Director's Digest
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By-Products: Inedible By-Product

Introduction

Inedible meat byproducts have a prehistoric significance that was established before the advent of the meat industry. As animal protein (meat) was acquired primarily by hunting, and individual animals were "cleaned" for food purposes, the inedible portions were left for nature's disposal or used for clothing, components for housing, fuel and other life-support functions that complemented the use of the animal as a basic component of nutrition. In the early days of the modern meat industry, the inedible meat and fat remaining after the removal of hide were likewise disposed of by various methods, but it was most often dumped into trenches or rivers. The earliest non-life support usage of inedible animal by-products was probably their use as fertilizer. The protein and mineral fraction that remained following the removal of a portion of fat was generally disposed of by spreading it around the crops. With the modern world's more environmentally sensitive and dense population, the disposal alternatives of un-processed by-products soon became unacceptable. This evolution began in the nineteenth and early twentieth centuries in most of the world's industrialized countries. It was during this period that rendering was adopted as a means of processing animal raw material via heating or cooking and extracting the fat. Soap-making and candle-making utilized the rendered fat during this era. The protein fraction was not used extensively until the early 1900s. A recorded benefit is documented for the use of digester tankage animal protein in 1901 by Professor C.S. Plumb of Purdue University. He published research conducted with swine that dramatically enhanced the growth rate with the inclusion of animal protein ingredients as a supplement to ear corn.(1) The research documented dramatic improvements in growth rate. Since that important discovery, the literature has been abundant in exploring the benefits of animal protein and fat ingredients for all livestock, poultry, domestic animals and aquaculture species.

In recent years the emergence of bovine spongiform encephalopathy (BSE), other transmissible spongiform encephalopathies (TSEs) and other emerging diseases that become endemic throughout regions of the world have dictated modifications in processes and precautionary principles to meet these geographic differences. Currently, the North American regulations differ from those adopted in Europe for the utilization of animal by-products as well from those in other parts of the world. The United States has prohibited mammalian-derived proteins from use in any feed for cattle or other ruminant animals with specific exemptions (21CFR589.2000) since 1997.

The European Union has issued Regulation (EC) No. 1774/2002 on the use of animal by-products (ABPs). Detailed requirements for the processing and use of ABPs are currently divided into three categories. Meat and bone meal (MBM) is at present not allowed as feed for farmed animals. MBM produced from category 3 animal by-product material can be used for pets (companion animals). The conditions for rendering animal by-products are also specified in the EU regulation. It specifies maximum particle size and temperature, time and pressure for heat treatment. All category 1 must finally be incinerated while category 2 ABPs can be used, e.g. as fertilizer or for landfill. The categories according to the EU regulations are defined in Table 1.

Table 1: Basic Categories of Animal By-Products

Category 1 ABPs	Category 2 ABPs	Category 3 ABPs
Animals suspected of TSE Specified BSE risk material (including dead ruminants) Material from treatment of waste water (cat. I plants) Pet, zoo and circus animals Experimental animals Products from animals with residues of prohibited substances or environmental contaminants International catering waste	Manure or digestive tract content from mammals Material from treatment of waste water (cat. 2 or 3) Products containing veterinary drug residues Farmed Animals, which have died or been killed at farm Fish with clinical signs of disease	Animal waste fit for human consumption Non-ruminant blood, hides and skins, which have passed ante-mortem inspection Shells, hatchery by-products and cracked eggs with no sign of clinical disease Raw milk from healthy animals Food destined for animal consumption Fish and fish offal Blood, hides, hooves, feathers and hair from animals with no sign of disease Catering waste including used cooking oil

Regulations and directives that govern the processing and utilizations/disposal of animal co-products are under constant review and possible change as dictated by current issues affecting individual countries, thus change can be expected.

The Office International des Epizooties (OIE) is an organization that addresses animal health policy on a global basis. Future direction and policy will undoubtedly source from this organization which currently represents 164 members. It is considered by most authorities as the 'World Organization for Animal Health'. The incidence of transmissible spongiform encephalopathies as well as all emerging diseases, ethnic and ethical issues will continue to dictate specific geographical policies. OIE is an organization structured to evaluate science and assess risk.

Processed animal by-products are generally classified as either animal proteins or fats. This article will provide a discussion of the products these major classifications.

Inedible By-Products

Production and processing of edible meat and poultry results in an inedible fraction as with nearly any other food brought to our table. Edibility is a relative term and is determined by a number of factors including consumer acceptance, demographics, regulatory requirements, economics, tradition, hygiene and religious beliefs. From animal production the inedible raw material consists of such tissues as hides, skin, hair, feathers, hoofs, horn, feet, heads, bone, toe nails, blood, organs, glands, intestines, muscle and fat tissues, egg shells and whole diseased carcasses. Using basic approximations these tissues comprise 50% of the live weight of cattle, 40% of the live weight of pigs, 30% of the live weight of broilers. As further processing, pre-packaging and table ready meat products are brought to the marketplace, the inedible portions have increased in relation to the original weight of the animal. In recent years, global regulations and directives have arisen via precautionary principles for the inclusion of specific animal tissues to be categorized as inedible fractions. These trends are expected to continue and contribute even more inedible tissue to the by-product pool.

World production of animal by-products is not known in exact quantities. Nor is there consistency of terminology, specifications, processing and end usage. Thus, the diversity associated with animal by-products necessitates a general review of the subject.

Processing

Several processes are utilized to handle or dispose of inedible raw animal tissues. The most frequently referenced are those of burial, landfill, composting, which are basically all versions of burial, as well as burning (pyre), incineration or rendering. Rendering, composting and biogas production are the only processing methods that result in the ability to recycle and provide value to the by-product tissues. The other processes are disposal procedures. Rendering and incineration are the only process in which temperature-time and other controlled process procedures are used in the treatment of raw animal tissue. The rendering process results in the separation of fat from the proteinacious and mineral components, removes most of the moisture and inactivates a spectrum of microorganisms and parasitic organisms. The rendering process completely decharacterizes the muscle, connective, structural, organ and adipose tissues into a rich granular-type substrate and fats with specific nutritional components that have absolutely no resemblance to the original raw material. Biosecurity questions arise with all disposal procedures that do not incorporate sterilization principles provided by the controlled application of heat or other treatments. A summary of potential health risks has been provided by the UK Department of Health for various methods of handling animal by-products. (see Table 2). This summary associates a risk factor with the most common methods for handling animal by-products. Rendering still remains the primary method for processing animal by-products in most countries.

