Wealth from Meat Industry By-Products and Waste: A Review

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Abstract

Slaughterhouses and meat processing industries produce large amounts of waste water with high fat, grease and protein content. Waste from animal by-products can be a significant source of physical and biological animal contamination. Waste material is also a potential source of food for pests, which may give rise to further microbiological contamination. These contaminations can pose a great impact on the health of consumers and hence must be prevented and reduced. By slaughtering and processing of animals for meat, large qualities of waste and by-products are generated, which need to be adequately processed and utilized. Animal by-products and wastes are a good source of renewable energy as well and its production is economically feasible. This chapter deals with the management of waste and utilization of by-products of meat, poultry and fish processing industries.

Keywords

Slaughterhouses · By-products · Animal waste · Meat processing industries

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11.1 Introduction

Food industries across the globe are under immense pressure to efficiently minimize and manage the wastes generated by them. The wastes with regards to the meat industry may be defined as "carcasses or animal parts that are not intended for direct human consumption" (Commission of the European Communities 1990). Consumption of meat by the world population is related to diet, living standards and production of livestock. The livestock industry including fish and poultry plays a vital role in economic growth of a country. It contributes to Agricultural Gross Domestic Product (AGDP) and serves as means of income for the common population. The Global production of meat including broiler meat for the year 2017 was around 263 million tonnes and is projected to increase by 16% in 2025 (OECD FAO 2016).

India is the 6th largest meat producing country in the world and produces around 6.90% of the total meat, owing to its large livestock population (Birthal 2008). According to the data released by the Ministry of Agriculture, India presently possesses 190.9 million cattle, 135.2 million goats, 108.7 million buffaloes, 10.3 million pigs, 65.07 million sheep and 729.2 million chickens (19th Livestock Census). The statistics suggest that the largest meat producer species is poultry, followed by bovines (cattle and buffaloes), goats, sheep and pigs (Table 11.1). The major importers of Indian meat are Vietnam, Malaysia, Thailand, Australia, UAE, Saudi Arabia and Egypt. Although meat is considered as an important component of human diet with very high biological value, its consumption has always been the subject of social and cultural prejudice in India.

Because of the increasing global demand for animal products, Indian meat sector has an opportunity to increase its exports for meat and meat products. Among the Indian agricultural produce, buffalo meat is an important component of export and is valued at USD 29 million annually, which makes India the world's biggest exporter of buffalo meat (FICCI). India exports fresh and frozen meat to 54 countries. Overall, there has been significant contribution of livestock products to GDP of the country and accounts for more than 40% of total agriculture sector and more than

Table 11.1 Production and domestic supply of meat

Specie	Production (1000 MT)	Import (1000 MT)	Export (1000 MT)	Total domestic supply	Total per capital supply (kg/year)
Poultry	2358	0	6	2352	1.88
Mutton and goat	747	0	21	725	0.58
Pig meat	354	1	0	354	0.28
Other	180	0	1	171	0.14
Meat offal	529	0	54	475	0.38
Total meat	6215	1	1589	4619	3.69

12% of GDP (Jayathilakan et al. 2012). This chapter discusses the waste management and by-product utilization in meat, poultry and fish processing industries.

11.2 Meat Industry and Waste Generated

Although the contribution of meat industries towards the economy of the country is enormous, the environmental risks and hazards posed by slaughtering and processing of meat cannot be undermined. They have the potential to generate large amounts of solid waste and waste waters with high organic matter content. Furthermore, inefficient utilization of by-products may lead to increased environmental hazards and cataclysmic health problems. The first step in meat processing involves slaughtering of animals in abattoirs (slaughterhouses), followed by secondary operation like deboning, grinding and processing for final consumption. Wastes generated in slaughterhouses consist of those parts and portions of a slaughtered animal that cannot be sold as meat or used in meat products and are unfit for consumption by humans. Both solid and liquid wastes are generated. Solid wastes include bones, skin, tendons, viscera, hoofs, horns, nails, etc. and liquid wastes include blood, waste water generated as a result of washing carcasses, cleaning and sanitizing equipment and facilities, etc. Table 11.2 lists the specific quantities of waste generated with respect to type of animal (Russ and Pittroff 2004). The waste characteristics depend largely upon the type of animal being slaughtered. So, the first step for determining the type of treatment(s) and evaluating costs is to measure the organic load of the effluent. Organic load can be measured and expressed in terms of BOD (Biological oxygen demand), COD (Chemical oxygen demand), SS (Suspended solids), TDS (Total dissolved solids), FOG (fats, oils and grease).

