Principles and Practices of Modern Meat Technology

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ABSTRACT

Technological advances offer considerable potential for the meat industry, and many of these advances may directly influence the microbiological characteristics of meat and meat products. Current and potential industry practices are summarized in light of their impact on not only the microbiological and sensory qualities of meat and meat products, but also processing efficiencies. Microbiological implications of various technologies are emphasized in an effort to indicate some critical control points that should be understood if the industry is to realize the full potential of those technologies.

The annual production of red meat in the United States in recent years has been approximately 38 billion lb on a carcass weight basis. This translates into about 135 lb of retail product annually per person in the U.S. (20). Even though red meats have a dramatic impact on the U.S. economy and nutritional well-being of the population, variety meats, fish and poultry contribute significantly to overall meat consumption. Because of the importance of meat, it is imperative that we understand those factors which influence the microbiological characteristics of this highly perishable commodity. Even though the meat industry has consistently provided quality meat and meat products, but also processing efficiencies. Microbiological implications of various technologies are emphasized in an effort to indicate some critical control points that should be understood if the industry is to realize the full potential of those technologies.

Some of these practices are designed specifically for microbial control. Others are used primarily to enhance product sensory quality or improve processing efficiencies, but frequently also have microbiological implications. Principles and practices within the red meat industry will be emphasized; however, this discussion will have application to meat in general.

After animals are bled and dressed, carcasses are normally chilled to slow the activity of deteriorative forces (principally microorganisms) and prepare the carcass for grading and fabrication. After chilling, carcasses may be cut into primal (wholesale cuts), or subprimals, or less frequently retail cuts at a centralized facility, or shipped to the retail outlet where the carcasses are fabricated. Carcasses or their components may be packaged before shipping to minimize microbial contamination and growth. A predominant trend in the red meat industry is to cut carcasses into primal or subprimal units which are then vacuum packaged and boxed before shipment. This trend toward more centralized processing has been attributed to a variety of economically related advantages among which is improved shelf-life of the packaged, boxed product. The concept of centralized processing is not unique to the red meat industry as poultry and fish processors capitalize on its advantages. Additionally, some red meat species such as pork have been traditionally centrally processed, but beef has been the species with the greatest recent growth in centralized processing (14).

At the initial processing facility or retail outlet, the carcass or its components may be subjected to a variety of treatments to enhance product quality or processing efficiencies. Some of these technologies have been used for many years (i.e. curing practices). Others have gained renewed interest because of economic pressures (i.e. hot processing), or are new concepts which are used in a limited way (i.e. electrical stimulation). Several are the focus of research efforts. The technologies summarized below, by broad categories, are occasionally applicable to only one species, but some are applied to several species.

IMPROVED PROCESSING EFFICIENCY

Cutting and processing of carcasses soon after slaugh-
ter and before conventional chilling holds considerable potential in improving processing efficiencies. Hot processing involves removal of excess fat and bone before chilling and can result in significant savings, particularly in energy, labor and product weight loss (12,13,14). However, because one is working with a product that is near body temperature, special care must be taken to prevent excessive microbial growth. Researchers have defined chilling and handling conditions required to produce a microbially acceptable hot-processed product (10,17). Some aspects of hot processing are being applied in the U.S. industry; however, other countries are using this technique more extensively.

**TENDERIZATION TECHNOLOGY**

Because tenderness is an extremely important quality of meat, the industry is currently using a variety of techniques to insure tenderness and reduce its variability. Historically cooler aging has been used to increase tenderness and this technique is still employed even though for most meat today the time period between slaughter and marketing has been reduced as compared to previous years. Most of the tenderizing benefits of aging are realized within the current slaughter-to-marketing time frame, and the risks (i.e. excessive microbial growth) associated with prolonged aging are minimized. The aging process, caused principally by muscle enzymes, begins soon after death and continues until cooking unless the product is frozen. Aging primals or subprimals in vacuumed packages is a growing trend as it allows the aging process to continue yet retards microbial growth, and reduces trim and moisture losses (14,21). Nonetheless, microbial spoilage will result if the product is aged too long, whether or not it is packaged. An aged, partially degraded product is an excellent source of nutrients for microorganisms.

