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Original Article

An estimation of optimum dietary concentration of soy bean meal for carps (*Catla catla*, *Labeo rohita* and *Cirhinus mrigala*)

Uma estimativa da concentração dietética ideal de farinha de soja para carpas (*Catla catla*, *Labeo rohita* e *Cirhinus mrigala*)

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Abstract

Soybean meal is an inexpensive plant origin protein which has been used in practical diets as a replacement of animal protein such as fish meal or chicken meal, due to the uneconomical price of animal protein diets. Consequently, a research study was conducted on some commercial species of Indian major carps i.e. Catla (*Cattla cattla),* Rohu *(Labeo rohita)* and Mrigala *(Cirhinus mrigala)* (Hamilton, 1822) to estimate optimum dietary protein requirement of soy bean meal in diet in an intensive polyculture. Three different diets (SBM I, SBM II and SBM III) were formulated by 80%, 50% and 20% replacement of fish meal with soybean meal from a 45% fish meal diet (control).Highest monthly mean weight gain was obtained by SBM II (with 35% CP and about 50% substitution of fish meal), while SBM III (45% Crude Protein and about 20% substitution of fish meal) was stood second. All tested diets respond enormously by producing high yield as compare to control diet, though SBM II generated highest yield among all. On the bases of the following research, it was revealed that the SBM can surrogate even50% fish meal without any augmentation of other amino acids in the diet of Indian major carps.

Keywords: soy bean meal, carps, protein, polyculture.

Resumo

O farelo de soja é uma proteína de origem vegetal de baixo custo que tem sido usada em dietas práticas como um substituto da proteína animal, como farinha de peixe ou farinha de frango, devido ao preço não econômico das dietas com proteína animal. Consequentemente, um estudo/pesquisa foi realizado com algumas espécies comerciais de carpas principais indianas, ou seja, Catla (*Cattla cattla*), Rohu (*Labeo rohita*) e Mrigala (*Cirhinus mrigala*) (Hamilton, 1822), para estimar a necessidade ideal de proteína dietética de farelo de soja na dieta em uma policultura intensiva. Três dietas diferentes (SBM I, SBM II e SBM III) foram formuladas por 80%, 50% e 20% de substituição de farinha de peixe por farelo de soja de uma dieta de 45% de farinha de peixe (controle). O maior ganho de peso médio mensal foi obtido por SBM II (com 35% PB e cerca de 50% de substituição de farinha de peixe), enquanto SBM III (45% de proteína bruta e cerca de 20% de substituição de farinha de peixe) ficou em segundo lugar. Todas as dietas testadas respondem enormemente produzindo alto rendimento em comparação com a dieta controle, embora SBM II tenha gerado o maior rendimento entre todas. Com base na pesquisa a seguir, foi revelado que o SBM pode substituir até 50% da farinha de peixe sem qualquer aumento de outros aminoácidos na dieta das carpas principais indianas.

Palavras-chave: farelo de soja, carpas, proteína, policultura.

1. Introduction

In aquaculture, feed constitute the major sole operating cost of the system. Fish meal being a chief source of protein, is extensively used in animal feeds. Due to its pricey cost and high demand, it is imperative to replace this expensive ingredient by some other inexpensive plant by products to achieve maximum revenue by reducing operating cost of aquaculture system. Accordingly, a variety of low-priced ingredients have been investigated by researchers from past few years, to reduce feed cost (Hardy and Masumoto, 1990; Rumsey, 1993; Karim and Shoaib, 2018).

Soybean meal is an inexpensive plant origin protein which has been used in practical diets for many years as a replacement of animal protein such as fish meal or chicken meal, due to the uneconomical price of animal

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protein diets. Although some studies illustrated that the outcome from the alternate sources of fish meal such as soybean in practical fish feed was not as effective as fish meal (Alexis, 1990; Dabrowski et al., 1989) because of the occurrence of some anti-nutritional elements and low level of sulfur-containing amino acids (Jackson et al., 1982; Wilson and Poe, 1985) but a number of studies confirmed the efficacy of soy bean meal in diet of fishes (Reinitz, 1980; Shiau et al., 1990; Krogdahl and Bakke-McKellep, 2001) as a complete or partial substitute. Trypsin inhibitors, non-saponins, digestible carbohydrates, lectins, and phytates in soybean meal were also considered to reduce rate of absorption in rainbow trout (Spinelli et al., 1983; Bureau et al., 1998; Dabrowski et al., 1989; Rumsey et al., 1994; Olli et al., 1994).

