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CONSIDERATIONS IN USING PROTEIN MEALS FOR MONOGASTRIC ANIMALS

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Abstract

Protein sources are important in animal feeding to meet nutrient requirements for digestible amino acids. Generally, protein sources have higher unit cost as compared to the grain sources that are used mainly to meet energy requirements. The use of less expensive protein meals can potentially reduce feed costs and give reasonable performance but only if formulated correctly. Ingredient price, source, nutrient levels, bioavailability, anti-nutritional factors, palatability, pellet quality and effect on animal performance must all be considered. Soybean meal has become the industry standard to which other protein meals are compared. Soybean meal is rich in protein and the essential amino acid lysine but is a relatively poor sources of methionine and cystine. Dehulling of soybean meal improves not only its protein and amino acid content but its metabolizable and digestible energy content as well. Soybean meal digestibility is affected by heat application during processing for oil extraction. The best soybean meal has precisely enough heat to inactivate anti-nutritional factors but not essential amino acids. Canola meal and its relative rapeseed meal are the second most widely used of the protein meals. Canola and rapeseed meal have a reasonably well balanced amino acid profile but are deficient in lysine. In general, amino acid digestibility is lower than soybean meal especially for poultry. Rapeseed meal in particular may also contain the anti-nutritional factor glucosinolate. This compound and similar ones present result in poor growth, skeletal abnormalities and off odors in eggs and meat. Cottonseed meal ranks third among the total oilseed meals produced. Cottonseed meal has a slightly lower protein content than soybean meal but a much higher and more variable fiber content. Cottonseed meal has less digestible lysine, methionine, threonine and tryptophan than soybean meal. Gossypol is a recognized toxic component of cottonseed meal that can cause cardiac edema, dyspnea, weakness and anorexia. Corn gluten meal, peanut meal, fishmeal, meat and bone meal, sunflower meal, copra meal and others are all potentially useful in poultry feeds. Each has both beneficial and limiting traits associated with them. This paper will discuss the nutritional and economic considerations for using various protein meals in poultry feed.

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Introduction

Since the mid 1980s, the feed milling industry in Asia has undergone rapid expansion. High quality raw materials are often in short supply. This forces nutritionists to use lower priced protein meals, often without fully considering their quality aspects or nutrient availability. Competition among feed mills results in a squeeze on profit margins that puts further pressure on the nutritionist to lower production costs. Since protein sources generally have high unit cost, the measure most often adopted, is to partially replace the traditional high quality soybean meal and fish meal with less expensive rapeseed, sunflower, peanut, copra, sesame, and poorer quality fish or animal protein meals. The use of less expensive protein meals can potentially reduce feed costs and give reasonable performance but only if formulated correctly. Ingredient price, source, nutrient levels, bioavailability, anti-nutritional factors, palatability, pellet quality and effect on animal performance must all be considered. The objective of this paper is to highlight the most important factors to consider in setting restrictions for protein meals commonly used in Asian poultry feed.

Soybean meal

Soybean meal is the largest produced oilseed meal in the world with production estimated to be 115 million metric tonnes in 2000 (Figure 1).

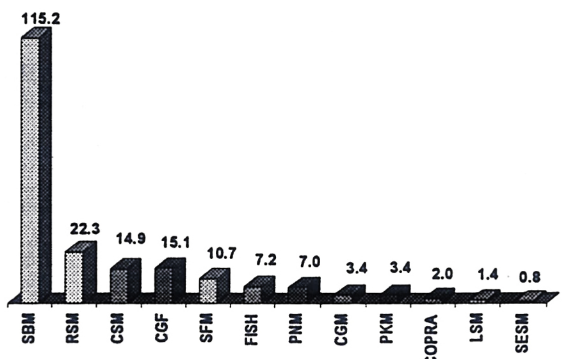

Figure 1. 2000 World Production of Protein Meals, million metric tonnes
source: Oilwords Statistics, 2000

The largest producer was USA - 31%, followed by Brazil - 15%, China/Taiwan - 14%, Argentina - 12%, and India - 3.2% (Mielke, 2000). Most countries with feed industries have soybean crushing facilities but the size and sophistication of operations differ widely making the final product variable between sources. An

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understanding of quality control and product specifications of this important ingredient is economically prudent especially when one considers that up to 75% of the amino acid requirements of a typical broiler or swine grower feed may come from soybean meal. Soybean meal used in Asian countries exists in several forms with solvent extracted material containing hulls being the most common. Many locations use imported dehulled soybean meal obtained mostly from the USA and to a lesser extent Brazil and Argentina. In less developed areas, meal derived from expeller cake is used. Full fat soybean meal is also available, produced by extrusion or dry roasting in small scale plants.

Protein and energy content vary in soybean meal depending on protein level of the beans, residual fat after processing and whether or not hulls have been removed. The protein content of dehulled material ranges from 47.5 to 49% or more and material with hulls ranges from 40 to 50% with 44% considered the norm (Table 1).

