

The Open Access Israeli Journal of Aquaculture – Bamidgeh

As from **January 2010** The Israeli Journal of Aquaculture - Bamidgeh (IJA) will be published exclusively as **an on-line Open Access (OA)** quarterly accessible by all AquacultureHub (<http://www.aquaculturehub.org>) members and registered individuals and institutions. Please visit our website (<http://siamb.org.il>) for free registration form, further information and instructions.

This transformation from a subscription printed version to an on-line OA journal, aims at supporting the concept that scientific peer-reviewed publications should be made available to all, including those with limited resources. The OA IJA does not enforce author or subscription fees and will endeavor to obtain alternative sources of income to support this policy for as long as possible.

Editor-in-Chief

Dan Mires

Editorial Board

Rina Chakrabarti	Aqua Research Lab, Dept. of Zoology, University of Delhi, India
Angelo Colorni	National Center for Mariculture, IOLR Eilat, Israel
Daniel Golani	The Hebrew University of Jerusalem Jerusalem, Israel
Hillel Gordin	Kibbutz Yotveta, Arava, Israel
Sheenan Harpaz	Agricultural Research Organization Beit Dagan,
Gideon Hulata	Agricultural Research Organization Beit Dagan,
George Wm. Kissil	National Center for Mariculture, IOLR, Eilat, Israel
Ingrid Lupatsch	Swansea University, Singleton Park, Swansea, UK
Spencer Malecha	Dept. of Human Nutrition, Food & Animal Sciences, CTAHR, University of Hawaii
Constantinos Mylonas	Hellenic Center for Marine Research, Crete, Greece
Amos Tandler	National Center for Mariculture, IOLR Eilat, Israel
Emilio Tibaldi	Udine University Udine, Italy
Jaap van Rijn	Faculty of Agriculture, The Hebrew University of Jerusalem, Israel
Zvi Yaron	Dept. of Zoology, Tel Aviv University, Tel Aviv, Israel

Published under auspices of
The Society of Israeli Aquaculture and Marine Biotechnology (SIAMB),
University of Hawai'i at Mānoa Library

&

University of Hawai'i at Mānoa
Aquaculture Program
in association with
AquacultureHub

<http://www.aquaculturehub.org>



UNIVERSITY
of HAWAII[®]
MĀNOA
LIBRARY



AquacultureHub.org

AquacultureHub
educate • learn • share • engage

ISSN 0792 - 156X

© Israeli Journal of Aquaculture - BAMIGDEH.

PUBLISHER:

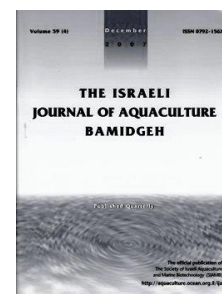
Israeli Journal of Aquaculture - BAMIGDEH -
Kibbutz Ein Hamifratz, Mobile Post 25210,
ISRAEL

Phone: + 972 52 3965809

<http://siamb.org.il>



The IJA appears exclusively as a peer-reviewed on-line open-access journal at <http://www.siamb.org.il/>. To read papers free of charge, please register online at [registration form](#).
Sale of IJA papers is strictly forbidden.



Effect of Total Fish Meal Replacement with Vegetal Protein Alone or Combined with Rendered Animal Protein on Growth Performance and Tissue Composition of European Catfish (*Silurus glanis* L.)

Máté Havasi¹, Shivendra Kumar^{1*}, Zoltán Nagy¹, László Pál², Gábor Beliczky², Miklós Bercsényi², Dénes Gál¹

¹National Agricultural Research and Innovation Centre, Research Institute for Fisheries and Aquaculture (NARIC – HAKI), Szarvas, Annaliget 8., 5540 Hungary

²University of Pannonia, Georgikon Faculty, Keszthely, Deák F. u. 16., 8360 Hungary

(Received 7.8.2015, Accepted 9.8.2015)

Key words: European catfish, fish meal replacement, growth, rendered animal protein, *Silurus glanis*

