23

Meats – Beef and Pork Based

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23.1 Introduction

Beef and pork are two commonly consumed meats that can be processed in many different ways. The primary reason for processing beef and pork is to improve consumer acceptability and convenience of preparation, and to extend shelf life. To achieve this, processing usually accomplishes the following.
1. Remove bones, if applicable.
2. Make connective tissue less objectionable, by removal of extremely tough or inedible pieces.
3. Ensure the fat to lean ratio is appropriate.
4. Maintain the nutritional value of the beef and pork.

Most people associate “meat” with skeletal muscle, but there are also sources of meat that are primarily internal organs. Skeletal muscle makes up most of the meat that is processed and consumed from cattle and pigs but there are several uses and processes for variety meats. Variety meats include the liver, heart, tongue, kidneys, tripe (edible part of the bovine stomach), oxtail, brains, intestines, and blood. Variety meats can be minimally processed before being sold to consumers or used in the formulation of value-added or processed meats.

Beef comes from all classes of cattle, but can vary greatly in quality and processing characteristics depending upon the class of cattle and management of the cattle prior to slaughter and processing. The classes of cattle include steers, which are young castrated males; heifers, which are young females that have not had a calf or been pregnant; cows, which are mature females that have produced offspring; bulls, which are mature uncastrated males. There are other classifications of cattle such as bullocks (young bulls) and heiferettes (young cows that have had one or two calves). Worldwide, there are other terms used to define classes of cattle, such as oxen, which can refer to any castrated male beef, but often is used to indicate a more mature steer, and stag, which refers to an uncastrated male.

Pork is meat from pigs (Sus scrofa or Sus scrofa domesticus), and in many parts of the world is referred to as pigmeat. Pork is often referred to as the most commonly consumed meat in the world despite many cultures that prohibit its consumption. Pork is primarily sourced from young castrated males, called barrows, and young females that have not produced offspring, called gilts. Cull sows, which are mature females that have produced offspring, and boars, which are intact males, are also sources of pork for processing.

23.2 Beef and pork characteristics and quality

23.2.1 Composition of beef and pork

Beef and pork are composed of the same basic components as any other meat, namely protein, water, fat, and a small amount of ash (inorganic matter such as minerals) and very little carbohydrate. The composition of beef and
pork can vary greatly, with protein generally being the least variable and fat and water content being inversely related (Kauffman, 2011). For example, 85% lean beef trimming has a composition of 18% protein, 15% fat, and 64% water, with the remaining 3% being ash and carbohydrate, whereas 75% lean beef trimming has a composition of 16% protein, 25% fat, 56% water, and 3% ash/carbohydrate. Lean pork has a composition that is approximately 75% water, 20% protein, and 2–5% fat, with the remaining amounts being ash and carbohydrate. Approximate values for these meat components are given in Table 23.1.

### 23.2.2 The relationship between beef and pork color, pH, and water-holding capacity

Consumers equate “bright” colors of beef and pork with freshness and quality. Therefore, meat processors attempt to provide consumers with bright-colored beef and pork while still maintaining an acceptable shelf life.

Meat color is determined primarily by the state of the muscle pigment myoglobin (Mancini & Hunt, 2005). Myoglobin is a protein that binds and stores oxygen in living muscle tissue, and does the same thing in meat. When oxygen is present, myoglobin is in the state called oxymyoglobin, and has a bright red color. When there is no oxygen present, myoglobin has a dark color, which is often characterized as being “purple,” which is the color of vacuum-packaged meat. Other molecules can bind to myoglobin to form various colors; for example, carbon monoxide binding results in a bright red color, whereas nitric oxides from meat curing process will cause the familiar pink cured meat color. When myoglobin has been exposed to heat or light, it can become oxidized and form metmyoglobin, which has a brown color. Metmyoglobin can be reduced under certain rare conditions to myoglobin, and regain a bright red color. Other factors that affect meat color include light reflectance, which is influenced by water-holding capacity of the meat. Water-holding capacity is subsequently affected greatly by pH. Beef and pork with a pH of greater than 5.8 are often referred to as being dark, firm, and dry (DFD). Beef and pork that is DFD is generally considered to have lessened consumer acceptance (Wulf et al., 2002). Beef and pork with a pH of less than 5.3 are often pale in color, and referred to as being pale, soft, and exudative (PSE) (Warner et al., 1997).

### 23.2.3 Beef and pork tenderness

Tenderness is the most important palatability factor influencing enjoyment of meat. For beef and pork, tenderness is defined as the amount of force it takes to bite into and chew a piece of meat. Tenderness of meat is often measured using mechanical means that shear through or compress a meat sample. Two common instruments used to measure tenderness are Warner–Bratzler shear force and slice shear force. Both instruments measure the tenderness of cooked meat samples. The Warner–Bratzler shear force involves removing 1.27 cm cores parallel to the muscle fibers and shearing them across the fibers using a dull, V-shaped blade attached to a scale that measures the force required to cut through the sample. Slice shear force uses a flat blade to slice through a single 1 cm thick, 5 cm long sample (Shackelford et al., 1999). Protocols for shear force determination were developed by a committee of the American Meat Science Association and are found in the bulletin *Research Guidelines for Cookery, Sensory Evaluation and Instrumental Tenderness Measurements of Fresh Meat* (AMSA, 1995).

