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ORIGINAL ARTICLE

Utilization of byproducts and waste materials from meat, poultry and fish processing industries: a review

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Abstract India is bestowed with vast livestock wealth and it is growing at the rate of 6% per annum. The contribution of livestock industry including poultry and fish is increasing substantially in GDP of country which accounts for >40% of total agricultural sector and >12% of GDP. This contribution would have been much greater had the animal by-products been also efficiently utilized. Efficient utilization of by-products has direct impact on the economy and environmental pollution of the country. Non-utilization or under utilization of by-products not only lead to loss of potential revenues but also lead to the added and increasing cost of disposal of these products. Non-utilization of animal by-products in a proper way may create major aesthetic and catastrophic health problems. Besides pollution and hazard aspects, in many cases meat, poultry and fish processing wastes have a potential for recycling raw materials or for conversion into useful products of higher value. Traditions, culture and religion are often important when a meat by-product is being utilized for food. Regulatory requirements are also important because many countries restrict the use of meat by-products for reasons of food safety and quality. By-products such as blood, liver, lung, kidney, brains, spleen and tripe has good nutritive value. Medicinal and pharmaceutical uses of by-product are also highlighted in this review. Waste products from the poultry processing and egg production industries must be efficiently dealt with as the growth of these industries depends largely on waste management. Treated fish waste has found many applications among with which the most important are animal feed, biodiesel/biogas, dietectic products (chitosan), natural pigments (after extraction) and cosmetics (collagen). Available information pertaining to the utilization of by-products and waste materials from meat, poultry and fish and their processing industries has been reviewed here.

Keywords By-products · Meat industry · Poultry · Rendering · Utilization · Fish waste

Waste in the food industry is characterized by a high ratio of product specific waste not only does this mean that the generation of this waste is unavoidable, but also that the amount and kind of waste product which consists primarily of the organic residue of processed raw materials, can scarcely be altered if the quality of the finished product is to remain consistent. The utilization and disposal of product specific waste is difficult, due to its inadequate biological stability, potentially pathogenic nature, high water content, potential for rapid auto oxidation and high level of enzymic activity. The diverse types of waste generated by various branches of the food industry can be quantified based on the respective level of production.

Waste disposal and by-product management in food processing industry pose problems in the areas of environmental protection and sustainability (Russ and Pittroff 2004). Generally speaking, raw and auxiliary materials, as well as processing acids, enter the production process and exit as one of the following: a desired product, a non-product-specific waste or a product-specific waste. Product-specific waste unavoidably accumulates as a result of processing of raw materials. It is produced during the various steps of production, in which the desired components are extracted from the raw materials. After extraction, there are often other potentially useful components present in the remaining materials.

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The current methods for further utilization of product-specific waste have been developed along traditional lines and are closely bound to the agricultural origins of the raw materials themselves. The two general methods of traditional waste utilization have been to use the waste as either animal feed or fertilizer. Many of the existing agricultural solutions to waste disposal balance out between legal regulations and the best ecological and economical solutions. Another characteristic of product-specific waste is that the generated mass of waste relative to production levels can only be altered through technical means, which unavoidably leads to a change in product quality. Typical examples of product-specific waste are spent grains from beer production or slaughter house waste from meat production. The product-specific waste from the food industry is characterized by its high proportion of organic material.

The disposing of this waste can be difficult for the following reasons:

Biological stability and the potential growth of pathogens Many types of waste material either already contain large numbers of microbes and/or will be altered quickly through microbial activity. If regulations concerning infections/diseases are not properly observed, then hygienically unacceptable condition can arise, eg., maggots or molds. The breakdown of protein is always characterized by the evolution of strong odours.

- ➢ High water content: The water content of meat and vegetable waste lies between 70 and 95% by mass. A high water content increases transport cost of the waste. Mechanical removal of water through use of a press can lead to further problems with waste disposal due to the high levels of organic matter in the water.
- ➢ Rapid autoxidation: waste with a high fat content is susceptible to oxidation, which leads to the release of foul smelling fatty acids.
- ➢ Changes due to enzymatic activity: In many types of waste arising enzymes are still active which accelerate or intensify the reactions involved in spoilage (Russ et al. 1997; Werschrictzky et al. 1985).

According to the current literature on levels of production and the generation of waste in the food industry, the types of waste and their origin (Table 1) have been identified as especially significant (Frauhofer-Institut 1990).

Meat industry

The majority of the waste, in the meat industry is produced during slaughtering. Slaughter house waste consists of the portion of a slaughtered animal that cannot be sold as meat or used in meat-products. Such waste includes bones, tendons, skin, the contents of the gastro-intestinal tract, blood and internal organs. These vary with each type of animal (Sielaff 1996; Grosse 1984). The specific amounts of generated waste for each type of animal are listed in Table 2.

Efficient utilization of meat by-products is important for the profitability of the meat industry. It has been estimated that 11.4% of the gross income from beef and 7.5% of the income from pork, come from the by-products. In the past, by products were a favourite food in Asia, but health concerns have led to an increased focus on non-food uses, such as pet foods, pharmaceuticals, cosmetics and animal feed (Rivera et al. 2000). Meat by-products are produced by slaughter houses, meat processors, wholesalers and rendering plant. Traditional markets for edible meat by-products have gradually been disappearing because of low prices and health concerns. In response to these problems, meat processors have directed their marketing and research efforts towards non-food uses.

The literature indicates that by-products (including organs, fat or lard, skin, feet, abdominal and intestinal contents, bone and blood) of cattle, pigs and lambs represents 66.0, 52.0 and 68.0% of the live weight respectively. More than half the animal by-products are not suitable for normal consumption, because of their unusual physical and chemical characteristics. As a result, a valuable source of potential revenue is lost, and the cost of disposing of these products is increasing. The United States Dept. of Agriculture Economic Research Service has found that 11.4% of the gross income from beef is from the by-products. The figure for pork is 7.5%. In addition to economic losses, unused meat products cause serious environmental pollution. However with improved utilization, meat by-products can give a good profit to meat processors.

Statistics and production of by products

There are 2,702 registered slaughter houses in the country, which are mostly service oriented performing only slaughtering and dressing. Live stock available for slaughtering comprises of animals namely buffaloes, cattle, sheep, goats, pigs and poultry. As per the recent data published by the Ministry of Agriculture, live stock population is 84.2 million buffaloes, 204.5 million cattle, 50.8 million sheep, 115.3 million goats, 12.8 million pigs and 307.1 million poultry. In the year 1992–93, meat production was 1.5 million tones which increased to 2 million tones in 1997–98.

