AN OVERVIEW OF THE RENDERING INDUSTRY

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Summary

One-third to one-half of each animal produced for meat, milk, eggs, and fiber is not consumed by humans. These raw materials are subjected to rendering processes resulting in many useful products. Meat and bone meal, meat meal, poultry meal, hydrolyzed feather meal, blood meal, fish meal, and animal fats are the primary products resulting from the rendering process. The most important and valuable use for these animal by-products is as feed ingredients for livestock, poultry, aquaculture, and companion animals.

There are volumes of scientific references validating the nutritional qualities of these products, and there are no scientific reasons for altering the practice of feeding rendered products to animals. Government agencies regulate the processing of food and feed, and the rendering industry is scrutinized often. In addition, industry programs include the use of good manufacturing practices, hazard analysis and critical control point (HACCP), codes of practice, and third-party certification. The Food and Drug Administration (FDA) regulates animal feeds and prohibits certain ruminant proteins from being used in ruminant diets to prevent the spread of bovine spongiform encephalopathy (BSE). Though often frustrated by the attention it receives, the rendering industry clearly understands its role in the safe and nutritious production of animal feed ingredients and has done it very effectively for over 100 years.

The availability of rendered products for animal feeds in the future depends on regulation and the market. Renderers are innovative and competitive and will adapt to changes in both. Regulatory agencies will determine whether certain raw materials can be used for animal feed. The National Renderers Association (NRA) supports the use of science as the basis for regulation while aesthetics, product specifications, and quality differences should be left to the marketplace. Customer expectations, consumer demand, and economic considerations will dictate product specifications and prices.

Without the continuing efforts of the rendering industry, the accumulation of unprocessed animal by-products would impede the meat industries and pose a serious potential hazard to animal and human health.

Raw Material

A by-product is defined as a secondary product obtained during the manufacture of a principal commodity. A co-product is a product that is usually manufactured together or sequentially with another item because of product or process similarities. Some prefer the more positive connotation of the term co-product, but for simplicity, this book will mostly use the term by-product. A portion of the profit returned to animal production and processing industries depends on the utilization of the by-products or co-products ancillary to the production of meat, milk, and eggs for human food production. The FDA regulates which materials can be included in animal feed, and in 1997 banned the feeding of ruminant materials back to ruminant animals. Considerable debate has taken place recently on whether more bovine materials should be banned from all animal feeds.

The approximately 300 rendering facilities in North America serve animal industries by utilizing the by-products which amount to more than half of the total volume produced by animal agriculture. The United States currently produces, slaughters, and processes approximately 100 million hogs, 35 million cattle, and eight billion chickens annually. By-products include hides, skins, hair, feathers, hoofs, horns, feet, heads, bones, toe nails, blood, organs, glands, intestines, muscle and fat tissues, shells, and whole carcasses. These by-product materials have been utilized for centuries for many significant uses. The products produced from the "inedible" (meaning not consumed by humans) raw material make important economic contributions to their allied industries and society. In addition, the rendering process and utilization of these by-products contribute to improvements in environmental quality, animal health, and public health.

Approximately 49 percent of the live weight of cattle, 44 percent of the live weight of pigs, 37 percent of the live weight of broilers, and 57 percent of the live weight of most fish species are materials not consumed by humans. Some modern trends, such as pre-packed/table ready meat products, are increasing the raw material quantities for rendering. The current volume of raw material generated in the United States is nearly 54 billion pounds annually with another 5 billion pounds generated in Canada. Raw materials vary, but an overall approximation of content would be 60 percent water, 20 percent protein and mineral, and 20 percent fat before the rendering process. These organic materials are highly perishable and laden with microorganisms, many of which are pathogenic to both humans and animals. Rendering offers a safe and integrated system of animal raw material handling and processing that complies with all of the fundamental requirements of environmental quality and disease control.

