Director's Digest
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Rendering 101: Raw Material, Rendering Process, and Animal By-Products

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This subject area is important to nearly every facet of the animal agriculture production chain. It likewise is a subject that a number of those working in the disciplines of meat production and most consumers know very little about. As the demographics of agriculture have and continue to change, the close familiarity of its production practices becomes more distant. Each year fewer people are living on farms and actively involved in meat animal production. Therefore, as a population of consumers, students, instructors, regulators, legislators, researchers, etc., there is less awareness as to the origin of our food. This is particularly evident with meat. It is important that the animal agriculture industries deliver the message and the facts that actually are responsible for the safe, nutritious, and health conscious practices that are behind the scenes of each meal. The production of each animal for meat, milk, eggs, and fibers are accompanied with portions that are determined as inedible. The reasons are of multiple origin. But the fact remains that animal production for meat results in the ancillary production of by-products or co-products. It is therefore the objective of this basic training document to discuss the rendering process and the animal by-products.

Raw Material

Nearly all industrial manufacturers for a variety of products use the words raw material. For car manufacturers, these are steel, plastic, leather, glass, electronics, and a number of other basic components. For the rendering industry, these are the inedible components or tissues. While edible meat, poultry, and fish are the primary products of the livestock, poultry, and fishery industries and represent the majority of the animal value, the by-products are an important key in maintaining a symbiotic relationship with the production, processing, and preparation functions of providing meat, milk, and eggs. Edibility is determined by a number of criteria including consumer acceptance, regulatory requirements, economics, hygiene, tradition, and ethnic background.

Raw material, in a literal definition as it relates to rendering, is the by-products. The terms by-products and co-products as they relate to animal production are often used interchangeably. The need to debate, which is most appropriate or descriptive, is not extremely important except to draw attention to one fact. By-product is defined as a secondary product obtained during the manufacture of a principal commodity. Co-product possesses the meaning of being together or joined. Thus the important fact for the animal production and processing industries is the utilization and opportunities that exist for the by-products that are produced ancillary to the production of meat, milk, and eggs for human food production.

The market for U.S. meat and meat-based products requires the production and annual slaughter of approximately 139 million head of livestock as well as 36 billion pounds of poultry and a growing aquaculture industry. The current average slaughter and processing of 100 million hogs, 35 million cattle, and approximately eight billion chickens in the United States makes it first in beef and poultry and second in pork production in the world. The animal numbers, when processed into edible meat, results in raw material by-products to include hides, skins, hair, feathers, hoofs, horns, feet, heads, bones, toe nails, blood, organs, glands, intestines, muscle and fat tissues, shells, and whole carcasses. As has been documented via centuries of utilization of these by-product materials as resources for other significant uses as well as volumes of scientific references validating their nutritional qualities, the products produced from the inedible raw material make important economic, environmental, human, and animal health contributions to their allied industries and society.

Using basic approximates, these by-products comprise 50 percent of the live weight of cattle, 42 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. There are current existing factors that are resulting in even higher inedible raw material quantities being generated. These include further processing, pre-packed/table ready meat products, which leave increasing amounts of the inedible portions at the processing locations. Additionally, the removal of non-ambulatory cattle and specific tissues from slaughtered cattle from foods due to recent and impending regulations contribute to the raw material quantity increases. The current annual amount of raw material generated exceeds 50 billion pounds and if all could be accounted for may exceed 54 billion pounds. Animal raw material is a highly perishable material, highly laden with microorganisms, many of which are pathogenic to both humans and animals, and research has validated the presence of a high incidence of foodborne pathogens within its content. Rendering, as a means of animal raw material handling and processing, offers a safe and integrated system that complies with all of the fundamental requirements of environmental quality and disease control.

Rendering Process

Rendering is accomplished via a variety of equipment and processes. It is a process of both physical and chemical transformation. Utilizing tissues from the production and processing of food animals for meat, the 200-plus rendering facilities operating in North America function to serve animal industries by utilizing the more than half the volume of its total annual production. All of the rendering processes involve the application of heat, the extraction of moisture, and the separation of fat. The methods to accomplish such are varied and are illustrated in Chart 1.

The time and temperature at which this cooking process is accomplished are critical and the primary determinant of the quality of the finished product. The processes vary according to the raw material composition. Meat and bone meal, meat meal, poultry meat meal, hydrolyzed feather meal, blood meal, fish meal, and animal fats are the primary products resulting from the rendering process.