Table 2 Summary of Potential Health Risks for Various Methods of Handling Animal Byproducts*

	Exposure of humans to hazards from each option				
Disease/Hazardous Agent	*Rendering*	*Incineration*	*Landfill*	*Pyre*	*Burial*
Campylobacter, E. Coli, Listeria,	Low	Low	Moderate	Low	High
Salmonella, Bacillus anthacis,	Low	Low	Moderate	Low	High
Clostridium botulinum, Leptospira,	Low	Low	Moderate	Low	High
Mycobacterium tuberculosis var bovis, Yersinia	Low	Low	Moderate	Low	High
Cryptosporidium, Giardia	Low	Low	Moderate	Low	High
Clostridium tetani	Low	Low	Moderate	Low	High
Prions for BSE, Scrapie	Moderate	Low	Moderate	Moderate	High
Methane, CO_2	Low	Low	Moderate	Low	High
Fuel-specific chemicals, Metal slats	Low	Low	Low	High	Low
Particulates, SO_2, NO_2, nitrous particles	Low	Moderate	Low	High	Low
PAHs, dioxins	Low	Moderate	Low	High	Low
Disinfectants, detergents	Low	Low	Moderate	Moderate	High
Hydrogen sulfide	Low	Low	Moderate	Low	High
Radiation	Low	Moderate	Low	Moderate	Moderate

BSE, bovine spongiform encephalopathy
PAH, polyaromatic hydricarbons

The 2002 market for the United States meat and meat-based products requires the production and animal slaughter of approximately 139 million head of livestock as well as 16 billion kilograms of poultry and a growing aquaculture industry. This makes animal food production one of the largest economic industries within the United States. The annual production makes it second in pork and first in beef and poultry meat production in the world. Animal production is similarly important in most other countries. Animal protein and fat are also important components of human diets. China currently produces over 50 million pigs annually, nearly five times the production of the United States. China is also the largest producer of aquaculture foods. It has been projected that in the next thirty years, the world will need to produce 250% more meat, milk and eggs than it currently does. This production challenge requires the adaptation of new technology and production practices perhaps above the historical models.

On a global scale, modern efficient rendering facilities are concentrated in countries and regions possessing strong and well-established animal production industries. In the United States the current annual quantity of inedible raw material generated from animal processing is approximately 23.4—24.3 billion kg. World or country data for individual countries are not readily available. An estimate of European Union production is 16.1 million tonnes of animal by-products annually of which 14.3 million tonnes is sourced from fit-for-human-consumption sources and 1.8 million tonnes from unfit-for-human-consumption sources. Argentina, Australia, Brazil and New Zealand collectively process another 11 million tonness of animal by-products per year. In China the rendering process is virtually non-existent and the inedible portions derived from each animal species is considerably lower than in other parts of the world.. The protein, mineral matter, fat and water derived from specific animal by-product materials are outlined in Table 3.

TABLE #3 Reference data for animal and slaughterhouse by-product use. The sum of protein, mineral matter, fat and water portions need not be 100%, as there are other ingredients in the substances mentioned, e.g. starch, nucleic acid and raw fibres. The figures serve only as a guide, as they depend on the actual composition of the raw material.

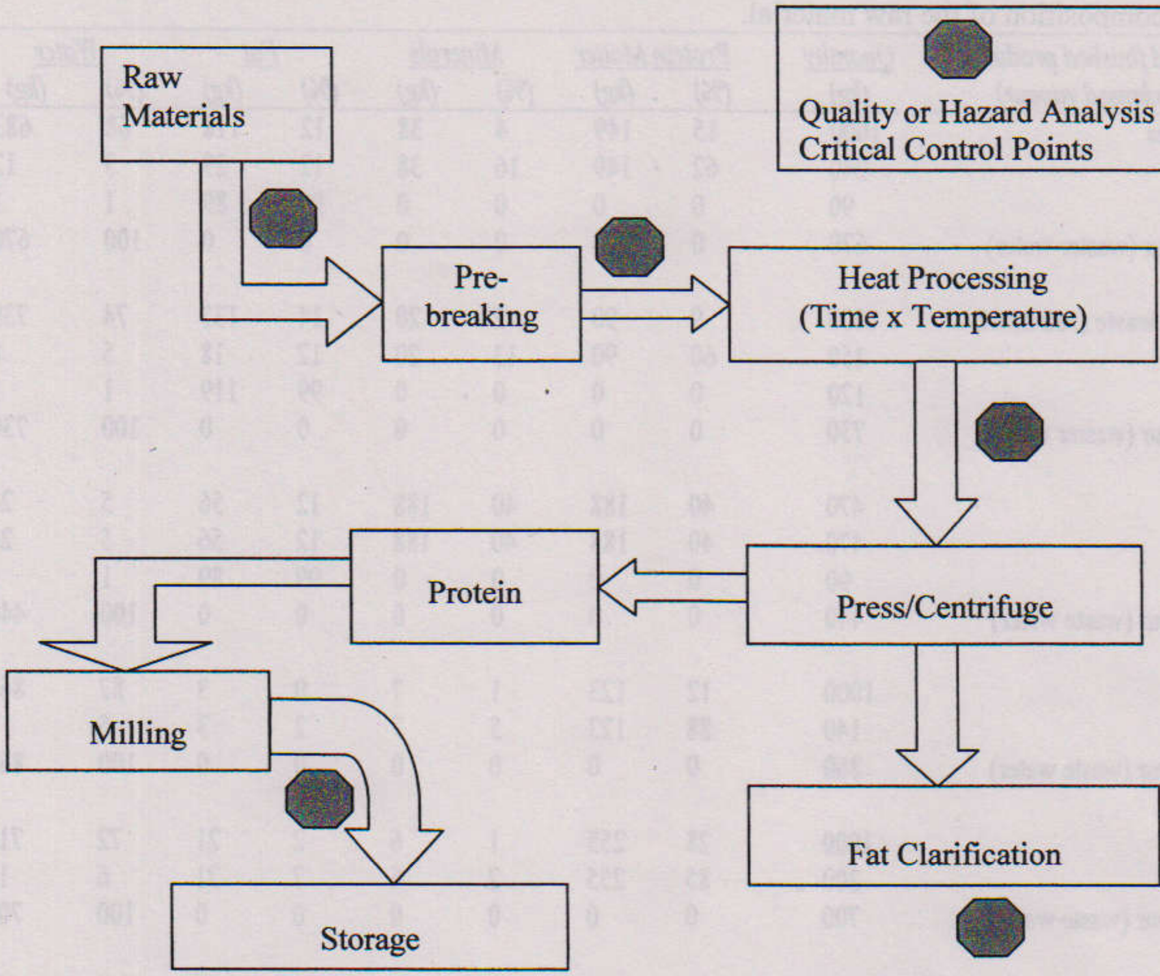
Raw material and finished products: Waste water (condensed vapour)	*Quantity (kg)*	*Protein Matter (%)*	*Protein Matter (kg)*	*Minerals (%)*	*Minerals (kg)*	*Fat (%)*	*Fat (kg)*	*Water (%)*	*Water (kg)*
Animal carcasses	1000	15	149	4	38	12	118	68	683
Animal meal	240	62	149	16	38	12	29	5	12
Animal fat	90	0	0	0	0	99	89	1	1
Condensed vapour (waster water)	670	0	0	0	0	0	0	100	670
Slaughterhouse waste (red meat)	1000	9	90	2	20	14	137	74	739
Animal meal	150	60	90	13	20	12	18	5	8
Animal fat	120	0	0	0	0	99	119	1	1
Condensed vapour (waster water)	730	0	0	0	0	0	0	100	730
Bones	470	40	188	40	188	12	56	5	24
Bone meal	470	40	188	40	188	12	56	5	24
Animal fat	90	0	0	0	0	99	89	1	1
Condensed vapour (waste water)	440	0	0	0	0	0	0	100	440
Blood	1000	12	123	1	7	0	3	87	867
Blood meal	140	88	123	5	7	2	3	5	7
Condensed vapour (waste water)	860	0	0	0	0	0	0	100	860
Hair	1000	28	255	1	6	2	21	72	718
Hair Meal	300	85	255	2	6	7	21	6	18
Condensed vapour (waste water)	700	0	0	0	0	0	0	100	700
Poultry waste	1000	12	124	2	21	18	181	66	663
Poultry meal	190	65	124	11	21	12	23	6	11
Animal fat	160	0	0	0	0	99	158	1	2
Condensed vapour (waste water)	650	0	0	0	0	0	0	100	650
Feathers	1000	28	281	1	7	2	23	69	690
Feather meal	330	85	281	2	7	7	23	6	20
Condensed vapour (waste water)	670	0	0	0	0	0	0	100	670

