INTERNATIONAL JOURNAL OF SCIENTIFIC INFORMATION

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Review Article

Replacement of Fishmeal with plant origin Soybean Protein for Sustainable Aquaculture: A Review Article

Anupam Sehra[1], Meenakshi Jindal[2*], Jyoti, M[3] and Nirmala Rathee1

1. Department of Zoology, Govt. College, Hisar
2. Department of Zoology, Govt. College, Hisar
3. Department of Botany, Govt. College, Hisar

*Corresponding author: meenjind@gmail.com

Article Received on: 14/04/23 Revised on: 03/05/23 Approved for publication: 22/05/23

ABSTRACT

To get nutritionally rich fish flesh, a nutritionally balanced diet is necessary. The use of rice bran and oil cakes alone does not contain enough nutrients for the better growth of fish. Fishmeal (FM) is major protein source in aqua feeds, but not affordable due to its high price. Therefore, many plant proteins like Soybean, canola, guar etc. are recommended by many nutritionists due to their low price. But among all these plant protein ingredients, soybean is considered as the good nutritive and affordable ingredient in fish feed. The literature under this review revealed how anti nutritional factors present in soybean interfere with the growth of fish and how they can be removed after processing. This review also revealed how the use of processed soybean results in good growth of fish.

Keywords: *Anti-nutritional factors, fish, growth, soybean*

INTRODUCTION

Fish is the rich nutritive source of animal proteins. To achieve maximum yield in shortest possible time, it is necessary to provide artificial feed, by which fish grows rapidly and attains maximum weight. The usual traditional diets *i.e.* Rice bran and oil cakes do not contains enough nutrients for the better growth of fish and also pollute the water. Therefore, fish feed should contain a nutritionally balanced diet to get nutritionally rich fish flesh. Such fishes also fetch better price in the market.

Fishmeal (FM) is the preferred protein ingredient in aquaculture feed because of its nutritive value and palatability. Increasing demand, unstable supply, and high prices of FM along with the continuous expansion of aquaculture are reasons for many nutritionists to realize that soon they will no longer be able to afford it as a major protein source inaqua feeds (Peng *et al*., 2013).To solve this problem, studies have been conducted to evaluate the replacement of FM protein by other sources of vegetable origin (Gatlin III *et al.*, 2007) without any adverse affect on fish growth. Many plant proteins like soybean, canola, guar, moong, sorghum *etc*. Offer considerable promise in this regard owing to their low prices and market availability. Their relative composition of proteins, carbohydrates and oils is desirable as an alternative dietary protein and energy source for fish.

Among plant protein ingredients Soybean (*Glycine max)* is considered as the most nutritive affordable ingredient in fish feed because of its well balanced amino acid profile(NRC, 2011) along with enough quantity of sulphur containing essential amino acids (EAA) such as lysine, cystine and methionine, yet they are not available to the fish as they remain bound to the mailliard compounds. In addition, sufficient amount of minerals and vitamins (Thiamin and Riboflavin) are also present in it. Its sprouting grains contain considerable quantity of vitamin C. Although, vitamin A is present in the form of its precursor carotene which is converted into vitamin A in the intestine. Furthermore, Soybean meal (SBM) has the advantage of being resistant to oxidation and spoilage and is naturally clean from organisms such as fungi, viruses and bacteria that are harmful to fish (Swick *et al*., 1995). Therefore, SBM can be used to partially replace FM from the fish feeds. But when compared with FM, soybean protein concentrate is deficient in methionine (Drew *et al.*, 2007). This deficiency can be compensated by adding some amino-acid and mineral mix while preparing diets for fish (Jindal, 2001; Jindal and Garg, 2005). Moreover, Economic analysis also indicated that inclusion of

SBM in the diet reduces feeding cost also (Hernandez et al, 2007)

Feeding of soybean as a plant protein and its associated effects on the fish growth has been reviewed under the following heads:

I. Anti-Nutritional Factors (ANF's) present in Soybean
II. Soybean as a plant source of Protein

I. Anti-Nutritional Factors present in Soybean

Soybean is widely used as the cost effective replacer of FM in fish feeds due to its high protein content, low carbohydrate and fiber content, high digestibility, excellent amino acid profile, low cost, easy availability and steady supply as compared to the other plant protein sources (Kushwaha, 2013;Gamboa-Delgado *et al.*, 2013). However, at high replacement levels the growth rates of fish are reduced. The growth depression effect of SBM at high inclusion levels may be related to the ANF's present in SBM such as trypsin inhibitor, antigens, lectins, saponins and oligosaccharides *etc.* (Liener, 1989), which interfere with appetite, absorption and metabolism. The contradiction among researchers regarding the use of SBM as a quality protein source may be related to the quality and processing of SBM. Heating SBM helps to rupture the cellulose membrane surrounding the cell and release the cell contents making them more available (Tacon and Jackson, 1985). Heating also inactivates and destroys the anti-nutritional factors (anfs) found in SBM (Tacon, 1993).

Trypsin/ Protease inhibitor

In soybean, there are two groups of protease inhibitors: the Kunitz soybean trypsin inhibitor that is relatively heat- and acid-sensitive, and the more stable Bowman–Birk protease inhibitor. One molecule of the former blocks either one trypsin or one chymotrypsin molecule, while one molecule of the latter blocks either two trypsin or chymotrypsin molecule or one trypsin and one chymotrypsin molecule at the same time (Norton, 1991)their potency depends on their origin and the target enzyme.

Literature studies showed that soybean trypsin inhibitor (TI) activity is negatively correlated with digestibility of protein and lipid and growth rate in carps (Viola *et al.*, 1983), channel catfish (Wilson and Poe, 1985), Nile tilapia (Wee and Shu, 1989) and salmon (Olli *et al.* 1994).Wilson and Poe (1985) reported that when raw or inadequately heated SBM was fed to channel catfish, the growth ratewas reduced in fish. Reducing TI activity improved the growth performance of the fish. The authors indicated that the diets were not deficient in any of the 10 eaas, rather the reduced growth rate might be related to heat stable ANF's. Rumsey (1991) found little effect on growth of trout when feeding at levels of TI ranging from 2.6 to 51.0 mg/g. It seems that below the 5 mg/g TI level, most cultured fish are able to compensate by increasing trypsin production.

Huisman and Van der Poel (1991) concluded that TI can be eliminated by atmospheric steaming (102^0 C) for long processing times. However, processing time which exceeds 40 minutes do not further increase apparent digestibility for nitrogen (Garg, 1999). In addition, high temperature steaming for a short time may also provide an extra beneficial effect on nitrogen and amino acid digestibility. The heat process thus must guarantee sufficient inactivation of ANF's, while avoiding significant degradation of EAA.

Phytates

Phytate (hexaphosphates of myo-inositol) is common in plant seeds. SBM contains about 10–15 g/kg phytate.They can chelate with di- and trivalent mineral ions such as Ca^{2+}, Mg^{2+}, Zn^{2+}, Cu^{3+} and Fe^{3+} resulting in these ions becoming unavailable for consumers (Duffus and Duffus, 1991). Since phytates cannot be broken down by non-ruminants, their occurrence in feed reduces the availability of phosphorus to these animals (Liener, 1989). Phytates also form sparingly digestible phytate–protein complexes, thus reducing the availability of dietary protein (Richardson *et al.,* 1985). Spinelli *et al*. (1983) observed reduced growth rates in rainbow trout when fed a diet containing 5 g/kg synthetic phytic acid. Formation of sparingly digestible phytic acid–protein complexes was found to be the main reason for growth depression. High dietary phytic acid (synthetic, 25.8 g/kg) dramatically depressed the rate of growth in Chinook salmo(Richardson *et al*., 1985). Yang *et al* (2011) indicated that the optimal level of dietary Phytase treated SBM replacement for maximum growth was 26.90 % such replacement led to an increase in nitrogen excretion but reduce total phosphorus excretion