All rendering system technologies include the collection and sanitary transport of raw material to a facility whereupon it is ground into a consistent particle size and conveyed to a cooking vessel, whether of continuous or batch configuration. Cooking is accomplished generally via steam at temperatures of 245 degrees to 290 degrees Fahrenheit (F) for 40 to 90 minutes depending upon the system type. Most North American rendering systems currently are continuous units. Regardless of the type of cooking, the melted fat is separated from the protein and bone solids and a portion of the moisture is removed. Most importantly, cooking is similar to a sterilization process functioning to inactivate microorganisms to include bacteria, viruses, protozoa, and parasites.

Fat is separated from the cooked material via a screwpress within a closed vessel. Following the cooking and fat separation, the "cracklings" or "crax," which are comprised of the 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.

Processes and technology of rendering have and continue to undergo significant changes. 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 death values for specific microorganisms are achieved consistent with the nutritional quality of the finished products. Regulatory practices concerning animal by-products are not consistent among countries. Even the process of rendering is interpreted and regulated differently between countries. As an example, a European Union directive requires mammalian derived raw material to be processed under the conditions of 133 degrees Celsius, three bars of pressure for 20 minutes. The North American processes generally do not incorporate pressure conditioning except for feathers and other high keratin containing tissues. Processing conditions incorporating pressure treatment generally lowers the nutritional value of the resultant protein meals (10 to 15 percent), excepting those tissues of high keratin content. The rendering processes are consistent as time/temperature treatment for the inactivation of microbiological organisms. Temperatures exceeding the thermal death time requirements are correlated with lowered nutritional values especially referencing protein and amino acids.

Rendering provides a controlled heating process of time/temperature, which provides for the inactivation of bacteria, viruses, protozoa, and parasitic organisms. This asset is not accompanied with other alternatives for raw material disposal such as burial, composting, or landfill applications. Research has demonstrated that raw material derived from food animal processing is heavily laden with microorganisms. Table 1 provides data that illustrates the high incidence and content of foodborne microorganisms within raw animal by-product material. Further, the table provides data to demonstrate the efficacy of the rendering process in killing this group of foodborne pathogens.

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

Pathogen	Raw Tissue[2]	Post Process[2]
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

1. Troutt et al. (2001) Samples from 17 different rendering facilities taken during the winter and summer.
2. Percent of the number of samples found to be positive for pathogen out of the total samples collected.

Salmonella is a bacteria species that is commonly associated with feed ingredients and often incriminating of animal by-product ingredients. It is now recognized that post processing and handling of all ingredients can be responsible for re-contamination. It is a concern for all feed ingredients and not restricted to animal protein. Databases from around the world illustrate this fact in Table 2. This summary as well as other databases suggests that all feed ingredients may contain *Salmonella.* 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 2. Incidence of *Salmonella* in Feed Ingredients

	Country					
Ingredient	Item	Netherlands[1]	Germany[2]	USA[3]	Canada[4]	United Kingdom[5]
Animal Proteins	Samples	2,026	17	101	Not reported	120
	% Positive	6	6	56	20	3
Vegetable Proteins	Samples	1,298	196	50	Not reported	2,002
	% Positive	3	26	36	18	7
Grains	Samples		37		Not reported	1,026
	% Positive		3		5	1
Fish Meal	Samples				Not reported	1,316
	% Positive				22	22

1. Beumer and Van der Poel (1997)
2. Sreenivas (1998)
3. McChesney et al. (1995)
4. Canadian Food Inspection Agency (1999)
5. Brooks (1989)

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), it is not inactivated with any of the currently available rendering processes. Thus, rendering methods, nor any other industrially operational process, have proven to be capable of completely inactivating the TSEs under practical conditions even though infectivity levels are lowered.

The North American rendering industry recognizes its role in assuring food safety and in protecting human and animal health. The rendering process is an effective method for insuring biosecurity. Its infrastructure, products, and the rendering industry are regulated by state and federal agencies. Rendering industry organizations provide technical support and education in quality assurance, feed safety, and animal health. The Fats and Proteins Research Foundation (FPRF), Inc., solicits and funds industry and university research to address pertinent biosecurity and nutrient value issues. The Animal

Protein Producers Industry administers industry-wide programs for biosecurity, *Salmonella* reductions, and third-party certification for compliance to bovine spongiform encephalopathy (BSE) regulations. Additionally, North American rendering companies have adopted voluntary Hazard Analysis and Critical Control Point (HACCP) programs as an important component of their biosecurity and food safety programs.