In India there are presently 1176 slaughterhouses, 80 registered abattoirs-cum-meat processing plants and 28 registered meat processing plants approved by APEDA. There are 10 fully integrated plants that are eco-friendly and have the capacity of producing 50,000–1,20,000 tons of meat per annum. The slaughterhouses have been classified into 3 categories: small, medium and large, based on the number of animals slaughtered. The classification basis is mentioned below:

(i) *Small*: Less than 50 large animals, i.e. bovines per day, or less than 300 small animals, i.e. goat and sheep per day (any day in a week).

Table 11.2 Specific waste index for abattoirs

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

a: Mass of accumulated waste divided by the mass of saleable product (Russ and Pittroff 2004)

(ii) *Medium*: 50–200 large animals, i.e. bovines per day, or 300–1000 small animal, i.e. goat and sheep per day (any day in a week)
(iii) *Large*: More than 200 large animals, i.e. bovines per day, or more than 1000 small animal, i.e. goat and sheep per day (any day in a week).

11.3 Waste Water Characteristics from Meat and Poultry Processing Industry

Water is a pre-requisite for proper functioning of slaughterhouses and animal and fowl processing industries. All the operations carried out in abattoirs and processing industries are largely depended upon the availability of water. Water is used in slaughterhouses for washing carcasses, hide and hair removal, evisceration, defeathering, scalding, cutting, rendering, cleaning and sanitizing of equipment and facilities. Some waste water is also produced by associated facilities like cafeteria, toilets, lairages, refrigeration and chilling equipment and from packaging and storage areas. This waste water (effluent) generated by meat industries has much higher BOD, nitrogen, phosphorus and grease concentration than domestic sewage. The standards for effluent discharge for meat and sea food industries have been provided by CBCP and are given in Table 11.3.

Based on the CPCB advice, the Central Government has revised the above standards and notified the revised standards under the Environment (Protection) Rules 1986 on 28.10.2016, which are is given in Table 11.3.

11.4 Waste Water Treatment

The quantities of waste water generated vary with the number and type of animals slaughtered. The waste waters may contain pathogens including *Salmonella* sp. *Shigella* sp., amoebic cysts and parasite eggs, pesticide residues, high levels of chloride (up to 77,000 mg/l). In India, most of the slaughterhouses do not implement

Table 11.3 Standards for effluent discharge from meat industries, abattoirs and sea food industries

S. No.	Industry	Effluent parameter	Standard (mg/l, except for pH)
1.	Abattoirs or meat processing units or both	pH	6.5–8.5
		Biological oxygen demand (BOD) [3 days at 27 °C]	30
		Chemical oxygen demand (COD)	250
		Suspended solids	50
		Oil and grease	10
2.	Sea food industry	Biological oxygen demand (BOD) [3 days at 27 °C]	30
		Suspended solids	50
		Oil and grease	10

proper effluent treatment methods, owing to which extremely harmful effluent is discharged into land and water bodies and thus can lead to "*eutrophication*". In such cases, the guidelines for effective management and treatment of effluent laid down by the Ministry of Urban Development in the *Manual of Sewage treatment* shall be followed.

The most effective method for treating such waste waters is to develop a design that combines various treatments including:

(i) *Pre-treatment* or *preliminary* treatment of water which removes solids (both large and small), fats and grease and is capable of reducing up to 35% BOD, 90% fats and 65% solids. This can be done by using screens, with pore sizes of 10 mm and 4 mm for larger and smaller solids, respectively. Remaining suspended solids, fats, oils and grease can be separated from the water by using a method known as *dissolved air flotation*. It works by producing micro-air-bubbles that get attached to the suspended matter, forming a scum that rises to the surface and can be removed easily. This method can be aided by the addition of chemicals like ferrous sulphate, ferric chloride, ferric sulphate, aluminium sulphate (alum), calcium carbonate (lime), sodium carbonate (soda ash), polyelectrolytes, etc. Proteins and remaining organic matter can be removed by using *physio-chemical* treatment which involves the use of cationic (Fe^{3+} and Al^{3+} salts) and anionic coagulants (sodium alginate, sodium hexametaphosphate and lignosulfonate). The change in pH causes precipitation and agglomeration of proteins into larger flocs. This is followed by physical removal of flocs using DAF or sedimentation.

