The use of soya protein in aquafeeds

By Yueming Dersjant-Li, ADM Specialty Ingredients Division

Fish meal is an excellent protein source in fish feed due to its balanced amino acid profile and high digestibility. Traditionally, fish meal is the main dietary protein source in fish feed formulation, especially for carnivorous fish species such as salmon and eel. In general, fish feed contains 5 to 50% of fish meal.

In commercially manufactured feeds for shrimp culture, marine animal protein sources such as fish, shrimp and squid meals are the primary protein sources being included in the feed, at a level between 30 to 50%.

Statistical data from the Food and Agriculture Organization (FAO) of the United Nations indicated that aquaculture is continuously increasing and the supplies from fisheries stabilised and even tend to decrease. However, the demand on fish production for human consumption is increasing and leading to reduced fish meal and fish oil production. For example, fish meal production was 6,83, 6,86, 6,70, 5,28 and 6,06 million metric tons in 1995, 1996, 1997, 1998 and 1999 respectively.

Fishmeal Information Network estimated that approximately 35% of fish meal is consumed by the fish feed industry, while 29% of fish meal is consumed by the pig feed industry. As for land farmed animals such as poultry and ruminants, up to 10% (maximum) of fish meal is included in the diets. In contrast, up to 55% of fish meal is included in fish feed. In fact, aquaculture has become the fastest growing food production sector of the world, with an average annual increase of about 10% since 1984 compared to a 3% increase for livestock meat and a 1,6% increase for capture fisheries (FAO, 1997).

The rapid development of aquaculture will result in a high demand and a shortage of supply of fish meal. Furthermore, the contamination of certain fish meal with dioxins has reduced the quality of fish meal as a raw material to be included in fish feed. Those factors are forcing feed industries and scientists to search for alternative protein sources in fish feed.

Table 1 shows the use of fish meal by species in 1994 and estimated fish meal use in 2010. It is predicted that, generally, aquaculture feeds will use lower levels of fish meal. To meet the high dietary protein requirement of fish, alternative protein sources will be used in fish feed as replacement of fish meal.

Alternative protein sources

Animal proteins such as poultry by-products, meat and bone meal have been used to replace fish meal in fish feed. Animal proteins are good protein sources with a low price, which can be used to partially replace fish meal. However, due to the occurrence of bovine spongiform encephalopathy (BSE), consumers are questioning feeding practices based on the use of animal proteins as raw materials in animal feed. In some countries, animal proteins are banned in animal feed.

Therefore, the future development of animal feed will head towards a vegetable-based formulation.

Plant ingredients which contain high protein content, such as oilseeds, are alternative protein sources for fish meal. These ingredients are readily available worldwide and at a low cost. However, plant proteins in general are low in some essential amino acids and contain anti-nutritional factors (*Table 2*). Therefore, the inclusion levels of raw or under-processed plant materials are limited in fish feed.

On the other hand, proper processed plant ingredients with high-protein content and with high digestibility of crude protein and low anti-nutritional components, are potential alternative protein sources for replacement of fish meal in fish and shrimp diets.

Among oilseeds produced, soya bean meal contributes more than 50% of the production.

Nutritional value of soya bean meal

Soya bean meal (SBM) is considered as the most nutritive plant ingredient widely used in pig, poultry and fish feed. Among plant

Table 1: Estimated production (thousand metric tons) of aquaculture feeds and the use of fish meal in aquaculture feed. (Source: Dudley-Cash, 1998)

Species	1994			2010		
	Feed produced	Fish meal used	%	Feed produced	Fish meal used	%
Salmon	685	351	51	1 600	480	30
Trout	446	171	38	560	140	25
Shrimp	922	241	26	2 940	588	20
Eels	186	93	50	155	47	30
Bream/bass	97	58	60	240	72	30
Carp	300	45	15	1 040	52	5
Yellow tail	70	42	60	90	27	30
Catfish	530	22	4	1 218	12	1
Others	337	61	18	820	88	11
Total	3 573	1 084	30	8 663	1 506	17

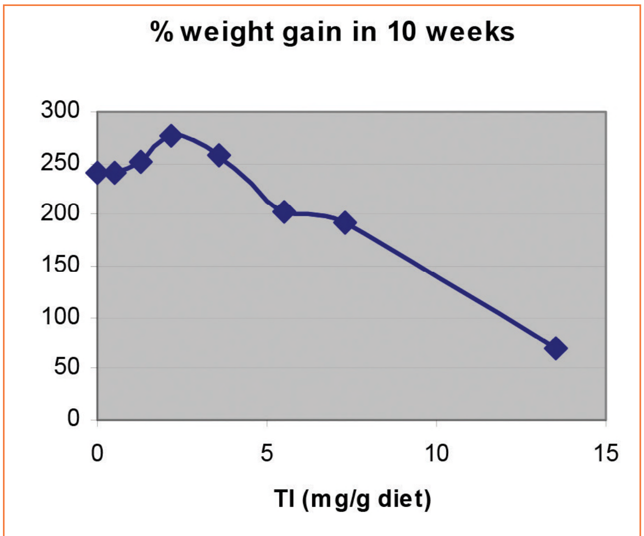
Table 2: Nutritional values of common protein ingredients in fish diets. (Data on as-fed basis, NRC, 1998)