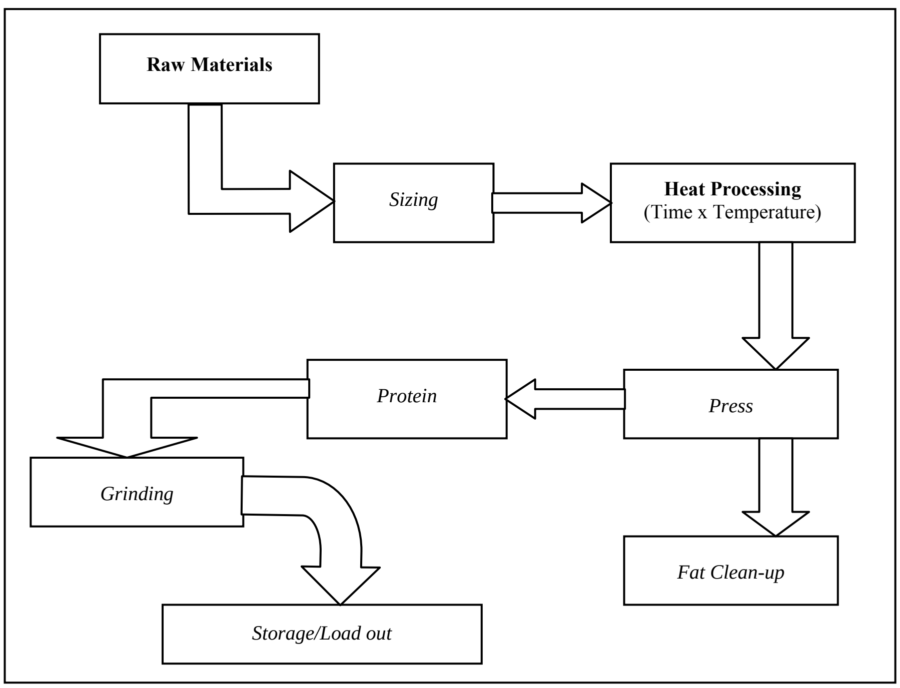
The Rendering Process

Rendering is a process of both physical and chemical transformation using a variety of equipment and processes. All of the rendering processes involve the application of heat, the extraction of moisture, and the separation of fat. The methods to accomplish this are schematically illustrated in Figure 1 (Hamilton, 2004). The processes and equipment are described in detail in the chapter in this book on operations.

The temperature and length of time of the cooking process are critical and are the primary determinant of the quality of the finished product. The processes vary according to the raw material composition. All rendering system technologies include the collection and sanitary transport of raw material to a facility where it is ground into a consistent particle size and conveyed to a cooking vessel, either continuous-flow or batch configuration. Cooking is generally accomplished with steam at temperatures of 240º to 290ºF (approximately 115º to 145ºC) for 40 to 90 minutes depending upon the type of system and materials. Most North American rendering systems are continuous-flow units. Regardless of the type of cooking, the melted fat is separated from the protein and bone solids and a large portion of the moisture is removed. Most importantly, cooking inactivates bacteria, viruses, protozoa, and parasites. Alternative methods of raw material disposal such as burial, composting, or landfill applications do not routinely achieve inactivation of microorganisms.

Fat is separated from the cooked material via a screw press within a closed vessel. Following the cooking and fat separation, the "cracklings" or "crax," which includes protein, minerals, and some residual fat, are then further processed by additional moisture removal and grinding, then transferred for storage or shipment. Storage of the protein is either in feed bin structures or enclosed buildings. The fat is stored and transported in tanks.

Figure 1. The Basic Production Process of Rendering.



Processes and technology of rendering have changed over the years and continue to improve. Modern rendering facilities are constructed to separate raw material handling from the processing and storage areas. Process control is performed and monitored via computer technology so that time/temperature recordings for appropriate thermal kill values for specific microorganisms are achieved. Temperatures far in excess of the thermal kill time requirements are unnecessary and avoided because they can lower nutritional values and digestibility. Processes in North America generally do not incorporate cooking under pressure except for feathers and other high keratin containing tissues.

Research has demonstrated that raw material derived from food animal processing is heavily laden with microorganisms. Data illustrating the high incidence of foodborne pathogenic microorganisms within raw animal by-product material and the efficacy of the rendering process in killing these pathogens are listed in Table 1. It is recognized that handling of ingredients after cooking can be responsible for re-contamination—a concern for all feed ingredients and not restricted to animal protein. *Salmonella* is a bacteria species that is commonly associated with feed and often wrongly suspected of originating from the animal by-product ingredients. Data from around the world illustrate that all feed ingredients, including vegetable proteins and grain, may contain *Salmonella* (Beumer and Van der Poel, 1997; Sreenivas, 1998; McChesney et al., 1995; European Commission, 2003). Thus, it is important to follow industry feed safety guidelines or codes of practice in both pre- and post-handling of ingredients and manufactured feed.

Table 1. Efficacy of the U.S. Rendering System in the Destruction of Pathogenic Bacteria.

Pathogen	Raw Tissue % samples positive	Post Process % samples positive
Clostridium perfringens	71.4	0
Listeria species	76.2	0
L. monocytogenes	8.3	0
Campylobacter species	29.8	0
C. jejuni	20.0	0
Salmonella species	84.5	0

Source: Troutt et al., 2001. Samples from 17 different rendering facilities taken during the winter and summer.

