

BETTER UTILIZATION OF BY-PRODUCTS FROM THE MEAT INDUSTRY

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ABSTRACT

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 favorite food in Asia, but health concerns have led to an increased focus on non-food uses, such as pet foods and pharmaceuticals. The Bulletin discusses the use of meat by-products for food and in various industries, and the various ways in which they can be processed to increase their value.

INTRODUCTION

Meat by-products are produced by slaughterhouses, meat processors, wholesalers and rendering plants. 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, such as pet food, pharmaceuticals, cosmetics and animal feed.

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.

PRODUCTION AND UTILIZATION

The meat industry in the United States considers everything produced by or from the animal, except dressed meat, to be a by-product. Animal by-products in the United States are divided into two classes, edible and inedible. In United States terminology, offal means slaughter by-products, and includes all of the animal which is not a 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 U.S. Meat Inspection Service. In some parts of the world, blood is also utilized as an edible product for human beings. In the United States, meat trimmed from the head is described as edible offal, or an edible by-product. Edible fats are fat obtained during slaughter, such as the caul fat surrounding the rumen or stomach, or the cutting fat which is back fat, pork leaf fat or rumen fat.

In commercial slaughterhouse practice in England, 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 trimmings. The English Food Standard Committee also separates offal into two categories. List A items from mammalian species may be used in cooked or uncooked

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products. The list includes tissues such as diaphragm (skirt, cattle only), head meat (ox cheek, cattle only), and the heart, kidneys, liver, pancreas, tail meat, thymus and tongue.

This 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). It also includes poultry parts such as the heart and liver.

List B 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 parts such as gizzards and necks. The average quantity of the different by-products from pigs, beef and sheep is shown in Table 1.

The yield of edible meat by-products from pigs is around 6.7% of the carcass weight. The world production of edible by-products from pigs in 1996 is shown in Table 2. A total of 5,65 million mt of pork edible by-products were produced in 1996, 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 poultry mechanically separated meat as an ingredient, this must be listed. Details of potential uses and preparations of meat by-products are listed in Table 3.

NUTRITIONAL VALUE

Edible meat by-products contain many essential nutrients. Some are used as medicines because they contain special nutrients such as amino acids, hormones,

Table 1. By-products as a percentage of market live weight

Item	Pigs		Cattle		Sheep	
	(%)	(kg)	(%)	(kg)	(%)	(kg)
Market live weight		100.0		600.0		60.0
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	0.26	0.156

Table 2. World production of edible by-products* from pigs, 1996

Unit: 1000 mt

Country	Carcass weight	Production	Percentage
World	77,985	5225.0	100.0
Asia	42,534	2849.8	50.4
China	40,000	2680.0	47.4
Japan	1,264	84.7	1.5
Taiwan	1,270	85.1	1.5
North America	9,005	603.3	10.7
United States	7,765	520.2	9.2
Canada	1,240	83.1	1.5
South America	1,560	104.5	1.8
Brazil	1,560	104.5	1.8
Europe	16,269	1090.0	19.3
Germany	3,085	206.7	3.7
France	2,193	146.9	2.6
Spain	2,180	146.1	2.6
Russia	1,679	112.5	2.0
Netherlands	1,619	108.5	1.9
Poland	1,600	107.2	1.9
Denmark	1,528	102.4	1.8
Italy	1,355	90.8	1.6
Belgium- Luxemburg	1,030	69.0	1.2
European Union	15,043	1007.9	17.8

Source: National Pork Producers' Council (NPPC), *Pork Facts* 1997/1998, USA (85).

* Based on 6.7% of carcass weight

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.

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. The lowest protein level is found in the brain, chitterlings and fatty tissue. The United States Dept. of Agriculture (1983, 1986) 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/100g), 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 100g serving of liver from pork or beef contributes 450% - 1100% of the RDA of vitamin A, 65% of the RDA of vitamin B₆,

