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Biochemical Composition and Nutritive Value of Common Fish Feed Ingredients of Plant and Animal Origin†

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Formulated fish feed has a very important role in the field of intensive fish farming. Therefore it is essential to assess biochemical and nutritional composition of the ingredients used in the manufacture of the feed to formulate a feed according to the nutritional requirements of fish. In the present study, an attempt has been made to analyze the biochemical composition of some of the common feed ingredients, of both plant origin (Commercial wheat flour, Wheat gluten, Wheat bran, Commercial maida, Commercial atta, Maize, Maize bran, Soya flour and Rice flour) and animal origin (Indian fish meal, Danish fish meal, Peruvian fish meal and Shrimp head meal). A greater amount of variation was observed in the moisture content among ingredients ranging from 4.8-12.8%. The total protein content except in the case of wheat gluten and soya flour was lower in ingredients from plant sources. The essential amino acid composition was also found to be lower in proteins of plant origin when compared to that of animal proteins. The fatty acid analysis of the feed ingredients showed that the n-3 fatty acids were present in higher concentration in all fishmeals and shrimp head meal as compared to ingredients of plant origin. $C_{16:0}$, $C_{18:0}$ and $C_{18:2}$ were the major fatty acids present in the lipids of the ingredients of plant origin, accounting for more than 80%. In the present study, the notable difference was observed between ingredients of plant and animal origin with respect to the proportion of essential amino acids and n-3 polyunsaturated fatty acids ($C_{20:5}$ and $C_{22:6}$) indicating that ingredients of animal origin were superior in nutritional composition as compared to the ingredients derived from plants.

Key words : Fish feed ingredients, amino acid composition, fatty acid profile

Many countries have resorted to large-scale aquaculture of several varieties of fishes, as the production from capture fishery is stagnating. More than half of the world's population has an insufficient and nutritionally unbalanced diet (Agrawal, 1999). Aquaculture can make a significant contribution to nutrition in many parts of the world by virtue of its high productivity and by the fact that aquaculture crops are protein crops rather than sources of starchy staple food. Aquaculture has the potential of producing large quantities of low cost, protein-rich food (Bardach *et al.*, 1972). The importance of aquaculture in the overall economy of India has now been well recognized.

Because the nutrient contribution from natural food available in the market cannot meet the requirements of the fish in intensive fish farming, nutrients and energy are provided primarily through prepared feeds. Fish requires protein, vitamins, minerals, lipids and energy for normal growth and other physiological functions (New, 1987). Protein in the feed functions as the source of amino acids. Animals can synthesize some amino acids within the body, which are termed as non-essential amino acids, where as the rest, termed as essential amino acids should be given through the diet. So it is essential that feed should always be formulated to include the essential amino acids in

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the proper rátio when such ratios are known (Agrawal, 1999).

A properly formulated feed should fulfill the minimum daily nutritional requirements of the animal and also should lead to a reasonable rate of growth (Agrawal, 1999). No single feed ingredient can supply all the nutrients and energy required for optimum growth of fish. Thus, commercial fish feeds contain a mixture of feed ingredients and vitamin and mineral premixes that provide adequate amounts of essential nutrients. The amount of each feed ingredient used depends on several factors including nutritional requirements, cost of ingredients, availability of each ingredient and processing characteristics. Many ingredients are used for feed manufacturing. But information about the nutrient content of many of these ingredients is not available. So the present study is aimed at generating information on the nutritional components of some of the common fish feed ingredients.

Materials and Methods

The feed ingredients used in the present study were procured from one of the leading fish feed manufacturer in Cochin. Nine ingredients of plant (Commercial wheat flour, Wheat gluten, Wheat bran, Commercial maida, Commercial atta, Maize, Maize bran, Soya flour and Rice flour) and four ingredients of animal origin (Indian fish meal, Danish fish meal, Peruvian fish meal and Shrimp head meal), which are commonly used in manufacture of fish feeds, were analyzed for the proximate composition. They were finely powdered and moisture content, crude protein, crude fat and ash content were analyzed according to standard AOAC procedures (1990).