India ranks top most in the world in livestock holding and the total availability of offal/bones in the country

Table 1 Types of waste and their origin in the food industry

Type of Waste	Origin of Waste
Waste from the preparation, processing and rendering of meat, fish and other food stuffs originating from animals	Slaughter house, butcher shops, fish processing plants, egg processing plants, tallow processing plants
Waste from the preparation and processing of fruit, vegetables, grain, edible oil, cocoa, coffee and tobacco, production of canned foods.	Fruit and vegetable processing plant, starch manufacturers, malt houses, grist and husting mill, oil mills, manufacturers of coffee, tea, cocoa, and canned foods, tobacco processing plants.
Waste from sugar production	Sugar manufacturers
Waste from milk processing	Dairies
Waste from production of baked foods and sweets	Bakeries, confectioners, candy producers.
Waste from the production of both non-alcoholic and alcoholic beverages	Breweries, wineries, liqueur producers, distilleries, non-alcoholic beverage and fruit juice producers

Frauhofer-Institut 1990

generated from large slaughter houses is estimated to be more than 21 lakh tones/annum. Based on the data collected during survey, the solid waste quantity generated in the bovine, goat and sheep and pig slaughter house is shown in Table 3.

Average solid waste generation from bovine slaughter house is 275 kg/tonne of total live weight killed (TLWK) which is equivalent to 27.5% of the animal weight. In case of goat and sheep slaughter house, average waste generation from pig slaughtering is 2.3 kg/head equivalent to 4% of animal weight.

In India, the slaughter house waste management system is very poor and several measures are being taken for the effective management of wastes generated from slaughter houses. Effective management of liquid waste/effluent by proper treatments, as per the guidelines contained in the Manual of Sewage treatment published by the Ministry of Urban development may be followed. The blood available from the slaughter houses should be collected and made use of its full potential in pharmaceutical industry. Provisions should be made for improved method of dressing, evisceration, safe disposal of waste products, control of odours, curbing activities of illegal slaughtering of animals, provisions of dry rendering plants and modernization of slaughter houses. (http://urbanindia.nic.in).

Table 2 The specific waste index for slaughter houses with respect to the type of animal

Animal	Specific waste index[a]
Cow	0.56
Calf	0.87
Pig	0.2
Sheep	0.1

Russ and Pittroff 2004.

[a] Mass of accumulated waste divided by the mass of saleable product

By-products in the meat industry and their utilization

United States considers everything produced by or from the animal, except dressed meat, to be a by-product. Animal by-products in the USA are divided into two classes, edible and inedible. In United States terminology, offal means slaughter by-products, and includes the entire animal which is not part of the carcass.

Variety meats are the wholesale edible by-products. They are segregated, chilled and processed under sanitary conditions and inspected by the US Meat Inspection Service. In some parts of the world, blood is also utilized as an edible product for human beings. In US, meat trimmed from the head is described on edible offal or an edible by-product. Edible fats are obtained during slaughter, such as the cowl fat surrounding the rumen or stomach, or the cutting fat which is back fat, pork leaf fat or rumen fat. In commercial slaughter house practice in U.K, the offal is divided into red (head, liver, lungs, tongue, tail etc.) and white (fat), plus the set of guts and bladder, the set of tripe (rumen), and the four feet and trimming. The list originally included the spinal cord and brain, but these are now banned for food use since the outbreak of BSE (Bovine Spongiform Encephalopathy, popularly known as Mad Cow Disease) (Schrieber and Seybold 1993). It also includes poultry parts such as the heart and liver.

Table 3 Quantity of solid waste generated from the bovine, goat, sheep and pig slaughter houses

Animal	Quantity of solid waste		
	Kg/head	Kg/TLWK	% of animal weight
Bovine	83	275	27.5
Goat/sheep	2.5	170	17
Pig	2.3	40	4

USDA 2001

Some items may not be used in uncooked products. This list includes mammalian parts such as blood, blood plasma, feet, large intestines, small intestines, lungs, oesophagus meat, rectum, stomach (non-ruminant), first stomach (tripe, after cooking), second stomach (tripe, after cooking), fourth stomach, testicles and udder. It also includes poultry part such as gizzards and necks. The average quantity of the different by-products from sheep, cattle and pig are shown in Table 4. The yield of edible meat by-products from pigs is around 6.7% of the carcasses weight. The world production of edible by-products from pigs in 2004 was 625 million MT, most of it from Asia (50.4%). Europe is the second largest producer, with 37.1% of the world total. Asia and Europe are also the two major consumers of meat by-products, including beef and lamb. Usage of meat by-products often requires treatments such as collection, washing, trimming, chilling, packaging and cooling. Whether these products are widely accepted by consumers depends on various factors. These include the nutrient content, the price and whether there are comparable competing products.

Traditions, culture and religion are often important when a meat by-product is being utilized for food. Regulatory requirements are also important, because many countries restrict the use of meat by-products for reasons of food safety and quality. An example is the USDA requirement that mechanically separated meat and variety meats must be specifically identified as an ingredient on labels. If frankfurters and bologna are made with heart meat or mechanically separated poultry meat as an ingredient, this must be listed.

Nutritive value of meat by-products

Edible meat by-products contain many essential nutrients. Some are used as medicines because they contain special nutrients such as amino acids, hormones, minerals, vitamins and fatty acids. Not only blood, but several other meat by-products, have a higher level of moisture than meat. Some examples are lung, kidney, brains, spleen, and tripe. Some organ meat, including liver and kidney, contains a higher level of carbohydrate than other meat materials (Devatkal et al. 2004b).

Pork tail has the highest fat content and the lowest moisture content of all meat by-products. The liver, tail, ears and feet of cattle have a protein level which is close to that of lean meat tissue, but a large amount of collagen is found in the ears and feet (Unsal and Aktas 2003). The lowest protein level is found in the brain, chitterlings and fatty tissue. The United States Dept. of Agriculture (2001) requires that mechanically deboned beef and pork contain at least 14% protein and a maximum of 30% fat. The amino acid composition of meat by-products is different from that of lean tissue, because of the large amount of connective tissue. As a result, by-products such as ears, feet, lungs, stomach and tripe contain a larger amount of proline, hydroxyproline and glycine, and a lower level of tryptophan and tyrosine. The vitamin content of organ meats is usually higher than that of lean meat issue. Kidney and liver contain the largest amount of riboflavin (1.697–3.630 mg/100 g), and have 5–10 times more than lean meat. Liver is the best source of niacin, vitamin B12, B6, folacin, ascorbic acid and vitamin A. Kidney is also a good source of vitamin B6, B12, and folacin. A 100 g serving of liver from pork or beef contributes 450%–1,100% of the RDA of vitamin A, 65% of the RDA of vitamin B6, 3,700% of the RDA of vitamin B12 and 37% of the RDA of ascorbic acid. Lamb kidneys,pork, liver, lungs, and spleen are an excellent source of iron, as well as vitamins. The copper content is highest in the livers of beef, lamb and veal. They contribute 90–350% of the RDA of copper (2 mg/day). Livers also contain the highest amount of manganese (0.128–0.344 mg/100 g). However, the highest