However, several efforts have been renewed to maximize the incorporation of soy bean meal and other plant byproducts in fish feed to minimize the cost of the feed which constitute the major part of the total aquacultural expenditure. This results a considerable decline in incorporation level of animal protein and even the total substitution with plant byproducts (Rumsey , 1993; Kaushik et al., 1995) and combination of corn gluten and soybean meal (Ketola and Harland, 1993; Gomes et al., 1995) in diets for rainbow trout.

Due to efficacy of soy bean meal as diet for fishes and its economical price, a research trial was conducted to find out the potential of integration of varying levels of soybean meal (SBM) as a fractional substitute of fish meal and to evaluate optimum dietary requirement of soybean meal for Indian major carps i.e. *Catla catla, Labeo rohita* and *Cirhinus mrigala* in intensive farming.

2. Materials and Methods

2.1. Formulation of feed

All trials were carried out in triplicates to minimize chances of errors. The fingerlings of *Cirhinus mrigala, Labeo rohita* and *Catla catla* were reared into raceways with the dimension 22′×50′ (W×L) for a period of one year in a proportion of 34:33:33 fish/raceway correspondingly (Wahab et al., 2002). Three different diets (SBM I, SBM II and SBM III) were formulated by 80%, 50% and 20% replacement of fish meal with soybean meal from a 45% fish meal diet (control) which constituted 63% of total crude protein. Fish meal and soybean meal, with some other ingredients (Table 1) were pulverized and emulsified to make dough. Pellets were made by a pellet maker machine. Formulated pellets were sun dried for 24 hours before freezing. By following Dada et al. (2002) fish were fed at the rate of 3% body weight.

Dissolved oxygen meter (HI-9146), the microprocessor pH meter (HANNA-HI-8520) and TDS meter (HANNA-HI-98302) were used respectively to determine dissolved oxygen, temperature, pH and total dissolved solids. The temperature of water throughout the experimental trial ranged from 10.1 °C to 30.5 °C, pH ranged 7.8-8.4, while dissolved oxygen was observed within the range of 5.1-8.4 mg/l.

2.2. Formulation estimation of growth parameters

After each 30 days, monthly weight gain, average daily growth (ADG), feed conversion ratio (FCR),daily feed allowance (DFA) and specific growth rate (SGR) (Khan et al.,

Table 1. Ingredient percentages and their proximate values per 100 gram of soy bean meal based test diets.

	Control	SBM I	SBM II	SBM III
Ingredients (%)				
Fish meal	45	8.69	21.79	34.87
Soy bean meal	-	25	35	45
Corn gluten meal	30.98	-	-	-
Rice polish	14.00	56.29	33.20	10.12
Starch	5	5	5	5
Canola oil	4.5	4.5	4.5	4.5
Vitamins and mineral mixture	0.5	0.5	0.5	0.5
Proximate composition (%)				
Crude protein	44.98	24.98	34.98	44.98
Crude fat	10.42	14.26	12.52	10.79
Crude fiber	2.38	3.74	3.69	3.64
Ash	13.25	10.61	11.49	12.37
Nitrogen –free extract	28.39	45.82	36.77	27.64
*DE (K cal/Kg)	3263.44	3037.6	3141.2	3244.9
**GE (K cal/Kg)	4587.67	4552.3	4572.0	4591.3

*DE = Digestible energy; **GE = Gross energy

2004) were calculated from each raceway by using the following Formulas 1 to 4.

$$ADG\left(g/day\right) = weight\ gain/number\ of\ days \quad (1)$$

$$DFA\left(g\right) = Av\ body\ weight\ X\ Number\ of\ stocks\ X\ \%\ Survival\ X\ Feeding\ rate \quad (2)$$

$$SGR\left(\%/day\right) = Log\ Fish\ final\ weight - Log\ Fish\ initial\ weight\ /\ Time\ X\ 100 \quad (3)$$

$$FCR = Weight\ of\ food\ presented/Weight\ of\ animal\ gained \quad (4)$$

2.3. Proximate composition of flesh

After consuming the formulated feed, experimental carps were analyzed for proximate composition by following Association of Official Analytical Chemist (AOAC, 2005) to confirm the efficacy of feed, as the main objective of the use of formulated diet was to produce highly nutritious plumped fish.