Though research has demonstrated that rendering lowers the infectivity of the prion, the agent most commonly believed to be the cause of the transmissible spongiform encephalopathies (TSEs), is not totally inactivated with any of the currently available rendering processes (Taylor et al., 1995). This is why the FDA requires that raw materials containing ruminant by-products not be used to make ingredients used in ruminant feed.

The North American rendering industry recognizes its role in ensuring food safety and in protecting human and animal health and has developed programs for biosecurity, *Salmonella* reduction, and third-party certification for compliance to feed regulations. In addition, North American rendering companies have endorsed the APPI Code of Practice—a voluntary HACCP-based program.

Rendered Animal By-Products

The rendering process converts raw animal tissue into various protein, fat, and mineral products—rich granular-type meals and liquid fats with specific nutritional components. Annual volume in the United States is approximately 11.2 billion pounds of animal derived proteins and 10.9 billion pounds of rendered fats. About 85 percent of this production is utilized as animal feed ingredients. Applications for rendered fats in the chemical, metallurgy, rubber, and oleochemical industries combined account for the second largest market, with over 3,000 industrial uses identified. The manufacture of soaps and personal care products remain a major use for animal fats, especially tallow, and new uses such as biofuels are increasing.

Animal Fats and Recycled Greases

Fats are the most caloric-density feed ingredient available. The animal feed and ingredient industry is a major user of rendered animal fats and recycled restaurant and cooking oils which provide valuable dietary energy. Also, fats and fatty acids provide for essential and indispensable body functions separate from their caloric function. Including recycled vegetable oils from restaurants, the rendering industry processes some 10.9 billion pounds annually of fats (Table 2).

Table 2. Fats Produced by the U.S. Rendering Industry Annually.

Edible Tallow	1.8 billion pounds
Inedible Tallow	3.9 billion pounds
Lard	0.3 billion pounds
Yellow Grease	1.5 billion pounds
Other Grease	1.2 billion pounds
Poultry Fat	1.2 billion pounds
Fats Used in Pet Food[a]	1.0 billion pounds
Total	**10.9 billion pounds**

Source: U.S. Census Bureau Current Industrial Report M311K, 2005.

[a] Editor's note: Poultry, beef, and pork fats used in pet foods (estimated to be approximately 1.0 billion pounds) are not included in the U.S. Census Bureau categories.

The term lipid includes both fats and oils. Lipids are chemically structured primarily as triglycerides—a structure consisting of one unit of glycerol and three units of fatty acid. The fatty acids are the components that give the respective fats their individual chemical and physical characteristics. Most fatty acids found in natural fats vary in chain lengths from eight to 24 carbons. Feeding fats contain mostly fatty acids of 14 to 18 carbon lengths. Fatty acids are considered unsaturated if they have double bonds within their chemical structure. Structures without double bonds are saturated fatty acids. If more than two double bonds are present in the structure, fatty acids are referred to as polyunsaturated. As a triglyceride contains more saturated fatty acids, the melting point increases, and the physical nature of the fat is referred to as a "harder." A measure of hardness is titer, determined by the solidification point of the fatty acids. Iodine value (IV) is another measurement of hardness/softness with unsaturated fats having higher IV values than saturated fats. Table 3 provides a guide of various animal fats comparing titer and IV.

Table 3. Titer and Iodine Values for Fat from Various Livestock Species.

Species	Titer	Iodine Value
Sheep	111º – 118ºF (44º – 48ºC)	42 – 43
Cattle	108º – 113ºF (42º – 45ºC)	43 – 45
Hogs	97º – 104ºF (36º – 40ºC)	63 – 65
Poultry	89º – 95ºF (31º – 35ºC)	77 – 80

Source: Fats and Proteins Research Foundation Directors Digest No. 269.

Feed grade fats are often stabilized blends of animal and vegetable fats. They are produced (1) by rendering the tissues of mammals and/or poultry, and (2) through recycling cooking oils. Feed fats consist predominately of triglycerides of fatty acids and contain no added free fatty acids (NRA, 2003).

Products bearing a name descriptive of its kind or species origin must correspond thereto as beef, pork, or poultry. Poultry fat consists of fats derived from 100 percent poultry offal. Blended feed fat is a category that includes blends of tallow, grease, poultry fat, and restaurant grease/cooking oils. Blended animal and vegetable fats include blends of feed grade animal fats, poultry fats, vegetable fats, and/or restaurant grease/cooking oil. It may also include by-products such as soap stock. Fats within this category may be referenced as animal/vegetable blends.