Table 3. Potential uses and preparation of edible meat by-products

Kind of meat	Storage and preparation	Way in which it is used
Beef and veal		
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
Heart	Whole or sliced Frozen, fresh or refrigerated	Braised, cooked in liquid
Brains	Whole, sliced	Broiled, braised and cooked in liquid
Tongue	Frozen, fresh or refrigerated	Cooked in liquid
Tripe	Whole, Fresh, refrigerated, smoked and pickled	Fried, broiled or cooked in liquid
Sweetbread	Fresh, refrigerated and precooked, pickled, soaked before use	Fried, broiled, braised and cooked in liquid
Oxtail	Frozen, fresh, refrigerated	Cooked in liquid
Intestines (small and large)	Whole, frozen, fresh, refrigerated Remove faeces. Soak, wash, salt before use	Sausage casings
Cheek and head trimmings	Frozen, fresh, refrigerated	Cooked sausages, stews, soup, bouillon
Udder	Frozen, fresh, refrigerated	Boiled, fried, smoked and salted
Skin	Fresh, refrigerated	Gelatin
Feet	Frozen, fresh, refrigerated	Jelly
Fat	Frozen, fresh, refrigerated	Shortening, drippings, chewing gum
Blood	Frozen, refrigerated	Black pudding, sausage, blood and barley loaf
Bone	Frozen, fresh, refrigerated	Gelatin, soup, jellied products, refined sugar
Pork		
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, sliced	Sausage ingredient. Broiled, braised and cooked in liquid, poached, scrambled

Tongue	Frozen, fresh or refrigerated. Whole	Cooked in liquid, cured, sausage ingredient, salad, jelly
Stomach	Fresh, refrigerated, smoked and pickled	Broiled and cooked in liquid, sausage casing, sausage ingredient
Spleen	Fresh, refrigerated and precooked	Fried, in pies, in blood sausage
Tail	Frozen, fresh, refrigerated	Cooked in salty liquid
Intestines (small and large)	Whole. Frozen, fresh, refrigerated. Remove faeces. Soak, wash, salt before use	Sausage casing
Cheek and head trimmings	Frozen, fresh, refrigerated	Cooked sausage
Ear	Frozen, fresh, 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, refrigerated	Shortening, lard
Blood	Frozen, refrigerated	Black pudding, sausage, blood and barley loaf
Bone	Frozen, fresh, refrigerated	Gelatin, soup, jellied products, rendered shortening, mechanically deboned tissue
Lung	Frozen, refrigerated, fresh	Blood preparations, pet food
Lamb		
Liver	Frozen, fresh or refrigerated	Braised, broiled, fried; in loaf, patties and sausages
Kidney	Whole, sliced or ground Fresh or refrigerated	Broiled, cooked in liquid, braised, fried, in stew and soup
Heart	Whole or sliced Frozen, fresh or refrigerated	Braised, cooked in liquid, roasted, stuffed, in luncheon meat, patties, loaf and as sausage ingredient
Brains	Whole or sliced	Broiled, braised and cooked in liquid, poached, fried
Tongue	Frozen, fresh or refrigerated Whole	Broiled, stewed, jellied, grilled, cooked in liquid
Stomach	Fresh, refrigerated	Honeycomb tripe and as container for haggis
Sweetbread	Fresh and refrigerated	Fried, broiled, braised, poached with sauce or cream, cooked in liquid
Spleen	Frozen, fresh, refrigerated Whole	Ingredient in pies, blood sausage, variety meats

Intestines (small and large)	Frozen, fresh, refrigerated Remove faeces. Soak, wash, salt before use	Sausage casing
Cheek and head trimmings	Frozen, fresh, refrigerated	Cooked sausages, stews, soups
Testicles	Frozen, fresh, refrigerated	Fried
Lungs	Fresh, refrigerated	Haggis, pet food
Feet	Frozen, fresh, refrigerated	Jelly
Fat	Frozen, fresh, refrigerated	Shortening, dripping, oleomargarine, chewing gum
Blood	Frozen, refrigerated	Black pudding, sausage, blood and barley loaf
Bone	Frozen, fresh, refrigerated	Gelatin, soup, jelly, mechanically deboned tissue

3700% of the RDA of vitamin B₁₂ and 37% of the RDA of ascorbic acid.

Lamb kidneys and 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/100g). However, the highest level of phosphorus (393-558 mg/100g) and potassium (360-433 mg/100g) in meat by-products is found in the thymus and sweetbreads.

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/100g).

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. There is three to five time more cholesterol (260-410 mg/100g) in organ meats than in lean meat, and large quantities of phospholipids. Brain has the highest level of cholesterol (1352-2195 mg/100g) 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, are 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. 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. It is also used for non-food items such as fertilizer, feedstuffs and binders.

The Meat Inspection Act of the United States states that 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 a 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 is 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.

Isolation of blood

Plasma is widely used in the meat industry. It contains one-third of the total blood protein (The red blood cells contain the other two-thirds). In large-scale processing, the edible whole blood is separated into two parts, plasma (60 - 80%) and red cells (20 - 40%). The plasma consists mainly of 7.0 - 8.0% protein and 91% water. It is cooled, frozen and dried.