2.4. Statistical analysis

All data was analyzed by MINTAB version 17. To confirm the associations among variables, Two-way analyses of variance were also applied. Fisher's least-significant-difference (LSD) test was also performed to compare mean values.

3. Results

Mean values of weight, average daily growth (ADG), feed conversion ratio (FCR), daily feed allowance (DFA), and specific growth rate (SGR) are illustrated in Table 2. Highest monthly mean weight gain was obtained by SBM II (with 35% CP and about 50% substitution of fishmeal) as 80.77±1.73g while SBM III contain 45% CP (almost20% substitution of fishmeal) was stand second by producing 75.33±0.81g monthly mean weight gain of carps. Fisher's least-significant-difference (LSD) test also confirmed considerable variation among treatments. Not any specific specie of carps showed a persistent pattern of growth in all treatments with respect to average daily growth (ADG). In SBM I and SBM III maximum average daily growth (ADG) was obvious in *Labeo rohita* (2.56g and 2.42g respectively), while in SBM II, it was evident in *Cirhinus mrigala* as 2.79g. Values of growth parameters, for all test diets were considerably high as compare to control, a 45% crude protein diet in which fish meal constituted 63% of total crude protein.

However, maximum value of daily feed allowance (DFA) was obtained by SBM II (842.6±180 g), but the lowest value of feed conversion ratio (FCR) was also noted by SBM III (with 20% replacement of fish meal) as 2.91±0.31.

By the analysis of fish biomass against different inclusion levels of soybean meal, it was evident by percent individual contribution that *Labeo rohita* depicted a higher growth

Table 2. Values of different growth variables for observed carps fed with experimental diets.

	Weight (g)				ADG (g/day)[2]	DFA (g)[3]	SGR (%/day)[4]	FCR[5]
	Initial	Final	Monthly WG[1]	Mean WG				
				Control				
C. catla	27.3	466.4	36.59 ±5.5c	39.67±2.55c	1.21	532.3± 89a	0.36±0.05ab	3.82±0.33a
L. rohita	37.5	490.5	37.68 ±3.9c		1.25	0.32±0.07ab		
C.mrigala	62.5	599.3	44.73 ±4.1bc		1.49	0.27±0.03b		
				SBM I				
C. catla	36.11	883.14	70.58±13.7ab	67.56±3.98b	2.46	718.0±130a	0.38±0.11ab	3.68±0.51a
L. rohita	18.90	892.42	72.79±15.5ab		2.56	0.46±0.13ab		
C.mrigala	44.25	763.28	59.9±10.3abc		2.50	0.34±0.07ab		
				SBM II				
C. catla	28.5	997.8	80.77±13.2a	80.77±1.73a	2.69	842.6±180a	0.42±0.06ab	2.92±0.33a
L. rohita	24.7	958.1	77.78±12.2a		2.59	0.44±0.07ab		
C.mrigala	38.35	1043.55	83.76±12.3a		2.79	0.39±0.05ab		
				SBM III				
C. catla	33.44	921.94	74.0±10.5ab	75.33±0.81ab	2.35	793.3±169a	0.40±0.05ab	2.91±0.31a
L. rohita	15.75	938.35	76.8±12.3a		2.42	0.49±0.09a		
C.mrigala	41.25	943.65	75.2±11.4ab		1.99	0.37±0.04ab		

Values are means ± SE of three replicates. Non-Significantly value of mean (at $P = 0.05$) in a column was represented by same letter (by Fisher's least-significant-difference test). [1]Monthly weight gain (WG) (g) = Final value of growth variable – Initial value of growth variable; [2]Average daily gain (ADG) (g/day) = weight gain/number of days; [3]Daily Feed Allowance (DFA) (g)= Av body weight X Number of stocks X % Survival X Feeding rate; [4]Specific growth rate (SGR) (%/day) = Log Fish final weight – Log Fish initial weight / Time X 100; [5]Feed conversion ratio (FCR) = Weight of food presented/Weight of animal gained.

in SBM I and *Cirhinus mrigala* in SBM II and SBM III than *Catla catla* (Table 3).

Total harvested weight was yielded as 66.77 Kg, 79.02 Kg and 73.84 Kg per treatment for SBM I, SBM II and SBM III for *Cattla cattla, Labeo rohita, Cirhinus mrigala* respectively. At the end of the experimental period, this harvested weight was computed for one hectare. It was experiential that it would be 790.29 Kg.

