

FACTORS INFLUENCING THE
MICROBIAL CHARACTERISTICS OF UNCURED
RESTRUCTURED MEAT PRODUCTS /

by

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INTRODUCTION

Huffman (1978) reported that the hotel, restaurant and institutional (HR & I) trade was placing pressure on the meat industry to provide menu items which were uniform in size, shape, density, fat levels, and had acceptable sensory attributes. An aging U.S. population, increasing numbers of women working outside the home (Blacher, 1983), the greater number of meals eaten outside the home (40%) (Mandigo, 1975), the increase in amount of consumer food dollars spent on those meals (35%) and the fact that one-half of the commercially prepared meals include some type of meat (Ernst, 1979), provide considerable impetus for the meat industry to develop new products to meet the demands of our changing society. The demands are not only for portion and composition (fat) controlled product, but also for convenient products (Blacher, 1983). Kent (1986) reported that per capita consumption of red meat was declining. That trend has continued (Knutson and Schuck, 1988) and does not show any indication of change. Therefore, the meat industry has targeted population segments with lines of fully-cooked convenient meat products in an effort to increase demand. Increased availability of microwaves (Dziezak, 1987) defines the requirements for convenient meat products. Developing

products for microwave heating or cooking places more emphasis on uniformity of size, shape, and product quality.

Restructured meat products can meet demands for portion and compositional control and lend themselves readily to microwave or conventional cooking or heating due to their uniformity. Restructuring also offers the industry an opportunity to effectively use low value muscles and trimmings to yield products which approach the structure and mouth feel of whole muscle items (Breidenstein, 1983). Culinova, a venture group established by General Foods, has determined that typical Americans buy most of their fresh refrigerated foods on a weekly basis intending to use the foods within a day or two (El-Hag, 1989). This company estimates that ready-to-eat meal and entree sales will grow 45% over the next five years. To maintain red meat sales, the meat industry will have to expand production of lower fat, convenient, competitively priced products that are perceived as 'healthy' and 'safe' by consumers.

Several articles have been published on the process of restructuring meat products (Pearson and Tauber, 1984; NLSMB, 1985; Schmidt, 1986; Secrist, 1987). Those authors identified variations of restructuring, but basically the process entails the blending or mixing of meat particles which are formed into logs, then frozen or cooked.

Restructuring systems utilize protein for adhesion to produce frozen, raw or cooked products. The process entails blending or mixing meat particles, which are packaged, then frozen or cooked. If cooked at this time the product takes the shape of the package. If not cooked, the frozen logs are tempered (-4 to -2°C), pressed into the desired shape and sliced into steaks or chops. Omitting the slicing at this time yields a roast product approximating a sub-primal in shape. After pressing and slicing or just pressing, the product can be frozen, then if applicable breaded and/or cooked. If not pre-cooked, the product is usually frozen for distribution and sale. The desired bind, which yields the acceptable texture and mouth feel of this type of restructured product, is the result of heat denaturation of protein during cooking (Breidenstein, 1983). The proteins responsible for product particle binding can be salt soluble myofibrillar proteins, plant proteins (Endres and Monagle, 1987), milk proteins (Endres and Monagle, 1987; Duxbury, 1986; Morr, 1984) or crude myosin fractions (Siegel and Schmidt, 1979). Restructured products utilizing protein bind can be marketed as fresh frozen and partially or fully cooked in either a fresh or frozen condition.

Restructured meats can also be produced with an algin/calcium binder which does not rely on a heat induced

gel for binding (Means and Schmidt, 1986; Means et al., 1987a; Clarke et al., 1988a, 1988b). This process does not require use of salt and/or phosphates to extract myosin. These restructured products can be marketed similar to fresh meats, or thermally processed to produce a ready-to-eat product.

Restructured products, due to the nature of their processing, are more susceptible than intact muscle to microbial contamination and growth. However, many factors including raw materials, binders/extenders, salt, phosphates, thermal processing, antioxidants and packaging also affect the finished product's microflora. Traditionally, refrigeration at 5°C has been used to slow microbial spoilage and to inhibit pathogenic microorganisms. This method of insuring food safety is no longer completely acceptable because many of the 'new' emerging pathogens are capable of growth at 5°C (Palumbo, 1986). Also Salmonella, Staphylococcus aureus and Bacillus cereus are capable of growth at temperatures which coincide with mild temperature abuse (5°C to 12°C), which frequently occurs with refrigerated foods.

The purpose of this review is not to discuss restructuring methods, but to examine the factors which may affect the microflora of fresh and thermally processed restructured meat products produced without added nitrite.

Some of the publications reviewed will not directly address restructured products, however many of the characteristics will be comparable. Specific attention will be given to pathogenic microorganisms capable of growth on restructured meat products.

MEAT SOURCES

Muscle tissue of healthy animals is essentially free of bacteria (Gill, 1980; Kraft, 1986). The microbial flora of carcass meats is primarily a result of the conditions under which animals are raised, slaughtered and processed (Nottingham, 1982). Growing conditions vary among livestock producers, resulting in differing levels of microbial contamination on carcasses within slaughter houses (Stringer et al., 1969). Stern (1980) reported that lambs on chlortetracycline supplemented diets yielded chops which had lower psychrotrophic plate counts than lambs on unmedicated feed. Salmonella were recovered from swine at seven of nine slaughter plants and in 13% of fecal samples collected at swine production units within a six state area during 1978 (McKinley et al., 1980). Microorganisms present on meat animals at time of slaughter are subsequently transferred to the meat during slaughtering, chilling and further processing. A nationwide surveillance program in Canada resulted in Salmonella isolated from

17.5% of the pork, 2.6% of the beef and 4.1% of the veal carcasses sampled (Lammerding et al., 1988). The same program also identified thermophilic Campylobacter from 16.9 % of the pork, 22.6% of the beef and 43.1% of the veal carcasses. Stern (1981) found Campylobacter fetus spp. jejuni on 38% of the swine, 24% of the sheep and 2.0% of the beef carcasses sampled (53 swine, 59 sheep and 58 beef). Clostridium perfringens, Salmonella, Escherichia coli, Yersinia enterocolitica, Campylobacter jejuni, Streptococcus, Listeria monocytogenes, Bacillus and Clostridium botulinum often inhabit healthy appearing animals (Banwart, 1981; Roberts, 1982; Gravani, 1984; Grau, 1988; Brackett, 1988)

Processing

Levels of carcass contamination vary between meat slaughter houses, caused by differing plant sanitation and handling procedures (Kotula et al., 1975). Differences in microbial counts are also partially due to varied animal growth and holding conditions. Levels of bacterial contamination also vary on carcasses, with higher levels found on the forequarter (Kotula et al., 1975). Depending upon slaughter and boning methods, various areas of the carcass are more prone to contamination which results in higher levels of microbes on those areas. Smulders and

Woolthuis (1983) reported that aerobic colony counts on loin cuts were reduced by using increased hygienic boning practices. Although the methods used by those authors might not be totally practical in a commercial setting, they demonstrated that boning practices significantly affect the number of bacteria on the final product.

The microflora on carcass beef is heterogenous, consisting of mesophilic and psychrotrophic bacteria (Lee et al., 1982). In their study, they identified Micrococcus and Lactobacillus as the predominant species on conventionally chilled carcasses. Konuma et al. (1988) reported 6.6% of 534 raw meat samples (except seafood) were positive for Bacillus cereus with small populations (less than 1 to 3 log per gram).

Scalded pork carcasses have a more uniformly distributed microflora than skinned carcasses (Salm et al., 1978; Schaefer-Seidler et al., 1984). Schaefer-Seidler and associates found higher numbers of bacteria on the ham and shoulder of scalded carcasses than on those areas of the skinned carcasses. Those authors found the microflora consisted of mesophilic organisms.

Accelerated Processing (Hot-boning) and
Electrical
Stimulation

Accelerated processes for further fabrication and processing of carcass meats have been studied extensively. Advantages of accelerated boning systems are space, energy and labor savings in addition to other factors not as easily measured (Henrickson, 1975; Kastner, 1977; Erickson et al., 1980). The literature contains excellent reviews on the optimal processing systems for hot-boned pork (Reagan, 1983; Miller et al., 1984) and hot-boned beef (Kastner, 1983). Hot-boned meats, due to the availability of myofibrillar proteins, are functionally conducive for use in restructured meat systems (West, 1983).

Lin et al. (1979) reported higher initial counts of mesophilic, psychrotrophic and lipolytic bacteria on prerigor ground pork. Choi (1987) found higher counts of mesophilic and psychrotrophic organisms on pre-rigor pork preblends and higher levels of psychrotrophs on pre-rigor ground pork were reported by Judge and Cousin (1983). However the number of organisms reported were well below the generally accepted level of spoilage, not greater than 10^6 organisms/cm² (Fung et al., 1980a).

Hot-boned (HB) beef primal cuts were found to have higher psychrotrophic and mesophilic bacterial populations than conventionally processed (CB) beef (Fung et al., 1980b; Kotula and Emswiler-Rose, 1981). However, immediately prior to boning, surface plate counts from

rounds of HB beef and CB chilled carcasses did not differ significantly. Boning of rounds from either hot or cold carcasses was found to increase bacterial counts by more than 1 log (Kotula et al., 1987a). Cooling HB beef cuts to 21°C within 3 to 9 hours was found to keep the meat in acceptable microbial condition (Fung et al., 1981). Lee et al. (1985) identified the microflora on HB and CB beef using three different chilling rates (cooled to 21°C within 6, 9 or 11.3 hours) for the HB beef. At the time of fabrication no differences in mesophilic or psychrotrophic counts were found. The mesophilic flora at fabrication included Staphylococcus. However after 14 days of storage, slower cooled HB meat had bacterial populations between 1 and 3 log units higher than the CB beef. Enteric bacteria had increased dramatically on the slower chilled (21°C in 9 and 11.3 hours) HB beef by the time surface temperatures reached 21°C.