Fermentation has been done to reduce the phytic acid content of grains because of the action of phytases produced by yeast or lactic acid bacteria (Duffus and Duffus, 1991).Phytase significantly enhanced growth whether included with or without phosphorus. Study of Imanpoor and Bagheri (2012) showed that FM is more sufficient for Persian ed forsturgeon and SBM could be partly an alternative protein source if phosphorus is suppli fish by incorporation with microbial phytase or phosphorus It is advisable to maintain the level of phytates below 5 g/kg in fish feeds. The addition of minerals such as Zn has been shown to partially counteract the negative effects of dietary phytate.

Lectins (phytohaemagglutinins)

Plant lectins are found in many legume seeds and are able to bind reversibly to carbohydrate moieties of complex glyco-conjugates present on membranes. Their common biological effects include disruption of the small intestinal metabolism and morphological damage to the villi (Grant, 1991) and results in reduced absorption of nutrients. Irritation caused by lectins to the intestinal membrane resulting in over secretion of mucus may impair the enzymatic and absorptive capacity of the intestinal wall. Their deleterious effect may be more potent when present along with other antinutrients (Aregheore *et al.,* 1998).

Soybean products which are toasted in a proper way contain generally very low levels of lectin. Lectins can be removed by aqueous heat treatment (100°C for 10 min) or by autoclaving(Grant, 1991).

Oligosaccharides

Soybean meal contains approximately 15% of oligosaccharides (sucrose, raffinose and stachyose). Oligosaccharides can have a negative effect on nutrient utilization in fish, whichmay be either due to binding to bile acids or obstructing action against digestive enzymes and movement of substrates in the intestine (Storebakken *et al.*, 1998). It was reported that removal of oligosaccharides from SBM significantly improved the utilization efficiency of nutrients in salmon (Krogdahl *et al.*,2000)and rainbow trout (Murai *et al.*,1986).

Extrusion at high temperature has the potential to improve the carbohydrate digestibility in legume seeds (Burel *et al.*, 2000) because of a higher break up of cell walls and/or a partial degradation of α-galactosides.

Soy antigens

Soy antigens can cause allergic response of animals and lead to intestinal damage. Rumsey (1991) found that trout fed diet containing high levels of the globular antigenic proteins glycinin and β-conglycinin from SBM had inferior growth performance, impaired utilization of dietary protein and intestinal pathology. It was observed that fish fed SBM based diet caused enteritis-like changes in the distal intestine in Atlantic salmon (Krogdahl *et al.,* 2000) and in rainbow trout (Bureau *et al*., 1998) and caused an altered immune response (Bakke-mckellep *et al.,* 2000) and might lead to increased susceptibility to furunculosis (Krogdahl *et al*., 2000).

Saponins

Soyasaponins can contribute an undesirable taste and may alter intestinal functions. Soybean meal and soy flour contain between 0.43-0.67% soyasaponins. In water, Saponins are highly toxic to fish because by the detergent action, they damage gill's respiratory epithelium (Francis *et al.*, 2001). Saponins can be carried over with the protein during extraction in water, therefore, soy protein concentrate and isolate produced by extraction with water alone may contain high levels of saponins (Freeland *et al*., 1985). Soy protein concentrates produced by alcohol extraction are devoid of saponins since alcohol is a 'bond-breaker' and helps to remove saponin from proteins (Bureau *et al*., 1998).

Antivitamin factors

Soybean meals are known to contain a variety of antivitamin factors(Liener,1989)that might affect their efficiency as nutrient sources. These are heat labile therefore, are not of much physiological significance in fish. Most commercially available seed meals are free from antivitamins because they are heat-treated to inactivate trypsin inhibitors and lectins.