The red cells, consisting of 34 - 38% protein and 62% water, are dried to form a powder or meal. Sometimes the haem group is removed to obtain globin. Anticoagulants (0.2% sodium citrate or citric acid or 10.0 gram of a mixture of phosphates-22% Na_2HPO_4 , 22.0% $\text{Na}_4\text{P}_2\text{O}_7$, 16.0% $\text{Na}_2\text{H}_2\text{P}_2\text{O}_7$ and 40.0% NaCl per liter of blood) are normally used when whole blood is being collected. The anticoagulant is injected via a hollow knife if a vacuum transport system is adopted.

Blood separation equipment which operates continuously is used. The separation of the fractions is accomplished with a high-speed centrifuge or separator. After separation, the plasma is frozen or spray dried at a low temperature, in order to maintain its solubility and functional ability. To freeze blood plasma, it is normally placed on a vertical rotating drum that has a temperature of between -10°C and -40°C . The frozen plasma is scraped from the surface in the form of flakes.

When blood is dried, great care must be taken to prevent denaturation of the protein, since this lowers the quality of the dried fraction. Concentration is the first step in the blood plasma drying process in most plants. This is generally accomplished by membrane filtration and evaporation. The drying of the concentrated plasma is finished by a spray system, or a fluidized bed drying system. Dried blood plasma can be produced with a 96.4% protein content and a 2.4% moisture content, using this processing technique.

Removal of haem from red blood cells

Haem derived from animal blood is a valuable source of organic iron. This can be used as a food supplement or as a red colorant in food. It is also used as an ingredient in Chinese semi-dried sausage. Several methods have been developed to remove the haem group from the hemoglobin of red blood cells. These include an acid-acetone method, hydrogen peroxide decoloration, and decoloration with carboxy methyl cellulose (NaCMC9 (19) and sodium alginate. Any of these methods can be used to separate and recover the globin and haem.

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. 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.

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.

Blood plasma also has excellent foaming capacity, and can be used to replace egg whites in the baking industry. 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 a 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, was found. 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. Glycerophosphates, albumins, globulins, sphingomyelins, and catalase are also used for biological assay. Many blood components such as fibrinogen, fibrinolysin, serotonin, kalikrenin, immunoglobulins and plasminogen are isolated for chemical or medical uses.

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.

Pork-blood fibrin extract is used as a source of amino acids which are incorporated into solutions to nourish some surgical patients. Superoxide dismutase (SOD) is an enzyme which protects cell membranes of the animal body from serious damage by oxidation. SOD can be extracted from cattle blood and used to treat osteoarthritis, ischemia and in inflammation etc.

Crude SOD from porcine blood showed a high level of activity (1570 unit/mg), with results similar to those from the bovine erythrocyte SOD. A thin film can be made from fibrinogen and used to control bleeding in surgery. It can also be used as a spray or oral drug for gastric and intestinal haemorrhages. Fibrinogen treated from porcine blood with citrate-saline is an effective hemostat in animal surgery.

Blood also has industrial uses, as an adhesive and in the manufacture of paper, plywood, fiber, plastics and glue. It is used in sprays, as in insecticides and fungicides, and as a stabilizer in cosmetics. It is also

used as a foaming agent in fire extinguishers.

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.

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. Some chemicals or insecticides are often used, to help protect the hides from insect damage or for short-term preservation before tanning. These include sodium sulfite, acetic acid, white arsenic (As_2O_3), sodium silicofluoride (Na_2SiF_6), 1,2,3,4,5,6-hexachlorocyclohexane (Lindane; $C_6H_6Cl_6$), 1,4-dichlorobenzene ($C_6H_4Cl_2$), pyrethrum etc.

Processing hides and skins

A general description of leather production can be found in the reports of Hague, and Ockerman and Hansen.

The cured hides should be stored in a cool, well-ventilated place when they arrive at the tannery. The first step in tanning is grading the hides, and sorting them into packs of uniform size, weight and type. The next

step is soaking. This means that enough moisture needs to be added to the cured hides for the subsequent tanning operations. The soaking of hides is finished in cylindrical vats, into which the hides are put in water with wetting agents and disinfectant. The hides are stirred in this solution by a paddle-wheel for 8.0 to 20.0 hours, in order to let the hides reabsorb the needed water. After being soaked, the hides are washed to remove any remaining dirt, manure, salt and blood.