Table 1. Selected Nutrient Levels of Asian Protein Meals

Ingredient	Protein	Fat	Fiber	DM	Ca	P av	Na
Soybean meal 44	44	2.50	6.0	89	0.32	0.25	0.02
Soybean ml, dehulled	48	1.30	3.1	89	0.39	0.25	0.02
Rapeseed meal, solvent	37	2.00	11.5	89	0.70	0.25	0.04
Canola meal	38	3.70	11.1	91	0.68	0.25	0.04
Cottonseed meal, solvent	47	3.50	7.8	89	0.25	0.25	0.05
Corn gluten meal 60	60	3.00	1.5	90	0.05	0.10	0.02
Sunflower meal 34	34	1.50	23.0	90	0.30	0.22	0.03
Fishmeal 60	60	9.00	-	92	6.20	2.50	0.98
Peanut meal, solvent	49	1.30	10.0	91	0.20	0.20	0.03
Copra meal 21	21	1.15	15.5	91	0.14	0.18	0.04
Palm kernel meal	17.5	1.80	18.0	88	0.26	0.18	0.02
Sesame meal 45	45	3.00	7.2	90	2.20	0.33	0.02
Lupin meal	30	5.00	13.0	90	0.22	0.20	0.04
Peas	24	2.00	6.0	90	0.17	0.16	0.01

Adapted from: RPAN Nutrition Guide, 1993
NRC, 1994
Novus Raw Material Compendium, 1994.

Table 2. Anti-nutritional Factors of Asian Protein Meals

Ingredient	Anti-nutritional factor
Soybean meal	Protease inhibitors*, allergens*, oligosaccharides, phytin, lipoxygenase*,
Rapeseed meal	lectins*, saponin
Canola meal	Erucic acid, glucosinolates, sinapine, tannins, pectins, oligosaccharides
Cottonseed meal	Glucosinolates, sinapine, pectins, oligosaccharides
Corn gluten meal	Gossypol, cyclopropenoid fatty acids, tannins
Sunflower meal	Mycotoxins (high xanthophyll)
Fish meal	Chlorogenic acid, fiber
Peanut meal	Oxidized fat, high minerals, biogenic amines
Copra meal	Mycotoxins, tannins, oligosaccharides, protease inhibitors*, lectins
Palm Kernel meal	Fiber, mannans
Sesame meal	Fiber and sharp shells, galactomannans
Lupin meal	Quinolizidine alkaloids, pectins, oligosaccharides, high manganese, saponin
Peas	Protease inhibitors, tannins, lipoxygenase

* destroyed during proper heat processing

All processed soybean meal uses a heating or cooking process to destroy anti-nutritional factors contained in raw beans. These components if not deactivated reduce nutrient availability to the animal. The most notable of these factors are the protease inhibitors which bind and render unavailable the digestive enzymes trypsin and chymotrypsin. Also important are allergenic proteins such as conglycinin and □-conglycinin that reduce efficiency and increase scouring in very young animals such as piglets. Table 2 shows the various anti-nutritional factors present in poorly processed soybean meal and other protein meals.

Table 3. Total Content of Selected Amino Acids of Asian Protein Meals

Ingredient	Lys	Met	Cys	Arg	Trp	Thr
Soybean meal 44	2.70	0.63	0.70	3.43	0.63	1.70
Soybean ml, dehulled	3.07	0.68	0.69	3.66	0.66	1.94
Rapeseed meal,solvent	2.03	0.75	0.89	2.13	0.43	1.53
Canola meal	2.06	0.78	99	2.38	0.42	1.63
Cottonseed meal, solvent	1.70	0.76	1.05	4.83	0.62	1.66
Corn gluten meal 60	1.07	1.51	1.07	2.00	0.31	2.13
Sunflower meal 34	1.18	0.72	0.55	2.68	0.45	1.21
Fishmeal 60	4.49	1.51	0.54	3.47	0.62	2.42
Peanut meal, solvent	1.70	0.50	0.62	3.47	0.50	1.28
Copra meal 21	0.73	0.41	0.34	2.79	0.15	0.68
Palm kernel meal	0.72	0.30	0.37	2.61	0.17	0.56
Sesame meal 45	1.10	1.27	1.01	5.34	0.61	1.53
Lupin meal	1.47	0.21	0.61	3.00	0.22	1.13
Peas	1.67	0.22	0.34	2.23	0.20	0.83

Adapted from: RPAN Nutrition Guide, 1993
NRC, 1994
Novus Raw Material Compendium, 1994.

Table 4. Digestibility Coefficients of Selected Amino Acids in Asian Protein Meals.

Ingredient	Lysin		Metionine		Cys		Arginine		Threonine	
	Plt	Swn	Plt	Swn	Plt	Swn	Plt	Swn	Plt	Swn
Soybean meal 44	90	85	91	86	82	76	87	90	87	78
Soybean ml, dehulled	92	86	94	87	92	77	92	90	92	77
Rapeseed meal,solvent	80	73	89	84	75	75	91	82	78	69
Canola meal	73	71	90	86	71	75	90	80	76	67
Cottonseed meal, solvent	67	82	73	84	73	73	87	88	71	78
Corn gluten meal 60	88	73	97	90	86	88	96	85	92	80
Sunflower meal 34	84	76	93	87	78	74	93	91	85	75
Fishmeal 60	88	91	92	91	73	78	92	91	89	88
Peanut meal, solvent	83	82	88	84	78	78	84	95	82	77
Copra meal 21	58	50	83	80	48	54	85	84	58	52
Sesame meal 45	88	72	94	88	82	83	92	94	87	71
Lupin meal	92	66	86	54	88	70	96	88	91	69
Peas	87	82	89	77	78	62	89	86	88	71

Poultry (Plt) : True digestibility estimates
Swine (Swn) : Apparent ileal digestibility estimates.
Source: NRC, 1994
RPAN - Nutrition Guide, 1989

Table 5. Variation in Nutrient Levels of Soybean Meal, Fish Meal, Rapeseed Meal and Canola Meal.

