SECTION 4

MEAT AND POULTRY PRODUCTS INDUSTRY OVERVIEW

This section provides an overview of the meat and poultry products (MPP) industry. Section 4.2 provides a general overview of the MPP industry. Sections 4.3, 4.4, and 4.5 provide more detailed information related meat, poultry, and rendering operations, respectively.

4.1 INTRODUCTION

The meat and poultry products industry includes facilities that slaughter livestock (e.g., cattle, calves, hogs, sheep, and lambs) and/or poultry or process meat and/or poultry into products for further processing or sale to consumers. In some facilities, slaughter and further processing activities are combined. The industry is often described in terms of three categories: (1) meat slaughtering and processing; (2) poultry slaughtering and processing; and (3) rendering. A facility may perform slaughtering operations, processing operations from carcasses slaughtered at the facility or other facilities, or both. Companies that own meat or poultry product facilities may also own facilities that raise the animals or further process the meat or poultry products into final consumer goods. Raising of animals, however, is not covered by the meat and poultry products industry effluent limitations guidelines.

Since the 1970s when EPA issued the existing regulations for the meat and rendering industry sectors, the meat and poultry products industry has become increasingly concentrated and vertically integrated through alliances, acquisitions, mergers, and other relationships. This vertical integration is particularly pronounced in the broiler sector of the poultry industry. Most of the broiler and other chicken products that reach the consumer have been under the control of the same company from the hatching through the processing of the birds. Vertical integration is not seen to the same extent in the meat sector, although there is increasing vertical integration, particularly in the hog sector.

The meat and poultry products industry encompasses four North American Industry Classification System (NAICS) codes developed by the Department of Commerce. These

NAICS codes include Animal Slaughtering (Except Poultry), NAICS 311611; Meat Processed from Carcasses, NAICS 311612; Poultry Processing, NAICS 311615; and Rendering and Meat Byproduct Processing, NAICS 311613.

4.2 MEAT PRODUCTS INDUSTRY DESCRIPTION

4.2.1 Animal Slaughtering (Except Poultry)

Animal Slaughtering (Except Poultry) (NAICS 311611) includes meat first processing facilities that slaughter cattle, hogs, sheep, lambs, calves, horses, goats, and exotic livestock (e.g., elk, deer, buffalo) for human consumption. Slaughtering (first processing) is the first step in the processing of meat animals into consumer products. Slaughterhouse operations typically encompass the following steps: (1) receiving and holding of live animals for slaughter; (2) stunning prior to slaughter; (3) slaughter (bleeding); and (4) initial processing of animals. Slaughterhouse facilities are designed to accommodate this multistep process of first processing. In most slaughterhouses, the major steps are carried out in separate rooms.

In addition, many first processing facilities further process carcasses on-site to produce products such as hams, sausages, and canned meat. Otherwise, carcasses may be shipped to other facilities for further processing. Also, many first processing facilities include rendering operations that produce edible products, such as lard, and inedible products, including ingredients for animal feeds and products for industrial use.

Based on the 1997 U.S. Census of Manufacturers, the animal first processing industry sector includes 1,300 companies, which operate approximately 1,400 facilities. The industry sector employs 142,000 people and generates a total value of shipments of $54 billion. Twelve states reported shipments in excess of $1 billion; Texas, California, Illinois, Iowa, and Wisconsin contain the largest number of first processing establishments (at least 60 establishments in each state). Nebraska ranks seventh in the number of facilities located in the state, but it has the highest number of employees engaged in animal first processing of any state. Nebraska accounts for almost 17 percent of the value added and 16 percent of total shipments in this industry sector. Industry activity is most heavily concentrated in Nebraska, Kansas, Iowa, and Texas.

The Animal First Processing sector comprises a large number of facilities (72 percent of the sector) that have fewer than 20 employees. These facilities employ less than 5 percent of the sector workforce and contribute an even smaller percentage of value added and value of shipments to this sector. Thirty-nine facilities employ between 1,000 and 2,500 employees and while constituting 3 percent of the total number of establishments, provide 43 percent of the industry employment and 46 percent of the value of shipments.

Revised production rate thresholds exclude most smaller meat product processing facilities from the January 31, 2002, proposed revisions to 40 CFR Part 432. Based on the current screener survey data, EPA is defining small meat facilities as those that produce fewer than 50 million pounds live weight kill (LWK) per year. See Figures 4-1 and 4-2 for the distribution of small and non-small (facilities producing more than 50 million pounds (LWK) per year) meat first and further processing facilities, also, categorized by discharge type, throughout the United States.

4.2.2 Meat Processed from Carcasses

Meat Processed from Carcasses (NAICS 311612) includes facilities engaged in processing or preserving meat and meat by-products (but not poultry or small game) from purchased meats. These facilities do not slaughter animals or perform any initial processing (e.g., defleshing, defeathering).

The meat further processing industry sector includes 1,164 companies, which own and operate about 1,300 facilities. This sector employs about 88,000 people, and the value of shipments is more than $25 billion, of which $9 billion is value added by manufacture.

California, Illinois, New York, and Texas have the highest concentration of meat further processing facilities, each with more than 90 meat further processing facilities. The highest levels of employment, however, are found in Illinois, Pennsylvania, Texas, and Wisconsin, which together generate one-third of the meat further processing employment. In Wisconsin more than half of the meat further processing facilities employ more than 20 workers, and the state also accounts for the largest share of both total shipments and value added in the industry.

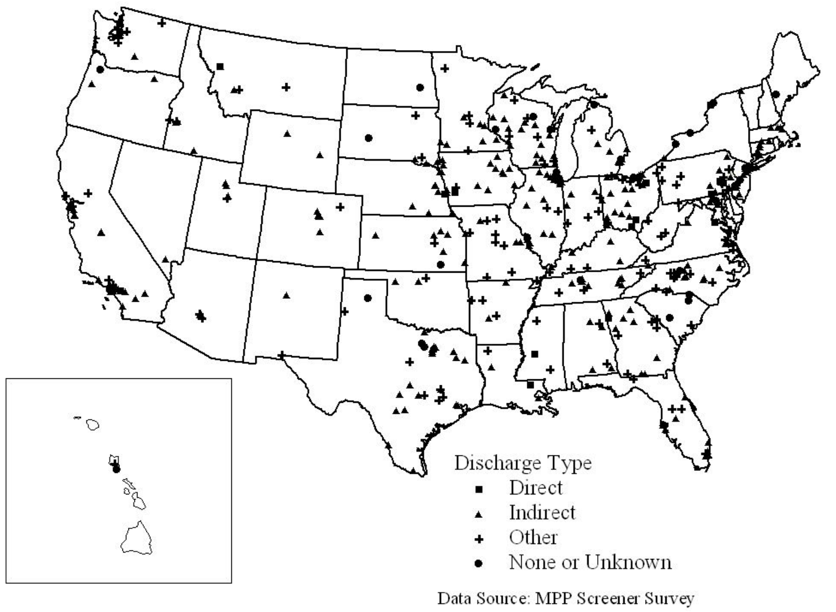

Figure 4-1. Location of Small Meat Facilities in the United States (Based on MPP Screener Survey Data).

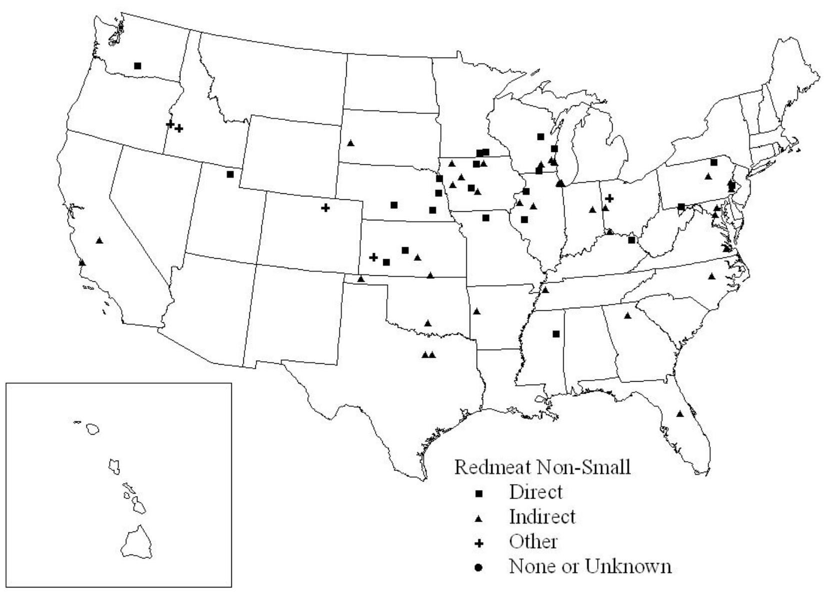

Figure 4-2. Location of Non-Small Meat Facilities in the United States (Based on MPP Screener Survey Data).

As with the animal first processing sector, more than half of the meat further processing facilities employ fewer than 20 workers. The bulk of the employment (54 percent), value added (55 percent), and total shipments (57 percent) is accounted for by meat further processing facilities employing between 100 and 500 workers. The difference between the animal first processing sector and the meat further processing sector is that while the value of shipments in the animal first processing industry sector is heavily concentrated in the largest facilities, the value of shipments in the meat further processing sector is more evenly distributed across meat further processing facilities of all different sizes.

See Figures 4-1 and 4-2 for the locations of small and non-small meat and mixed meat first and further processing facilities throughout the United States that have been further classified by discharge type. EPA defines small meat facilities as those producing fewer than 50 million pounds per year (LWK).

4.3 DESCRIPTION OF MEAT FIRST AND FURTHER PROCESSING OPERATIONS

The meat processing industry produces meat products and by-products from cattle, calves, hogs, sheep, lambs, horses, and all other animal species except poultry, other birds, rabbits, and small game. Equine meat production has declined in the United States in the past 5 years. Total annual production of equine meat was 47,134 head in the year 2000 (USDA, 2001). Most horse meat is exported to Europe for consumption because of the cultural aversion to horse meat consumption in the United States. It is not known whether European demand for horse meat will increase in the future, given concerns about transmissible bovine spongiform encephalopathy in cattle.

The processing of animal species other than cattle and hogs accounts for only a small fraction of total production. The live weight of cattle and hogs slaughtered annually is consistently more than 90 percent of the total live weight of meat animals slaughtered for the production of meat products and by-products. Given that there is little difference in the processing of cattle, calves, sheep, lambs, and horses, only the processing of cattle is described in the sections that follow; parallel discussions are provided where cattle and hog processing procedures differ.

Meat processing begins with the assembly and slaughter of live animals and may end with the shipping of dressed carcasses or continue with a variety of additional activities. Meat processing operations are classified as slaughter (first processing) or further processing operations or an integrated combination of both. First processing operations include those operations which receive live meat animals and produce a raw or dressed meat product, either whole or in parts. In this classification system, first processing operations simply produce dressed whole or split carcasses or smaller segments for sale to wholesale meat distributors or directly to retailers. These operations are often prerequisites to further processing activities such as cutting, deboning, grinding, sausage production, curing, pickling, smoking, cooking, or canning. Demand for whole or split carcasses gradually has declined since the mid-1970s with a concurrent increase in demand for a greater degree of carcass cut-up ranging from separation of whole or split carcasses into front and hind quarters or smaller sections (e.g., “boxed beef”), to the preparation of packaged, case-ready, fresh cuts of meat. Most first processing operations today perform some cutting, deboning, and grinding operations. Further processing operations such as sausage production, curing, pickling, smoking, cooking, and canning can occur on-site or at off-site facilities.

Therefore, EPA considers the reduction of whole or split carcasses into quarters or smaller segments (including case-ready cuts, which may be with or without bone and may be ground) to be part of first processing operations when performed at first processing facilities. Conversely, EPA considers the cutting, boning, and grinding operations to be further processing operations when performed at facilities not also engaged in first processing activities. The reduction of whole or split carcasses or smaller carcass segments (e.g., “boxed beef”) into case-ready cuts at the retail level is an example of a case in which cutting, boning, or grinding would be further processing.

4.3.1 Meat Slaughter and Packing Operations

Common to all meat first processing operations are the series of steps necessary to transform live animals into either whole or split carcasses. These steps include the assembly and holding of animals for slaughter; killing, which involves stunning before and bleeding after killing; hide or hair removal in the case of hogs, evisceration and variety meat (organ) harvest; carcass washing; trimming; and carcass cooling. Depending on the market served, cutting, deboning, and grinding and other further processing operations may occur at the same location.

Most meat facilities for which site visits were conducted slaughtered animals 5 days per week, Monday through Friday. Slaughtering may also be performed on Saturdays during peak production periods. Employees of meat facilities generally work 8 to 9.5 hours per day, Monday through Friday, and when necessary 4 to 5 hours on Saturday. Meat facilities generally have two slaughter shifts per day, one starting at approximately 6 a.m. and the other starting at approximately 3 p.m.

Generally, larger meat first processing operations specialize in the processing of one type of animal (e.g., cattle, calves, sheep, lambs, hogs, or horses). Differences in animal size and some processing steps preclude the design of processing equipment for multiple animal types. If a single facility does slaughter different types of meat animals, separate lines, if not buildings, are used (Warriss, 2000). However, very small meat first processing operations may process several types of meat animals in a single building. Figure 4-3 shows the general sequence of steps in the process of transforming live meat animals into carcasses. Detailed descriptions of each of these steps are given in the following sections.

4.3.1.1 Live Animal Receiving and Holding

Meat processors schedule receipt of live animals for slaughter from producers not only to provide a continuous supply of animals for processing but also to minimize holding time to no more than 1 day. This practice eliminates the need for feeding and reduces manure accumulation in holding pens. However, processors provide water to minimize weight loss. With the

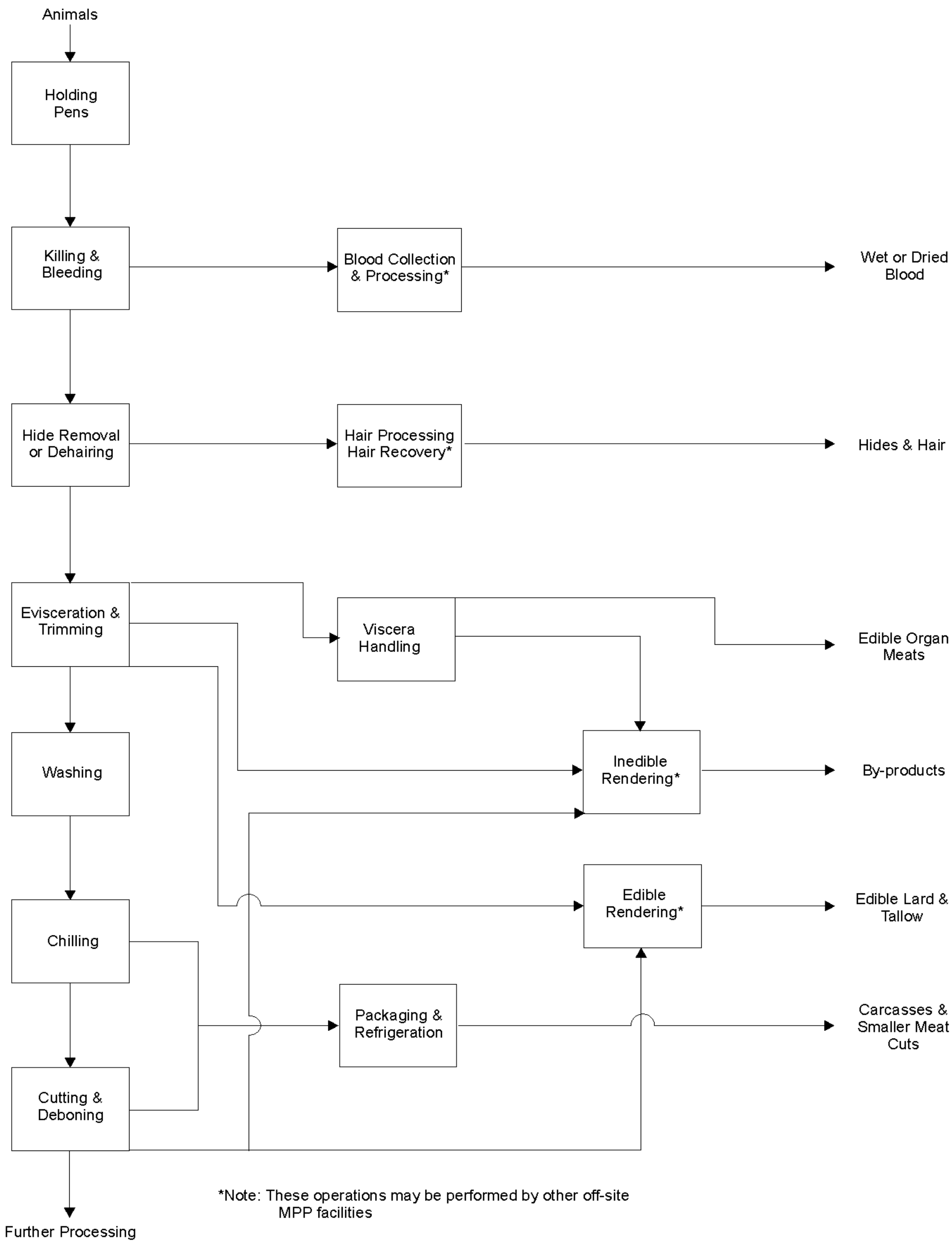

Figure 4-3: Process Flow in a Meat Slaughtering and Packing Facility. (USEPA, 1974)

relocation of first processing operations to areas of animal production, movement by truck has replaced rail transportation of live animals.

Holding pens, which allow recovery from shipping-related stress, may be covered or totally enclosed, especially in cold climates, to provide some protection from extreme weather conditions but primarily to reduce contaminated runoff from precipitation events. Holding pens are, however, sources of wastewater resulting from pen washing and drinking water spillage. Water pollutant concentrations depend on whether pens are scraped (dry cleaned) prior to wash-down to remove accumulated manure. Animals are herded from the holding pens to the killing area of the processing plant through connecting alleys. These alleys also are sources of wastewater generated during precipitation events (if uncovered) as well as from cleaning.

4.3.1.2 Methods Used to Stun Animals

Humane slaughter legislation requires that animals be stunned to produce an unconscious state before killing to reduce pain and suffering. Some exemptions are made for religious meat processing (e.g., kosher, halal). Cattle typically are stunned by mechanical means using a captive bolt pistol, percussion stunner, or free bullet to inflict brain trauma and the immediate loss of consciousness. Electric shock is most commonly used to stun hogs because mechanical stunning can result in convulsions, making subsequent shackling difficult. Electric shock also is commonly used to stun sheep, lambs, and calves before killing.