Though specifications are clearly defined and guarantees specified under several references, including the Association of American Feed Control Officials (AAFCO), suppliers of feeding fats can provide products that are labeled and guaranteed outside the trading standards. Suggestions for quality specifications for animal feed fats are listed in Table 4. As with any feed ingredient, specifications should be thoroughly understood between supplier and purchaser. The following are common feeding fat guidelines:

1. Fats should be stabilized with an acceptable feed- or food-grade antioxidant added at levels recommended by the manufacturer. Stability tests can be performed to monitor.
2. No cottonseed soap stock or other cottonseed by-products should be included in fats for layer, breeder, or broiler rations.
3. Fats must be certified that polychlorinated biphenyls (PCBs) and pesticide residues are within the allowable state and federal limits.
4. The supplier should make every effort to provide a uniform fat structure in each delivery. A specification for minimum and/or maximum IV can be established for the type of fat purchased. Monitoring IVs can determine if the product's fat structure is uniform.

Table 4. Suggested Quality Specifications for Feed Fats.

	%	Animal	Poultry	Blended Fat: Feed Grade Animal	Blended Fat: Animal/ Vegetable	Vegetable Soap Stock
Total Fatty Acids	min.	90	90	90	90	90
Free Fatty Acids	max.	15	15	15	15*	50
Moisture	max.	1	1	1	1	1.5
Impurities	max.	0.5	0.5	0.5	0.5	1
Unsaponifiable	max.	1	1	1	1*	4
Total MIU	max.	2	2	2	2	6

MIU = moisture, impurities, and unsaponifiables.

* When blended feed fats contain acidulated soap stock, this specification can be adjusted to allow higher free fatty acids found in this fat (i.e., five FFA per 10 percent added). Blended fats containing soap stock may also have higher unsaponifiable levels.

Fat Terminology

Total fatty acids (TFA) include both the free fatty acids and those combined with glycerol (intact glycerides). Fat is composed of approximately 90 percent fatty acids and 10 percent glycerol. Glycerol contains about 4.32 calories per gram compared with 9.4 calories for fatty acids. Since fatty acids contain over twice the energy of glycerol, the TFA content in fat acts as one indicator of energy.

One measure of fat quality is the FFA content. Fats are normally composed of three fatty acids linked to glycerlol via ester bonds. FFA are produced when those fatty acids are freed by hydrolysis. Therefore, the presence of high levels of FFA indicates the fat was exposed to water, acids, and/or enzymes. Fats should be processed to contain as low a moisture level as feasible so that hydrolysis does not occur during storage.

In the past, some have associated increased FFA with increased oxidation of the fat during processing or storage. Oxidation is not the same as hydrolyses and it occurs when oxygen and unsaturated fatty acids combine in the presence of a catalyst, such as heat, iron, copper or light. The role of heat in promoting both oxidation and fat hydrolysis may be the root of the confusion. Adding antioxidants, the most common practice to prevent oxidation, to prevent FFA production is not recommended because many antioxidants are acidic and may contribute to higher FFA measurements.

Insoluble impurities usually consist of small particles of fiber, hair, hide, bone, or soil. These can cause clogging problems in fat handling screens, nozzles, and other equipment, and contribute to the build-up of sludge in fat storage tanks.

Moisture is detrimental in fats since it accelerates corrosion of fat handling equipment and may promote the formation of rust, which is a powerful catalyst of oxidation and rancidity. Moisture also contributes no energy, lubricity, or other benefits to feed and should be kept to a minimum. Moisture settles in fat storage, making accurate sampling difficult.

Saponification value (SV) is an estimate of the mean molecular weight of the constituent fatty acids in a fat sample and is defined as the number of milligrams of potassium hydroxide required to saponify one gram of the fat. Higher SV indicate lower mean chain lengths of the triglycerides.

Unsaponifiable fats contain a number of compounds such as sterols, hydrocarbons, pigments, fatty alcohols, and vitamins, which are not hydrolyzed by the alkaline saponification. Normal unsaponifiables have unknown and variable feeding values comparable to the fats involved and can dilute the energy content.

Iodine value: Each double bond in a fatty acid will take up to two atoms of iodine. By reacting fatty acids with iodine, it is possible to determine the degree of unsaturation of the fat or oil. The IV is defined as grams of iodine absorbed by 100 grams of fat. Unsaturated fats naturally have higher IVs than saturated fats so IV can be used to estimate complete fat structures.