Tenderness of meat is influenced by four primary factors, briefly described here.

- **Protein effects.** Proteins that allow living muscle to do work are called contractile proteins and are primarily made up of actin and myosin. After the animal is slaughtered, these contractile proteins become disrupted over time, mostly due to the action of muscle enzymes called calpains (Goll et al., 2008).
- **Sarcomere length.** The distance between Z-lines in a myofibril is the sarcomere length. In living muscles, contraction results when Z-lines are moved closer together; that is, contracted muscles have a shorter sarcomere length. After slaughter, the sarcomere length becomes fixed at the time of rigor mortis. Shorter sarcomeres result in tougher meat (Wheeler et al., 2000).

### Table 23.1 Composition of beef and pork per g/100 g (USDA, 2011b)

<table>
<thead>
<tr>
<th>Product</th>
<th>Water</th>
<th>Protein</th>
<th>Fat</th>
<th>Ash</th>
<th>Calories (kJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef (lean)</td>
<td>75.0</td>
<td>22.3</td>
<td>1.8</td>
<td>1.2</td>
<td>116</td>
</tr>
<tr>
<td>Beef carcass</td>
<td>54.7</td>
<td>16.5</td>
<td>28.0</td>
<td>0.8</td>
<td>323</td>
</tr>
<tr>
<td>Pork (lean)</td>
<td>75.1</td>
<td>22.8</td>
<td>1.2</td>
<td>1.0</td>
<td>112</td>
</tr>
<tr>
<td>Pork carcass</td>
<td>41.1</td>
<td>11.2</td>
<td>47.0</td>
<td>0.6</td>
<td>472</td>
</tr>
<tr>
<td>Beef fat (subcutaneous)</td>
<td>4.0</td>
<td>1.5</td>
<td>94.0</td>
<td>0.1</td>
<td>854</td>
</tr>
<tr>
<td>Pork fat (back fat)</td>
<td>7.7</td>
<td>2.9</td>
<td>88.7</td>
<td>0.7</td>
<td>812</td>
</tr>
</tbody>
</table>
• **Connective tissue.** The amount and type of connective tissue is very important in beef and pork tenderness. In general, meat from older animals has greater amounts of connective tissue than that from younger animals (Koohmaraie et al., 2002).

• **Composition of the meat.** The amount of fat, water, and protein in meat will affect tenderness. While this is not always a major factor, in general greater amounts of intramuscular fat (marbling) are associated with greater tenderness (Savell & Cross, 1988).

### 23.3 General categories of beef and pork processing

Processing of beef and pork is the utilization of the carcass in a way that makes the products more accessible for consumption or further processing. Following slaughter and dressing, beef and pork carcasses are chilled and initial processing involves cutting of carcasses into smaller pieces. These first, large cuts are referred to as primals and subprimals in the US and as joints in other parts of the world. Further processing of beef and pork involves continuing to break down primals and subprimals into cuts suitable for retail sale and consumption, grinding, making of sausages, cured meats, marinated meats, or cooked meats, and many other less common processing practices.

There are many ways to classify the various processing methods of beef and pork but the two major considerations are whole muscle versus ground, and fresh versus cooked. This gives essentially four major categories of beef and pork products: whole muscle fresh, whole muscle cooked, ground fresh, and ground cooked. In addition, there are several subcategories related to the addition of non-meat ingredients that include functional ingredients, such as salt or nitrites, or flavorings, such as spices and seasoning. There are other ingredient categories such as binders and extenders that will not be covered in depth here but exist to improve product quality or reduce costs. Alternatively, beef and pork products could be classified as whole muscle and ground, with subcategories of cooked, cured, sausage, and many others. Table 23.2 provides a general overview of the different sorts of beef and pork processing commonly undertaken.

### 23.3.1 Fresh whole-muscle beef and pork processing

Fresh beef and pork processing results in products that are sold to consumers while still in the raw or uncooked state. There are two broad categories of fresh beef and pork:

<table>
<thead>
<tr>
<th>Fresh or cooked meat</th>
<th>Ground or whole muscle</th>
<th>Other ingredients</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh beef and pork processing</td>
<td>Whole muscle</td>
<td>No added ingredients</td>
<td>Steaks, chops, roasts</td>
</tr>
<tr>
<td></td>
<td>Ground</td>
<td>Added ingredients</td>
<td>Seasoned or marinated steaks, roasts or chops</td>
</tr>
<tr>
<td></td>
<td>Restructured</td>
<td>No added ingredients</td>
<td>Ground beef, ground pork</td>
</tr>
<tr>
<td></td>
<td>Tenderized</td>
<td>Added ingredients</td>
<td>Fresh sausage, breakfast sausage</td>
</tr>
<tr>
<td>Cooked beef and pork processing</td>
<td>Whole muscle</td>
<td>No added ingredients</td>
<td>Restructured beef roasts</td>
</tr>
<tr>
<td></td>
<td>Ground</td>
<td>Added ingredients (uncured)</td>
<td>Needle tenderized steak and chops, cube steaks, cutlets</td>
</tr>
<tr>
<td></td>
<td>Restructured</td>
<td>Added ingredients (cured)</td>
<td>Cooked beef or pork roast</td>
</tr>
<tr>
<td>Meat</td>
<td></td>
<td></td>
<td>Marinated and cooked roast beef or pork, jerky</td>
</tr>
<tr>
<td>Fermented, dry and semi-dry</td>
<td>Ground</td>
<td></td>
<td>Ham, bacon, dried beef, jerky</td>
</tr>
<tr>
<td>Dried</td>
<td>Whole muscle</td>
<td>Added ingredients (uncured)</td>
<td>Cooked ground beef or pork patties, precooked meatballs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Added ingredients (cured)</td>
<td>Pizza toppings, some sausages</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Most sausages, hot dogs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Restructured cooked roasts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pepperoni, summer sausage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Some jerky</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Country-cured ham, prosciutto</td>
</tr>
</tbody>
</table>
whole-muscle cuts, and ground or minced. Each of these categories can be further broken into those products that have no added ingredients and those with ingredients added. For example, a whole beef roast could be sold at retail, or could have a solution or flavorings added to alter the eating quality. Ground beef and pork could have ingredients added to make them into fresh sausages. In addition, both whole-muscle cuts and minced meat are used as ingredients in further processing.