A less commonly used alternative to electric shock for stunning hogs is exposure to a 70 to 90 percent carbon dioxide environment in a pit or tunnel. Inhalation of a high concentration of carbon dioxide causes a drop in brain fluid pH and loss of consciousness. Current research is being performed to evaluate argon as a substitute for carbon dioxide. While stunning with argon is believed to be less stressful to the animal than using carbon dioxide, use of argon requires longer exposure periods to achieve unconsciousness (Warriss, 2000).

4.3.1.3 Killing and Bleeding

Immediately after stunning, shackles are attached to the animal’s rear legs for suspension from an overhead rail conveyor used to move the carcass through the processing plant. After hanging the animals, processors kill them within seconds by severing main arteries and veins in the neck region to cause death by massive and rapid blood loss (exsanguination). This process is generally known as “sticking,” and somewhat different techniques are used for cattle, hogs, sheep, and horses.

Troughs or gutters collect blood lost following sticking for recovery in the form of various by-products. If blood is collected for subsequent human consumption in products such as blood sausage, a hollow knife connected to a special tank under partial vacuum is used. While approximately 40 to 60 percent of the blood exits the body during bleeding, about 3 to 5 percent remains in the muscles and the remainder is in held in the viscera (Wilson, 1998).

Certain religious practices require an alternative slaughter process for cattle. In these cases, the animal is not stunned prior to slaughter. Instead, the animal is restrained while the slaughterer makes a transverse cut that severs the major vessels in the throat (Warriss, 2000). The Jewish slaughter practice, called Shechita, requires a single cut without pause, pressure, stabbing, slanting, or tearing. The cut severs the skin, muscles, trachea, esophagus, jugular veins, and carotid arteries. After bleeding ceases, the slaughterer searches for lung adhesions. The meat is unfit for consumption if the sores are believed to have been detrimental to the animal while alive. Next, the removal of blood vessels and sinews, called porging, completes the slaughter ritual. Halal, the Muslim slaughter practice, is similar to Shechita; the main difference is that searching and porging do not take place (Wilson, 1998).

Although not common, the slaughtering process may include electric stimulation of the carcasses to improve meat quality and to facilitate removal of the hide. Typically, this process calls for a skull probe, which is inserted into the skull of the carcass through the hole from the captive bolt for 30 seconds (Wilson, 1998). One of the primary goals of electric stimulation is to prevent cold shortening, which makes the meat less tender. Plants use both high-voltage (>500 volts) and low-voltage (30 to 90 volts) electric stimulation systems (USEPA, 1997).

4.3.1.4 Hide Removal from Cattle and Sheep and Hair Removal from Hogs

Before evisceration, slaughterers remove hides from cattle and sheep, and hair from hog carcasses to reduce the potential for contamination of the carcasses after evisceration from hair, dirt, and manure. Hides usually are removed from cattle and sheep mechanically after the removal of the head, tail, and hooves. The process of hide removal begins with some initial separation from the carcass manually, using either conventional or air-driven knives, to enable attachment of mechanical pullers. The pullers then remove the hide by either pulling up from the neck to the tail or pulling in the reverse direction, which is less common.

On-site hide processing can consist of salting for preservation before shipment to leather tanning operations, or it can involve washing, defleshing, and salting before shipment. However, on-site hide processing options also may include curing before shipment for off-site tanning or complete processing followed by the marketing of tanned hides.

Hogs typically are not skinned. Rather, they are scalded by immersion for about 4 to 5 minutes in hot water having a temperature of about 54 to 60 ˚C (130 to 140 ˚F). The objective of scalding to relax hair follicles is to facilitate subsequent mechanical hair removal by passing the carcass between rotating drums with rubber fins or fingers. A constant flow of water washes away the hair removed from the carcass. Any remaining hair is removed by singeing by passing the carcass through a gas flame followed by passing the carcass through a water spray for cooling and washing, and then by manual shaving.

Meat processing facilities usually collect hog hair and other particulate matter from processing wastewater by screening for rendering before any subsequent on-site or off-site wastewater treatment. Hog hair also may be recovered, washed, and baled for sale for various uses, but demand for this material has become quite limited. Also limited is the demand for pigskin leather, which is why most hogs are not skinned.

4.3.1.5 Evisceration

After hide or hair removal from hogs, the carcasses are washed with water sprays to remove any manure, soil, and hair present to retard microbial growth and spoilage. This step is followed by evisceration to remove internal organs. Evisceration begins with a ventral incision made manually that spans the length of the carcass, followed by removal of the gastrointestinal tract (stomach, intestines, and rectum). Then, an incision is made through the diaphragm to allow removal of the remaining organs (trachea, lungs, heart, kidneys, liver, and spleen).

After evisceration, carcasses are federally or state-inspected for indicators of disease and suitability for human consumption. Condemned carcasses are segregated with salvage of usable parts when possible. Following evisceration and inspection, with the possible exception of calf and lamb carcasses, carcasses usually are split into two halves by sawing them down the middle of the spinal column.

After evisceration, different organs may be separated for sale as variety meats or pet food ingredients prior to the removal of viscera from the processing plant; otherwise, viscera are generally disposed of through rendering. Liver and kidneys are the organs most commonly harvested from cattle, calf, and lamb viscera; some stomach tissue is harvested from cattle for sale as tripe. Less common is the harvesting of the thymus from calves for sale as sweet breads. Lung tissue also may be harvested for sale as food for mink.

Variety meat harvesting from hogs is more extensive than from cattle and sheep and includes not only liver and kidneys, but also the small and large intestine. The former is sold as chitterlings while the latter is sold as natural casing for sausage. In addition, hog ears and feet, jowls, and the sphincter muscle may be harvested for sale.

4.3.1.6 Washing

After carcass inspection and splitting, a second washing takes place to remove blood released during evisceration, bone dust from carcass splitting, and any other foreign matter present. Processors may add bactericide such as an organic acid, chlorine, or potassium chloride to the wash water to reduce microbial populations and the potential for growth and spoilage. Acetic and lactic acids in very dilute concentrations (2 to 3 percent) are the organic acids used as bactericides. Large operations often use automated carcass washing equipment to maintain appropriate pressure to maximize efficiency of water use (USEPA, 1997). The time from stunning to the second and final carcass wash varies to some degree, but it is less than 1 hour.

Before refrigeration or freezing, all variety meats are washed to remove blood and any other contaminants. The washing of the small and large intestines of hogs is a very labor-intensive process requiring substantial amounts of water to completely removal fecal material.

4.3.1.7 Chilling

The next step in the meat slaughtering process is carcass chilling to remove residual body heat to inhibit microbial growth and reduce evaporative weight loss. Carcasses are chilled for at least a 24-hour period but are chilled for 48 hours over weekends and during weeks with holidays. Typically, carcass chilling is a two-step process beginning with snap (flash) chilling at temperatures substantially below freezing to effect a rapid initial rate of reduction in carcass temperature (USEPA, 1997). After snap chilling, carcasses are moved into chill rooms for the remainder of the chilling process. Chill room temperatures are maintained at a temperature of 1 ˚C (34 ˚F) to reduce carcass temperature to no higher than 7 ˚C (45 ˚F) before further handling (Warriss, 2000). Chilling facilities separate the “dirty” and “clean” sides of meat processing plants.

4.3.1.8 Packaging and Refrigeration or Freezing

Larger carcass sections usually are packaged in heavy plastic bags, which then may be placed in cardboard boxes (e.g., “boxed beef”) for shipping. Large quantities of ground meat also are packaged in heavy plastic bags. Smaller cuts sold as case-ready are placed on Styrofoam trays, wrapped with thin plastic film, and boxed for shipment. Case-ready cuts also may be weighed and labeled showing weight and price. The packaging of case-ready cuts usually is a completely automated process.

Packaged meats then are refrigerated until and during shipment. Freezing of meats that have not been further processed is rare given consumer food safety concerns about refreezing previously frozen meats. However, some meat is frozen before shipment, especially for commercial use and export markets.

4.3.1.9 Cleaning Operations

Federal and state regulations require that equipment and facilities used for the first processing of all animals for human consumption be completely cleaned at least after every 8 hours of operation to maintain sanitary conditions. Therefore, the daily schedule for meat processing facilities consists of one or two 8-hour production shifts followed by a 6- to 8-hour cleanup shift. During cleanup, first all equipment, walls, and floors are rinsed to remove easily detachable particulate matter. Then they are scrubbed and rinsed again to remove detached particulate matter, detergents, and sanitizing agents used during the scrubbing phase of cleanup activities. In states where phosphorus-based detergents are banned, phosphorus-based detergent use in food processing plants is generally exempted, so phosphorus-based detergents are commonly used. Chlorine solutions and other bactericidal compounds are also commonly used.

4.3.2 Meat Further Processing

As previously discussed, EPA considers the reduction of whole or split carcasses into quarter or smaller segments as further processing operations when they do not occur in conjunction with first processing operations. The segments produced include case-ready cuts with or without bone and ground meat. Other activities, including sausage production, curing, pickling, smoking, marinating, cooking, and canning, also are considered further processing operations.

In the meat industry, further processing activities may be combined with first processing activities at the same site or they may be stand-alone operations. Where first and further processing activities occur at the same site, usually some fraction of the carcasses produced is marketed as fresh meat and the remainder is transformed into processed products. Stand-alone further processing operations may receive carcasses, or more commonly carcass parts, from first processing operations for further processing.

4.3.2.1 Raw Material Thawing

The frozen raw materials received by a meat processing plant are handled in one of three different ways:

- Wet thawing
- Dry thawing
- Chipping

Materials that are wet thawed are submerged in tanks or vats containing warm water for the time required to thaw the particular pieces of meat. The devices used for wet thawing include simple carts with water covering the meat, vats with water flowing in and out with the exit temperature of the water controlled at 10 to 16 ˚C (50 to 60 ˚F) to avoid heating the outer surfaces of the meat, and equipment where the meat pieces are suspended in a tank of water and moved by some conveyance through that tank for a time sufficient to thaw the meat (USEPA, 1974).

Dry thawing involves placing the frozen meat pieces in a refrigerated room at a temperature above freezing and allowing sufficient time for the particular pieces of meat to fully thaw (USEPA, 1974).

Chipping involves size-reduction equipment designed to handle frozen pieces of meat and to produce small particles of meat that readily thaw and can be used directly in subsequent mixing or grinding operations. This type of thawing is usually associated with the production of comminuted (flaked) meat products (USEPA, 1974).

Both wet and dry thawing generally are used when the entire piece of meat, or a substantial portion of it, is required for a finished product, such as hams or bacon (USEPA, 1974).

Wet thawing of raw materials generates the largest quantity of contaminated wastewater. The water used to thaw the materials is in contact with the meat and thereby extracts water-soluble salts and accumulates particles of meat and fat. The water used in thawing is dumped into the sewer after thawing is complete. The waste load generated in dry thawing is from the thawing materials dripping onto the floor and from the washing of these drippings into the sewer. The waste from the chipping of frozen meat materials includes the meat and fat particles remaining on the chipping equipment that are washed into the sewer during cleanup. Juices extruded from the meat product in the chipping process are wasted to the sewer, although it is not a large wasteload (USEPA, 1974).

4.3.2.2 Carcass/Meat Handling and Preparation

This operation includes seven different operations that may be involved in handling and preparing meat materials for subsequent processing, depending on the processing plant. Each of the seven operations is described separately. All seven operations are usually not required to produce a processed meat product (USEPA, 1974). These operations are also illustrated in Figure 4-4.

4.3.2.2.1 Breaking

Beef is frequently received by meat processors as carcass halves or quarters. Breaking involves the cutting of these half and quarter carcasses into more manageable sizes for further handling and preparation following this operation. The waste load originates from the cutting and sawing and includes small meat and fat particles and relatively little liquid, all of which fall to the floor and are washed into the sewer during cleanup (USEPA, 1974).

4.3.2.2.2 Trimming

The removal of excess or unwanted fat and of specific cuts from larger pieces of meat is done in the trimming operation. The unwanted fat trimmed from meat products is usually disposed of through rendering. The materials for disposal are collected and stored in drums, which are picked up by renderers. The waste load generated in trimming might be greater than that generated by the breaking operation. Trimming requires a greater number of cuts on a specific piece of meat to obtain the required quality or particular cut desired from the raw

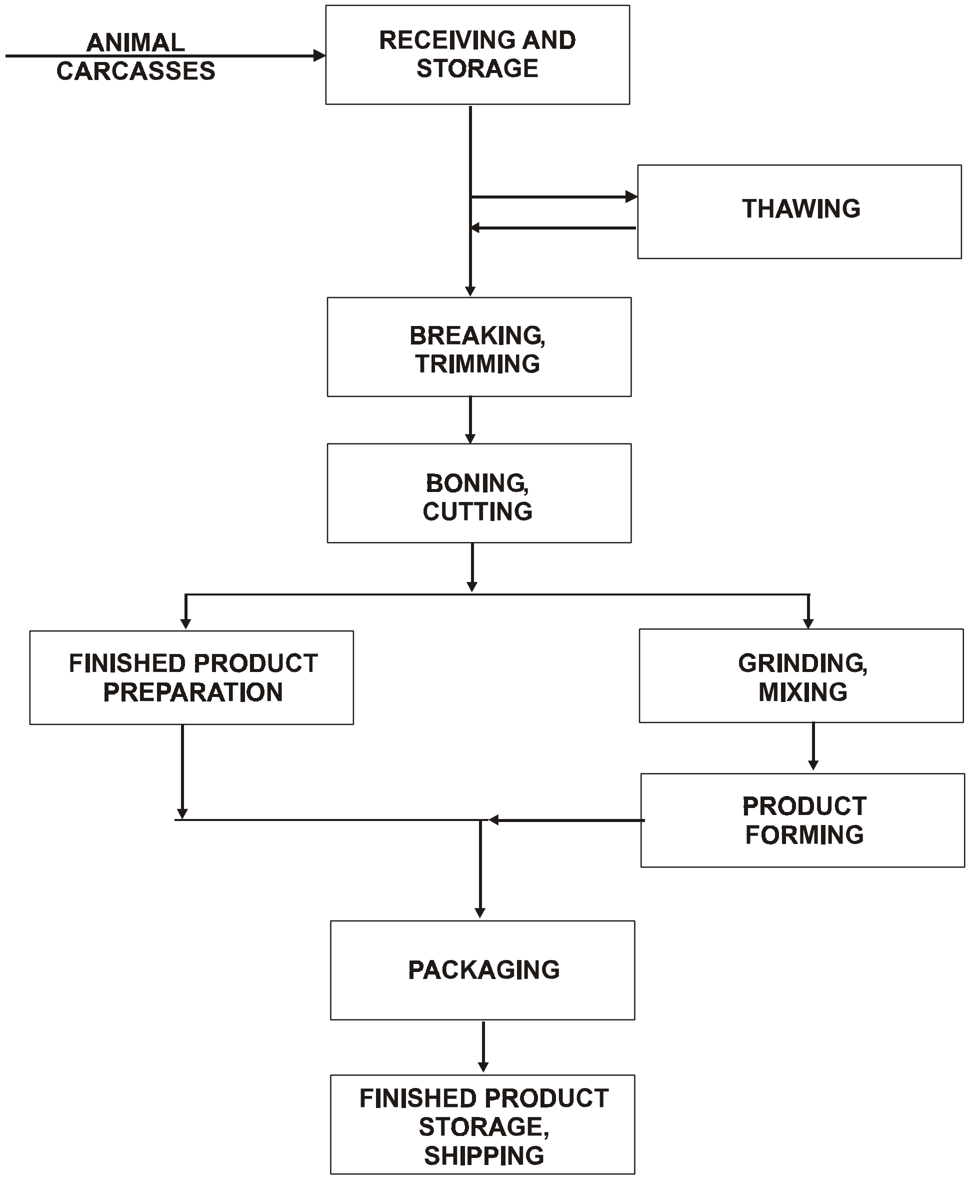

Figure 4-4. General Process for Meat Cuts and Portion Control Procedures (USEPA, 1974).

material. The wastewater generated by this operation results from the use of water by the personnel involved in the operation during the operating day and water required to clean the equipment and floor of the trimming operation (USEPA, 1974).

4.3.2.2.3 Cutting

In the cutting operation, the larger pieces of meat are cut or sawed for the direct marketing of the smaller sections or individual cuts, or for further processing in the production of processed meat products. The solid waste materials generated in cutting are similar to those produced in trimming, plus the bone dust from sawing the bones. The large pieces are useful in sausages or canned meats or can be rendered for edible fats and tallows. The waste materials from the equipment and floor washdown contribute to the waste load of the meat processing plant (USEPA, 1974).

4.3.2.2.4 Deboning

Some raw materials are prepared for the consumer by the removal of internal bones prior to manufacturing particular products such as hams and Canadian bacon. Deboning might also be performed at the same location as trimming, prior to the production of various meat cuts. The bones removed in this operation are disposed of through rendering channels. Meat and fat particles produced from this operation are normally washed into the sewer of a meat processing plant (USEPA, 1974).

4.3.2.2.5 Skinning

The removal of the pork skin from a piece of meat can be done by machine or by hand. Skinning is most frequently used in the preparation of pork bellies for processing into bacon and in ham production. The common practice in the industry is to use machines for the skinning process. The skins removed are disposed of through rendering channels. Other products that require skinning, such as picnic hams, are manually skinned, frequently at the same time that the raw hams are deboned. In either type of skinning operation, meat and fat particles are generated and wasted by falling on the floor or by becoming attached to the skinning equipment. The subsequent cleanup washes these particles into the sewer. In addition, tempering frequently precedes pork belly skinning, generating a waste load comparable to that generated by wet thawing of frozen meat materials by direct meat contact with water (USEPA, 1974).

4.3.2.2.6 Comminution (Mincing, Bowl Chopping, Flaking)

Comminution is the process of reducing large pieces of meat into small pieces for products such as sausage and hamburger patties. There are three general methods of comminution: mincing, bowl chopping, and flaking. Each method affects the size and shape of meat differently, influencing other meat properties. The general processes for comminuted meat products are illustrated in Figure 4-5.

Meat is minced by being pushed through a perforated plate positioned against a rotating knife with a screw auger. The size of perforation varies, depending on the desired meat particle size. The meat is then broken into very small pieces through bowl chopping. Meat is bowl chopped by being placed into a rotating bowl and carried by conveyor belt through a set of vertically rotating knives. Comminuted (flaked) meat is produced when a sharp blade cuts frozen meat blocks into small flakes.