Use of accelerated processing methods have been evaluated in production of ground beef (Contreras et al., 1981), restructured steaks (Newsome et al., 1987) and precooked beef products (Weiffenbach, 1988). Contreras et al. (1981) reported that ground beef from electrically stimulated HB beef and CB beef were comparable in cooking, sensory characteristics and raw product microbial counts. Newsome et al. (1987) found restructured steaks produced

from HB beef to have higher microbial counts than restructured steaks produced from CB beef and that restructured products, regardless of boning method, had higher counts than conventional steaks. Newsome and associates (1987) used chuck muscles for the HB restructured steak preblend and trim generated during boning for the CB restructured steak preblend. Also separated muscles for restructuring were mechanically tenderized with four passes through a blade tenderizer. Boyd et al. (1978) reported four passes through a mechanical tenderizer increased both aerobic and anaerobic microbial counts from those found after one or two passes through the tenderizer.

Weiffenbach et al. (1988) found precooked CB loin steaks had higher mesophilic and psychrotrophic counts than precooked HB loin steaks. In the same study, precooked HB rib roasts had higher bacterial counts than precooked CB rib roasts.

Bacterial Attachment

Bacteria, when contacting a meat surface adhere to that surface. The nature of that adhesion is not yet fully understood. The number of bacteria which become attached in model system studies increased proportionally with the initial cell concentration exposed to the meat surface

(Benedict, 1988; Chung et al., 1989). Electrical stimulation of meat tissue with 25 or 50 volts DC or AC affected initial and total numbers of Salmonella typhimurium attached to tissue in a model system (Dickson and Crouse, 1989). Increased attachment was reported when the tissue was connected to the positive terminal of a 50 volt source, however a slight bactericidal effect was noted and the treatments were reported to not affect the bacterium's sensitivity to acetic acid.

CARCASS DECONTAMINATION

Several methods and compounds have been used to remove bacteria from carcass surfaces or inactivate them. Stringer (1976) reported carcass washing results obtained with a model system using 4% acetic acid, 100 ppm iodophor, 150 and 200 ppm chlorine, 150°F hot water and 70°F tap water. The respective reductions in bacterial populations were (in percent): 99.5, 98.2, 81.9, 81.8, 68.0 and 65.4. Automated beef carcass washing with 13°C water reduced aerobic bacterial counts by 0.87 log colony forming units (CFU)/200 cm² and Enterobacteriaceae counts by 1.57 log CFU/200 cm² (Crouse et al., 1988). Different spray pressures and chain speeds had no significant effect in decreasing the microbial flora. A 10 second carcass wash with 83.5°C water caused a mean reduction of 99% of

inoculated E. coli (Smith, 1988). The hot water wash reportedly did not appreciably damage the carcass surface tissues.

Phosphate buffer, ethanol and sodium chloride washes did not reduce selected bacterial populations in a model system (Dickson, 1988). However, sodium hydroxide (NaOH) and potassium hydroxide (KOH) were comparable in reducing bacterial loads by more than 1 log cycle.

Organic acid treatments (1 or 2% concentrations) of carcass surfaces reduced total microorganisms, especially Enterobacteriaceae and Salmonella and enhanced lactic acid bacterial growth (Bacus, 1988). These treatments, particularly lactic and acetic acid, are widely accepted because they are perceived as not adding anything to the carcass. Initially the carcass surface pH was lowered by the acid treatment, but returned to normal within 48 to 72 hours after treatment. Intermittent spraying of carcasses (30 seconds, twice an hour for 12 hours) with 1% solutions of acetic or lactic acid was more successful than a single 30 second treatment of the same solutions (Hamby et al., 1987). Lactic acid was more effective than acetic acid in reducing bacterial populations on all carcass areas sampled. Stringer (1982) reported that a 3% acetic acid solution was more effective than hot water or chlorine in

reducing carcass bacterial populations and also had a residual effect.

Emswiler-Rose and Kotula (1984) reported that the type and concentration of chlorine compound used along with the type of microorganisms present determine the effectiveness of aqueous chlorine treatments. Hypochlorous acid (HClO) was more effective than chlorine dioxide (ClO₂) in inhibiting Gram-negative bacteria, but chlorine dioxide was more effective against Gram-positive bacteria in a model system. Inhibition increased as chlorine concentration increased, however concentrations of 200 ppm and below had no effect on most organisms tested. No increase in bacterial quality of ground beef was found by Johnson et al. (1979) when a hypochlorous acid spray treatment was applied to forequarters used for grinding.

SANITATION

Intact muscle tissue is normally relatively free of bacteria, but becomes contaminated as muscle is converted to meat (Nottingham, 1982). Proper design, installation and maintenance of equipment in slaughter and processing plant environments assist in elimination of sources of microbial contamination (Gabis and Faust, 1988). Ensuring that equipment and facilities are accessible to facilitate thorough cleaning and sanitation is important.

Water is an essential microbial growth factor, which is in plentiful supply in slaughter or processing plants. Eliminating areas in the plant and on equipment which collect, trap or otherwise allow water to pool, removes this bacterial growth factor. Continuous, periodic environmental microbial sampling of plant equipment, structures and air will not only identify possible microbial sources and harborages, but also indicates the thoroughness of clean-up and sanitation (Kotula and Emswiler-Rose, 1988).

The inception of Hazard Analysis Critical Control Point (HACCP) inspection programs accentuates the need for employees to be aware of microbial contamination risks (Kotula and Emswiler-Rose, 1988). Good sanitation programs include training involving management, maintenance and production employees as well as workers involved with the cleaning and sanitizing of equipment (Gabis and Faust, 1988; Fung, 1986).

PROTEIN EXTENDERS AND BINDERS

Non-meat substances and alternate meat sources are used in restructured meat products to reduce formulation costs and/or for a specific function (Seideman, 1982; Pearson and Tauber, 1984; Endres and Monagle, 1987).

Milk Proteins

Milk proteins lower the cost of formulation, have excellent nutritive value and are functional binders (Morr, 1984; Pearson and Tauber, 1984; Endres and Monagle, 1987). Milk products (nonfat dry milk) of poor microbial quality can introduce potential pathogens and other bacteria to restructured product. Banwart (1981) reported that dried milk had aerobic plate counts in the range of 2 - 3 log CFU per gram. Grade A pasteurized, condensed whey and nonfat dry milk microbial standards allow maximums of 30,000 standard plate counts and 10 coliforms per gram.

Plant Proteins

Plants are another source of protein which can reduce formulation costs, increase moisture absorption and retention, reduce fat and water cooking losses and provide some bind to the restructured system (Pearson and Tauber, 1984; Endres and Monagle, 1987). Harrison et al. (1981) reported four bacterial species (2- Micrococcus, 1- Bacillus, 1- Acinetobacter) isolated from hydrated textured soy protein (TSP) were present in quantities up to 2.3 log CFU per gram. Bacterial species found on TSP did not materially contribute to the spoilage microflora of TSP extended ground beef, however the extended product had a higher rate of microbial growth. Those findings agree with

earlier reports by Thompson et al. (1978) and Bell and Shelof (1978) who reported that the spoilage microflora of soy-beef blends was essentially the same as unextended ground beef, except that microbial spoilage occurred earlier in soy added products. Konuma et al. (1988) found 27 of 51 vegetable protein samples positive for Bacillus cereus with up to 3 log CFU per gram. Thompson et al. (1978) reported less than 10 organisms per gram of proteolytic, coliform and Staphylococcus bacteria on rehydrated TSP concentrate flakes. An increase of pH (from 5.8 to 6.1) in raw ground beef when extended with 30% TSP contributed to increased heat resistance of Salmonella (Craven and Blankenship, 1983).

Decreased Clostridium perfringens generation times were reported using isolated soy protein (ISP) and soy glycinin in a model system as compared to generation time achieved in trypticase broth (Busta and Schroder, 1971). In that study, a commercial soy flour slowed C. perfringens' growth rate (increased generation times), however those authors reported no effect due to soy products in a meat loaf product. Sporulation of inoculated C. perfringens was higher in a cooked 30% ISP-beef blend than in cooked TSP, soy protein concentrate (SPC)-beef blends or in the all beef control (Craven and Mercuri, 1979). The TSP and SPC blends had less sporulation than

the control. Spores survive low temperature storage better than vegetative cells. Sporulated C. perfringens can produce an enterotoxin which is ingested with the food.

Addition of soy protein had no practical effect on the microflora of frozen raw or precooked beef patties (Emswiler et al., 1979). Precooking patties to an internal temperature of 60 to 65°C reduced APC's by up to 2 logs. Most Probable Numbers (MPN's) of frozen raw patties showed that 49% contained fewer than 10 E. coli per gram and 86% had less than 10 S. aureus per gram. Additionally 90% of the precooked patties contained no detectable E. coli or S. aureus and 9% had less than 10 organisms of each species per gram.

Mechanically Deboned Meat

Field et al. (1977) reported addition of 5% mechanically deboned meat (MDM) to restructured steaks did not change steak quality while reducing fabrication costs. MDM has a greater water holding capacity and a higher pH (ca. 6.1) than intact muscle partially due to bone marrow incorporated into the MDM (Field, 1981). Field also indicated a temperature rise of 1 to 10°C from starting material temperatures was expected in MDM due to deboning. Microbiological quality of MDM varied among eight plants and only three plants consistently (90% or more of lots

sampled) produced MDM which contained APCs (35°C and 21°C) of less than 6 log CFU per gram (Krautil and Tulloch, 1987). Those authors indicated that plants which held bones below 10°C and mechanically deboned in the same plant within eight hours produced MDM of high microbial quality. In that study 68 (38.4%) of 177 samples contained Salmonella. Ray et al. (1984) compared growth rates of E. coli, Salmonella, Staphylococcus aureus, Clostridium perfringens and naturally occurring psychrotrophic bacteria in mechanically separated beef (MSB) and lean ground beef. Psychrotrophs grew faster in MSB than in lean ground beef at all incubation temperatures (3, 7 and 10°C).

Ray et al. (1984) inoculated samples with pathogens and incubated them for up to 24 hours at 37°C. Clostridium perfringens had a higher growth rate in lean ground beef and S. aureus growth rates were initially equally as fast in the ground beef, but in 24 hours MSB had higher CFU counts of this organism. MSB and lean ground beef supported rapid growth of E. coli and S. anatum.