Table 4 By-products as a percentage of market live weight

Item	Pigs		Cattle		Sheep	
	%	kg	%	kg	%	kg
Market live weight		100		600		60
Whole carcass	77.5	77.5	63.0	378.0	62.5	37.5
Blood	3.0	3.0	18.0	4.0	2.4	
Fatty tissue	3.0	3.0	4.0	24.0	3.0	1.8
Hide or skin	6.0	6.0	6.0	36.0	15.0	9.0
Organs	7.0	7.0	16.0	96.0	10.0	6.0
Head	5.9	5.9				
Viscera(chest and abdomen	10.0	10.0	16.0	96.0	11.0	6.6
Feet	2.0	2.0	2.0	12.0	2.0	1.2
Tail	0.1	0.1	0.1	6.0		
Brain	0.1	0.1	0.1	6.0	2.6	0.156

USDA 2001

level of phosphorus (393–558 mg/100 g) and potassium (360–433 mg/100 g) in meat by-products is found in the thymus and sweetbreads (Devatkal et al. 2004b). With the exception of brain, kidney, lungs, spleen and ears, most other by-products contain sodium at or below the levels found in lean tissue. Mechanically deboned meat has the highest calcium content (315–485 mg/100 g).

Many organ meats contain more polyunsaturated fatty acids than lean tissue. Brain, chitterlings, heart, kidney, liver and lungs have the lowest level of monounsaturated fatty acids and the highest level of polyunsaturated fatty acids. (Liu 2002). There is three to five times more cholesterol (260–410 mg/100 g) in organ meats than in lean meat, and large quantities of phospholipids. Brain has the highest level of cholesterol (1,352–2,195 mg/100 g) and also has the highest amount of phospholipids compared to other meat by-products. For this reason, the United States Department of Health recommends that limited amounts of these by-products be eaten, because of health concerns. The high cholesterol content of many other organ meats, and the possible accumulation of pesticides, drug residues and toxic heavy metals, is another reason for limited consumption.

Utilization of blood

Animal blood has a high level of protein and heme iron, and is an important edible by-product (Wan et al. 2002). In Europe, animal blood has long been used to make blood sausages, blood pudding, biscuits and bread. In Asia, it is used in blood curd, blood cake and blood pudding (Ghost 2001). It is also used for non-food items such as fertilizer, feedstuffs and binders. According to the Meat Inspection Act of the United States, blood is approved for food use when it has been removed by bleeding an animal that has been inspected and passed for use in meat food products.

Blood is usually sterile in a healthy animal. It has high protein content (17.0), with a reasonably good balance of amino acids. Blood is a significant part of the animal's body mass (2.4–8.0% of the animal's live weight). The average percentage of blood that can be recovered from pigs, cattle and lambs are 3.0–4.0, 3.0–4.0 and 3.5–4.0%, respectively. However, the use of blood in meat processing may mean that the final product is dark in color, and not very palatable. Plasma is the portion of blood that is of greatest interest, because of its functional properties and lack of color.

Use of blood plasma in food

Blood is used in food as an emulsifier, a stabilizer, a clarifier, a color additive, and as a nutritional component (Silva and Silvestre 2003). Most blood is used in livestock feed in the form of blood meal. It is used as a protein supplement, a milk substitute, a lysine supplement or a vitamin stabilizer, and is an excellent source of most of the trace minerals. Blood plasma has ability to form a gel, because it contains 60.0% albumin (Silva and Silvestre 2003). Plasma is the best water and fat binder of the blood fraction. Plasma gels appear very similar to cooked egg whites. Plasma forms a gel at a protein concentration of 4.0–5.0%. The strength of the gel increases with increasing concentration. Cooked ham to which were added 1.5 and 3.0% frozen blood plasma, and hot dogs with 2.7% added plasma, were more satisfactory in color than those without it (Autio et al. 1985).

Blood plasma also has an excellent foaming capacity (Del et al. 2008), and can be used to replace egg whites in the baking industry (Ghost 2001). The application of transglutaminase (TGase) from animal blood and organs or microbes to meat products has received a great deal of research. Blood factor XIII is a transglutaminase that occurs as an enzymogen in plasma, placenta and platelets. Transglutaminase was first extracted from bovine blood in 1983, in order to improve the binding ability of fresh meat products at chilling temperature. It showed how myosin was cross-linked by TGase. An important property of the TGase reaction was documented when cross-linking between myosin and proteins (soy, casein and gluten), all commonly used in meat processing Moreover, the restructured meat products can be processed without heating, and their salt and phosphate content reduced, by the addition of TGase from animal blood.

Medicinal and pharmaceutical uses of blood

Blood can be separated into several fractions that have therapeutic properties. Liquid plasma is the largest fraction (63.0%). It consists of albumin (3.5%), globulin and fibrinogen (4.0%). In the laboratory, many blood products are used as a nutrient for tissue culture media, as a necessary ingredient in blood agar, and as peptones for microbial use (Kurbanoglu and Kurbanoglu 2004). Glycerophosphates, albumins, globulins, sphingomyelins, and catalase are also used for biological assay. Many blood components such as fibrinogen, fibrinolysin, serotonin, kalikreninsa, immunoglobulins and plasminogen are isolated for chemical or medical uses (Young and Lawrie 2007). Purified bovine albumin is used to help replenish blood or fluid loss in animals. It is used in testing for the Rh factor in human beings, and as a stabilizer for vaccines. It is also used in antibiotic sensitivity tests.

Utilization of hides and skins

Animal hides have been used for shelters, clothing and as containers by human beings since prehistoric times. The hides represent a remarkable portion of the weight of the live animal, from 4% to as much as 11% (e.g. cattle: 5.1–8.5%, average: 7.0%; sheep: 11.0–11.7%; swine: 3.0–8.0%). Hides and skins are generally one of the most valuable by-products from animals. Examples of finished products from the hides of cattle and pigs, and from sheep pelts, are leather shoes and bags, rawhide, athletic equipment, reformed sausage casing and cosmetic products, sausage skins, edible gelatine and glue (Benjakul et al. 2009).

Stacking of hides and skins

After the hide is removed from the animal, it should be cured quickly to avoid decomposition by bacteria and enzymes. There are four basic treatments. One is air-drying, the second is curing with salt, and the third and fourth are curing by mixer and raceway respectively. Salt curing is often used for the raw hides. The quality of cured hides and skins is usually based on their moisture and salt content. The moisture level of hides should be in the range 40–48%, if they are to remain in good condition during storage or shipping.

Gelatin from hides and skins

Gelatin is produced by the controlled hydrolysis of a water-insoluble collagen derived from protein. It is made from fresh raw materials (hides or bone) that are in an edible condition. Both hides and bones contain large quantities of collagen. The processing of gelatin from hide consists of three major steps. The first step is the elimination of non-collagenous material from the raw material. This is followed by controlled hydrolysis of collagen to gelatin. The final step is recovery and drying of the final product.