Removal of the hair is the next step. This was originally carried out by a process known as sweating, in which the hides were placed in vats in a warm environment together with an dehairing agent. The most common chemical depilatory agents are a saturated solution of calcium hydroxide ($\text{Ca}(\text{OH})_2$) and sodium sulfide (Na_2S), sodium sulphhydrate (NaHS), or milk of lime.

Some hides, such as sheepskins and pigskins, contain a large quantity of fat. It is often desirable to reduce this to approximately 3.0% on a dry-weight basis. This process is sometimes done by a hydraulic press.

"Bating" is another soaking process which removes all the dehairing chemicals and other non-leather substances from the hide structure, and is carried out in a large wooden drum. Bating makes the hide softer and cleaner.

The next step is "picking", which soaks the pelts in acid. The hides need to have a low pH so that they can absorb tanning materials such as chrome. The major purpose of tanning is to convert the collagen fibres of the skin into a stable non-rotting leather. "Chrome tanning" is the most popular method of tanning today, because it can be finished quickly and gives a good final product.

After tanning, the next procedure is "setting". The purpose is to reduce the moisture content, smooth the grain and remove wrinkles from the hide. Splitting and shaving follow, so that the piece of leather is a uniform thickness. The leather is colored by "dyeing". "Fat-liquoring" is used to adjust the firmness or softness of the leather by lubricating the fibers after coloring, and improve the strength of the leather. "Setting out" is done to smooth and stretch the leather, and to squeeze out all the excess moisture and grease.

The purpose of drying is to remove all

but an equilibrium moisture content of 10 - 12%. One popular drying technique is called "pasting", in which the hides are pasted onto large stainless steel or glass plates. After drying the leather is hard, and additional moisture is applied by shower-like nozzles. This procedure is called "conditioning" or "wetting back".

"Buffing" is necessary to improve the appearance of the leather and to reduce any blemishes by light mechanical sanding. The next process is "finishing", which is the application of a film of foaming materials that provide abrasion and stain resistance, enhance the color and make the leather easy to care for.

After the leather is finished, it must be dried in a long heating tunnel with steam-heated air. The final step is "grading", based on the flexibility and uniformity of the leather.

The average total time it takes to process raw hides into leather is four weeks. Leather is sold by the square meter, so the hide must be measured by a planimeter to calculate the total area of the piece of leather. The pieces are then grouped into batches of four to five hides, rolled into a bundle, covered with paper and packed in a wooden box for 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.

Generally, a collagen stock will be used to extract gelatin by combinations of an alkaline-procedure, an acid-procedure and high-pressure steam extraction. The alkaline procedure is the most widely used commercial system for the processing of collagen to gelatin. A saturated solution of calcium hydroxide made by the addition of lime is

used in this procedure. The amount used is approximately 10% of the weight of the stock. This procedure causes the non-collagen compounds such as keratin, globulin, mucopolysaccharides, elastin, mucins and albumins to be changed to a more soluble products. Some of the fat is converted into polar compounds, so that can be removed easily by washing. After the liming of the hides, the collagen fibers are swollen and the internal cohesion of each fiber is decreased.

The next step is washing and neutralization. The collagen is washed in cold running water for 1 - 2 days. The pH of the collagen is lowered and the lime is removed, by washing with dilute hydrochloric acid (HCl) or sulfuric acid (H₂SO₄) until the collagen is limp. At this point, the collagen stock should have a pH between 5.0 and 8.0 and is ready to be extracted.

Extraction is normally started at 54 - 60°C for 3.0 - 5.0 hours, and continues up to boiling. The highest quality product is obtained at the lower extraction temperature, but yield is increased at higher temperatures.

The liquid extract needs be filtered to remove small particles. Sometimes activated carbon is also added, to decolorize the gelatin solution. Generally, the extract obtained from higher temperatures needs to be vacuum evaporated in a pan so that a sufficient concentration and gel strength can be obtained when cooled. After being concentrated, the gelatin is dried by one of many methods, such as a cooled drying tunnel, drum drying or spray drying.