Hamburger patties are formed of minced or flaked beef traditionally, although other meats can be used. Reformed steaks are made from comminuted meat that is shaped to resemble a natural steak. Sausages are made from chopped or comminuted meat and additional ingredients, which are filled into a casing. The casing can be made from the collagen layer of animal intestines or from the reconstituted collagen from other animal parts (Warriss, 2000).

4.3.2.2.7 Grinding, Mixing, and Emulsifying

All processed meat products that are not marketed as cuts or as specific items such as bacon or ham, or used in large pieces, are processed at least through a grinding step to produce a finished product. Grinding is the first step in reducing the size of meat pieces for use in processed meat products such as hamburger, or in preparation for further mixing, blending, or additional size reduction. Grinders are frequently equipped with plates through which meat is forced or extruded. Grinder plates with holes measuring 1/8 to 3/8 inch are most commonly used. In addition to size reduction, grinding equipment may be used to prepare a mixture of various ingredients such as meat products from different types of animals or lean and fatty meat products. The particle size of the meat ingredients in a product is critical. Larger particle size is

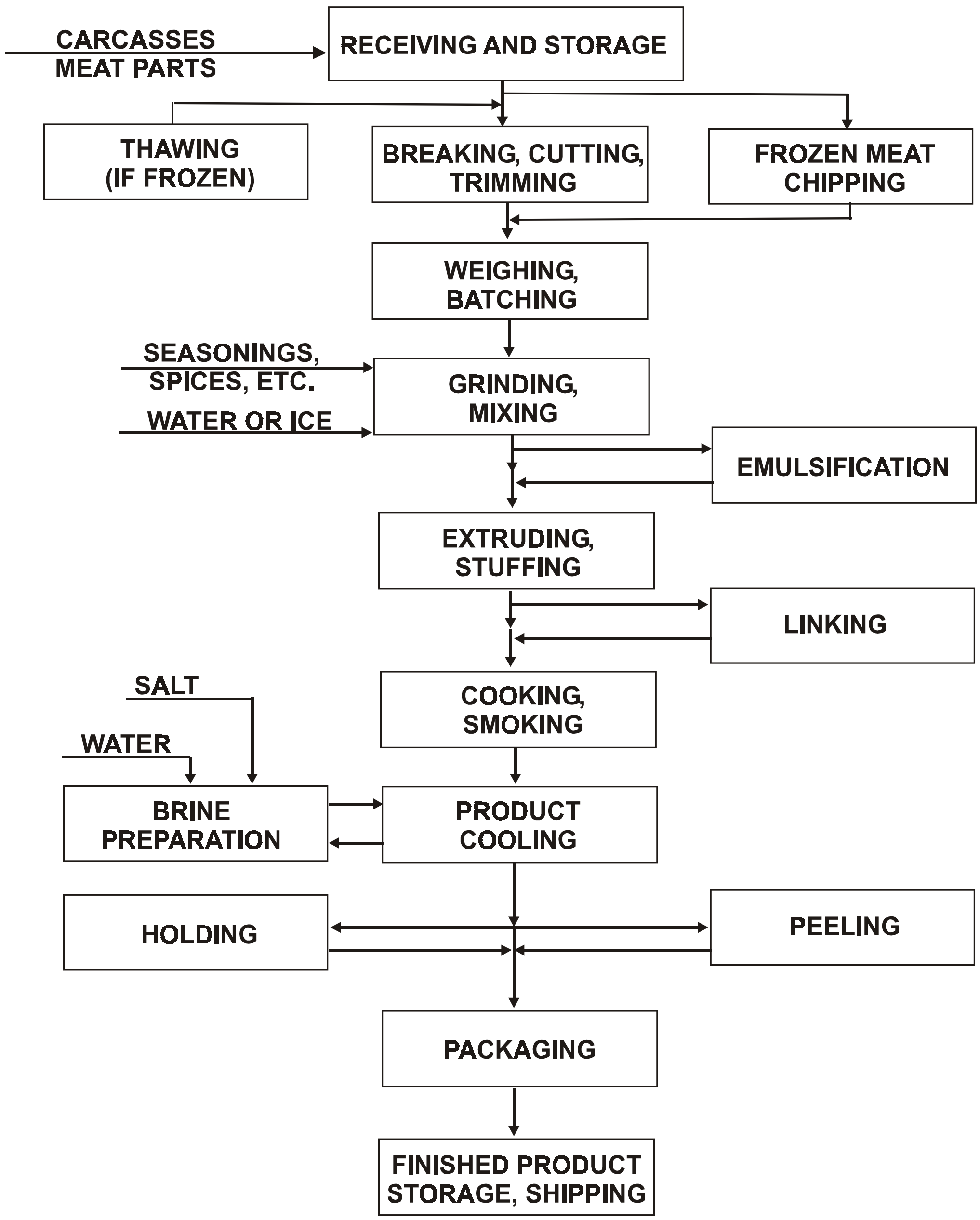

Figure 4-5. General Process for Comminuted Meat Products (Sausage, Wieners, Luncheon Meats, etc.) USEPA, 1974).

required for hamburger or fresh pork sausage products. A slightly smaller particle size is required for manufacturing dry or semi-dry sausages. Various sausages, including wieners and some luncheon meats, are prepared by a substantial size reduction or comminution of the meat raw materials. These products involve a stable sausage emulsion whereby the fat droplets or globules are uniformly dispersed throughout the mixture so that it will take on a homogenous appearance (USEPA, 1974).

Equipment is available to the meat processor that blends or mixes the various ingredients, including the meat materials, to produce stable emulsions. One type of equipment—the “silent cutter”— uses numerous knife blades spinning at a high velocity to reduce the particle size and to produce a stable emulsion. The other type of equipment used to produce an emulsion has the appearance of a common type of dry blender comparable to the ribbon blender (USEPA, 1974).

Control of the type of raw materials used, the sequence of addition, and the time and intensity of grinding, blending, or emulsifying are all critical to the quality of the finished product. Some movement of materials is usually involved in these operations because stepwise processing is required for each batch. This movement is accomplished by pumping or manually using portable containers (USEPA, 1974).

Solid waste materials are generated from these operations by spillage in handling and movement of materials and in cleanup and preparation of equipment for different types of products (USEPA, 1974).

These manufacturing operations are among the major contributors to the waste load in a meat processing plant as a result of equipment cleanup. Because the processing step involves size reduction of lean and fatty materials and the preparation of stable mixtures of meat and other ingredients, these materials tend to coat equipment surfaces and collect in crevices, recesses, and dead spaces in equipment. All of these materials are removed in cleanup and washed into the sewer. This is in contrast to larger particles that can be readily dry-cleaned off a floor prior to washdown, thereby reducing the raw waste load in the wastewater stream. Any piece of equipment that is used in any of these operations is cleaned at least once per processing day and may be rinsed off periodically throughout the day, thereby generating a fairly substantial quantity of wastewater and contributing to the raw waste load (USEPA, 1974).

4.3.2.3 Tenderizing and Tempering

Meat can be tenderized either by marinating or by being injected with salt solutions or acids. Meats have been traditionally marinated in vinegar or wine because their acidic properties break down the muscle structure. Also, the myofibrils swell and hold water, improving tenderness and juiciness. More recently, solutions, especially calcium chloride solutions, have been injected into the meat to achieve the same results (Warriss, 2000).

The processing of some meat products can be enhanced by adjusting the temperature or moisture content prior to a specific processing step. This is particularly true in the production of bacon from pork bellies. If the pork bellies are to be skinned, tempering in a water-filled vat is frequently used to improve skin removal. Hams and bacon are frequently tempered following cooking and smoking by being kept in refrigerated storage long enough for the desired temperature to develop within the particular product. See Figure 4-6 for the general processes for hams and bacon. Some meat processors also find it advantageous to allow the cooked bacon slab to temper in refrigerated storage, following pressing and forming of the slab into the rectangular shape used in the bacon-slicing machines. The holding of essentially finished products generates very little, if any, waste load. However, the water-soaking tempering technique employed prior to skinning pork bellies does generate a waste load comparable to that generated by wet thawing of frozen meat materials by the direct meat contact and subsequent dumping of this water into the sewer (USEPA, 1974).

4.3.2.4 Curing

Curing employs salt compounds to preserve meat and develop a characteristic appearance and flavor. There are two methods of curing meats—dry curing, which entails rubbing solid salts into the meat surface, and immersion, a much more common method wherein meat is submersed into a liquid solution of salts. Injecting brine into the meat and tumbling the meat with rotating drums often aid in distribution. Other salts, such as potassium nitrate, sodium nitrate, and sodium nitrite, often substitute for common table salt (sodium chloride) in the brine solution. The curing brine typically contains additional substances, including sugars to enhance flavor,

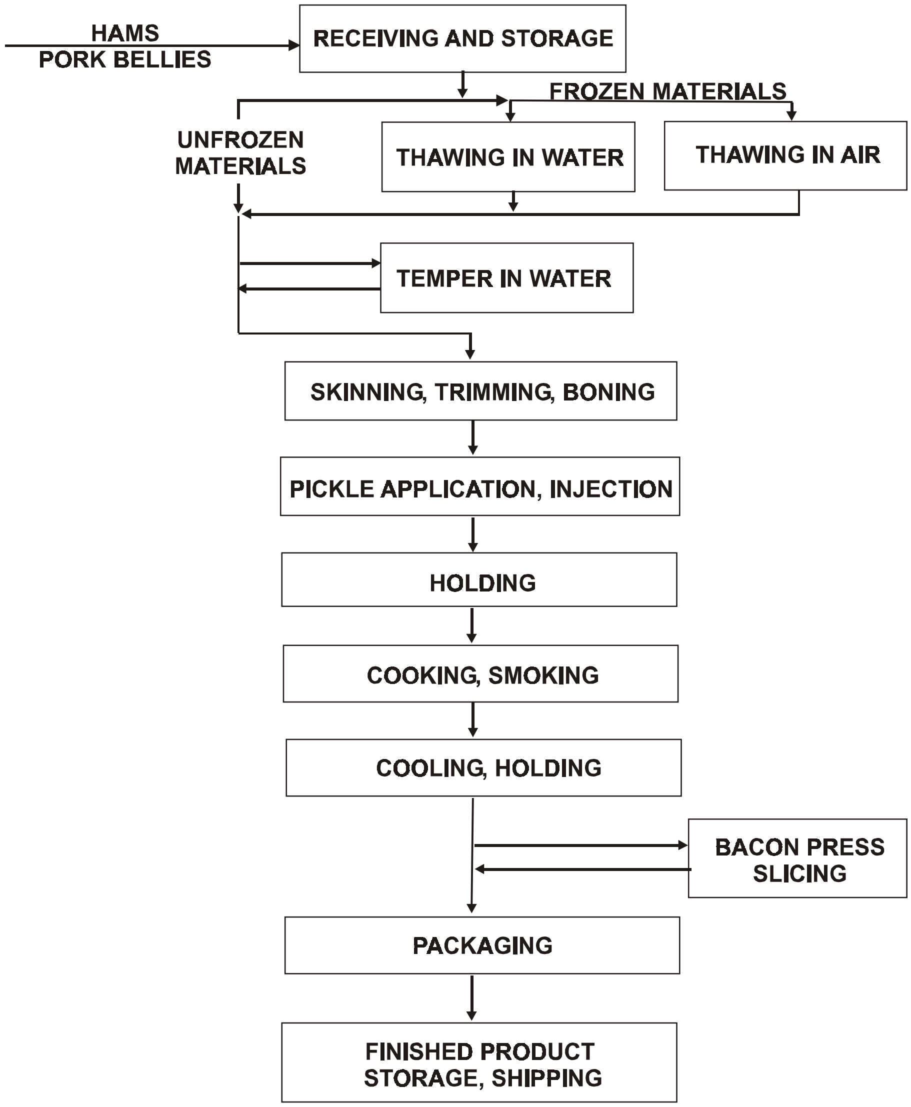

Figure 4-6. General Process for Hams and Bacon. (USEPA, 1974).

ascorbic acid to prevent discoloration, and polyphosphates to improve the water-holding capacity of the meat (Warriss, 2000).

4.3.2.5 Pickle Application/Injection

A pickle or curing solution is prepared with sugar, sodium nitrite, sodium nitrate, and salt as the main ingredients in water. The pickle solution preparation area frequently is separated physically within the plant from the actual point of use. Various types of injection are used to introduce the pickle solution into the interior of a meat product. Pickle solution may also be applied by holding the meat product in a curing brine long enough for the pickle to be absorbed. Or the pickle may be injected or pumped into hams or similar products by introducing the brine through an artery or the vascular system, if it is relatively intact. The product may be injected through numerous needles that penetrate the ham over a large area. Hams, for example, are usually pumped to 110 or 120 percent of their green (or starting) weight. The injection may also be done on both sides to ensure thorough and uniform pickling. Following the pickle injection or application, it is common practice to store the product in tubs with a covering of pickle solution for some time (USEPA, 1974).

Pickling solutions are high in sugar and salt content, particularly the latter. The large amount of spillage in this operation comes from runoff from the pickle injection, from pickle oozing out of the meat after injection, from dumping of cover pickle, and from dumping of residual pickle from the injection machine at the end of each operating day. These practices contribute substantially to the wastewater and waste load from a meat processing plant. Many of the ingredients of pickle solutions represent pollutional material in high concentrations and add significantly to the raw waste load from the pickle operation. Cleanup of the tubs or vats holding the product in brine solutions and cleanup of the pickle injection machines is required at least once per day, or after each use in the case of the vats. This necessity generates additional waste load and wastewater from a meat processing plant (USEPA, 1974).

4.3.2.6 Cooking, Smoking, and Cooling

Although smoking has traditionally functioned as a method of preservation by drying the meat and preventing fat oxidation, it now primarily serves to flavor the meat. Liquid smokes that contain liquid extract of smoke commonly substitute for real smoke (Warriss, 2000).

Most of the meat products are cooked as part of the standard manufacturing procedure. Notable exceptions are fresh pork sausage, bratwurst, and bockwurst. Processed meat products may be cooked with moist or dry heat. Cooking sausages coagulates the proteins and reduces the moisture content, thereby firming up the product and fixing the desired color of the finished product. Large walk-in ovens or smokehouses are in general use throughout the industry. These smokehouses are equipped with temperature controls, humidity controls, water showers, and facilities to provide smoke for smoking products (USEPA, 1974).

The smoking of meat products gives the finished meat product a characteristic and desirable flavor, some protection against oxidation, and an inhibiting effect on bacterial growth in the finished product. Smoke is most commonly generated from hardwood sawdust or small-size wood chips. Smoke is generated outside the oven and is carried into the oven through ductwork. A small stream of water quenches the burned hardwood sawdust before dumping the sawdust to waste. Water overflow from this quenching section is commonly wasted into the sewer. One plant slurried the char from the smoke generator, piped it to a static screen for separation of the char from the water, and then wasted the water (USEPA, 1974).

The actual cooking operation generates wastewater when steam or hot water is used as the cooking medium, such as in cooking luncheon meats in stainless steel molds. The steam condensate and hot water are wasted to the sewer from the cooking equipment. It is standard practice to shower the finished product immediately after cooking to cool it. This practice also generates a wastewater stream containing a waste load primarily of grease (USEPA, 1974).

Cleanup of the cooking ovens is not done every day, but at the discretion of the plant management. The typical practice is to clean each oven and the ductwork for the heated air and smoke circulation at least once a week. This cleaning includes the use of highly caustic cleaning solutions to cut grease and deposits from the smoking operation that have been deposited on the walls, ceiling, and ductwork in the ovens. The effluent from such a cleaning operation is noticeably dark-colored. This color is thought to be the result of creosote-type deposits and fatty acids from the smoke. The other waste load generated in oven cleanup is the grease from the walls and floors resulting from cooking the various products (USEPA, 1974).

In total quantity, the waste load and wastewater generated in this cleanup is not particularly significant. However, there is the noticeable coloration of the wastewater during cleanup and, depending on the extent of the use of caustic, an increase in the pH of the wastewater (USEPA, 1974).

Facilities cool processed meat products in different ways, depending on the type of product. Sausage products may be cooled while still in the oven or smokehouse with a spray of cold water or brine solution. Alternatively, they may be cooled in the aisle immediately outside the smokehouse to save heat and increase productivity. The brine solution is used to achieve a lower spray temperature and thereby a more rapid cooling of the product. The brine is recirculated until it is judged to be excessively contaminated to permit efficient use, at which point it is usually discharged into the sewer (USEPA, 1974).

Hams and bacon products (Figure 4-8) are not exposed to water but instead are moved quickly from the smokehouse to a refrigerated room with a very low temperature (-35 ˚C, or -31 ˚F) and higher-than-normal air circulation to achieve rapid cool-down. The hams and bacon may drip a small quantity of juice or grease onto the floor of the cold room before the surface temperature of the product reaches a point that precludes any further dripping. Cleanup of the floor results in wasting of these drippings into the sewer (USEPA, 1974).

Canned meat products and products prepared in stainless steel molds are usually cooled by submersion in cold water. The water is usually contained in a tank or raceway, where it may flow at a very low speed in a direction countercurrent to the movement of the cans or molds. Depending on the type of installation and product, it was found that the water used in cooling need not be dumped and in fact can be continually recirculated with only a nominal amount of blow-down to remove accumulated solids, just as would be done in operating a boiler. In other situations, usually where smaller quantities of water are involved and luncheon meat molds are being cooled, the water is dumped more frequently (up to once a day). This dumping is necessary because the seal on the molds is not tight enough to prevent leakage of juices and grease to the exterior of the molds (USEPA, 1974).

The only cleanup of cooling equipment that would generate a waste load is cleanup of the floors in the cold rooms where hams and bacon are cooled. This load is small in comparison to others from the plants (USEPA, 1974).

4.3.2.7 Mechanically Recovered Meat

Mechanically recovered meat (MRM) is meat separated from bone by first grinding it to produce a paste. The paste is then forced through a perforated stainless steel drum to separate meat and bone particles. High-pressure air also can be used to remove meat from bone (Warriss, 2000).

4.3.2.8 Canning and Retorting

Canning is another method of preserving and packaging meat for convenient consumption. After meat is sealed in a container, it is heated using steam under pressure at a temperatures of at least 116 ˚C (240 ˚F) to achieve adequate sterilization. However, lower temperatures are used in the canning of cured ham because sterilization by heat is not necessary because of the bactericidal effect of curing agents. Containers used for meat canning usually are steel, which may be coated with tin or a temperature-resistant plastic polymer (Warriss, 2000). See Figure 4-7 for the general processes used for canning meat products.