Uses of gelatin in the food and pharmaceutical industries

Gelatin extracted from animal skins and hides can be used for food (Choa et al. 2005). The raw material can also be rendered into lard. In the United States, Latin America, Europe and some Asian countries, pork skin is immersed, boiled, dried and then fried to make a snack food (pork rinds) and in U.K they are called “pork scratching”. Collagen from hides and skins also has a role as an emulsifier in meat products because it can bind large quantities of fat. This makes it a useful additive or filler for meat products. Collagen can also be extracted from cattle hides to make the collagen sausage used in the meat industry.

Gelatin is added to a wide range of foods, as well as forming a major ingredient in jellies and aspic (Jamilah and Harvinder 2002). Its main use is the production of jellied desserts, because of its “melt in the mouth” properties, but is also added to a range of meat products, in particular to meat pies. Gelatin is also widely used as a stabilizer for ice cream and other frozen desserts. High-bloom gelatin is added as a protective colloid to ice cream, yoghurt and cream pies. The gelatin is thought to inhibit the formation of ice crystals and the recrystallization of lactose during storage.

Approximately 6.5% of the total production of gelatin is used in the pharmaceutical industry (Hidaka and Liu 2003). Most of it is used to make the outer covering of capsules. Gelatin can also be used as a binding and compounding agent in the manufacture of medicated tablets and pastilles. It is used as an important ingredient in protective ointment, such as zinc gelatin for the treatment of ulcerated varicose veins. Gelatin can be made into a sterile sponge by whipping it into foam, treating it with formaldehyde and drying it.(Estaca et al. 2009). Such sponges are used in surgery, and also to implant a drug or antibiotic directly into a specific area. Because gelatin is a protein, it is used as a plasma expander for blood in cases of very severe shock and injury. Gelatin is an excellent emulsifier and stabilizing agent for many emulsions and foams. It is used in cosmetic products, and in printing for silk screen printing, photogravure printing etc. (Arvanitoyannis 2002).

Collagen casing products were developed in Germany in the 1920s, but only gained popularity in the United States in the 1960s. The processing does not convert the collagen into a soluble product, as in the case of gelatin. Instead, it results in a product which retains a relatively high degree of the native collagen fiber, and is strong enough to be used as a casing for sausages and other products. The extracted collagen is mixed with water and converted into a dough, which is extruded by either a wet or a dry process. The tube of extruded collagen is then passed through a concentrated salt solution and a chamber of ammonia to precipitate the collagen. The swollen gel contracts to produce a film of reasonable strength. It can be improved by the addition of glycerin, to make it more flexible. The tube is then dried to 10.0–15.0% water content.

Medicinal and pharmaceutical uses of hides and skins

A product made from extracted collagen can stimulate blood clotting during surgery. Pork skin is similar to human skin, and can be converted into a dressing for burns or skin-ulcers. Pork skin used as a dressing needs to be cut into strips or into a patch, shaved of hair, split to a thickness of 0.2–0.5 mm, cleansed, sanitized and packaged. It can be used for skin grafting. When used for skin grafting, it is removed from the carcass within 24 h of the death of the pig.

Utilization of bone

Eleven percent of pork carcasses, 15% of beef carcasses and 16% of lamb carcasses are bone. These values are higher if they include the meat clinging to the bone. The marrow inside some of the bones can also be used as food. The marrow may be 4.0–6.0% of the carcass weight (West and Shaw 1975). For centuries, bones have been used to make soup and gelatine. In recent years, the meat industry has been trying to get more meat from bones, and new techniques have been used for this purpose. The beef, pork or lamb produced by mechanical deboning produces tissue that is called "mechanically separated", "mechanically deboned" or "mechanically removed". Such meat is now approved for use in meat products (mixed or used alone) in many countries (Field 1981). In 1978, mechanically separated red meat was approved for use as red meat in the United States.

Normally, if a high percentage of mechanically separated red meat is incorporated into products, the flavor and quality are reduced. The color becomes darker, and the meat is softer with higher water content. For this reason, the level of mechanically separated meat is usually limited. It should be noted that mechanically recovered meat has a bad consumer perception in some countries connected with health concerns with Bovine Spongiform Encephalopathy (BSE) contamination (Arvanitoyannis and Ladas 2008). A level of 5.0–20.0% in hamburger and ground beef, and 10.0–40.0% in sausages, has been suggested by the meat industry.

Many countries already have regulations covering products which contain mechanically separated red meat. In the United States, mechanically separated meat cannot be used for hamburgers, baby food, ground beef or meat pies. A level of 20% is the maximum in sausage emulsion. In Denmark, if mechanically separated red meat is used at levels of more than 2% it has to be declared on the label. In Australia, if mechanically deboned beef or mutton is present in exported products, the quantity must be shown on the label, plus the maximum level of calcium, the moisture content and the minimum protein level.

Meat and bone meal (MBM) was widely recommended and used in animal nutrition as a protein source in place of proteinaceous feeds because of its content of available essential amino acids, minerals and vitamin $B_{12.}$ MBM and related rendered protein commodities have potential for use in applications other than animal feed, including use as a fuel or a phosphorus fertilizer

Utilization of glands and organs

Glands and organs as food

Animal organs and glands offer a wide variety of flavors and textures, and often have a high nutritional value. They are highly prized as food in many parts of the world, particularly Southeast Asia. Those used as human foods include the brain, heart, kidneys, liver, lungs and spleen. They also include the tongue, the bovine pancreas and udder, the stomach and uterus of pigs, the rumen, reticulum, omasum and absomasum of sheep and cattle, and the testes and thymus of sheep and pigs (Liu 2002). Potential applications and storage and preparation aspects of meat by-products are illustrated in Table 5.

The brain, nervous system and spinal cord are usually prepared direct for the table rather than processed for industrial use. They are blanched to firm the tissue before cooking, because of the soft texture. The membranes are peeled from the brain before cooking. Heart meat is generally regarded as relatively touch, reflecting the nature of the cardiac muscle. Heart is used as a table meat. Whole hearts can be roasted or braised. Sliced heart meat is grilled or braised. Heart meat is often also used as an ingredient in processed meats. Kidneys are generally removed from the fatty capsule which holds the kidney in place. The ureter and blood vessels need to be trimmed before the kidneys are prepared for cooking. Kidneys may be cooked whole or in slices, and are generally broiled, grilled, or braised. Liver is the most widely used edible organ. It is used in many processed meats, such as liver sausage and liver paste (Devatkal et al. 2004a). Livers from lambs, veal calves and young cattle are preferred for the table in the United States and Europe, because they have a lighter flavor and texture. Consumers in Southeast Asia, However, generally prefer livers from pigs. Livers are braised or broiled. Pig, calf and lamb lungs are mainly used to make stuffing and some types of sausages and processed meats (Darine et al. 2010).