(ii) *Biological or secondary treatment* of waste water can be performed by using biological treatment systems which involve providing and maintaining controlled and favorable environment for mixed culture of micro-organisms. These micro-organisms utilize the organic matter present in the waste water to reproduce and synthesize new cells. Secondary treatment can be *anaerobic* or *aerobic*. In anaerobic processes, the BOD is reduced by the bacteria in absence of oxygen and is thus performed in enclosed system. This system is of great advantage if the BOD is higher than 2000 mg/l. In this process some of the carbon in the waste water is transformed into a revalorizable mixture of carbon dioxide and methane or biogas. In aerobic treatment, the bacteria utilize air to breakdown the complex organic matter and to remove the residual BOD and suspended solids. The main treatments include *activated sludge*, *lagoons*, *trickling filters, evaporation* and *irrigation*. Both the systems are robust and efficient but anaerobic treatment is economical and cost efficient than aerobic treatment due to its lower energy consumption and production of biogas.

(iii) *Tertiary treatment* involves processes that render the effluent free of contaminants or at least in permissible levels. The effluent after tertiary treatment is discharged into the environment.

11.5 Novel Methods for Waste Water Treatment

(A) *Radio-frequency diathermy/electro-coagulation/short wave electrolysis:*
Electro-coagulation (EC) system is a novel and affordable technique used for treatment of waste water and industrial processed water. This treatment technology removes TSS (total soluble solids), heavy metals, bacteria, emulsified oils, total petroleum hydrocarbon and other contaminants from waste water. There are 3 steps involved:
   (i) *Dissolution* of water into H^+ and OH^-.
   (ii) *Coagulation* of suspended solids and emulsified oils and dissolved metals.
   (iii) *Floc* removal from water in downstream solid separation and filtration process steps.

   A fully automated electro-coagulation system has no requirement of coagulants and filters. It can be integrated into existing treatment processes for rapid and more efficient effluent treatment.

(B) *Membrane separation:*
Membrane separation process is used to separate fine particles and dissolved substances from waste waters. The separation of particles depends on their molecular size. There are 4 membrane separation processes used in waste water treatment from meat plants: Ultrafiltration (UF), microfiltration (MF), nanofiltration (NF) and reverse osmosis (RO).

   Ultrafiltration is used to separate oil, fats and grease; microfiltration for recovery of slurries and nanofiltration and reverse osmosis for purification, disinfection and desalination.

11.6 Solid Waste Management

As discussed earlier, the solid wastes generated in the slaughtering and processing of meat is a threat to the environment. The amount of solid waste typically generated in slaughterhouses in India has been given in Table 11.4.

The solid waste can be classified into two categories and for the efficient treatment these two steams should always be segregated. The classification is mentioned below:

(i) *Type I/Vegetable matter:* this type consists of agricultural residues, dung, stomach and intestine content, rumen content, etc.
(ii) *Type II/Animal matter:* this type consists of meat trimmings, offal, bones, tissues, etc.

Table 11.4 Quantities of waste generated by slaughterhouses per day

Type of slaughterhouse	Daily waste generated
Small	0.5–1 tonne/day
Medium	2–6 tonnes/day
Large	6–7 tonnes/day

Table 11.5 Typical characteristic of solid waste

Parameter	Value (%)
Total solids	15–40
Total volatile solids	70–92
Total nitrogen	2.5–4.2
Phosphorous	0.2–0.4
Potassium	0.3–0.4
Organic carbon	22–28
Moisture content	60–85

Table 11.5 reports the characteristics of solid waste generated from slaughterhouses. The usual practice is to dispose of this solid waste in landfills along with other municipal wastes. Such a malpractice can lead to environmental contamination due to emission of methane gas and carbon dioxide on decomposition.