The Rendering Process

The rendering process uses animal by-products from meat production. All animal by-products are the direct result of animal food production and originate from the animal food production chain e.g. slaughter houses (abbatoirs), meat processing plants, butcher's shops, supermarkets and livestock rearing.

The rendering process comprises a number of processing stages as depicted in Figure 1.

Figure 1 The Basic Rendering Process



The raw material is received at the installation in regulated, closed transportation units. Processing is usually initiated within a short time following their receipt. Preparation for rendering involves pre-breaking to reduce the particle size, which is important to provide the proper provide heat penetration during the cooking process. The material is then heated under controlled conditions for specific monitored time.

EU regulations require that mammalian by-product materials be processed at 133°C for at least 20 minutes without interruption at a pressure (absolute) for at least 300 kPa produced by saturated steam. Sterilization by pressure cooking is not required for non-mammalian (poultry) material. Pressure cooking is not a standard practice in the United States and some other countries. Thus, processing specifications and the equipment used vary between installations and facilities.

Although the heat processing vessels vary between batch or continuous systems the process provides for the sterilization function and also to separate the fat from the nonfat matrix surrounding it. Batch systems (dry rendering cookers) of varying sizes that are surrounded by a steam heated jacket and the pressure cooking occurs for a batch at a time. Most newer installations use continuous cylindrical containers in which material is preheated and conveyed into the heating vessel in a continuous flow calibrated to meet the required temperature and time while being conveyed through the vessel. In facilities requiring pressure treatment, the material is held in a pressure chamber of 300 kPa at the end of the cooking phase and then released.

In either case, systems rely on heat to release fat from the cells of the fatty tissues, either the absence (dry rendering) or presence (wet rendering) of added water/steam. In dry rendering the pre-broken fatty tissues are heated in a steam-jacketed vessel to disintegrate the fat cells, release the melted fat and drive off moisture. Most batch cookers for dry rendering are equipped with rotating agitators, which may be steam-heated. Agitation aids in the heat transfer in both batch and continuous systems while also serving as part of the conveyor action for the continuous systems. Dry rendering can be achieved at atmospheric pressure, under vacuum or most commonly at elevated pressure.

Cooking times vary but average about 2.5 h, during which the content is heated and sterilized and water is evaporated. After discharge from the cooking vessel into a percolator, which allows free fat to drain, the material then passes to an expeller or centrifuge for further defatting. For efficient fat removal a solvent extraction plant is sometimes used. This can reduce the fat content in the residue to 2-5%, but it is not often used today. The cooked proteinaceous residue, most often referred to as cracklings or CRAX is then cooled and milled to produce meat and bone meal.

Processing of Feathers and Pig Hair

Processing of feathers and pig hair, first releases keratin, an indigestible protein, by hydrolyzing it. The hydrolyzed protein is then dried to produce a digestible high protein meal, which before the European ban on use of certain animal proteins in animal feed, could be sold separately, but it was normally mixed with other types of meal and used as a protein concentrate.

Pig hair and feathers are treated separately, as the conditions (temperature/time) for a suitable hydrolysis of the two products are different. A more powerful heat treatment is required to 'open' pig hair.

The processing can be done in batches in dry rendering cookers, where the keratin containing material is exposed to high temperature and pressure (135 – 145 °C) for 30 – 60 minutes. The pressure is then released and the product is dried and milled. This can eliminate the requirement for mechanical de-watering.

Special rendering equipment is also available for the continuous hydrolysis of feathers and/or hair. The material is transported in small batches to a compression chamber, where it is preheated, and then to the hydrolysis unit, where it is treated with direct steam under suitable pressure conditions for a shorter period (normally 10 – 15 min). The hydrolyzed material leaves the reactor at the bottom. Part of the water is then removed in a decanter. An evaporative unit is used for the concentration of the liquid phase. The de-watered product is dried separately or with other rendering products.

Feather processing produces high sulfide emissions in the waste water. The removal of hydrogen sulfide is therefore important. Sulfide can impair the activity of the activated sludge and thus the biological treatment process.

Statutory Requirements for Rendering

Regulatory practices concerning animal by-products are not consistent between countries and considerable differences exist. The very severe restrictions in the EU have already been mentioned. Regulations are altered frequently as a result of geographical incidence of specific animal and human diseases. Permitted disposal methods are evaluated differently in different 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 °C, 300 kPa pressure for 20 min. Processing conditions incorporating pressure treatment generally lower the nutritional value of the resultant protein meals, excepting those tissues of high keratin content. The rendering processes are consistent as a time-temperature treatment for the inactivation of microbiological organisms (bacterial, virus, protozoa, parasitic).

The raw materials processed by the rendering industry are known to contain significant numbers of microorganisms. A number are potential foodborne pathogens, including a large number of *Salmonella* serovars. Clinically normal animals presented for slaughter and processing harbour microbial organisms, especially within their digestive systems. The presence of digestive tissue and intestional content, other contaminated tissue from processing and fallen animals all contribute to raw materials with high microbiological content. This is illustrated by the data for isolations from raw material representing multiple species of food animals shown in Table 4.