Ingredients	%	Prot.	Moist.	Fat	Fiber	Ash	Lys	Arg	Met	Cys	Trp	Thr
SBM w/hulls	Avg	44.0	11.7	2.5	5.2	6.0	2.64	3.28	0.60	0.67	0.61	1.66
(22 samples)	CV	2.1	6.4	73.5	10.7	11.3	10.90	4.40	10.10	11.00	6.90	10.30
SBM dehulled	Avg	48.4	11.0	1.3	2.9	6.7	3.20	3.70	0.70	0.73	0.69	1.96
(15 samples)	CV	2.1	14.4	28.6	15.9	7.9	5.10	4.20	3.50	3.60	4.60	4.70
Fish meal	Avg	60.2	8.8	8.9	0.8	20.2	4.04	3.67	1.61	0.81	0.59	2.41
(37 samples)	CV	2.7	21.4	29.4	88.7	13.4	17.90	9.50	18.00	51.60	21.1	9.70
Rapeseed meal,	Avg	37.4	10.1	2.3	10.7	9.1	1.69	2.09	0.73	1.01	0.44	1.48
China	CV	3.7	5.0	31.9	20.1	25.9	14.00	7.20	8.20	5.90	4.50	4.10
(5 samples)												
Rapeseed meal,	Avg	38.0	9.1	0.72	8.4	8.1	1.99	2.53	0.69	1.05	1.05	1.50
India	CV	1.3	6.6	18.1	7.4	3.7	4.00	3.20	1.40	2.90	1.90	2.00
(7 samples)												
Canola	Avg	36.3	9.4	3.7	10.7	6.7	2.14	2.31	0.75	0.94	0.48	1.56
(28 samples)	CV	3.1	17.6	26.9	5.8	3.5	3.20	3.40	4.10	6.20	9.70	2.60

Assays conducted by Novus International

Table 6. Suggested Energy Levels of Asian Protein Meals for Monogastrics

Ingredients	Poultry ME (kkal/kg)	Swine ME (kkal/kg)	Swine DE (kkal/kg)
Soybean meal 44	2325	3025	3410
Soybean ml, dehulled	2525	3250	3580
Rapeseed meal, solvent	1790	2710	2940
Canola meal	2000	3025	3285
Cottonseed meal, solvent	1570	2810	3090
Corn gluten meal 60	3500	4040	4500
Sunflower meal 34	1300	1810	2060
Fishmeal 60	3040	3560	3990
Peanut meal, solvent	2180	3200	3550
Copra meal 21	1280	2700	2820
Palm kernel meal	1340	3520	2720
Sesame meal 45	1930	2770	3090
Lupin meal	2500	3350	3620
Peas	2650	3420	3600

Adapted from: RPAN Nutrition Guide, 1993
Novus Raw Material Compendium, 1994

Table 7. Glucosinolate Content of Canola and Rapeseed Meal

Source	Level µmol/g
Canola (Canola Council)	11
Canola (Bell and Keith)	21 (7-30)
Brassica napus	72
Brassica campestris	53
Indian rapeseed meal	99-144

Signs of glucosinolate intoxication:
Leg problems hemorrhagic livers in hens, poor performance, fishy smell in eggs and meat (esp. in brown egg layers).

No effect level: 1 to 5 umol/g in finished feed.

Soybean meal is an excellent source of lysine, tryptophan and threonine but is deficient in methionine as shown in Table 3. The amino acids in corn protein and soy protein combine well to provide a balanced mixture for most poultry requiring only minimal levels of synthetic methionine to be used. Digestibility of lysine and methionine is over 89% in properly processed soybean meal (Table 4). Variation in total amino acid content of soybean meal is lower than that observed in fishmeal, canola and rapeseed and most likely other protein meals although little published information is available (Table 5).

The energy level of soybean meal depends on residual oil, fiber content and ash levels. Metabolizable energy levels for poultry have been estimated to be 120 to 250 kcal/kg higher for dehulled meal versus meal containing hulls (Novus, 1994; Rhone Poulenc, 1993). Suggested values are given in Table 6.

Properly processed soybean meal is an excellent ingredient that can be used as the sole protein supplement for virtually any class of animal with no restrictions except perhaps in piglet prestarter feed (20 to 25% maximum) or shrimp feed (15 to 20%). Table 9 shows recommended maximums for each of the protein meals.

Rapeseed and canola meal

Rapeseed meal ranks second to soybean meal in terms of total world production of protein meals. According to Oilworld (2000) estimates, total world production of rapeseed meal in 2000 was 22.3 million metric tonnes. The major producers are China, India, Germany, Canada and Japan.

The rapeseed meal produced in China, India and certain parts of Europe have high levels of glucosinolates, erucic acid and other anti-nutritional factors. The new varieties developed in Canada in the middle of the 1970s have much lower levels of glucosinolates (<30 micromoles per gram) and erucic acid (<2%). These nutritionally superior 'double zero' varieties are commercially known as Canola.