Rendered Animal By-products

The rendering process converts raw animal tissue into various protein, fat, and mineral products, all of which are decharacterized into rich granular-type substrates and fats with specific nutritional components that has absolutely no resemblance to the original raw material. As a very broad estimate, the raw material is in excess of 60 percent water and yields approximately 20 percent protein and 20 percent fat. These protein, fat, and mineral fractions are then available for a variety of uses. Their primary use has traditionally been livestock, poultry, aquaculture, and companion animal feed ingredients.

Annual volume in the United States approximates 9.2 billion pounds of animal derived proteins and 9.2 billion pounds of rendered fats. About 85 percent of this production is utilized as animal feed ingredients. Industrial use applications in chemical, metallurgy, rubber, and oleochemical are the second largest utilization, with over 3,000 modern industrial use applications being identified. The manufacture of soaps and personal care products remain a major use for animal fats, especially tallow, and newer uses as biofuels are increasing on an annual basis.

Animal Fats and Recycled Greases

As previously referenced, the animal feed and ingredient industry is a major user of rendered animal fats and recycled restaurant and cooking oils. Fats are the highest caloric-dense feedstuff and foodstuff. In addition, fats and certain of their component fatty acids provide essential and indispensable body functions separate and aside from their caloric function. The rendering industry processes some 11.6 billion pounds annually of the respective fats as follows:

Edible Tallow	1.625
Inedible Tallow	3.859
Lard and Grease	1.306
Yellow Grease	2.633
Poultry Fat	2.215
Total	11.638

Source: U.S. Department of Agriculture (2002) (in billion pounds annually)

This annual volume is approximately one-third of the total U.S. production of fats and oils (lipids).

The term lipid includes both fats and oils. Lipids are chemically structured primarily as triglycerides. Basically described as a structure consisting of one unit of glycerol and three units of fatty acid. The fatty acids are actually the components that give the respective fats their individual chemical and physical characteristics. For example, tallow and corn are both lipids consisting mostly of triglycerides. However, tallow is solid at room temperature whereas corn oil is a liquid. The difference exists because of the specific kinds of fatty acids associated with each product. Similarly, the fat from each animal species possesses fat with varying fatty acid composition. Table 3 illustrates the variance in fatty acid composition of various fats and oils as expressed in percentages.

Table 3. Fatty Acid Composition of Various Fats and Oils as Expressed in Percentages

Fatty Acid Composition	Tallow	Hog Grease	Lard	Restaurant Grease	Poultry	Corn	Soy-bean	Saf-flower	Peanut	Palm	Canola	Cotton-seed	Coco-nut
C8 Caprylic													6.5
C10 Capric		.2	.1										6.0
C12 Lauric		.2	.2		.1								49.5
C14 Myristic	3.0	1.9	1.3	1.9	1.1					1.5		1.0	19.5
C16 Palmitic	25.0	21.5	25.8	16.2	20.8	12.5	11.5	8.0	11.5	42.0	4.0	26.0	8.5
C16-1 Palmitoleic	2.5	5.7	2.7	2.5	5.9							1.0	
C17 Margaric	0.5	.7		1.0									
C18 Stearic	19.5	14.9	13.5	10.5	8.5	2.5	4.0	3.0	3.0	4.0	2.0	3.0	2.0
C18-1 Oleic	45.0	41.1	42.2	47.7	48.8	29.0	24.5	13.5	53.0	43.0	60.0	17.5	6.0
C18-2 Linoleic	3.0	11.6	10.2	17.5	19.1	55.0	53.0	73.0	26.0	9.5	20.0	51.5	1.5
C18-3 Linolenic		.4	1.0	1.9	.8	.5	7.0	.5			10.0		
C20 Arachidic		.4		.3	.3				1.5				
C20-1 Eicosenic		.9	1.0	.1	.6				1.5		2.0		
C22 Behenic		.4		.2	.4				2.5				
C22-1 Eurcic		.1		.4	.1						2.0		
C24 Lingoceric									1.0				
Iodine Value	50	60	65	75	80	125	130	140	92	50	118	105	10
Unsaturated to Saturated Ratio	.96	1.49	1.45	2.33	2.22	5.67	5.45	8.09	5.90	1.10	15.70	2.33	.10
Total Unsaturated	49.0	59.8	59.1	70.0	67.6	85.0	84.5	89.0	85.5	52.5	94.0	70.0	7.5
Total Saturated	51.0	42.0	40.0	30.0	30.4	15.0	15.5	11.0	14.5	47.5	6.0	30.0	92.5