II. Replacement of Fishmeal with Processed Soybean

Promotion and practice of aquaculture on large scale will depend ultimately on the food that is cheap and easily digestible, have high conversion value, readily acceptable and not easily disintegrated in water. Usually, protein is the basic and expensive component of animal tissues and is, therefore, an essential nutrient for both growth and maintenance. Protein constitutes 45-75% of tissue dry matter. The capacity of the fish to synthesize protein *de novo* from carbon skeleton is limited and most of the protein should be supplied through the diet. There have been numerous studies on the utilization of SBM in the diet of various species of fish (Table 1). A considerable amount of FM in the diet can be replaced with SBM in omnivorous fresh-water species, such as carp, tilapia and catfish (Viola *et al.*, 1988; Shiau *et al.*,1989 and Webster *et al.*,1995).

Additionally, Webster *et al.* (1995) showed that blue catfish could be grown successfully with the diet containing SBM as the sole protein source. Similar studies with rainbow trout (Tacon *et al.*, 1983), yellowtail (Shimeno *et al.*, 1993) and red drum (Mc Googan and Gatlin, 1997) have reviewed that SBM is also a viable source of protein for carnivorous fishes. Preliminary study on commercial SBM showed that substituting 20 to 50% of FM protein with SBM and supplemental amino acids did not give serious adverse effects on growth of juvenile flounder (Kikuchi *et al.*, 1994). 60% of FM could be replaced by phytase treated SBM in the diets of juvenile rainbow trout without compromising weight gain or feed efficiency (Yu Hong Yang *et al*, 2011). Results of Yu *et al*. Study (2012) indicated that 40% FM could be replaced by SBM in practical feeds of Chineese sucker. Bonvini *et al*. (2018) while formulating the practical diets in on-growing European seabass, suggested that SBM upto 30% can be successfully incorporated into feeds containing low FM inclusions.

Many studies have considered SBM as a partial or total FM alternative for tilapia, with varying results. Depending on fish species and size, dietary protein level, SBM source, processing methods and culture systems employed, SBM can replace 67 to 100% FM. With or without methionine supplementation, 75% of FM can be successfully replacedby SBM in test diets fed to Nile tilapia fry*o. Mossambicus* (Jackson *et al.*, 1982and Tacon *et al.*, 1983) and 67% in case of tilapia hybrids (Shiau *et al.*, 1989). Viola *et al.*(1983) also showed that 50% of FM can be replaced with SBM supplemented with methionine, lysine and 1% oil in the diet of common carp. It appears from these results that SBM can be used to replace up to half of the FM in tilapia feeds without requiring any other supplements. These results were further proved by Liang *et al*. (2017). According to them, in the diets of Japanese seabass 50% FM was replaced with fermented SBM in which crystallized amino acids like lysine, methionine, threonine were balanced. But flesh quality was poorer than those group fed with 25% replacement with SBM. To maintain optimal growth and feed utilization in European seabass, SBM upto 30% can be successfully incorporated into rthe feeds containing low FM inclusion (Bonvini*et al.*, 2018). Ming He *et al*. (2020) concluded that fermented SBM could replace 30% FM in the diet of largemouth bass without negative impact on growth performance, wheras SBM should be controlled below 30%.

It appears that carnivorous fish species such as salmon and trout are more sensitive to the ANF's in SBM than herbivorous or omnivorous species such as carp. In general, however, SPC has been proved to have better nutritional value and produced better growth performance in fish compared to SBM. Partial replacement of FM by SPC can be expected to have economical benefit due to the better growth performance as illustrated by the literature studies. Furthermore, using SPC in fish feed can assure a healthy status of fish whereas using SBM in fish feed may cause altered immune response and susceptible to pathogens. In addition, it was reported that application of SPC in extruded salmon feed pellets improved pellet durability, fat absorption, fat leakage, sinking rate and water holding capacity (Herzog *et al.*, 2002).