Abstract

A feeding trial was conducted for six weeks to determine the effect of the replacement of fishmeal (FM) either with vegetal protein (mainly soybean) and rendered animal protein combined or vegetal protein alone on growth and carcass composition of European catfish, *Silurus glanis*. One hundred and thirty five fish (average weight $70.90 \pm 5.10\text{g} \pm \text{SD}$) were randomly distributed into three treatments in triplicate. Fish were fed with either of three isonitrogenous (35% crude protein) and isocaloric (16.70 MJ/kg DE) experimental diets. The diets were: fish meal (FM) based diet, fish meal protein replaced with a combination of vegetal protein and rendered animal protein (AP), and fish meal replaced with vegetal protein only (SM). Weight gain (%), specific growth rate, protein efficiency ratio, and apparent net protein utilization of FM diet fed groups were similar ($P > 0.05$) with AP diet fed group being significantly higher ($P < 0.05$) than the SM group. Feed conversion ratio with FM diet was similar ($P < 0.05$) to that of the AP diet, and significantly lower than SM diet. The present experiment indicated that vegetal protein alone cannot replace total FM protein in the diet of *Silurus glanis*, however, vegetal protein and rendered animal protein combined, can replace total fish meal protein, with no detrimental effect on growth performance, feed utilization, and body composition.

* Corresponding author. Tel. +36-66-515-312; Fax. +36-66-312-142;
email: shivdholi@rediffmail.com; shivendrakumar@haki.hu

Introduction

European catfish *Silurus glanis*, is a favoured farmed fish species in Europe because of its large size, rapid growth, delicious meat, and high market price. It has been cultivated extensively in ponds in Central and Eastern Europe for over 100 years, but development of new diets and feeding regimes for cost effective production and satisfactory quality of the final edible product is crucial in order to establish viable European catfish farming.

To date, diets for European catfish have been based on high quality fish meal (FM). Fish meal is the most important and widely used protein ingredient in aquaculture, especially for the production of piscivorous fish species. However, with the expansion of aquaculture, increasing demand, uncertain availability, and high price has necessitated the search for alternate protein sources. Vegetal proteins, the most common of which is soybean meal (SM) (Kissil and Lupatsch, 2004), which has high protein content and contains most of the essential amino acids required by fish, currently represent the only economic and sustainable protein alternative to fishmeal and are increasingly being used in commercial fish feed. However, soybeans are also used for human food, so there is a need to identify other protein-rich resources that could be used in aquatic diets. Finding other protein sources will reduce price volatility and European Union dependency on imports. Rendered by-products of terrestrial animals may also be a suitable alternative for replacement of fishmeal as a protein source (Altan et al., 2010). Meat and bone meal (MBM), one of the economically rendered animal by-products, has been widely used in poultry feed (Parsons et al., 1997; Wang and Parsons, 1998). MBM has relatively higher protein content, and better growth promotion effect in comparison with alternative plant proteins. Recently, MBM was introduced to replace FM in fish diets. Some studies have shown that MBM could partially replace dietary FM without affecting growth and feed efficiency of experimental fish (Davies et al., 1991; El-Sayed, 1998; Bureau et al., 2000; Webster et al., 2000). 80% of the fish meal can be successfully replaced with meat and bone meal (4:1) in grouper (*Epinephelus coioides*) feeds (Millamena, 2002).

Previous research has indicated that neither vegetal protein nor animal protein alone can replace total fish meal protein in the diet of carnivorous fish. The present experiment aims to study the effect on growth performance and body composition of total FM replacement with only vegetal protein or in combination with animal protein in the diet of European catfish (*Silurus glanis* L.)

Materials and Methods

Diets. Three isonitrogenous (35% crude protein) and isocaloric (16.70 MJ/kg DE) experimental diets were formulated: Fish meal (FM) based diet, fish meal protein replaced with a combination of vegetal protein and rendered animal protein (AP), and fish meal replaced with vegetal protein only (SM). All ingredients were ground before final mixing with a hammer mill and then blended with the oils. Ingredients were steam pelleted and dried in a forced air oven at 50°C. The dry pellets were placed in covered plastic containers and stored at 4°C. All diets were analysed in duplicate to establish their proximate composition.

Experimental animals and layout. Juvenile European catfish (*Silurus glanis*) were brought from a commercial farm in Hungary. Prior to the start of the six week experiment the juveniles were reared in a recirculation tank system and fed with fish meal for 2 weeks to acclimate them to the experimental conditions.