***Table 4** Microbiological isolations of foodborne pathogens from raw material at 17 US/Midwestern rendering establishments during two periods of sampling: winter and summer*[a]

Organism	*Number of isolates/number of samples including replicates*			
	Winter	*Summer*	*Total*	*Percentage*
Clostridium perfringens[b]	30/42	30/42	60/84	71.4%
Listeria spp	33/42	31/42	64/84	76.2%
Listeria monocytogenes	4/42	3/42	7/84	8.3%
Camplobacter spp	19/42	6/42	25/84	29.8%
Campylobacter jejuni	15/42	2/42	17/84	20.0%
Salmonella spp	37/42	34/42	71/84	84/5%
Coliform[b]	42/42	42/42	84/84	100%

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[a] Some establishments operated more than one rendering line. Sampling occurred twice at each visit for each line, hence the denominator is based on 21 lines sampled twice each visit = 42.

[b] Characterization of the bacterial organisms and aerobic plate counts were not possible owing to the nature of the material.

Table 5 illustrates the efficacy of properly managed time/temperature processes of rendering.

Table 5 *Microbiological isolations of foodborne pathogens from crax at 17 US/Midwestern rendering establishments during winter and summer*[a]

Organism	**Number of isolates/number of samples including replicates**			
	Winter	**Summer**	**Total**	**%**
Clostridium perfringens[b]	0/42	0/42	0/84	0%
Listeria spp	0/42	0/42	0/84	0%
Listeria monocytogenes	0/42	0/42	0/84	0%
Camplobacter spp	0/42	0/42	0/84	0%
Campylobacter jejuni	0/42	0/42	0/84	0%
Salmonella spp	0/42	0/42	0/84	0%
Coliform[b]	0/42	2/42	2/84	2.4%

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[a]Some establishments operated more than one rendering line. Sampling occurred twice at each visit for each line, hence the denominator is based on 21 lines sampled twice each visit = 42

[b]Other organisms were isolated and recorded as laboratory observations but not identified within the scope of this pilot study.

Temperatures exceeding the thermal death values for specific microorganisms and exposure to excessive temperature are correlated with lowered nutritional values especially protein and amino acids. Although research has shown that rendering lowers the infectivity of the prion, the agent most commonly believed to be the cause of the transmissible spongiform encephalopathies, it is not inactivated with any of the currently available rendering processes. Thus rendering methods have never been capable of completely inactivating TSEs, nor has any other industrially described operational process.

Industrial Uses of Animal By-Products

Although the significant historical utilization of animal by-products has been for use as feed ingredients, they have also been used in a variety of industrial applications. Rendered animal fat has been used to provide fuel sources and to make soap for more than 2000 years. These uses have declined in nearly all countries with the increased use of petroleum-based and synthetic ingredients. To illustrate this point, during the 1950's and 1960's more than of 75% of all tallow production was directed to the soap-making industry. Today the figure is approximately 6-7%. Nevertheless, usage has expanded into other areas such as hand and body lotions, creams and other cosmetic and bath products. Several hundred categories of chemical processes and formulations use animal-derived fatty acids. These include rubber and plastic polymerization, heavy metal salts, fabric softeners, lubricants and plasticizers, and oleochemical compounds. Gelatin, collegen and glycerine have been basic ingredients for surfactants, paints, varnishes, adhesives, antifreeze, cleaners, polishes and numerous pharmaceuticals. During the past few years animal fats have proved to be a potentially valuable resource as an alternative fuel. When they are used as a biofuel (biodiesel or burner fuel), there are significant reductions in emission pollutants when compared to the combustion of petroleum-based products. Thus the industrial applications for non-food, non-feed uses have provided an important market for the utilization of inedible animal by-products. It is projected that the conversion of unused animal tissues into value products will become increasingly important to the world's huge meat and poultry industry.

Animal By-Product Feed Ingredients

Animal protein supplements and fats have long been utilized by the feed compounding industry, primarily for their protein (amino acid), their mineral content (calcium and phosphorus), and their energy contributions. Over 125 individual animal by-products listed in the American Feed Control Officials (AAFCO) 2002 Ingredient Manual, but only 11 are major high-volume ingredients. This listing includes 46 different animal protein ingredients. The major protein ingredients are meat and bone meal (meat meal), poultry meal, hydrolyzed feather meal, blood meal, blood and plasma meal, and fish meal. Similarly, five primary categories comprise the major quantity of animal fats, these being tallow, choice white grease (lard), yellow grease, poultry fat, and fish oil. All of these ingredients have different nutrient and product specifications. They all make specific contributions when used as components of livestock, poultry, companion animal and aquaculture diets. The term nutrient is applied to any food constituent or group of constituents of the same general chemical composition that aids in the support of life. Protein, carbohydrates, fat, minerals, and vitamins are the generally recognized classes of nutrients. Animal by-product ingredients contribute most to protein, fat and mineral nutritional requirements of animals, but also provide several sources of fat-soluble and B vitamins. The nutrient qualities complement other feed ingredients and particularly the feed grains, which are primary carbohydrate sources. During the early development of the modern nutrient requirement and nutrient allowance data, meat and bone meal provided unidentified growth factors (UGF) that contributes to unexplained improvements in growth, feed utilization, reproduction, and disease prevention. Most of the UGFs have now been identified as either specific vitamins, amino acids or microminerals that can be included in diets from synthetic or refined sources. However, both modern commercial and experimental diets exhibit improved performance when animal by-products are included in the diets under a variety of management and production practices. Several antinutritional compounds and contaminates associated with other ingredient classes are not problematic with animal by-products. Specifically, these include trypsin inhibitors, goitrogenic compounds, gossypol, mycotoxin/aflatoxins, glucosinolates, tannis, lectins, phytates, lathyrism, oxalates, alkaloids and cyanogens. In addition animal proteins do not contain oligosaccharides and other non-starch polysaccharides (NPS) that have been shown to alter gut viscosity and reduced digestibility of fats and proteins.

The animal feed and ingredient industries are a major users of rendered animal fats and proteins. The subsequent text will address the specific characteristics and specifications for each of the basic animal fats and protein ingredients.

MAJOR ANIMAL DERIVED FATS

Inedible Tallow –

Tallow is primarily derived from rendered beef tissue but could contain other animal fat. In terms of total volume and economic value, tallow is one of the most important animal fats. The term 'inedible' does not define any specific grade or specification other than the rendering or processing was not conducted under food regulatory supervision. Edible animal fat in the United States can be rendered only in food grade plants under inspection of the US Department of Agriculture (USDA). Most countries have similar requirements. Tallow is accompanied by many grades, specifications, and criteria depending on its end use. Titer is a basic specification requiring solidification above 40°C (104°F) after saponification. In contrast, greases solidify below this temperature. Fat quality is determined by hardness, colour, moisture, impurities, stability and free fatty acids (FFA) content. For reference, the commodity trading standards for tallow and greases are included in Table 6.

