar BWG values. Fish receiving the SBM₃ diet had significantly lower BWG values than those on the other treatments. Fish fed the Control, SBM₁ and SBM₂ diets had similar FCR, SGR and PER values while those on the SBM₃ diet had significantly lower FCR, SGR and PER values. Fingerlings receiving the diet SBM₃ where 60 % of SBM protein replaced by HM had the lowest and poorest performance results.

Table 5 Whole body composition (%) (wet weight basis) of mirror carp fed test diets in Experiment I where fish meal protein was partially replaced by protein in hazelnut meal (n = 6)

Constituents (%)	Control	FM ₁	FM ₂	FM ₃
Dry matter	28.1 ^a ± 0.9	29.4 ^{ab} ± 0.7	30.8 ^b ± 0.6	28.1 ^a ± 0.9
Protein	12.5 ^a ± 0.1	12.7 ^a ± 0.1	12.6 ^a ± 0.2	12.7 ^a ± 0.2
Fat	12.7 ^a ± 0.2	13.3 ^a ± 0.4	11.7 ^b ± 0.3	9.5 ^c ± 0.1
Ash	1.7 ^a ± 0.2	2.3 ^a ± 0.3	2.3 ^a ± 0.2	2.2 ^a ± 0.1

^{abc} Row means with common superscript do not differ ($P > 0.05$)

Diets FM₁, FM₂, FM₃ contain 180, 280, 380 g hazelnut meal/kg, respectively

The effect of diets on whole body composition of the mirror carp fingerlings at the end of the feeding Experiment II is given in Table 7. Fish fed on the Control and SBM₁ diets had a similar fat content. However, fish receiving the diet SBM₂ had a significantly lower fat content than those fed the Control diet.

Table 6 Growth parameters of mirror carp obtained in Experiment II where soyabean meal (SBM) protein was partially replaced by protein in hazelnut meal (n = 20)

Replacement (%)	Experimental diets			
	0	20	40	60
Parameters	Control	SBM ₁	SBM ₂	SBM ₃
In W (g)	10.9 ^a ± 0.2	10.9 ^a ± 0.1	10.4 ^a ± 0.1	10.6 ^a ± 0.1
Fi W (g)	45.0 ^a ± 0.1	43.1 ± 0.1	43.1 ^a ± 0.1	37.8 ^b ± 0.1
BWG (g)	34.1 ^a ± 0.9	32.2 ^a ± 0.7	32.6 ^a ± 0.7	27.1 ^b ± 0.7
FCR	1.4 ^a ± 0.1	1.4 ^a ± 0.2	1.4 ^a ± 0.1	1.7 ^b ± 0.2
FI (g/fish)	47.2 ^a ± 2.3	46.3 ^a ± 2.1	46.6 ^a ± 2.1	42.3 ^b ± 1.8
SGR	2.2 ^a ± 0.1	2.2 ^a ± 0.2	2.2 ^a ± 0.2	1.8 ^b ± 0.1
PER	2.1 ^a ± 0.1	2.0 ^a ± 0.1	1.9 ^a ± 0.2	1.7 ^a ± 0.2

^{abc} Row means with common superscript do not differ ($P > 0.05$)

Diets SBM₁, SBM₂, SBM₃ contain 100, 200, 300 g hazelnut meal/kg, respectively

In W - initial body weight; Fi W - final body weight; FI - feed intake; BWG - body weight gain; FCR - feed conversion ratio; SGR - specific growth rate, PEF - protein efficiency ratio

Table 7 Whole body composition (%) (wet weight basis) of mirror carp fed the test diets in Experiment II where soyabean meal (SBM) protein was partially replaced by protein in hazelnut meal (n = 6)

Constituents (%)	Control	SBM ₁	SBM ₂	SBM ₃
Dry matter	28.8 ^a ± 0.9	29.9 ^a ± 0.7	29.5 ^a ± 0.7	29.0 ^a ± 0.8
Protein	12.9 ^a ± 0.1	13.0 ^a ± 0.2	12.1 ^a ± 0.1	12.3 ^a ± 0.2
Fat	13.0 ^a ± 0.2	12.5 ^{ab} ± 0.2	11.6 ^b ± 0.3	12.4 ^{ab} ± 0.4
Ash	1.6 ^a ± 0.2	1.7 ^a ± 0.1	1.7 ^{ab} ± 0.1	2.1 ^b ± 0.1

^{abc} Row means with common superscript do not differ ($P > 0.05$)

Diets SBM₁, SBM₂, SBM₃ contain 100, 200, 300 g hazelnut meal/kg, respectively

Discussion

The present study demonstrated the potential of HM for inclusion in commercial carp diets. There is no information in the scientific literature concerning the use of HM in carp diets, particularly feeds produced under commercial conditions. There is a considerable benefit related to the replacement of part of the FM and SBM currently used in feeds. One of the most commonly encountered difficulties when alternative protein sources are used, is acceptability due to the palatability of the diets fed to fish (Rodriguez *et al.*, 1996). In the current study, no palatability problem was encountered with any of the treatments during the experiments.

