Raw and heat-treated culban (*Vicia peregrina*) seed as protein source for mirror carp (*Cyprinus carpio)* fingerlings

H.M. Buyukcapar[1#] and A. Kamalak[2]

[1] Department of Fisheries, Faculty of Agriculture, University of Kahramanmaras Sutcu Imam, 46100 Kahramanmaras, Turkey

[2] Department of Animal Sciences, Faculty of Agriculture, University of Kahramanmaras Sutcu Imam, 46100 Kahramanmaras, Turkey

Abstract

An 80-day feeding trial was conducted in a recirculation system aquarium operating at 26 ± 0.3 °C, to evaluate the nutritive value of *Vicia peregrina* seed as a possible protein source in the diet of mirror carp (*Cyprinus carpio*) fingerlings. *Vicia peregrina* seed was included in the diets at different levels, *viz.* 100, 200, 300 g heat-treated and 100, 200, 300 g raw seed in experimental diets designated A_1, B_1, C_1, A_2, B_2 and C_2, respectively. Growth parameters of the fish fed these diets were compared to fish receiving a fish meal and soyabean meal based control diet. On the basis of the specific growth rate (SGR), feed conversion ratio (FCR) and protein efficiency ratio (PER), the control and diets A_1, B_1, C_1 and A_2 were similar and significantly better than diets B_2 and C_2. Fish fed diets B_2 and C_2 showed a lower growth performance compared to those fed diets A_1, B_1, C_1 and A_2. Whole body fat content of the fish fed the diets containing the higher levels (>10%) of raw *V. peregrina* was significantly lower than in fish in the other treatments. *Vicia peregrine* seed has a potential as an alternative feed ingredient. It can be used without any adverse effects at up to 10% of the diet as a protein source in diets for fingerling mirror carp. However, the seed should be heat-treated if inclusion rates are to exceed 10% of the diet.

Keywords: Culban, *Vicia peregrina,* nutritive value, heat treatment**,** mirror carp, growth
[#] Corresponding author. E-mail: hakanmurat@ksu.edu.tr

Introduction

Fish meal is becoming a scares commodity due to increasing demands and decreasing marine fishery resources. Therefore, alternative protein sources including plant and animal protein sources have been evaluated by many fish nutritionists and the feed industry (Tacon & Jackson, 1985). This becomes imperative since availability of unconventional protein feedstuffs used in fish feed formulation in developing countries is a prerequisite for increased fish production (Adebyo *et al*., 2004). Soyabean products in particular have been used to replace a significant proportion of fish meal protein in fish diets, resulting in nutritional, environmental and economical 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 the feedstuffs produced, thus increasing the cost of conventional crops including legume feedstuffs used in aquaculture feeds**.** Although other grain legumes have not been used widely in fish feeds, they represent a good source of dietary protein and energy (Siddhuraju & Becker, 2002). Recently, researchers have begun to evaluate the acceptability of other grain legumes such as lupins (Sudaryono *et al*., 1999), cowpeas and rice beans (Eusebia, 1991) in shrimp diets. Another legume with potential is the feed pea, *Pisum sativum*. This crop has long been used in livestock feeds as a source of energy and protein but has only recently been evaluated in diets for aquatic species (Davis *et al*., 2002). Investigations have now been focused on utilizing less expensive and readily available plant protein sources to replace fish meal, without reducing the nutritional quality of the feed.

Vicia peregrina, known locally as "culban", is a legume crop widely available in South Mediterranean Turkey. The major use of the *V. peregrina* crop has been as fodder for livestock. To date there have been no published studies on the use of raw and cooked *V. peregrina* seed as protein source in fingerling mirror carp (*Cyprinus carpio* L) diets. The aim of the present study was to determine the potential of including raw and

heat-treated *V. peregrine* seed as a protein source for fingerling mirror carp and to identify the limitations to its use arising from palatability or apparent toxicity factors.