	Fish meal menhaden	Soya protein concentrate[1]	Soya bean meal	Potato protein	Sunflower meal	Corn gluten meal	Cottonseed meal
Composition %							
Dry matter	92	93	89	91	93	90	90
Crude protein	62,9	65	44	73,8	42,2	60,2	41,4
AA composition %							
Lysine	4,81	4,23	2,83	5,83	1,17	1,02	1,72
Methionine	1,77	0,91	0,61	1,68	0,66	1,43	0,67
Met & Cys	2,34	1,89	1,31	2,88	1,35	2,52	1,37
Threonine	2,64	2,73	1,73	4,3	1,28	2,08	1,36
Isoleucine	2,57	3,19	1,99	4,09	1,69	2,48	1,3
Tryptophan	0,66	0,78	0,61	1,02	0,54	0,31	0,48
Arginine	3,66	4,94	3,23	3,8	3,59	1,93	4,55
Phenylalanine	2,51	3,45	2,18	4,89	2	3,84	2,2
Valine	3,03	3,38	2,06	4,89	2,33	2,79	1,78
Histidine	1,78	1,82	1,17	1,71	1,07	1,28	1,17
Leucine	4,54	5,2	3,42	7,61	2,57	10,19	2,47
Antinutritional factors							
	Biogenic amine dioxin	Very low	Protease inhibitors, allergens, oligosacch arides, lectins, saponin	Solanidine glycol alkaloids (solanine, chaconin), sulfite	Chlorogenic acid, fibre	Mycotoxins (high xanthophylls)	Gossypol, cyclopropenoid fatty acids, tannins

[1] Using Soycomil FG as an example, a soya protein concentrate produced by ADM Europoort B,V, Rotterdam, The Netherlands.

protein ingredients, SBM has a well-balanced amino acid profile. Furthermore, 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 shrimp and fish (Swick *et al.*, 1995).

Figure 1: The relationship between trypsin inhibitor activity (TI) and growth performance of channel catfish. (Wilson & Poe, 1985)



SBM can be used to partially replace fish meal or animal protein in fish and shrimp diets. In general, however, at high replacement levels the growth rates of fish and shrimp are reduced. The growth depression effect of soya bean meal at high inclusion levels may be related to the antinutritional components presented in SBM, as illustrated in *Table 2*. It has been observed in many fish species that antinutritional components in SBM, such as trypsin inhibitor, antigens, lectins, saponins and oligosaccharides, can have a negative effect on digestibility of nutrients and performance of fish.

Trypsin inhibitor

Literature studies showed that soya bean trypsin inhibitor activity is negatively correlated with digestibility of protein and lipid and growth rate in salmon (Olli *et al.*, 1989), rainbow trout (Sandholm *et al.*, 1976), carps (Viola *et al.*, 1983, Abel *et al.*, 1984), Nile tilapia (Wee & Shu, 1989) and channel catfish (Wilson & Poe, 1985). Alarcon *et al.* (1999) observed that sea bream alkaline digestive proteases was inhibited by 42,6% after incubation of an extract with a solution containing raw soya bean meal.

Wilson & Poe (1985) observed that the best growth of channel catfish occurred when 83% (e.g. 3,2g TI/g diet) of the trypsin inhibitor activity in the soya bean meal had been destroyed (see *Figure 1*).

Lectins

Lectins can cause morphology changes in the intestine and therefore reduce the absorption of nutrients. Hendriks *et al.*, (1990) demonstrated the high sensitivity of the distal small intestine to the toxic effect of soya bean lectin in Atlantic salmon.

Oligosaccharides

Soya bean meal contains approximately 15% of oligosaccharides (sucrose, raffinose and stachyose). Oligosaccharides can have a negative effect on nutrient utilisation in fish. It was reported that removal of oligosaccharides from SBM, significantly improved the utilisation efficiency of nutrients in salmon and rainbow trout (Murai *et al.*, 1987; 1989, cited by Krogdahl, 1989).

Arnesen *et al.* (1989) found that alcohol soluble carbohydrate from SBM had a negative influence on digestibility of protein and lipid in salmon and in trout (tendency). For both species, alcohol soluble carbohydrate showed a negative effect on faecal dry matter content.

Table 3: Essential amino acids composition of SPC and requirement of fish (% of diet).