The present study indicated that HM can replace up to 35% of the protein in FM and 40% of the protein in SBM in fingerling carp diets without adverse effects on growth performance, feed utilization efficiencies and body composition. Several researches reported that FM in fish diets can be replaced by plant protein sources. Carter & Hauler (2000) found that a pea protein concentrate could replace at least 33% FM protein in the diets of Atlantic salmon. Extruded salmon feeds that contained up to 27% pea protein concentrate or 22% lupin protein concentrate had no significant effect on the growth performance of Atlantic salmon parr, compared to FM and solvent-extracted SBM (Watanabe & Pongmaneerat, 1993). Several plant protein sources gave promising results when partially substituting FM (Hasan *et al.*, 1997). At inclusion levels of between 25 and 50%, linseed gave the best results followed by groundnut and sesame.

The source of dietary carbohydrate, inclusion level and balance between macronutrients affect glucose metabolism to a large degree in fish. In terms of feed utilization, protein sparing and growth stimulation, omnivorous species do show improved growth if fed a low-starch diet compared with a diet altogether devoid of starch (Hemre *et al.*, 2002). However, these findings are different from that of Olvera *et al.* (1998) who observed reduced growth in tilapia fry fed diets containing 9 to 33% *Sesbania grandiflora* meal. However, in this study very small-sized tilapia fry (0.32 g) were used. The smaller fish may have been more sensitive to the effect of anti-nutritional factors than bigger ones. Again, the effect of anti-nutritional factors may vary from species to species (Makkar & Becker, 1999). In the present study all growth parameters of the fish on the FM₃ and SBM₃ diets were lower ($P < 0.05$) than those on the other diets. The results suggest the 45% replacement of FM protein and a 60% replacement of SBM protein with HM may not provide optimal growth performance in carp, while partial replacement (up to 35% FM and 40% SBM) may be advantageous and would lead to a reduction in feed costs. Weight gain is affected by the quantity and quality of the protein in the diet. Since the diets were calculated to be isonitrogenous and isoenergetic, the poorer performances of carp receiving the diets where HM protein replaced 45% of the protein from FM and 60% of that from SBM might be due to an inferior quality of the HM protein. Furthermore, the growth depression at these high levels of HM could be attributed also to a high fibre content of the diets, which would reduce the digestibility of the diet. Fibre causes dilution of nutrients and reduces digestibility because the diet becomes inconsistent (Adebayo *et al.*, 2004). In addition, this could be the result of several factors, including reduced nutrient and energy digestibility and efficiency of energy utilization. The PER also decreased and FCR increased with increasing inclusion level of HM. This may reflect a deficiency of one or more amino acids in these diets. All these values in diets FM₃ and SBM₃ were significantly lower and decreased with the higher inclusion of HM in the diets.

Diets containing higher levels of HM produced the lowest whole body fat values (Table 5). This result is in agreement with findings of Yurkowski *et al.* (1978) who observed similar reductions in whole body fat in rainbow trout fed diets containing rapeseed meal that contains tannin and glucosinolates. The whole body protein content of mirror carp fingerlings fed different diets did not show large variations. However, the whole body lipid contents showed large variations. This result is in agreement with findings of Atack *et al.* (1979) and Hasan & Macintosh (1993) who suggested that the lipid content of fish always tend to show greater fluctuations than other carcass components. This observation is also in agreement with the study by Hossain & Jauncey (1989) who observed a reduction in carcass lipids in common carp fed diets containing mustard oilcake, which contains tannin and glucosinolates. Applier & Jauncey (1983) also observed marked decreases in carcass lipid contents on *Oreochromis niloticus* fed diets containing filamentous algae as the partial or sole source of dietary protein.

One of the limitations of the current study is the small number of fish used. Before large-scale implementation, further investigations with a larger number of fish are required to validate the obtained results.