Materials and Methods

Mirror Carp (*C. carpio*) fingerlings from brood stock held at the State Hydraulic Works (Adana, Turkey) were transferred to the Department of Fisheries, Faculty of Agriculture, University of Kahramanmaras, Sutcu Imam, Turkey. The fingerlings were kept in a 250 L fibreglass tank until they reached the target body weight of *ca.* 12.0 g. In this preparatory phase the carp were kept in high quality water at 24 ± 1 °C on a diet containing *ca.* 350 g crude protein (CP)/kg, 80 g lipid/kg, 7 g ash/kg and with a metabolisable energy content of 13.54 MJ /kg dry matter. During this period the carp were fed twice a day at maintenance level. At the start of the experimental period this diet was replaced by the test diets.

Five days prior to the onset of the experiment carps of comparable body weights were selected from the original population, weighed and placed in respiration aquaria. At the onset of the study the mean initial individual weight of the fish fry was 13.03 ± 0.45 g. The fingerlings were randomly allocated to the respective treatments, with three replicate aquariums for each experimental diet. They were kept at a stocking rate of 10 fish per aquarium for the duration of the experimental period of 80 days. A recirculation system containing a set of aquaria, each with a capacity of *ca.* 80 L maintained at 26 ± 0.3 °C, was used under a photoperiod of 12 h light and 12 h darkness. Water quality was controlled by a biologic filter and an electronic heater and was monitored throughout the study (temperature and dissolved oxygen daily, pH and nitrogenous compounds every week). Mean recorded values (± s.e.) were: a temperature of 26 ± 0.3 °C, a pH of 7.21 ± 0.67, dissolved oxygen at 7.9 ± 0.88 mg/L, total ammonium at 0.244 ± 0.021 mg/L and nitrite at 0.049 ± 0.004 mg/L.

Vicia peregrina seed was sun-dried and ground into a powder to pass through a 1 mm sieve. The ground seed was heat-treated in an autoclave at 121 °C for 10 min (Rehman & Salariya, 2005) to eliminate the possible detrimental effects of anti-nutritional factors. The chemical composition of raw and heat-treated *V. peregrina* seed is presented in Table 1.

Table 1 Chemical composition of raw and heat-treated *Vicia peregrina* seed (g/kg)

Constituents	Raw	Heat-treated
Dry matter	880.0	928.0
Crude protein	253.6	252.1
Crude fat	15.0	15.3
Crude ash	39.0	39.0
Crude fibre	80.0	81.2
Condensed tannin	14.5	7.4

Experimental diets were formulated with raw and heat-treated *V. peregrina* seed replacing fish meal and soyabean meal on a dry matter basis to maintain the CP and energy levels. Seven isonitrogenous and isoenergetic diets were formulated (Table 2) to evaluate the nutritive value of *V. peregrina* for the carp fingerlings. The control diet contained 20% fish meal and 40.6% of soyabean meal as main protein sources. The raw and heat-treated *V. peregrina* seed were included in the diets at levels of 10, 20 and 30%. The composition of the experimental diets is given in Table 2. Ingredients were mixed, compressed into a moist pellet of about 2 mm in diameter and then dried in a forced-air oven at 45 °C. All fish were fed twice daily at a fixed feeding rate of 3% body weight per day. Growth performances were evaluated as body weight gain (BWG), feed conversion ratio (FCR) and specific growth rate (SGR):

Body weight gain (BWG) (g) = (final body weight (W_2) (g) – initial weigth (W_1) (g))
Feed conversion ratio (FCR) = (dry feed consumed (g)/live body weight (g))
Specific growth rate (SGR) = 100 X ($\ln W_2$-$\ln W_1$)

At the end of the experiment, three fish per aquarium were sacrificed to determine whole body composition.

Vicia peregrina seed, the experimental diets and fish samples were analysed for their proximate composition according to the methods of AOAC (1990). Total condensed tannin was determined by the butanol-HCl method, as described by Makkar *et al*. (1995). Mimosa tannin was used as an external standard.

A complete randomized design was adopted with three replicates per diets. Each replicate had 10 fish and was 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 analyses of variance (ANOVA) were 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 $P < 0.05$.