Increasing levels of MDM (10% to 30%) in restructured lamb roasts slightly increased mesophilic and psychrotrophic aerobic and anaerobic plate counts in uncooked roasts (Ray and Field, 1983). All counts were less than 5 log CFU per gram. Coliforms and fecal coliforms (CFUs below 2.5 log per gram) followed the same

trend in an uncooked product which was negative for Salmonella, Yersinia enterocolitica, Campylobacter jejuni, Staphylococcus aureus and Clostridium perfringens. Cooking roasts to 62.5°C internal temperature reduced mesophilic and psychrotrophic counts to less than 30 per gram and eliminated coliforms and fecal coliforms.

Calcium Alginate

Several papers have been published on the acceptability of calcium alginate bind in restructured meat products and factors associated with that restructuring system (Means and Schmidt, 1986, 1987; Means et al., 1987; Clarke et al., 1988a, 1988b; Schmidt et al., 1988). Algin/calcium restructured steaks, with and without glucono-delta-lactone were compared to steaks restructured with 1.4% NaCl and 0.32% sodium tripolyphosphate and to an all beef control for microbial growth in aerobic and anaerobic packages at 4-6°C (Means et al., 1987). Psychrotrophic counts exceeded 8 log CFU per gram in 7 days for the aerobically packaged control and algin/calcium steaks, but not until 9 to 11 days for the NaCl/phosphate steaks. Bacterial levels of 8 log CFU per gram were reached in anaerobic conditions by the algin/calcium steaks

in 8 days and in 13 days for the all beef control and NaCl/phosphate steaks.

Williams et al. (1978) reported a calcium alginate film applied externally to beef steaks tended to slow total aerobic bacterial and coliform growth. This treatment also kept total aerobic and coliform counts of inoculated steaks lower than on inoculated control samples. In a study using lamb carcasses, Lazarus et al. (1976) reported a calcium alginate coating slightly reduced total surface microbial counts at five and seven days compared to the control. The calcium alginate film used in these studies was formed by gelling a malto-dextran sodium alginate solution with a calcium chloride-carboxymethylcellulose solution. The authors attributed the lower microbial counts of the coated samples to a calcium chloride ionic effect.

ORGANIC AND INORGANIC COMPOUNDS

Salt

Many compounds have been studied for use in restructured meats to impart a variety of characteristics to the product. Salt is integral to some restructuring processes and is used in 0 to 5% quantities in processed meats (NSLMB, 1985). Salt (NaCl) can have undesirable

effects on meat systems, promoting oxidation and discoloration (Means and Schmidt, 1987). Also health conscious consumers are seeking to lower dietary sodium intake in an effort to avoid hypertension and other possible related health problems. Investigators have looked at replacing some or all of the sodium chloride in restructured meat systems. The calcium alginate system discussed earlier is such a replacement. However, replacing NaCl in restructuring systems can possibly create microbial problems. Salt is known to have antimicrobial action, depending on the levels used and the microorganisms present (Banwart, 1981; Pearson and Tauber, 1984). Minarik (1989) reported restructured beef roast treatments (2% NaCl and/or 0.5% tripolyphosphate and/or 2% glucose in combinations) not containing NaCl resulted in higher mesophilic and psychrotrophic CFU counts in a ten day period. Excluding salt from pork preblends tended to increase mesophile CFUs (Choi, 1986).

Listeria monocytogenes is capable of growth in 10% NaCl (Doyle, 1988). In a model system 7% NaCl inhibited Yersinia enterocolitica at 3 and 25°C but, unlike other Enterobacteriaceae, Yersinia grew in 5% NaCl concentrations at 3°C (Stern et al., 1980). Campylobacter jejuni growth was retarded with NaCl concentrations as low as 1%, but 0.5% NaCl was conducive to Campylobacter growth in media

(Doyle and Roman, 1982). Abram and Potter (1984) reported that increasing salt levels (1 and 2%) decreased survival rates of C. jejuni. Szabo et al. (1986) reported 0.5% NaCl in tryptone bile agar enhanced growth of E. coli. Wagner and Busta (1984), who postulated that higher levels of NaCl might restrict spore germination and that media without salt contained insufficient ions for spore germination. They reported that Clostridium botulinum growth was enhanced by 1.25% NaCl in media when compared to either 2.5% or no NaCl in the media. Staphylococcus aureus enterotoxin production is inhibited with 10% NaCl, but growth is not restricted until NaCl concentrations of 15 to 18% are reached (Davidson et al., 1983).

Miller et al. (1986a) reported restructured steaks made with 0.5 and 1.0% potassium chloride (KCl) were comparable to restructured steaks with the same levels of NaCl in juiciness, tenderness and flavor desirability. Replacement of NaCl with KCl had little effect on bacterial growth (Nielson and Zeuthen, 1986).

Phosphates

Salt has been shown to have synergistic effects when used with other compounds. Salt (0.2%) and 0.2% of a commercial blend of sodium pyrophosphate decreased cooking loss and increased bind in restructured beef steaks equal

to a 0.5% phosphate treatment without NaCl (Lamkey et al., 1986).

Phosphates are included in restructured meat formulations to inhibit oxidation, to increase water retention and bind strength as well as decrease flavor and color deterioration (Lindsay, 1985; Gray and Pearson, 1987; Trout and Schmidt, 1987). Miller et al. (1986b) reported that 0.5% Sodium tripolyphosphate (STP) or sodium hexametaphosphate (SHMP), in addition to 0.75% NaCl resulted in more desirable raw color scores of restructured steaks than sodium acid pyrophosphate (SAPP) or no added phosphate. Those authors concluded that adding STP and/or SHMP to precooked restructured steak products might be beneficial from a color viewpoint. Schwartz and Mandigo (1976) reported that 0.75% salt and 0.125% STP to be the most desirable salt and STP levels to use in restructured pork. Phosphate compounds are also reported to have antimicrobial activity (Davidson et al., 1983). But as shown above, different phosphate preparations have varying effects, this is apparently true in their antimicrobial role, too.

No significant antimicrobial effects by 0.4% STP, tetrasodium pyrophosphate (TSPP) and three commercial phosphate blends on mesophilic and presumptive Staphylococcus aureus in frozen ground beef patties were

reported by Molins et al. (1987a). However, one commercial blend and TSPP inhibited bacteria growth upon temperature abuse of the patties, but did not prevent spoilage. In a separate report, Molins (1987b) showed that 1.0% SAPP had inhibited psychrotrophic growth in fresh ground pork more than 0.5% SAPP-0.5% sodium orthophosphate monobasic (ORTHO) or ORTHO treatments. The straight chain polyphosphates (chain length: 3, 13, 15 and 21) inhibited S. aureus growth while SAPP, TSPP and sodium tetrametaphosphate had no effect in brain heart infusion broth (Jen and Shelef, 1986). Trisodium pyrophosphate (PYRO-3) and SAPP reduced mesophilic and facultative anaerobic bacteria counts after 21 days of refrigerated storage (7°C) in cooked pork sausage and after 48 hours of temperature abuse (Marcy et al., 1988a). They used a sausage formulation which contained 2.0% salt and the total phosphate was 0.4% singularly or in combination. Marcy et al. (1988b) in a similar study with four commercial phosphate blends and a neutral pyrophosphate determined that the level of phosphates was more important than the kind of phosphate used in reducing mesophilic and psychrotrophic bacterial numbers in vacuum packaged cooked pork sausage. STP, SHMP and TSPP were more effective against gram-positive than gram-negative bacteria strains in nutrient broth (Zessin and Shelef, 1988). Antibacterial action was higher for

phosphates when they were sterilized with filters instead of heat. Heat sterilization caused hydrolysis of the phosphates into compounds which were not antimicrobial. Zessin and Shelef (1988) found inhibition to be greatest for STP and least for TSPP.

SAPP at 0.2 and 0.4% concentrations was reported to slow C. botulinum growth and toxin formation in a model system (Wagner and Busta, 1984). Phosphates, in addition to sequestering heavy metals, increase solution ionic strength. Wagner and Busta (1984) reported that SAPP, at 0.2 and 0.4% levels, made little contribution to the overall ionic strength of the system, but suggested that SAPP's sequestering activity may have made ions necessary for C. botulinum cell development unavailable.

Antioxidants

Antioxidants are used to slow the onset and rate of lipid oxidation. Several investigators have reported on the antimicrobial activities of various antioxidants, including the phenols in wood smoke mentioned earlier. Butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), tertiary butylhydroquinone (TBHQ) and propyl gallate (PG) at 100, 200 or 400 ppm reduced counts of psychrotrophic, coliform and fecal coliform bacteria in ground pork after four weeks of 4°C storage (Gailani and

Fung, 1984). BHA was reported to inhibit strains of C. perfringens in fluid thioglycollate medium with 150 ppm and in a dilution buffer with 100 and 200 ppm concentrations (Klindworth et al., 1979). Staphylococcus aureus growth was inhibited in trypticase soy broth with 3, 4 or 7% NaCl plus 100 ppm added BHA (Stern et al., 1979). Raccach and Henningsen (1981) reported differing minimum concentrations of TBHQ effective in inhibiting different gram positive bacteria and a synergistic effect with NaCl. Ethylenediaminetetraacetic acid (EDTA) at 500 ppm inhibited S. aureus growth in brain heart infusion broth (Kraniak and Shelef, 1988). TBHQ (50 and 100 ppm) was inhibitory alone or with sorbate towards S. aureus in media (Lahellec et al., 1981). Those authors also reported a greater bactericidal action with BHA than BHT and PG when used in combination with potassium sorbate.

Parabens

Lindsay (1985) reported that the parabens (synthetic phenolic compounds) are effective mold and yeast inhibitors but have little effect on bacteria. Davidson (1983) reported that gram-positive bacteria are usually more sensitive to paraben activity than gram-negative bacteria and that paraben antimicrobial action increases as their alkyl chain length increases. Robach and Pierson (1978)

reported that 100 ppm of propyl paraben inhibited C. botulinum toxin production in pre-reduced thiotone-yeast extract-glucose broth. Eklund et al. (1981) reported propyl paraben antimicrobial activity towards two strains of Salmonella typhimurium, but when bovine serum albumin was added to the media, antimicrobial activity was not observed. Effectiveness of propyl paraben as an antimicrobial in an actual situation may be decreased in the presence of proteins or other protective substances.