Titer value is determined by melting the fatty acids after a fat has been hydrolyzed. The fatty acids are slowly cooled and the congealing temperature in degrees Centigrade is the titer. Animal fats are referred to as "tallow" if they possess a titer of 40 or higher, and are considered "grease" if the titer is below 40, regardless of the animal origin, though most tallow is a by-product of beef processing.

Fat color varies from the pure white of refined beef tallow, to the yellow of grease and poultry fat, to the very dark color of acidulated soap stock. Color does not affect the nutritional value of fat but may be a consideration in pet foods and other consumer oriented products because of the potential to affect the appearance of finished products.

Fat stability and antioxidants: To prevent the development of oxidative rancidity, which can destroy vitamins A, D, and E and cause other problems in feeds, antioxidants are recommended for all feed fats. Rancidity is a descriptive or qualitative term that was derived from human thresholds in detecting off-flavors associated with the oxidation of fats. Rancidity is not chemically defined, nor is it quantifiable. As a result, the industry has tried to describe rancidity by measuring various intermediates or products of oxidation. Two such tests that are commonly used as indicators of the stability of fats are:

1. Peroxide value (PV) – This test measures the milliequivalents (me) of peroxide per kilogram (/kg) and reveals the current state of oxidative rancidity. A low PV (sometimes defined as less than 10.0 me peroxide/kg) indicates a non-rancid sample.
2. Active Oxygen Method (AOM) test for 20 hour stability – This is a measure of the peroxide value after 20 hours of bubbling air through the sample. This test is intended to determine the ability of the fat to resist oxidative rancidity in storage.

Tallow is primarily derived from rendered beef tissue but could contain other animal fat. Most chemical and soap manufacturers require a minimum titer of 40.5 to 41.0. A titer of at least 40 is required for a tallow designation.

Choice white grease is derived primarily from pork tissue. The soap industry requires color specifications, but color is less important for feeding fats.

Thus, considerable savings can often be acquired by developing feeding fat specifications that concentrate on the nutritional value of the respective fat.

Yellow grease has been a term used for a number of years and often confused with off-color choice white grease. Yellow grease is primarily restaurant grease/cooking oil sources but can contain other sources of rendered fat.

There are several documented benefits for use of animal fats in livestock, poultry, aquaculture, and companion animal diets including enhancing energy concentration of diets. Depending on the species to which it is being fed, the energy contributions of fat range from 2.6 to 3.8 times the energy content of corn. Energy values for the commonly used animal fats are listed in Table 5. In addition to the nutritional contribution, fat addition to animal diets contributes to dust control, feed mill cleanliness, worker comfort, enhanced pelleting efficiencies, improved palatability of feed, reduced respiratory disease, increased stability of fat soluble vitamins and other nutrients, and enhanced life of feed equipment.

Table 5. Energy Values for Fats Commonly Added to Swine and Poultry Feeds.[1]

Fat Source	Poultry ME, kcal/lb	Swine ME, kcal/lb[2]
Yellow Grease[3]	3,582	3,663
Poultry Fat	3,539	3,641
Choice White Grease	3,424	3,585
Brown Grease	3,332	3,534
Tallow	3,167	3,452
Palm Oil	3,069	3,401

[1] Calculated using equations from Wiseman et al. (1991) for poultry and Powles et al. (1995) for swine.

[2] These equations calculate digestible energy (DE). Metabolizable energy (ME) was calculated as 96 percent of DE.

[3] Recovered frying fat.

Animal Protein Ingredients

Proteins are essential constituents of all biological organisms and are found in all body tissues of animals. Proteins are found in higher concentrations in organ and muscle tissue, and range from very insoluble types in feather, hair, wool, and hoofs, to highly soluble proteins such as those in serum or plasma. Animal derived foods are primary sources of protein and other nutrients in human diets. Similarly, the tissues from animal production and processing not utilized in human food are processed into an array of protein meals used in animal feeds.

AAFCO defines the composition of all legally used feed ingredients including rendered animal products. The *2006 AAFCO Ingredient Manual* references some 125 individual animal by-products, and is updated annually. The primary animal protein by-products are meat and bone meal (MBM), meat meal, blood meal, poultry by-product meal, poultry meal, feather meal, and fish meal. Using MBM as an example, AAFCO defines it as the rendered product from mammalian tissues including bone but exclusive of blood, hair, hoof, horn, hide trimmings, manure, and stomach and rumen contents. MBM as defined by AAFCO must contain a minimum of four percent phosphorus with a calcium level not to exceed 2.2 times the actual phosphorus level. Ingredients of lower phosphorus content must be labeled meat meal.