Table 2. Ingredients and chemical composition of the experimental diets containing raw (R) and heat-treated (HT) *Vicia peregrina* seed (as fed)

	Experimental diets						
	Control O	A_1 100 HT	B_1 200 HT	C_1 300 HT	A_2 100 R	B_2 200 R	C_2 300 R
Ingredients (g/kg)							
Fish Meal	200	186	170	154	186	170	154
Soyabean meal	406	390	362	342	390	362	342
V. peregrina	0	100	200	300	100	200	300
Maize flour	302	226	161	84	226	161	84
DCP [1]	6	7	8	9	7	8	9
Sunflower oil	70	78	85	95	78	85	95
Vit-Min [3]	5	5	5	5	5	5	5
Salt (NaCl)	2	2	2	2	2	2	2
Limestone	5	5	5	5	5	5	5
Kavilamisin ®[2]	1	1	1	1	1	1	1
Lysine	1	1	1	1	1	1	1
Methionine	1	1	1	1	1	1	1
Bentonite	1	1	1	1	1	1	1
Total	1000	1000	1000	1000	1000	1000	1000
Composition (g/kg)							
Dry matter	889.0	883.1	890.0	899.0	880.7	890.4	899.4
Crude protein	352.0	353.1	352.6	349.6	356.3	355.2	352.6
Crude fat	95.0	95.5	102.5	109.5	97.5	103.2	105.6
Crude ash	67.8	66.3	65.0	64.0	63.2	64.5	65.4
Crude fibre	33.6	35.9	39.0	40.2	36.4	39.6	40.6
Gross energy (MJ/kg [4])	18.0	18.0	18.0	18.0	18.0	18.0	18.0

[1] Dicalcium phosphate; [2] Kavilamisin ® containing Avilamycin 10.000 mg/kg

[3] 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 K_3; 20.000 mg vitamin B_1; 30.000 mg vitamin B_2; 200.000 mg niacin; 50.000 mg Ca-panthothenate; 20.000 mg vitamin B_6; 50 mg vitamin B_{12}; 500 mg D-biotin; 1.200 mg folic acid; 200.000 mg; 300.000 mg inositol; 1.200.000 mg choline chloride; 40.000 mg manganese; 30.000 mg zinc; 800 mg copper; 1.000 mg iodine; 150 mg selenium; 40.000 mg magnesium

[4] Calculated

Results

No rejection of feed was recorded for the duration of the experiment. The acceptability of the diets was similar. No mortality or any signs of disease was observed in any of the dietary groups during the period of study.

Growth performances in terms of body weight are presented in Table 3. The body weight of fish increased with increasing age. At 20-, 40-, 60- and 80-days of age there were no significant ($P > 0.05$) differences in the body weight between treatments A_1, B_1, C_1, A_2 and the control diet. However, fish fed diets B_2 and C_2 showed reduced ($P < 0.001$) growth performance compared with fish fed the control and the other diets. At the end of the experiment the body weights of fish ranged from 27.9 to 41.7 g.

Table 3 Mean body weights (g) of the fish at different stages of the study (n = 30)

Treatments	Days in the study				
	0	20	40	60	80
Control	12.9 ± 0.5	17.6^{a} ± 0.6	25.3^{a} ± 0.8	32.4^{a} ± 0.9	41.7^{a} ± 1.0
A_1	12.8 ± 0.6	17.5^{a} ± 0.8	23.8^{a} ± 1.1	30.7^{a} ± 1.4	40.3^{a} ± 1.5
B_1	13.5 ± 0.6	17.4^{a} ± 0.7	23.4^{a} ± 0.9	29.4^{a} ± 1.1	39.4^{a} ± 1.1
C_1	13.6 ± 0.5	17.5^{a} ± 0.7	23.7^{a} ± 0.9	30.3^{a} ± 1.0	39.3^{a} ± 1.1
A_2	12.7 ± 0.6	17.0^{a} ± 0.8	23.5^{a} ± 1.0	30.9^{a} ± 1.4	41.0^{a} ± 1.6
B_2	12.3 ± 0.5	14.3^{b} ± 0.5	18.6^{b} ± 0.6	22.6^{b} ± 0.7	28.6^{b} ± 0.7
C_2	13.1 ± 0.5	14.4^{b} ± 0.5	17.0^{b} ± 0.6	21.5^{b} ± 0.7	27.9^{b} ± 0.7