Sorbate

Potassium sorbate (0.1, 0.2 and 0.3% concentrations) slowed C. sporogenes spore outgrowth and this effect was enhanced with the addition of NaCl to the medium (Robach, 1980). However, C. sporogenes growth was found in temperature abused vacuum packaged cooked pork treated with 2.5% potassium sorbate dip. Decreased growth rates of C. botulinum due to 0.13 and 0.26% concentrations of potassium sorbate in liquid media were reported by Wagner and Busta (1984). Staphylococcus aureus was only slightly inhibited by 0.2 or 0.3% concentrations of potassium sorbate with or without added NaCl at 2.0 or 3.0% (Larocco and Martin, 1987). Restaino et al. (1981) reported that potassium sorbate (0.1 or 0.2% levels) in media adjusted to pH 5.5

with citric, lactic, phosphoric or hydrochloric acids was bacteriostatic against Y. enterocolitica and Salmonella. Sorbic acid (0.21 to 10%) slowed the growth rate and increased the lag phase of vacuum packaged beef microflora (Zamora and Zaritzky, 1987).

Antibacterial action of potassium sorbate against S. aureus was found to be greater at pH 5 than pH 7 in media with or without added antioxidants (Lahellec et al., 1981). Thomas and Wagner (1987) reported increased inhibition of S. aureus when 0.4% SAPP was used with potassium sorbate in brain heart infusion broth. More inhibition was seen at pH 5.5 than at pH 5.8 with either treatment. Decreased enterotoxin production accompanied the increased growth inhibition.

Organic acids

The effect of lactic and acetic acid as carcass treatments were discussed earlier in this paper. Precooked, microwave reheated beef roasts treated with a 3.0% acetic acid dip contained lower mesophilic and psychrotrophic bacterial levels than untreated roasts throughout a 45 day study (Paterson and Parrish, 1988). Enterobacteriaceae growth on vacuum packaged pork chops was inhibited with a 3.0% acetic acid dip (Mendonca et al., 1989). This effect was also reported for aerobic

mesophilic and psychrotrophic bacterial counts. NaCl at 2.0 or 3.0% concentrations added to the 3.0% acetic acid further reduced microbial counts.

Lactic acid is produced by lactic acid bacteria metabolism of carbohydrates and inhibits other spoilage microorganisms (Banwart, 1981). The antimicrobial action of the organic acids is enhanced in lower pH products.

SPICES, FLAVORINGS AND BATTERS AND BREADINGS

Spices

Natural spices are ground or cracked seeds or stems which impart a long lasting flavor. Konuma et al. (1988) reported a 39.7% incidence of Bacillus cereus on spices sampled at meat processing and retail facilities. Approximately 4% of the samples contained viable cell counts higher than 4 log CFU per gram. Spices can carry high levels of bacterial spores as well as vegetative cells (Fung, 1983). Use of soluble spices (extracted oils or resins of natural spices) avoids the microbial contamination of natural spices (Everson, 1978; Pearson and Tauber, 1984).

Flavorings

Flavorings often increase acceptability of a product. Flavored (NaCl and hydrolyzed plant protein) restructured beef steaks rated higher for overall acceptability than steaks restructured with meat only (Hand et al., 1981). Sweeteners are used to mask saltiness and to improve product flavor (Everson, 1978; Pearson and Tauber, 1984). Sugars and sorbitol are also used as cryoprotectants to prevent denaturation of muscle proteins during freezing and subsequent storage (Kotula et al., 1987b). Konuma et al. (1988) found 3 of 50 sugar samples positive for Bacillus cereus. Addition of 2% glucose to ground beef extended the average shelf life 3-5 days by causing a shift in nutrient utilization by spoilage bacteria (Shelef, 1977). The pH and total aerobic, gram-negative and coliform bacterial counts were lower in the glucose/ground beef than in the all beef control. However Lactobacillus counts were essentially the same in the glucose/ground beef and the control. The lower pH inhibited some spoilage bacteria, which delayed the onset of slime and off odors. Gill (1982) reported that most spoilage bacteria on meat preferentially utilize glucose. Once the glucose is depleted microorganisms attack amino acids and produce ammonia. A phosphate-glucose treatment of restructured beef roasts resulted in higher mesophilic (4.57 log CFU per

gram) and psychrotrophic (4.49 log CFU per gram) counts after a 10 day display than salt-phosphate-glucose, salt-glucose or salt-phosphate treatments (Minarik, 1989).

Wood smoke has traditionally been used as a preservative, however the availability of mechanical refrigeration has decreased the significance of its preservative effect (Derosier and Derosier, 1977; Banwart, 1981). Traditional smoking of meats has antimicrobial action due to the combined effects of heating, drying and chemical compounds deposited on the meat surface (Pearson and Tauber, 1984). The drying occurs at the meat surface, presenting a barrier to microbial invasion (Ayres et al. 1980). Wood smoke is now generally used for flavor and the color imparted to meat systems.

Extracts of wood smoke (liquid smoke) can be applied in liquid form without the limitations encountered with traditional smoking (Gilbert and Knowles, 1975; Toth and Potthast, 1984). Several authors report liquid smoke has antimicrobial action, which varies depending upon smoke preparation, concentration and microflora present (Gorbatov et al., 1971; Hollenbeck, 1979; Wendorff, 1981; Toth and Potthast, 1984; Maga, 1988). The major compounds of wood smoke (acids, phenols and aldehydes) are present in liquid smoke. Acetic and formic acids are reported by Toth and Potthast (1984) to have the most antimicrobial activity of

the compounds in liquid smoke. However, Pearson and Tauber (1984) attributed minor preservative action to the organic acids and recognized the phenolic fraction of liquid smoke as the primary antimicrobial agent.

Sofos et al. (1988) screened 20 different liquid smokes (ether extracts) for antimicrobial activity in model systems which were adjusted to within a pH range of 5.78 to 6.81. They found variation in inhibition of growth among the different smokes, and between species and strains of microorganisms tested. Staphylococcus aureus tended to be more inhibited than Aeromonas hydrophila. The more inhibitory smokes were from the sapwood of douglas fir, birch, southern yellow pine and aspen.

Batters and Breadings

The microbiology of batters and breadings are a result of the microbial contamination of their ingredients (Fung, 1983). Spice and milk microflora were addressed earlier in this paper. Generally Salmonella is known to contaminate egg products. Dry ingredients usually have less spoilage than liquid products, however when hydrated the dry product will readily spoil like a liquid product. Water microbial quality must also be high to prevent contamination of the batter and subsequently the meat system. The U.S. Public Health Service microbial standards for potable water

include a standard plate count (not more than 500 organisms per milliliter) and a coliform count by either the membrane filter method (average not more than one organism per 100 milliliter per month) or the fermentation tube method (not more than 10% of five 10 milliliter portions positive in a month) (Banwart, 1981).

THERMAL PROCESSING

Precooked, convenient to prepare restructured meat products are produced to meet the demands of today's consumer. Many cooking systems are applicable to restructuring systems. Stites et al. (1989) reported that chuck roll roasts cooked in a vacuum bag 24 hours after packaging (stored at 4°C) had lower bacterial counts than roasts vacuum packaged and stored frozen (-20°C) prior to being cooked in their bag. Also roasts vacuum packaged and stored at 4°C prior to cooking in their vacuum bag had higher bacterial counts than roasts cooked 24 hours after packaging. Roasts were reheated or cooked and evaluated at 0, 14 and 28 days of storage. Only the fresh roasts reached spoilage levels of bacteria (7 log CFU per gram). Precooking was accomplished in a 71°C water bath to an internal temperature of 65°C. Roasts were reheated or cooked to an internal temperature of 70°C in a 100°C water bath. These results agree with earlier work done with

precooked pork roasts by Jones et al. (1987). The above reports indicate that if a precooked product is to be produced, cooking-in-the-bag soon after vacuum packaging should result in a lower microbial counts on products for 28 plus days.

Ockerman and Crespo (1977) indicated that cooking to an internal roast temperature of 60°C gave added microbial protection over cooking to 54.5°C internal temperature. However, cooking to 65.6°C final temperature did not significantly change microbial counts from the 60°C cook. Pork chops sliced from precooked loins (66°C internal temperature) subjected to either a 2.5% potassium sorbate, 1.0% acetic acid or 5.0% polyphosphate dip, vacuum packaged and cooked-in-the-bag to 66°C internal temperature had a shelf life of 60 plus days at 2-4°C storage (Prabhu et al., 1988). Vacuum packaged pork chops not subjected to the second cook spoiled within 15-21 days. The polyphosphate and acetic acid dips prevented growth of surface inoculated C. sporogenes during temperature abuse (48 hours at 24-25°C) of the cooked-in-the-bag pork chops.

Microwave heating or cooking is a possible time and energy saving method available to consumers and processors. Fung and Cunningham (1980) found that microwaves used in combination with other conventional heating methods resulted in more uniform heating in foods and destruction

of bacteria. They also indicated that wrapping the food to be heated yielded better results. Conventional oven cookery of beef patties inoculated with C. perfringens reduced counts by 3.1 to 3.5 logs per gram, while microwave cooking of inoculated beef patties to the same internal temperature reduced counts by 0.8 to 1.5 log per gram (Wright-Rudolph et al. 1986). Conventional cooking was also more effective in lowering numbers of aerobic microorganisms than microwave cooking.

Thermal processing to produce a precooked or pasteurized restructured meat entree will partially destroy the microflora on the raw product. The amount of bacterial destruction is a function of time and temperature of heat processing. Reducing microflora by cooking aids in prolonging product shelf life, but also alters the intrinsic characteristics of meat. Cooking (63°C) alters microflora in that most spoilage bacteria and some pathogens (vegetative cells) are destroyed, but does not affect bacterial spores or S. aureus enterotoxin (Banwart, 1981). Lowering the numbers of vegetative cells reduces microbial competition for substrate, allowing noncompetitive organisms which survived cooking to flourish. This shows the importance of preventing post thermal processing contamination. Following heat treatment, chilling of cooked beef to 4°C within two hours

essentially prevented the growth of Salmonella (Stern and Custer, 1985). They also reported that of Salmonella inoculated in ground beef stored at 23°C for 6 hours increased less than 1 log cells per gram.