The containers used to hold the canned meat products must be prepared before filling and covering. The cans are thoroughly cleaned and sterilized. The wet cans are transported from the preparation area to the processing area for filling and covering. Water is present all along the can lines from preparation to filling and covering. The cans go through one last steaming just before they enter the can filling machine (USEPA, 1974).

Can filling is a highly mechanized high-speed operation. It requires moving the meat product to the canning equipment and delivering that product into a container. The high speed and the design of the equipment result in an appreciable amount of spillage of the meat product as the cans are filled and conveyed to the covering equipment. At the can covering station, a small amount of steam is introduced under the cover just before the cover is sealed to create a vacuum within the can when it cools. This steam use also generates a quantity of condensate, which drains off the cans and equipment onto the floor.

The operation of the filling and covering equipment results in a substantial quantity of wastewater containing product spills that is wasted to the sewer. Canning plants that have more

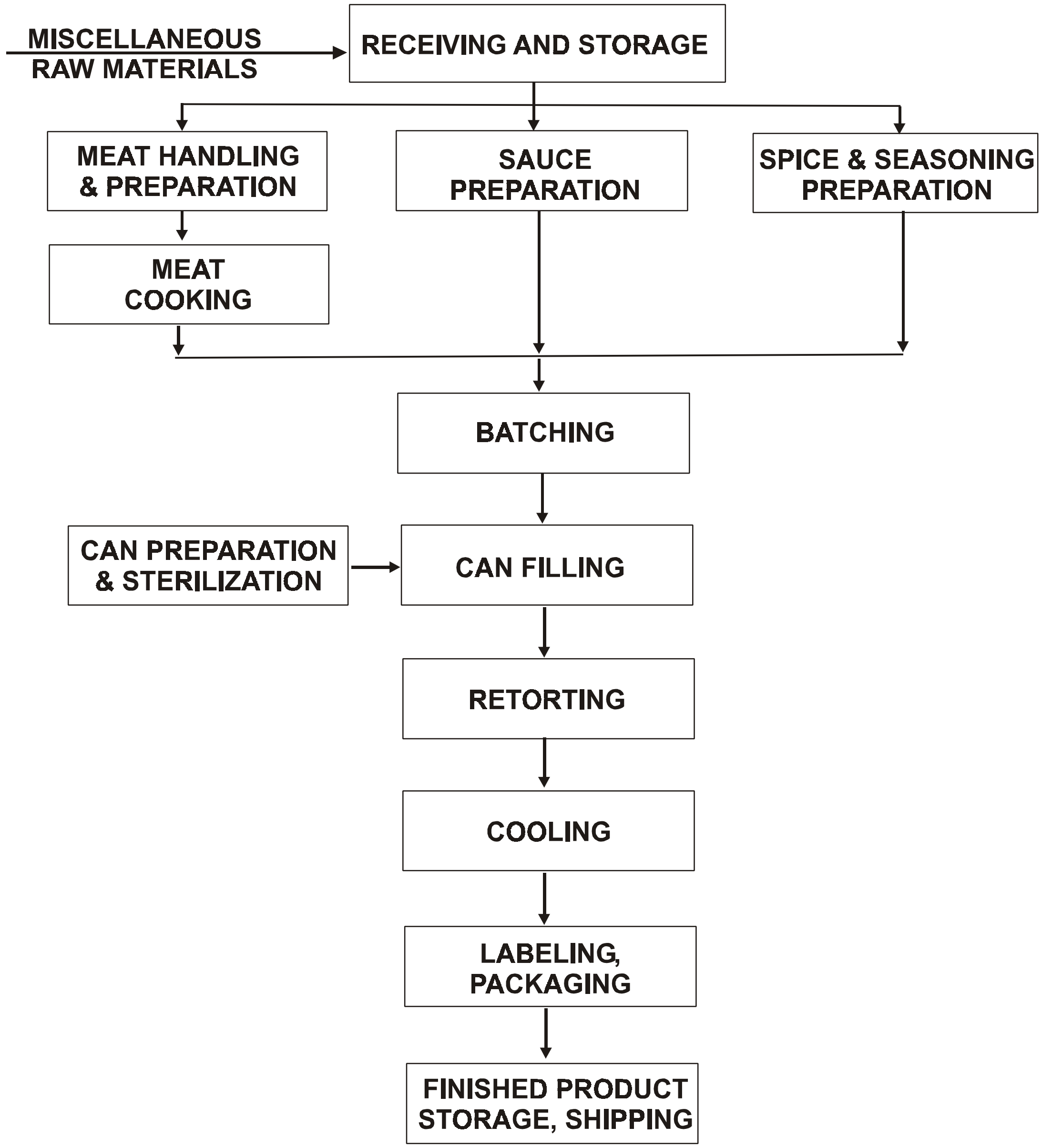

Figure 4-7. General Process for Canned Meat Products (USEPA, 1974).

than one filling and covering line have a waste load that is roughly proportional to the number of such lines in use (USEPA, 1974).

All of the equipment is washed at least once per day at the end of the processing period. If a can filling machine is to be used for different products during the day, it is usually cleaned between product runs. Meat products are frequently canned with gravy-type sauces, or the meat product itself has been comminuted to a small particle size and mixed to produce a flowable mixture. This type of canned product results in a greater contamination of equipment wash water because of the tendency of the product mixture to coat surfaces it comes in contact with and to fill all dead spaces and crevices in the equipment. The equipment is highly mechanized with many moving parts and is designed to be cleaned intact rather than being dismantled first, as is grinding and mixing equipment. Cleaning the equipment while it is intact requires a high-velocity water stream or steam to remove all food particles from the equipment. The tendency of operating personnel is to use greater quantities of water than necessary to clean the equipment. This practice results in large quantities of wastewater with substantial waste loads from canning operations (USEPA, 1974).

The equipment used in transporting the meat product to the can filling equipment also must be cleaned after it has been used on a specific product, and it is always cleaned at the end of the processing day. This equipment is usually broken down, and the product characteristics that contribute to large waste loads, as described above, also generate large waste loads in cleanup of the transport equipment (USEPA, 1974).

Some ham products are canned by manually placing ham pieces in cans. Manpower is used in place of mechanical equipment because the pieces are randomly sized and the packer is able to create a full, uniform appearance for the canned product. A small amount of gelatin is added to provide moisture to the product. The quantity of waste generated from this type of operation probably is somewhat less than that from high-speed canning equipment (USEPA, 1974).

4.3.2.9 Freezing

Blast, belt, plate, and cryogenic freezers are used for freezing meat. The specific type used depends on the type of product being frozen. Blast freezers blow frigid air (-40 ˚C, or -40 ˚F) over the meats in a tunnel. Belt freezers freeze small meats such as burgers that are carried on a conveyor belt. Plate freezers consist of cold metal plates that are pressed onto the meat surface. Finally, cryogenic freezing freezes items through immersion into liquid nitrogen (-196 ˚C, or -321 ˚F) (Warriss, 2000).

4.3.2.10 Packaging

Packaging for transport, distribution, and sale is the final step in further meat processing. Appropriate packaging fulfills three purposes. The first is to protect meat from contamination and inhibit microbial growth, the second is to reduce evaporative weight loss and surface drying, and the last is to enhance the appearance of the meat. Plastic film and antioxidants play an important role in successful packaging (Warriss, 2000).

Various packaging techniques are used in the meat processing industry. These techniques include use of the standard treated cardboard package, the Cry-O-Vac (plastic film sealed under vacuum) type of package, and the bubble enclosure package used for sliced luncheon meats and wieners, and the boxing of smaller containers of pieces of finished product for shipment. In some packaging techniques a substantial amount of product handling is involved, which may result in some wasted product. The size of the pieces of wasted finished product, however, are such that there is little reason for it to be wasted to the sewer. Instead, it should be returned for subsequent use in another processed product or directed to a rendering channel (USEPA, 1974).

The only time water is generated by the packaging operation is during cleanup of the equipment. Small quantities of water are adequate for cleanup of this equipment, and only small quantities of wastewater are generated (USEPA, 1974).

4.3.2.11 Seasonings, Spices, and Sauce Preparation

A wide variety of chemicals is used by meat processing to improve product characteristics such as taste, color, texture, appearance, shelf-life, and other characteristics important to the industry. These chemicals include salt, sugar, sodium nitrate, sodium nitrite, sodium erythrobate, ascorbic acid, and spices like pepper, mustard, and paprika. Other common materials added in the preparation of processed meat products are dry milk solids, corn syrup, and water, either as a liquid or as ice (USEPA, 1974).

Other than water, most of these materials are solids and are handled in the solid state. The product formulations for the various finished products produced by a meat processor call for specific quantities of chemicals and seasonings. These spices and chemicals are preweighed and prepared for use in a specific batch in a dry spice preparation area. They are weighed into containers and added to batches in the grinding or mixing operation. Very little waste of either a dry or wet nature is generated by the specific operation of seasoning and spice formulation. Sauces are prepared for use in canned meat products particularly. Sauces are wet mixtures of seasonings, spices, and other additives described above, as well as meat extracts and juices, and are used to prepare a gravy-type of product. Significant quantities of waste are generated in the preparation and handling of sauces and in kettle cleaning. The residual materials are washed out of the kettles directly into the sewer and contribute significantly to the raw waste load of a meat processor that prepares a canned meat product (USEPA, 1974).

4.3.2.12 Weighing and Batching

The meat processing industry uses batch-type manufacturing operations in all but a few instances. The type and quantity of materials that go into each unit of production, or batch, are controlled according to specifications established by the individual meat processing companies in accordance with government standards for the finished product. The lean and raw materials that go into each batch are weighed and placed in portable tubs. The portable tubs of weighed raw material are identified for a specific product and moved to the next manufacturing operation (USEPA, 1974).

The weighing and batching area is frequently located in one of the refrigerated raw material storage areas. The operation involves considerable manual handling of meat products and pieces of trim fat. Liquids, including meat juices and water, frequently drip from the raw materials onto the floor of the batching area. Particles also drop off in the handling process. The tubs used to hold the raw materials and the batches of raw material contain liquids and solids that are wasted to the sewer after batches have been dumped into subsequent processing equipment. The tubs and handling equipment are cleaned as needed during the production period and at least once a day (USEPA, 1974).

4.3.2.13 Extrusion, Stuffing, and Molding

Following the preparation of a stable emulsion or mixture of ingredients for a processed meat product such as wieners or sausage, the mixture is again transported by pump or in a container to a manufacturing operation where the mixtures are formed or molded into the finished product. Sausage casings and stainless steel molds are commonly used as containers in this operation. Either natural casings, which are the intestines from some types of animals, or synthetic casings, which are used only in the formation of the products and then peeled and disposed of before the product goes to the consumer, may be used in producing sausages and wieners and in some kinds of luncheon meats. The stainless steel molds are most commonly used to obtain the square shape characteristic of some luncheon meats (USEPA, 1974).

In the casing, stuffing, or mold-filling operation a product mixture is placed in a piece of equipment from which the product mixture is either forced by air pressure or pumped into the container to form a uniform, completely filled container resembling the shape of the finished product (USEPA, 1974).

Water is used to prepare the natural casings for use in the stuffing operation, and the stainless steel molds are cleaned and sterilized after every use. The primary source of waste load and wastewater is the cleanup of the equipment used in this operation. As in the previous operation, the residual emulsions and mixtures contribute significantly to the waste load because of their propensity to stick to most surfaces with which they come in contact and to fill crevices and voids. All equipment used in this operation is broken down at least once a day for a thorough cleaning. This cleanup is designed to remove all remnants of the mixtures handled by the equipment, and this material is wasted with the wastewater into the sewer, thereby contributing to the waste load (USEPA, 1974).

Some spillage of material occurs in this operation. Spillage occurs during transport of the material from grinding and emulsifying to the extrusion operation, and particularly in the extrusion or stuffing of the container and overflows (USEPA, 1974).

4.3.2.14 Linking

This manufacturing operation is simply the formation of links or specific-sized lengths of product in a casing. Linking is done by twisting or pinching the casing at the desired length for the specific finished product, mechanically or manually. A small stream of water is used to lubricate the casing to avoid breakage or splitting. When the full length of each casing has been linked, the product is hung on a rail hanger, called a “tree,” in preparation for the next manufacturing operation (usually cooking and smoking) (USEPA, 1974).

Unless a casing splits or breaks, no significant amount of raw waste load should be contributed by this operation. The equipment used is thoroughly washed after use. The hangers that hold the products through the cooking and smoking step become coated with greasy substances, which are washed off and into the sewer after each use. In addition, a standard maintenance practice is to coat the hangers with a thin film of edible oil to protect them from rusting. This oil is ultimately washed off in the overshowering or in the washing of the hangers following each use. Some large operations use automated spray cabinets for “tree” washing (USEPA, 1974).

4.3.2.15 Casing Peeling

Synthetic casings made from a plastic material are used in the production of a large number of wieners in the meat processing industry. These casings are not edible and therefore must be removed from the wieners after cooking and cooling but prior to packaging for sale to the consumer. The peeling equipment includes a sharp knife that slits the casing material, a small spray of steam to part the casing from the finished wiener, and a mechanism to peel the casing away from the wiener. Casing material is solid waste that results from this operation; it is collected and disposed of as part of the plant refuse. The slitting mechanism occasionally penetrates the wiener in addition to the casing and cuts the wiener, rendering it useless as a finished product. However, these pieces of wiener are not wasted but are used in other products prepared in the plant. The steam used in the casing peeling results in a small water stream from this operation, but it is so small that it is of no real consequence (USEPA, 1974).

The equipment is cleaned at the end of every processing day and may contribute a small quantity of waste load as a result of wiener particles that may be attached to various parts of the mechanism and are subsequently washed into the sewer during cleanup. The volume of waste-water and the waste load are relatively insignificant in comparison with other waste sources (USEPA, 1974).

4.3.2.16 Product Holding/Aging

Some processed meat products require holding or aging as part of the production process. Hams, dry sausage, and some bacon, for example, require intermediate or finished holding periods before the product is shipped out of the meat processing plant. The holding operation requires space and some means of storing the particular meat product in the holding area. These holding areas are refrigerated, and some drippings accumulate on the floor. The floor area, like other processing floors, is cleaned once every processing day. The quantity of wastewater and the waste load from the cleanup of these holding areas is minimal compared to that of many other sources within meat processing plants (USEPA, 1974).

4.3.2.17 Bacon Pressing and Slicing

After the bacon has been smoked, cooled, and held for the required time, two processing steps are required before the product is ready for packaging (Figure 4-6). Bacon slabs are irregular in shape after smoking and cooling, and bacon slicing equipment is designed to handle a slab with a fairly rectangular shape. This design facilitates the production of the typical uniform bacon slice expected by the consumer. The bacon slabs are placed in a molding press, which forms the slabs into the desired rectangular shape (USEPA, 1974).

Two different slicing procedures are used in the processing industry after the slabs have been made rectangular. Some plants slice the bacon slabs immediately after pressing. Others prefer to return the molded bacon slabs to a refrigerated holding area to allow the temperature of the slab to cool down. Each approach is successful, and the method actually used appears to depend only on individual preference for a given operation (USEPA, 1974).

Bacon slicing is usually a high-speed operation in which slabs are rapidly cut, the strips of bacon are placed on a cardboard or similar receptacle until a specified weight is reached, and then the bacon is fed onto a conveying system that delivers the bacon to packaging (USEPA, 1974).

There is little waste generated in bacon pressing and slicing except for random pieces of bacon that fall on the floor. These pieces are of sufficient size to be readily picked up by dry cleaning the floors before washdown. The equipment is cleaned at the end of every processing day. There are some particles, as well as a fairly complete covering of grease, on all parts of the equipment that come in contact with the bacon slabs. All of this material is washed off in the cleanup operation. The quantity of wastewater generated in cleanup and the waste load from this cleanup is again relatively small in comparison to other sources (USEPA, 1974).

4.3.2.18 Receiving, Storage, and Shipping

The meat-type raw materials and virtually all the finished product in a meat processing plant require refrigerated storage. Some of the raw materials and finished products are frozen and require freezer storage. The meat-type raw materials are brought into meat processing plants as carcasses, quarters, primal cuts, and specific cuts or parts packaged in boxes. The seasonings, spices, and chemicals are usually purchased in the dry form and are stored in dry areas convenient to the sauce and spice formulation area (USEPA, 1974).

The meat processing plants of companies with nationwide sales and plants located throughout the country also use the storage facilities of meat processing plants as distribution centers for products not manufactured at each plant (USEPA, 1974).

The cleaning of freezers is always a dry process and only on rare occasions does it generate a wastewater load. Refrigerated storage space does require daily washdown, particularly of the floors, where juices and particles have accumulated from the materials stored in the refrigerated area. The general policy of the industry is to encourage dry cleaning of all floors, including storage areas, before the final washdown of the floors. Frequently, actual practices do not include dry cleaning of the floors before washdown (USEPA, 1974).

Shipping and receiving always involve truck transportation. The primary source of waste material in this operation is the transport of carcasses, quarters, and large cuts of meat from the trucks to the storage area within the meat processing plant (USEPA, 1974).

Meat and fat particles falling from the raw material are the primary source of waste material in this operation. The receipt and transport of other raw materials and finished products essentially generate no waste load (USEPA, 1974).

4.4 POULTRY PROCESSING INDUSTRY DESCRIPTION

Poultry Processing (NAICS 311615) includes the slaughter of poultry and small game animals (e.g., quails, pheasants, and rabbits) and exotic poultry (e.g., ostriches) and the processing and preparing of these products and their by-products. Slaughtering is the first step in processing poultry into consumer products. Poultry slaughtering (first processing) operations typically encompass the following steps:

- Receiving and holding of live animals
- Stunning prior to slaughter
- Slaughter
- Initial processing

Poultry first processing facilities are designed to accommodate this multistep process. In most facilities, the major steps are carried out in separate rooms.

In addition, many first processing facilities further process carcasses, producing products that may be breaded, marinated, or partially or fully cooked. Also, many first processing facilities include rendering operations that produce edible products such as fat and inedible products, primarily ingredients for animal feeds, including pet foods.

The 1997 U.S. Census of Manufacturers reported 260 companies engaged in poultry slaughtering. These companies own or operate 470 facilities, employ 224,000 employees, and produce about $32 billion in value of shipments. The poultry slaughtering sector has relatively few facilities with fewer than 20 employees; as in the meat sectors, however, a few very large facilities dominate the sector. Almost 50 percent of the sector employment and over 40 percent of the value of shipments were accounted for by 75 facilities, which employ more than 1,000 workers each. Eighty percent of employment and 74 percent of total shipments are produced by facilities that employ more than 500 workers. Yet these facilities compose only 36 percent of the poultry processing industry.