^{ab} Column means with common superscripts do not differ ($P > 0.05$)
Diets A_1, B_1 and C_1 containing 100, 200 and 300 g heat-treated *Vicia peregrina* seed/kg, respectively
Diets A_2, B_2 and C_2 containing 100, 200 and 300 g raw *V. peregrina* seed/kg, respectively

Feed intake (FI) and growth parameters such as BWG, FCR, SGR and protein efficiency ratio (PER) are presented in Table 4. Feed intakes of fish fed the B_2 and C_2 treatments were lower ($P < 0.05$) than in the other treatments. Fish fed diets A_1 and A_2 had similar BWG values to the control diet, while those receiving diets B_2 and C_2 had significantly lower BWG values than the other treatments. Fish receiving diets A_1, B_1, C_1 and A_2 had similar FCR, SGR and PER values to the control diet whereas those receiving diets B_2 and C_2 had significantly lower FCR, SGR and PER values than the control diet. The lowest and poorest results were obtained for fish receiving diets containing 20% and 30% raw *V. peregrina* seed.

Table 4 Growth parameters of mirror carp receiving diets containing raw or heat-treated *Vicia peregrina* seed (n = 30)

Parameters	Dietary treatments						
	Control	A_1	B_1	C_1	A_2	B_2	C_2
FI	53.2^{a} ± 1.8	51.1^{b} ± 1.2	50.5^{b} ± 2.0	51.4^{b} ± 2.9	50.7^{b} ± 1.7	40.7^{c} ± 2.8	39.4^{c} ± 2.6
BWG	28.9^{a} ± 0.9	27.5^{ab} ± 1.1	25.9^{bc} ± 1.3	25.6^{c} ± 1.1	28.3^{a} ± 1.2	16.3^{d} ± 0.8	14.8^{d} ± 1.0
FCR	1.8^{b} ± 0.2	1.8^{b} ± 0.1	1.9^{b} ± 0.1	2.0^{b} ± 0.1	1.8^{b} ± 0.1	2.4^{a} ± 0.2	2.6^{a} ± 0.2
SGR	1.5^{a} ± 0.1	1.5^{a} ± 0.1	1.3^{ab} ± 0.1	1.3^{ab} ± 0.1	1.5^{a} ± 0.1	1.1^{bc} ± 0.1	0.9^{c} ± 0.2
PER	1.6^{a} ± 0.2	1.6^{a} ± 0.1	1.5^{ab} ± 0.1	1.4^{ab} ± 0.1	1.6^{a} ± 0.1	1.1^{bc} ± 0.1	1.0^{c} ± 0.2

^{abc} Row means with common superscript do not differ ($P > 0.05$)
FI - feed intake (g/fish); BWG - body weight gain; FCR - feed conversion ratio; SGR - specific growth rate; PEF - protein efficiency ratio
Diets A_1, B_1 and C_1 containing 100, 200 and 300 g heat-treated *V. peregrina* seed/kg, respectively
Diets A_2, B_2 and C_2 containing 100, 200 and 300 g raw *V. peregrina* seed/kg, respectively

The effect of diets on whole body composition of mirror carp fingerlings at the end of the feeding trial is presented in Table 5. Fish fed the A_1, B_1, C_1 and A_2 diets had similar body fat and ash content to that of the control. However, fish receiving the diets B_2 and C_2 had a significantly lower fat but a significantly higher ash content than those on the control diet.