Principally enzyme preparations from plant sources have and are being used to tenderize meat. These may be applied by spraying or dipping cuts into the enzyme solution. Antemortem or postmortem distribution via the vascular system and random muscle pumping are also used. The antemortem injection is the patented Swift Pro­­ten process. The proteolytic plant enzymes (fycin, papain and bromelin) have received the most emphasis and act primarily during the cooking process. Even though product uniformity is difficult to control, this practice continues to grow. All solutions and application equipment should have low microbial counts to avoid unnecessary product contamination (14,21).

Mechanical blade tenderization is accomplished by passing meat under a bank of long slender needles or blades which disrupt the integrity of the muscle, thus tenderizing it. This is a very effective, commercially applicable method of tenderization. However, unless strict sanitation of equipment and product is maintained, large quantities of meat can be unnecessarily inoculated with microorganisms (14,21). These microorganisms may not pose a health hazard, but can increase the rate of color deterioration which shortens the display life and reduces the value of the product.

Conditioning carcasses or cuts at elevated temperatures of approximately 15°C (60°F) for up to 24 h after slaughter speeds the aging process and avoids the toughening effects that may accompany rapid chilling soon postmortem. Carcass insulation has also been used to accomplish this same end. When the concept of elevated temperature conditioning of carcasses was patented (Tenderay process) several years ago, it was recognized that microbial growth could be a problem upon prolonged conditioning; therefore, ultraviolet lights were used to limit the growth. More recently shorter elevated temperature conditioning times have been used to help insure muscle tenderness, and microbial problems have been avoided (14,21).

Suspension of the carcass by the pelvic girdle stretches and improves tenderness in some muscles in the carcass that would normally contract and become less tender during the process of rigor mortis. Even though this process, developed by Texas A&M University, is effective, it has not been used commercially because of the unconventional shape of the chilled carcass. Other methods of stretching the muscles during the onset of rigor mortis have also proved effective in increasing tenderness, but are seldom used commercially (14,21).

Electrical stimulation of the carcass, usually within 1 h postmortem, improves the tenderness of some muscles either by accelerating the aging process, disrupting muscle integrity, increasing connective tissue solubility, avoiding cold-induced toughening, or a combination of these mechanisms. It has been proposed that electrical stimulation might also be effective in controlling microbial growth, but this proposition has not been consistently demonstrated (14,16,17,21). The meat industry in the U.S. and other countries is using this technique.

Pre-rigor muscle subjected to rapid cooking or a pressure heat treatment is significantly improved in tenderness because of super-contraction which disrupts the muscle integrity. Even though it is an effective method of tenderization, it is not being used commercially (14). Cooking the product, before marketing to the ultimate consumer, will significantly lower microbial counts found on the raw product; however, recontamination of the product must be controlled as potential pathogens may flourish in the absence of the normal microbial flora (23).

**PRODUCT SANITATION**

The most desirable approach to achieving a high quality product from a microbial standpoint is to minimize product contamination during slaughter and subsequent processing. However, some technologies are designed to retard or prevent microbial growth as invariably microorganisms will be found on the product. Refrigeration, freezing, canning, curing, smoking and dehydration are examples of technologies used in achieving this end.

Aqueous chlorine solutions have also been applied to carcasses of a variety of species (15). The patented Swift Clor-Chil process of intermittent spraying of a dilute
chlorine solution on carcasses during the first few hours of chilling has been effective in reducing microbial populations and growth (14). Other compounds not necessarily approved or controlled in their usage on the whole spectrum of meat products also possess antimicrobial potential. These include acetic acid, sorbic acid, ethylene diamine-tetraacetic acid (EDTA), polyphosphates, phenolic compounds such as butylated hydroxyanisole (BHA), and naturally occurring compounds such as those produced by lactic acid producing bacteria (7). Unless the surface has been violated, the interior of the muscle from healthy animals is virtually free of microorganisms, thus surface sanitizing treatments are quite effective.