It is necessary that the solid waste be managed and dealt with properly by adopting the techiques mentioned below:

(A) *Composting:*

Composting provides a better alternative over land filling for the disposal of meat industry waste. Composting is the process of biological decomposition of organic matter into relatively stable form under aerated conditions, brought about by the action of micro-organisms such as bacteria, fungi and protozoa. It reduces waste volumes, kills the pathogens present in the waste, converts nitrogen from ammonia to stable organic forms and improves quality of the waste. Almost all wastes generated by slaughterhouses can be composted. Typically, the compost pit is 4–5 feet deep. The first 6 inches underneath should be layered with coarse materials like banana stems, grass, straw, twigs, etc. to provide proper ventilation. Then alternate layering of Type I and Type II waste should be done. In case the waste consists of large organs like liver and kidneys, then it is advisable to grind them to small pieces of 2–3 inches in order to increase the surface area. There is no requirement for water in the initial stage because the wastes have high moisture content of around 70% which is adequate for the start of microbial activity. It is advisable to use an inoculum of microbes (mesophiles and thermophiles) specially selected for the purpose of decomposition. This practice aids in speeding up the process and improves humus quality. To ensure optimum conditions for the bacteria during composting, the solid waste should be regularly aerated by mixing and/or inverting the material. The total time required for the completion of the process is usually 45 days depending on factors such as type and quantity of waste, aeration, temperature and inoculation level. The entire process is divided into two stages:

(i) *Stabilization:* Stabilization further consists of three phases. The first phase involves vigorous multiplication of mesophilic, and breakdown of easily oxidized carbon compounds to relatively simpler compounds of lower molecular structure. This results in a rapid rise in temperature. The second stage is the thermophilic phase in which at high temperature organic compounds are attacked by the thermophilic bacteria that are not easily degraded. Third stage is marked by a gradual decrease in temperature to ambient and leads to mesophilic phase, in which the growth of actinomycetes and fungi is observed. The biological degradation of remaining organic compounds occurs in this stage.

(ii) *Maturation:* Mineralization of organic matter at a very slow rate occurs in this stage. This process continues until the volatile matter content is reduced below 50% and carbon: nitrogen (C: N) ratio of 10: 1 is achieved.

The final decomposed, nutrient-rich product is referred to as *humus*, which can be used as a soil amendment to improve soil quality, fertilize gardens and improve growing conditions for plants.

(B) *Incineration:*

Incineration is the process of waste treatment process that involves combustion of organic matter present in the waste. This is a high temperature treatment also known as “thermal treatment”. The process of incineration converts the inorganic constituents of waste into *ash*. This ash may take the form of particulates carried by the *flue gas*. The flue gas needs to be cleaned of pollutants before releasing into the atmosphere and the non-combustible residue is disposed to landfills. Incineration can be used to treat the solid waste from meat industries, slaughterhouses and the wastes left after treatment of effluent. The waste is incinerated at high temperatures between 850 °C and 1100 °C in specially designed chambers. The process of ignition is initiated and sustained by supplying an auxiliary fuel. Proper aeration and temperature control are vital for effective combustion. Direct incineration of wet waste is unfeasible due to difficulties in ignition. This may result in unsteady and incomplete combustion of organic substances with the emission of large amounts of volatile pollutants. Therefore, it is recommended to pre-treat the waste by dewatering the solids and palletizing them (Chiang et al. 2012). There are concerns from experts about using incineration as a treatment for waste due to rising environmental issues and health problems faced by the workers. The emission of toxic heavy metals like manganese, vanadium, chromium, arsenic, lead, mercury, nickel and cadmium is a cause of serious concern.

11.7 By-Product Production and Utilization

India is bestowed with a large livestock resource and therefore has the capacity of generating a lot of offal/bone waste after slaughtering and processing the animals. The waste produced is estimated to be approximately 21 lakh tones/annum (Jayathilakan et al. 2012). Only one-third part of the slaughtered and processed animal can be referred to as meat. The rest comprises waste and by-products. Every part of the slaughtered animal, except dressed meat (fifth- quarter or offal) may be