Canola is becoming widely accepted and is also grown in the USA, Europe and Australia.

Table 8. Suggested Use Restrictions for Protein Meals in Poultry and Swine Diets

Ingredients	Suggested maximum limitation (%)	Comments
Soybean meal	no limitation	Limit to 20% in creep piglet feeds unless supplemented with protease enzyme.
Rapeseed meal	2-4	Depends on glucosinolate level. Swine are more sensitive than poultry.
Canola	9-12	Depends on glucosinolate level and sulphur content of feed.
Cottonseed meal	2-6	May result in egg discorosation, depends on gossypol level and fat content.
Corn Gluten meal	10	Self limiting by price;lysine level and desired pigmentation. Possible mycotoxin contamination. Feces may turn yellow.
Sunflower meal	10-15	Energy limiting. Broilers are more sensitive than young pigs.
Fish meal	2-10	High variability in nutrient content, high minerals. May be oxidized and contain biogenic amines.
Peanut meal	5-10	Avoid if contaminated with mold, mycotoxins or rancid fat.
Copra meal	5-15	Growing and finishing swine are more tolerant than broilers. Deficient in lysine and threonine.
Palm Kernel Oil	1-10	Interferes with pellet quality , unpalatable. Poor amino acid digestibility. High NSP and residual shells.
Sesame meal	5-10	May cause soft fat in swine carcasses. Contains phytates and oxalates. Protein may be heat damaged. Unpalatable.
Lupin meal	4-20	Depends on alkaloid content and hulls content. Swine tolerant more tolerant than broilers.
Peas	10-20	Feed must cantain adequate methionine and availability lysine. Swine more tolerant than poultry. May contain protease inhibitors and lectins.

Canola meal is more yellow in color than the darker brown color of rapeseed meal. The yellow varieties are derived from *Brassica campestris* while darker types are derived from *B. napus.* Table 7 shows the levels and variation of glucosinolates in canola and rapeseed meal.

The quality of rapeseed meal is influenced by the varieties of rapeseed used for oil extraction and the method of extraction process. The optimum temperature for conditioning ranges from 100 to 105 degrees Celsius for a duration of 15-20 minutes. The conditioning process destroys the enzyme myrosinase which converts glucosinolates to the goitrogenic and "hot" tasting compounds: oxazolidone-2-thione and isothiocyanate. The excessively high processing temperature often encountered in production of rapeseed meal reduces digestibility of essential amino acids.

In terms of nutrient composition, canola and rapeseed meal have lower protein (total nitrogen) and energy than soybean meal. In addition to high fiber content, the low energy value of these meals are also attributed to the presence of pentosan polymers, a form of non-starch polysaccharide with poor digestibility. The combination of high fiber and lower energy value seriously limit the use of canola and rapeseed in high-density broiler diets. In terms of mineral content, rapeseed and canola have higher calcium and phosphorus content than soybean meal, although about 65% of the phosphorus is in the phytate form and not available. Canola and rapeseed meal also contain high levels of sulfur (around 1.1% versus 0.4% in soybean meal) that may cause leg abnormalities (Summers, 1989). Therefore sulfur level in feed and water should be monitored when using canola and/or rapeseed meal. Total sulfate and sulfur intake expressed as elemental sulfur in the feed should be kept below 0.4%.

Canola and rapeseed meal have a reasonably well balanced amino acid profile but are deficient in lysine. In general, amino acid digestibility is lower than soybean meal especially for poultry (Table 4). Therefore, when using rapeseed meal in swine and poultry feeds, it is crucial to pay particular attention to the balance as well as the digestibility of amino acids in the final formulation.

Because of its glucosinolate content, the use of rapeseed meal is often associated with a reduction in growth rate and poor palatability of feed. If the level of inclusion is higher than 5% in layer feed, a fishy taint or off flavor in the yolk of eggs from heavy strain brown egg layers will occur. This is due to the presence of a choline ester, sinapine, which promotes the accumulation of trimethylamine in the yolk. Above the 10% inclusion level, hemorrhagic fatty liver is often observed with associated higher levels of mortality. In broilers, the use of rapeseed meal has been suggested to off-flavors in meat. At 30% inclusion in broiler diets, leg abnormalities have been reported. At dietary levels higher than 5% rapeseed meal may result in enlarged thyroids, kidneys and livers in certain species especially starting and growing swine. The use of canola meal instead of rapeseed meal reduces considerably the problems described above except those related to sinapine. The Canola Council of Canada recommends the maximum inclusion rates as follows: Poultry starter/grower - 20%, poultry layer/breeder - 10%, swine starter - 8%, swine grower/breeder - 12% and swine finisher - 18%.

Cottonseed meal

Cottonseed meal ranks third among the total oilseed meals produced in the world. Total production in 2000 was 14.9 million metric tons. China, India and the USA are major producers. Typical yield from whole cottonseeds are 50% meal, 22% hulls and 16% oil. When compared to soybean meal, cottonseed meal has a slightly lower protein of about 41% but a much higher fiber content of 11 to 13%. Depending on the processing method employed, the energy content is influenced by the residual oil present in the meal. In terms of amino composition, cottonseed meal is inferior in four of the most important essential amino acids, lysine, methionine, threonine and tryptophan. Digestibility of these amino acids is lower than that found in soybean meal. The use of cottonseed meal in poultry feed will require supplementation with both L-lysine HCl and D,L-methionine.