PACKAGING

Vacuum Packaging

Packaging affects meat stability by changing the meat's environment (Taylor, 1982). With packaging additional contamination is avoided and the gaseous atmosphere can be altered. Secrist (1982) reported that restructured product should be packaged in oxygen-barrier films to prevent flavor deterioration of the product.

Vacuum packaging utilizes gas impermeable films to prevent oxygen transfer into the package after the atmosphere inside the package has been evacuated and the film sealed (Breidenstein, 1982). The evacuation of the package atmosphere can not remove 100% of the oxygen from the package, but does drastically reduce the O₂ partial pressure in the package. The residual O₂ in the package is consumed by microorganism metabolism and tissue respiration, leaving an approximate atmosphere of 20-40% CO₂ and 60-80% N₂ (Egan et al., 1987).

Vacuum packaging beef top round steaks decreased total bacterial counts (20°C incubation) and allowed lactobacilli to predominate while aerobically packaged steaks had rapidly increasing bacterial counts with Pseudomonas predominating (Pierson et al., 1970). Vanderzant et al. (1982) substantiated the above findings with steaks retail packaged from aerobically and vacuum packaged beef strip loins using 25°C APCs. Commercial vacuum packaged beef knuckles sampled prior to distribution to retail stores by Johnston et al. (1982) contained higher 20°C APC counts (by a factor of 100), lactic acid bacteria (by a factor of 1,000), Enterobacteriaceae (by a factor of 10) and coliforms (by a factor of 100) than hanging beef knuckles sampled at the same time in the same processing facilities. Those authors also recovered Y. enterocolitica from 66 of 150 samples of vacuum packaged beef but only from 4 of 150 samples of hanging beef. The microflora of beef knuckles packaged in various oxygen permeable films was altered from predominant Pseudomonas in 400 cc/m²/24 hours oxygen transmission rate (OTR) packages to Lactobacillus in packages with less than 12 cc OTR (Savell et al., 1986). Packages with 13 cc and 30 cc OTR were predominated by Leuconostoc. Listeria monocytogenes grew in vacuum packaged beef of pH 5.6 and 6.0 at 0 and 5.3°C (Grau and Vanderlinde, 1988). L. monocytogenes growth was greater

with the higher pH and temperature and its growth was more rapid on fatty tissue than on lean.

Modified Atmosphere Packaging

Modified atmosphere packaging utilizes the bacterial inhibitory effect of carbon dioxide (CO₂) (Ansoborlo, 1988). Psychrotrophic counts of steaks initially packaged in 100% CO₂ were lower than steaks packaged in 100% oxygen, 100% nitrogen or in a vacuum (Seideman et al. 1979). Analysis of the CO₂ package atmosphere at 28 days revealed only 80% CO₂. Packaging precooked beef roasts with 100% CO₂ reduced mesophilic and psychrotrophic counts at 14 and 21 days of 4°C storage, but a package atmosphere of 15% CO₂, 30% O₂ and 55% N₂ did not reduce microbial counts from those of vacuum packaged roasts (McDaniel et al., 1984). The modified atmosphere packaged roasts had decreased quality characteristics by 14 days of storage. A 15% CO₂, 40% O₂ and 45% N₂ atmosphere did not inhibit psychrotrophic organisms at 6 or 10°C on precooked beef slices, but inhibition did occur at 2°C storage (Carr and Marchello, 1986). Carr and Marchello (1987) found a packaging atmosphere containing 15% CO₂, 10% O₂, 75% N₂ restricted psychrotrophic growth more than 15% CO₂, 40% O₂, 45% N₂ or 15% CO₂, 20% O₂, 65% N₂ atmospheres. However, none of those

modified atmospheres reduced psychrotrophic counts as much as vacuum packaging. A 10% CO₂, 5% O₂, 85% N₂ atmosphere was more effective than 15% CO₂, 40% O₂, 45% N₂ or 60% CO₂, 40% O₂ atmospheres in reducing psychrotrophic growth on steaks (Ahmad and Marchello, 1989). Serratia liquefaciens increased during storage, with Enterobacter aerogenes found after 6 and 12 days of storage in the gas atmospheres. Yersinia enterocolitica was recovered from steaks packaged in the 15% CO₂, 40% O₂, 45% N₂ atmosphere after 12 days of storage. Egan et al. (1988) and Ansoborlo (1988) indicated that modified atmosphere packages should contain at least 20% CO₂ to obtain efficient microbial inhibition.

Vacuum packaging of refrigerated restructured meat items can create a potentially hazardous food. Vacuum or modified atmosphere packaging changes the product environment to one suitable for C. botulinum growth and toxin formation. Although few incidences in meat have been reported, C. botulinum type E and non-proteolytic strains of types B and F are capable of growth in temperatures as low as 3.3°C (Simunovic et al., 1985). As cooking eliminates vegetative cells, less competition or inhibition by microbial by-products (lactic acid) are present in a cooked vacuum packaged product. This environment would promote the growth of any anaerobic pathogenic bacteria which survive the heat processing temperatures.

REFRIGERATION

Normal refrigeration (5°C) can no longer be relied upon to ensure the safety of meat products. However, refrigeration at 5°C will slow bacterial growth thereby delaying spoilage (Banwart, 1981). Storage temperatures of 2-4°C will prevent most pathogenic growth and reduce growth rates of spoilage bacteria (Rosset, 1982). Meat stored aerobically at 0°C with initial bacterial contamination of 3 log CFU per square centimeter developed putrefaction after 11 days. The onset of putrefaction can possibly be retarded by 14-21 additional days, depending upon refrigeration conditions and the use of other microbial controls.

Freezing is an effective method of meat preservation which acts by internal dehydration of the product (Hultin, 1985). The freezing/thawing process may destroy some bacterial cells, but generally freezing is only bacteriostatic, not bactericidal (Banwart, 1981). E. coli 0157:H7 (hemorrhagic E. coli) survived nine months of storage at -20°C (Doyle and Schoeni, 1984). Bacterial spores are not sensitive to freezing. Gram-positive bacteria such as staphylococci are more resistant than the gram-negative bacteria such as Salmonella (Rosset, 1982). Table 1 lists recommended maximum storage times for fresh,

cooked and processed meats (Romans et al., 1985). The authors did not differentiate the recommended storage times based on type of packaging, especially for the fresh product. The recommended refrigerated storage has to be for aerobically packaged product. Some of the papers reviewed earlier mentioned 28-60 days for different treatments, packaged under a vacuum or modified atmosphere. Table 2 consists of recommended storage times for some precooked products stored at -18°C . These storage times are considered the maximum storage before product quality begins to deteriorate (Forrest et al., 1975).

Advantages of frozen storage involve savings on overhead, labor and decreased product loss (less rework and shrinkage), especially when products are produced at centralized processing facilities (Kropf, 1982). In the context of this paper, freezing allows for greater flexibility in distribution and marketing without compromising the microbial quality of the product. There are also disadvantages and possible problems which can be overcome. The cost of freezing, labor and overhead is shifted to the processing center but requires the retail facility to shift overhead from processing equipment to frozen storage and display equipment.

Consumer acceptance of the frozen versus fresh product can be enhanced by the convenience and appearance of the

product. A critical control point in producing and marketing frozen product is ensuring that proper temperature (-18°C) is maintained and that product packaging withstands the additional handling and frozen temperatures. When thawed or tempered, previously frozen meat is no more microbially stable than fresh meat.

Table 1.
Recommended Storage Times and Temperatures for
Fresh, Cooked and Processed Meats.

(months) Product lower)	Refrigerated (days) (3.3 to 4.4 $^{\circ}\text{C}$)	Frozen (-18°C or lower)
Beef (fresh)	2-4	6-12
Veal (fresh)	2-4	6-9
Pork (fresh)	2-4	3-6
Lamb (fresh)	2-4	6-9
Ground beef, veal and lamb	1-2	3-4
Ground pork	1-2	1-3
Sausage, fresh pork	7	2
Sausage, smoked	3-7	1
Leftover cooked meat	4-5	2-3
Meat pies	-	3
Swiss steak	-	3
Stews	-	3-4
Prepared meat dinners	-	2-6

(Romans et al., 1985)

Table 2.
Recommended Storage Times for some Precooked
Meat Products Stored at -18°C.

Product	Packaging type	Storage Time (months)
Broiled beef patties	layer packed	6
Broiled beef patties (with textured soy flour)	layer packed	6
Roast beef, unsliced	vacuum	18
Sandwiches	saran overwrapped	2

(Forrest et al. 1975)

MICROBIAL MONITORING

Due to concerns of food safety, knowing the microbial quality of the product is important. Several methods of microbial monitoring of equipment and product are available. Some which require small investments of time and equipment, others require extensively equipped microbiology laboratories with trained personnel. The standard plate count requires serial dilutions and a minimum of 24 or 48 hours incubation time. Recently alternate methods have been developed to enumerate and identify bacteria on foods (Fung et al. 1980a; Fung 1984; Fung et al., 1986; Firstenberg-Eden and Zindulis, 1987). Fung et al (1980a) and Lee and Fung (1982) reported the use of Mylar adhesive tape to estimate bacterial populations on meat surfaces. Petrifilm SM (3M Company) involves a

dilution of a solid sample added to a dry culture medium (Firstenberg-Eden and Zindulis, 1987). The Petrifilm SM system is very simple, but requires incubation times similar to conventional pour plate methods. The spiral plate count method eliminates tedious serial dilutions of the sample and allows for estimation of bacterial concentrations over a range of approximately 3 to 6 log CFU per milliliter. The Limulus test is available to estimate gram-negative bacteria and requires about one hour to complete (Fung, 1984). Methods which indirectly measure cell metabolism in various ways have been developed (Fung, 1984; Firstenberg-Eden and Zindulis, 1987). Each method has its own advantages, disadvantages and required equipment. A method should be evaluated for the situation to which it is applied and the desired results. For a more thorough and detailed discussion of these methods the reader is referred to the following papers: Fung et al., 1986; Anon, 1987; and Firstenberg-Eden and Zindulis, 1987. Use of monitoring devices will not only yield a measure of product microbial quality, but also a measure of sanitation efficiency.