Table 11.6 Approximate yield of by-products from small and large animals

By-product	Cattle/buffalo (% yield)	Sheep/goat (% yield)
Boneless meat	28.57	–
Dressed weight	–	40.00
Bone, head, feet/hoofs	22.85	6.40
Lungs and oesophagus	2.00	1.00
Hide/skin	7.57	9.20
Paunch content	16.00	22.00
Blood	3.14	3.00
Liver	1.42	1.20
Fat/fatty tissue	1.71	2.00
Heart	0.42	0.40
Spleen	0.28	0.20
Kidney	0.14	0.40
Stomach	0.71	–
Pancreas	–	0.16
Head meat and brain	0.28	–
Gut and tripe/other offals	4.00	8.00
Tongue	0.28	–
Casings	2.00	–
Urine, body fluids, bile, dung	3.50	–

defined as "animal by-product" (Ockerman and Hansen 2000). The approximate yield of by-products from animals is given in Table 11.6 (Chatterjee et al. 1991). These by-products should be appropriately utilized to minimize wastage and contribute to the economy of livestock industries. Further, animal by-products may be categorized into *edible* and *inedible*.

(i) *Edible by-products:* Edible by-products (EBPs) can be consumed as food and are fit for human intake. This category includes variety meats, such as poultry giblets, heart, liver, brain, intestines, kidney, meat trimmings from head, etc. Blood can also be included in this category, as it is used as an edible by-product in some parts of the world. Edible by-products are processed and stored under sanitary conditions. Before processing, EBPs are thoroughly examined and should be free from any infections like echinococcosis, fasciolosis, tuberculosis, etc. and structural abnormalities (Yibar et al. 2015; Gonulalan et al. 2004). Because of the possible presence of disease-causing harmful micro-organisms, the offal is washed and heated to high temperatures of more than 100 °C, which ensure microbial destruction.

(ii) *Inedible by-products:* Inedible by-products (IEBPs) are unsuitable for human consumption and are either discarded or re-processed as secondary by-products. IEBPs include skin, hides, bones, feathers, horns, hair, hooves, snout, ear, etc. Dead animals and rejected parts and organs are also included. These are commonly used to manufacture pet food, MBM, gelatin, etc. This category has been further divided into *elementary* and *secondary* by-products (Sharma and Sharma 2011). Primary or elementary by-products are directly harvested after the animal is slaughtered and includes skin, hide, hoofs, bones, blood, pancreas, intestines and horns. Secondary by-products are derived from elementary by-products and may include bone meal, fat, gelatin, etc. from bones, casings from intestines and others.

The EBPs are widely accepted by consumers due to their high nutritive value and affordability; however, their utility varies by country, traditions, religion and culture. Regulatory requirements also restrict the use of some by-products concerning matters of food safety and quality. The uses of both edible and inedible by-products are described below:

(A) *Utilization of bones:*

Bones account for 20–30% of the total live weight of animals, while the bone marrow may constitute 4–6% of the carcass weight (West and Shaw 1975). Bones are composed of organic and inorganic matter. The organic matter includes proteins. The inorganic matter includes calcium and phosphorus which are essential for the growth of plants. Thus, bones can be used as "fertilizers". The traditional practice for utilization of bones includes preparation of nutritious soups, stews and broth. The bones which come as a waste product from slaughterhouses and processing industries can be utilized much profitably by extracting gelatin from them. Recovery of all the meat adhering to the bone had been a challenge for meat processing industries, until recently a novel separation technique was developed. This technique is referred to as "mechanical deboning" and the tissue/meat recovered is known as "mechanically deboned", "mechanically separated" or "mechanically removed". This mechanically separated meat can be added to other products like patties, burgers, sausages, nuggets, etc. but it affects the quality and flavour of the product if used in higher percentages than required. The end product may become darker and mushy. Therefore, mechanically separated meat must be incorporated into products at levels prescribed by the meat industries, viz. 5–20% in ground beef and burgers; 10–40% in sausages. There are regulations concerning the use of mechanically deboned meat in products. These regulations vary across countries. An example is that mechanically separated meat cannot be incorporated in baby food, hamburger, meat pies and ground beef in the USA. In Denmark, if the level of usage exceeds 2%, it has to be mentioned on the label. Likewise, in Australia, the presence of mechanically deboned meat has to be mentioned on the label of products intended for export.