Gossypol is a recognized toxic component of cottonseed meal limiting its use in monogastric animals. Free gossypol can damage the myocardium and liver resulting in cardiac edema, dyspnea, weakness and anorexia. Dietary gossypol also causes olive-green yolks in stored eggs as a result of a chemical reaction between the gossypol and iron in the egg. Cottonseed also contains the cyclopropenoid fatty acids, malvalic and sterculic acid. These cause pink discoloration of egg albumin when fed to layers and are also know to alter liver metabolism making aflatoxin more toxic.

Glandless cotton varieties devoid of gossypol have been developed and are much better suited for feeding of poultry and swine. However due to the lower cotton production potential of these varieties only limited quantities are available. Traditional cottonseed meal is normally limited to 2% in broiler and layer feed, and should be avoided in duck formulations if aflatoxin is a concern.

Corn Gluten Meal and Feed

World production of corn gluten meal was estimated to be 3.4 million metric tonnes in 2000. Over 15 million metric tonnes of corn gluten feed was produced during the same period. Corn gluten feed and meal are produced in the wet milling of corn. A slurry of corn and water is processed with enzymes and other chemicals to produce corn starch, fructose, corn syrup and corn oil. Two types of residue are produced depending on the residual bran content. Corn gluten feed contains 20 to 25% protein and 7 to 10% crude fiber. This ingredient is mostly used in ruminant feed although has been used valuable in layer feed at levels up to 25% has bee demonstrated without adverse affects. Corn gluten meal contains from 40 to 60% protein and is an excellent source of methionine and xanthophyll but is deficient in lysine. The higher protein material is used in widely in poultry feed to supply amino acids and as a source of yellow pigment. Its use is usually limited by high price. Corn gluten meal is susceptible to contamination with aflatoxin from residue contained in the raw material and mold growth during storage. The use of corn gluten meal is sometimes restricted to 2% in swine diets to prevent yellow fecal color that may alarm some producers. In poultry, price and the low lysine content in corn gluten meal are the major limiting factors for this excellent ingredient.

Sunflower Seed Meal

Total world production of sunflower meal was 10.7 million metric tonnes in 2000. The main producers are the former USSR, EEC, Argentina, USA and China.

The nutrient composition of sunflower meal varies according to the quality of the seed and methods used for oil extraction. Expeller sunflower meal has a higher energy level than solvent extracted meal because of higher residual oil content. The quality also depends on whether or not the seeds are dehulled prior to oil extraction. Dehulled sunflower meal will have a protein content in excess of 40% and a crude fiber of 13% or less. Partial dehulling will produce meals of 30 to 35% protein whereas whole sunflower meal has about 25% crude protein. The crude fiber of partially dehulled or non-dehulled sunflower meal exceeds 20% and thus is a major limiting factor for use in poultry and swine feed. The high variability in quality of sunflower meal due to differing levels of hulls present is the most important limiting factor with the use of this ingredient. Further, the processing temperature has a significant influence on the quality of sunflower meal. Low temperature processing is desirable to prevent denaturation of lysine and other valuable amino acids.

Sunflower meal contains high levels of chlorogenic acid a tannin like compound that inhibits activity of digestive enzymes including trypsin, chymotrypsin, amylase and lipase (Cheeke and Shull, 1985). Because chlorogenic acid is uncondensed and non-hydrolyzable, its content of 1% or more of a total of 3-3.5% phenolic compounds in sunflower meal is not reported in tannin assays. Additions of methionine and choline are required to counteract the effect of chlorogenic acid. Chlorogenic acid is also a precursor of ortho-quinones that occur through the action of the plant enzyme polyphenol oxidase. These compounds react to polymerize lysine during processing or in the gut. The requirement for both methionine and lysine are thus increased when sunflower meal is used in the diet.

Unlike soybean meal, sunflower meal is high in methionine but low in lysine and threonine. Therefore the two ingredients, when used together, improve the amino acid balance of the feed. If the sunflower meal inclusion rate is high, further supplementation with lysine will still be necessary. Sunflower meal generally has lower amino acid digestibility than soybean meal. This should be taken into consideration when sunflower meal is used to partially replace either soybean meal or fishmeal.

Sunflower meal is not recommended for use in high nutrient density feeds because of its high fiber and low energy content. In broiler and layer feed, up to one-half of the soybean meal may be substituted with good quality sunflower meal provided synthetic L-lysine HCl is supplemented. However, when partially dehulled sunflower meals are used, feed efficiency will be reduced significantly, reflecting the additional fiber and lower energy in the sunflower meal. In broiler diets, it is recommended that only high quality dehulled sunflower meal be used.

Fish Meal

Approximately one-third of the annual world fish catch is used to produce fishmeal for animal feeding. The 2000 annual world production of fishmeal was estimated to be 7.2 million metric tonnes up significantly from the previous year. The fish catch varies greatly from year to year and is declining over the long term. Major producers are USA, Peru, Chile and Denmark. Most fishmeal is produced by cooking the fish, pressing to remove much of the oil and water and then drying the presscake. Concentrates of the removed liquid are sometimes added back to the meal. Many other variations also exist. In some factories the pressing stage may be omitted altogether if there is little oil to be recovered as with whitefish (Barlow and Windsor, 1984). Locally produced fishmeal may consist of fish dried in the sun on the beach and cannery waste may consist of heads, tails and offal of different types of fish such as tuna that are dried and ground. Differences in processing, raw materials, cooking methods, drying, grinding and storage have dramatic impact on the quality and nutritive composition of fishmeal.