	SPC[1] (cp 65%) % as is	SPC % at 30% protein level	Requirement[2] Channel catfish	Rainbow trout	Common carp	Tilapia
Arginine	4,94	2,3	1,2	1,5	1,31	1,18
Histidine	1,82	0,8	0,42	0,7	0,64	0,48
Isoleucine	3,19	1,5	0,73	0,9	0,76	0,87
Leucine	5,2	2,4	0,98	1,4	1	0,95
Lysine	4,23	2,0	1,43	1,8	1,74	1,43
Met + Cys	1,89	0,9	0,64	1,0	0,94	0,9
Phe + tyr	3,45*	1,6*	1,4	1,8	1,98	1,55
Threonine	2,73	1,3	0,56	0,8	1,19	1,05
Tryptophan	0,78	0,4	0,14	0,2	0,24	0,28
Valine	3,38	1,6	0,84	1,2	1,10	0,78

*[1]Soycomil FG, ADM Europoort bv, Rotterdam, The Netherlands; [2]NRC, 1993; *Only phenylalanine*

Soya antigens

Soya antigens can cause allergic responses in animals and lead to intestinal damage. Rumsey *et al.* (1994) found that trout fed a diet containing high levels of the globular antigenic proteins, glycinin and β-conglycinin from SBM, had inferior growth performance, impaired utilisation of dietary protein and intestinal pathology.

Fish fed a full-fat SBM based diet showed damaged epithelium, with an increased number of goblet cells and a marked decrease or even absence of absorptive vacuoles. The microvilli of the enterocytes were shortened, with increased microvillar vesicle formation (Van den Ingh *et al.*, 1991), whereas fish that received a soya protein concentrate based diet have a normal, healthy intestinal structure, which is comparable to the fish that received a fish meal diet. The authors suggested that these changes might be due to the presence of antinutritional factors in a full-fat soya bean meal diet.

It was observed that a soya bean meal based diet caused enteritis-like changes in the distal intestine in Atlantic salmon (Baeverfjord & Krogdahl, 1996; Krogdahl *et al.*, 2000; Refstie *et al.*, 2001) and in rainbow trout (Bureau *et al.*, 1998) and caused an altered immune response (Rumsey *et al.*, 1994; Bakke-McKellep *et al.*, 2000) and might lead to increased susceptibility to furunculosis (Krogdahl *et al.*, 2000).

The alcohol extract of SBM (soya bean molasses) has been found to cause the enteritis-like changes (Van den Ingh *et al.*, 1996; Krogdahl *et al.*, 2000) and correspondingly alcohol-extracted soya protein concentrate has been found to be of high nutritional value in salmonid diets (Olli & Krogdahl, 1994).

Saponins

Soya saponins can contribute an undesirable taste and may alter intestinal functions. The presence of soya saponins in soya products is highly dependent on the mode of preparation. Soya bean meal and soya flour contain between 0,43 and 0,67% soya saponins (Ireland *et al.*, 1986). Saponins can be carried over with the protein during extraction in water. Therefore, soya protein concentrate and isolate produced by extraction with water alone, may contain high levels of saponins.

It was found that a soya isolate (90% cp) contained 0,8% of saponins (Ireland *et al.*, 1986). Soya 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). It was reported that purified alcohol extracts from soya bean meal and soya protein isolate (prepared by an extraction process aimed at the isolation of soya saponins) depressed feed intake and growth dramatically in Chinook salmon and depressed growth of rainbow trout (Bureau *et al.*, 1998). The authors suggested that soya saponins were responsible for the effect of the extract used in this study.

Saponins in water are highly toxic to fish because of the damage caused to the respiratory epithelium of the gills by the detergent action of the saponins (Francis *et al.*, 2001). It was observed that soya protein isolate, which is produced by aqueous solubilisation and iso-electric precipitation of protein from soya flakes, appears to depress feed intake in a similar manner as soya bean meal in Chinook salmon (Hajen *et al.*, 1993).

Since soya protein isolate contains very low levels of antitrypsin factors, lectins and oligosaccharides, it indicated that heat stable, alcohol-soluble factors appear to be responsible for the depression of feed intake in salmon and may be also in other fish.

Nutritional value of SPC

The amino acid profile in fish meal in general reflects dietary amino acids requirement of fish. Compared to fish meal, soya protein concentrate (SPC) has a balanced amino acids profile. *Table 3* presents an example of amino acids provided by SPC at a dietary protein level of 30%. Assuming SPC is used as the sole protein source in fish feed, the essential amino acids provided by SPC meet the dietary requirement of channel catfish, common carp and tilapia very well. For rainbow trout, methionine concentration in the diet may need to be balanced by other protein ingredients or synthetic amino acid.

This article was originally published on *www.researchgate.net* and has been shortened and edited for this publication. For the complete article and references, email the author at Ydersjantli@admworld.com.