Another extraction procedure for gelatin is acid processing. This is usually applied to pig skin or bone. Pigskins are first washed to remove salt from salted skin and to remove extraneous matter and/or blood. Since pigskin often contains 8.0 - 15.0% fat, this must be extracted before the acid extraction procedure. This is done by heating in hot water (55 - 60°C) two to three times, stirring for 4.0 - 6.0 hours and then washing in 40-55°C water. After washing and removal of fat, the skins are soaked in a 5.0% inorganic acid (such as hydrochloric acid, sulfuric acid, or phosphoric acid) which results in a pH of approximately 4.0. This pH causes the collagen to swell and a great deal of solubilization to occur. After 10.0 to 72.0 hours of soaking, the acid is then drained and the collagen is washed to

raise the pH of the skin to approximately 4.0 - 5.0. At this pH the native collagen is still swollen.

After acid treatment the collagen stock is extracted at a lower starting temperature than cow hides. The procedure is almost the same as the alkaline treatment. However, the gelatin produced from pigskins has a higher gel strength and better clarity and color than alkaline-treated cattle hides.

It also should be recognized that alkaline and the acid-precursor produced gelatin are two different classes of gelatin. Two grades of gelatin may be extracted. Class A is a high-grade, relatively undamaged molecular material. Class B is extracted by harsh means, and consequently has a range of molecular weights and altered properties. All gelatins are soluble and able to form gels on cooling from hot solution, and thus are an important food additive.

Uses of gelatin in the food and pharmaceutical industries

Gelatin is added to a wide range of foods, as well as forming a major ingredient in jellies and aspic. 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. 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 a foam, treating it with formaldehyde and drying it. 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.

Hides and skins for food and sausage casings

Gelatin extracted from animal skins and hides can be used for food. The raw material can also be rendered into lard. In the United States and some Asian countries, pork skin is immersed, boiled, dried and then fried to make a snack food (pork rinds). 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.

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 gelatine. 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 a 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 hours of the death of the pig.

UTILIZATION OF BONE

Eleven percentage of pork carcasses, 15% of beef carcasses and 16% of lamb carcasses is 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.

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. In 1978, mechanically separated red meat was approved for use as red meat in the United States.

Gelatin from bone

Ossein is normally produced from bone for gelatin extraction. The bones must first be pretreated by cooking them at 80 - 95°C to remove the adhering meat, gristle and fat. They are then washed several times to get the bones clean. Next, the bones are washed in dilute hydrochloric acid to remove the minerals.

In general, the final ossein is about 1.0 - 2.0% of the total raw bone weight. The clean ossein is then dried quickly in ovens to an 8.0 - 10.0% moisture level. The product is stored in moisture-proof bags and processed into gelatin within six months. The ossein is processed through liming, deliming, washing and gelatin extraction. The drying of gelatin made from bone is similar to the process used for gelatin extracted from hide or skin.

Bones used to flavor liquid concentrate

In Asian countries, chicken bones are often used to flavor a concentrate used in

cooking. In this process, crushed bones are cooked with water for 8 - 12 hours. The product is cooled and the fat skimmed off. The liquid remaining contains approximately 5.0% solids.

Currently, the time of processing has been reduced to one or two hours by using a high-pressure extraction system (4-6 kg/cm² or 57-85 lb/in²). This technique yields 66.0% liquid extract, which contains approximately 10% solids. It can be concentrated by vacuum to 60.0% solids. Nine percent salt is added to stabilize the product. These extracts are often used as a soup base, or in noodle products, sauces, stews and curries, as well as in processed hams and sausages.

Mechanically separated meat from bones

The technique for separating flesh from bone was first developed by the fisheries industry in the 1940s. It was then applied to poultry, since fish and poultry bones have some similarities. The structure of mechanically deboned red meat is a paste-like product. Most of it comes from meat which adhered to the bone, plus some marrow and small quantities of powdered bone.

An average of 30.0% mechanically separated meat in relation to bone weight is the expected yield for beef, pork and lamb. It is estimated that an average of 6.5 kg of mechanically separated meat can be obtained from a beef carcass, while 1.5 kg of meat can be obtained from a pork carcass.

The vertebral column, ribs and sternum are best suited for mechanical separation, because of the large quantities of meat tissue and marrow. Mechanically separated meat has at least as good an emulsifying capacity and water-holding capacity, and slightly higher emulsion stability, than products which have been deboned by hand. Mechanically separated red meat may be added to hamburger patties, fresh and smoked sausages, stews, sauces, and even to chunked and formed products.

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 a higher water content. For this reason, the level of mechanically separated meat is usually limited.

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.

Medicinal and pharmaceutical uses of bone

Specially processed cartilage from the breast-bone of young cattle is used by plastic surgeons to replace facial bones in human beings. Red bone marrow is used to treat patients who have a low red blood cell count. Bone meal is also a nutritional source of calcium and phosphorus in the diet.