In order to determine the amino acid composition, 8 ingredients of plant origin (Commercial wheat flour, Wheat gluten, Wheat bran, Commercial maida, Maize, Maize bran, Soya flour and Rice flour) and four ingredients of animal origin (Indian fish meal, Danish fish meal, Peruvian fish meal and Shrimp head meal) were hydrolyzed in 6N HCl for 24 h at 110^{0}C. The acid was removed by vacuum evaporation. Made up to a known volume with 0.05N HCl and analyzed using HPLC (Ammu *et al.*, 1994). Tryptophan content of the samples was determined after alkali hydrolysis (Sastry & Tummuru, 1985).

Fatty acid compositions of 5 ingredients from plant source (commercial wheat flour, commercial atta, maize, maize bran and soya flour) and 4 ingredients from animal source were determined by GLC. Lipid extraction was done using Bligh and Dyer method (1959) and analyzed by gas chromatography using packed column, 2mx1/8", packed with 15% OV 275 and flame ionization detector and nitrogen as carrier gas (Metcalfe *et al.*, 1966). Identification and quantification of fatty acids were done using Sigma standards.

Results and Discussion

The proximate composition of the various ingredients analyzed during the investigation is given in Table 1. Notable variation was observed in the moisture content of different ingredients, ranging from 4.8-12.8%. Though moisture does not directly contribute to the nutritional value of the feed, the increased moisture content supports the growth of microorganisms and ultimately leads to the production of toxins (Gomez *et al.*, 1997).

In fish feed formulations, the protein supplements are either plant proteins or animal proteins. Feed ingredients containing 20% crude protein or more are considered protein supplements and less than 20% are considered to be only as energy supplements (Robinson *et al.*, 2000). In the present study, plant protein sources were observed to be of lower in protein content (<20%), except Wheat gluten (86.5%) and Soya flour (58%), indicating that most of the ingredients of plant origin could be used as energy supplements rather than protein supplements in fish feed formulations. The results

Table 1. Proximate composition of common fish feed ingredients of plant and animal origin

Ingredients	Moisture (%)	Protein (% of dry matter)	Crude fat (% of dry matter)	Ash (% of dry matter)
Ingredients of plant origin				
Commercial wheat flour	11.9	11.1	2.3	0.6
Wheat gluten	7.9	86.5	4.1	0.5
Wheat bran	10.5	18.4	3.5	4.3
Commercial maida	11.1	14.0	1.3	0.7
Commercial atta	10.3	11.1	1.4	1.0
Maize	11.8	12.9	1.6	2.5
Maize bran	12.8	12.7	1.4	2.1
Soya flour	8.6	58.0	2.2	9.7
Rice flour	10.8	13.6	0.55	1.8
Ingredients of animal origin				
Indian fish meal	7.6	61.9	8.0	20.1
Danish fish meal	5.1	75.7	10.1	14.0
Peruvian fish meal	7.1	75.0	8.0	17.0
Shrimp head meal	4.8	40.6	7.6	28.9

in the present study were comparable with the lower protein content of plant ingredients reported by Alagarswami & Gopakumar (1995). According to Adelizi *et al.* (1998) ingredients of plant origin are deficient in most of the essential amino acids, especially lysine and methionine, which are the limiting amino acids in the feeds. In the present study also, most of the plant ingredients were lower in essential amino acids, such as aspartic acid, lysine, methionine and tryptophan (Table 2). Soybean meal contains 58.5% protein and is the prominent source used in fish feeds. The high protein content of soya hull was reported by Poore *et al.* (2002). Nyirenda *et al.* (2000) reported that soya meal could be used as a substitute for fish meal in the feed. It has the best amino acid profile of all common plant proteins and is highly digestible in fish (Lovell, 1988; Lim & Akiyama, 1992). Fish meal, which accounts for 40-60% of total dietary protein in fish feed (Weerd, 1995), generally promotes good growth of aquaculture animals when it is supplied as primary protein source. It is assumed that the amino acid balance in fish meal approximates the required ratio for cultured fish (Agrawal, 1999). Since fish meal is a good source of essential amino acids, it is often used to supplement feeds containing plant proteins. Fishmeal is also rich in energy, minerals and essential fatty acids.