Most fishmeal is a brown powder containing high levels of protein, fat and minerals. Protein may vary from 50 to 72%, fat from 2 to 12 % or more for non-extracted fish. Salt content may vary from 1.3 to 4%. Fishmeal usually contains higher levels of lysine, amino acids and aromatic amino acids as compared to soybean meal but variation among samples is large (Table 5). The fatty acid composition of fishmeal varies depending on the variety of fish used. Sardine meal contains the highest levels of omega-3 fatty acids followed by whitefish and anchovy meal. The unsaturated oils in fishmeal are highly susceptible to oxidation which creates toxic free radicals and lowers energy content. Oxidation may also cause heating during storage that reduces amino acid digestibility and sometimes causes spontaneous combustion to occur.

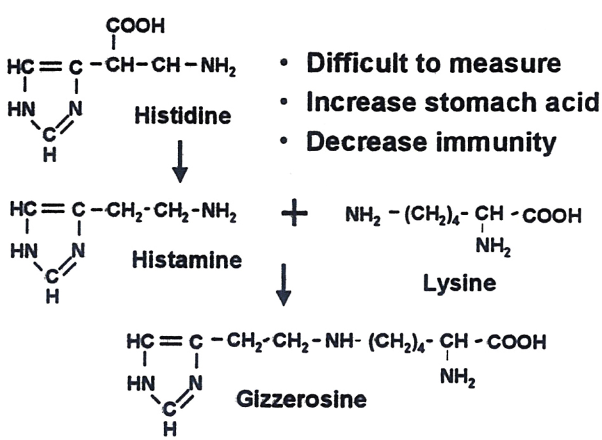

Figure 2. Formation of Biogenic Amines

Fishmeal is also prone to contamination with biogenic amines. Substances such as gizzerosine and histamine are formed during heat processing of fish that have been allowed to spoil or putrefy. These substances increase stomach acid secretion and have been documented to cause gizzard erosion and other lesions in poultry (Okazaki *et al.,* 1983). Figure 2 shows the biochemical mechanism of biogenic amine production in fishmeal.

High quality fishmeal is an exceptionally rich source of well balanced protein, energy, available phosphorus and trace nutrients such as selenium and vitamin B12 and the price is usually reflective of this. Fishmeal is highly palatable to most species and is generally used in starter diets when amino acid requirements are highest. Fishmeal should be avoided in diets in the period before slaughter to avoid fishy taint in the meat caused by amines that are abundant in fishmeal. More than 1-2% fishmeal in layer diets may result in a fishy taint in eggs. Depending on quality and composition, fishmeal should be limited to between 2 and 10% of the diet for growing broilers to prevent over supplementation with minerals such as P and Na. Mineral analysis is recommended.

Peanut Meal

Peanut meal is a readily available protein source by-product from the extraction of peanut oil which is a popular human food in many parts of the world. Total world production in 2000 was estimated to be 7.0 million metric tonnes. China and India were the major producing countries.

The nutrient composition of the meal varies greatly according to the oil extraction method used. The quantity of hulls present directly affects fiber and therefore energy content of the meal. Solvent extracted peanut meal generally has less than 1.5% fat. The fat content of expeller peanut meal is variable depending on the efficiency of oil extraction. With prolonged storage under the warm and humid conditions in the tropics, residual oil is a negative feature as it is easily oxidized. The meal quality is then greatly reduced due to poor palatability, toxicity and decreased energy value.

Peanut meal has a poor amino acid profile that is deficient in methionine, lysine and tryptophan relative to soybean meal. Moreover, the poorly balanced amino acids have low digestibility (Table 4). It is therefore necessary to supplement the feed with additional crystalline amino acids when peanut meal is used.

Like most legume seeds, peanuts contain trypsin inhibitors and other protease inhibitors. Proper processing is required to destroy these anti-nutritional factors. The other undesirable constituent often associated with peanut meal is aflatoxin produced by the fungus *Aspergillus flavus* that infests peanuts before, during and after harvest. Ducklings, turkey poults and broiler chicks are most sensitive to aflatoxin. This mycotoxin causes hemorrhages in the liver, kidneys and breast muscle and reduced immune competence. Aflatoxin B1 levels as low as 250 ppb are known to exert these effects. Because of the widespread occurrence of aflatoxin and its impact on human health, many authorities have now set limits on the amount permitted in the feed ingredients and feeds. The US Food and Drug Administration, for example, has set a limit of 100 ppb for interstate shipment of feeds. Generally, peanut meal is not recommended in young poultry diets for fear of contamination with mycotoxins. High quality peanut meal can be used at levels up to 6% in broilers and 9% in layers with good results.