Table 5 The whole body composition analyses (%) (wet weight basis) of mirror carp receiving diets containing raw or heat-treated *Vicia peregrina* seed (n = 9)

%	Dietary treatments						
	Control	A_1	B_1	C_1	A_2	B_2	C_2
DM	$27.7^{a} \pm 0.9$	$25.6^{a} \pm 2.1$	$28.3^{a} \pm 2.1$	$27.6^{a} \pm 0.4$	$27.3^{a} \pm 0.5$	$27.2^{a} \pm 0.1$	$26.6^{a} \pm 0.3$
Protein	$19.9^{a} \pm 0.9$	$19.1^{a} \pm 0.9$	$18.1^{a} \pm 3.3$	$18.4^{a} \pm 0.3$	$18.4^{a} \pm 0.3$	$17.5^{a} \pm 0.6$	$17.2^{a} \pm 1.0$
Fat	$12.6^{a} \pm 0.6$	$11.6^{a} \pm 0.4$	$11.3^{ab} \pm 0.4$	$10.8^{abc} \pm 0.1$	$11.9^{a} \pm 1.1$	$9.7^{bc} \pm 0.4$	$9.5^{c} \pm 0.3$
Ash	$2.4^{a} \pm 0.1$	$2.34^{a} \pm 0.1$	$2.6^{ab} \pm 0.2$	$2.6^{abc} \pm 0.1$	$2.6^{abc} \pm 0.1$	$2.8^{bc} \pm 0.1$	$2.9^{c} \pm 0.1$

DM - dry matter; ^{abc} Row means with common superscript do not differ ($P > 0.05$)
Diets A_1, B_1 and C_1 containing 100, 200 and 300 g heat-treated *V. peregrina* seed/kg, respectively
Diets A_2, B_2 and C_2 containing 100, 200 and 300 g raw *V. peregrina* seed/kg, respectively

Discussion

There was an inverse relationship between the growth rate of mirror carp fingerlings and dietary levels beyond a 10% inclusion level of raw *V. peregrina* seed. This could be the result of several factors, including reduced nutrient and energy digestibility and energy utilization efficiency. The FI and PER also decreased and FCR increased with increasing inclusion levels of raw *V. peregrina* seed. This may reflect a deficiency of one or more amino acids in these diets. This result is in agreement with the findings of Borlongan *et al.* (2003) who found that there was an inverse relationship between the growth of milkfish and dietary levels beyond the 10% inclusion level of feed pea meal due to the deficiency of essential amino acid with each feed pea meal increment, and that the inclusion of feed pea meal might have contributed to the inferior protein utilization. Borlongan *et al*. (2003) suggested that the inclusion level of feed pea meal could be increased by supplementing amino acids. This result is also in agreement with the findings of Hossain *et al*. (2002) who showed that fish fed diets containing 9.7% of sesbania meal had a growth performance similar to those on the control diet. However, the fish consuming diets containing > 9.7% sesbania meal grew significantly slower than those on the control diet.

Plant protein sources have the potential to contain anti-nutritional factors such as oligosaccharides, phytate, tannins and tripsin inhibitory factors. These anti-nutrients tend to limit the potential of plant protein sources in replacing protein sources such as fish meal (Tacon, 1997). These anti-nutrients might have impaired the absorption of some essential amino acids in the diets containing *V. peregrina* seed, thus causing a growth depression in mirror carp fingerlings at high levels of dietary inclusion (Adebayo *et al*., 2004). However, the current experiment clearly showed that the inclusion level of *V. peregrina* seed into the diet of mirror carp fingerlings could be increased with heat-treatment (Table 3 and 4). The growth performance of the fingerlings fed diets containing more than 10% of heat-treated *V. peregrina* seed was comparable with the control diet, except for bodyweight gain (Table 4). As can be seen from Table 1 that heat treatment reduced the condensed tannin content of *V. peregrina* seed. The tannin in diets in the present study might have had negative effects on the growth and feed utilization of fingerlings. The presence of tannin has been associated with lower nutritive values and biological availability of protein, carbohydrates, amino acids, vitamins and minerals (Makkar *et al*., 1987). Negative effects of anti-nutritional substances on carp growth have been reported previously. Becker & Makkar (1999) found that 2% phenolic substance (tannic acid) in the diet reduced the growth of carp.