Another breakthrough use includes extraction of "Bone morphogenic protein" or "BMP". This protein can be used in aesthetic, dental and facial surgeries. BMP is reportedly safe to use and has no antigenic sensitivity.

Meat and bone meal (MBM) is widely used to provide nutrition and proteins to animals. It has replaced proteinaceous feeds because of high mineral, essential amino acid and cyano-cobalt-amine (Vitamin B_{12}) content. Apart from being used as food, bones which are solid hard materials can be made into buttons, handles, bowls, decorative items like hairpins, hair combs, pendants (BBC 2000). The energy released from burning bones can be used as “fuel”.

(B) *Utilization of blood:*

Blood is a body fluid that is responsible for delivering oxygen and essential nutrients to the cells and transporting carbon dioxide and metabolic wastes away from the same cells. It is composed of plasma and blood cells (red blood cells, white blood cells and platelets). It also contains high level of protein (17%), hormones, glucose, carbon dioxide and mineral ions (particularly iron), which makes it an important edible by-product. Blood represents about 4–8% of the animal’s live weight. Blood from the slaughter industries may be utilized as listed below:

(i) In food industries blood is used as an emulsifier, colour enhancer, binding agent, stabilizer, meat curing agent, as a nutritional component and clarifier (Silva and Silvestre 2003; Toldrá et al. 2012; Ofori and Hsieh 2014).
(ii) It is used to make pan cakes, blood curd, blood sausages, blood cake, black pudding (Wan et al. 2002; Ghost 2001; Davidson 2014).
(iii) It is used as a vitamin stabilizer and lysine supplement.
(iv) Blood plasma contains high level of albumin (60%) and therefore has the ability to form a gel (Silva and Silvestre 2003).
(v) Frozen blood plasma can be added to ham and hot dogs at suitable concentrations to enhance the colour of the product (Autio et al. 1985).
(vi) Spray dried plasma is an excellent foaming and leavening agent and can be used to replace eggs in baking industries (Hsieh and Ofori 2011).
(vii) Transglutaminase (TGase) extracted from bovine blood can be used as a binding agent to improve the binding ability of meat products at low temperatures.
(viii) In feed industry, blood meal can be used in pet food and feedstuff (Bah et al. 2016; Toldrá et al. 2012).
(ix) In medicinal and pharmaceutical industries blood is used as a medium for the growth of microbes (probiotics), nutrient for tissue culture, vaccine stabilizer, production of porphyrin derivative, biological assays, production and purification of thrombin.
(x) Blood albumin is used to replenish fluid and blood loss.
(xi) In serology laboratories it is used as a reagent for blood clotting.
(xii) Other applications: plywood adhesive, finishing agent, mordant and fertilizer.

The blood intended to be used in food products must be collected from disease free, healthy animals. The resulting product may be dark in colour, rendering it unacceptable.

(C) *Utilization of skin and hides:*

Hides and skin represent about 7% of the live weight of large animals and around 11% of the live weight of small animals (Jayathilakan et al. 2012). Hides and skin are valuable by-products obtained from the animals and are mainly converted to leather after reprocessing for the production of secondary by-products like shoes, bags, clothing, seat covers, among other things (DAFF 2012). India ranks first in the production and export of hides and skin and their products, with a share of 10–12% in the World's leather market. Miscellaneous uses include production of sausage casings and skin, glue, cosmetics and edible gelatin. Collagen extracted from hides/ skin can help coagulate blood during surgery and prevent excessive blood loss. Pig skin, which is very similar to human skin, can be used for skin grafting in case of burns and ulcers.

(D) *Utilization of Feathers:*

Feathers are a distinctive feature of the avian species and account to about 7% of their live body weight (Lortscher et al. 1957). Feathers are a rich source of protein. They contain about 90% protein, 8% water and 1% fat. Feathers can be used as livestock feed, bedding, ornamental purposes, sporting equipment and as filler in chemical fertilizer. However, the protein complex needs to be broken down to protein hydrolysates before utilizing the feathers as an animal feed. This is done by hydrolysing the complex protein (keratin) structure to make it digestible. These protein hydrolysates are used as protein fortification agent for concentrated soups and beverages as well as valuable component of solid and liquid seasoning. This can also be used as a diet for patients for faster and better postoperative recovery because of high biological value and digestibility. These protein hydrolysates find use in various industries such as textile (for dyeing), paper (for coating), paint (as ingredient), match stick (for shaft), leather industry (as filter syntax), animal/ poultry feed, detergents (as foaming and sequestering agent), cosmetics (face creams and lotions), microbiology (media ingredients), pharmaceuticals, tissue culture techniques, etc.