Table 6 Commodity Trading Standards for Tallow and Grease

	Titer	FFA	M. I. U.	
	Min.	Min.	Basis	Max.
TALLOW				
Extra Fancy	42.0	2	1	
Fancy	40.5	4	1	
Bleachable Fancy	40.5	4	1	2
Prime	40.5	6	1	2
Edible	42.5		1	1
DARK TALLOW				
Special	40.5	10	1	3
#1	40.5	15	2	4
#3	40.5	20	2	4
#2	40.0	35	2	4
GREASE				
Choice White (all hog)	36	4	1	2
Yellow (feed fat)	36	15	2	4

FFA-free fatty acids, MIU – moisture, impurities and unsponifiables

These specifications place an emphasis on titre and FFA content in determining grade and value. For soap production, 'hard fats' or fats of high titre, make soap of hard textures, while lower-titre fats make softer textured soap. Fats with higher FFA contents have a greater glycerine loss in the soap-making process, which lowers their value.

These same specifications, however, do not have the same influence on the value of their utilization when used as feed ingredients. The primary benefit of using fat in animal diets is their energy contributions. Fats provide the most concentrated energy of all food/feed materials, containing about 37 kJ of energy per gram. As a general rule, fat provides at least 2.25 times the energy content supplied from the same weight of corn. In some formulations, management conditions and species, the difference may be as high as 3.8 times that of feed grains.

TABLE 7 Properties of Fats and Greases

Test	*Chicken Fat*	*Yellow Grease*	*Choice Grease*	*White Tallow*
Fatty Acid Profile (% Relative)				
C08:0	<0.10%	<0.10%	<0.10%	<0.10%
C10:0	<0.10%	<0.10%	<0.10%	<0.10%
C11:0	<0.10%	<0.10%	<0.10%	<0.10%
C12:0	<0.10%	<0.10%	<0.10%	<0.10%
C14:0	0.57%	0.70%	1.57%	2.73%
C14:1	0.26%	0.14%	0.36%	0.50%
C15:0	<0.10%	0.11%	0.26%	0.43%
C15:1	<0.10%	<0.10%	<0.10%	<0.16%
C16:0	22.76%	14.26%	22.04%	22.99%
C16.1	8.37%	1.43%	5.03%	2.86%
C16.2	<0.10%	<0.10%	<0.10%	<0.10%
C16.3	<0.10%	<0.10%	<0.10%	<0.10%
C16.4	<0.10%	<0.10%	<0.10%	<0.10%
C17.0	0.11%	0.33%	0.63%	1.35%
C17.1	0.12%	0.23%	0.43%	0.75%
C18.0	5.36%	8.23%	9.95%	19.44%
C18.1	42.07%	43.34%	42.45%	41.60%
C18.2	17.14%	26.25%	13.17%	3.91%
C18.3	1.07%	2.51%	0.97%	0.49%
C18.4	0.22%	0.47%	0.29%	0.36%
C20.0	<0.10%	0.33%	0.14%	0.14%
C20.1	0.45%	0.48%	0.56%	0.33%
C20.2	0.20%	<0.10%	0.19%	0.10%
C20.3	0.19%	<0.10%	0.12%	<0.10%
C20.4	0.45%	<0.10%	0.34%	<0.10%
C20.5	<0.10%	<0.10%	0.11%	<0.10%
C21.5	<0.10%	<0.10%	<0.10%	<0.10%
C22.0	<0.10%	3.50%	<0.10%	<0.10%
C22.1	<0.10%	<0.10%	<0.10%	<0.10%
C22.2	<0.10%	<0.10%	<0.10%	<0.10%
C22.3	<0.10%	<0.10%	<0.10%	<0.10%
C22.4	<0.10%	<0.10%	<0.10%	<0.10%
C22.5	<0.10%	<0.10%	<0.14%	<0.10%
C22.6	<0.10%	<0.10%	<0.22%	<0.10%
C24.0	<0.10%	<0.12%	<0.10%	<0.10%
C24.1	<0.10%	<0.10%	<0.10%	<0.10%
Unknown Components	0.56%	0.72%	1.03%	1.96%
MIU Analysis				
Moisture & volatiles	0.12%	0.38%	0.24%	0.17%
Insoluble impurities	0.08%	0.06%	0.29%	0.12%
Unsponifiable matter	0.51%	0.42%	0.73%	0.30%

MIU, moisture, impurities and unsaponifiables

[a]Data from Woodson-Tenent Laboratories, Memphis, TN, USA

Table 8 Fatty acid composition of common feed animal fats, fish oils, and vegetable oils

Lipid source	IFN[a]	Percentage of total fatty acids																
		14:0	16:0	16:1	18:0	18:1 n-6	18:2 n-3	18:3 n-3	18:4	20:1 n-6	20:4 n-3	20:5 n-3	22:1	22:5	22:6	Σn-6	Σn-3 ratio	n-3/n-6
Animal fat																		
Beef tallow	4-08-127	3.7	24.9	4.2	18.9	36.0	3.1	0.6	-b	0.3	-	-	-	-	-	3.1	0.6	0.19
Pork fat	4-04-790	1.3	23.8	2.7	13.5	41.2	10.2	1.0	-	1.0	-	-	-	-	-	19.6	1.0	0.05
Poultry fat	4-09-319	0.9	21.6	5.7	6.0	37.3	19.5	1.0	1.1	0.1	-	-	-	-	-	19.6	1.0	0.05
Fish oils																		
Anchovy		7.4	17.4	10.5	4.0	11.6	1.2	0.8	3.0	1.6	0.1	17.0	1.2	1.6	8.8	1.3	31.2	24.0
Cod liver	7-01-994	3.2	13.5	9.8	2.7	23.7	1.4	0.6	0.9	7.4	1.6	11.2	5.1	1.7	12.6	3.0	27.0	9.0
Capelin	7-16-709	7.9	11.1	11.1	1.0	17.0	1.7	0.4	2.1	18.9	0.1	4.6	14.7	0.3	3.0	1.8	12.2	6.78
Channel catfish, cultured		1.4	17.4	2.9	6.1	49.1	10.5	1.0	0.2	1.4	0.3	0.4	-	0.3	1.3	12.7	3.2	0.25
Herring, Atlantic	7-08-048	6.4	12.7	8.8	0.9	12.7	1.1	0.6	1.7	14.1	0.3	8.4	20.8	0.8	4.9	1.4	17.8	12.71
Herring, Pacific		5.7	16.6	7.6	1.8	22.7	0.6	0.4	1.6	10.7	0.4	8.1	12.0	0.8	4.8	1.0	15.7	15.7
Menhaden	7-08-049	7.3	19.0	9.0	4.2	13.2	1.3	0.3	2.8	2.0	0.2	11.0	0.6	1.9	9.1	1.5	25.1	16.73
Redfish		4.9	13.2	13.2	2.2	13.3	0.9	0.5	1.1	17.2	0.3	8.0	18.9	0.6	8.9	1.2	19.1	15.92
Salmon, sea caught		3.7	10.2	8.7	4.7	18.6	1.2	0.6	2.1	8.4	0.9	12.0	5.5	2.9	13.8	2.1	31.4	15.00
Vegetable oil																		
Canola	4-06-144	-	3.1	-	1.5	60.6	20.2	12.0	-	1.3	-	-	1.0	-	-	20.2	12.0	5.94
Coconut	4-09-320	16.8	8.2	-	2.8	5.8	1.8	-	-	-	-	-	-	-	-	1.8	0.0	0.0
Corn	4-07-882	-	10.9	-	1.8	24.2	58.0	0.7	-	-	-	-	-	-	-	58.0	0.7	0.01
Cottonseed	4-20-836	0.8	22.7	0.8	2.3	17.0	51.5	0.2	-	-	-	-	-	-	-	51.5	0.2	0.0
Linseed	4-14-502	-	5.3	-	4.1	20.2	12.7	53.3	-	-	-	-	-	-	-	12.7	53.3	4.2
Palm		1.0	43.5	0.3	4.3	36.6	9.1	0.2	-	0.1	-	-	-	-	-	9.1	0.2	0.02
Peanut	4-03-658	0.1	9.5	0.1	2.2	44.8	32.0	-	-	1.3	-	-	-	-	-	32.0	0.0	0.0
Safflower	4-20-526	0.1	6.2	0.4	2.2	11.7	74.1	0.4	-	-	-	-	-	-	-	74.1	0.4	0.0
Soybean	4-07-983	0.1	10.3	0.2	3.8	22.8	51.0	6.8	-	0.2	-	-	-	-	-	51.0	6.8	0.13
Sunflower	4-20-833	-	5.9	-	4.5	19.5	65.7	-	-	-	-	-	-	-	-	65.7	0.0	0.0