Although peas are considered to contain relatively low levels of anti-nutritional factors, performance of the fish could be impaired by such factors (Francis *et al*., 2001). However, extrusion reduces the efficacy

of the majority of these (Rumsey *et al*., 1993). The inclusion of a co-extruded plant protein made from rapeseed and filed peas had no effect at up to 15% replacement of the protein, but at a 45% inclusion rate, growth performance of rainbow trout was significantly lower than those on the control diet (Gomes *et al*., 1993). The low digestible energy of both raw and autoclaved field peas was predicted to limit their use in rainbow trout feeds (Pfeffer *et al*., 1995). Carter & Hauler (2000) found that at least 33% fish meal protein can be replaced with pea protein concentrate fed to 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 when compared to fish meal and solvent-extracted soybean meal, ingredients often used in salmon feeds (Watanabe & Pongmaneerat, 1993). The source of dietary carbohydrate, inclusion level and balance between macro-nutrients influence glucose metabolism in fish substantially. In terms of feed utilization, protein sparing and growth stimulation, omnivorous species did 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 those 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, and smaller fish might be more sensitive to the effect of anti-nutritional factors. Again the effect of anti-nutritional factors may vary from species to species (Makkar & Becker, 1999).

Trypsin inhibitors (TI) are widely distributed in the plant kingdom and are present in most legume seeds and cereals (Francis *et al*., 2001). The common culture fish species differ in their ability to tolerate dietary TI (Francis *et al*., 2001). Carp fed diets containing meal of *Jatropha curcas* seed with 24.8 mg TI/g and heat-treated meal with 1.3 to 8.3 mg TI/g showed no differences in growth performance, implying that the fish were able to tolerate the high levels of TI. The reduction in growth of carps and tilapia fed a diet containing TI might have been caused by amino acid imbalances in the protein sources used (Francis *et al*., 2001).

Many legume seeds contain lectins. Their biological effects include disruption of small intestinal metabolism and morphological damage to villi. Lectin content of seed can be removed by aqueous heat treatment or autoclaving (Grant, 1991). The heat-treatment employed in this experiment might have limited or reduced the deleterious effect of lectin on the utilization of *V. peregrina* seed for mirror carp fingerlings.

It would be essential to present sufficient information about anti-nutritional factors in *V. peregrina* seed to allow adequate interpretation of the results and in comparison to other research. This is particularly important in the current experiment. No information is available on anti-nutritional factors except for condensed tannins in the *V. peregrina* seed used in this experiment.

In the present study the FCR, PER and SGR% values obtained with diets B_2 and C_2 were similar to the values reported by Makkar & Becker (1999) for carp fed diets containing 25% unheated jatropha meal. All these values in diets B_2 and C_2 were significantly lower and decreased with the higher inclusion rates of *V. peregrina* seed in the diet. Diets containing a higher level of raw *V. peregrina* seed produced significantly lower whole body fat values (Table 5). This finding is in agreement with Yurkowski *et al*. (1978) who observed similar reductions in whole body fat values in rainbow trout fed diets containing rapeseed meal that contained 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 and moisture content showed large variations. This result is in agreement with the findings of Atack *et al*. (1979) and Hassan & Macintosch, (1993) who suggested that carcass moisture and lipid content of fish always tend to show greater fluctuations than other carcass components.

Conclusion

Vicia peregrina seed has a potential as an alternative feed ingredient. It can be used without any adverse effects as a protein source at up to 10% in diets of fingerling mirror carp. *Vicia peregrina* seed should be heat-treated if inclusion rates should exceed 10% of the diet. Where locally available and relatively cheap, the use of *V. peregrina* seed would reduce the feeding cost considerably as an alternative protein source for fingerling mirror carp

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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. Association of Official Analytical Chemists. Official methods of analysis. (16th ed.). A.O.A.C. Washington, D.C., USA. pp. 69-88.

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.

Becker, K. & Makkar, H.P.S., 1999. Effects of dietary tannic acid and quebracho tannin on growth performance and metabolic rates of common carp (*Cyprinus carpio* L.). Aquaculture 175, 327-335.