The “rules” of meat cutting were likely developed by our cavean ancestors and have not changed much since.

- Separate thick from thin, for example the rib and loin from the plate and flank.
- Separate tough from tender, for example the round from the sirloin.
- Separate more valuable from less valuable. Value of cut is often tied to tenderness, but not always. For example, the flank steak has much higher value than the rest of the flank.
- Always cut retail across the grain of the meat. This is not always done for every cut, but is pretty closely followed. The initial processing of beef and pork involves the fabrication of cuts from the whole carcase or carcass sides (Figure 23.1); this is referred to as “breaking” carcases. The next step in most beef processing, and some pork is called “boning” as many of the bones are removed to allow for easier further processing. The resulting large pieces are referred to as primals, which can be further processed into subprimals. In large meat processing operations, it is subprimals that are often sold to other businesses for further processing. The subprimals of beef are found in Table 23.3, along with typical percentage yields. Beef subprimals are often categorized into end cuts such as beef chuck and beef rounds, middle meats, such as the beef rib and loin, and thin or rough cuts such as the beef plate, flank, brisket, and shanks. Table 23.4 lists the primal cuts of pork, which broadly fall into two categories: the “four lean cuts” and the fatty and bony cuts. The four lean cuts contain much of the muscle in the carcase, while the other cuts have greater fat and bone content.

Before reaching consumers, whole muscles from beef and pork are typically broken or further processed into retail cuts. Processing typically includes trimming of excess fat, and fabrication into retail cuts such as steak, chops, and roasts. Retail meat cutting often occurs at the point of sale, such as market and groceries, or at the wholesale level, where processors, often referred to as purveyors, cut retail products for the hotel, restaurant, and institutional markets. Some retail portioning also occurs at the large processor level, where steaks, chops, and roasts are cut and packaged for consumers. This processing method is referred to as case-ready packaging and requires that retail cuts be shipped and stored in packages that limit oxygen exposure to ensure adequate shelf life of the product.

### 23.3.1.1 Institutional meat purchase specifications

Institutional meat purchase specifications (IMPS) are a series of meat product specifications maintained by the United States Department of Agriculture’s Agricultural Marketing Service (NAMP, 2007). These specifications are developed as a voluntary consensus that describes the anatomical location including muscles, bone, and fat present in various wholesale cuts of pork and beef. The IMPS also provide specification for various fresh and cooked meat cuts products. Large-volume purchasers such as federal, state and local government agencies, schools, restaurants, hotels, and other food service users reference the IMPS for procuring meat products.

### 23.3.1.2 Value cuts

Producer groups in the US, especially the National Cattlemen’s Beef Association and the National Pork Board, have investigated alternative cut fabrication to increase the variety of retail cuts available to consumers. These cuts are often referred to as “value cuts” and are generally steak or chops that are fabricated from muscles and cuts that were previously used as roasts or other lower value meats such as shanks or shoulders (von Seggren et al., 2005). The most common of these value cuts is the flat iron steak, which comes from the beef clod, a large cut from the beef shoulder that was typically marketed as a boneless shoulder roast. The flat iron, specifically, is the infraspinatus muscle, which is very tender but has a large band of connective tissue that prevents easy use by consumers. Research in the area showed an economical method to remove the connective tissue, resulting in a retail cut that is now more consumer friendly.

Ultimately, the decision to change cut fabrication for beef and pork carcasses has to be driven by greater profit potential. This may come from the ability to market various muscles at a greater price or to meet the needs of valued customers. In general, the “low hanging fruit” of value cuts have been found and are being produced. For example, removal of the teres major (shoulder tender) from the beef shoulder clod is now common, and cutting of the flat iron is also routine for many processors. These muscles are fairly easy to remove from the associated subprimal.
especially the shoulder tender, which does not require much modification of the processing line or training of personnel, nor does it devalue the rest of the cut. The next step in anatomical deboning is removal of whole muscles without concern for traditional breaking into primals. Research shows that tenderness variation within muscle should provide guidance as to the separation point of cuts, especially in beef (Searls et al., 2005).
23.3.2 Beef and pork bind values

Bind refers to the ability of meat pieces to attach to each other, resulting in textures and products that meet consumer expectations. For example, consumers expect cooked sausages to have a cohesive texture, and chunked and formed boneless hams to have an appearance that is similar to whole-muscle hams. There are three essential parts to achieving bind:

- intrinsic binding proteins must be brought to the meat surface to form a protein-protein interaction
- the meat must be pliable so it can be formed
- the proteins must be coagulated (bound) by cooking or heating (Pearson & Gillett, 1996).