Two-way analysis of variance against treatments (levels of Soy bean meal) and months showed significant differences with weight and DFA (Table 4), where as considerable differences were only evident among months in case of SGR and FCR.

Table 5 and 6 represent regression analysis, which reveal that Increase fish yield (IFY) communicated significantly with DFA and SGR among all treatments, except in SBM I regressed with SGR.

In terms of nutrient profile no significant differences were observed among all levels of FM. All species did not show any specific trend in relation to concentration of FM. The percentage of differed significantly in treatments, while fat, crude protein, carbohydrate, moisture and ash respond non-significantly. An inverse relationship was existed between protein and fat in all species. Rohu was found to be superior owing higher protein and fat and low moisture.

In case of proximate analysis, protein and fat showed an inverse association against moisture (Table 7). Considerable differences were observed among means of crude protein, moisture, fat, ash and carbohydrate, while crude protein, fat and ash depicted a significant P value among treatments by one-way analysis of variance.

4. Discussion

A number of studies confirmed the efficacy of soy bean meal in diet of fishes (Reinitz, 1980; Shiau et al., 1990; Krogdahl and Bakke-McKellep, 2001) as a complete or partial substitute. Anti-nutritional elements, found in SBM such as protease (trypsin) inhibitors, phyto-haem agglutinin (lectins), anti-vitamins, phytic acid, saponins, and phytoestrogens (El-Sayed, 1999; Francis et al., 2001). Phytates, protease inhibitors, lectins and anti-vitamins can easily be denatured by heat processing or any other means. Many researchers employed SBM at levels from 25-80% in the diets of rainbow trout and obtained successful results (Tacon and Silva, 1983; Smith and Johnson, 1988; Refstie et al., 1997). McGoogan and Gatlin III (1997) concluded that SBM can replace 90 to 95% of fish meal in fish diets with no adverse effects on fish growth but with additions of amino acids. In the same way, Gallagher (1994)

Table 3. Total observed and computed fish production by Soy bean meal based diets.

	Control	SBM I	SBM II	SBM III
Total harvested weight (Kg/treatment)	41.06	66.77	79.02	73.84
Total fish production (Kg/hectare/year)	410.60	667.73	790.29	738.46
Percent individual contribution				
C. catla	29.53	34.38	32.82	32.45
L. rohita	31.05	34.74	31.52	33.03
C.mrigala	39.40	30.86	35.65	34.40

Table 4. Two-way ANOVA among months and treatments (inclusion of Soybean meal).

Variables	Weight (g)			DFA (g)	SGR (%/day)			FCR
	C. catla	*L. rohita*	*C. mrigala*		*C. catla*	*L. rohita*	*C. mrigala*	
Levels of *SBM	0.074	0.001**	0.002	0.020**	0.833	0.737	0.277	0.064
Months	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**

*SBM = Soy bean meal; **Significant.

Table 5. Regression analysis of increase fish yield (IFY) on Daily feed allowance (DFA).

	Regression equations	R-Sq	R-sq (adj)	Prob.
***SBM I**	IFY = 21.91 + 0.2526 DFA	72.4%	69.6%	0.000**
SBM II	IFY = 81.13 + 0.1913 DFA	86.6%	85.2%	0.000**
SBM III	IFY = 75.81 + 0.1895 DFA	89.9%	88.9%	0.000**

*SBM = Soy bean meal; **Significant.

Table 6. Regression analysis of Daily feed allowance (DFA) on Specific growth rate (SGR) forIndian Major Carps.

Level of SBM*		Regression equations	R-Sq	R-sq (adj)	Prob
SBM I	*C. catla*	SGR of *C. catla* = 0.6479 - 0.000365 DFA	18.1%	9.9%	0.168
	L. rohita	SGR of *L.rohita* = 0.8084 - 0.000478 DFA	22.3%	14.5%	0.121
	C.mrigala	SGR of *C. mrigal* = 0.5477 - 0.000284 DFA	24.7%	17.2%	0.100
SBM II	*C. catla*	SGR of *C. catla* = 0.6536 - 0.000267 DFA	50.5%	45.5%	0.010**
	L. rohita	SGR of *L.rohita* = 0.6972 - 0.000304 DFA	47.7%	42.4%	0.013**
	C.mrigala	SGR of *C. mrigal* = 0.6036 - 0.000243 DFA	59.5%	55.5%	0.003**
SBM III	*C. catla*	SGR of *C. catla* = 0.6079 - 0.000262 DFA	61.4%	57.5%	0.003**
	L. rohita	SGR of *L.rohita* = 0.8140 - 0.000405 DFA	54.5%	50.0%	0.006**
	C.mrigala	SGR of *C. mrigal*= 0.5499 - 0.000217 DFA	55.2%	50.7%	0.006**

*SBM = Soy bean meal; **Significant.