Products of the poultry processing sector can be divided into two major categories: broilers and turkeys. Broilers account for more than half of the industry's shipments; processed poultry accounts for about 30 percent of the shipments; and turkeys account for about 12 percent.

Poultry processing is largely concentrated in the southeastern states. Arkansas and Georgia have the largest number of facilities, employment, and value of shipments. Alabama and North Carolina rank third and fourth in all of these measures. California is the only state in the top 10 poultry-producing states that is not in the Southeast. California ranks 10^{th} in terms of employment and value of shipments and 8^{th} in number of facilities.

EPA is using revised production rate thresholds to exclude most smaller poultry product processing facilities from the proposed revisions to 40 CFR Part 432 because the technologies on which the options were based are not cost-effective for facilities with the lowest production threshold. Based on the current screener survey data, EPA defines small poultry first and further processing facilities as those that produce fewer than 10 million pounds (LWK) and 7 million pounds (LWK) per year, respectively. See to Figures 4-8 and 4-9 for the distribution of small and non-small (facilities producing more than 50 million pounds (LWK) per year) poultry first and further processing facilities, also categorized by discharge type, throughout the United States.

4.5 DESCRIPTION OF POULTRY FIRST AND FURTHER PROCESSING OPERATIONS

Poultry processing plants are highly automated facilities designed for the slaughter of live birds with whole carcasses as the end product. The operations of these plants differ significantly from their meat counterparts in several respects. For example, poultry slaughtering (first processing) operations typically involve more steps than do meat first processing operations. A poultry processing plant can encompass up to 10 steps, including unloading, stunning, killing, bleeding, scalding, defeathering, eviscerating, chilling, freezing, and packaging (Sams, 2001). Each of these operations occurs in a separate section of the processing plant and involves the use of different types of equipment. Because broiler chickens constitute most of the poultry industry's annual production, and the same sequence of operations is used in the processing of

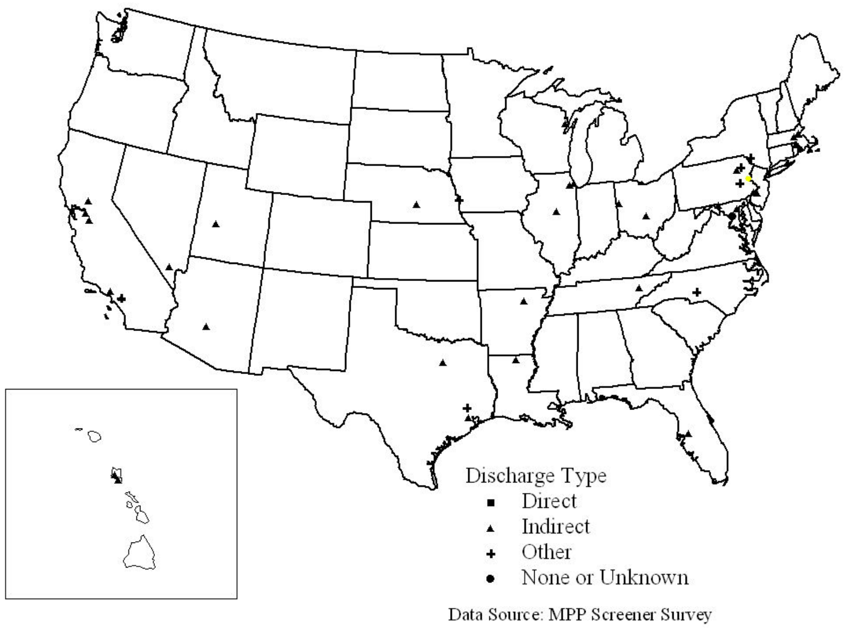

Figure 4-8. Location of Small Poultry Facilities in the United States (Based on Screener Survey Data).

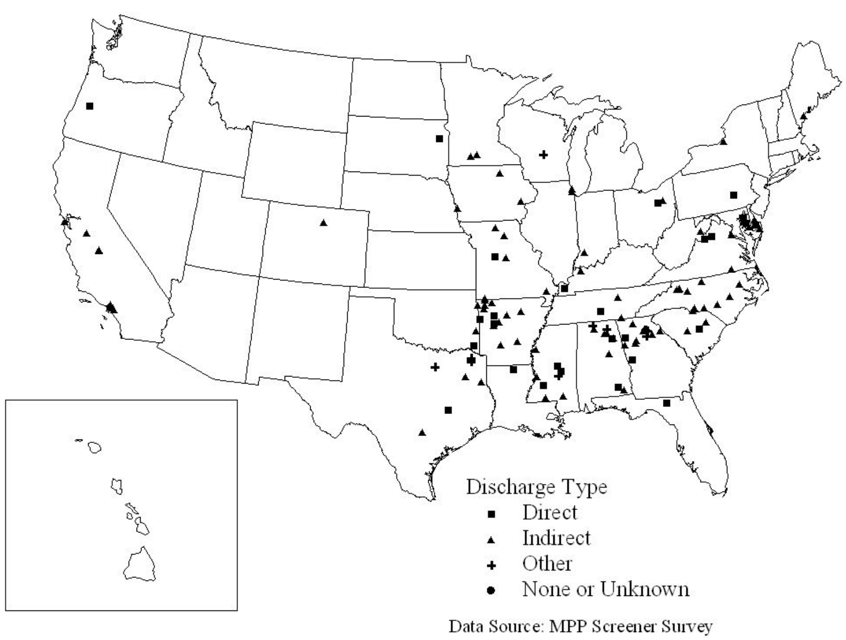

Figure 4-9. Location of Non-Small Poultry Facilities in the United States (Based on Screener Survey Data).

turkeys and other birds, the following sections describe only broiler processing operations unless otherwise noted.

Poultry processing begins with the assembly and slaughter of live birds and may end with the shipment of dressed carcasses or continue with a variety of additional activities. Poultry processing operations are also classified as first or further processing operations or as an integrated combination. First processing operations include those operations which receive live poultry and produce a dressed carcass, either whole or in parts. In this classifications system, first processing operations simply produce dressed whole or split carcasses or smaller segments for sale to wholesale distributors or directly to retailers. First processing operations offer supply products for further processing activities such as breading, marinating, and partial or complete cooking, which may occur on- or off-site.

Following the same logic applied to the meat processing industry, EPA considers the reduction of whole poultry carcasses into halves, quarters, or smaller pieces, which may be with or without bone and may be ground as part of first processing when performed at first processing facilities. Consequently, EPA also considers cutting, boning, and grinding operations to be further processing operations when performed at facilities not also engaged in first processing activities.

4.5.1 Poultry First Processing Operations

Common to all poultry first processing operations is a series of operations necessary to transform live birds into dressed carcasses. Figure 4-10 illustrates this series of operations, and the following sections describe these operations.

4.5.1.1 Receiving Areas

Birds are transported to processing plants with delivery scheduled so that all birds are processed on the day they are received. Live bird holding areas are usually covered and have cooling fans to reduce bird weight loss and mortality during hot weather conditions (Sams, 2001).

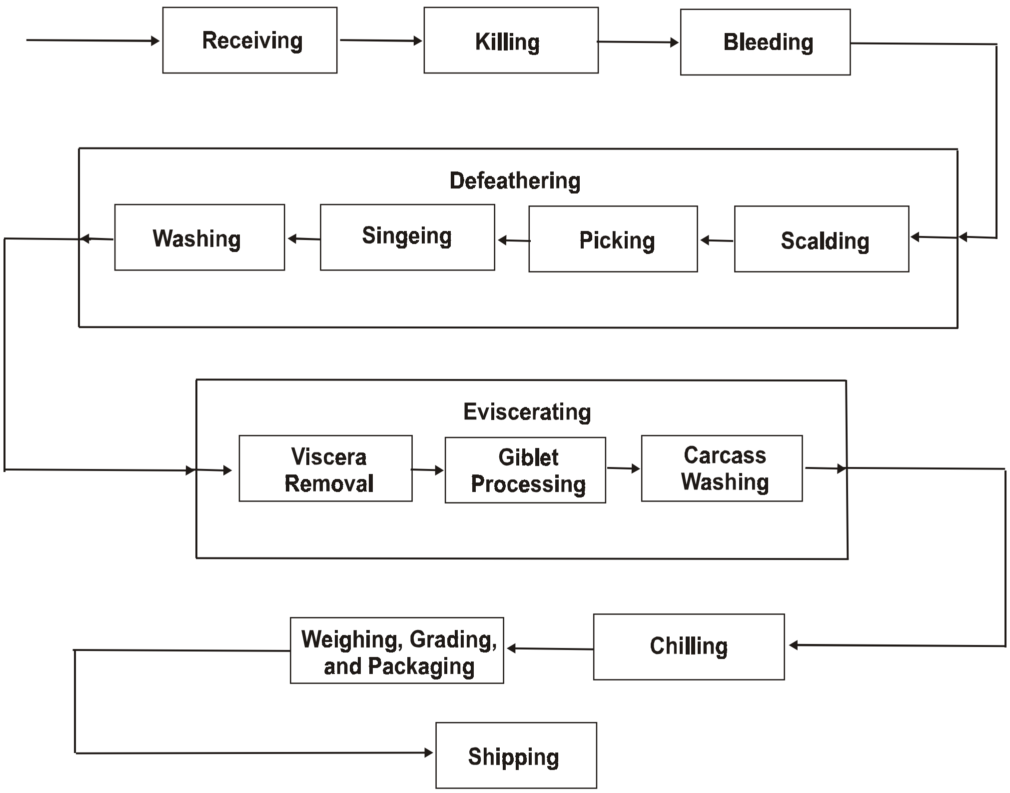

Figure 4-10. General Process for Poultry First Processing Operations (USEPA, 1975).

Broiler chickens are typically transported to processing plants in cage modules stacked on flatbed trailers. These cage modules can hold about 20 average-size broiler chickens. The cage modules are removed from the transport trailer and tilted using a folklift truck to empty the cage. Alternatively, tilting platforms can be used to empty the cage modules after they have been removed from the transport trailer. When the cage module tilts, the lower side of the cage opens and the birds slide onto a conveyor belt, which moves them into the hanging area inside the plant. In the hanging area, the live birds are hung by their feet on shackles attached to an overhead conveyer system, commonly referred to as the killing line, that moves the birds into the killing area. The killing-line moves at a constant speed, and up to 8,000 birds per hour (133 birds per minute) can be shackled in a modern plant, although in practice this number is much lower because workers cannot unload broilers fast enough to fill every shackle (Wilson, 1998). Cage modules also are used to transport ducks, geese, and fowl.

Turkeys are generally transported in cages permanently attached to flatbed trailers. The cages are emptied manually into a live bird receiving area located outside the confines of the processing plant. Turkeys are unloaded manually to minimize bruising. They are more susceptible than broilers to bruising from automatic unloading because of their heavier weight and irregular body shape. Turkeys are then immediately hung on shackles attached to an overhead conveyer system that passes from the unloading area into the processing plant (Sams, 2001).

Following the unloading process, cages and transport trucks may be washed and sanitized to prevent disease transmission among grower operations. The washing and sanitizing of cages and trucks is common in the turkey industry but not in the broiler chicken industry (USEPA, 1975).

4.5.1.2 Killing and Bleeding

Almost all birds are rendered unconscious through stunning just prior to killing. Some exemptions are made for religious meat processing (e.g., kosher, halal). Stunning immobilizes the birds to increase killing efficiency, cause greater blood loss, and increase defeathering efficiency. Stunning is performed by applying a current of 10 to 20 milliamps (mA) per broiler and 20 to 40 mA per turkey for approximately 10 to 12 seconds (Sams, 2001). Poultry are killed by severing the jugular vein and carotid artery or less typically by debraining. Usually a rotating circular blade is used to kill broilers, while manual killing is often required for turkeys because of their varying size and body shape. Decapitation is not performed, because it decreases blood loss following death (Stadelman, 1988).

Immediately after being killed, broilers are bled as they pass through a “blood tunnel” designed to collect blood to reduce wastewater biochemical oxygen demand and total nitrogen concentrations. The blood tunnel is a walled area designed to confine and capture blood splattered by muscle contractions following the severing of the jugular vein and corotid artery. The blood collected is processed with recovered feathers in the production of feather meal, a by-product feedstuff used in livestock and poultry feeds as a source of protein. On average, broilers are held in the tunnel from 45 to 125 seconds for bleeding, with an average time of 80 seconds;

turkeys are held in the tunnel from 90 to 210 seconds, with an average time of 131 seconds. Blood loss approaches 70 percent in some plants, but generally speaking only 30 to 50 percent of a broiler's blood is lost in the killing area. Depending on plant operating conditions, blood is collected in troughs and transported to a rendering facility by vacuum, gravity, or pump systems, or it is allowed to congeal on the plant floor and collected manually. Virtually all plants collect blood for rendering either on- or off-site and thereby limit the amount of blood present in their wastewater (USEPA, 1975).

4.5.1.3 Scalding and Defeathering

After killing and bleeding, birds are scalded by immersion in a scalding tank or by spraying with scalding water. Scalding is performed to relax feather follicles prior to defeathering. Virtually all plants use scald tanks because of the high water usage and inconsistent feather removal associated with spray scalding. Scalding tanks are relatively long troughs of hot water into which the bled birds are immersed to loosen their feathers. Depending on the intended market of the broilers, either soft (semi-scald) or hard scalding is used. Soft scalding is used for the fresh, chilled market, whereas hard scalding is preferred for the frozen sector (Mead, 1989). The difference between these two types of scalding techniques lies in the scalding temperature used. Soft scalding is performed at about 53 ˚C (127 ˚F) for 120 seconds; it loosens feathers without subsequent skin damage. Hard scalding is performed at 62 to 64 ˚C (144 to 147 ˚F) for 45 seconds; it loosens both feathers and the first layer of skin. Sometimes chemicals are added to scald tanks to aid in defeathering by reducing surface tension and increasing feather wetting. The USDA requires that all scald tanks have a minimum overflow of 1 liter (0.26 gallon) per bird (FSIS, 2001) to reduce the potential for microbial contamination (Sams, 2001).

Because scalding and mechanical defeathering do not completely remove duck and goose feathers, immersion in a mixture of hot wax and rosin follows. After this mixture partially solidifies, it is removed with the remaining feathers (Stadelman et al., 1988).

The next stage is automated defeathering, which is done by machines with multiple rows of flexible, ribbed, rubber fingers on cylinders that rotate rapidly across the birds. The abrasion caused by this contact removes the feathers and occasionally the heads of the birds. At the same time, a continuous spray of warm water is used to lubricate the bird and flush away feathers as they are removed. Feathers are flumed to a screening area using scalding overflow for dewatering prior to processing for feather meal production. Different defeathering machines may be used for different types of birds (USEPA, 1975).

Following defeathering, pinfeathers may be removed manually because they are still encased within the feather shaft and thus are resistant to mechanical abrasion. After pinfeather removal, birds pass through a gas flame that singes the remaining feathers and fine hairs. Next, feet and heads are removed. Feet are removed by passing them through a cutting blade, and heads are removed by clamps that pull upward on the necks. Removing the head from a bird is advantageous because the esophagus and trachea are removed with it. Removing the head also loosens the crop and lungs for easier automatic removal during evisceration (Mead, 1989). At this point, blood, feathers, feet, and the heads of broilers are collected and sent to a rendering facility, where they are transformed into by-product meal (Sams, 2001). Chicken feet also may be collected for sale primarily in export markets.

After removal of the feet, the carcasses are rehung on shackles attached to an overhead conveyer, known as an evisceration line, and washed in enclosures using high-pressure cold water sprays prior to evisceration. The purpose of this washing step is to sanitize the outside of the bird before evisceration to reduce microbial contamination of the body cavity. This transfer point is often referred to as the point separating the “dirty” and “clean” sections of the processing plant (Wilson, 1998). The killing-line conveyor then circles back, and the shackles are cleaned before returning to the unloading bay (USEPA, 1975).

4.5.1.4 Evisceration

Evisceration is a multistep process that begins with removing the neck and opening the body cavity. Then, the viscera are extracted but remain attached to the birds until they are inspected for evidence of disease. Next, the viscera are separated from the bird, and edible components (hearts, livers, and gizzards) are harvested. The inedible viscera, known as offal, are collected and combined with heads and feet for subsequent rendering. Entrails are sometimes left attached for religious meat processing (e.g., Buddhist, Confucius). Depending on the plant design, a wet or dry collection system is used. Wet systems use water to transport the offal by fluming it to a screening area for dewatering before rendering. Dry systems, which are not common, may use a series of conveyor belts or vacuum or compressed air stations for offal transport (USEPA, 1975).

Automation of the evisceration process varies depending on plant size and operation. A fully automated line can eviscerate approximately 6,000 broilers per hour (Mead, 1989). The type of equipment available for plant use varies by location and manufacturer. Many parts of the process can be performed manually, especially for turkeys. Though a fully automated evisceration line may be used for broilers, the variation in size among turkeys makes automation more difficult. Female turkeys (hens) are significantly smaller than male turkeys (toms) (USEPA, 1975).

When broilers first enter the evisceration area, they are rehung on shackles by their hocks to a conveyor line that runs directly above a wet or dry offal collection system (Wilson, 1998). The birds' necks are disconnected by breaking the spine with a blade that applies force just above the shoulders. As the blade retracts the neck falls downward and hangs by the remaining skin while another blade removes the preen gland from the tail. The preen gland produces oil that is used by birds for grooming and has an unpleasant taste to humans (Sams, 2001). Next, a venting machine cuts a hole with a circular blade around the anus for extraction of the viscera. Great care must be taken not to penetrate the intestinal lining of a broiler because the resulting fecal contamination will result in condemnation during inspection (USEPA, 1975).

Following venting, the opening of the abdominal wall is enlarged to aid in viscera removal. At this point all viscera are drawn out of the broiler by hand, with the aid of scooping spoons, or more commonly by an evisceration machine. The evisceration machine immobilizes the broiler and passes a clamp through the abdominal opening to grip the visceral package. Once removed, this package is allowed to hang freely to aid in the inspection process. Every bird must be inspected by a USDA inspector or a USDA-supervised plant worker for evidence of disease or contamination before being packaged and sold. The inspector checks the carcass, viscera, and body cavity to determine wholesomeness with three possible outcomes: pass, conditional, and fail. If the bird is deemed conditional, it is hung on a different line for further inspection or to be trimmed of unwholesome portions. Failed birds are removed from the line and disposed of, usually by rendering (Stadelman, 1988).