Meat proteins, especially the contractile proteins actin and myosin, are brought to the surface of the meat ingredients through salt addition and mechanical action. The proteins that cause bind are often referred to as salt-soluble proteins and are made up of the contractile muscle fiber proteins, myosin and actin. Salt is required, as these proteins are not soluble in water; the salt changes the ionic strength of the water and allows proteins in the meat to come to the surface. The most common salt used to achieve bind is simple table salt, sodium chloride (NaCl), but potassium chloride can be used in the production of low-sodium products. This is referred to as protein extraction. Massaging or tumbling of raw materials increases the amount of protein that comes to the surface. The surface of the meat pieces becoming “shiny” after the
addition of salt and mechanical action (tumbling or massaging) are the muscle proteins that allow the meat to bind. In addition, tumbling or massaging also improves the pliability of the raw meat, allowing it to be formed. Finally, when exposed to cooking temperature, the proteins will bind together, ideally forming a bond that is almost undetectable in formed meat products.

There are alternatives to using muscle proteins to bind meat, such as alginates, transglutaminase enzyme (Kuraishi et al., 1997), or other products called cold binders. These bind meat pieces together by forming a layer between the pieces, causing them to bind, or by linking proteins on the meat surface. The most common examples of whole-muscle formed products are formed hams, turkey breast, and beef roasts.

23.3.2.1 Fresh whole muscle product with added ingredients

Whole-muscle cuts can also have added ingredients to increase options available to consumers. The simplest ingredients added to beef and pork whole-muscle cuts are seasoning and spices that are applied to the surface of the meat and then packaged. These products allow processors to add flavors to products without greatly increasing processing complexity. For example, lemon pepper pork tenderloin is produced by simply adding spices to the pork. Another strategy besides adding ingredients to whole-muscle cuts is the practice of “enhancing” or injecting solutions into fresh meats. A typical enhancement solution, utilized to improve palatability traits, includes water, salt, phosphates, and possibly an antioxidant (Hoffman, 2006). In addition, it is possible to add tenderizing enzymes, such as those derived from tropical plants such as papain from papaya or bromelin from pineapples, to tenderize tougher cuts of meat (Ashie et al., 2002).

23.3.2.1.1 Preseasoned or flavored beef and pork

The simple addition of spices or flavoring to whole-muscle cuts is another common industry practice and is referred to as “preseasoning.” One example of preseasoned and marinated product is pork tenderloins that have been marinated and have flavors such as pepper and citrus added, which are common in many markets in the US. Flavorings or marinades can be added as part of an injection or added via tumbling. Flavorings can also be simply added to a container and absorbed by meat over time. Seasonings added to whole muscle include spices, herbs, and other flavorings, and the marinades can be simple salt and water solutions. However, seasonings often have an acid component, such as dilute acetic acid (vinegar) or citric acids added to improve tenderness.

23.3.2.2 Fresh whole muscle tenderized

A common method used to improve tenderness of almost any beef or pork cut is mechanical tenderization (Loucks et al., 1984). Needles penetrating the cut disrupt muscle fibers and connective tissue. The primary issue with mechanical tenderization is a possible reduction in the safety of steaks and roasts, which may not be cooked to temperatures high enough to kill bacteria introduced by the needles during tenderization. Therefore, mechanical tenderization is most appropriate for those cuts that will be fully cooked. It is also the best option for cuts with large amounts of connective tissue, for example round steaks. Mechanical tenderization also occurs at the retail and restaurant level to help ensure the tenderness of product being served. Enzymatic tenderization can also be used to improve the tenderness of tough cuts of meat. In general, enzymes are derived from tropical plants or from bacterial or fungal sources (Wang et al., 1958).
The production of ground beef has been drastically changed in recent years, mostly in response to safety concerns, and the need to test and hold product. However, even if food safety is the most important consideration of ground beef production, efficiency and yield are essential. Safe production of ground beef has created the need for many processors to rethink process design to ensure safety while still being profitable. Reports of food-borne illness are published by the US government, but it is difficult to determine the source of many outbreaks. Pathogens associated with meats, and especially ground meats, are a major concern (CDC, 2011).

For larger processors, the standard design for ground beef processing is: receiving of trimmings, either from an in-plant source or from the outside; a quality control check; initial grinding; fat testing; final grinding; bone collection; forming and/or packaging. For some processors, the addition of boneless, lean beef trimmings may also occur. At various points the beef is put through metal detectors, and other quality assurance evaluations, such as temperature checks, visual evaluation of finished product, and microbial testing for common pathogens such as *E. coli* and *Salmonella*, take place.

23.3.3.1 Fresh ground beef and pork with added ingredients

The addition of ingredients to ground meat is a common processing method that results in products typically referred to as sausages, but also includes other products such as meatballs, pizza toppings, and others. Salt, specifically sodium chloride, is the essential ingredient added to turn ground beef and pork into sausage. Salt is added at levels of 0.5–2.5% of the weight of the meat, with the product being mixed to give the proper flavor and consistency. In addition, spices and other flavoring are added to provide for an almost unlimited variety of products. Some common fresh sausages are bratwurst, pork sausage, beef sausage, breakfast sausages and many others that vary by culture and custom.