At onset of the experiment, the fish were fasted for 24 h and weighed. 135 juveniles (average individual weight 70.90 ± 5.10 g) were randomly distributed into three treatment groups with three replicates each in 9 glass aquaria (130x50x60 cm) equipped with a recirculation system. The water flow rate through the aquaria was about 2 L/min and water exchange was 10%/day. Continuous aeration was provided to all from a compressed air pump. During the 6 week experimental period the groups were fed with the three experimental diets respectively. Juveniles in all groups were fed twice a day with 2.5% of actual stock body weight. All water quality parameters were analysed on alternate days and found to be within the normal range for rearing of *Silurus glanis* (Copp et al., 2009).

Growth study. Fish in each aquarium were measured individually at the end of the experiment to assess weight gain. Growth performance of fish such as weight gain (WG), specific growth rate (SGR), feed conversion ratio (FCR) and protein efficiency ratio (PER) were calculated based on the following standard formulae:

$$\text{WG (\%)} = [(\text{Final weight} - \text{Initial weight}) / \text{Initial weight}] \times 100$$

$$\text{SGR} = [\ln \text{Final weight} - \ln \text{Initial weight} / \text{Number of days}] \times 100$$

$$\text{FCR} = \text{Total dry feed intake (g)} / \text{wet weight gain (g)}$$

$$\text{PER} = \text{Net weight gain (wet weight)} / \text{Protein fed (dry weight)}$$

$$\text{ANPU} = [(\text{Final carcass protein} - \text{Initial carcass protein}) / \text{Protein fed}] \times 100$$

Sampling. At the end of experiment, five juveniles from each aquarium i.e fifteen juveniles from each treatment group, were randomly collected for proximate analysis. Another three juveniles from each aquarium of each treatment were anesthetized with clove oil (50 µl/L), sacrificed with a blow to the head, and dissected to collect the liver and visceral fat for determination of weight of liver and visceral fat (g/100 g fish).

Analysis of samples. Proximate composition of the feed and fish was analyzed by standard methods of AOAC (1990). Moisture was determined by drying the sample at 105°C to a constant weight. Nitrogen content of the sample was analyzed using Kjeltex system (FOSS, Denmark), and crude protein (CP) was calculated by multiplying nitrogen percentage by 6.25. Lipid was determined using Soxtec system (FOSS, Denmark) using diethyl ether (boiling point, 40° - 60°C) as a solvent, and ash content was estimated by incinerating the sample in a muffle furnace at 600°C for 6 h. Crude fiber content was analyzed by alkali and acid digestion. Nitrogen free extract (NFE) was calculated by differences as, 100-(%CP + %EE + %ash + %fiber). The content of amino acids in different diets was determined by low pressure ion exchange chromatography according to European standards. The dietary energy value of experimental diets was calculated as described in Kumar et al., (2013).

Statistical analysis. Mean value of all parameters were subjected to one-way analysis of variance (ANOVA) to study the treatment effect, and Tukey and Tamhane's post hoc tests were used to determine the significant differences between the mean value. Comparisons were made at 5% probability level. All the data were analysed using statistical packages SPSS (Version 16; spss Inc., Chicago, IL, USA).

Results

For the proximate composition of the different experimental diets (% DM) see Table 1.

Table 1. Formulation and proximate composition of different experimental diets (% DM basis)

Ingredients (%)	Experimental diets			
	FM	AP	SM	
Fishmeal ¹	19.00	0.00	0.00	¹ HALTAP, Szarvas, Hungary.
Rendered animal protein ²	0.00	17.00	0.00	² Animal feed production
Soybean meal, solvent extracted ³	30.30	25.05	40.00	company (ATEV), Budapest,
Corn ³	26.50	27.14	16.48	Hungary.
Corn gluten ³	12.20	18.80	19.10	³ UBM, Feed Kft, 2085
Wheat ³	10.00	10.00	10.00	Pilisvörö svár, Főv. 130.
Canola meal, solvent extracted ³	0.00	0.00	10.00	*Vitamin and Mineral
Mono-calcium phosphate ³	0.00	0.00	1.30	Premix (per kg): Vitamin A:
DL- Methionine ³	0.00	0.10	0.00	400 000 IU, Vitamin D ₃ : 200
L-lysine ³	0.00	0.54	0.42	000 IU, Vitamin E: 6000 mg,
Sunflower oil ³	1.50	0.87	2.20	Vitamin K ₃ : 918 mg, Vitamin
Vitamin and Mineral Premix ^{3*}	0.50	0.50	0.50	B ₁ : 500 mg, Vitamin B ₂ : 1200
Proximate composition (% DM basis)				
Dry matter	89.40	90.70	88.90	mg, Vitamin B ₆ : 1000 mg,
Moisture	10.60	9.30	11.10	pantothenic acid: 3000 mg,
Crude protein	34.55	35.6	34.65	folic acid: 500 mg, Vitamin C:
Crude lipid	5.05	5.15	4.39	10 000 mg, Ca: 228 g, Fe:
Crude fibre	0.44	1.52	3.62	6000 mg, Zn: 40 324 mg,
Nitrogen free extract	52.86	51.83	51.74	Mn: 5022 mg, Cu: 1000 mg,
Ash	7.10	5.90	5.60	Se: 22.5 mg, I: 496 mg,
Dietary energy (MJ/kg)	16.61	16.83	16.72	antioxidant: 2000 mg.