Conclusion

It was concluded that protein in HM can effectively replace up to 35% of protein in FM and 40% of that in soyabean meal in mirror carp fingerling diets without any adverse effects on growth, survival, FCR, PER, BWG, FI and body composition. These results therefore demonstrate that HM can be included in diets formulated for commercial production of mirror carp fingerling. However, it should be emphasized that in none of diets FM was replaced completely. Even in the SBM trial FM supplied a large proportion of the amino acids in the diets.

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References

- Adebayo, O.T., Fagbenro, O.A. & Jegede, T., 2004. Evaluation of *Cassia fistula* meal as a replacement for soybean meal in practical diets of *Oreochromis niloticus* fingerlings. *Aquaculture Nutr.* 10, 99-104.
- AOAC, 1990. Official Methods of Analysis (15th ed.) Association of Official Analytical Chemists, Washington, D.C., USA. pp. 69-88.
- Applier, H.N. & Jauncey, K., 1983. The utilization of filamentous green algae (*Cladophora glomerata*) as protein source in pelleted feeds for *Sarotherodon (tilapia) niloticus* fingerlings. *Aquaculture* 30, 21-30.
- Atack, T.H., Jauncey, K. & Matty, A., 1979. The utilization of some single cell protein by fingerling mirror carp (*Cyprinus carpio*). *Aquaculture* 18, 337-348.
- Bilgin, O. & Turker, A., 2006. The possibility of usage hazelnut meal as a substitute for soybean meal in rainbow trout diets *Oncorhynchus mykiss*. Meeting Abstract. Florence, Italy, May 9-12, AQUA 2006.
- Buyukcapar, H.M. & Kamalak, A., 2006. Raw and heat treated Culban (*Vicia peregrine*) seeds as dietary protein source for mirror carp (*Carpinus carpio*) fingerlings. *S. Afr. J. Anim. Sci.* 36, 235-242.
- Carter, C.G. & Hauler, R.C., 2000. Fish meal replacement by plant meals in extruded feeds for Atlantic salmon, *Salmo salar* L. *Aquaculture* 185, 299-311.
- Davies, S.J., McDonnell, S. & Bateson, R.I., 1990. Potential of rapeseed meal as an alternative protein sources in complete diets for tilapia (*Oreochromis mossambicus*). *Aquaculture* 87, 145-154.
- Fabgenro, O., 1999. Comparative evaluation of heat processed Winged bean (*Psophocarpus tetragonolopus*) meals as partial replacement for fish meal in diets for the African catfish (*Clarias garipenius*). *Aquaculture* 170, 297-305.
- Gouveia, A. & Davies, S.J., 1998. Preliminary nutritional evaluation of pea seed meal (*Prism sativum*) for juvenile European sea bass (*Dicentrarchus labrax*). *Aquaculture* 166, 311-320.
- Hasan, M.R. & Macintosh, D.J., 1993. Effect of environmental temperature and feeding rate on the growth, food utilization and body composition of common carp (*Cyprinus carpio*) fry. In: *Fish Nutrition in Practice*. Eds. Kaushik, S.J. & Luquet, M.R., INRA, Paris. pp. 767-778.