Meat and Bone Meal

In addition to the above AAFCO description, MBM shall contain not more than 12 percent pepsin indigestible residue and not more than nine percent of the crude protein shall be pepsin indigestible. Pepsin is a proteolytic enzyme which is secreted by the stomach where it hydrolyzes proteins to polypeptides and oligopeptides. If a protein is pepsin indigestible, animals may not be able to digest it. MBM can be used in all species of livestock, poultry, and aquaculture feed, but only non-ruminant source material must be utilized for ruminant feed (by FDA regulation).

Poultry By-Product Meal

Poultry by-product meal (PBM) consists of ground, rendered, clean parts of the carcass of slaughtered poultry such as necks, feet, undeveloped eggs and intestines, exclusive of feathers, except in the amounts as might occur unavoidably in good processing practices. The label shall include guarantees for minimum crude protein, minimum crude fiber, minimum phosphorus, and minimum and maximum calcium. The calcium level shall not exceed the actual level of phosphorus by more than 2.2 times. The quality of PBM, including critical amino acids, essential fatty acids, vitamins, and minerals along with its palatability, has led to its demand for use in pet foods and aquaculture.

Hydrolyzed Poultry Feather Meal

Hydrolyzed poultry feather meal (FeM) is pressure-cooked, clean undecomposed feathers from slaughtered poultry, free of additives and/or accelerators. Not less than 75 percent of its crude protein content must be digestible by the pepsin digestibility method. Modern processing methods that cook the feathers under pressure with live steam partially hydrolyze the protein and break the keratinaceous bonds that account for the unique structure of feather fibers. The resulting feather meal is a free-flowing palatable product that is easily digested by all classes of livestock. Modern feather meals greatly exceed the minimum level of AAFCO required digestibility. In cattle, 64 to 70 percent of FeM protein escapes degradation in the rumen and remains highly digestible in the intestinal tract. A specific characteristic is its excellent source of the sulfur containing amino acids, especially cystine.

Blood Meal, Flash-Dried

Blood meal flash-dried is produced from clean, fresh animal blood, exclusive of extraneous material such as hair, stomach belchings, and urine, except as might occur unavoidably in good manufacturing processes. A large portion of the moisture (water) is usually removed by a mechanical dewatering process or by condensing by cooking to a semi-solid state. The semi-solid blood mass is then transferred to a rapid drying facility where the more tightly bound water is rapidly removed. The minimum biological activity of lysine shall be 80 percent.

Blood products are the richest natural sources of both protein and the amino acid lysine available to the feed industry. However, throughout the 1960s and 1970s its use was limited because blood meal was considered to be unpalatable. Blood meal is inherently low in the amino acid isoleucine and the vat-drying procedures used at the time to process raw blood were severe enough to lower the bioavailability of lysine. Processing changes have improved the product considerably. Newer methods of processing (ring or flash-drying) produce blood meals with amino acid digestibilities of 90 percent or greater. Improved amino acid availability, in combination with improved formulation techniques, allows nutritionists to balance more of the essential amino acids, including isoleucine, which also eases concerns about the palatability of blood meal. Today, nutritionists are interested in blood meal because it is high in protein and is considered to be an excellent source of lysine. Its properties as a high rumen bypass protein have been highlighted in research findings in dairy, feedlot, and range cattle.

Fish Meal

Fish meal is generally considered in the animal protein class of ingredients though it is described in the marine products section of AAFCO. Fish meal is the clean, dried, ground tissue of undecomposed whole fish or fish cuttings, either or both, with or without the extraction of part of the oil. It must contain not more than 10 percent moisture. If it contains more than three percent salt, the amount of salt must constitute a part of the brand name, provided that in no case must the salt content of this product exceed seven percent.

Menhaden and anchovy are the main wild-caught fish species used for meal manufacture, with lesser quantities of herring used for meal. With an increase in aquaculture directed at the human food industry, by-products from these processing sites are being utilized. Fish meal is usually an excellent source of essential amino acids and fat soluble vitamins. Digestibility of its amino acids is excellent, but as with other ingredients, highly correlated to processing. Fish meals can be used in all types of rations. In some products, such as companion animal food diets, the palatability factors and the fishy smell and flavors are benefits. When used for other species, strong fishy odors and flavors in eggs, milk, or meat can be a disadvantage.