Table 7. Proximate values of experimental carps fed with Soybean meal based diets.

Specie	Moisture %	Crude Protein %	Crude Fat %	Carbohydrate %	Total Ash %
Control I					
Catlacatla	78.23	16.50	1.94	1.52	1.81
Labeo rohita	76.76	17.54	2.25	1.60	1.57
Cirhinusmrigala	78.44	17.33	1.89	0.19	2.14
Mean	**77.81ab**	**17.12a**	**2.02b**	**1.10b**	**1.84c**
***SBM I**					
Catlacatla	76.47	15.52	2.87	2.75	2.23
Labeo rohita	77.23	15.06	3.77	0.85	2.91
Cirhinusmrigala	76.65	16.83	3.24	0.77	2.43
Mean	**76.78b**	**15.80ab**	**3.29a**	**1.45b**	**2.52bc**
SBM II					
Catlacatla	82.45	10.08	1.49	2.02	4.11
Labeo rohita	79.30	10.91	2.01	4.24	3.54
Cirhinusmrigala	77.96	13.31	1.80	3.90	3.02
Mean	**79.90a**	**11.43c**	**1.76b**	**3.38a**	**3.55a**
SBM III					
Catlacatla	76.99	14.38	2.60	3.36	2.67
Labeo rohita	77.41	14.27	3.44	1.75	3.12
Cirhinusmrigala	76.66	16.06	2.92	1.72	2.64
Mean	**77.02b**	**14.90b**	**2.98a**	**2.27ab**	**2.81b**
P Value	**0.06**	**0.00****	**0.00****	**0.09**	**0.00****

Significantly different values of mean (at $P = 0.05$) in a column were represented by different letters. *SBM = Soy bean meal; **Significant.

replaced up to 75% of fish meal with SBM along with the addition of methionine in the diet of hybrid striped bass and attained optimum growth.

SBM contain lower energy and protein contents as compare to other animal source protein. Nevertheless, increased level of protein as compare to the control fish meal diet is essential to obtain high yield due to the differences in proximate composition of SBM and fish meal. Probably due to this reason, feed intake was quite high in treatments receiving SBM-containing diets.

Soybean meal (SBM) could be added up to 30% in defatted form instead of fish meal (substitution of about 55% fish meal) as a protein source in the diet of yellowtail without any adverse effects on growth (Viyakarn et al., 1992). Palatability and acceptability in terms of total feed intake were not influenced by the inclusion of 30% SBM.

But in the present feed trial, SBM replaced up to 80% fish meal protein in the diet of the Indian major carps i.e. Cattla, Rohu, and Mrigal without any adverse effect on growth. In terms of performance and production of major carps, the suitability of these diets was also revealed by Pereira and Oliva-Teles (2003). The authors obtained considerable increase in yield by using products of maize, corn gluten meal, soy bean, moong, cow pea and guar. A mixture of animal and plant by products is relatively more practical to supply required nutrients for both Indian and Chinese carps (Abbas et al., 2008). In another trial, Nandeesha et al. (1995) found improvement in weight and SGR by using a diet with combination of animal and plant by products.

The findings of the present trial vary with the evaluation of Du and Niu (2003), who concluded that SBM is not an appropriate protein ingredient for the diet of freshwater prawn *M. rosenbergii* when they tested 0, 20, 50, 75 and 100% fishmeal replaced diets, until and unless some amino acids or additives are augmented.

In the line of Singh et al. (2005) and El-Saidy and Gaber (2005), protein and fat contents were found to be inversely correlated with moisture by analysis of carcass composition of carps. Though protein, moisture, carbohydrate, fat, and ash respond non-significantly, but alike Pereira and Oliva-Teles (2003) and Ramachandran et al. (2005), integration of Soybean meal in diet ultimately reduced moisture and ash by increasing protein and lipid in tissues.