- Hasan, M.R., Macintosh, D.J. & Jauncey, K., 1997. Evaluation of some plant ingredients as dietary protein sources for common carp (*Cyprinus carpio* L.) fry. *Aquaculture* 151, 55-70.
- Hemre, G.I., Mommsen, T.P. & Krogdahl, A., 2002. Carbohydrates in fish nutrition; effects on growth, glucose metabolism and hepatic enzymes. *Aquaculture Nutr.* 8, 175-194.
- Hossain, M.A. & Jauncey, K., 1989. Nutritional evaluation of some Bangladeshi oil seed meals as partial substitutes for fish meal in the diets of common carp *Cyprinus carpio* L. *Aquacul. Fish. Manage.* 20, 255-268.
- Hossain, M.A., Focken, U. & Becker, K., 2001. Evaluation of an unconventional legume seed, *Sesbenia aculeata*, as a dietary protein source for common carp, *Cyprinus carpio* L. *Aquaculture* 198,129-140
- Kaushik, S.J., Cravedi, J.P., Lalles, J.P., Sumpter, J., Fauconneau, B. & Laroche, M., 1995. Partial or total replacement of fish meal by soybean protein on growth, protein utilization, potential estrogenic or antigenic effects, cholesteroles and flesh quality in Rainbow trout, *Oncorhynchus mykiss*. *Aquaculture* 133, 257-274.
- Lim, C. & Akiyama, D., 1992. Full fat utilization of soybean meal by fish. *Asian Fish. Sci.* 5, 181-197.
- Makkar, H.P.S. & Becker, K., 1999. Nutritional studies on rats and fish (carp, *Cyprinus carpio*) fed diets containing unheated and heated *Jatropha curcas* meal of a non-toxic provenance. *Plant Foods Human Nutr.* 53, 183-192.
- Naylor, R.L., Goldberg, J., Primavera, J.H., Kayutsky, N., Beveridge, M.C.M., Clay, J., Folke, C., Lubchenco, J., Money, H. & Troell, M., 2000. Effect of aquaculture on world fish supplies. *Nature* 405, 1017-1024.
- NRC, 1993. *Nutrient Requirements of Fish*. National Academy Press, New York, USA.
- Oliva-Teles, A., Gouveia, A.J., Gomes, E. & Rema, P., 1994. The effect of different processing treatments on soybean meal utilization by rainbow trout, *Oncorhynchus mykiss*. *Aquaculture* 124, 343-349.
- Olvera, N.M.A., Martinez, P., Carlos, A., Galvan, C.R. & Chavez, S.C., 1998. The use of seed of the legumes plant *Sesbenia grandiflora* as a partial replacement for fish meal in diets for tilapia (*Oreochromis mossambicus*). *Aquaculture* 158, 107-116.
- Refstie, S., Storebakken, T. & Roem, A.J., 1998. Feed and consumption and conversion in Atlantic salmon (*Salmo salar*) fed diets with fish meal, extracted soybean meal or soybean meal with reduced content of oligosaccharides, trypsin inhibitors, lectins and soya antigens. *Aquaculture* 162, 302-312.
- Rodriguez, S.M., Overa, N.M.A. & Carmona, O.C., 1996. Nutritional value of animal by-product meal in practical diets for Nile tilapia, *Oreochromis niloticus* (L) fry. *Aquaculture Res.* 27, 67-73.
- Rumsey, G.L., Hughes, S.G. & Winfree, R.A., 1993. Chemical and nutritional evaluation of soybean protein preparations as primary nitrogen sources for rainbow trout (*Oncorhynchus mykiss*). *Anim. Feed Sci. Technol.* 40, 135-151.
- Siddhuraju, P. & Becker, K., 2001. Preliminary nutritional evaluation of Macuna seed meal (*Macuna pruriens utilis*) in common carp (*Cyprinus carpio* L.); an assessment by growth performance and feed utilization. *Aquaculture* 26, 223-236.
- Siddhuraju, P. & Becker, K., 2002. Effect of phenolic nonprotein amino acid L-dopa (L-3, 4-dihydroxyphenylalanine) on growth performance, metabolic rates and feed nutrient utilization of common carp (*Cyprinus carpio* L.). *Aquaculture Nutr.* 8, 69-77.
- SIS, 2004. *The Summary of Agricultural Statistics*. State Institute of Statistics, Prime Ministry of the Republic of Turkey. Publication Number: 2921. Printing Division of State Institute of Statistics. Ankara, Turkey.
- Statistica, 1993. *Statistica for windows release 4.3*, StatSoft, Inc. Tulsa, O.K., USA.
- Tacon, A.G.J. & Jackson, A.J., 1985. Utilization of conventional and unconventional protein sources in practical fish feeds. In: *Nutrition and Feeding in Fish*. Eds. Cowey, C.B., Mackie, A.M. & Bell, J.G., Academic Press, London. pp. 119-145.
- Watanabe, T. & Pongmaneerat, J., 1993. Potential of soybean meal as protein source in extruded pellets for rainbow trout diets. *Nippon Suisan Gakkaishi* 59, 1415-1423.
- Webster, C.D., Yancey, D.H. & Tidwell, J.H., 1992. Effect of partially or totally replacing fish meal with soybean meal on growth of blue catfish (*Ictalurus furcatus*). *Aquaculture* 103, 141-152.

- Yalcın, S., Oguz, F. & Yalcın, S., 2005. Effect of dietary hazelnut meal supplementation on the meat composition of quails. *Turk. J. Vet. Anim. Sci.* 29, 1285-1290.
- Yurkowski, M., Baily, J.K., Evans, R.E., Tabachek, J.A.L., Ayles, G.B. & Eales, J.G., 1978. Acceptability of rape seed proteins in diets of rainbow trout (*Salmo gairdnerii*). *J. Fish Res. Board, Canada.* 35, 951-962.