[a]IFN, International Feed Number,

[b]Dash indicates that measurements were taken but no values were detected.

Tallow is used extensively as a feed ingredient. Chemically, animal feeding fats are triacylglycerols, whose structure consists of 1 unit of glycerol and 3 units of fatty acids. The fatty acids are actually the components that give the respective fats their individual characteristics. Table 7 provides fatty acid profiles for the respective mammalian-derived fats. Most fatty acids found in natural fats vary in chain length between 8 and 24 carbon atoms. Feeding fats are their predominantly of chain lengths between 14-18 carbon atoms. Fatty acids that contain double bonds are termed 'unsaturated' (the number of double bonds is indicated after the number of carbon atoms; thus $C_{16:3}$ is a 16-carbon fatty acid with 3 double bonds). Conversely, structures without double bonds are termed 'saturated' fatty acids. As the carbon chain length increases in saturated fatty acids, the melting point increases. In other words, they possess higher titer and thus 'harder'. A comparison of various animal fats, marine oils and vegetable oils are provided in Table No. 8.

Tallow can be categorized as a saturated fat with its primary fatty acid profile consisting of palmitic (16:0) stearic (18:0) and oleic (18:1). These qualities position tallow to be most appropriate for use in ruminant diets. When dairy cattle diets are fortified with tallow at 0.45 - 0.90 kg per cow per day a routine positive milk production response is achieved. Studies have demonstrated a 6% improvement in feed efficiency with the incorporation of tallow in feedlot cattle rations.[(3)(4)] Tallow has been utilized most recently in finishing diets for swine and in sow diets to improve pork quality. Research continues to explore the benefits of tallow as a feed supplement for improving feed efficiency, reducing feed dust, preventing segregation of ingredients, improving meat quality, modifying fatty acid profiles in meat, milk and egg products as well as numerous expanded uses in both the industrial and feed ingredient industries.

Choice White Grease –

Choice White Grease (CWG) is commonly the inedible fat derived from swine. As described for tallow, an inedible designation for fats derived from swine is determined by a similar procedure. Edible fat from swine is most commonly labeled lards, although edible lard may likewise be used as a feeding fat. The composition, characteristics and consistency of lard vary greatly according to the part of the animal or tissue from which it is extracted. (Tables 7 and 8). Both lard and CWG possess titers of less than 40. CWG contains less saturated fatty acids than does tallow and a more even distribution among the respective C_{16} and C_{18} chain-length fatty acids.

Choice White Grease and lard are quite similar in composition. Their use has been primarily for feed or food although several important industrial applications utilize these fat sources. Industrial dependence or applications are not as extensive as for tallow. CWG as feeding fat is generally directed to swine, poultry and companion animal diets, although it is not restricted to these species. Baby pig diets routinely contain from 5% to 8% fat, with animal fat being a primary source and CWG most often being the preferred source. A substantial database exists to predict a 2% improvement in feed efficiency for each 1% supplemental fat incorporated into swine growing-finishing diets. The most common formulation level is 2-5% supplemental fat. The use of fat in late gestation and lactation is a very common feeding strategy. Feeding fat to sows prior to and during lactation increases both milk fat percentage and total milk yield, thus increasing the survival potential of the litter. Enhanced energy intake during lactation provides reproductive benefits that include shorter return to oestrus and increased sow longevity. The beneficial effects of fats may be more pronounced in environments of elevated temperatures.

The literature abounds with the utilization of CWG, lard or pork fat for various applications of feed formulation and production. Similarly the importance of pork to the global supply of animal protein foods indicates that lard and CWG will remain a source of these fats for both feed and food purposes.

Poultry Fat –

Poultry fat is derived from the slaughter and processing of chickens, turkeys, duck and other avian species. The majority of poultry fat is derived from broiler chickens. The available quantity has increased, and continues to increase, as further processing increases. As with further processing of other major categories of meat, this practice leaves more tissues for rendering at the processing sites and less as table waste at the home. The fats rendered from poultry are of the lowest titer and have the highest ratio of unsaturated fatty acids compared to their saturated fatty acid components of the fats of any other species. A fatty acid profile determination is included in Table #7.

The use of poultry fat in domestic pet diets has been extremely useful. Fat extracted from feathers has a high content of cholesterol and provides a resource for the pharmaceutical industry.

Yellow Grease -

Yellow grease has been a very misunderstood product both in respect of both its source and its utilization. It is a category of fat that evolved from the practice of renderers assuming their responsibility to collect, process and utilize used cooking oils and restaurant greases as part of their raw material resources. Traditionally, fat/grease acquired from restaurants was of animal origin; tallow and lard. With the controversy surrounding the health effects of saturated and unsaturated fatty acids, the major components of frying media became plant oils. These changes were made despite a lack of sound empirical data and the fact that most taste panels preferred foods prepared in animal fats. This major change had drastic effects on the tallow and lard markets and provided for the evolution of a new category of fats: feed grade animal fat or yellow grease.