The protein content in all three diets averaged 35%. The amino acid compositions of the different experimental diets are presented in Table 2. The methionine and lysine content in all experimental diets were similar. At the end of experiment, the carcass compositions of *Silurus glanis* whole body were significant among the treatments (Table 3).

Table 2. Amino acid profile (% DM basis) of different experimental diets

Amino acid	Diet		
	FM	AP	SM
Cysteine	0.49	0.51	0.58
Asparagine	2.98	2.53	2.82
Methionine	0.76	0.79	0.80
Threonine	1.30	1.17	1.24
Serine	1.50	1.55	1.60
Glutamine	5.30	5.31	5.81
Proline	1.89	2.56	2.07
Glycine	1.73	2.27	1.28
Alanine	1.95	2.13	1.80
Valine	1.53	1.47	1.54
Isoleucine	1.38	1.24	1.40
Leucine	2.78	2.96	2.98
Tyrosine	1.23	1.22	1.35
Phenylalanine	1.52	1.49	1.62
Histidine	0.86	0.79	0.86
Lysine	1.86	1.81	1.89
Arginine	1.93	1.98	1.79

Table 3. Carcass composition (%) of *Silurus glanis* juveniles fed with different experimental diets (wet weight basis; mean \pm standard deviation)

Carcass composition	Diets			
	FM	AP	SM	Initial*
Dry matter	21.60	21.70	21.20	22.90
Moisture	78.40	78.30	78.80	77.10
Crude protein	14.46	14.57	13.96	13.84
Lipid	4.81	5.22	4.79	6.81
Ash	2.52	2.13	2.27	2.37

* Fish sample taken before start-up of the experiment

No mortality was registered in any of the groups throughout feeding experiment. The growth performance (weight gain and SGR) and feed efficiency (FCR, PER and ANPU) were significantly different ($P < 0.05$) among the treatment groups (Table 4).

Table 4. Effect of different treatments on the Growth parameters of *Silurus glanis* (mean \pm standard deviation)

Parameters	Diets		
	FM	AP	SM
Initial weight (g)	70.3 \pm 9.0	71.2 \pm 10.0	71.2 \pm 9.3
Final weight (g)	131.0 \pm 23.3 ^a	121.4 \pm 21.2 ^a	97.7 \pm 13.0 ^b
Weight gain (%)	86.2 \pm 8.6 ^a	70.5 \pm 6.2 ^a	37.2 \pm 6.6 ^b
SGR	1.26 \pm 0.09 ^a	1.10 \pm 0.12 ^a	0.70 \pm 0.06 ^b
FCR	1.40 \pm 0.08 ^b	1.64 \pm 0.10 ^b	2.63 \pm 0.18 ^a
PER	2.13 \pm 0.17 ^a	1.84 \pm 0.10 ^a	1.05 \pm 0.11 ^b
ANPU	31.38 \pm 2.60 ^a	26.73 \pm 2.17 ^a	15.67 \pm 1.36 ^b

Values within same row with different superscripts are statistically different ($P < 0.05$)

The weight gain (%), SGR, PER, and ANPU, of fish fed FM or AP diets were similar ($P > 0.05$) but significantly higher than those of fish fed diet SM. Feed conversion ratio (FCR) of FM diet fed group were similar ($P > 0.05$) to the AP group, and lower ($P < 0.05$) than in the SM group. Visceral fat (%) and liver weight (%) of *Silurus glanis* did not differ (Figure 1).