The viscera are removed from the birds that have passed inspection and are pumped to a harvesting area where edible viscera are separated from inedible viscera. A giblet harvester is used to collect the edible viscera, including heart, liver, neck, and gizzard, and to prepare each appropriately. The heart and liver are stripped of connective tissue and washed. The gizzard is split, its contents are washed away, its hard lining is peeled off, and it is given a final wash. The minimum giblet washer flow rate required by USDA is 1 gallon of water for every 20 birds processed (25 CFR 61.144). Meanwhile, the inedible viscera, including intestines, proventriculus, lower esophagus, spleen, and reproductive organs, are extracted and sent to a rendering facility. Finally, the crop and lungs are mechanically removed from each bird. The crop is pushed up through the neck by a probe, and the lungs are removed by vacuum. A final inspection is required to ensure the carcass is not heavily bruised or contaminated, and then the carcass is cleaned (USEPA, 1975). Bruised birds are diverted to salvage lines for recovery of parts.

The second carcass washing of the broilers is very thorough. Nozzles are used to spray water both inside and outside the carcass. These high-pressure nozzles are designed to eliminate the majority of remaining contaminants on both carcass and conveyor line, and the water is often mixed with chlorine or other antimicrobiological chemicals. From here, the conveyor system travels to the chilling area (USEPA, 1975).

Kosher and halal poultry producers pack the birds (inside and out) in salt for 1 hour to absorb any residual blood or juices. The birds are then rinsed and shipped to kosher/halal meat distributers. On an average day a typical kosher poultry facility (generating approximately 2 million gallons wastewater per day) would use approximately 80,000 pounds of salt in its operations (Thorne, 2001). Industry has stated that most kosher operations (meat and poultry) are located in urban areas with sewer connections.

4.5.1.5 Chilling

After birds have been eviscerated and washed, they are chilled rapidly to slow the growth of any microorganisms present to extend shelf life and to protect quality (Sams, 2001). USDA regulations require that broilers be chilled to 4 ˚C (40 ˚F) within 4 hours of death and turkeys within 8 hours of death (9 CFR 381.66). Most poultry processing plants use large chilling tanks containing ice water; very few use air chilling. Several types of chilling tanks are used, including (1) a large enclosed drum that rotates about a central axis, (2) a perforated cylinder mounted within a chilling vat, and (3) a large open chilling tank containing a mechanical rocker to provide agitation. In all cases, birds are cascaded forward with the flow of water at a minimum overflow rate per bird specified by the USDA (FSIS, 2001).

Most poultry plants use two chilling tanks in series, a pre-chiller and a main chiller. The direction of water flow is from the main chiller to the pre-chiller, which is opposite to the direction of carcass movement. Because water and ice are added to only the main chiller, the water in the pre-chiller is somewhat warmer than that in the main chiller. Most plants chlorinate chiller makeup water to reduce potential carcass microbial contamination. The USDA requires 0.5 gallon (2 liters) of overflow per bird in the chillers (FSIS, 2001); the flow typically is about 0.75 gallon (3 liters) per bird (Sams, 2001). The effluent from the first chiller usually is used for fluming offal to the offal screening area (USEPA, 1975).

USDA requires pre-chiller water temperature to be less than 18.3 ˚C (65 ˚F) (9 CFR 381.66), and temperature values typically range between 7 and 12 ˚C (45 and 54 ˚F) (Stadelman, 1988). Agitation makes the water a very effective washer, and the pre-chiller often cleans off any remaining contaminants. Most broiler carcasses enter the pre-chiller at about 38 ˚C (100 ˚F) and leave at a temperature between 30 and 35 ˚C (86 and 95 ˚F). The cycle lasts 10 to 15 minutes, and water rapidly penetrates the carcass skin during this time period (Sams, 2001). Water weight gained in the pre-chiller is strictly regulated and monitored according to poultry classification and final destination of the product by the USDA. Cut-up and ice-packed products are allowed to retain more water than their whole carcass pack or whole frozen counterparts (FSIS, 2001).

The main chill tank's water temperature is approximately 4 ˚C (39 ˚F) at the entrance and 1 ˚C (34 ˚F) at the exit because of the countercurrent flow system. Broiler carcasses stay in this chiller between 45 and 60 minutes and leave the chill tank at about 2 to 4 ˚C (36 to 39 ˚F). Air bubbles are added to the main chill tanks to enhance heat exchange. The bubbles agitate the water and prevent a thermal layer from forming around the carcass. If not agitated, water around the carcass would reach thermal equilibrium with the carcass and retard heat transfer (Sams, 2001).

If air chilling is used, it normally involves passing the conveyor of carcasses through rooms of air circulating at between -7 and 2 ˚C for 1 to 3 hours. In some cases water is sprayed on the carcasses, increasing heat transfer by evaporative cooling (Sams, 2001). Giblets, consisting of hearts, livers, gizzards, and necks, are chilled similarly to carcasses, though the chilling systems are separate and smaller (USEPA, 1975).

4.5.1.6 Packaging and Freezing

After the birds are chilled, they are either packed as whole birds or processed further. Whole birds are sold in both fresh and frozen forms. Chickens are primarily sold as fresh birds and turkeys are primarily sold as frozen birds. Fresh birds not sold in case-ready packaging are packed in ice for shipment to maintain a temperature of 0 ˚C (32 ˚F). Poultry sold frozen is cooled to approximately -18 ˚C (0 ˚F) (Wilson, 1998).

4.5.2 Poultry Further Processing Operations

Further processing can be as simple as splitting a carcass into two halves or as complex as producing a breaded or marinated, partially or fully cooked product. Therefore, further processing may involve receiving, storage, thawing, cutting, deboning, dicing, grinding, chopping, canning, and final product preparation. Final product preparation includes freezing, packaging, and shipping. Further processing may be performed after first processing in an integrated operation, or it may be performed at a separate facility. Further processing is a highly automated process designed to transform eviscerated broiler carcasses into a wide variety of consumer products. Depending on the type of product being produced, plant production lines may overlap, especially for producing cooked, finished products (USEPA, 1975). The following sections describe poultry first processing operations. Figure 4-11 illustrates these series of operations.

4.5.2.1 Receiving and Storage

If further processing takes place at a location separate from first processing, carcasses, cut-up parts, and deboned meat are usually transported by truck. The vast majority of first processing products received for further processing are whole carcasses. Further processing operations separate from first processing or killing operations may receive poultry that already has been further processed to some degree, typically cut-up or deboned. Further processing plants that are separate from killing operations usually process poultry received packed in ice or frozen, whereas further processing operations combined with killing operations usually process whole carcasses directly following chilling. Thus, further processing plants separate from killing operations require refrigerated or freezer storage facilities before further processing, whereas further processing operations combined with killing operations do not require these facilities except for the preservation of final products. Seasonings, spices, and chemicals are usually received in dry form and stored in dry areas conveniently located near sauce, spice, butter, and breading formulation areas (USEPA, 1975).

4.5.2.2 Thawing

Frozen poultry carcasses and components thereof received by further processing plants can be thawed by immersing in water, by spraying with water, or by thawing in air with adequate protection against contamination. In immersion, poultry is submerged in tanks or vats of lukewarm potable water for the time required to thaw the poultry throughout. To prevent spoilage, the USDA does not permit the continuous running tap water temperature to exceed 21 ˚C (70 ˚F) (9 CFR 381.65). Ice or other cooling agents may be used to keep the thawing water within the acceptable temperature range. The vats used for thawing range from pushcarts of 10 to 20 cubic feet in volume to substantially larger permanently installed tanks. Agitation may be induced to enhance thawing by adding water continuously or by pumping filtered air through flexible hoses into the immersion tank (USEPA, 1975). In thawing units that have no

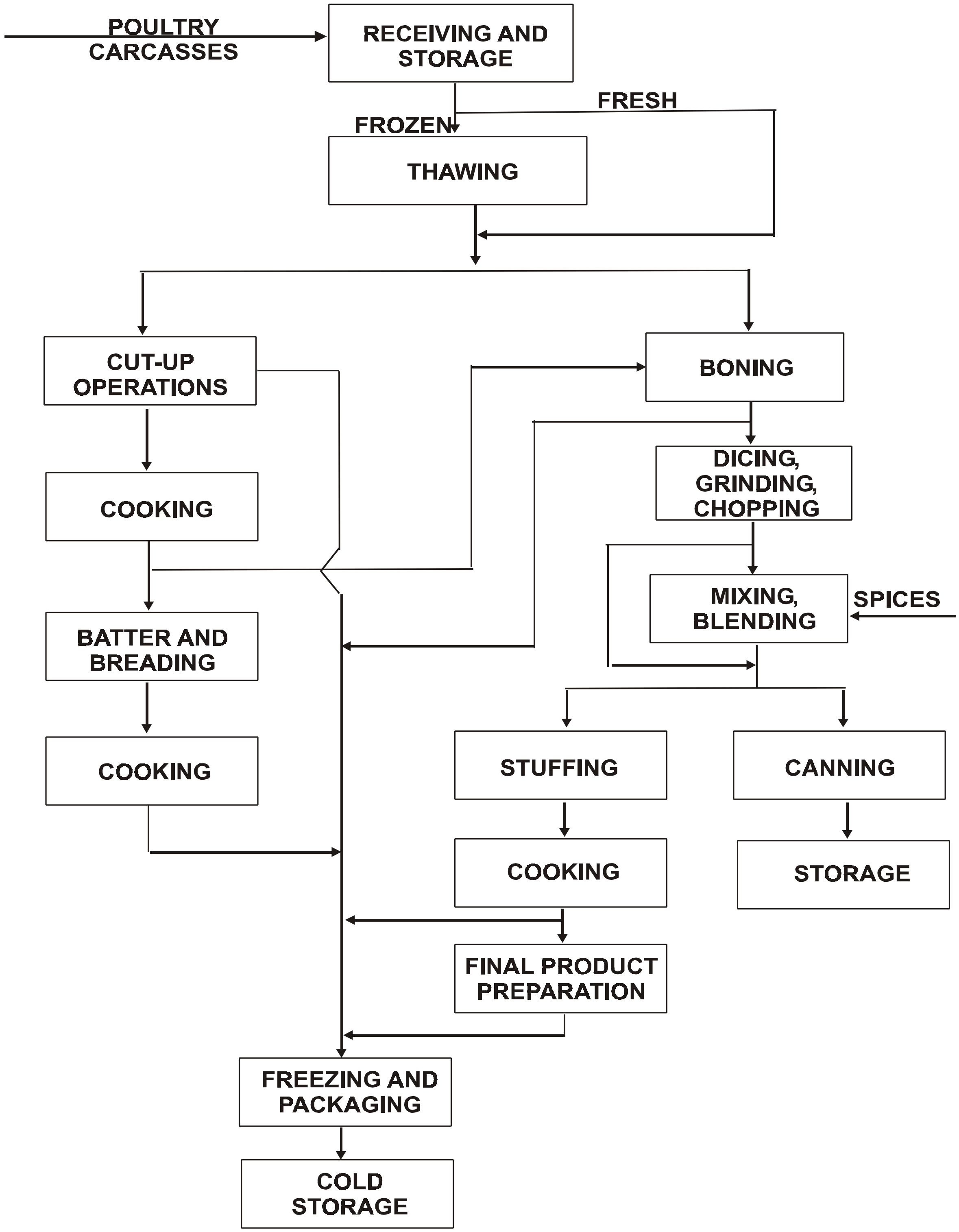

Figure 4-11. General Process Flowsheet for Poultry Further Processing Operations (USEPA, 1975)

freshwater added (no overflow) or where the thawing water leaves the unit for reconditioning prior to returning to the thawing unit, the water is not allowed to exceed 10 ˚C (50 ˚F), as required by the USDA (9 CFR 381.65).

Complete thawing is necessary to permit thorough examination of poultry prior to any further processing. When the poultry has adequately thawed for reinspection, the product is removed from the water and drained. Some plants prefer to place frozen poultry directly into cooking kettles prior to thawing. This practice is permitted only when representative samples of the entire lot have been thawed and found to be in sound and wholesome condition. In this case, cookers filled with water are heated to enable the cooking process to begin immediately following completion of thawing. USDA requires that thawing practices and procedures result in no net gain in weight over the frozen weight (9 CFR 381.65).

If the only further processing operation is repackaging whole carcasses or parts for shipment to market, USDA regulations prohibit recooling the thawed parts in slush ice. Mechanical refrigeration is required; however, the whole carcasses or parts may be held in tanks of crushed ice with open drains, pending further processing or packaging (9 CFR 381.65).

4.5.2.3 Cutting

Cutting of poultry is normally the first further processing step for fresh ice-packed and just-thawed poultry. Cutting involves disjointing and sawing of poultry into various parts. The specifics of these parts became regulated by the government in 1986, when the Food Safety Inspection Service (FSIS) of the USDA published guidelines for cuts of poultry (FSIS, 2001). Using these guidelines as the standard, further processing plants cut poultry into parts manually or automatically. Mechanized equipment that processes entire carcasses into various cut portions is available. The following parts are removed in descending order: neck skin, wings, breasts, backbone, and finally thighs (which can be separated from the drumsticks, if desired). Manual cuts can be made or a machine can be used to make horizontal and vertical cuts, if further portion uniformity is desired. Up to 2,000 birds an hour can be processed this way. The only manual labor required is feeding carcasses into the machine (Mead, 1989).

4.5.2.4 Deboning

After poultry has been cut into parts, the parts may be deboned (separation of meat from bone). Both raw and cooked poultry can be deboned. Frequently turkeys, because of their size, are deboned raw, while chickens and similarly sized poultry can be deboned either raw or cooked (USEPA, 1995). Chicken cooked before deboning will retain its characteristic chicken flavor, while chicken cooked after deboning tastes like meat; therefore, cooked chicken is deboned for products for which chicken flavor is desired, and raw chicken is deboned for products for which a meat flavor is desired. Additional seasonings can be added to the raw chicken after it has been deboned to further enhance its flavor (Mead, 1995). Deboning is usually performed with specially designed machines, but it may be done manually. Bones are collected for rendering (USEPA, 1975).

When deboning is mechanized, the meat either retains its original shape or is ground into a thick paste. If the original shape is desired, the portions are fed into machines where a specially designed mold fits over the poultry cut. As the mold compresses the portions, the meat slides away from the bone. If cooked meat is to be used in other food products, it is placed into a machine that acts much like a hydraulic press, compacting the meat and bone against several different screens. The meat passes through these screens while the bone remains behind, creating a thick paste of condensed poultry meat (Mead, 1989).

4.5.2.5 Grinding, Chopping, and Dicing

Many poultry products such as patties, rolls, and luncheon meats require size reduction of boned meat. Grinding, chopping, and dicing vary the degree of size reduction, with grinding producing the greatest degree of size reduction, chopping the next, and dicing the least. Each of these operations is accomplished by mechanical equipment. In grinding, the meat is forced past a cutting blade and then extruded through orifice plates with holes between 1/8 and 3/8 inch. Chopping likewise is usually accomplished by forcing the meat past a cutter and through an orifice plate; however, the holes are greater than 3/8 inch in diameter (the specific orifice size is chosen based on the desired nature of the final product). Dicing is more like a cutting operation in that it makes distinct cuts in the meat to produce square-shaped chunks (USEPA, 1975).

4.5.2.6 Cooking

Some further processed poultry products are cooked at some point in processing. This step is done in preparation of a final product or in preparing whole birds for subsequent deboning, the latter applying particularly to processing chickens. Partially and fully cooked poultry products are frequently prepared in further processing operations, especially for the hotel, restaurant, institutional and fast-food markets (USEPA, 1975).

Most poultry products are cooked by immersion in water in steam-jacketed open vats. Gas-fired ovens are used for some products, such as breasts that are not breaded. A small number of microwave ovens are used in place of immersion cookers, and deep fat frying is used for breaded products (USEPA, 1975).

Chicken parts, whole birds, and products such as rolls and loaves may be cooked by immersion in hot water cookers. Overflow wires are used in these cookers to collect edible chicken or turkey fat during the actual cooking operation. At the end of the processing day, the contents of cooking vats are dumped into the wastewater collection system (USEPA, 1975).

Gas-fired ovens require essentially no water for operation. A small quantity of steam may be added for humidity control, but it is usually vented through the facility’s stack system (USEPA, 1975).

The use of microwave ovens frequently requires a preliminary injection of spices and preservatives using multiple-needle injection equipment similar to the equipment used in ham and bacon processing. The solution remaining at the end of the operating day is discarded into the into the wastewater collection system (USEPA, 1975).

All cooked products are cooled before any further processing. The most common cooling technique for cooked products is immersion into a cold-water tank with continuous overflow (USEPA, 1975).

4.5.2.7 Batter and Breading

Fully cooked poultry parts or fresh fabricated products may be battered and breaded to produce a desired finished product. The batter is a water-based pumpable mixture, usually containing milk and egg solids, flour, spices, and preservatives. A new batch of batter is prepared each operating day. The batter is pumped through the application equipment, and the excess flows back to the small holding tank. Some of the batter clings to the application equipment; this is cleaned off during the day (USEPA, 1975).

The breading is a mixture of solids deposited on the poultry product after the batter is applied. There is no liquid used in breading the products, and the residual solids are not disposed of into the wastewater collection system. The breading is "set," "browned," or cooked by deep fat frying in vegetable oil. Breaded products are conveyed through a deep-fat fryer that is heated directly by gas flame or is heated by the circulation of hot oil from a heater separate from the fryer. The vegetable oil in the fryer is reused repeatedly. When vegetable oil disposal is necessary (after the end of each production shift), it is shipped to a renderer (USEPA, 1975).

4.5.2.8 Mixing and Blending

Some of the further processed products require mixing of several ingredients, including ground or chopped meat, dry solids, spices, and water. The required intermixing speed and intensity of these ingredients varies, depending on the product, from a gentle blending action to an intense high-shear mixing action. Gravies and sauces are prepared in mixers that usually are steam jacketed for heating. The ingredients are pumped or manually transported to the mixing equipment for the preparation of batches of the product mix (USEPA, 1975).

4.5.2.9 Stuffing and Injecting

Following the preparation of a mixture of ingredients for a processed poultry product, the mixture is pumped or transported manually in a container to a manufacturing operation, where the mixtures are formed into the finished products. Either natural or synthetic sausage casings are commonly used as containers in this operation (USEPA, 1975).

To stuff cases, a product mixture is placed in a piece of equipment from which the product mixture is either forced by air pressure or pumped to fill the casing uniformly and completely to form the finished product. Water is used to lubricate casings for use in the stuffing operation (USEPA, 1975).