Other Products

There are several other specialty ingredients of animal protein origin such as plasma. Plasma in recent years has become a common component of early pig and calf formulas. Plasma is a highly digestible protein source in addition to providing immune response benefits in young animals.

Nutrient Value of Proteins

The major animal protein ingredients, MBM, meat meal, and PBM, are important feed ingredients for livestock, poultry, aquaculture, and companion animal diets throughout the world. These products contribute over three million tons of ingredients annually to the U.S. feed industry. In addition to protein, these meals are also excellent sources of essential amino acids, fat, essential fatty acids, minerals, and vitamins. The typical nutrient composition of the four most common animal proteins is shown in Table 6.

As can be noted, all of these ingredients are higher in protein than soybean meal and other plant proteins. In addition, MBM is higher in phosphorus, energy, iron, and zinc than soybean meal. The phosphorus level in MBM is seven-fold greater than that found in soybean meal and is in a form that is highly available to livestock and poultry. The phosphorus in both MBM and poultry meal is similar in bioavailability to feed-grade mono-dicalcium phosphate.

Table 6. Nutrient Composition of Animal Proteins.[1]

Item	Meat and Bone Meal	Blood Meal[2]	Feather Meal	Poultry By-Product Meal
Crude Protein, %	50.4	88.9	81.0	60.0
Fat, %	10.0	1.0	7.0	13.0
Calcium, %	10.3	0.4	0.3	3.0
Phosphorus, %	5.1	0.3	0.5	1.7
TME_N, kcal/kg	2,666[3]	3,625	3,276	3,120
Amino Acids				
Methionine, %	0.7	0.6	0.6	1.0
Cystine, %	0.7	0.5	4.3	1.0
Lysine, %	2.6	7.1	2.3	3.1
Threonine, %	1.7	3.2	3.8	2.2
Isoleucine, %	1.5	1.0	3.9	2.2
Valine, %	2.4	7.3	5.9	2.9
Tryptophan, %	0.3	1.3	0.6	0.4
Arginine, %	3.3	3.6	5.6	3.9
Histidine, %	1.0	3.5	0.9	1.1
Leucine, %	3.3	10.5	6.9	4.0
Phenylalanine, %	1.8	5.7	3.9	2.3
Tyrosine, %	1.2	2.1	2.5	1.7
Glycine, %	6.7	4.6	6.1	6.2
Serine, %	2.2	4.3	8.5	2.7

[1] National Research Council, 1994.
[2] Ring or flash-dried.
[3] Dale, 1997.
TME_N = true metabolizable energy nitrogen corrected.

Individual suppliers of animal protein meals can often provide more detailed specifications than derived from published papers based on averages or dated analyses. Analytical precision for chemical and nutrient availability values in animal protein ingredients is improving (Parsons et al., 1997). However, the most precise values have been derived from animal feeding studies.

Modern rendering processes, improved equipment, and computer monitored systems have resulted in significant improvements in the digestibility of animal proteins. Data collected from 1984 to the present demonstrate the digestibility improvements in the essential amino acids of lysine, threonine, tryptophan, and methionine. These data are summarized in Table 7.

Table 7. Digestibilities of Meat and Bone Meal Analyzed in Different Years Have Shown Improvement.

Amino Acid	1984 [a]	1989 [b]	1990 [c]	1992 [d]	1995 [e]	2001 [f]
Lysine, %	65	70	78	84	94	92
Threonine, %	62	64	72	83	92	89
Tryptophan, %	---	54	65	83	---	86
Methionine, %	82	---	86	85	96	92
Cystine, %	---	---	---	81	77	76

[a] Jorgensen et al., 1984.
[b] Knabe et al., 1989.
[c] Batterham et al., 1990.
[d] Firman, 1992.
[e] Parsons et al., 1997.
[f] Pearl, 2001.

Lysine digestibility in high quality MBM improved from 65 percent to over 90 percent during this time period. Dramatic improvements in the digestibility of tryptophan and threonine have also been documented. Cystine digestibility is between 76 percent and 81 percent but values were not reported in studies conducted prior to 1992. Similar improvements in amino acid digestibility have occurred in poultry meal, feather meal, and especially in blood meal.