The levels of different essential amino acids (Table 2) of the ingredients showed that aspartic acid was present at higher concentration in animal feed ingredients as compared to plant ingredients except in the case of rice flour and soya flour. Histidine did not show notable variation between the plant and animal protein sources except the low levels observed in Maize (1.9%) and Wheat gluten (2.1%). There were no significant difference in the levels of branched chain amino acids, leucine, isoleucine and valine between animal and plant derived ingredients other than in shrimp head meal. Shrimp head meal had a high-level of isoleucine. The levels of arginine and lysine were also low in plant ingredients. Animal ingredients had a methionine content of 1.3-7.7% where as plant ingredients were low (<2.2%), except maida (4.1%) in methionine content. The decreased level of methionine in vegetable diet was reported earlier by Krajvcovivcova-

Table 2. Amino acid composition of the ingredients of common fish feed ingredients of plant and animal origin (g/ 16g nitrogen)

Amino acid	Ingredients of plant origin								Ingredients of animal origin			
	Wheat gluten	Wheat bran	Wheat flour	Maida	Maize	Maize bran	Soya flour	Rice flour	Indian fish meal	Danish fish meal	Peruvian fish meal	Shrimp head meal
Aspartic acid	3.9	4.5	7.5	4.1	6.5	6.1	14.5	10.4	13.4	12.9	9.2	9.4
Threonine	2.7	2.3	3.4	2.6	3.0	3.4	4.0	3.6	4.5	4.2	3.7	3.4
Serine	5.8	4.5	4.8	4.3	4.6	4.8	6.0	5.2	4.9	5.1	3.2	4.4
Glutamate	50.5	34.7	22.2	38.2	22.5	19.4	23.4	23.9	12.8	19.4	14.3	14.2
Proline	-	9.2	7.2	8.3	8.5	6.4	6.0	5.3	4.8	4.4	4.1	4.1
Glycine	3.0	4.0	6.1	3.5	3.1	4.1	5.2	6.2	9.6	10.3	6.3	6.4
Alanine	0.6	3.7	6.0	2.7	11.0	6	5.8	0.2	11.9	12.5	7.6	7.1
Cysteine	-	-	1.1	-	1.1	1.2	1.1	-	0.7	0.4	1.4	-
Valine	4.4	2.8	5.3	1.3	4.8	9.1	5.4	6.8	4.1	3.9	5.6	3.3
Methione	1.3	0.6	1.4	4.1	1.2	1.8	0.5	2.2	3.4	3.2	7.7	1.3
Isoleucine	3.9	2.7	3.5	3.3	4.2	3.8	3.7	4.6	4.5	4.1	7.4	12.8
Leucine	8.5	6.3	7.0	6.4	13.4	12.4	7.5	9.7	9.6	9.1	9.0	7.4
Tyrosine	2.7	2.4	2.4	1.5	2.3	2.4	1.8	1.2	3.8	3.5	2.9	2.9
Phenylalanine	6.5	3.8	4.6	4.1	5.1	5.3	5.0	6.4	4.3	4.1	4.9	4.3
Histidine	2.1	2.7	3.8	3.0	1.9	4.1	2.7	2.3	3.4	2.6	2.7	5.7
Lysine	0.6	1.7	2.4	2.5	0.4	1	1.5	1.4	2.6	2.3	1.4	2.7
Arginine	3.3	4.2	-	3.6	-	-	1.1	-	6.5	6.2	5.5	5.7
Tryptophan	0.19	2.3	3.1	-	1.13	0.4	-	0.7	2.5	2	1.3	1.9

Kudlavckova *et al.* (2001). It was also observed in the present study that the essential amino acid phenylalanine was higher in plant proteins. But tryptophan concentration was low in plant ingredients except in wheat bran (3.1%) and wheat flour (2.3%). Among the non-essential amino acids, glycine and alanine, were present in significantly higher levels in Indian fish meal and Danish fish meal when compared to all other ingredients except maize which was having a high alanine content. Since increased level of glycine leads to increased synthesis of collagen (Khatib *et al.*, 2002), which is a texture-limiting factor especially in fish processing, it may not be advisable to incorporate these meals in fish feed formulation at higher levels. The iminoacid, proline, was found to present at 4.1-5.3% level in animal ingredients and in plant ingredients 5.3% to 9.2% level. Glutamic acid was present at higher concentrations in ingredients of plant origin as compared to ingredients of animal origin.