(E) *Utilization of glands and organs:*

(i) As food: Animal organs and glands offer a wide variety of flavours 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 abomasum of sheep and cattle and the testes and thymus of sheep and pigs (Liu 2002). Various parts of the digestive and excretory tracts like oesophagus, large and small intestines, caecum, rectum and bladders are processed into natural casings that serve as containers or packaging materials for comminuted meat products like sausages, salami, etc. The intestines of sheep and calves are used for the manufacture of catgut, to make internal surgical sutures.

(ii) In Pharmaceutical Industries: 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. 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). 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.

The liver is the largest gland in animals. 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. 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.

11.8 Fish Waste/By-Product Utilization

Processing of fish leads to enormous amounts of waste. It is estimated that fish processing waste after filleting accounts for approximately 75% of the total fish weight. About 30% of the total fish weight remains as waste in the form of skins and bones during preparation of fish fillets. This waste is an excellent raw material for the preparation of high value products including protein foods. The important products that can be developed from the wastes and rejections of the fish processing industry is summarized below.

(A) Fish meal: Fish meal is highly concentrated nutritious feed supplement consisting of high-quality protein, minerals, vitamins B group and other vitamins and other unknown growth factors. Fish meal is rich in essential amino acids. It is produced by cooking, pressing, drying and grinding the fish, by-catch fish, miscellaneous fish, filleting waste, waste from canneries and waste from various other processing operations.
(B) Fish oil: The main source of fish body oil in our country is oil sardine. The method of extraction followed is cooking the fish in iron vessels and pressing and separating the oil. Apart from sardine oil, fish body oil is also obtained from the fish meal plants operating in the country. During the peak season fish has oil content of 17%. By the wet rendering process the fish will yield, on average 12% oil having analytical characteristics similar to other fish oils. Fatty acid composition of oil revealed that they contain high amounts of polyunsaturated fatty acids (PUFA). At present the medicinal values of fish oils are well known.
(C) Fish ensilage: When fish is available and which cannot be used for direct consumption for several reasons, it is used for production of fish meal. This has got ready market as an animal feed. Fish silage can be defined as a product made from whole fish or parts of the fish to which no other material has been added other than an acid and in which liquefaction of the fish is brought about by enzymes already present in the fish (Raa and Gildberg 1982). Almost any species of fish can be used to make fish silage though cartilaginous species like shark and rays liquefy slowly. The ensilage can be used as a fish meal replace for the production of feeds.
(D) Fish scales: Scales in fresh water fish generally constitute 1–2% of the body weight and commercially are not of much importance. Though the scales look unhygienic and litter the market, they can be used for ornamental and other purposes. Activated charcoal can be obtained by burning fish scales.
(E) Fish Hydrolysate: This is also a liquefied fish product but it differs from silage. These are products produced by a process employing commercially available proteolytic enzymes for isolation of protein from fish waste. By selection of suitable enzymes and controlling the conditions the properties of the end product can be selected. Hydrolysates find application as milk replace and food flavouring. Enzymes like papain, ficin, trypsin, bromelain and pancreatin are used for hydrolysis. The fish protein hydrolysate has desirable functional properties with potential applications as emulsifiers and binder agents, and can be used in place of diary based and plant based protein hydrolysates as well as protein powders currently available in market place.
(F) Fish Collagen: Collagen extracted from fish skin, a polymer that is a by-product of food manufacture, has various industrial applications in cosmetology and medicine. Dermis fish collagen presents an interesting new source of collagen as it is a by-product of food fabrics and already has cosmetic uses.

11.9 Waste-to-Energy (WTE) or Energy-from-Waste (EFW): Meat Waste as Fuel Source

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 in order to dispose this waste. The thermal recycling of residues as secondary fuel is of increasing interest for power plant operators. 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. Biodiesel fuel acquired 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).