Animal intestines are used as food after being boiled in some countries. Animal intestines are also used in pet food or for meat meal, tallow or fertilizer. However, the most important use of the intestines is as sausage casings (Bhaskar et al. 2007). Animal intestines, when removed from the carcass, are highly contaminated with microbes and very fragile. They must be cleaned immediately after the slaughter of the animal. To make them into sausage casing, they are removed from the abdomen. The ruffle fat is separated from the intestines, and the faeces stripped out. Sometimes they are fermented, though this is not often done today. The inner mucosa membrane is separated from the casing, all strings and blood are removed, and the intestines are finally soaked salted and packaged.

Table 5 Potential uses and preparation of edible meat by-products

Kind of meat	Storage and Preparation	Way in which it is used
Liver	Frozen, fresh or refrigerated	Braised, broiled, fried, in loaf, patty and sausage
Kidney	Whole, sliced or ground Fresh or refrigerated	Broiled, cooked in liquid, braised, in soup, grilled, in stew
Heart	Whole or sliced Frozen, fresh or refrigerated	Braised, cooked in liquid, luncheon meat, patty, loaf
Brains	Whole or sliced	Sausage ingredient, broiled, braised and cooked in liquid, poached, scrambled
Tongue	Frozen, fresh or refrigerated Whole	Cooked in liquid, cured, sausage casing, sausage ingredient
Stomach	Fresh, refrigerated, smoked and pickled	Broiled and cooked in liquid, sausage casing, sausage ingredient
Spleen	Fresh, refrigerated and pre-cooked	Fried, in pies, in blood sausage
Tail	Frozen, fresh or refrigerated	Cooked in salty liquid
Intestines (small & large)	Whole, frozen, fresh, refrigerated. Remove faeces, soak, wash, add salt before use	Sausage casing
Cheek and head trimmings	Frozen, fresh or refrigerated	Cooked sausage
Ear	Frozen, fresh or refrigerated	Smoked and salted, stewed with feet
Skin	Fresh, refrigerated	Gelatin
Feet	Frozen, fresh, refrigerated	Jelly, pickled, cooked in liquid, boiled, fried
Fat	Frozen, fresh or refrigerated	Shortening, lard
Blood	Frozen, refrigerated	Black pudding, sausage, blood and barley loaf
Bone	Frozen, fresh or refrigerated	Gelatin, soup, jellied products, rendered shortening, mechanically deboned tissue
Lung	Frozen, refrigerated, fresh	Blood preparations, pet food

Ockerman and Hansen 2000

Medicinal and pharmaceutical uses of glands and organs

Animal glands and organs are traditionally used as medicine in many countries, including China, India and Japan. The endocrine glands secrete hormones (i.e. enzymes that regulate the body's metabolism). These include the liver, lungs, pituitary, thyroid, pancreas, stomach, parathyroid, adrenal, kidney, corpus luteum, ovary and follicle. The glands are collected only from healthy animals. Locating the glands needs some experience. They are often small and encased in other tissue.

Different animals have different glands that are important. The function of glands also depends on the species, sex and age of the animal. The best method of preserving most glands to stop tissue breakdown from bacterial growth is by rapid freezing. Before freezing, the glands need be cleaned, and the surrounding fat and connective tissue trimmed off. The glands are then placed onto waxed paper and kept at −18 °C or less. When the glands arrive at the pharmaceutical plant they are inspected, then chopped and mixed with different solutions for extraction, or placed in a vacuum drier. If the dried gland contains too much fat, solutions such as gasoline, light petroleum, ethylene or acetone are used to remove the fat. After drying and defatting, the glands or extracts are milled into a powder and made into capsules, or used in a liquid form. They are tested for safety and potency before they are sold.

Brains, nervous systems and spinal cords are a source of cholesterol which is the raw material for the synthesis of vitamin D3. Cholesterol is also used as an emulsifier in cosmetics (Ejike and Emmanuel 2009). Other materials can be isolated from the hypothalamus of the brain for the same purpose. The hormone melatonin, extracted from the pineal gland, is being evaluated for the treatment of schizophrenia, insomnia and other problems, including mental retardation.

Bile consists of acids, pigments, proteins, cholesterol etc., and can be obtained from the gall bladder. It is used for the treatment of indigestion, constipation and bile tract disorders. It is also used to increase the secretory activity of the liver. Bile from cattle or pigs can be purchased as a dry extract or in liquid form. Some ingredients of bile, such as prednisone and cortisone, can be extracted separately, and used as medicines. Gallstones are reported to have aphrodisiac properties, and can be sold at a high price. They are usually used as ornaments to make necklaces and pendants.

The liver is the largest gland in animals. The liver of mature cattle usually weighs about 5 kg, while that of a pig weighs approximately 1.4 kg. Liver extract is produced by mixing raw ground liver with slightly acidified hot water. The stock is concentrated into a paste in a vacuum at a low temperature, and is used as a raw material by the pharmaceutical industry. Liver extract can be obtained from pigs and cattle, and has been used for a long time as a source of vitamin B12, and as a nutritional supplement used to treat various types of anaemia. (Colmenero and Cassens 1987; Devatkal et al. 2004a, b). Heparin can be extracted from the liver, as well as the lungs and the lining of the small intestines. It is used as an anticoagulant to prolong the clotting time of blood. It is also used to thin the blood, to prevent blood clotting during surgery and in organ transplants.

Progesterone and oestrogen can be extracted from pig ovaries. It may be used to treat reproductive problems in women. Relaxin is a hormone taken from the ovaries of pregnant sows, and is often used during childbirth.

The pancreas provides insulin, which regulates sugar metabolism and is used in the treatment of diabetes. Glucagon extracted from the cells of the pancreas is used to increase blood sugar, and to treat insulin overdoses or low blood sugar caused by alcoholism. Chymotrypsin and trypsin are used to improve healing after surgery or injury.

The intestines of sheep and calves are used for the manufacture of catgut, to make internal surgical sutures. The lining of the small intestines of pigs and cattle can be collected while the intestines are being processed into casings. It is either preserved in a raw state, or processed into a dry powder for shipment to heparin manufacturers.

Utilization of edible tallow and lard

Animal fats are an important by-product of the meat packing industry. The major edible animal fats are lard and tallow. Lard is the fat rendered from the clean tissues of healthy pigs. Tallow is hard fat rendered from the fatty tissues of cattle or sheep. Lard and edible tallow are obtained by dry or wet rendering. In the wet rendering process, the fatty tissues are heated in the presence of water, generally at a low temperature. The quality of the lard or tallow from this process is better than that of products from dry rendering. Low-quality lard, and almost all of the inedible tallow and greases, are produced by dry rendering. Rendered lard can be used as an edible fat without any further processing. However, because of consumer demand, lard and tallow are now often bleached and given a deodorizing treatment before being used in food.