Yellow grease is thus best defined as a fat product that does not meet the definitions for animal fat, vegetable fat or oil, hydrolysed fat or fat ester. Like any other grade of fat, it must be sold on its specifications, which include the minimum percentage of total fatty acids, the maximum percentage of unsaponifiable matter, the maximum percentage of insoluble impurities, the maximum percentage of free fatty acids and the amount of moisture. Most importantly, it must meet the Food and Drug Administration (FDA) established criteria for pesticides or other toxic chemicals.

The basic specifications for yellow grease are:

Total Fatty Acids (min.)	90%
Free Fatty Acid (max.)	15.0%
Moisture (max.)	1%
Impurities (max.)	0.5%
Unsaponifiable (max.)	1%
Total MIU (max.)	2%
(Moisture, impurities and unsaponifiables)	

Although these are basic specifications they are subject to negotiatiations between buyer and seller on a contract-by-contract basis. The presence of FFA in fats or animal by-products was once considered an indication of rancidity. Questions are still raised regarding the utilization of fat sources with high FFA content when used as feeding fat ingredients. A very reliable research data base exists to indicate that FFA per se is not on its own a qualitative monitor for fat quality. Dr. Park Waldroup and co-workers at the University of Arkansas reported no difference in performance in broilers fed diets supplemented with fats low or high (44.7%) free fatty acid content.(5) Dr. Richard Zinn has likewise reported similar findings in feedlot cattle. In the University of California studies a comparison of 10% FFA yellow grease to that containing 50% FFA on growth-performance failed to demonstrate differences.(6) Thus a higher FFA content without the indicators of rancidity (rancid odor, palatability influences or high peroxide values) does not affect the feeding value of yellow grease. There are specific industrial uses that high FFA levels may become a factor, such as in the esterification process associated with biodiesel. Yellow grease has many uses. It is a primary contributor to the total fats and oils used as feeding fats. It has several industrial end uses, including its use as a biofuel either in biodiesel or perhaps as a burner fuel. Its properties and its recyclable benefits makes it anything but a waste grease.

Fish Oils-

Fish oils are produced during the processing of fish meal similarly to the processing of other rendered products. The raw materials are derived from fishing specifically for species of fish for fish meal and fish oil production, such as menhaden, sand eel and Norway pout. The increase in aquaculture production has resulted in an increase in use of both the fish oil and meal derived as a by-product from seafood production and processing. Fish oil is used extensively in aquaculture diets for all species, providing specific fatty acids not available in other fats and oils. It is likewise a common ingredient in companion animal diets especially in the feline species. The industrial, pharmaceutical and neutraceutical uses have been replaced by other fats and oils, synthetic vitamins, and other products that in the past relied on fish oil.

Fish oil derived from different species varies considerably in their characteristics and it is difficult to quote specifications. Tables 8 and 9 details the fatty acid content of various fish oils. Fatty acids designated as 'omega-3' and 'omega-6' (symbolized as *n*-3 and *n*-6 in Table 8) have received considerable support for their beneficial effects in human health, but this is not a subject not to be dealt with in this by-product review.

Table 9 Principal fatty acids (percentages) of major marine oils of commerce[a]

		Ma	SM	P	C	H	A	CL	MA	HM	NP	S	Sa
Myristic	C14:0	9	7	8	7	7	9	3	8	8	6	1	7
Palmitic	C16:0	20	15	18	10	16	19	13	14	18	13	16	15
Palmitoleic	C16:1	12	10	10	10	6	9	10	7	8	5	7	8
Oleic	C18:1	11	15	13	14	13	13	23	13	11	14	16	9
Eicosaenoic	C20:1	1	3	4	17	13	5	0	12	5	11	10	15
Eurucic	C22:1	0.2	2	3	14	20	2	6	15	8	12	14	16
Omega-3 fatty acids	C20:5	14	17	18	8	5	17	11	7	13	8	6	9
	C22:6	8	10	19	6	6	9	12	8	10	13	9	9

[a]Ma, menhaden; SM, specifically processed marine oil (menahden); P, pilchard; C, capelin; H, herrring; A, anchovy; CL, cod liver; MA, mackerel; HM, horse mackerel; NP, Norway pout; S, sprat; SA, sand eel.

Summary: Animal Fats

The inedible raw materials derived from the production and processing of food animals provide a resource of high-energy products that are available for feed ingredient, industrial and bioenergy uses. The available resources correlate with the numbers of animals processed for food, and the recycling efficiency of used cooking and restaurant greases. These energy byproducts are the direct result of livestock, poultry and marine animal production. They are highly recognized as economically and socially beneficial adjuncts to the primary meat products.

Major Animal-Derived Proteins

The primary animal products derived from the processing of inedible animal tissues are meat and bone meal (MBM), meat meal, blood meal, poultry meal, feather meal and fish meal. Tissues subjected to the rendering process are pressed to remove the fat, dried and milled to produce the respective animal protein products. The ingredient, or product specifications and definitions, are distinct for each product.

Meat and Bone Meal

The regulatory definition of meat and bone meal (MBM) in the United States is the rendered product from mammalian tissues including bone, but exclusive of blood, hair, hoof, horn, hide trimmings, manure and stomach and rumen contents. The definition describes materials that are used in the manufacture and, more importantly, those tissues that cannot be included. MBM as defined must contain a minimum of 4% phosphorus with a calcium level not to exceed 2.2 times the actual phosphorus level. Ingredients containing the same tissues but less bone content, thus a lower phosphorus content, are defined as meat meal. Although regulations and directives vary worldwide and from country to country, MBM can be used nutritionally in all species of livestock, poultry and as aquaculture rations for providing protein, amino acids, phosphorus, calcium, energy and other nutrients. Exclusively nonruminant-sourced and processed raw material must be used in ruminant rations in the United States. The European Union has suspended the feeding of MBM to all farm animals. It is important to consult with the current regulations in each country of use.

Both MBM and meat meal (MM) have protein levels that generally meet or exceed 50%. The 1998 *Nutrient Requirements of Swine* (National Research Council) references MBM as containing 51.5% protein and MM as containing 54.0% protein. Standards for specific product specifications vary according to country of origin and must be referenced by using peer-reviewed databases. Although no standard is required for MBM and MM products, guarantees for protein as well as minimum calcium and minimum fat contents must be stated on the identifying label. Unfortunately MBM and MM are often combined into formatting common databases. This is illustrated in Table 10, showing data from 29 samples of MBM assembled by the Fats and Proteins Research Foundation and analyzed at the University of Illinois. Though all of the products were identified as MBM over 50% were below phosphorus minimums. Supplier guarantees are often much more reliable indicators of nutrient content than reliance on product names.