Based on the present findings, it was concluded that the SBM can surrogate even up to 80% fish meal protein easily in the diet of the Indian major carps i.e. Cattla, Rohu, and Mrigal without any augmentation of other amino acids. It can not only save the dietary cost but can also boost the production up to the double than control. Due to economic viability and local availability, SBM has a great potential for being used in carps feed as compare to other plant byproducts. No doubt, the extreme inclusion level of SBM is a great attempt to replace locally available expensive fishmeal from the diet of the Indian major carps.

References

ABBAS, S., AHMED, I., HAFEEZ-UR-REHMAN, M. and MATEEN, A., 2008. Replacement of fish meal by canola meal in diets for major carps in fertilized ponds.*Pakistan Veterinary Journal*, vol. 28, no. 3, pp. 111-114.

ALEXIS, M.N., 1990. Comparative evaluation of soybean meal and carob seed germ meal as dietary ingredients for rainbow trout fingerlings.*Aquatic Living Resources*, vol. 3, no. 3, pp. 235-241. http://dx.doi.org/10.1051/alr:1990024.

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS – AOAC, 2005. *Official methods of analysis*.16th ed. Arlington: AOAC, 1193 p.

BUREAU, D.P., HARRIS, A.M. and YOUNG CHO, C., 1998. The effects of purified alcohol extracts from soy products on feed intake and growth of chinook salmon (*Oncorhynchus tshawytscha*) and rainbow trout (*Oncorhynchus mykiss*).*Aquaculture*, vol. 161, no. 1-4, pp. 27-43. http://dx.doi.org/10.1016/S0044-8486(97)00254-8.

DABROWSKI, K., POCZYCZYNSKI, P., KÖCK, G. and BERGER, B., 1989. Effect of partially or totally replacing fish meal protein by soybean meal protein on growth, food utilization and proteolytic enzyme activities in rainbow trout (*Salmo gairdneri*).New in vivo test for exocrine pancreatic secretion.*Aquaculture*, vol. 77, no. 1, pp. 29-49. http://dx.doi.org/10.1016/0044-8486(89)90019-7.

DADA, A.A., FAGBENRO, O.A. and FASAKIN, E.A., 2002. Determination of optimum feeding frequency for *Heterobranchus bidorsalis* fry in outdoor concrete tanks.*Journal of Aquaculture in the Tropics*, vol. 17, no. 3, pp. 167-174.

DU, L. and NIU, C.J., 2003. Effects of dietary substitution of soya bean meal for fish meal on consumption, growth, and metabolism of juvenile giant freshwater prawn, *Macrobrachium rosenbergii. Aquaculture Nutrition*, vol. 9, no. 2, pp. 139-143. http://dx.doi.org/10.1046/j.1365-2095.2003.00239.x.

EL-SAIDY, D.M. and GABER, M., 2005. Effect of dietary protein levels and feeding rates on growth performance, production traits and body composition of Nile tilapia, *Oreochromi sniloticus* (L.) cultured in concrete tanks.*Aquaculture Research*, vol. 36, no. 2, pp. 163-171. http://dx.doi.org/10.1111/j.1365-2109.2004.01201.x.

EL-SAYED, A.F.M., 1999. Alternative dietary protein sources for farmed tilapia, *Oreochromis* spp.*Aquaculture*, vol. 179, no. 1-4, pp. 149-168. http://dx.doi.org/10.1016/S0044-8486(99)00159-3.

FRANCIS, G., MAKKAR, H.P. and BECKER, K., 2001. Antinutritional factors present in plant-derived alternate fish feed ingredients and their effects in fish.*Aquaculture*, vol. 199, no. 3-4, pp. 197-227. http://dx.doi.org/10.1016/S0044-8486(01)00526-9.

GALLAGHER, M.L., 1994. The use of soybean meal as a replacement for fish meal in diets for hybrid striped bass (*Moronesaxatilis*× M. chrysops).*Aquaculture*, vol. 126, no. 1-2, pp. 119-127. http://dx.doi.org/10.1016/0044-8486(94)90253-4.

GOMES, E.F., REMA, P. and KAUSHIK, S.J., 1995. Replacement of fish meal by plant proteins in the diet of rainbow trout (*Oncorhynchus mykiss*): digestibility and growth performance.*Aquaculture*, vol. 130, no. 2-3, pp. 177-186. http://dx.doi.org/10.1016/0044-8486(94)00211-6.