Fresh sausage is a very common type of processed meat product and is the easiest to make. Fresh sausages must be kept refrigerated and are cooked by the consumer before consumption. Sometimes, fresh sausages are cooked at the processing plant before sale; these sausages are called “fresh cooked.”

Regulations for fresh sausage manufactured in the US (USDA, 2005) include the following.

- Fresh sausages must not contain any cure (nitrate or nitrite).
- Fresh sausage must not contain any phosphates.
- Fresh pork sausage may be 50% total fat.
- Fresh pork sausage may have the chemical antioxidants butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) or propyl gallate added at a level of 0.01% of the weight of the fat in the formulation.
- Fresh beef sausage may be 30% fat.
- Water or ice may be added to fresh sausage at the level of 3%.
- Whole hog sausage is a fresh sausage made from the meat of an entire hog in the proportions normally found in a hog carcass; that is, the entire pig carcass, after the removal of skin, bones and other inedible tissue, is ground and made into sausage.
- Italian sausage is limited to 35% fat, and must contain fennel and/or anise.

The process of making fresh sausage is relatively simple and involves: grinding of raw meat; addition of salt, spices, and other ingredients; mixing to extract proteins and disperse the non-meat ingredients; and stuffing of the raw meat into packaging or casings. The final product is then either sold directly to consumers at small markets or packaged for distribution.

The use of casings is also important in many meat products. Casings are the material that encloses the filling of a sausage or other formed meat product. Casings are divided into two categories: natural and artificial. Artificial casings, such as collagen, cellulose, plastic, and lately extruded casings, are manufactured via various methods. Natural casings are made from the internal organs of livestock, such as both the large and small intestines, bladder, and occasionally stomach of pigs, cattle, and sheep. Collagen casings are made primarily from beef hides. The collagen in the hides is removed chemically and the resulting product extruded to form a tube. Collagen casings have the advantage of a large variety of sizes that are consistent in size, strength, and other attributes. Casing sizes can vary depending upon product, with sizes from 12 to 35 mm widely available. Cellulose and plastic casings are generally inedible and meant to be removed from the product before consumption. Cellulose casings are derived from plant material and plastic casings from petroleum sources. Some common products packaged in cellulose casings include large-diameter sausages such as salami or summer sausage. Plastic casings are often used to form meat during the cooking process and then removed before being offered to consumers. Products made with plastic casings include skinless franks, and many deli meats such as turkey rolls or boneless ham. Natural casings are the submucosa portion of the internal
organs, primarily intestines that have been stripped of the outer fat and mucosa. Natural casings are washed and packaged in salt for storage and are often used in products such as bratwurst or smoked sausages.

### 23.3.4 Cooked and precooked, uncured, whole-muscle cuts

Precooking is a common method of adding convenience and value to whole-muscle meat products. In many cases, the shelf life and safety of meat products can be improved through precooking, as the cooking process will destroy most microbes that can cause illness and spoilage. It is possible to precook almost any meat product and achieve customer satisfaction with product quality if done properly. Fully cooked meat products are a growing segment of meat processing and offer potential for increasing profit by utilizing low-valued muscles to make higher valued items. Classically, deli-style roast beef is the product made by precooking beef; however, there is great potential to precook other types of beef and pork.

Precooking whole-muscle products can involve several technical hurdles, the most common being to avoid introduction of off-flavors or other product defects (Boles & Shand, 2001). The most common off-flavor associated with precooked meats in general, and beef in particular, is warmed-over flavor (WOF), often described as the “cardboard-like” flavor that occurs when meat is cooked and reheated (Gene & Pearson, 1979). It is possible to minimize off-flavors in precooked beef products through knowledge about factors that cause off-flavors in beef. Preventing WOF and other defects requires several quality control procedures noted here.

- **Degree of doneness (final cooking temperature).** Most off-flavors in precooked beef items are the result of the oxidation of fat, causing rancidity (Gene & Pearson, 1979). The addition of heat during cooking is the primary source of oxidation which leads to rancid flavors. Lesser doneness results in less fat oxidation and the potential for fewer off-flavors (Wadhwani et al., 2010). Depending upon the product, meat should be cooked to the lowest degree of doneness that is feasible.

- **Ingredients.** Many ingredients are strong antioxidants and prevent the formation of WOF in cooked beef and pork. Most notably, nitrite (cure) is a very effective antioxidant, which is why hams and sausages generally do not have problems with oxidation flavors. However, nitrite is not an option for precooked fresh meat items, as the nitrite is not an effective antioxidant until after heat treatments have been applied. In addition, regulations prevent the addition of nitrites and nitrates to fresh meat, as this will change meat color. Some common ingredients are also good antioxidants, including phosphates, organic acids (lactic acid, citric acid, lemon juices), and several other products commercially available specifically to prevent oxidation. WOF development can also be decreased by the addition of natural antioxidants such as vitamin E or chemical antioxidants such as BHA and BHT. It is important to note that BHA and BHT are limited in the US to only fresh pork sausage, and are not permitted in cooked meat products.