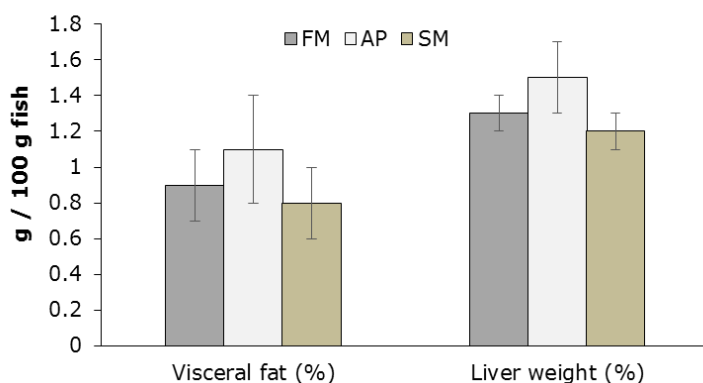


Figure 1. Effect of different treatments on visceral fat (%) and liver weight (%) of *Silurus glanis*.

Discussion.

Research has been conducted to examine the replacement of FM by different protein sources fed to different fish species, but very few studies have been conducted on European catfish, *Silurus glanis* (Bekcan et al., 2006). This is due to limited knowledge of the nutrient requirements of *Silurus glanis*. In the present study different experimental feeds were formulated according to the requirements of a related species, *Ictalurus punctatus* (Li et al., 2004). Soybean meal and rendered animal protein, similar to meat and bone meal have been shown to be nutritionally adequate protein sources for many species (Altan, 2010;; Robaina et al., 1997; Higgs et al., 1995). Essential amino acid deficiency is one of the factors limiting the utilization of less expensive protein sources as FM substitutes (Glencross et al., 2007). Compared to FM, SM proteins are lower in lysine content whereas rendered animal proteins are lower in methionine and lysine contents (Kissil and Lupatsch, 2004; Hertrampf and Piedad-Pascual, 2000). In the present study, test diets were formulated to be isonitrogenous and similar in methionine and lysine contents.

Whole body carcass composition of *Silurus glanis* was not affected by the replacement of FM either with soybean meal protein (SM diet) only, or SM protein combined with rendered animal protein (AP diet). This is in agreement with Takagi et al (2000) who reported no significant difference in whole body composition of red sea bream fed different level of poultry by-product meal. Similar results were also reported in grouper (Shapawai et al., 2007 and Gunben et al., 2014), in rainbow trout (Bureau et al., 2000) and in gilthead seabream (Robaina et al., 1997). However, significantly similar ($p > 0.05$) but higher carcass lipid content was found in the treatment group fed AP diet compared to FM and SM diet. This may be due to slightly higher lipid content in AP diet. This may also be caused by higher but significantly similar ($p > 0.05$) visceral fat content in AP treatment group. Higher liver weight of fish fed the AP diet were similar ($P > 0.05$) to other groups. This indicates that the inclusion of animal protein has little influence on body indices of *Silurus glanis* (Fig. 1).

The present study showed that the total replacement of FM with SM in the diet of *Silurus glanis* significantly decreased ($P < 0.05$) the growth performance, whereas no effect ($P > 0.05$) was seen in the treatment group fed a diet where FM was substituted with SM along with rendered AP. The limitation of use of alternative protein sources may be due to three factors: (i) lower feeding rate with replacement of FM by alternate protein (Robaina et al., 1997); (ii) lower digestibility of the alternate proteins (Bureau, et al., 1999); (iii) imbalance of the essential amino acids (Ai and Xie, 2005). The amino acid composition of different experimental feeds in the present study is quite similar, therefore lower feeding rate, lower digestibility, or both may be the cause of lower growth performance in the SM fed diet group. The reduced digestibility of SM diet may be due to high fibre content. Excretory waste of energy in *Silurus meridionalis* increased as the portion of soybean meal in the feed increased which subsequently provided less available energy for growth (Ai and Xie, 2005). Very promising results were obtained in

the present study that show that the replacement of FM protein with a combination of plant protein and rendered animal protein in the diet did not affect the growth performance of *Silurus glanis*. Fish meal was successfully replaced with meat and bone meal up to 25% digestible protein in the diet of rainbow trout without compromising feed utilization and growth performance (Bureau et al., 2000). In the diet of grouper (*Epinephelus coioides*) 80% fishmeal was replaced with meat and bone meal with no effect on growth performance (Millamena, 2002).