HARDY, R.W. and MASUMOTO, T., 1990. Specifications for marine by-products for aquaculture.In *Proceedings of theInternational Conference on Fish By-products*, 1990, Anchorage, Alaska. Anchorage: Alaska Sea Grant College Program, pp. 109-120.

JACKSON, A.J., CAPPER, B.S. and MATTY, A.J., 1982. Evaluation of some plant proteins in complete diets for the tilapia *Sarotherodon mossambicus*.*Aquaculture*, vol. 27, no. 2, pp. 97-109. http://dx.doi.org/10.1016/0044-8486(82)90129-6.

KARIM, A. and SHOAIB, M., 2018. An evaluation of optimal dietary protein requirements of all parts chicken meal for Indian major carps (*Catla catla, Labeo rohita and Cirhinus mrigala). Turkish Journal of Fisheries and Aquatic Sciences*, vol. 18, no. 2, pp. 223-227. http://dx.doi.org/10.4194/1303-2712-v18_2_01.

KAUSHIK, S.J., CRAVEDI, J.P., LALLES, J.P., SUMPTER, J., FAUCONNEAU, B. and LAROCHE, M., 1995. Partial or total replacement of fish meal by soybean protein on growth, protein utilization, potential estrogenic or antigenic effects, cholesterolemia and flesh quality in rainbow trout, *Oncorhynchus mykiss*.*Aquaculture*, vol. 133, no. 3-4, pp. 257-274. http://dx.doi.org/10.1016/0044-8486(94)00403-B.

KETOLA, H.G. and HARLAND, B.F., 1993. Influence of phosphorus in rainbow trout diets on phosphorus discharges in effluent water.*Transactions of the American Fisheries Society*, vol. 122, no. 6, pp. 1120-1126. http://dx.doi.org/10.1577/1548-8659(1993)122<1120:IOPIRT>2.3.CO;2.

KHAN, M.A., AHMED, I. and ABIDI, S.F., 2004. Effect of ration size on growth, conversion efficiency and body composition of fingerling mrigal, *Cirrhinus mrigala* (Hamilton).*Aquaculture Nutrition*, vol. 10, no. 1, pp. 47-53. http://dx.doi.org/10.1046/j.1365-2095.2003.00279.x.

KROGDAHL, A. and BAKKE-MCKELLEP, A.M., 2001. Soybean in salmonid diets: antinutrients, pathologies, immune responses and possible solutions. In: *Proceedings of the Aquaculture 2001*, 2001, Lake Buena Vista, FL. USA: World Aquaculture Society.

MCGOOGAN, B.B. and GATLIN III, D.M., 1997. Effects of replacing fish meal with soybean meal in diets for red drum *Sciaenops ocellatus* and potential for palatability enhancement.*Journal of the World Aquaculture Society*, vol. 28, no. 4, pp. 374-385. http://dx.doi.org/10.1111/j.1749-7345.1997.tb00284.x.

NANDEESHA, M.C., SILVA, S.S. and MURTHY, D.K., 1995. Use of mixed feeding schedules in fish culture: performance of common carp, *Cyprinus carpio L.* on plant and animal protein based diets.*Aquaculture Research*, vol. 26, no. 3, pp. 161-166. http://dx.doi.org/10.1111/j.1365-2109.1995.tb00898.x.

OLLI, J.J., HJELMELAND, K. and KROGDAHL, Å., 1994. Soybean trypsin inhibitors in diets for Atlantic salmon (*Salmo salar, L*): effects on nutrient digestibilities and trypsin in pyloric caeca homogenate and intestinal content.*Comparative Biochemistry and Physiology. Part A, Physiology*, vol. 109, no. 4, pp. 923-928. http://dx.doi.org/10.1016/0300-9629(94)90240-2. PMid:7828032.

PEREIRA, T.G. and OLIVA-TELES, A., 2003. Evaluation of corn gluten meal as a protein source in diets for gilthead sea bream (*Sparus aurata L.*) juveniles.*Aquaculture Research*, vol. 34, no. 13, pp. 1111-1117. http://dx.doi.org/10.1046/j.1365-2109.2003.00909.x.

RAMACHANDRAN, S., BAIRAGI, A. and RAY, A.K., 2005. Improvement of nutritive value of grass pea (*Lathyrus sativus*) seed meal in the formulated diets for rohu, Labeo rohita (Hamilton) fingerlings after fermentation with a fish gut bacterium. *Bioresource Technology*, vol. 96, no. 13, pp. 1465-1472. http://dx.doi.org/10.1016/j.biortech.2004.12.002. PMid:15939274.