The effects of nitrite were not discussed in this paper because of the focus on uncured, restructured products. However, the preservative effect of nitrite would certainly eliminate many microbial concerns. Nitrite

inhibits the growth of most organisms, especially anaerobic and aerobic spore-forming bacteria (Trout and Schmidt, 1987). Inclusion of nitrite in restructured product could significantly alter the microbiological characteristics of the product.

SUMMARY

Advancing technologies are available to produce restructured meat products which can meet the demand of today's market place. To ensure microbial safety of the final product, producers must be aware of the potential bacterial hazards and the critical control points for restructured products to insure their wholesomeness.

Essentially all meat type animals are in contact with and harbor pathogenic bacteria. Care must be taken to minimize meat contamination during slaughter and further processing. Although the actual microflora is not significantly altered, accelerated processing methods can result in slightly higher mesophilic and psychrotrophic bacterial counts than conventional chilling and boning.

Ingredients used in restructured meat must be of high microbial quality to prevent addition to the microbial population of a product. Soy proteins, even if not adding to the bacterial population can enhance microbial growth. MDM often contains higher bacterial numbers than the meat

block to which it is added. Natural spices can introduce vegetative cells and spores of Bacillus. Varying concentrations of salt can have differing effects on different species of bacteria, however salt reduction normally encourages microbial growth. Some ingredients, such as the phenolic antioxidants, are also bacteriostatic towards some bacteria and have synergistic bacteriostatic effects as they interact with other ingredients. The literature concerning phosphates is varied and the amounts used and product pH are important in determining their effectiveness. The antimicrobial effects of phosphates are limited and should be individually considered for each product.

The time and temperature of thermal processing, in addition to the method of thermal processing, have significant effects on the product's microflora. The cook-in-the-bag system aids in preventing post cooking contamination. Prevention of post cooking contamination is important to prevent the growth of pathogens in an environment where their microbial competitors have been eliminated by heat treatments.

Packaging with modified atmospheres or vacuum alter the microflora of products and extend shelf-life. A 20% CO₂ concentration in modified atmosphere packages appears

to be the minimum needed to effectively inhibit most spoilage bacteria.

Refrigeration can not be relied upon completely to ensure product wholesomeness by preventing potential pathogen growth but remains an effective and important means of preservation. Freezing can maintain microbial quality of product for longer periods, allowing marketing flexibility. Effects of refrigeration used with other means of microbial control are synergistic.

Utilization of high microbial quality ingredients, proper temperatures for processing and storage and selection of functional packaging for specific products can result in safe and convenient restructured meat products.

REFERENCES

- Abram, D.D. and Potter, N.N. 1984. Survival of Campylobacter jejuni at different temperatures in broth, beef, chicken and cod supplemented with sodium chloride. J. Food Prot. 47(10):795.
- Ahmad, H.A. and Marchello, J.A. 1989. Effect of gas atmosphere packaging on psychrotrophic growth and succession on steak surfaces. J. Food Sci. 54(2):274.
- Ansoborlo, M.J. 1988. The use of modified atmosphere for meat packaging. Proc. 34th Int. Congress Meat Sci. Technol. p. 548.
- Ayres, J.C., Mundt, J.O. and Sandine, W.E. 1980. Meat and Meat Products. In "Microbiology of Foods." Schweigert, B.S. ed. p. 391. W.H. Freeman and Company, San Francisco.
- Bacus, J. 1988. Microbial control methods in fresh and processed meats. Proc. Recip. Meat Conf. 41:7.
- Banwart, G.J. 1981. Basic Food Microbiology. AVI. Westport, Conn.
- Bell, W.N. and Shelef, L.A. 1978. Availability and microbial stability of retail beef-soy blends. J. Food Sci. 43:315.
- Benedict, R.C. 1988. Microbial attachment to meat surfaces. Proc. Recip. Meat Conf. 41:1.
- Blacher, N. 1983. Demographic and consumer trends in fast food. R & D Associates, San Antonio. 35(1):8.
- Boyd, K.J., Ockerman, H.W. and Plimpton, R.F. 1978. Sensory characteristics and microbiological evaluation of stored mechanically tenderized beef semimembranosus muscle. J. Food Sci. 43:670.
- Brackett, R.E. 1988. Presence and persistence of Listeria monocytogenes in food and water. Food Technol. 42(4):162.
- Breidenstein, B.C. 1982. Wholesale packaging for fresh meat. Proc. Int. Symp. Meat Sci. Technol. p. 343. National Live Stock and Meat Board, Chicago.

- Breidenstein, B.C. 1983. Restructured meat products today and tomorrow. R & D Associates, San Antonio. 35(1):75.
- Busta, F.F. and Schroder, D.J. 1971. Effect of soy proteins on the growth of Clostridium perfringens. Appl. Microbiol. 22(2):177.
- Carr, T.P. and Marchello, J.A. 1986. Microbial changes of precooked beef slices as affected by packaging procedure. J. Food Prot. 49(7):534.
- Carr, T.P. and Marchello, J.A. 1987. Growth of aerobic psychrotrophs and color changes of precooked beef slices as affected by packaging procedure. J. Food Prot. 50(9):733.
- Choi, Y.I. 1986. Effects of hot boning, varying levels of salt and phosphate and storage period on characteristics of preblended pork used in frankfurters. PhD Dissertation. Kansas State University, Manhattan, Ks.
- Choi, Y.I., Kastner, C.L. and Kropf, D.H. 1987. Effects of hotboning and various levels of salt and phosphate on microbial, TBA, and pH values of preblended pork during cooler storage. J. Food Prot. 50(12):1037.
- Chung, K.T., Dickson, J.S. and Crouse, J.D. 1989. Attachment and proliferation of bacteria on meat. J. Food Prot. 52(3):173.
- Clarke, A.D., Sofos, J.N. and Schmidt, G.R. 1988a. Effect of algin/calcium binder levels on various characteristics of structured beef. J. Food Sci. 53(3):711.
- Clarke, A.D., Sofos, J.N. and Schmidt, G.R. 1988b. Influence of varying pH and algin/calcium binders on selected physical and sensory characteristics of structured steak. J. Food Sci. 53(5):1266.
- Contreras, S., Harrison, D.L., Kropf, D.H. and Kastner, C.L. 1981. Electrical stimulation and hot-boning: Cooking losses, sensory properties, and microbial counts of ground beef. J. Food Sci. 46:457.
- Craven, S.E. and Mercuri, A.J. 1979. Sporulation of Clostridium perfringens in meats supplemented with soy materials. J. Food Sci. 44:755.

- Craven, S.E. and Blankenship, L.C. 1983. Increased heat resistance of Salmonellae in beef with added soy proteins. J. Food Prot. 46(5):380.
- Crouse, J.D., Anderson, M.E. and Naumann, H.D. 1988. Microbial decontamination and weight of carcass beef as affected by automated washing pressure and length of time of spray. J. Food Prot. 51(6):471.
- Davidson, M.P. 1983. Phenolic compounds. In "Antimicrobials in Foods." Brannen, A.L. and Davidson, M.P. eds. p. 37. Marcel Dekker, Inc., New York.
- Davidson, M.P., Post, L.S., Brannen, A.L. and McCurdy, A.R. 1983. Naturally occurring and miscellaneous food antimicrobials. In "Antimicrobials in Foods." Brannen, A.L. and Davidson, M.P. eds. p 371. Marcel Dekker, Inc., New York.
- Desrosier, N.W. and Desrosier, J.N. 1977. Principles of food pickling and curing. In "The Technology of Food Preservation." 4th ed. p.340. AVI, Westport, CT.
- Dickson, J.S. 1988. Reduction of bacteria attached to meat surfaces by washing with selected compounds. J. Food Prot. 51(11):869.
- Dickson, J.S. and Crouse, J.D. 1989. Effect of electrical charge on attachment of Salmonella typhimurium to meat surfaces. J. Food Sci. 54(3):516.
- Doyle, M.P. and Roman, D.J. 1982. Response of Campylobacter jejuni to sodium chloride. Appl. Environ. Microbiology. 43(3):561.
- Doyle, M.P. and Schoeni, J.L. 1984. Survival and growth characteristics of Escherichia coli associated with hemorrhagic colitis. Appl. Environ. Microbiol. 48(5):855.
- Doyle, M.P. 1988. Effect of environmental and processing conditions on Listeria monocytogenes. Food Technol. 42(4):169.
- Duxbury, D.D. 1986. Whey protein concentrate binds restructured steaks. Food Processing. 47(12):58.

- Dziezak, J.D. 1987a. Microwavable foods-industry's response to consumer demands for convenience. Food Technol. 41(6):52.
- Dziezak, J.D. 1987b. Rapid methods for microbiological analysis of food. Food Technol. 41(7):56.
- Egan, A.F., Eustace, I.J. and Shay, B.J. 1988. Meat packaging-maintaining the quality and prolonging the storage life of chilled beef, pork and lamb. Proc. 34th Int. Congress Meat Sci. Technol. P. 68.
- Eklund, T., Nes, I.F. and Skjelkvale, R. 1981. Control of Salmonella at different temperatures by propyl paraben and butylated hydroxyanisole. In "Psychrotrophic Microorganisms in Spoilage and Pathogenicity." Roberts, T.A., Hobbs, G, Christian, J.H.B. and Skovguand, N. eds. p. 376. Academic Press Inc., New York.
- El-Hag, N. 1989. The refrigerated food industry: Current status and developing trends. Food Technol. 43(3):96.
- Emswiler, B.S., Pierson, C.J., Kotula, A.E. and Cross, H.R. 1979. Microbiological evaluation of precooked beef patties containing soy protein. J. Food Sci. 44(1):154.
- Emswiler-Rose, B. and Kotula, A.W. 1984. Inhibition of bacterial growth by two chlorine sources in a model system. J. Food Sci. 49:931.
- Endres, J.G. and Monagle, C.W. 1987. Nonmeat protein additives. In "Advances in Meat Research; Vol 3: Restructured Meat and Poultry Products." Pearson, A.M. and Dutson, T.R. eds. p. 331. Van Nostrand Reinhold Co., New York.
- Erickson, D.B., McCoy, J.H., Riley, J.B., Chung, D.S., Nason, P.G., Allen, D.M., Dikeman, M.E., Fung, D.Y.C., Hunt, M.C., Kastner, C.L. and Kropf, D.H. 1980. Economic feasibility of hot processing beef carcasses. Bulletin 639. Agricultural Experiment Station, Kansas State University, Manhattan, Ks.
- Ernst, L.J. 1979. Changing demands for meat. Proc. Meat Ind. Res. Conf. p. 1. Amer. Meat Inst. Foundation, Washington, D.C.