Borlongan, I.G., Eusebia, P. & Welsh, T., 2003. Potential of feed pea (*Pisum sativum*) meal as a protein source in practical diets for milkfish (*Chanos chanos* Forsskal). Aquaculture 225, 89-98.

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.

Davis, D.A., Arnold, C.R. & McCallum, I., 2002. Nutritional value of feed peas (*Pisum sativum*) in practical diet formulations for *Litopenaeus vannamei*. Aquaculture Nutr. 8, 87-94.

Eusebia, P.S., 1991. Effect of de-hulling on the nutritive value of some leguminous seeds as protein sources for tiger prawn, *Penaeus monodon*, juveniles. Aquaculture 99, 297-308.

Francis, G., Makkar, H.P.S. & Becker, K., 2001. Anti-nutritional factors present in plant-derived alternate fish feed ingredients and their effects in fish. Aquaculture 199, 197-227.

Grant, G., 1991. Lectins. In: Toxic Substances in Crop Plants. Eds. D'Mello, F.J.P., Duffus, C.M & Duffus, J.H., The Royal Society of Chemistry, Thomas Graham House, Science Park, CB4 4WF, Cambridge, pp. 49-67.

Gomes, E.F., Corraze, G. & Kaushik, S., 1993. Effects of dietary incorporation of a co-extruded plant protein (rapessed and peas) on growth, nutrient utilization and muscle fatty acid composition of rainbow trout (*Oncorhynchus mykiss*). Aquaculture 113, 339-353.

Hassan, 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.

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., Focken, U. & Becker, K., 2002. Nutritional evaluation of dhaincha (*Sesbania aculeate*) seeds as dietary protein source for tilapia *Oreochromis niloticus*. Aquaculture Res. 33, 653-662.

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, choloscrolema 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 Hum. Nutr. 53, 183-192.

Makkar, H.P.S., Blümmel, M. & Becker, K., 1995. Formation of complexes between polyvinyl pyrrolidones or polyethylene glycols and their implication in gas production and true digestibility *in vitro* techniques. Br. J. Nutr. 73, 897-913.

Makkar, H.P.S., Singh, B. & Dawra, K.K., 1987. Tannin nutrient interactions. Int. J. Anim. Sci. 2, 127-139.

Naylor, R.L., Goldburg, 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.

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.

Pfeffer, E., Kinzinger, S. & Rodelhutscord, M., 1995. Influence of the proportion of poultry slaughter byproducts and of untreated or hydrothermically treated legume seeds inn diets for rainbow trout, *Oncorhynchus mykiss* (Walbaum), on apparent digestibililities of their energy and organic compounds. Aquaculture Nutr. 1, 111-117.

Rehman, Z. & Salariya, A.M., 2005. The effects of hydrothermal processing on antinutrients, protein and starch digestibility of food legumes. Int. J. Food Sci.Technol. 40, 695-700.

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., 2002. Effect of phenolic nonprotein amino acid L-dopa (L-3,4-dihydroxphenyalanine) on growth performance, metabolic rates and feed nutrient utilization of common carp (*Cyprinus carpio* L.). Aquaculture Nutr. 8, 69-77.

Statistica, 1993. Stastica for windows release 4.3, StatSoft, Inc. Tulsa, OK, USA.

Sudaryono, A., Tsvetnenko, E. & Evans, L.H., 1999. Evaluation of potential of lupin meal as an alternative to fish meal in juvenile *Penaeus monodon* diets. Aquaculture Nutr. 5, 277-285.

Tacon, A.G.J., 1997. Fish meal replacers: review of antinutrients within oilseed and pulses. A limiting factor for the aqua feed green revolution? In: Feeding tommorrow's fish. Eds. Tacon, A.G.J. & Basurco, B., pp. 153-182. Cahiers Options Mediterraneennes. Instut Agronomique Mediterraneenne de Zaragoza, Spain.

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.

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 Can. 35, 951-962.