Whole bird stuffing, which is performed primarily with turkeys, involves pumping a stuffing mixture into the body cavity of a dressed bird at a stuffing station, followed by trussing and freezing of the stuffed bird (USEPA, 1975).

Whole birds are often injected with edible fats and oils, such as butter, margarine, corn oil, and cottonseed oil, to enhance their palatability. Again, this is primarily done with turkey carcasses. This step is normally accomplished by inserting small, perforated needles into the carcass in such a manner as to direct the injected fat or oil between the tissue fibers. The preferred method is to inject longitudinally into the carcass without penetrating the skin of the carcass, so the intact overlying skin will retard escape of the injected materials. The injection material can be used for 1 day after preparation, but it must be discarded at the end of the second processing day. Most plants minimize or avoid any disposal of this high-cost material by preparing only the quantity needed (USEPA, 1975).

4.5.2.10 Canning

The containers used to hold canned poultry products must be prepared before filling and covering. The cans must be cleaned and sterilized before being filled. The sterilized cans are transported from the preparation area to the processing area for filling and closure. Water is frequently present all along the can lines from preparation to filling and covering to remove any spilled product from equipment used, from outer can surfaces, and from condensed steam. The cans go through one last steaming just before entering the can filling area. Can filling can be done by hand or mechanically. However, canning of whole birds or disjointed parts necessitates hand filling (USEPA, 1975).

Can filling by machine is a high-speed operation. It requires moving the poultry food products to the canning equipment, and it provides the automated delivery of those products into a container. The high speed and the design of the equipment result in an appreciable amount of spillage of product as the cans are filled and conveyed to the closure equipment. At the can closure station, a small amount of steam is introduced under the cover just before the cover is sealed to create a vacuum in the can when it cools. Steam use also generates a quantity of condensate that drains off the cans and equipment onto the floor. The operation of the filling and covering equipment results in a substantial quantity of wastewater containing product spills, which is wasted to the wastewater collection system. Filling cans by hand does not appear to generate as much spillage. Canning plants that have more than one filling and covering line have a waste load that is generally proportional to the number of such lines in use (USEPA, 1975).

Canned poultry food products are preserved by heating to destroy any bacteria present. This is accomplished by cooking or by retorting (the pressurized cooking of canned products). Steam is used as the heating medium in retorting, and it is common practice to bleed or vent steam from the retort vessels to maintain a constant cooking pressure. Cooking without pressure is used for cured boneless canned poultry products; the products are considered perishable and must be kept refrigerated. Virtually no wastewater or solid waste is generated by retorting or cooking operations unless a can in a particular batch accidentally opens and spills its contents. This event requires wasting of the contents of that can and cleanup of the cooking vessel. Such accidents rarely happen; thus the retorts or cooking vessels, as a matter of normal practice, are not cleaned (USEPA, 1975).

4.5.2.11 Final Product Preparation

Many of the final products from a poultry plant are ready to serve after heating and are prepared for the hotel, restaurant, and institutional markets. These products are portion-controlled, may have gravy or a sauce added, and are packaged in containers of an appropriate size and design for immediate heating and serving. Poultry meat patties, slices of turkey loaf, and chicken parts are examples of the types of poultry products prepared in this manner. Equipment is used to convey and slice the meat product and deposit it into containers. The same equipment delivers and adds the sauce or gravy to the meat in the container, as required for specific products. As the final operation, this equipment closes the individual containers (USEPA, 1975).

4.5.2.12 Freezing

The first step in the freezing of further processed poultry products is usually accomplished by blast freezing, in which the product is frozen by high-velocity air within the range of -40 to -29 ˚C (-40 to –20 ˚F) or by first passing the product through a carbon dioxide or nitrogen tunnel in which the change in phase of carbon dioxide or nitrogen from liquid to gas causes rapid surface freezing. The products are then placed in holding freezers in which the temperature is maintained at between -29 and -18 ˚C (-20 and 0 ˚F) (USEPA, 1975).

4.5.2.13 Packaging

Packing protects products against damage, contamination, and dessication. Packaging also can extend the shelf-life of fresh poultry and improves product presentation (Mead, 1995). A variety of packaging techniques are used for further processed poultry products. These techniques include the use of plastic film sealed under vacuum (Cry-O-Vac packaging), the bubble enclosure packages used for sliced luncheon meats, and the boxing of smaller containers or pieces of finished product for shipment (USEPA, 1975).

In some techniques of packaging, a substantial amount of product handling is involved, which may result in some wasted finished product. However, pieces of wasted finished product are usually returned for subsequent use in another processed product or directed to a renderer (USEPA, 1975).

4.5.2.14 Shipping

Shipping involves the transportation of finished products and material collected for rendering. Truck transportation is the primary mode of shipping, and products are distributed according to market orders (USEPA, 1975).

Trucks must be pre-chilled prior to loading to maintain the shelf-life of fresh poultry products. Fresh poultry must be maintained at temperatures near freezing with 90 to 100 percent humidity during transport to maintain a shelf-life of 1 to 4 weeks (USDA, 1997). Trucks are loaded through overhead doors leading directly from inside the facility into the truck. Therefore, there typically is no loading dock exposed to the elements, so that pollutants in any runoff from truck loading areas are only those commonly associated with vehicle parking areas. The pollutant load is wastewater concentrated by cleanup of inside loading areas, and it is variable depending on the method of packaging. Ice pack products generate a higher pollutant load from icemelt than do packaged products. However, loading areas are not a significant source of wastewater pollutant loads.

4.6 DESCRIPTION OF RENDERING OPERATIONS

This section provides an overview of the U.S. rendering industry for the preparation of edible and inedible rendered products. This section is divided into three subsections: industry characterization, process description, and emerging technologies.

4.6.1 Industry Characterization

The Rendering and Meat Byproduct Processing (NAICS 311613) sector includes facilities engaged in the rendering of inedible (i.e., not suitable for human consumption) stearin, grease, and tallow from animal fat bones and meat scraps, and the manufacturing of animal oils, including fish oil, and fish and animal meal. The edible (i.e., suitable for human consumption) rendering industry is included in Standard Industrial Classification (SIC) Code 2011. Many facilities not classified as rendering facilities perform rendering operations but are not classified as such because they are also engaged in slaughtering (first processing). These facilities are often on-site (or "integrated") rendering facilities that are part of an animal or poultry slaughtering facility. Integrated rendering plants normally process only one type of raw material, whereas independent rendering plants often handle several types of raw material that require either multiple rendering systems or significant modifications in the operating conditions for a single system.

The rendering sector consists of 137 companies that own or operate 240 facilities. The sector employs 8,800 workers and generates $2.6 billion in shipments. Texas and California have the largest number of rendering facilities. Unlike the meat or poultry industry sectors, the rendering industry sector includes few large facilities; only 11 rendering facilities employed more than 100 workers per facility in 1997. Rendering facilities tend to collect most of their raw material from farms, animal feeding operations, first processors, further processors, and restaurants (e.g., grease from traps and fryers). Rendering collection areas for raw material are limited by cost of transportation and travel time for the raw material to reach the rendering facility. Many rendering facilities have limited overlap of collection areas with other rendering facilities. The 132 rendering facilities that employ between 20 and 99 workers account for the largest share of the industry shipments (66 percent).

As with the meat and mixed meat animal first and further processing sectors, EPA is using revised production rate thresholds to exclude most smaller rendering facilities from the January 31, 2002, proposed revisions to 40 CFR Part 432. Based on the current screener survey data, EPA is defining small rendering facilities as those which produce less than 10 million pounds of rendered product per year. See to Figures 4-12 and 4-13 for the distribution of small and non-small rendering facilities further categorized by discharge type throughout the United States.

4.6.2 Rendering (Meat and Poultry By-product Processing) Description

Rendering processes are processes used to convert the by-products of meat and poultry processing into marketable products, including edible and inedible fats and proteins for agricultural and industrial use. Materials rendered include viscera, meat scraps including fat, bone, blood, feathers, hatchery by-products (infertile eggs, dead embryos, etc.), and dead animals. Lard and foodgrade tallow are examples of edible rendering products. Inedible rendering products include industrial and animal feedgrade fats, meat and poultry by-product meals, feather meal, dried blood, and hydrolyzed hair.

Rendering plants that operate in conjunction with animal slaughterhouses or poultry processing plants are called integrated rendering plants. Plants that collect their raw materials from a variety of off-site sources are called independent rendering plants. Independent plants

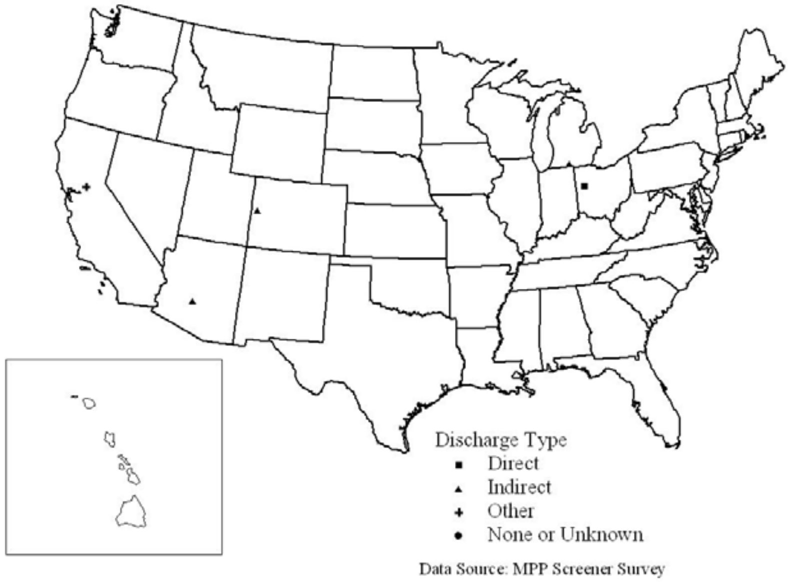

Figure 4-12. Location of Small Rendering Facilities in the United States (Based on Screener Survey Data).

Figure 4-13. Location of Non-Small Rendering Facilities in the United States (Based on Screener Survey Data).

obtain animal by-product materials from a variety of sources, including butcher shops, supermarkets, restaurants, fast-food chains, poultry processors, slaughterhouses, farms, ranches, feedlots, and animal shelters (USEPA, 1995).

Edible rendering plants separate fatty animal tissue into edible fats and proteins. The edible rendering plants are normally operated in conjunction with meat packing plants. The USDA Food Safety and Inspection Service (FSIS) is responsible for regulating and inspecting meat and poultry first and further processing facilities and facilities engaged in edible rendering (i.e., suitable for human consumption) to ensure food safety. The U.S. Food and Drug Administration (FDA) covers inedible rendering operations. Inedible rendering plants are operated by independent renderers or are part of integrated rendering operations. These plants produce inedible tallow and grease, which are used in livestock and poultry feed, pet food, soap, chemical products such as fatty acids, and fuel blending agents.

4.6.2.1 Edible Rendering

A typical edible rendering process is shown in Figure 4-14. Fat trimmings, usually consisting of 14 to 16 percent fat, 60 to 64 percent moisture, and 22 to 24 percent protein, are ground and then belt conveyed to a melt tank. The melt tank heats the materials to about 43 ˚C (110 ˚F), and the melted fatty tissue is pumped to a disintegrator, which ruptures the fat cells.

The proteinaceous solids are separated from the melted fat and water by a centrifuge. The melted fat and water are then heated with steam to about 93 ˚C (200 ˚F) by a shell and tube heat exchanger. A second-stage centrifuge then separates the edible fat from the water, which also contains any remaining protein fines. The water is discharged as sludge, and the "polished" fat is pumped to storage. Throughout the process, direct heat contact with the edible fat is minimal, and no cooking vapors are directly emitted (USEPA, 1995).

Edible lard and tallow are the main foodstuffs produced from continuous edible rendering of animal fatty tissue. Either the low temperature option or the high temperature option edible rendering processes may be used to render edible fat. The low temperature option uses temperatures below 49 ˚C (120 ˚F) and the high temperature option uses temperatures between

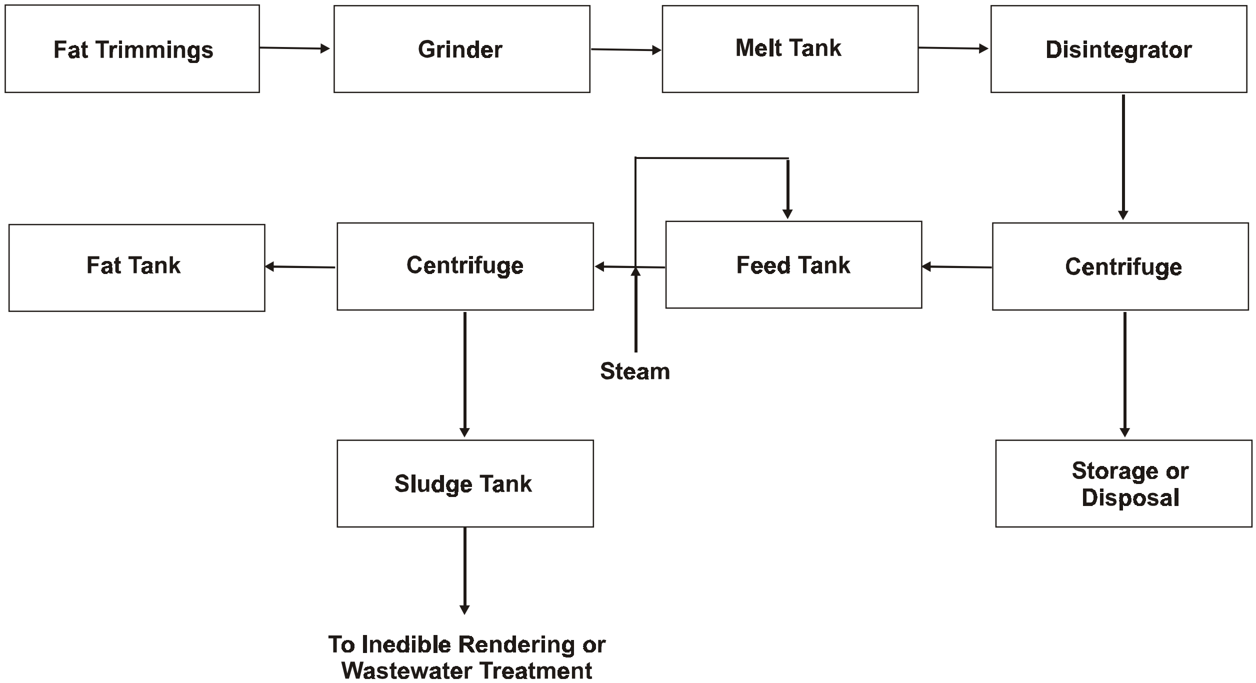

Figure 4-14. General Process for Edible Rendering (USEPA, 1995).

82 and 100 ˚C (180 and 210 ˚F) to melt animal fatty tissue and to separate the fat from the protein. A better separation of fat from protein can be achieved with the high temperature option; however, the protein obtained from the low temperature option is of acceptable quality, wheras the protein obtained from the high temperature option cannot be sold as an edible product (Prokop, 1985).

4.6.2.2 Inedible Rendering

Table 4-1 shows the fat, protein, and moisture contents for several raw materials processed by inedible rendering plants. There are two processes for inedible rendering: the wet process and the dry process. Wet rendering separates fat from raw material by boiling in water. The process involves adding water to the raw material and using live steam to cook the raw material and separate the fat. Dry rendering is a batch or continuous process in which the material being rendered is cooked in its own moisture and grease with dry heat in open steam-jacketed drums until the moisture has evaporated. Following dehydration, as much fat as possible is removed by draining, and the residue is passed through a screw press to remove some

Table 4-1. Composition of Raw Materials for Inedible Rendering

Source	Tallow/grease Wt %	Protein Solids Wt %	Moisture Wt %
Packing house offal[a] and bone			
Steers	30-35	15-20	45-55
Cows	10-20	20-30	50-70
Calves	10-15	15-20	65-75
Sheep	25-30	20-25	45-55
Hogs	25-30	10-15	55-65
Poultry offal	10	25	65
Poultry feathers	None	33	67
Dead stock (whole animals)			
Calves	10	22	68
Sheep	22	25	53
Hogs	30	28	42
Butcher shop fat and bone	31	32	37
Blood	None	16-18	82-84
Restaurant grease	65	10	25

[a] Waste parts; especially the viscera and similar parts from a butchered animal.
Source: USEPA, 1995.

of the remaining fat and moisture. Then the residue is granulated or ground into a meal. At present, only dry rendering is used in the United States. The wet rendering process is no longer used because of the high cost of energy and because of its adverse effect on the fat quality (USEPA, 1995).

Inedible rendering can be divided into two subcategories: feed grade and pet food grade rendering. In addition, the poultry industry uses a third subcategory of inedible rendering called glomerate rendering. Glomerate rendering is the oldest rendering process, dating back to the beginnings of slaughterhouses when all animal by-products were rendered and fed back to animals as a feed. The glomerate process involves combining meat and feathers and cooking them together to produce feed for poultry. Because more plants further process poultry than they did in the past, a greater amount of bones, backs, and necks are included in the rendering process. The ratio of meat to feathers varies throughout the day, generally resulting in increased protein concentrations toward the end of the day. Glomerate rendering is not widely used today because of the highly variable protein concentrations of the final products (Christensen, 1996).

Feed grade rendering has the largest market because livestock and poultry feed manufacturers purchase the products produced in bulk to use as feed ingredients. This process requires that fat and protein and hog hair or poultry feathers be separated, though crude techniques are used. The meat is cooked down into meal and the feathers or hair are hydrolyzed before they are sold to the livestock and poultry feed manufacturers (Christensen, 1996).

Pet food grade rendering is the most profitable type of rendering and has an $8 billion market worldwide each year. Strict separation of materials is required because purchasers are very concerned with texture, color, ash content, and quality of the final product. Blood and feathers or hair cannot be included in pet food (Christensen, 1996).

The following sections describe the two typical inedible rendering processes, batch rendering and continuous rendering. Both can be used to produce either feed grade or pet food grade protein meal and fat. As discussed previously, the grade of the rendered products depends on the types of raw materials included and excluded. Since the 1960s continuous rendering systems have been installed to replace batch systems at most plants. Currently, only a few batch cooker plants remain in operation in North America (Lehmann, 2001).