Vielma *et al. (*2000) reported that when trout with an average body weight of 0.25 - 2.02 kg, fed a diet containing 69% of the protein from soy ingredients (55.6% from SPC and 13.8% from SBM) grew significantly faster than fish fed FM based diet. With SBM, however, Dabrowski *et al*. (1989) reported that the growth rate of rainbow trout fry was reduced significantly when 50% of FM was replaced by SBM, and 100% replacement resulted in severe growth depression and mortality.But, When Haghbayan and Mehrgan (2015)used enzyme treated (HP310) as FM alternative in rainbow trout diet, they found that 50%

HP310 had a positive effect on growth performance. Whereas, according to Vorhees *et al.* (2019) bioprocessed SBM could replace atleast 80% of FM in adult rainbow trout diets without any adverse effect.

Jackson *et al.* (1982) showed that 25% of dietary protein from FM could be replaced by SBM without significantly influence growth performance of tilapia. At higher SBM inclusion levels, however, the growth rate of fish was lower (up to 33% decrease at 100% replacement). The authors indicated that the low methionine level as well as the incomplete denaturing of the trypsin inhibitor and haemagglutinins during treatment of the meal might contribute to the inferior growth rate of fish fed a diet with high SBM inclusion level. The similar results were also observedby Davis and Stickney (1978) in *O. Aureus*. Shiau *et al. (*1989) observed that without methionine supplementation, FM could be partially (30%) replaced by SBM when the dietary protein level was sub-optimal (24%) for tilapia growth. The replacement of FM by SPC can also have positive effect on environment. It was observed that inclusion of SPC in the diet reduced P losses in salmon (Storebakken *et al.*,1998). Trout fed SBM diet had reduced fecal dry matter content, indicating diarrhoea. Whereas the trout fed SPC diet had constantly high fecal dry matter content (Olli *et al.*, 1994).

Khan and Jafri (1994) reported that incorporation of soybean protein above 43% depressed the growth of *Labeo rohita*. On the other hand, Kim *et al.(*1995 a,b) reported that increasing the incorporation of full-fat or roasted soybean in the diets of *C. Carpio* also resulted in decreased weight gain. No such reduction or depression in fish growth and digestibility was observed in teleost, *C. Punctatus*, even when FM was totally replaced by processed soybean (Jindal, 2001and Jindal and Garg, 2005).

Mambrini *et al.* (1999) demonstrated that SPC (Soycomil) could replace 50% of dietary protein from FM in rainbow trout. Medale *et al.* (1998) observed that up to

75% of dietary protein from FM could be replaced by SPC without negative influence on voluntary feed intake and growth of trout fed with demand feeders. However, 100% replacement of FM by SPC reduced growth rate of fish. Similar results were obtained by Stickney *et al.* (1996), trout fed a diet with 50% of protein from SPC as replacement of FM grew as well as the fish fed FM diet. However, 70 to 100% replacement reduced growth rate of trout.

According to Yessica silva *et al*. (2012), weight gain in shrimp increased when fed on SBM based diets with 25% protein replacement. There was a negative linear trend for growth parameters and feed intake as protein replacement with SPC increased (Soares *et al.,* 2015). According to Chen *et al.* (2019) juvenile pearl gentian grouper fed with SPC 30 and SPC 15 showed significantly higher protein and amino acid retention than SPC 45, 60 and 75. Fish meal by-product can be replaced by up to 75% of SPC, with no harm to the growth of Pacific white shrimp. High levels of inclusion of soybean protein, without the use of FM, are usually tolerated and result in good performance results when the nutritional requirements of shrimp are properly balanced (Forster *et al.*, 2002;Sookying and Davis, 2011,2012and Sookying *et al.,* 2013). Yang *et al.* (2015) indicated that 20% FM could be replaced with extruded SBM in the basic diets containing 40% protein and 30% FM in the diets of juvenile white shrimp.

Another study, using the same species and levels of replacement by SPC, but with different levels for lysine, histidine, phenylalanine, and methionine in some diets tested, showed no significant differences in growth between treatments (Bauer *et al.*, 2012). Thus, it is assumed that a factor other than the absence of EAA is limiting growth. Sa*et al.* (2013) found that FM can be completely replaced by SPC when the minimum levels of fish oil are met, without compromising shrimp growth. The removal of specific carbohydrates duringspc processing may reduce palatability, which is frequently reported when vegetable protein sources are used for aquatic species (Forster *et al.*, 2002).