- Everson, C.W. 1978. Use of additives in manufactured meat products. Proc. 20th Meat Sci. Inst., Univ. Georgia, Athens. p. 52.
- Field, R.A., Booren, A., Larsen, S.A. and Kinnison, J.L. 1977. Characteristics of restructured beef steaks containing mechanically deboned meat. J. Anim. Sci. 45(6):1289.
- Field, R.A. 1981. Mechanically deboned red meat. In Adv. Food Res. 27:23.
- Firstenberg-Eden, R. and Zindulis, J. 1987. Rapid Automated Methods. In "Food Microbiology, Vol II New and Emerging Technologies. Montville, T.J. ed. p. 15. CRC Press, Inc., Boca Raton, FL.
- Forrest, J.C., Aberle, E.D., Hedrick, H.B., Judge, M.D. and Merkel, R.A. 1975. Methods of storing and preserving meat. In "Principles of Meat Science." p. 257. W.H. Freeman and Company, New York.
- Fung, D.Y.C. and Cunningham, F.E. 1980. Effect of microwaves on microorganisms in foods. J. Food Prot. 43(8):641.
- Fung, D.Y.C., Lee, C.Y. and Kastner, C.L. 1980a. Adhesive tape method for estimating microbial load on meat surfaces. J. Food Prot. 43(4):295.
- Fung, D.Y.C., Kastner, C.L., Hunt, M.C., Dikeman, M.E. and Kropf, D.H. 1980b. Mesophilic and psychrotrophic bacterial populations on hot-boned and conventionally processed beef. J. Food Prot. 43(7):547.
- Fung, D.Y.C., Kastner, C.L., Lee, C.Y., Hunt, M.C., Dikeman, M.E. and Kropf, D.H. 1981. Initial chilling rate effects on bacterial growth on hot-boned beef. J. Food Prot. 44(7):539.
- Fung, D.Y.C. 1983. Microbiology of batter and breading. In "Technology of Batter and Breading." Suderman, D. and Cunningham, F.E. eds. p. 106. AVI, New York.
- Fung, D.Y.C. 1984. Rapid and automatic methods of microbiological analysis. Proc. Meat Ind. Res. Conf. p. 1. Amer. Meat Inst. Foundation, Washington, D.C.

- Fung, D.Y.C. 1986. Microbiology of meats. MF-792. Cooperative Extension Bulletin. Kansas State Univ. Manhattan.
- Fung, D.Y.C., Hart, R.A. and Chain, V. 1986. Rapid methods and automated procedures for microbiological evaluation of seafood. In "Seafood Quality Determination." Kramer, D.e. and Liston, J. eds. p. 247. Elsevier Sci. Publisher, Amsterdam.
- Gabis, D. and Faust, R.E. 1988. Controlling microbial growth in food processing environments. Food Technol. 42(12):81.
- Gailani, M.B. and Fung, D.Y.C. 1984. Antimicrobial effects of selected antioxidants in laboratory media and ground pork. J. Food Prot. 47(6):428.
- Gilbert, J. and Knowles, M.E. 1975. The chemistry of smoked foods: A review. Food Technol. 10:245.
- Gill, C.O. 1980. Total and intramuscular bacterial populations of carcasses and cuts. Proc. Recip. Meat Conf. 33:47.
- Gill, C.O. 1982. Microbial interaction with meats. In "Meat Microbiology." Brown, M.H. ed. p. 225. Applied Sciences Publishers LTD., New York.
- Gorbatov, V.M., Krylova, N.N., Volovinskaya, V.P., Luaskovskaya, Ya.N., Bazarova, K.I., Khlamova, R.I. and Yakovleva, G.Ya. 1971. Liquid smokes for use in cured meats. Food Technol. 25:71.
- Grau, F.H. and Vanderlinde, P.B. 1988. Growth of Listeria monocytogenes on vacuum packaged beef. Proc. 34th Int. Congress Meat Sci. Technol. p.518.
- Grau, F.H. 1988. Campylobacter jejuni and Campylobacter hyointestinalis in the intestinal tract and on the carcasses of calves and cattle. J. Food Prot. 51(11):857.
- Gravani, R.B. 1984. Food science facts. Dairy Food Sanitation. 7:279.
- Gray, J.I. and Pearson, A.M. 1987. Rancidity and warmed over flavor. In "Advances in Meat Research; Vol 3: Restructured Meat and Poultry Products." Pearson, A.M.

- and Dutson, T.R. eds. p. 221. Van Nostrand Reinhold Co., New York.
- Hamby, P.L., Savell, J.W. Acuff, G.R., Vanderzant, C.W. and Cross, H.R. 1987. Spray-chilling and carcass decontamination systems using lactic and acetic acid. *Meat Sci.* 21:1.
- Hand, L.W., Crenwelge, C.H. and Terrell, R.N. 1981. Effects of wheat gluten, soy isolate and flavorings on properties of restructured beef steaks. *J. Food Sci.* 46:1004.
- Harrison, M.A., Melton, C.C. and Draughon, F.A. 1981. Bacterial flora of ground beef and soy extended ground beef during storage. *J. Food Sci.* 46:1088.
- Henrickson, R.L. 1975. Hot boning. *Proc. Meat Ind. Res. Con.* p. 25. Amer. Meat Inst. Foundation, Washington, D.C.
- Hollenbeck, C.M. 1979. Liquid smoke flavoring-status of development. *Food Technol.* 33(5):88.
- Huffman, D.L. 1978. Structured meat products. *Proc. 20th Annual Meat Sci. Inst., Univ. Georgia, Athens.* p. 62.
- Hultin, H.O. 1985. Characteristics of muscle tissue. In "Food Chemistry." Fennema, O.R. ed. p. 725. Marcel Dekker, Inc., New York.
- Jen, C.M.C. and Shelef, L.A. 1986. Factors affecting sensitivity of Staphylococcus aureus 196E to polyphosphates. *Appl. Environ. Microbiol.* 52(4):842.
- Johnson, M.G., Titus, T.C., McCaskill, L.H. and Acton, J.C. 1979. Bacterial counts on surfaces of carcasses and in ground beef from carcasses sprayed or not sprayed with hypochlorous acid. *J. Food Sci.* 44(1):169.
- Johnston, R.W., Harris, M.E., Moran, A.B., Krumm, G.W. and Lee, W.H. 1982. A comparative study of the microbiology of commercial vacuum packaged and hanging beef. *J. Food Prot.* 45(3):223.
- Jones, S.L., Carr, T.R. and McKeith, F.K. 1987. Palatability and storage characteristics of precooked pork roasts. *J. Food Sci.* 52(2):279.

- Judge, M.D. and Cousin, M.A. 1983. Psychrotrophic bacteria in prerigor ground pork. *J. Food Sci.* 48:1348.
- Kastner, C.L. 1977. Hot processing: Update on potential energy and related economies. *Proc. Meat Ind. Res. Conf.* p. 43. Amer. Meat Inst. Foundation, Washington, D.C.
- Kastner, C.L. 1983. Optimal hot-processing systems for beef. *Food Technol.* 37(5):96.
- Kent, G. 1986. Convenience retail meat products for microwaving. *Proc. Recip. Meat Conf.* 39:75.
- Klindworth, K.J., Davidson, M.P., Brekke, C.J. and Brannen, A.L. 1979. Inhibition of Clostridium perfringens by butylated hydroxyanisole. *J. Food Sci.* 44(2):565.
- Knutson, J. and Schuck, P. 1989. *Meat Facts 1988*. Amer. Meat Inst. Foundation, Washington, D.C.
- Konuma, H., Shinagawa, K., Tokumaru, M., Onoue, Y., Konno, S., Fujino, N., Shigehisa, T., Kurata, H., Kuwabara, Y. and Lopes, C.A.M. 1988. Occurrence of Bacillus cereus in meat products, raw meat and meat product additives. *J. Food Prot.* 51(4):324.
- Kotula, A.W., Lusby, W.R. and Crouse, J.D. 1975. Variability in microbiological counts on beef carcasses. *J. Anim. Sci.* 40(5):834.
- Kotula, A.W. and Emswiler-Rose, B.S. 1981. Bacteriological quality of hot-boned primal cuts from electrically stimulated beef carcasses. *J. Food Sci.* 46:471.
- Kotula, A.W., Emswiler-Rose, B.S. and Berry, B.W. 1987a. Microbial counts of selected hot-boned primals and ground beef. *J. Food Prot.* 50(11):915.
- Kotula, A.W., Berry, B.W. and Emswiler-Rose, B.S. 1987b. Microbiology of restructured meat and poultry products. In "Advances in Meat Research; Vol 3: Restructured Meat and Poultry Products." Pearson, A.M. and Dutson, T.R. eds. p. 161. Van Nostrand Reinhold Co., New York.
- Kotula, A.W. and Emswiler-Rose, B.S. 1988. Airborne microorganisms in a pork processing establishment. *J. Food Prot.* 51(12):935.