Increased FCR correlated with increased vegetal protein inclusion in the fish diet and can be explained as a compensatory intake to meet the demand for protein to maintain maximum growth (Refstie et al., 2006). Reduced palatability of the SM diet may be another reason for high FCR. Loss of palatability has been responsible for reduced feed intake and growth of fish fed diets when high levels of dietary fish meal were replaced with cheaper plant or animal ingredients (Davis et al., 1995; Xue and Cui, 2001). This indicates that AP diets are more palatable when compared to SM diet.

Lower protein utilization of SM diet than FM may be due to the presence of anti-nutritional factors such as trypsin. These are in the range of 2-6 mg/g, averaging 4 mg/g (Francis et al., 2001) causing a decrease in mucosal enzymes that coincide with lower protein utilization and feed conversion (Krogdahl et al., 2003). Soybean meal also contains undigested fibre, which reduces the digestible energy causing amino acid oxidation and/or conversion of amino acids to glucose and/or fat. Lower fibre content in the AP diet compares to that of the SM diet. This suggests a higher level of digestible energy in the AP diet, and better utilization of amino acids leading to an increase of the PER and ANPU.

Our results showed that vegetal protein alone has a negative impact on growth performance and protein utilization efficiency. These results still need to be optimised for *Silurus glanis*. Supplemented rendered animal protein for fish, which is authorized in EU countries (*Commission Regulation EU No 56/2013*), may be a suitable alternative protein source to fishmeal in the diet of *Silurus glanis*.

Acknowledgements

We would like to thank Öreglaci Halász Ltd. for providing the fish. This study was supported by the European Union, co-financed by the European Regional Development Fund (GOP-1.1.1-11-2011-0028), and partially supported by the AQUAREDPOOT project funded by the European Commission (FP7-316266).

References

- Ai Q. and X. Xie**, 2005. Effects of dietary soybean protein levels on energy budget of the southern catfish, *Silurus meridionalis*. *Comp Biochem Physiol*, 141:461-469.
- Altan O., Gamsiz K. and A.Y. Korkut**, 2010. Soybean Meal and Rendered Animal Protein Ingredients Replace Fishmeal in Practical Diets for Sea Bass. *Isr. J. Aquacult. - Bamidgeh*, 62(2): 56-62
- AOAC**, 1990. *International: Official Methods of Analysis*, 1, 1990. 9 CFR 318.19 (b).
- Bekcan S., Dogankaya L. and G.C. Cakirogullari**, 2006. Growth and body composition of European catfish (*Silurus glanis* L.) fed diets containing different percentage of protein. *Isr. J. Aquacult. - Bamidgeh*, 58(2):137-142.
- Bureau D.P., Harris A.M. and C.Y. Cho**, 1999. Apparent digestibility of rendered animal protein ingredients for rainbow trout. *Aquaculture*, 180:345-358.
- Bureau D.P., Harris A.M., Bevan D.J., Simmons L.A., Azevedo P.A. and C.Y. Cho**, 2000. Feather meals and meat and bone meals from different origins as protein sources in rainbow trout (*Oncorhynchus mykiss*) diets. *Aquaculture*, 181:281-291.
- Copp G.H., Robert B.J., Cucherousset J., García-Berthou E., Kirk R., Peeler E. and S. Stakénas**, 2009. Voracious invader or benign feline? A review of the environmental biology of European catfish *Silurus glanis* in its native and introduced ranges. *Fish and Fisheries*, 10:252-282.
- Davies S.J., Nengs I. and M. Alexis**, 1991. Partial substitution of fishmeal with different meat meal products in diets for seabream (*Sparus aurata*). In: INRA (Ed.), *Fish Nutrition in Practice*, June 24-27, 1991 (Les Colloques, No. 61). Biarritz, France, pp. 907-911.