Fish meal and marine animal protein meals generally contain more fat and minerals than soy protein. When using soy protein to replace FM or marine animal protein, the nutritional balance in the diet should be considered, including EAA, fatty acids, energy and minerals. Phosphorous is the most critical mineral when formulating fish feeds with high level of soy protein (Akiyama, 1988). Soy protein concentrate (SPC) contains 0.8% P, however, a considerable amount of P is bound in phytic acid and unavailable in fish.

Minerals, rather than limiting EAA, may be the limiting factors in the efficient utilization of SBM for tilapia. Viola *et al.* (1988) found that when SBM based diet supplemented with lysine, methionine, oil and dicalcium phosphate (DCP) was fed to tilapia hybrids (*O. Niloticus x O. Aureus*), then growth was similar to that of fish offered a FM-based diet. In further studies, the authors reported that the non-inclusion of the limiting EAA to SBM-based diet did not result in any growth retardation, while SBM supplemented with 3% DCP + oil can completely replace FM without any adverse effects on fish growth. Saidy and Gaber (2007) suggested that a diet with 55% SBM (33.2% crude protein) supplemented with 0.5% L-lysine could totally replace FM in a diet for Nile tilapia fingerlings, without any adverse effect. The authors concluded that phosphorus was the limiting factor in SBM. The same results were also concluded by Jindal and Gulati (2016).

Jindal (2001) prepared 10isonitrogenous and isocaloric diets (D_1 to D_{10})containingprocessed soybean(PS) at various inclusion levels) without supplementation (D_1 to D_5) and with supplementation (D_6 to D_{10}) of mineral mix and amino-acids (MM) for *Channa punctatus*. Studies have revealed that significantly ($P < 0.05$) high growth, digestibility and carcass protein deposition were observed in the test fish fed on diets

D_4 (75% PS). Further, much more growth, digestibility and carcass protein deposition were recorded in the test fish fed on D_{10}(100% PS + Mineral mix).

The results of Wang *et al.* (2015) study showed that 40% of FM could be replaced by SBM in diets of juvenile *P. Ussuriensis*without having a significant negative effect on growth, but higher dietary SBM levels reduce fish performance. According to Chou*et al.* (2004) up to 40% of FM can be replaced by SBM without causing reduction in growth and protein utilization.Protein from SBM could substitute less than 75% for FM without influencing the growth of tilapia. The higher substitution levels of SBM induced negative influences on growth, feed utilization and serum lysozyme of tilapia (Shimei Lin, 2011).Jahan *et al.* (2007) after considering fish growth, FCR and PER suggested that FM might be replaced 50% by SBM in the diet of mrigal, *Cirrhinuscirrhosa* fry for better growth.

Nasir (2013) tested four experimental diets on common carp fingerlings containing different levels of soybean: I) 20% FM + 15% soybean, II) 15% FM+ 20% soybean, III) 10% FM+ 25% soybean, 1V) 5% FM + 30% soybean. The results suggested that FM can be replaced by cheaper and available local soya bean with small adverse effects on growth, survival and feed conversion ratio of the fish. The results also indicated that the possibility of using 5% FM and 30% soybean in the diet of fingerlings gave a similar growth patterns.

CONCLUSIONS

By this review, it is concluded that processed soybean, if supplemented with some essential minerals, can be recommended as a replacement of FM based diet for enhancing the growth, feed efficiency and nutrient retention of the test fish. Such fishes also fetch better price in the market.

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Cite this article as: *Sehra, Replacement of Fishmeal with plant origin Soybean Protein for Sustainable Aquaculture: A Review Article . Int. J. Sci. Info. 2023; 1(2):58-78.*

Source of support: Nil, Conflict of interest: None Declared

Table 1: Processed soybean as an alternative protein source tested and recommended for various fish species. Levels tested are a substitution of standard dietary protein (mainly fishmeal, FM) or whole diet. Recommended levels are based on biological and or economic evaluation.