11.10 An Insight into the Process of Rendering

Rendering is the process of converting the by-products of meat and poultry processing into more stable, useful and saleable product. The type II waste or animal waste that includes edible and inedible proteins and fats (inedible offal, meat trimmings, discarded meat, bones, offal, tissues, etc.) can be rendered. Feathers, hatchery by-products (dead embryos, infertile and stale eggs) and carcasses of condemned animals can also be processed in rendering system. Such waste mainly constitutes of fat, solids and water. Sheep, poultry, pork and beef are the main sources of plants. Rendering plants can be either *integrated* or *independent*. The integrated rendering plants work conjunctionally with slaughterhouses or fowl processing plants. The independent rendering plants outsource their raw materials from various slaughterhouses, restaurants, butcher shops, farms, supermarkets, etc. (USEPA 1995). The rendering process separates the fat, solids and water physically and simultaneously dries the material yielding a fat commodity (tallow, lard, grease, etc.) and a protein meal like MBM (meat and bone meal). The fat recovered during rendering is used for the manufacture of soap and grease. If the fat is rendered from healthy and eatable parts of animals, it can be used edible purposes. The bone meal is used as a feed for farm animals, pet food and as fertilizers.

The process of rendering can be wet or dry. The first step is size reduction that involves cutting, chopping and comminuting large animal parts like head, bones and large internal organs by shredders or other specialized machinery. Cleaning of intestines, stomach and other organs containing manure is also done prior to rendering. These two preliminary steps are common irrespective of the type of rendering. In *wet rendering,* water or steam is used to aid the process, whereas in *dry rendering* surplus moisture is removed from the waste before processing. In dry rendering suspended proteins and water-soluble extracts are not discarded. In this way the output of dry rendering process is approximately 20% higher than the wet rendering.

(i) *Rendering for edible products*:
Continuous edible rendering of healthy animal parts yields tallow and edible lard as the main by-product. After finely chopping the edible parts of the animal, the mixture is subjected to heat treatment with or without the addition of water or steam. The resulting thick slurry is then centrifuged to separate water and fat from solids. The fat is separated from water in the second stage of centrifugal separation. The temperature for rendering edible fat can be either low (below 120 °F/49 °C) or high (between 180 °F/82 °C and 210 °F/100 °C). High temperature rendering provides better separation of fats and proteins but the proteins obtained are of low quality and therefore cannot be sold as an edible product (Prokop 1985). The residue left behind after rendering fat is known as *greaves*. The offal can alternatively be processed and cooked to obtain a thick stew that is subsequently canned and sold as tinned cat and dog food.

(ii) *Rendering for inedible products*:
The materials that are not suitable for human consumption are processed under inedible rendering. Usually, the inedible material is processed by using the dry rendering method. The process of dry rendering is explained above. The ground material dehydrated and drained to remove fat followed by pressing to drive off residual fat and moisture. The remaining solid is ground into a meal.

11.11 Conclusion

The utilization of animal by-products is often ignored; however, these items contribute a significant value to the livestock and meat industries. Non-utilization of animal by-products in a proper way may create major aesthetic and catastrophic health problems. Value addition of animal by-products has two benefits. Firstly, the meat industry gets additional revenue by processing them to industrial, household and cosmetic products; livestock feed additives; pet foods; pharmaceutical and medical supplies, etc. that otherwise would have been unrealized. Secondly, the costs of disposing of these secondary items are avoided. Value addition can also sometimes act as a cushion to cover losses suffered in the trade. Furthermore, although the development of synthetic substitutes in the middle of the twentieth century decreased the value of many animal by-products, but their importance in the pet food industry and the medical/veterinary field are contributing to an increase in by-product values in recent years. Utilization of these by-products as fertilizer contributes a lot in organic farming and could reduce our dependence on synthetic fertilizers. Animal by-products and wastes are a good source of renewable energy as well its production is economically feasible. The utilization needs become significantly stronger due to competition. This is important because increasing profit and decreasing the cost is required in the future for the meat industry to remain viable. These contributions and efforts are also necessary for the meat industries to change in an innovative manner and to widen the opportunities to utilize by-products. However, the saying “the packer uses everything but the squeal” has always existed in the meat industry and will continue to influence the utilization of meat by-products.

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