Lipids play several important roles in animal metabolism, such as supplying essential fatty acids, serving as a vehicle for absorption of fat-soluble vitamins, and serving as precursors for steroid hormones and other compounds. Body lipid stores affect the flavor of fish also (Spanier *et al.*, 1997). The level of crude fat in animal feed ingredients was in the range of 7.6-10.1%. All plant feed ingredients was found to be low in fat content (Table 1).

In the present study, fatty acid analysis of the feed ingredients showed that n-3 fatty acids were present in higher concentration in the ingredients of animal origin (Table 3). Essential fatty acids (EFA) are the ones that cannot be synthesized in the animal's body. Thus, they must be provided in the diet. It

Table 3. The fatty acid profile of common fish feed ingredients of plant and animal origin (in percentage of total fatty acids)

Fatty acid (%)	Ingredients of plant origin					Ingredients of animal origin			
	Wheat flour	Atta	Maize	Maize bran	Soya flour	Indian fish meal	Danish fish meal	Peruvian fish meal	Shrimp head meal
$C_{14:0}$	-	-	-	-	-	9.6	5.0	5.7	3.1
$C_{15:0}$	-	-	-	-	-	0.9	0.3	-	0.7
$C_{16:0}$	18.6	18.2	11.5	8.5	18.02	31.4	17.3	20.8	19.1
$C_{16:1}$ n7	-	-	0.5	-	-	12.8	5.9	8.8	8.8
$C_{17:0}$	-	3.6	-	-	-	3.1	1.1	2.1	1.9
$C_{18:0}$	2.5	-	-	-	-	7.7	1.7	5.7	-
$C_{18:1}$ n9	16.6	19.9	26.9	27.6	25.4	13.7	18.1	17.0	29.2
$C_{18:2}$ n6	57.9	44.2	46.2	46.7	44.0	2.9	2.3	1.6	2.6
$C_{18:4}$ n3	-	-	-	-	-	-	8.3	-	0.9
$C_{20:1}$ n9	0.7	3.5	-	-	6.5	1.6	1.2	2.6	3.1
$C_{20:4}$ n6	-	-	-	-	-	1.1	0.8	0.9	3.7
$C_{20:5}$ n3	1.3	1.3	-	-	-	5.0	17.5	11.3	7.6
$C_{22:6}$n3	-	0.6	3.9	3.6	-	5.8	18.7	14.3	9.3
Others	2.4	8.7	11.0	13.6	6.1	4.4	1.8	9.2	10

appears that n-3 fatty acids are essential for fish (Takeuchi *et al.*, 1990). $C_{16:0}$, $C_{18:1}$ and $C_{18:2}$ were the major fatty acids in the lipids of the ingredients of plant origin. These three fatty acids together accounted for more than 80% of the total fatty acids. In the case of fish meals and shrimp head meal, the fatty acid pattern was more complex. $C_{16:0}$, $C_{16:1}$, $C_{18:1}$, $C_{20:5}$ and $C_{22:6}$ were the major components in all these samples. The most important difference between the two groups was the presence of significant proportion of n-3 polyunsaturated fatty acids ($C_{20:5}$ and $C_{22:6}$) in the ingredients of animal origin. Prawns require both n-3 and n-6 fatty acids (Glencross *et al.*, 2002). Hence plant ingredients rich in n-6 fatty acids can be appropriately incorporated in their diet. Lack of higher n-3 polyunsaturated fatty acids in plant sources was reported earlier (Krajvcovivcova-Kudlavckova *et al.*, 2001). But $C_{22:6}$ was present in maize and maize bran (3.9 and 3.6%). Wheat flour and atta showed negligible amount of $C_{20:5}$ (1.3%).

A properly balanced feed can be formulated by taking into account the detailed composition of the ingredients. This information is essential for adjusting the levels of various ingredients in such a way that feed supports maximum growth and is at the same time economical.

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