Source	**Level (%) tested**	**Level (%) Recommended**	**Species**	**References**
SBM± Methionine	**0-100**	**100**	*Oreochromis aureus*	Davis and Stickney (1978)
SBM	0 - 100	75	*O. Mossambicus*	Jackson *et al*. (1982)
SBM± Methionine	75	75	*O. Niloticus*	Pantha (1982)
SBM	0 - 100	25	*O. Aurea*	Jackson *et al*. (1982)
SBM± Methionine	75	75	*O. Niloticus*	Tacon *et al*. (1983)
SBM±EAA +Oil	0-100	50	*Cyprinus carpio*	Viola *et al*. (1983)
SBM	0 - 100	30	Tilapila hybrids *O.niloticus x O.aureus*	Shiau *et al*. (1989)
SBM	0- 20	10	*Anguilla anguilla*	Degani (1987)
SBM±EAA +DCP+Oil	0 - 100	100	Tilapila hybrids *O.niloticus x O.aureus*	Viola *et al*. (1988)
SBM +DCP+Oil	0 - 100	100	Tilapila hybrids *O.niloticus x O.aureus*	Viola *et al*. (1988)
SBM	0-100	50	*O.niloticus*	Teshima and Kanazawa (1988)
SBM + Methionine	0 - 100	67	Tilapila hybrids *O.niloticus x O.aureus*	Shiau *et al*. (1989)
SBM	0 – 100	50	Rainbow trout fry	Dabrowski *et al. (1989)*
SBM	0-57	43	*Labeo rohita* fingerlings	Khan and Jafri (1994)
SBM	0 - 100	75	*Oreochromis niloticus*	Mazid *et al*. (1994)

SB flour +PMM (75:25)	25 - 75	25	*Oreochromis niloticus*	Sadiku and Jauncey (1995)
FFS	0 - 56	<25	*Cyprinus capiro*	Kim *et al*. (1995b)
Soya flour	50 - 75	50	Polyculture *Macrobranchium rosenbergii* with *C. Catla* and *L.rohita*	Ramachandra and Shivnandamurthy (1996)
SPC	0 - 100	50-70	Rainbow trout	Stickney *et al. (*1996)
SPC	0 - 100	100	*O. Niloticus*	Abdelghany (1997)
SPC	0 - 100	75	Rainbow trout	Medale *et al.*(1998)
PS	0 - 100	75	*Cirrhinus mrigala* fingerlings	Garg (1999)
PS	0 - 100	75	*Channa punctatus*	Jindal (2001), Jindal and Garg (2005)
PS + MM	*0 - 100*	*100*	*Channa punctatus*	*Jindal (2001), Jindal and Garg (2005)*
SBM	*0 - 100*	*50*	*Cirrhinus cirrhosa fry*	*Jahan et al (2007)*
SBM	*0 - 100*	*75*	*O. Niloticus*	*Shimei Lin (2011)*
FM + SB	*5 – 20% FM* *15 – 30% SB*	*5% FM + 30% SB*	*Cyprinus capiro*	*Nasir (2013)*
SPC	*0 - 100*	*75*	*Shrimp*	*Sooking and Davis (2011, 2012);Sooking et al. (2013)*
SPC + Fish oil	*0 - 100*	*100*	*Shrimp*	*Sa et al. (2013)*
SBM	*0-100*	*40*	*P. Ussuriensis (juveniles)*	*Chou et al.(2004)* *Wang et al.(2015)*

PS - Hydrothermically Processed Soybean
DCP - Dicalcium Phosphate
SBM - Soybean Meal
PMM - Poultry Meat Meal
SB – Soybean
FFS - Roasted Full Fat Soybean
EAA - Essential Amino Acids
CP - Crude Protein
MM - Mineral mix and amino acids, Agrimin (Glaxo India Ltd.)
± sign refers to with or without supplementation