- **Raw product handling.** It is not possible to start with abused or low-quality raw product and end with a high-quality finished product. Temperature abuse allows for the rapid growth of bacteria, which are able to cause oxidation, protein degradation, and other spoilage issues. On the other hand, product that has freezer burn, which is a condition caused by sublimation of water from the meat surface, is also highly oxidized and will result in many off-flavors. The simple practice of maintaining proper cold storage of meat and preventing temperature abuse can improve the flavor of cooked beef products.

#### 23.3.4.1 Cured whole muscle cuts

Cured meat is a large category that includes ham, bacon, cured beef, and any other meat product that is whole muscle and has nitrite or nitrates in the ingredients. Meats are cured using the following common ingredients: water, salt, sugar, and nitrite. The curing ingredients can be added to the meat either in a dry rub form or as brine. A “brine” is when the dry ingredients are mixed with a specific amount of water to make a solution that can either cover or be injected into the meat. In addition, it is common for cured meats to have phosphates and erythorbates. Sometimes spices or flavorings, such as black pepper or honey, are added either to the surface of the meat or to the brine.

There are several ways to cure meat.

- **Dry curing.** This is the oldest method of meat curing. Dry curing is obtained by rubbing the surface of the meat (usually ham or bacon) with salt, sugar, and cure (usually nitrates). This process takes a long time (3 months to a year) and results in a great amount of shrinkage, up to 45%, and loss of product to drying out the surface. Examples of dry-cured products are country-cured hams and bacons, prosciutto hams, and country-cured bacons. Dry curing has become a very specialized industry and is limited in scope in the US. This type of product has a very intense flavor and is highly valued by chefs.
Cover curing. Cover curing involves mixing of a brine containing, salt, sugar, and nitrites or nitrates in water, placing the meat in a large vat and covering the meat with the cure. This type of curing also takes a long time (up to 6 weeks for large cuts such as pork hams, but a few days for thin cuts such as bacon). Cover curing improves the rate of ingredient penetration into the meat and results in much less loss of product weight due to shrinkage and spoilage.

Injection curing. Injection curing involves injecting brine, usually including a curing agent, such as sodium nitrite, salt, and usually a sweetener directly into the meat. This greatly reduces the amount of time it takes to cure meat, as the curing process happens within a few hours, and is the most common type of curing in the US. Injection curing is further broken into single-stitch or multiple-stitch injection. Single-stitch injection uses a small hand-held injector, whereas a multiple-stitch injector uses a large injection machine with many needles.

Artery injection. Some plants will inject hams by placing a needle into the femoral artery and use the existing blood vessels to distribute the cure. This is an uncommon process, as artery injection requires specialized equipment and knowledge.

Combination curing. This is a combination of injection and dry curing or cover curing. Typically, the meat is injected and then rubbed with a dry cure to enhance flavor and alter the appearance of the product. By injecting the meat, time to finish is decreased from weeks to a few days for thicker cuts such as hams.

23.3.5 Cooked ground beef and pork including cooked sausages

Cooked and/or emulsified sausages are the most widely available consumer sausage products (hot dogs). Cooked sausages are fully cooked prior to sale, but still must be kept refrigerated to prevent spoilage. Cooked sausages are sometimes reheated, for example, smoked sausages, but are also consumed without further cooking (bologna).

The process involved in producing cooked ground beef and pork starts in a similar manner to uncooked sausages. Meat trimmings are ground to the appropriate size, mixed with salt, spices, and other ingredients, and stuffed into casings or forms for cooking. A key difference is that nitrite, usually in the form of sodium nitrite, is commonly added to the product formulation. The addition of nitrite provides many benefits, including stabilizing color, preventing oxidation and formation of off-flavors, and preventing the growth of some pathogenic bacteria, especially Clostridium species.

Regulations and common facts for cooked beef and pork sausage products (USDA, 2005) include the following.

- Cooked sausages almost always contain cure (nitrite), which is added at 156 ppm nitrite (0.000156% of fresh weight of the product).
- Maximum fat in hot dogs is 30%, and the maximum water plus fat is 40%.
- Hot dogs and bologna are essentially the same, but stuffed into different-sized casings.
- Cooked sausages will often have phosphates added to prevent excessive cooking loss.
- Fully cooked sausages must be cooked to a minimum of 148°F (82.2°C), with most cooked to around 155°F (86.1°C).
- Water or ice is added to most cooked sausages, as moisture is lost during the cooking process. Regulations require that either the additional weight added by water is lost during the cooking process, or that water is included on the label. Ice may be added to emulsion type sausages to keep temperatures low during emulsification, especially when using a piece of equipment called a bowl chopper. During the emulsification process, mechanical energy of the emulsifier increases meat temperature, which may cause the fat in the meat to liquefy. If the fat liquefies, the meat will not form an emulsion.