Values do not always total 100 percent but represent means as obtained from various fat analyses via gas chromatography. FPRF source (1995). FPRF Directors Digest #269

Most fatty acids found in natural fats vary in chain lengths from eight to 24 carbons. Feeding fats contain their predominance of fatty acids as 14 and 18 carbon lengths. If fatty acids have within their chemical structure double bonds, they are considered unsaturated. Conversely, 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 the carbon chain increases with saturated fatty acids, the melting point increases, and their physical nature are referred to as "harder fats." A measure of hardness is titer. It is a measurement determined through a determination of the solidification point of the fatty acids in degrees as tallow if it possesses a titer of 40 or higher or grease if under 40 titer regardless of the animal origin. Iodine value (IV) is another measurement of hardness/softness and is defined as the grams of iodine absorbed by 100 grams of fat. Unsaturated fats have higher IV values than saturated fats. Table 4 provides a guide of various animal fats comparing titer and IV.

Table 4. Titer and Iodine Values (IV) for Fat from Various Livestock Species

Species	Titer, °Celsius (°F)	IV
Sheep	44 – 48 (111 – 118)	42 – 43
Cattle	42 – 45 (108 – 113)	43 – 45
Hogs	36 – 40 (97 – 104)	63 – 65
Horses	35 – 38 (95 – 100)	80 – 85
Poultry	31 – 35 (89 – 95)	77 – 80

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Animal Feeding Fats

The term "feed grade" requires that the specific type of product be adequately tested to prove its safety for feeding purposes. Feeding fats are regulated under that same guideline but the feed grade term is not required in the ingredient declaration.

Animal fat is obtained from the tissues of mammals and/or poultry in the commercial processes of rendering or extracting. It must contain and be guaranteed for not less than 2.5 percent unsaponifiable materials and not more than one percent insoluble impurities. Maximum free fatty acids (FFA) and moisture must also be guaranteed. Products bearing a name descriptive of its kind or species origin must correspond thereto as beef, pork, or poultry. Fats can be identified as tallow if the titer is 40 or higher or grease if under 40 titer.

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 includes blends of feed grade animal, poultry, vegetable fats, and/or restaurant grease/cooking oil. It may also include soap stock, chemical, and other industry by-products. Fats within this category are often referenced as animal/vegetable blends.

Table 5 contains suggestions for quality specifications for animal feed fats. Though specifications are clearly defined and guarantees specified under several references, including the American Association of Feed Control Officials (AAFCO), suppliers of feeding fats can provide products that are labeled and guaranteed outside the trading standards. As with any feed ingredient, specifications should be thoroughly understood between supplier and purchaser. The following are guidelines commonly used by the industry.

1. Fats must be stabilized with an acceptable feed or food grade antioxidant added at levels recommended by the manufacturer. Fats should pass the active oxygen method (AOM) stability test requirements.

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 any PCB and pesticide residues are within the allowable limits established by state and/or federal agencies.

4. Fats for poultry rations should be certified as being negative for the chick edema factor as measured by the Modified Liberman-Burchard test.

5. Fats shall not contain more than trace levels and a level that exceeds FDA requirement of any minerals or heavy metals.

6. 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 5. Suggested Quality Specifications for Feed Fats

		Blended Fat Categories				
		Animal	Poultry	Feed Grade Animal	Animal/ Vegetable	Vegetable Soap Stock
Total Fatty Acids	min. %	90	90	90	90	90
Free Fatty Acids	max. %	15	15	15	158*	50
Moisture	max. %	1	1	1	1	1.5
Impurities	max. %	0.5	0.5	0.5	0.5	1
Unsponifiable	max. %	1	1	1	1.0*	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.*

Dictionary of Fat Terminology

Total fatty acids (TFA) comprise 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.

Free fatty acids (FFA) are those fatty acids that are not linked to glycerol by an ester linkage but are in the free form. Oxidation of fat produces FFA as a by-product, therefore the presence of high levels of FFA in whole animal fats causes concern about rancidity. Hydrolyzed fats in which the FFAs are created by deliberately splitting glyceride from whole fat contain higher levels of FFA than whole fats. This high FFA level is not a problem if these fats contain antioxidants to prevent oxidation from creating additional FFA levels.