Copra Meal

Copra is obtained from the kernel of coconut fruit which has been sun dried or dried using drying machines. The major producing countries are the Philippines and Indonesia which account for about two-thirds of the world's total 2000 production of 1.8 million metric tons. From the copra, about 30 to 40% by weight is extracted as coconut oil. The residue, in the form of dried cake chunks, is further reduced by grinding to copra meal. Copra produced by the expeller process has a residual oil content of about 8%. This is sometimes reduced further by solvent extraction depending on the market demand for oil which at the present time is quite high. Copra meal is problematic because of the high variability in oil content, contamination with mold and high levels of poorly digested non-starch polysaccharides.

Most copra meal encountered in the trade falls between 9 and 16% residual oil content. However, some meals produced by small scale expeller extraction process or using poor equipment may have residual oil contents above 20% while solvent extracted meals may contain less than 2% oil. When it contains high residual level of oil copra meal is a valuable source of energy for swine and poultry. Coconut oil is composed predominantly of short chain saturated fatty acids (50% C12:0; 15% C14:0) that are easily digested and has high energy content.

High moisture, poor drying conditions and poor storage contribute to a high incidence of mold contamination in copra. Copra is an ideal medium for mycotoxin formation. Also, high moisture levels and high storage temperature favor oxidation of residual oil which in turn affects palatability of the meal. The high fiber content in copra meal seriously limits its use in poultry diets. The fiber is high in polymers called mannans that have low digestibility and often have a laxative effect in poultry and swine.Copra meal has a protein content much lower than soybean meal ranging from 19 to 23%. The protein quality is poor both in terms of its amino acid balance and digestibility (Table 4). The digestibility of amino acids may be further reduced when excessive temperatureare used during processing. The amino acid composition of copra meal is inferior to many other protein sources. It is deficient in important essential amino acids such as lysine, methionine, threonine and histidine but high in arginine. As excess arginine is known antagonize lysine utilization, high copra meal levels may have a negative effect on the growth rate in swine and poultry. Thus, lysine supplementation is very important when using copra meal to correct deficiency and reduce the antagonism by arginine. High quality copra meal is usually restricted to about 3 or 4% in poultry diets.

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Palm Kernel Meal

Palm kernel meal is produced mainly in Malaysia, Indonesia, Nigeria and Thailand as a residue of the oil extraction of palm fruit. Total world production in 2000 was estimated to be 3.4 million metric tons.

Palm kernels are covered by thick shells that must be cracked open, removed and subjected to steam conditioning before the oil extraction process. The quality of meal depends largely on the amount of shell removed. The meal is normally produced by an expeller process leaving a residual oil content of about 6%. With solvent extraction, the meal ranges from 1 to 2% residual oil. Among the oil meals, palm kernel meal has the lowest protein content normally ranging from 16 to 18%. Protein as low as 13% and a fiber exceeding 20% can occur if shells and fruit fiber are not removed efficiently. Due to the high fiber, the energy content of palm kernel meal is rather low, especially for poultry. Over half of the fiber in palm kernel meal is in the neutral detergent form and contains high levels of galactomannans such as □-(1,4)-D-mannan (Daud and Jarvis, 1992). The potential for improving nutritional value of palm kernel meal with supplemental feed enzymes is high.

As with the peanut and copra meal, the amino acid profile of palm kernel meal is very poor both in terms of amino acid balance and digestibility. It is deficient in lysine, methionine and tryptophan. In poultry, lysine and methionine digestibility has been estimated to be as low as 59% compared to 90% in soybean meal (Table 4). The digestibility of other essential amino acids is also low. The poor amino acid digestibility is attributed to protein entrapment in carbohydrate complexes as well as the high temperatures used during the oil extraction process.

Because of its high fiber and poor amino acid digestibility, palm kernel meal is probably best suited for use in ruminant feeds. The use of palm kernel meal in poultry feed should be restricted because of its poor protein quality, high fiber content and low energy value. Contamination of palm kernel meal with shell material has been reported to cause damage to the intestinal lining in poultry.

Sesame Meal

Sesame is a minor oilseed crop that is often available in Asian countries. Total world production in 2000 was 0.83 million metric tonnes with major producers being India, China, Sudan, Burma and Mexico. The nutrient composition of high quality sesame meal compares favorably with that of soybean meal. However variability exists depending on the varieties used, the degree of decortication and the processing methods. The hull of the sesame seed accounts for 15 to 29% of the whole seed. The hull can be separated from the kernel in decorticating machines or by soaking and rubbing the seed by hand. Most harvesting of sesame is also done by hand. Removal of the hull results in a reduction of fiber of approximately 50% and increase the protein content, digestibility and palatability of the meal. Occasionally, the seed is milled without decortication in order to improve the efficiency of oil extraction. However, the meal resulting from such processing is of relatively poor nutritive quality. The protein content of different varieties ranges from 41% to 58%. An average protein content of 40% and 5% fat is typical for expeller sesame meal. Solvent extracted meals contain slightly higher protein content of 42 to 45% and less than 3% fat. The energy content is lower than in the soybean meal and appears to be related to its high ash content of 10-12%.

Sesame meal is an excellent source of methionine, cystine and tryptophan but is very low in lysine and threonine. The amino acid composition of sesame meal complements most other oilseed proteins and in particular, soybean meal. Studies have shown that a soybean meal/sesame meal ratio of 2:1 gives good growth responses in chicks. Almost 80% of sesame protein is reported to be digestible. Prolonged heating during processing or grinding may severely depress the availability of amino acids. Processing sesame at high temperature can also result in the destruction of cystine causing a sulfur amino acid deficiency.