Competition

Rendered protein meals and fats compete with vegetable products on a daily basis. Shifts in usage, as well as new developments can change the business atmosphere in the future. One example is the development of the fast growing fuel ethanol industry. Currently, there are 97 ethanol plants in production, with an additional 33 ethanol plants under construction. These ethanol plants have an annual production capacity of 4.5 billion gallons (Renewable Fuels Association, August, 2006). Dry-grind ethanol plants represent the fastest growing segment of the fuel ethanol industry in the United States, and produce the majority (60 percent) of fuel ethanol. By-products from dry-grind ethanol plants include wet and dry distiller's grains, wet and dried distiller's grains with solubles (DDGS), modified "wet cake" (a blend of wet and dry distiller's grains), and condensed distiller's solubles. Of these dry-grind ethanol plant by-products, distiller's grains with solubles is the predominant by-product being marketed domestically (Shurson, 2005). Approximately 40 percent of the distiller's grains with solubles are marketed as a wet by-product for use in dairy operations and beef cattle feedlots. DDGS is marketed domestically and internationally for use in dairy, beef, swine, and poultry feeds. More than 15.4 billion pounds of DDGS was produced in the United States in 2005. Corn is the primary grain used in wet mills and dry-grind ethanol plants because of its high fermentable starch content compared to other feedstocks. Shurson (2005) identified the following challenges facing DDGS in the animal feed marketplace.

- Product identity and definition
- Variability in nutrient content, digestibility, and physical characteristics
- Lack of a quality grading system and sourcing
- Lack of standardized testing procedures
- Quality management and certification
- Transportation
- Research, education, and technical Support
- International market challenges
- Lack of a national distiller's by-product organization and industry cooperation

There is considerable variation in nutrient content and digestibility among DDGS sources compared to soybean meal (Shurson, 2005). Tables 8 and 9 compare the nutritional characteristics of DDGS to meat meal and soybean meal. Research shows that higher levels of DDGS in swine diets increases the amount of unsaturated fat and reduces fat firmness in pigs, which impacts the quality of the meat and consumer acceptance (Shurson, 2001). Meat quality concerns may limit the amount of DDGS that can be used in swine diets and the relatively high fiber content of DDGS may restrict its use in poultry diets. Also, since DDGS contains polyunsaturated fats, there are concerns about high levels in cattle diets that can result in the accumulation of unwanted trans-fats in meat animals and depressed milk fat production in dairy cows.

Table 8. Dry Matter, Energy, and Fat Composition of Meat Meal, Dehulled Soybean Meal, and Dried Distiller's Grains with Solubles (DDGS).

Feedstuff	Dry Matter %	Digestible Energy kcal/lb	Metabolizable Energy kcal/lb	Net Energy kcal/lb	Fat %
Meat meal [a]	94	1,224	1,178	987	12.0
Soybean meal [a]	90	1,673	1,535	917	3.0
DDGS	89	1,819	1,703	829	10.8

[a] NRC, 1998.

[b] University of Minnesota, www.ddgs.umn.edu/profiles.htm

Table 9. Protein and Amino Acid Composition of Meat Meal, Dehulled Soybean Meal, and Dried Distiller's Grains with Solubles (Percent).

Feedstuff	Prot.	Lys	Thr	Trp	Met	Cys	Ile	Val
Meat meal [a]	54.0	3.07	1.97	0.35	0.80	0.60	1.60	2.66
Soybean meal[b]	47.5	3.02	1.85	0.65	0.67	0.74	2.16	2.27
DDGS	30.9	0.91	1.14	0.24	0.64	0.60	1.17	1.57

[a] NRC, 1998.

[b] University of Minnesota, www.ddgs.umn.edu/profiles.htm

While the rendering industry is much more mature than the fuel ethanol industry in the United States and renderers have faced many of these same issues, and have solved some, it is instructive to keep an eye on the competition.

Future Availability

The availability of rendered products for animal feeds in the future depends on regulation and the market. In the FDA Docket No. 2002N-0273, the agency's proposed rule on substances prohibited from use in animal food or feed, FDA announced its intent to prohibit brains and spinal cords from cattle 30 months of age or older from being used in all feed, including for non-food animals. They are also proposing to ban all dead and downer animals (they term these "cattle not inspected and passed for human consumption") from any feed unless the brains and spinal cords are removed. The FDA estimates the rule will decrease the annual production of MBM available for feed by about 15 million pounds, which would be a tiny 0.3 percent of the total volume produced in the United States (Federal Register, 2005). Many renderers believe this restriction on dead stock will end the service of dead stock collection all together (about 2.2 billion pounds of raw material; Informa Economics, 2004). If this were the case, the proposed rule could decrease the annual production of MBM available for feed by about four percent of the total volume produced in the United States.

Renderers are innovative and competitive and will adapt to changes in both regulations and the market. Regulatory agencies will determine whether certain raw materials can be used for animal feed. Customer expectations, consumer demand, and economic considerations will dictate product specifications and prices.

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