- Davis D.A., Jirsa D. and C.R. Arnold**, 1995. Evaluation of soybean proteins as replacements for menhaden fish meal in practical diets for red drum, *Sciaenops ocellatus*. *J World Aquacult Soc*, 26:48-58.
- El-Sayed A.F.M.**, 1998. Total replacement of fish meal with animal protein sources in Nile tilapia. *Aquacult Res*, 29:275-280.
- Francis G., Makkar H.P.S. and K. Becker**, 2001. Antinutritional factors present in plant-derived alternate fish feed ingredients and their effect in fish. *Aquaculture*, 199:197-227.
- Glencross B.D., Booth M. and G.L. Allan**, 2007. A feed is only as good as its ingredients are view of ingredient evaluation strategies for aquaculture feeds. *Aquacult Nutr*, 13:17-34.
- Gunben E.M., Senoo S., Yong A. and R. Shapawi**, 2014. High potential of poultry by-product meal as a main protein source in the formulated feeds for a commonly cultured grouper in Malaysia. *Sains Malaysiana*, 43 (3):399-405.
- Hertrampf J.W. and F. Piedad-Pascual**, 2000. Handbook on Ingredients for Aquaculture Feeds. Kluwer Academic Publishers, Dordrecht, Netherlands, pp.482-483.
- Higgs D.A., Dosanjh B.S., Prendergast A.F., Beames R.M., Hardy R.W., Riley W. and G. Deacon**, 1995. Use of rapeseed/canola protein products in finfish diets. In: Lim, C.E., Sessa, D.J. (Eds.), *Nutrition and Utilization Technology in Aquaculture*. AOCS Press, Champaign, Illinois, pp.130-156.
- Kissil G.Wm. and Lupatsch I.**, 2004. Successful replacement of fishmeal by plant proteins in diets for the gilthead seabream, *Sparus aurata* L. [*Isr. J. Aquacult. - Bamidgeh*](#), 56(3): 188-199.
- Krogdahl A., Bakke-Mckellep A.M. and G. Baeverfjord**, 2003. Effects of graded levels of standard soybean meal on intestinal structure, mucosal enzyme activities, and pancreatic response in Atlantic salmon (*Salmo salar* L.). *Aquacult Nutr*, 9:361-371.
- Kumar S., Sahu NP., Pal AK., Saravanan S. and H. Priyadarshi**, 2013. Short term exposure to higher temperature triggers the metabolic enzyme activities and growth of fish *Labeo rohita* fed with high protein diet. *Aquacult Nutr*, 19:186-198.
- Li M.H., Robinson E.H. and B.B. Manning**, 2004. Nutrition. In: C.S. Tucker and J.A. Hargreaves (Ed.), *Biology and Culture of Channel Catfish*. Elsevier B.V., Amsterdam, PP. 279-319.
- Millamena O.M.**, 2002. Replacement of fish meal by animal by-product meals in a practical diet for grow-out culture of grouper *Epinephelus coioides*. *Aquaculture*, 204:75-84.
- Parsons C.M., Castanon F. and Y. Han**, 1997. Protein and amino acid quality of meat and bone meal. *Poultry Sci*, 76:361-368.
- Refstie S., Førde-Skjærvik O., Rosenlund G. and K.A. Rørvik**, 2006. Feed intake, growth, and utilisation of macronutrients and amino acids by 1 and 2 year old Atlantic cod (*Gadus morhua*) fed standard or bioprocessed soybean meal. *Aquaculture*, 255:279-291.
- Robaina L., Moyano F.J., Izquierdo M.S., Socorro J., Vergara J.M. and D. Montero**, 1997. Corn gluten and meat and bone meals as protein sources in diets for gilthead seabream (*Sparus aurata*): nutrition and histological implications. *Aquaculture*, 157: 347-359.
- Shapawi R., Ng W.K. and S. Mustafa**, 2007. Replacement of fish meal with poultry by-product meal in diets formulated for the humpback grouper, *Cromileptes altivelis*. *Aquaculture*, 273:118-126.
- Takagi S.T., Hosokawa H., Shimeno S. and M. Ukawa**, 2000. Utilization of poultry by-product meal in a diet for red sea bream *Pagrus major*. *Nippon Suisan Gakkaishi*, 66: 428-438.
- Wang X. and C.M. Parson**, 1998. Effect of raw material source, processing systems, and processing temperatures on amino acid digestibility of meat and bone meals. *Poultry Sci*, 77:834-841.
- Webster C.D., Thompson K.R., Morgan A.M., Grisby E.J. and A.L. Gannam**, 2000. Use of hempseed meal, poultry by-product meal, and canola meal in practical diets

without fish meal for sunshine bass (*Morone chrysops*×*M. saxatilis*). *Aquaculture*, 188:299-309.

Xue, M. and Y. Cui, 2001. Effect of several feeding stimulants on diet preference by juvenile gibel carp (*Carassius auratus gibelio*), fed diets with or without partial replacement of fish meal by meat and bone meal. *Aquaculture*, 198:281-292.