4.6.2.2.1 Batch Rendering Process

Figure 4-15 shows the basic inedible rendering process using multiple batch cookers. In the batch process, the raw material from the receiving bin is screw conveyed to a crusher, where it is reduced to 2.5 to 5 centimeters (1 to 2 inches) in size to improve cooking efficiency. Cooking normally requires 1.5 to 2.5 hours, but adjustments in the cooking time and temperature may be required to process the various materials. A typical batch cooker is a horizontal, cylindrical vessel equipped with a steam jacket and an agitator. To initiate the cooking process, the cooker is charged with raw material and the material is heated to a final temperature ranging from 121 to 135 ˚C (250 to 275 ˚F). Following the cooking cycle, the contents are discharged to

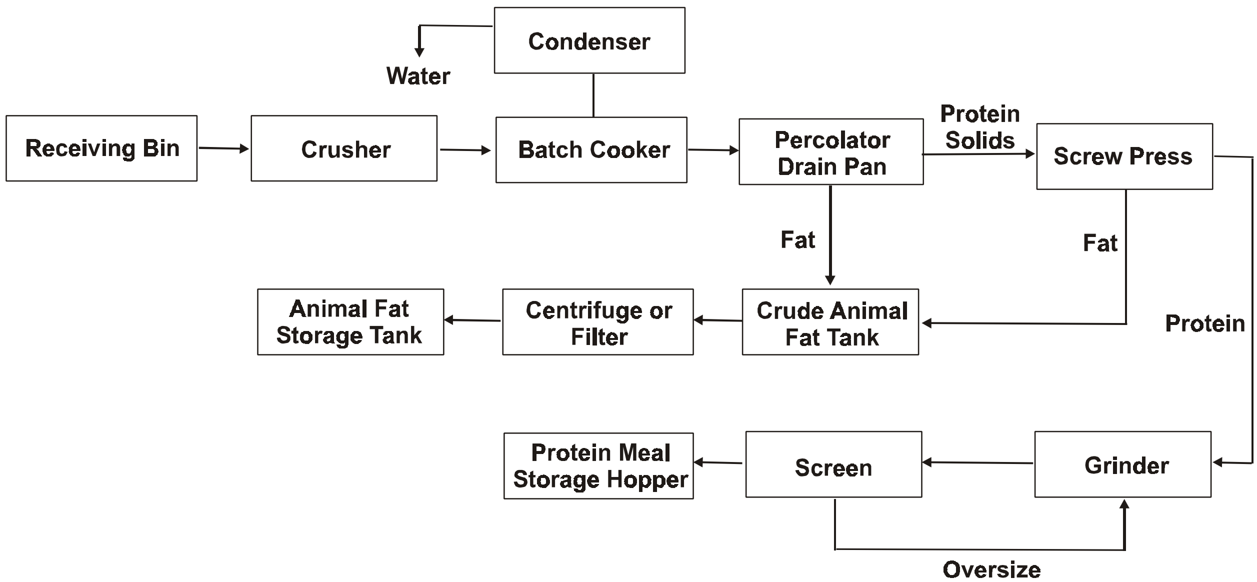

Figure 4-15. General Process for Inedible Batch Cooking Rendering (USEPA, 1995).

the percolator drain pan. Vapor emissions from the cooker pass through a condenser, which condenses the water vapor and emits the noncondensibles as volatile organic compound (VOC) emissions (USEPA, 1995).

The percolator drain pan contains a screen that separates the liquid fat from the protein solids. From the percolator drain pan, the protein solids, which still contain about 25 percent fat, are conveyed to a screw press. The screw press completes the separation of fat from solids and yields protein solids that have a residual fat content of about 10 percent. These solids, called cracklings, are then ground and screened to produce protein meal. The fat from both the screw press and the percolator drain pan is pumped to the crude animal fat tank, centrifuged or filtered to remove any remaining protein solids, and stored in the animal fat storage tank (USEPA, 1995).

4.6.2.2.2 Continuous Rendering Process

A typical continuous rendering process is shown in Figure 4-16. The system is similar to a batch system, except that a single, continuous cooker is used rather than several parallel batch cookers. A typical continuous cooker is a horizontal, steam-jacketed cylindrical vessel equipped with a mechanism that continuously moves the material horizontally through the cooker.

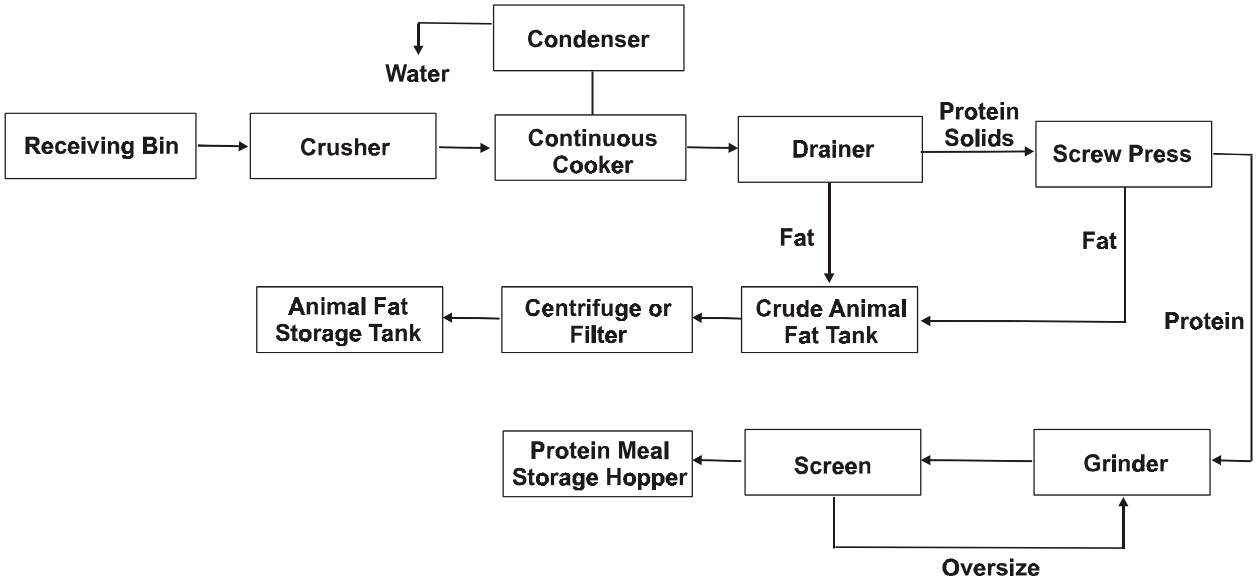

Figure 4-16. General Process for Inedible Continuous Rendering (USEPA, 1995).

Continuous cookers process the material faster than batch cookers and typically produce a higher quality fat product. From the cooker, the material is discharged to the drainer, which serves the same function as the percolator drain pan in the batch process. The remaining operations are generally the same as the batch process operations (USEPA, 1995).

In the 1980s newer continuous rendering systems were developed to precook the raw material and to remove moisture from the liquid fat prior to the cooker/drier stage. These systems use an evaporator operated under vacuum and heated by the vapors from the cooker/drier. One system, termed waste-heat dewatering (WHD), consists of treating the raw material in a preheater followed by a twin-screw press. The solids from the press are directed to the cooker/drier. The liquid fat is sent to an evaporator operated under a vacuum and heated by the hot vapors from the cooker/drier to a temperature of 70 to 90 ˚C (160 to 200 ˚F). In the evaporator, the moisture evaporates from the liquid fat and passes to a water-cooled condenser. The dewatered fat is recombined with the solids from the screw press prior to entry into the cooker/drier. These pretreatment systems may reduce fuel costs by 30 to 40 percent and increase production throughput by up to 75 percent (USEPA, 1995). Several inedible continuous rendering systems exist, including the Duke System, the Anderson C-G (Carver-Greenfield) System, and the Atlas Stord Waste Heat Dewatering System.

Duke Continuous Rendering System (Inedible Rendering)

The process of the Duke system is similar to that of the batch cooker described earlier. The main difference is that it operates on a continuous basis. The cooker portion of the system, called the Equacooker, is a horizontal steam-jacketed cylindrical vessel equipped with a rotating shaft. Paddles, which are attached to the rotating shaft, lift the material and move it horizontally through the cooker. The rotating shaft also has steam-heated coils to provide increased heat transfer. The Equacooker is divided into three separate compartments that are equipped with baffles to restrict and control the flow of materials through the cooker. Adjusting the speed of the variable-speed drive for the twin-screw feeder controls the feed rate to the Equacooker, while the discharge rate is controlled by the control wheel rotation speed. The control wheel has buckets that collect the cooked material from the Equacooker and discharge it into the Drainor. A site glass column, located adjacent to the control wheel, shows the operating level in the cooker; a photoelectric cell unit shuts off the twin-screw feeder when the upper level limit is reached. The Drainor is an enclosed screw conveyor that contains a section of perforated troughs, which allow the free melted fat to drain through as the solids are conveyed to the Pressor or screw press for additional separation of tallow. Similar to any other screw press used with a batch cooker, the Pressor reduces the grease level of the crackling (Prokop, 1985).

The central control panel, which consolidates the process controls for the system, houses a temperature recorder, stream pressure indicators, equipment speed settings, motor load gauges, and stop and start buttons. This design facilitates operation of the controls so that only one person is needed to operate the Equacooker portion of the Duke system (Prokop, 1985).

Anderson C-G (Carver-Greenfield) System (Inedible Rendering)

The Anderson C-G system differs from most other systems in several aspects. Instead of using screw conveyors, recycled fat carries the raw material as a pumpable slurry. An additional grinding step is included to further reduce the size of the particles. Also, the conventional evaporator system with a vacuum is powered by an electrical motor, rather than by steam injectors, to remove moisture from the slurry (Prokop, 1985).

The process begins with a triple-screw feeder that feeds the partially ground raw material continuously, and at a controlled rate, to a fluidizing tank. In the tank, fat that has been recycled through the system at a temperature of 104 ˚C (22 ˚F) suspends the material and carries it to a disintegrator to further reduce the particle size. The final particle size ranges from 0.25 to 1 inch. The slurry is next pumped to an evaporator, which can be either a single or a double-stage unit, and is held under vacuum. Because the vacuum facilitates moisture removal, the C-G system can operate at a lower temperature than other processes. The evaporator consists of a vertical shell and tube heat exchanger connected to a vacuum system. Gravity aids the flow of the slurry through the tubes of the heat exchanger while steam is injected into the shell. Next, the water vapor is separated from the slurry in the vapor chamber, which is under a vacuum pressure of 660 to 710 mm (26 to 28 inches) of mercury. Water vapor then travels through a shell and tube condenser that is connected to a steam-injection vacuum system. Once the vapors are condensed, they exit the condenser through a barometric leg, allowing the vacuum to be maintained. In a two-stage evaporator system, the vapor from the second stage functions as a heating medium for the first stage. Providing steam economy, the two-stage evaporator is especially useful for materials that have a high moisture content. The remaining dry slurry of fat and cracklings is then pumped from the evaporator to a centrifuge that separates the solids from the liquid. A portion of the fat is recycled back to the fluidizing tank, while the remainder is removed from the system. Discharged solids from the centrifuge are screw-conveyed to expellers (screw presses), which reduce the fat content of solids from 26 percent by weight to 6 to 10 percent (Prokop, 1985).

As in the Duke process, the central control panel allows a single person to operate the cooking process. The panel includes level indicators and controls to stabilize the flow through the fluidizing and other process tanks in addition to the vacuum chamber. It also monitors evaporator vacuum and temperature measurements. The panel also has equipment speed settings, motor current readings, and start/stop push buttons (Prokop, 1985).

Atlas Stord Waste Heat Dewatering (WHD) System /(Inedible Rendering)

The Atlas Stord system, formerly called the Stord Bartz WHD System, consists of a preheater, twin-screw press, and evaporator system. It is typically installed with an existing rendering system. As with other processes, the raw material is screw-conveyed from the raw material bin over an electromagnet and is fed to either a prebreaker or hogor for course grinding. The ground material travels through a preheater to melt the fat and condition the animal fibrous tissue properly for the subsequent pressing operation. The preheater is a horizontal, steam-jacketed, cylindrical vessel that has an agitator and rotating shaft to ensure continuous flow and adequate heat transfer. The temperature of the material is controlled within the preheater at 60 to 82 ˚C (140 to 180 ˚F), depending on the type of raw material.

After it is heated, the material is then subjected to the twin-screw press, where it is separated into a solid phase and a liquid phase. The press consists of intermeshing, counter-rotating screws that move inside a press cage assembly. A perforated screen, through which the liquid is pressed, is secured by vertical support plates. The shape of the screen follows the contour of the rotating flights of the twin screws. The material fills the space between the screws and the press cage. The twin screws have a lower diameter shaft and deeper flights at the feed end, providing a larger volume of space. As the screws rotate, the volume of space decreases, creating an increased pressure to the material to squeeze out the liquid through the perforated screen.

After the liquid, consisting of melted fat and water, is squeezed out, a presscake of solids of fat and moisture remains. The solids are screw-conveyed to the existing cooker or dryer, where the moisture is removed. The screw press completes the final separation of fats from the solids. The liquid extracted by the screw press is pumped from the feed tank to the evaporator, which is a tubular heat exchanger that is mounted vertically and is integral with the vapor chamber. Vapors from the existing cooker or drier serve as the heating medium for evaporation. The liquid enters the evaporator at the top and flows by gravity downward through the tubes, then discharges into the vapor chamber maintained under a vacuum of 24 to 26 inches of mercury. A shell and tube condenser with circulating cooling water condenses the vapor. Because the system makes use of vapors from the existing cooker, fuel costs are reduced by 30 to 40 percent (Prokop, 1985).

4.5.3 Blood Processing and Drying

Blood processing and drying is an auxiliary process in meat rendering operations. At the present time, less than 10 percent of the independent rendering plants in the United States process whole animal blood. Whole blood from animal slaughterhouses, containing 16 to 18 percent total protein solids, is processed and dried to recover protein as blood meal. The blood meal is a valuable ingredient in animal feed because it has a high lysine content. Continuous cookers have replaced the batch cookers originally used in the industry because of the improved energy efficiency and product quality provided by continuous cookers. In the continuous process, whole blood is introduced into a steam-injected, inclined tubular vessel in which the blood solids coagulate. The coagulated blood solids and liquid (serum water) are then separated in a centrifuge, and the blood solids are dried in either a continuous gas-fired, direct-contact ring dryer or a steam tube, rotary dryer (USEPA, 1995). Blood from poultry processing usually is processed with feathers to increase the available protein content of feather meal.

4.5.4 Poultry Feathers and Hog Hair Processing.

The raw material is introduced into a batch cooker and is processed for 30 to 45 minutes at temperatures ranging from 138 to 149 °C (280 to 300 °F) and pressures ranging from 40 to 50 pounds per square inch. This process converts keratin, the principal component of feathers and hog hair, into amino acids. The moist meal product, containing the amino acids, is passed either through a hot air, ring-type dryer or over steam-heated tubes to remove the moisture from the meal. If the hot air dryer is used, the dried product is separated from the exhaust by cyclone collectors. In the steam-heated tube system, fresh air is passed countercurrent to the flow of the meal to remove the moisture. The dried meal is then transferred to storage. The exhaust gases are passed through controls prior to discharge to the atmosphere (USEPA, 1995).

4.6 REFERENCES

Christensen, H. 2001. Looking at the basics of the "hidden industry." Dec. 1996: 7 pp. On-line. Internet. Available WWW: http://www.mtgplace.com/articles/p699.asp. (DCN 00120)

Food Safety Inspection Service (FSIS). 2001. "Guidelines for specified cuts of poultry." 26 Feb 1986: 2 pp. On-line. Internet. Available WWW: http://www.fsis.usda.gov/oppde/rdad/fsisdirectives/7110%2D1.pdf. (DCN 00247)

Lehmann, L. 2001. *Glancing back: changes in technology over the last 30 years*. Render, the National Magazine of Rendering. 2 pp. On-line. Internet. Available WWW: http://www.rendermagazine.com/February 2001/GlancingBack.html. (DCN 00121)

Mead, G.C., ed. 1989. *Processing of poultry*. New York, NY: Elsevier Science Publishing Co., Inc. Prokop, William H. *Rendering systems for processing animal by-product materials*. Papers from the Symposium on Animal Fats presented at the 74th AOCS Annual Meeting held in Chicago, Illinois, May 8-12, 1983. *Journal of the American Oil Chemists' Society* 62(4):805-811. 1985. (DCN 00124)

Prokop, W. 1985. *Rendering systems for processing animal by-product materials*. Papers From the Symposium on Animal Fats Presented at the 74th AOCS Annual Meeting Held in Chicago, Illinois, May 8-12, 1983. *Journal of the American Oil Chemists' Society*. 62(4):805-811.

Sams, A.R., ed. 2001. *Poultry meat processing*. Boca Raton, FL: CRC Press. (DCN 00108 and 00109)

Stadelman, W.J., et al. 1988. *Egg and poultry-meat processing*. New York, NY: Ellis Horwood Ltd. (DCN 00111)

Thorne, J. 2001. Personal Communication. (DCN 10028)

U.S. Department of Agriculture. 2001. *Livestock slaughter 2000 summary*. National Agricultural Statistics Service. Mt An 1-2-1 (01a), Washington, DC. (DCN 00183)

U.S. Department of Agriculture. 1997. *Agricultural transportation handbook*. On-line. Internet. Available WWW:http://www.ams.usda.gov/tmd/export/index.htm. (DCN 00239)

U.S. Environmental Protection Agency. *1997. Emission factor documentation for AP-42 Section 9.5.1. Meat packing plants*. Washington, DC. (DCN 00112)

U.S. Environmental Protection Agency. 1995. *Emission factor documentation for AP-42 Section 9.5.3. Meat rendering plants final report*. EPA Contract No. 68-D2-0159, Washington, DC. (DCN 00125)

U.S. Environmental Protection Agency. 1975. *Development document for proposed effluent limitations guidelines and new source performance standards for the poultry segment of the meat product and rendering process, point source category*. EPA/440/1-75/031-b, Washington, DC. (DCN 00140)

U.S. Environmental Protection Agency. 1974. *Development document for proposed effluent limitations guidelines and new source performance standards for the processor segment of the meat products point source category*. EPA/440/1-74/031, Washington, DC. (DCN 00186)

Wilson, A. *Wilson's practical meat inspection*. 1998. 6th ed. Malden, MA: Blackwell Science, Ltd. (DCN 00106 and 00107)

Warriss, P.D. 2000. *Meat science: an introductory text*. New York, NY: CABI Publishing. (DCN 00103, 00104, and 00105)