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

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

Unsaponifiable: Fats contain a number of compounds such as sterols, hydrocarbons, pigments, fatty alcohols, and vitamins, which are not hydrolyzed by the alkaline saponification used to split triglycerides into glycerol and fatty acids. Normal unsaponifiable has feeding value comparable to the fats involved. Certain problem compounds, such as the edema factor, are contained in the hydrocarbon diene portion of the unsaponifiable.

Iodine Value (IV): 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. Naturally, unsaturated fats have higher IVs than saturated and 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 with a titer over 40 are considered "tallow" and under 40 are considered "grease." Many buyers erroneously consider these terms as meaning beef or pork fats.

Fat color varies from the pure white of refined beef tallow, through the yellow of grease and poultry fat, to the very dark color of acidulated soap stock. Color does not effect the nutritional value of fat but may be a consideration in pet foods and other consumer oriented products. Two color scales are frequently used with fats: Fats Analysis Committee of the American Oil Chemist's Society and Lovibond. Lovibond is far more accurate with light colored fats.

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. Two main tests are used to measure stability of fats.

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 (less than 5.0 me peroxide/kg.) indicates a non-rancid sample.

2. AOM Test (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 but does not require it to be 100 percent cattle fat.

Choice white grease (CWG) is derived primarily from pork tissue. CWG is traded with a standard specification of 36 titer, four FFA, and 11 B color. This standard was again developed by the soap industry. In feeding fats, color has no nutritional value. Thus, considerable savings can often be acquired by developing feeding fat specifications that concentrate on the nutritional value of the respective fat.

Yellow grease (YG) has been a term used for a number of years and often confused with off-color CWG. Yellow grease is primarily restaurant grease/cooking oil sources but can contain other sources of rendered fat, and/or high FFA and high moisture, impurities, and unsaponifiable fat from any type of rendering operation. High FFA and dark tallow is often sold as yellow grease with a titer of over 40 and, when compared to YG containing near the minimum 36 titer, may be lower in energy value when fed to poultry or swine.

There are several documented benefits for use of animal fats in livestock, poultry, aquaculture, and companion animal diets. A very primary use is that of enhancing energy concentration of diets. Depending on the species to which it is being fed, the energy contributions range from 2.6 to 3.8 times the energy content of corn. Table 6 provides energy values for the commonly used animal fats. In addition to the nutritional contribution, fat addition to animal diets contributes to dust control, reduced respiratory disease, feed mill cleanliness, worker comfort, improved palatability of feed, enhanced pelleting efficiencies, increased stability of fat soluble vitamins and other nutrients, and enhanced life of feed mixing and handling equipment. Animal fat is also an ecologically and environmentally friendly ingredient. Specifically, "You are recycling an ingredient that is the end result of your feeding experience."

Table 6. 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. Characteristics for fats were taken from Table 5.
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 in animals are found in all body tissues. They are found in higher concentration in organ and muscle tissue. They may range from very insoluble types such as feather, hair, wool, and hoofs, to highly soluble proteins such as serum or plasma. Animal derived foods are primary sources of protein and other nutrients in human diets. Similarly, the inedible tissues from animal production and processing serve as a resourceful array of nutrients including protein into animal protein ingredients.

AAFCO defines the composition for rendered animal products as well as all feed ingredients. The *2004 AAFCO Ingredient Manual* references some 125 individual animal by-products, thus confusion often reigns supreme in matching definition to expectations. 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. It is important to have an understanding of ingredient specifications and definitions.

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.

MBM can be used in all species of livestock, poultry, and aquaculture. Non-ruminant source material must be utilized for ruminants.

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 its protein and critical amino acids, its essential fatty acids, vitamins, and minerals lends its use for all species. These traits, together with its palatability, have led to its demand for use in pet foods and aquaculture.

Hydrolyzed Poultry Feathers

Hydrolyzed poultry feathers is the product resulting from the treatment under pressure of clean un-decomposed 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 that breaks 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. Its protein is highly by-passed, ranging from 64 to 70 percent, and 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 all 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 source of both protein and the amino acid lysine as a natural ingredient available to the feed industry. Processing changes have altered the product considerably. In the past its use was limited due primarily to vat-drying procedures that produced blood meal with poor palatability and low bioavailability of its lysine. Newer methods of processing (ring or flash-drying) produce a blood meal with digestibilities that routinely exceed 90 percent acceptable palatability. The principal nutritional interest in blood meal is due to its high protein content and as an excellent source of lysine. Its properties as a high rumen bypass protein have been highlighted in research findings in both dairy, feedlot, and range cattle.