Precooking of meat to provide convenience products or as a part of the normal processing sequence, such as in cured cooked products, also lowers microbial counts found in raw product. Short-term treatment with microwaves may also be used to reduce microbial counts in an effort to increase the shelf-life of meat products (3,4,5,9). As with the cooking of pre-rigor meat, contamination of the product must be avoided as potential pathogens may flourish in the absence of the normal flora on fresh meat (23). The preservative properties of heat treatments have been demonstrated to increase shelf-life from a microbial standpoint, but because a product is heat treated, consumers and possibly processors may have a tendency to disregard proper post-heat treatment preservation and handling practices. The microbiological characteristics of these products must be understood and proper handling procedures conveyed to processors and ultimate consumers.

Irradiation of meat products is an effective means of controlling microorganisms but not enzymes. Therefore, combinations of irradiation and heat treatment are being studied to improve shelf-life. Sub-sterilization irradiation doses in combination with heat treatments and other forms of preservation increase shelf-life yet minimize the off-flavors caused by irradiation (2). Many of the shelf-life benefits to be realized by old, new and potentially beneficial technologies may be lost by handling products as if they would no longer have shelf-life or wholesomeness difficulties.

**CONTROLLED ATMOSPHERE STORAGE OF MEAT**

During the past several years there has been an increased interest in using modified atmospheres to increase the shelf-life of meat. This practice has fostered continued interest in centralizing processing practices such as the boxed beef concept. Vacuum packaging and packages containing elevated levels of carbon dioxide and nitrogen are examples of modified atmospheres used to effectively extend shelf-life. Storage in modified atmospheres has been demonstrated to improve shelf-life and limit growth of some potential pathogens, but may also encourage proliferation of other potential pathogens, if the product is temperature abused (23). Additional research is needed to realize the full potential and further define the limitations of this technology.

**COMMINUTED AND RESTRUCTURED MEAT PRODUCTS**

Comminuted meats continue to be an extremely important part of the industry. Fresh ground meat, such as ground beef, holds a prominent and growing position in the market. Comminuted meats used in sausages are also of vital importance. However, with the trend to decrease residual nitrite levels, one must consider the microbial implications of this practice on shelf-life and wholesomeness. The nutritional concerns over sodium intake will likely result in decreased levels of sodium chloride in cured meats. Such a practice holds potential for not only influencing functional and sensory properties of cured meats, but also the microbial characteristics of these products (18,22,24).

Recovering meat and marrow from bones by mechanical deboning is a relatively inexpensive way to recover over 2 million metric tons of red meat each year (6). In this process, meat and bone are forced against a screened or slotted face plate with meat and some marrow passing through the openings, thus being separated from broken or coarsely ground bone. Poultry and fish are treated in a similar way, to economically retrieve additional high quality protein (8,19). Mechanical deboning produces a highly nutritious product that can be easily used in other comminuted products (7). With any comminuted food, the product surface area is increased and exposed to microorganisms and the temperature of the product is increased during processing, both of which encourage microbial growth. To continue to realize and maximize the full economical and nutritional potential of comminuted products, in part, hinges on our understanding and control of those factors which influence their shelf-life and wholesomeness.

Coarsely ground, thinly sliced, or chunks of meat may be manipulated in the presence of small amounts of salt to solubilize structural proteins which coat and bind the particles together. This allows the forming and restructuring of the mixture to simulate the characteristics of intact steak, chop, roast, or ham products, for example. This allows the processor to maximize the value of lower price portions of the carcasses. Terms frequently used in reference to these types of products are engineered, flaked and formed, sectioned and formed, chunked and formed, and restructured products. The process of manipulation is frequently referred to as tumbling or massaging (11). Whole items, such as hams, are tumbled or massaged to improve cure distribution, binding and yield properties (11).

It is hoped that this overview presents some of the current and future technology available to the meat processing industry, and conveys a feeling for the great potential of modern meat technology and some of its microbiological implications.
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REFERENCES