23.3.6 Fermented sausages

Fermented sausages are the oldest type of sausages produced. Fermented sausages require that the pH of the product be lowered from normal meat pH of approximately 5.6 to less than 5.0, and potentially to 4.6, usually through bacterial action (USDA, 2005). There are several commercial starter cultures of bacteria available for meat fermentation, usually strains of Lactobacillus and/or Staphylococcus. The lower pH results in a distinct flavor and increased storage life. Fermented sausages fall into two broad categories: dry and semi-dry. True dried sausages are usually made from pork and rely on pH decline and dryness to ensure safety, as they are usually never cooked. The process of drying sausages can take from 4 to 6 weeks at the shortest, to over a year for some products. Semi-dry sausages are often cooked after the pH declines to less than 5.0 and then dried, usually in specialized drying rooms that have controlled temperature and humidity to prevent the growth of yeasts on the product surface, before sale or consumption.
Some additional facts about fermented sausages.

- Fermented sausages fall into two broad categories: semi-dry, which includes summer sausages (cervelat, thuringer, etc.) and snack sticks; dry sausages, which include pepperoni and salamis.
- Fermented sausages are generally shelf stable and may or may not be cooked before consumption.
- Dried sausages are generally never cooked; they rely on fermentation and drying to prevent microbial growth.
- If pork is used in dried sausages it must be “certified” to ensure the destruction of trichina worms. Pork is “certified” if it has been subjected to certain processes that kill trichina, such as freezing. The United States Department of Agriculture has regulations for certified pork (CFR, 1990).
- Sausages are fermented by the addition of starter cultures or using the natural microbes in the meat. Using starter cultures provides a much more consistent product than natural microbes. Old-time sausage makers would use a few pounds of an existing batch to spread microbes into a new batch. This was called “backslopping” and is potentially dangerous, as it can spread pathogens as well as other microbes.
- When making fermented sausages, simple sugars (dextrose) are added to provide an energy source for the microbes.

23.3.7 Dried whole muscle product

Jerky is a dried meat product that usually can be stored at room temperature. Jerky can be either whole muscle or ground and formed, with the process being substantially different depending upon the product. All jerky products typically have a moisture to protein ratio of 0.75:1 or less and can be made from any species, for example pork jerky or lamb jerky. Products may be cured or uncured, air or oven dried, and may be smoked or unsmoked. Some important considerations about jerky are as follows.
- All jerky products should have a moisture to protein ratio of 0.75:1 or less (USDA, 2005). This ensures that bacterial growth is very limited and it allows the product to be stored at room temperature. Jerky products may be cured or uncured, air or oven dried, and may be smoked or unsmoked.
- Jerky is produced from a single piece of meat.
- Jerky, chunked and formed is produced from chunks which are molded and formed and cut into strips. This allows for the addition of flavorings and for more precise portioning. Jerky ground and formed or chopped and formed is produced where the meat block may be finely ground before being molded and formed and cut into strips.
- Jerky may be dried at any stage of the process.

The process of making whole-muscle jerky is fairly simple. Large pieces of meat, usually beef round or shoulder, or pork hams, or large cuts of other species, are sliced into thin strips and mixed with a marinade. The marinade typically contains salt at levels of 10–20% and may contain a sweetener, such as sucrose, dextrose, or corn syrup solid, usually at a level of approximately 50% of the salt and may have other flavors or seasonings added such as pepper or teriyaki. In addition, the marinade may contain cure (nitrite) to prevent bacterial growth and to serve as an antioxidant. The meat may simply be allowed to soak in the marinade for several hours, or the meat and marinade may be tumbled to decrease production time. After the meat has absorbed the marinade, it is laid out and smoked or dried, usually in an oven or smokehouse or possibly in specialized drying equipment for drying foods, such as a dehydrator. After drying, the jerky can be portioned and packaged.

23.4 Equipment needed in beef and pork processing

Equipment used in beef and pork processing is varied and includes everything from small utensils such as knives and containers, to large pieces capable of processing several thousand pounds of meat per hour. Beef and pork processing equipment should have several characteristics related to ability to clean and sanitize, durability, efficiency, and ease of operator use. In general, meat processing equipment is made of stainless steel or other, smooth, easy-to-clean construction. Most types of equipment are available in various sizes. For example, small processors may use a meat grinder with the capacity to hold 20 kg of fresh product, whereas large processors may have equipment that will hold 2500 kg. However, the primary principles for each type of equipment are similar, not matter what the size.

23.4.1 Grinder

The meat grinder is used extensively in many beef and pork processing techniques; almost all sausage products start with grinding, and fresh ground beef and pork make up a large portion of meat products. Grinders have several components, which include the hopper, auger (worm), blade, and plate.
Some important grinder information is summarized below.

- The grinder auger must be correctly inserted and tightened. If the auger is loose, meat will not be pushed into the plate and blade correctly, and will be turned to mush.
- As the grinder works, the plate and blades wear together. If the plate and blades are not matched, they will wear differently and not grind as effectively. Make sure to always keep plates and blades together, especially during cleaning.
- Make sure there is meat or water in the grinder before starting. The plate and blade will heat up almost immediately if there is no liquid or meat for lubrication. If the blade gets hot, it will lose “temper,” become soft, and be useless.

### 23.4.2 Emulsifier/bowl chopper

Emulsifiers and bowl choppers achieve the same end-product, which is very finely chopped meat, called an emulsion. Emulsified products can hold a large amount of water and fat. Emulsifiers work by passing meat and the additional ingredients, usually salt, a sweetener, a curing agent such as sodium nitrite, and a cure accelerator such as sodium erythorbate, through a very rapidly spinning blade, resulting in meat pieces that are very small.