Traditionally, tallow and lard were used for deep frying (Weiss 1983). However, this use is declining in the fast-food industry, due to consumer health concerns. An alternative liquid tallow product has been developed for the preparation of French fries and other fast foods, since less fat is absorbed. Tallow and lard are also used for margarine and shortening (Ghotra et al. 2002). Some edible lards are used in sausages or emulsified products (Chrysam 1985).

Utilization of poultry by-products

Waste products from the poultry processing and egg production industries must be efficiently dealt with as the growth of these industries depends largely on waste management. Animal and poultry waste management center, at North Carolina State University, North Carolina, USA is engaged in conversion of wastes to valuable products and the work being supported by various organization, agencies, companies etc. (Anon 1995).

The intensive and large scale production of food animals and animal products has generated an enormous disposal problem for the animal industry. These wastes, including animal excreta, mortalities, hair, feathers and processing wastes are convertible to useful resources. An efficient thermophilic anaerobic digester system that converts animal manure to methane for an energy source was reported by Shih (1993). Properties of a feather degrading bacterium, Bacillus licheniformis, which can ferment and convert feathers to feather lysate, a digestible protein source for feed use. An enzyme, keratinase, secreted by this bacterium, was purified and characterized. The keratinase is a potent proteinase that hydrolyses collagen, elastin and feather keratin

Emulsion—based mutton nuggets, incorporating chicken by-products, i.e., skin, gizzard and heart (SGH) from spent hens were evaluated by Kondaiah et al. (1993). Incorporation of SGH resulted in better acceptability of mutton nuggets as compared to that containing mutton fat. Urlings et al. (1993) studied the proteolysis and amino acid breakdown of heated and irradiated poultry by products of muscle tissue and concluded that during processing of poultry meat and poultry wastes, enzymic activity has to be reduced or eliminated to ensure safe and high quality products. The main by-products from the poultry industry are shown in Table 6.

Egg white flavoprotein is abundant in low-cost egg processing by-products and could serve as a useful food ingredient, provided a cost effective procedure for its purification is available (Rao et al. 1997).

Volume of wastewater generated from meat and poultry industry

The meat industry is a branch of the food industry, which causes degradation of the environment to a large extent.

Table 6 Poultry industry by-products and their potential uses

Type of by-product	% of live weight	Uses
By-products from production phase		
Poultry litter and manure	–	Recycled feed, surface dressing of agricultural land
Hatchery by-products		
Egg shells, infertile eggs, unhatched eggs and dead as well as culled chicks	–	Hatchery by-product meal upto 3–5% into feed. Egg shell meal as high calcium diet
By-products of poultry dressing plant		
Feathers	7–8	Bedding material, decorative purpose, sporting equipment, manure or fertilizers, feather meal.
Heads	2.5–3.0	Poultry meal.
Blood	3.2–3.7	Blood meal.
Gizzard and proventriculus	3.5–4.2	Edible, source of chitinolytic enzyme.
Feet	3.5–4.0	Soup, technical fat/poultry grease
Intestines and glands	8.5–9.0	Sportgats,, meat meal, poultry grease and active principles (hormones and enzymes)

Sams 2001

The wastewater produced in it contains a variety of organic and inorganic pollutants, has a high concentration of etheric extract, suspended and biogenic matter as well as variable concentrations. Processes using ultrafiltration–reverse osmosis, chemical precipitation–reverse osmosis and chemical precipitation–ultrafiltration–reverse osmosis have been used in the treatment of meat industry wastewaters (Bohdziewicz and Sroka 2005).

In poultry processing, water is used primarily for scalding, in the process of feather removal, bird washing before and after evisceration, chilling, cleaning and sanitizing of equipment and facilities, and for cooling of mechanical equipment such as compressors and pumps. Although water also is typically used to remove feathers and viscera from production areas, overflow from scalding and chiller tanks is used. A number of studies also have shown that the volume of water used and wastewater generated by poultry processing on a per unit of production basis (such as per bird killed) can vary substantially among processing plants. Again, some of this variation is a reflection of different levels of effort among plants to reduce their wastewater treatment costs by minimizing their water use. One study of 88 chicken processing plants found wastewater flows ranged from 4.2 to 23 gallon per bird with a mean value of 9.3 gallon per bird (USEPA 1975).

Description of waste constituents and concentrations

The principal constituents in waste waters from rendering operations are the same as those in meat and poultry processing wastewaters. In addition, it appears that there is little difference in rendering wastewater constituents or concentrations attributable to the source of materials being processed. The principal sources of wastes in poultry processing are live bird holding and receiving, killing, defeathering, eviscerating, carcass washing, chilling, cut-up, and cleanup operations. Further processing and rendering operations are also major sources of wastes. These wastes include blood not collected, feathers, viscera, soft tissue removed during trimming and cutting, bone, soil from feathers, and various cleaning and sanitizing compounds. Further processing and rendering can produce additional sources of animal fat and other soft tissue, in addition to other substances such as cooking oils.

Thus, the principal constituents of poultry processing wastewaters are a variety of readily biodegradable organic compounds, primarily fats and proteins, present in both particulate and dissolved forms. To reduce wastewater treatment requirements, poultry processing wastewaters also are screened to reduce concentrations of particulate matter before treatment. An added benefit of screening is increased collection of materials and subsequent increased production of rendered by-products. Because feathers are not rendered with soft tissue, wastewater containing feathers is not commingled with other wastewater. Instead, it is screened separately and then combined with unscreened wastewater to recover soft tissue before treatment during the screening process of these mixed wastewaters. However, poultry processing wastewaters also remain high strength wastes even after screening in comparison to domestic wastewaters based on concentrations of BOD, COD, TSS, nitrogen, and phosphorus after screening. Blood not collected, solubilized fat, and feces are principal sources of BOD in poultry processing wastewaters. As with meat processing wastewaters, the efficacy of blood collection is a significant factor in determining BOD concentration in poultry processing wastewaters. Another significant factor in determining the BOD of poultry processing wastewaters is the degree to which manure (urine and feces), especially from receiving areas, is handled separately as a solid waste. Chicken and turkey manures have BOD concentrations in excess of 40,000 mg/kg on an as excreted basis (American Society of Agricultural Engineers 1999). The cages and trucks for transporting broilers are washed in U.K but in some Asian countries, although the cages and trucks used to transport broilers to processing plants usually are not washed, cages and trucks used to transport live turkeys to processing plants are washed to prevent transmission of disease from farm to farm. Thus, manure probably is a more significant source of wastewater BOD for turkey processing operations than for broiler processing operations.