Sesame seeds contain high levels of oxalic acid (35 mg/100 g) and phytic acid (5%). The darker colored varieties are higher in these anti-nutritional factors than red colored varieties. Oxalic acid and phytate are known to interfere with mineral metabolism and decrease availability of calcium, phosphorus, magnesium, zinc and iron. The oxalic acid may also cause kidney lesions and reduces palatability problem due to bitter taste. Decortication of seeds removes the oxalates, but has little effect on phytate. Phytate can be degraded through the use of feed enzymes containing active phytase or by using uncooked wheat in the feed which contains appreciable levels of phytase. Sesame meal is popular in poultry diets mainly due to its high sulfur amino acid and essential fatty acid content. It must be noted that due to its low lysine content and low lysine digestibility, supplementation with the synthetic lysine is necessary. The exclusive use of decorticated meal will help to avoid palatability problems.

Lupin Meal

Lupins are chiefly grown in the cooler climates of Australia, Canada and Western and Eastern Europe. Nutrient content and levels of antinutitional factors vary widely. With improvements in lupin genetics to reduce alkaloid content and larger areas being planted in Western Australia, lupin meal has become available in several Asian countries.

Lupin meal is a relatively good protein source and can be used as a feed ingredient if several conditions are met. Lupin meal should made from seeds low in quinolizidine alkaloid content (<.03%). These alkaloids are known to cause neurological problems and are bitter to the taste causing palatability problems. Alkaloid content varies with species of lupin. Although sweet lupins are low in alkaloids they are easily contaminated with seeds from bitter varieties. Lupin meal should be produced from decorticated seeds to avoid dilution of energy with indigestible hulls. Manganese levels should be monitored as certain varieties contain extremely high concentrations (6900 ppm) of this element which may favor fat oxidation or cause direct toxicity (Van Kempen and Jansman, 1994). Lupins also contain high levels (7-12%) of alpha-galactosides. The lack of intestinal alphagalactosidase allows the oligosaccharides to escape digestion in the small intestine and are later fermented in the ceca. There is conflicting evidence on whether these sugars have a growth depressing effect in poultry (Brenes, Trevino, Centeno and Yuste, 1989). The major polysaccharide of lupin is □-1-4 galactan, consisting of D-galactose, L-arabinose, L-rhamnose and galacturonic acid (Van Kempen and Jansman, 1994). The total non-starch polysaccharide content of lupin seeds is about 37% with hulls containing about 50% NSP. These components may cause wet sticky droppings and wet litter.

Western Australian lupins (Lupinus angustofolis) have lower metabolizable energy than soybean meal for poultry. Likewise, the protein content of 30% found in lupin meal is less than that found in soybean meal. Lupin protein is low in lysine and methionine but a rich in threonine. Amino acids in lupins are more digestible by poultry than swine (Table 4).

Use recommendations for dehulled sweet lupin meal: less than 4% in broiler starter diets, less than 6% in broiler grower diets, and less than 7% broiler finisher and layer diets.

Peas

Field peas grown in cooler climates may occasionally find their way into Asian countries. Peas are not crushed for oil and are normally used by grinding with the hull. Raw peas contain about one-tenth the level of trypsin inhibitor as do raw soybeans. This infrequently is a concern as peas are not heat processed. Peas also contain tannins and other poly phenols that decrease digestibility of amino acids. Peas also contain low levels of lipoxygenase (Savage, 1989).

Peas are markedly deficient in methionine but have reasonable energy level for both swine and poultry. Because of concern over anti-nutritional factors, inclusion of peas is usually limited to is between 10 and 20% of the diet. Pelleting of the finished feed would be a benefit when using this ingredient.

Conclusions

The availability of less expensive protein meals provides an avenue for reducing the cost of feed production. The foregoing discussion indicates that it is not sufficient to evaluate the suitability of use of a protein source solely on its proximate and total amino acid analysis. A broader evaluation criteria is necessary based on the following:

1. **Ingredient source and processing methods**
   Since quality of these alternative protein sources are more variable than soybean meal, it is important to know the source of the material and the processing methods used. The ability to use the most appropriate nutrient values and be aware of the limitations of each ingredient will determine to a great degree the

success or failure in reaching the intended objective of cost reduction without loss of animal performance.

2. **Amino acid balance and digestibility/ availability**
   These important considerations determine the efficiency of protein or amino acid utilization. Although information on this is still lacking for many ingredients some estimates should be used based on previous history and experience.

3. **Anti-nutritional factors**
   This could be a problem if the source and quality of ingredient cannot not be determined. The cost of analysis is normally high and facilities for analysis are not easily available. It should be emphasized that through the development of new varieties of oilseeds, improved methods of processing, and with the use of supplementary feed enzymes, problems related to presence of anti-nutritional factors should be of less significance in the future.

4. **Influence of ingredient constituents on animal products**
   This is often neglected in the trial use of any new feed ingredients including new protein sources. Any negative influence on the marketability of pork, broiler meat or egg, be it in terms of smell, color, taste and flavor, will seriously damage the acceptability of feeds produced. Also, with regard to quality of end product, it should be noted that what is desirable and acceptable in one country may not hold true in another.

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