Table 10 **Average Digestibility**

	Crude	Protein	Lysine	Tryptophane	Methonine & Cystine
MBM	1	69.13	68.60	67.34	61.55
MBM	2	66.43	71.72	73.46	64.74
MBM	3	66.03	65.57	67.33	61.45
MBM	4	73.84	76.07	72.40	68.41
MBM	5	60.63	57.05	61.65	51.99
MBM	6	76.24	77.75	73.95	69.51
MBM	7	73.00	78.20	76.74	69.27
MBM	8	74.00	75.24	72.68	71.29
MBM	9	75.59	79.35	68.75	73.25
MBM	10	67.52	67.64	74.23	61.56
MBM	11	55.68	50.10	53.62	57.36
MBM	12	75.19	77.74	74.11	71.32
MBM	13	72.59	77.24	78.20	68.56
MBM	14	78.95	82.48	76.23	70.45
MBM	15	74.28	80.46	78.27	65.54
MBM	16	60.48	63.83	53.06	52.52
MBM	17	76.92	78.30	72.32	70.43
MBM	18	69.66	68.38	69.74	67.94
MBM	19	69.83	76.31	76.67	68.05
MBM	20	No Sample Submitted			
MBM	21	65.45	67.47	63.98	65.74
MBM	22	59.46	61.42	63.04	49.42
MBM	23	65.91	71.26	71.91	61.78
MBM	24	65.67	63.38	57.19	57.11
MBM	25	65.56	66.34	66.92	66.18
MBM	26	68.05	69.57	72.04	65.07
MBM	27	70.13	76.59	79.73	77.72
MBM	28	62.95	63.42	65.18	63.68
MBM	29	63.74	70.14	76.59	65.29
MBM	30	68.80	73.58	67.11	49.56
Mean		68.68	70.87	69.70	64.37

Blood Meal

Approximately 4-5% of the live weight of animals is collectable blood. Dried blood is high in protein and rich in the amino acid lysine, and the amino acids are highly digestible. Procedures for processing blood into blood meal have experienced major improvements during the past decade. Flash drying techniques provide digestibility of the essential amino acids that exceed 90% and generally approaches 95%. Newer processes have tended to separate the plasma (serum) from the red cell portion. Both products, when dried properly, are value-added ingredients that are utilized extensively in animal nursery diets. Measured in value per unit, blood meal comprises the highest of all of the commodity terrestrial animal meals. Measured in total quantities or final dried meals (total tonnes), blood meal comprises a relative small amount compared to other animal by-product protein sources.

Poultry Meal

Poultry meal often referred to as poultry by-product meal consists of the milled, rendered, clean parts of the carcasses of slaughtered poultry. Inedible tissues comprising the raw material include heads, necks, feet, undeveloped eggs, intestines and skeletal frames from which muscle has been removed. The completeness of muscle removal for boneless chicken meat varies somewhat. Similarly, several of the tissues listed above also have edible markets. Poultry meal is to be exclusive of feathers with the exception of such amounts as might occur unavoidably with the use of good processing practices. A considerably higher quantity of inedible tissue from poultry processing is acquired from each carcass as the trends advance for further processing and more table ready foods.

Poultry meal is an excellent source of protein. It is a product used extensively in companion animal diets. Processing improvements have resulted in improvement of poultry meal as with most by-product ingredients. Improvements in digestibility have enhanced its usage in other animal species such as in aquaculture and starting pig diets. Specifications vary slightly depending upon its source. Broiler chickens, laying hens and turkeys comprise the major sources of poultry raw material. However, they all yield very similar final rendered products. Ducks and other less dominant avian species may show some variances.

Feather Meal -

Feather meal is most often referred to as hydrolyzed feather meal (HFM). Feathers contain a high protein level averaging 87%, but the protein is in an undigestible keratin helix. Special processing is thus necessary to break the disulfide-bonded helices. Pressure cooking is the most common processing procedure, although the use of enzymes under experimental conditions has also been effective.

Although HFM is high in protein, it is limited in the availability of the essential amino acids, lysine, methionine and histadine. However, the product is an excellent source of the sulfur-containing amino acid cystine as well as elemental sulfur and selenium. Its protein has limited degradation in the rumen of ruminant species, which allows passage and digestion in the intestinal tract. HFM has emerged as an important ingredient for ruminant animals. Recognizing the contribution of bioavailable amino acid, HFM can be supplemented via synthetic sources or combined with other by-product ingredients to supply its deficiencies and provide for a very useful feed ingredient. Hair meal derived from pig hair is a similar product, but it is produced in much lower quantities and requires even higher pressure and temperatures for its production.

Fish Meal -

Fish meal is acquired from the specialized industry that maintains fleets that harvest entire fish exclusively for processing into fish meal. Fish meal is also produced from the inedible portions of food fish. The protein derived from both sources is highly valuable to the feed and ingredient industry. Historically, fish meal has commanded premium prices compared to the other animal protein sources and most of the plant sources. It has an excellent amino acid composition that is highly bioavailable. Fish meal is appreciated as a feed ingredient for its palatability enhancing properties, especially in feline diets. Properties of fish meals vary with respect to the species of fish comprising the raw material. Species differentiation of the respective fish meals is often included in the ingredient name. In some countries it is prohibited to use fish meal for finishing pigs due to the risk of "fishy" off-flavour.

There has been concern recently regarding the depletion of free harvested fish and thus the future availability of fish meal. Each year a higher proportion of seafood and shellfish produced by aquaculture replaces that, which traditionally was sourced from commercial fishing. The processing of fish by-products from aquaculture production represents a supplementary income to producers and processors of fish for human consumption. The aquaculture industry is projected to continue its growth.

Summary –

The inedible by-products resulting from the production and processing of meat for edible use compris approximately 50% of the total of livestock, poultry and aquaculture production. This article has described the basic alternatives for maintaining a symbiotic utilization of both the edible and inedible fractions. The alternatives as well as the challenges surrounding the utilization or disposal of raw inedible by-products are controversial. The requirement that this highly perishable material must be collected, processed and utilized in a manner that satisifies ecological, economic, environmental and biosecure methodology is paramount. These criteria must be scientifically validated. Rendering has provided a time-temperature process that has met these criteria for bacterial, viral, fungal and parasitic organisms. The aetiology of transmissible spongiform encephalopathy (TSE) has presented an enigmatic assessment yet to be resolved in terms of animal byproduct processing and/or disposal. Realistically, the world is still trying to understand the biology of this complex group of diseases, which are unlike any other. This complicated group of diseases deserves the utmost of scientific scrutiny.

All the protein, fat, minerals and other compounds currently derived from the inedible fraction of food animals are the direct result of livestock and poultry production. Technologically advanced meat production does not produce meat, milk, eggs and animal fibers without the associated production of inedible tissues. Changes in technology will inevitably change the amount and nature of by-products. The responses to this will be influenced by consumers, legislators, myths/biases as well as scientific guidance, and will undoubtedly bring many unpredictable developments and opportunities. Historically, the performance of livestock agriculture would predict a strong future for animal-derived products to be utilized by both humans and animals.

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