Fish Meal

Fish meal is generally considered in the animal protein class of ingredients though they are described in the marine products section of AAFCO. Fish meal is the clean, dried, ground tissue of decomposed 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.

There are no protein restrictions for major minerals. Menhaden and anchovy are the main fish species used for meal manufacture, with lesser quantities of herring 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 food diets, the palatability factors and the taint is a benefit. When used for other species, taint of eggs, milk, or meat can be a disadvantage. Like other animal protein ingredients, they have been stigmatized for the alleged content of biogenic amines especially gizzerosine and histamine. Cause and effect relationship to lesions and performance depressions are limited.

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 are all important feed ingredients for livestock, poultry, aquaculture, and companion animal diets throughout the world. MBM, meat meal, and PBM comprise the largest available quantities. These contribute over two million tons of ingredients annually to the U.S. feed industry. Animal proteins contribute not only protein but are also excellent sources of amino acids, fat, essential fatty acids, minerals, and vitamins. Thus, when compared to other protein ingredients, multiple nutrients are derived from animal protein ingredient sources in addition to the protein and amino acids. The typical nutrient composition of the four most common animal proteins is shown in Table 7. 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 protein, phosphorus, energy, iron, and zinc than soybean meal. The phosphorus level in MBM is seven-fold 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 7. 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

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 in MBM. This data is summarized in Table 8. 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 the amino acid digestibility have occurred from poultry meal, feather meal, and especially for blood meal.

Table 8. Digestibility Coefficients of Selected Amino Acids in MBM as Reported in Literature since 1984

Amino Acid	1984[1]	1989[2]	1990[3]	1995[4]	1997[5]	2000[6]
Lysine, %	65	70	78	92	71	87.5 – 92
Threonine, %	62	64	72	89	-	80.2 – 88.9
Tryptophan, %	-	54	65	-	70	86.4
Methionine, %	82	-	86	91	-	87.4 – 92
Cystine, %	-	-	-	71	-	76.4

1. Jorgensen et al. (1984) Determined at the ileum of pigs.
2. Knabe et al. (1989) Determined at the ileum of pigs.
3. Batterham et al. (1990) Determined at the ileum of pigs.
4. Parsons (1995) High quality MBM in poultry using the precision fed cockerel balance assay.
5. Bellaver, Easter, Parsons. (1997) Determined at the ileum of pigs.
6. FPRF reports. (2000) Upper range values for meat and bone meal as determined via ileal, intestinal, and cockeral assays (Cromwell, Parsons, Klopfenstein projects).

Individual suppliers of animal protein meals can often provide more detailed specifications than derived from published databases. Analytical precision for chemical and nutrient availability values in animal protein ingredients is improving. However, the most precise values have been derived from animal feeding studies. Though AAFCO standards reference pepsin digestibility values, it has been shown that the standard pepsin digestibility test (using 0.2 percent pepsin) is poorly correlated with lysine digestibility in broilers. Using a more dilute concentration of pepsin (0.002 percent or 0.0002 percent) improved the correlation, but still accounted for less than 50 percent of the variation in digestibility of amino acids in MBM. Table 9 illustrates the lack of correlation of the pepsin invitro analysis when compared to the bioavailability as determined by animal studies.

Table 9. Analytical Predictors of MBM Quality[1]

Analysis	Correlation to True Lysine Digestibility
Pepsin Digestibility	
0.2% pepsin[1]	0.25
0.002% pepsin[2]	0.62
0.0002% pepsin[2]	0.70
Potassium Hydroxide Solubility[1]	0.08
Multi-enzyme pH Change[1]	0.10

1. Parsons (1996)
2. Parsons et al. (1997)

Summary

The rendering industry has and continues to be closely related with animal and meat production, especially in the United States and Canada. For decades, the industry's primary market has been animal feed ingredients. Certainly many other industrial use applications have provided marketing opportunities and perhaps new use applications are foreseeable, but feed, livestock, poultry, and companion animals have been the target market for animal by-products. There are no current scientific reasons for altering this practice as one evaluates the framework of industry, state, and federal feed safety guidelines, both voluntarily and regulatory, for safe feed and food. These regulations and procedures include good manufacturing practices, HACCP, and codes of practice to name only a few. In addition, the Food and Drug Administration's 1997 regulation, 21 CFR 589:2000, that prohibits certain ruminant proteins to be used in ruminant diets is only one part a series of regulations to prevent the amplification of BSE via feed ingredient channels. There may not be another industry that is subjected to a greater regulatory agenda nor subjects itself to more stringent requirements and utilization of third party validation as the rendering industry and its end user, the feed industry. 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.