Rendering (meat and poultry by-product processing) description

Rendering processes are processes used to convert the by-products of meat and poultry processing into marketable products, including edible and inedible fats and proteins for agricultural and industrial use. Materials rendered include viscera, meat scraps including fat, bone, blood, feathers, hatchery by-products (infertile eggs, dead embryos, etc.), and dead animals. Lard and foodgrade tallow are examples of edible rendering products. Inedible rendering products include industrial and animal feedgrade fats, meat and poultry by-product meals, feather meal, dried blood, and hydrolyzed hair. Rendering plants that operate in conjunction with animal slaughterhouses or poultry processing plants are called integrated rendering plants. Plants that collect their raw materials from a variety of off-site sources are called independent rendering plants. Independent plants obtain animal by-product materials from a variety of sources, including butcher shops, supermarkets, restaurants, fast-food chains, poultry processors, slaughterhouses, farms, ranches, feedlots, and animal shelters (USEPA 1995). Edible rendering plants separate fatty animal tissue into edible fats and proteins. The edible rendering plants are normally operated in conjunction with meat packing plants. The USDA Food Safety and Inspection Service (FSIS) is responsible for regulating and inspecting meat and poultry first and further processing facilities and facilities engaged in edible rendering (i.e., suitable for human consumption) to ensure food safety. The U.S. Food and Drug Administration (FDA) covers inedible rendering operations. Inedible rendering plants are operated by independent renderers or are part of integrated rendering operations. These plants produce inedible tallow and grease, which are used in livestock and poultry feed, pet food, soap, chemical products such as fatty acids, and fuel blending agents.

Edible rendering

Edible lard and tallow are the main foodstuffs produced from continuous edible rendering of animal fatty tissue. Either the low temperature option or the high temperature option edible rendering processes may be used to render edible fat. The low temperature option uses temperatures below 49 °C (120 °F) and the high temperature option uses temperatures between 82 and 100 °C (180 and 210 °F) to melt animal fatty tissue and to separate the fat from the protein. A better separation of fat from protein can be achieved with the high temperature option; however, the protein obtained from the low temperature option is of acceptable quality, whereas the protein obtained from the high temperature option cannot be sold as an edible product (Prokop 1985).

Inedible rendering

There are two processes for inedible rendering: the wet process and the dry process. Wet rendering separates fat from raw material by boiling in water. The process involves adding water to the raw material and using live steam to cook the raw material and separate the fat. Dry rendering is a batch or continuous process in which the material being rendered is cooked in its own moisture and grease with dry heat in open steam jacketed drums until the moisture has evaporated. Following dehydration, as much fat as possible is removed by draining, and the residue is passed through a screw press to remove some of the remaining fat and moisture. Then the residue is granulated or ground into a meal. At present, only dry rendering is used in the United States. The wet rendering process is no longer used because of the high cost of energy and its adverse effect on the fat quality (USEPA 1995).

Fish waste/by-products utilization

Fish waste is a great source of minerals, proteins and fat. Potential utilization of waste fish scraps from 5 marine species (white croaker, horse mackerel, flying fish, chub mackerel, Sardine) to produce fish protein hydrolysate by enzymic treatment was investigated by Khan et al. (2003) and indicated that fish protein hydrolysate could be used as a cryoprotectant to suppress the denaturation of proteins of lizard fish surimi during frozen storage Ohba et al. (2003) reported that collagen or keratin contained in livestock and fish waste may be converted to useful products by enzymic hydrolysis, providing new physiologically functional food materials. Collagens containing yellow tail fish bone and swine skin wastes were used as raw materials for production of protein hydrolysates and peptides. These hydrolysates could be of potential use as food ingredients (Morimura et al. 2002). Enzymes and bioactive peptides obtained from fish waste or by-catch and used for fish silage, fish feed or fish sauce production (Gildberg 2004). Auto-hydrolysis of waste fish viscera to produce peptone hydrolysates and their use in microbiological media to support growth and bacteriocin production by lactic acid bacteria are reported by Vanquez et al. (2004). There are several alternative uses of fish processing waste, like utilization of fish mince, applications of fish gelatin, fish as a source of nutraceutical ingredients, fishmeal production, the possible use of fish and protein concentrate as a food source. The potential uses of fish waste are depicted in Table 7.

Recovery of proteins from fish waste products by alkaline extraction resulted a good yield of protein from lake waste (Batista 1999).Production of organic acids and amino acids from fish meat by sub-critical water hydrolysis would be an efficient process for recovering useful substances from organic waste such as fish waste discovered from fish markets (Yoshida et al. 1999). Use of fish waste for animal feed production was investigated by Hammoumi et al. (1998) and the considerable potential for use of fish waste for poultry feeding was established. Fish waste (from *Sardine Pilchardus*) from food factories was processed by biological fermentation using a combined starter culture of Saccharomyces species and *Lactobacillus plantarium* in order to investigate its utility in high protein feedstuffs for animals. It was concluded that mixed fermentation by pure culture of yeasts and lactic acid bacteria strains is involved in preservation, transformation and improvement of quality of the final product (Faid et al. 1997). Development of restructured fish product enabled commercial use of under-exploited fish species and the economic use of previously discarded fish waste (Borderias and Mateos 1996).

The potential of fish waste effluent as a fermentation medium for production of antibacterial compounds, by lactic acid bacteria was evaluated by Tahajod and Rand (1996). Collagen and keratin contained in livestock and fish waste may be converted to useful products by enzymic hydrolysis, providing new physiologically-functional food materials. Peptones for microbiological purposes are obtained from good quality meat (beef, pork, horsemeat), but a review of the literature indicates that an equally good source is fish and high-protein fish waste (Skorupa and Sikorski 1993). A smoked catfish sausage prepared from catfish frames and miscut fillets and smoked for 4 h was reported by Rust (1995). It has been suggested that shrimp by-products may serve as a potential source of flavouring such as shrimp sauce. Characteristics of salt-fermented sauces from shrimp processing by-products has been reported by Kim et al. (2003) and found that shrimp processing by-products may lend themselves to the preparation of high quality salt-fermented sauces. The production of fish oil from by-products of matjes (Salted) and studies on its stability to evaluate the quality characteristics was reported by Aidos et al. (2001).

Fish collagens are of interest to the food processing industry as they are used to produce gelatin which is extracted from the collagen. World landings of fish and shellfish are approaching 100 million metric tons (MMT) annually, of this total, around 28% is processed into fish meal and oil. Fish waste which is either high in oil or has excessive bones or is unsuitable for edible purposes can be converted to valuable feed and industrial products (Bimbo and Crowther 1992).