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 abomasum of sheep and cattle, and the testes and thymus of sheep and pigs.

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 (the pia mater and arachnoid meninges) are peeled from the brain before cooking.

Heart meat is generally regarded as relatively tough, 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. 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.

The ruminant stomachs from cattle and lamb have four compartments: the rumen, the reticulum, the abomasum and the omnivore stomach. The rumen and reticulum are those most often used as food. They are generally processed at the place of collection by washing, scalding and bleaching. They are suitable for poaching or braising, or can be used in sausages and processed meat. They can also be sewn to form a casing and stuffed. Pig stomachs are composed mainly of smooth muscle and collagenous connective tissue. They are cleaned and scalded to remove the mucosa lining. They are suitable for braising, and sometimes also used as a casing for sausages.

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. 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.

The thymus glands are available only from young animals (lambs and calves). The glands are covered by a capsule of fibrous connective tissue which penetrates the gland and divides it into lobules. The amount of connective tissue and fat increases with the age of the animals. The thymus glands from lamb and calf are blanched to firm the tissue and peeled from the capsule before they are cooked by frying or stewing.

When the tongues are removed from the animals, they generally include a small portion of the trachea, larynx, hyoid bones, associated muscle and salivary glands. The mucous membrane which covers the tongues is removed by a knife before cooking. The tongues are used fresh or salted, and are usually boiled or braised.

Edible udders are available only from bovines. They are made up mainly of connective tissue. They are sliced, washed to remove the milk, and cooked by frying or boiling.

Spleens are minced and used in pies and as a flavoring in the United Kingdom, and as an ingredient in processed meat in the United States.

The only uteruses eaten as human food are those from non-pregnant pigs. They are generally poached or boiled.

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.

The adrenal gland consist of two parts. These are an outer cortex, and an inner medulla which secretes at least 20 steroids that are essential for maintaining life. Steroids from the cortex regulate the body's utilization of nutrients such as fat, carbohydrates, water and minerals. Steroids extracted from cattle, pigs or sheep are used as anti-inflammatory agents and for the treatment of shock and asthma. Epinephrine and nor-epinephrine, extracted from the medulla of cattle, pigs and sheep, are used to stop haemorrhaging, stimulate heart action and overcome shock.

Brains, nervous systems and spinal cords are a source of cholesterol which is the raw material for the synthesis of vitamin D_3 . Cholesterol is also used as an emulsifier in cosmetics. 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.

The pituitary gland, located at the base of the brain, produces hormones such as growth-promoting hormone (GH), thyroid-stimulating hormone (TSH) mammary-stimulating hormone and adrenal-cortex-stimulating hormone (ACTH). All these control growth and metabolism, and regulate

the activity of other endocrine glands. ACTH is the main hormone extracted from the pituitary. It is used as a treatment for rheumatism, arthritis, eye inflammation and multiple myeloma.

Bile consist 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 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 B_{12} , and as a nutritional supplement used to treat various types of anaemia.

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 are used for deep frying. 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. Some edible lards are used in sausages or emulsified products.

THE USE OF MEAT EXTRACT

Meat extract was first produced in France in the eighteenth century by alcoholic extraction. The early procedure for manufacturing meat extract included removing the meat from the bones, trimming away the fat

and chopping the meat into small pieces. The freshly chopped meat was then put in clean water and cooked at a low temperature (less than 90°C) to extract the juices.

A meat extract is the product obtained by extracting fresh meat with boiling water, removing the fat, and concentrating the liquid by evaporation. Meat extract should contain more than 75% total solid matter, 8.0% nitrogen and less than 0.6% fat.

Meat stock can be produced from edible meat by-products (e.g. meat trimmings, and mechanically separated meat) which are pressed or soaked in water. The liquid is then skimmed to remove the fat, and filtered to remove coagulated protein. The remaining liquid is concentrated in a vacuum, and later in an open pan, to produce meat extract.

The meat stock can be concentrated in an evaporator, operated at a temperature of 70 - 75°C. This produces a product with a final concentration of 80% solids. The final product should have a natural color (brown or light brown), odor and flavor, with no bitterness. Meat extract is used for making soups, stews, sauces, canned meat and gravies. Meat extract is also an excellent flavoring material in noodle soup mix, onion soup mix and dips. If meat extract is used as an ingredient in other meat products, it should be listed as a "flavoring" among the ingredients.

CONCLUSION

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 by-products.

Competition is also a strong incentive for meat packers 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.