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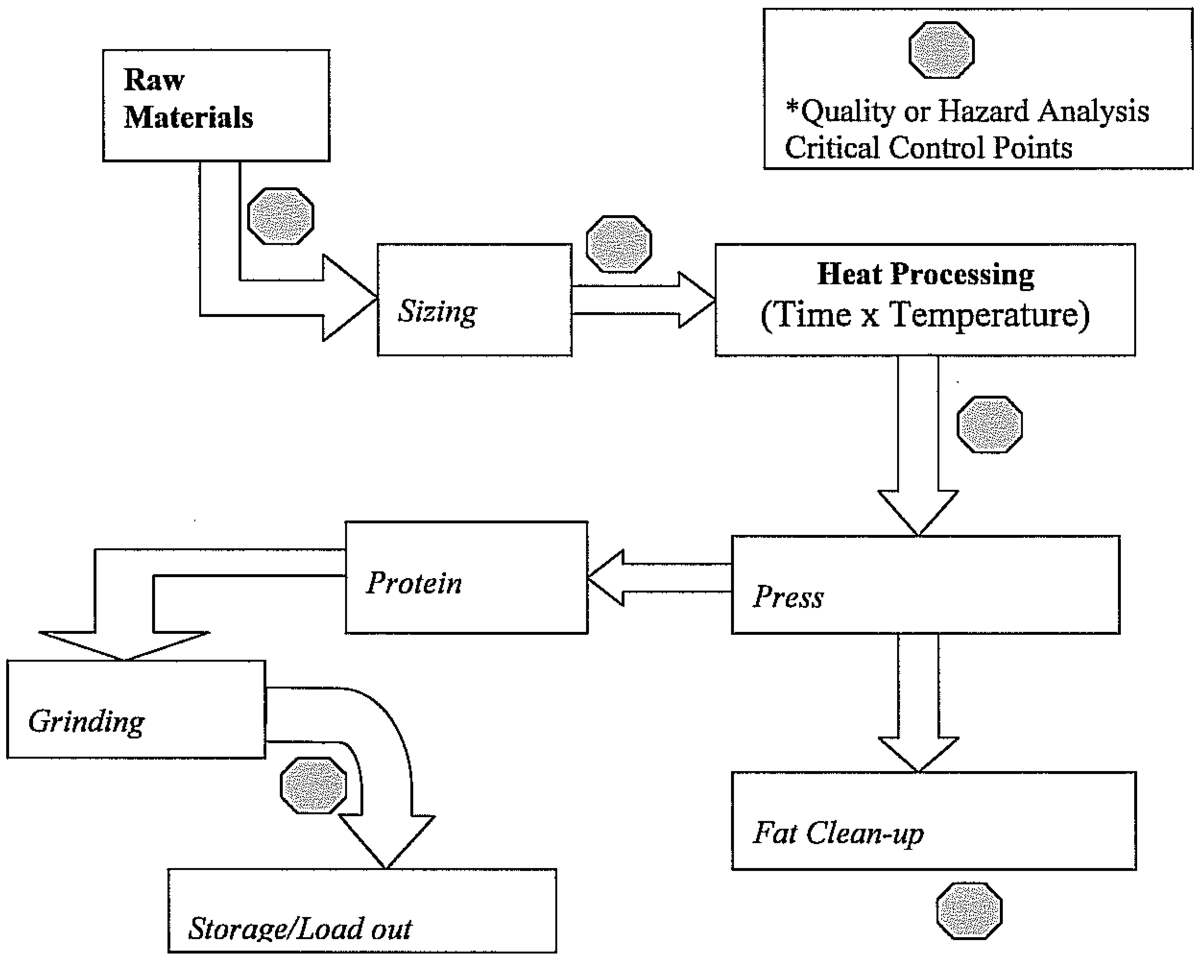
Appendix 1. The Basic Production Process of Rendering.



** Suggested quality or Hazard Analysis and Critical Control Points*