The recovery of chemical components from seafood waste materials, which can be used in other segments of the food industry, is a promising area of research and development for the utilization of seafood by-products. Researchers have shown that a number of useful compounds can be isolated from seafood waste including enzymes, gelatin and proteins that have antimicrobial and antitumor capabilities. Chitosan, produced from shrimp and crab shell, has shown a wide range of applications from the cosmetic to pharmaceutical industries (Arvanitoyannis and Kassaveti 2008). One of the important applications of chitosan is the removal of proteinaceous matter in the food industry. Chitosan, with its positive charge, can be used for coagulation and recovery of proteinaceous materials present in such food processing operations (Knorr 1991). Removal of proteinaceous matter from wastewater generated by food industry prior to discharge to municipal sewer system is becoming mandatory in many countries. Furthermore, chitosan is largely used as a non-toxic flocculent in the treatment of organic polluted wastewater and as a chelating agent for the removal of toxic (heavy and reactive) metals from industrial wastewater (An et al. 2001). Chitosan can potentially be used as a food preservative in food packaging materials since chitosan has film-forming ability with antimicrobial properties. Chitosan has wide spectrum antimicrobial activity against bacteria, yeast and fungi (Rabea et al. 2003; Shahidi et al. 1999). Chitosan may be used in various food preservation applications such as, direct addition of chitosan into food, direct application of chitosan film or coatings onto food surfaces, addition of chitosan sachets into packages, and use of chitosan incorporated packaging materials. Numerous researchers

Table 7 Potential uses of fish wastes

Final Products	Treatment	Physicochemical characteristics	Uses
Fish waste (mainly heads, bones, skin, viscera and sometimes whole fish and parsley)	Heat treatments at 65, 80, 105 and 150 °C for 12 h for moisture content reduction to 10–12%,	High source of minerals, 58% protein, 19% fat, detection of toxic substances (As, Pb, Hg and Cd) at non-problematic concentrations, decrease of waste digestibility with temperature	Fish waste (mainly heads, bones, skin, viscera and sometimes whole fish and parsley)
Raw fish oil	Filtration pretreatment with or without the presence of two catalysts (iron oxide and calcium phosphate monobasic) and ozone treatment (5 g/h, 16 g/m ^{3} (about 8000 ppm)) at room temperature for 1 h and 30 min, respectively	Almost identical HHV (10700 kcal/kg) and lower flash and pour points (37 °C and −16 °C, respectively) compared to commercial diesel fuel, no production of sulfur oxides, lowered or no soot, polyaromatic and carbon dioxide emissions	Raw fish oil
Fish skin, bone and fin	Collagen isolation	36–54% collagen recovery and denaturation temperatures of skin collagen (25.0±26.5 °C), bone collagen (29.5±30.0 °C) and fin collagen (28.0±29.1 °C)	Fish skin, bone and fin
Fish bone waste	Heat treatment of raw bone at 600 °C for 24 h or 900 °C for 12 h	Better removal capacity and well-crystallized hydroxyapatite at 600 °C, raw bone showed lower activity and crystallinity, bone sample heated at 900 °C showed developed similar activity with raw bone and developed crystallinity of hydroxyapatite	Fish bone waste
Fish waste (mainly heads, bones, skin, viscera and sometimes whole fish and parsley)	Heat treatments at 65, 80, 105 and 150 °C for 12 h for moisture content reduction to 10–12%,	High source of minerals, 58% protein, 19% fat, detection of toxic substances (As, Pb, Hg and Cd) at non-problematic concentrations, decrease of waste digestibility with temperature	Fish waste (mainly heads, bones, skin, viscera and sometimes whole fish and parsley)

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have reported the antimicrobial activities of chitosan in solutions or films (Staroniewicz et al. 1994). Antimicrobial packaging is considered a promising form of active packaging (Coma 2008) and incorporation of chitosan into packaging could be one type of active packaging.

The fish oil is a source of many unsaturated fatty acids. The ozone treated fish waste oil as a transportation diesel fuel was evaluated by Kato et al. 2004. The obtained oil was found to have suitable properties for use in diesel engines.

Utilization of waste as biofuel

The availability of wet biomass as waste from industrial processes and the need to meet the environmental standards stand for the main stimuli towards investigating all options inorder to dispose this waste. The thermal recycling of residues as secondary fuel is of increasing interest for power plant operators (Arvanitoyannis and Ladas 2008). Studies documented the usage of poultry litter as an alternative for natural fuel source generation. It is noteworthy that poultry litter with water contents less than 9% can burn without extra fuel. Therefore these samples were suitable for being used as fuel for generation of electrical power. Physicochemical treatment of meat industry wastewater is used to increase the organic matter removal efficiency, and it generates great amounts of sludge. Treatment using commercial ferric sulfate as coagulant for this specific wastewater gave high organic matter removals, decreasing considerably the amount of waste material to be treated in biological systems, and also allowing the obtention of 0.83–0.87 kg of biomass fuel for each m^3 of treated wastewater (De Sena et al. 2008). Due to sanitary, environmental problems and operational costs related to the discharge, land disposal and re-use of wastes, the utilization of this Biofuel (dried sludge) for steam generation has shown to be a viable alternative. This type of fuel has a high heating value, and it is a renewable energy source. The combustion test with a Biofuel to sawdust ratio of 4:1 met the technical requirements for the characterization of this promising fuel; nevertheless, operating conditions must be well designed to achieve NO_2 and SO_2 emissions below local and/or international limits.

Biodiesel fuel aquired from the oils and fats of meat and fish is a substitute for, or an additive to diesel fuel derived from petroleum. There is an extensive literature on biogas production from cattle manure, piggery waste waters and by-products of aquaculture (Arvanitoyannis and Kassaveti 2008).

Conclusion

Now a days our society, in which there is great demand for appropriate nutritional standards, is beset by rising cost and often decreasing availability of raw materials together with much more concern about environmental pollution, leading to the consequence that there is much occupation with recovery and recycling of wastes. This applies particularly to the meat and meat processing industry, which as a whole is among the least profitable industries despite its immense size and large gross sales. Thus, it becomes imperative that an effort be made to reduce expenses by employing the use of new or modified processing methods and through in plant treatment, where waste effluents and by products could be recovered and often upgraded to useful product of higher value. Beside pollution and hazard aspects, in many cases, meat processing waste have a potential for recycling raw materials, or for conversion into useful products of higher value as by product, or even as raw material for other industries, or for use as food or feed after biological treatment. Particularly utilization of meat industry wastes is receiving increased attention in view of the fact that these wastes represent a possible and utilizable resource for conversion to useful products. Fish waste stands for one of the continuously gaining ground waste management fields. Among the most prominent current uses for treated fish waste are collagen, biogas/biodiesel, dietic applications (chitosan) and food packaging.

Meat producers have been using meat by-products for a long time to process different products, some edible and some inedible. Today, with the increased concerns over health, technology has been developed to permit more efficient utilization of these byproducts. In India, the slaughter house waste management system is very poor and several measures are being taken for the effective management of wastes generated from slaughter houses. Competition is also a strong incentive for meat industries to use by-products more efficiently. This is important, because increased profits and lower costs are required in the future for the meat industry to remain viable. These innovations also increase the value of the carcass, and increase the profits of livestock raisers. We have not quite reached the point where “The packer uses everything but the squeal”, but we are improving all the time.

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