REFSTIE, S., HELLAND, S.J. and STOREBAKKEN, T., 1997. Adaptation to soybean meal in diets for rainbow trout, *Oncorhynchus mykiss.Aquaculture*, vol. 153, no. 3-4, pp. 263-272. http://dx.doi.org/10.1016/S0044-8486(97)00025-2.

REINITZ, G., 1980. Soybean meal as a substitute for herring meal in practical diets for rainbow trout.*Progressive Fish-Culturist*, vol. 42, no. 2, pp. 103-106. http://dx.doi.org/10.1577/1548-8659(1980)42[103:SMAASF]2.0.CO;2.

RUMSEY, G.L., 1993. Fish meal and alternate sources of protein in fish feeds update 1993.*Fisheries*, vol. 18, no. 7, pp. 14-19. http://dx.doi.org/10.1577/1548-8446(1993)018<0014:FMAASO>2.0.CO;2.

RUMSEY, G.L., SIWICKI, A.K., ANDERSON, D.P. and BOWSER, P.R., 1994. Effect of soybean protein on serological response, non-specific defense mechanisms, growth, and protein utilization in rainbow trout.*Veterinary Immunology and Immunopathology*, vol. 41, no. 3-4, pp. 323-339. http://dx.doi.org/10.1016/0165-2427(94)90105-8. PMid:7941311.

SHIAU, S.Y., LIN, S.F., YU, S.L., LIN, A.L. and KWOK, C.C., 1990. Defatted and full-fat soybean meal as partial replacements for fishmeal in tilapia (*Oreochromis niloticus*× O. aureus) diets at low protein level.*Aquaculture*, vol. 86, no. 4, pp. 401-407. http://dx.doi.org/10.1016/0044-8486(90)90328-K.

SINGH, P.K., GAUR, S.R., BARIK, P., SHUKLA, S. and SINGH, S., 2005. Effect of protein levels on growth and digestability in the Indian major carp, *Labeo rohita* (Hamilton) using slaughter house waste as the protein source.*International Journal of Agriculture and Biology*, vol. 7, no. 6, pp. 939-941.

SMITH, D.B. and JOHNSON, K.S., 1988. Single-step purification of polypeptides expressed in Escherichia coli as fusions with glutathione S-transferase.*Gene*, vol. 67, no. 1, pp. 31-40. http://dx.doi.org/10.1016/0378-1119(88)90005-4. PMid:3047011.

SPINELLI, J., HOULE, C.R. and WEKELL, J.C., 1983. The effect of phytates on the growth of rainbow trout (*Salmo gairdneri*) fed purified diets containing varying quantities of calcium and magnesium.*Aquaculture*, vol. 30, no. 1-4, pp. 71-83. http://dx.doi.org/10.1016/0044-8486(83)90153-9.

TACON, A.G.J. and SILVA, S.S., 1983. Mineral composition of some commercial fish feeds available in Europe.*Aquaculture*, vol. 31, no. 1, pp. 11-20. http://dx.doi.org/10.1016/0044-8486(83)90253-3.

VIYAKARN, V., WATANABE, T., AOKI, H., TSUDA, H., SAKAMOTO, H., OKAMOTO, N., ISO, N., SATOH, S. and TAKEUCHI, T., 1992. Use of soybean meal as a substitute for fish meal in a newly developed soft-dry pellet for yellowtail.*Nippon Suisan Gakkaishi*, vol. 58, no. 10, pp. 1991-2000. http://dx.doi.org/10.2331/suisan.58.1991.

WAHAB, M.A., RAHMAN, M.M. and MILSTEIN, A., 2002. The effects of common carp, *cyprinus carpio* (L.) and *Cirrhinus mrigala* (Hamilton) as bottom feeders in major Indian carp poly cultures. *Aquaculture Research*, vol. 33, no. 8, pp. 547-556. http://dx.doi.org/10.1046/j.1365-2109.2002.00654.x.

WILSON, R.P. and POE, W.E., 1985. Effects of feeding soybean meal with varying trypsin inhibitor activities on growth of fingerling channel catfish.*Aquaculture*, vol. 46, no. 1, pp. 19-25. http://dx.doi.org/10.1016/0044-8486(85)90171-1.