### 23.4.3 Mixer

There are various mixers used in beef and pork processing, most commonly to add ingredients to ground or minced meats. Grinders also can be used to combine ground beef or pork with varying fat levels to achieve a desired content in the final product.

### 23.4.4 Stuffer

Stuffers force meat pieces into packaging or casings. Stuffers can be piston type, in which a plunger forces meat through a small opening into the stuffing horn, or vacuum stuffers, which pull meat into a screw or paddle type drive assembly using vacuum and then push the meat through the stuffing horn.

### 23.4.5 Tumbler

Tumblers are used to apply spices and other flavors to the surface of fresh meat, and to extract proteins to the meat surface to aid in binding of formed products such as boneless hams. Meat surfaces in tumblers are subjected to friction, which causes contractile proteins to be extracted, facilitating bind. Most tumblers are essentially containers with baffles on the internal surface that rotate; however, some tumblers resemble large drums without baffles. Meat in the tumbler will move up the side and fall to the bottom repeatedly. Tumblers commonly use a vacuum pump to remove air from the chamber before starting, which reduces the amount of time required to tumble the product.

### 23.4.6 Massagers

Massagers work in a similar manner to tumblers but rather than relying on the meat falling to extract proteins, paddles within the massager provide friction to the meat surface.

### 23.4.7 Injector

Injectors are used to insert solutions into the interior of meat products. Injectors are commonly used to make hams, bacons, turkey, and other products such as deep marinated beef. They can have a single needle or multiple needles, and for larger capacities manufacturers may use a multistitch injector, which has several rows of needles and can process several thousand pounds per hour.

### 23.4.8 Slicer

The slicer uses a very sharp blade to slice various meats such as deli ham and roast beef. Slicers used in large processing plants are often automated and linked to portioning and packaging machines. Deli slicers are used by smaller or local processors to slice beef and pork for sale or sometimes to slice raw meats for jerky processing.

### 23.4.9 Smokehouse

The smokehouse is an oven that has a smoke generator attached. Smokehouses can range in size from those used by small or home processors that can hold 20–50 kg of meat to large commercial smokehouses that can process several thousand kilograms. Most commercial smokehouses can control humidity, air temperature, air movement, and smoke application. Modern smokehouses are computer controlled and can cook beef and pork to exacting specifications. Smoke generation is natural in many smokehouses, with small chips of wood being burned at low temperatures, the smoke being forced into the oven via fans. Wood chips are generally from hardwood sources, with hickory being the most common. It is possible to utilize wood from other sources, such as fruit...
trees, but this source is expensive and used for specialty products. Another option is the use of liquid smoke, which is made from the burning of hardwoods, with the volatile smoke components captured in water. Liquid smoke is available from ingredient suppliers and is not made by most processors. It is applied to the surface of meat in the smokehouse via nozzles supplied by a holding tank. Liquid smoke does not penetrate the meat surface as natural smoke will, resulting in smoke flavor only on the surface of the beef and pork.

23.5 Beef and pork processing and HACCP

Hazard Analysis Critical Control Point (HACCP) systems are required in the US for wholesale or commercial meat processors, with the exception being some retail stores that are allowed to operate under exemption from HACCP (CFR, 1990). Beef and pork processors follow HACCP systems developed by the National Advisory Committee for Microbiological Criteria for Food. Beef and pork processors follow HACCP with seven principles (Tompkin, 1990) along with additional information such as a flowchart that details steps in processing and a detailed description of the product. Additional regulations for meat processors include the development and implementation of sanitation standard operating procedures (SSOPs), which are detailed procedures for the cleaning and sanitation of processing plant facilities, equipment, and other product contact surfaces. In addition, the USDA has standards for processing plant facilities that include building materials, water testing, employee practices, and food handling. Several of these standards are addressed as Good Manufacturing Practices (GMPs). At various times, the USDA has issued additional rules regarding specific production practices to improve food safety. For example, control of Listeria species on cooked, ready-to-eat meat products was detailed with expectation for processors to routinely test for Listeria in the processing plant environment and make changes to sanitation or processing procedures if a positive Listeria test was found.

23.6 Sustainability

Sustainability in meat processing is commonly defined as reducing the use of resources during production and processing. The issue of sustainability in beef and pork processing usually involves the modern production of livestock, or utilizing the best science and production practices available. Beef and pork are available from many different production systems, including those that may be resource intensive and produce beef and pork in an economically efficient manner and extensive systems which require longer growing times but utilize fewer resources. For example, increasing the use of forages and rangelands for growing cattle rather than using high-grain diets can decrease the use of resources while potentially increasing economic efficiency of production. Choosing beef and pork from either system is a matter of personal preference.

Sustainability at the processor level usually involves reducing the use of resources such as water, electricity, and packaging materials, and utilizing the entire carcass in an efficient manner. Improvements in sustainability are generally driven by increased economic returns for producers and processors rather than government intervention. The other issue driving changes in sustainability is the demands of downstream customers. Some end users of beef and pork are increasing pressure on producers and processors to utilize fewer resources during production.

Beef and pork processing embrace the issue of sustainability by utilizing the entire carcass. During the slaughter and butchering process all of the carcass components are utilized in an efficient manner. The offal, which includes the internal organs, is even used as a food source in many ways, while trimmed fat and bone are utilized in a manner to maximize the use of each component.

References