- Kraft, A.A. 1986. Meat Microbiology. In "Muscle as Food." Bechtel, P.J. ed. p. 240. Academic Press, Inc., New York.
- Kraniak, J.M. and Shelef, L.A. 1988. Effect of Ethylenediaminetetraacetic acid (EDTA) and metal ions on growth of Staphylococcus aureus 196E in culture media. J. Food Sci. 53(3):910.
- Krautil, F.L. and Tulloch, J.D. 1987. Microbiology of mechanically recovered meat. J. Food Prot. 50(7):557.
- Kropf, D.H. 1982. Retail packaging of frozen meat. Proc. Int. Symp. Meat Sci. Technol. p. 367. National Live Stock and Meat Board, Chicago.
- Lahellec, C., Fung, D.Y.C. and Cunningham, F.E. 1981. Growth effect of sorbate and selected antioxidants on toxigenic strains of Staphylococcus aureus. J. Food Prot. 44(7):531.
- Lamkey, J.W., Mandigo, R.W. and Calkins, C.R. 1986. Effect of salt and phosphate on the texture and color stability of restructured beef steaks. J. Food Sci. 51(4):873.
- Lammerding, A.M., Garcia, M.M., Mann, E.D., Robinson, Y., Dorward, W.J., Truscott, R.B. and Tittiger, F. 1988. Prevalence of Salmonella, and thermophilic Campylobacter in fresh pork, beef, veal and poultry in Canada. J. Food Prot. 51(1):47.
- Larocco, K.A. and Martin, S.E. 1987. Effects of potassium sorbate alone and in combination with sodium chloride on growth of Staphylococcus aureus MF-31. J. Food Prot. 50(9):750.
- Lazarus, C.R., West, R.L., Oblinger, J.L. and Palmer, A.Z. 1976. Evaluation of a calcium alginate coating and a protective plastic wrapping for the control of lamb carcass shrinkage. J. Food Sci. 41:639.
- Lee, C.Y. and Fung, D.Y.C. 1982. Miniaturized methods and computer analysis in meat microbiology. In "Rapid Methods and Automation in Microbiology." Tilton, R.C. ed. p. 191. Amer. Soc. Microbiol. Washington, D.C.
- Lee, C.Y., Fung, D.Y.C. and Kastner, C.L. 1982. Computer-assisted identification of bacteria on hot-boned and conventionally processed beef. J. Food Sci. 47(2):363.

- Lee, C.Y., Fung, D.Y.C. and Kastner, C.L. 1985. Computer-assisted identification of microflora on hot-boned and conventionally processed beef: Effect of moderate and slow chilling rate. *J. Food Sci.* 50:553.
- Lin, H.S., Topel, D.G. and Walker, H.W. 1979. Influence of prerigor and postrigor muscle on the bacteriological and quality characteristics of pork sausage. *J. Food Sci.* 44:1055.
- Lindsay, R.C. 1985. Food additives. In "Food Chemistry." Fennema, O.B. ed. p. 629. Marcel Dekker, Inc., New York.
- Maga, J.A. 1988. Antimicrobial properties of smoke. In "Smoke in Food Processing." p. 107. CRC Press, Inc., Boca Raton, FL.
- Mandigo, R.W. 1975. Restructured meat. *Proc. Meat Ind. Res. Conf.* p. 43. Amer. Meat Inst. Foundation, Washington, D.C.
- Marcy, J.A., Kraft, A.A., Hotchkiss, D.K., Molins, R.A., Olson, D.G., Walker, H.W. and White, P.J. 1988a. Effect of acid and neutral pyrophosphates on the natural bacterial flora of a cooked meat system. *J. Food Sci.* 53(1):28.
- Marcy, J.A., Kraft, A.A., Hotchkiss, D.K., Molins, R.A., Olson, D.G., Walker, H.W. and Merkenich, K. 1988b. Effects of selected commercial phosphate products on the natural bacterial flora of a cooked meat system. *J. Food Sci.* 53(2):391.
- McDaniel, M.C., Marchello, J.A. and Tinsley, A.M. 1984. Effect of different packaging treatments on microbiological and sensory evaluation of precooked beef roasts. *J. Food Prot.* 47(1):23.
- McKinley, G.A., Fagerberg, D.J., Quarles, C.L., George, B.A., Wagner, D.E. and Rollins, L.D. 1980. Incidence of *Salmonella* in fecal samples of production swine and swine at slaughter plants in the United States in 1978. *Appl. Environ. Microbiol.* 40(3):562.
- Means, W.J. and Schmidt, G.R. 1986. Algin/calcium gel as a raw and cooked binder in structured beef steaks. *J. Food Sci.* 55:61.

- Means, W.J., Clarke, A.D., Sofos, J.N. and Schmidt, G.R. 1987. Binding, sensory and storage properties of algin/calcium structured beef steaks. *J. Food Sci.* 52:252.
- Means, W.J. and Schmidt, G.R. 1987. Restructuring fresh meat without the use of salt or phosphate. In "Advances in Meat Research; Vol 3: Restructured Meat and Poultry Products." Pearson, A.M. and Dutson, T.R. eds. p. 469. Van Nostrand Reinhold Co., New York.
- Mendonca, A.F., Molins, R.A., Kraft, A.A. and Walker, H.W. 1989. Microbiological, chemical, and physical changes in fresh, vacuum-packaged pork treated with organic acids and salts. *J. Food Sci.* 54(1):18.
- Miller, K.A., Reagan, J.O., Cordray, J.C., Abu-bakar, A., Huffman, D.L. and Jones, W.R. 1984. Comparison of hot processing systems for pork. *J. Anim. Science.* 58(3):605.
- Miller, M. F., Davis, G.W., Seideman, S.C. and Ramsey, C.B. 1986a. Effects of chloride salts on appearance, palatability, and storage traits of flaked and formed beef bullock restructured steaks. *J. Food Sci.* 51(6):1424.
- Miller, M.F., Davis, G.W., Seideman, S.C., Ramsey, C.B. and Rolan, T.L. 1986b. Effects of various phosphates on the palatability, appearance and storage traits of flaked and formed restructured beef steaks. *J. Food Sci.* 51(6):1435.
- Minarik, C.E. 1989. Effects of glucose, phosphate, salt and cooking temperatures on the microbiology of pre- and post-rigor restructured beef roasts. Masters Thesis. Kansas State University, Manhattan, Ks.
- Molins, R.A., Kraft, A.A., Walker, H.W., Rust, R.E., Olson, D.G. and Merkenich, K. 1987a. Effect of inorganic polyphosphates on ground beef characteristics: Microbiological effects on frozen beef patties. *J. Food Sci.* 52(1):46.
- Molins, R.A., Kraft, A.A. and Marcy, J.A. 1987b. Extension of the shelf-life of fresh ground pork with polyphosphates. *J. Food Sci.* 52(2):513.
- Morr, C.V. 1984. Production and use of milk proteins in food. *Food Technol.* 38(7):39.

- Newsome, R.L., Seman, D.L., Langlois, B.E., Moody, W.G., Fox, J.D. and Gay, N. 1987. Microbiological quality of restructured and conventional steaks manufactured from electrically stimulated hot- and cold-boned carcasses. 1987. J. Food Sci. 52(4):861.
- Nielson, H.-J.S. and Zeuthen, P. 1986. Influence of sodium substitution with potassium on microbial and organoleptic spoilage patterns in sliced vacuum-packed pasteurized pork loin. J. Food Prot. 49(12):999.
- NLSMB. 1985. Manufacturing guidelines...processed non-cured pork-products. National Live Stock and Meat Board, Chicago.
- Nottingham, P.M. 1982. Microbiology of carcass meats. In "Meat Microbiology," Brown, M.H. ed. p. 13. Applied Science Publishers LTD., New York.
- Ockerman, H.W. and Crespo, F.L. 1977. Cooking of fabricated beef. J. Food Sci. 42(5):1410.
- Palumbo, S.A. 1986. Is refrigeration enough to restrain foodborne pathogens? J. Food Prot. 49(12):1003.
- Paterson, B.C. and Parrish, F.C.Jr. 1988. Factors affecting the palatability and shelf life of precooked, microwave- reheated beef roasts. J. Food Sci. 53(1):31.
- Pearson, A.M. and Tauber, F.W. 1984. Processed Meats. 2nd ed. AVI Publishing Co. Inc. Westport, CT.
- Pierson, M.D., Collins-Thompson, D.L. and Ordal Z.J. 1970. Microbiological, sensory and pigment changes of aerobically and anaerobically packaged beef. Food Technol. 24:1171.
- Prabhu, G.A., Molins, R.A., Kraft, A.A., Sebranek, J.G. and Walker. 1988. Effect of heat treatment and selected antimicrobials on the shelf-life and safety of cooked, vacuum-packaged, refrigerated pork chops. J. Food Sci. 53(5):1270.
- Raccach, M. and Henningsen, E.C. 1981. Antibacterial effect of tertiary butylhydroquinone against two genera of gram positive cocci. J. Food Sci. 47:106.

- Ray, B. and Field, R.A. 1983. Bacteriology of restructured lamb roasts made with mechanically deboned meat. J. Food Prot. 46(1):26.
- Ray, B., Johnson, C. and Field, R.A. 1984. Growth of indicator, pathogenic and psychrotrophic bacteria in mechanically separated beef, lean ground beef and beef bone marrow. J. Food Prot. 47(9):672.
- Reagan, J.O. 1983. Optimal processing system for hot-boned pork. Food Technol. 37(5):79.
- Restaino, L., Komatsu, K.K. and Syracuse, M.J. 1981. Effect of acids on potassium sorbate inhibition of food-related microorganisms in culture media. J. Food Sci. 47:134.
- Robach, M.C. and Pierson, M.D. 1978. Influence of para-hydroxybenzoic acid esters on the growth and toxin production of Clostridium botulinum 10755A. J. Food Sci. 43:787.
- Robach, M.C. 1980. Interaction of salt, potassium sorbate and temperature on the outgrowth of Clostridium sporogenes PA 3679 spores in a pre-reduced medium. J. Food Sci. 45:742.
- Roberts, D. 1982. Bacteria of public health significance. In "Meat Microbiology." Brown, M.H. ed. p. 319. Applied Science Publishers LTD., New York.
- Rosset, R. 1982. Chilling, freezing and thawing. In "Meat Microbiology." Brown, M.H. ed. p. 265. Applied Science Publishers LTD., New York.
- Salm, C.P., Ray, F.K., Aberle, E.D., Okos, M.R. and Judge, M.D. 1978. Yield characteristics, microbial load and chilling rates of skinned pork carcasses. J. Food Sci. 43:1144.
- Savell, J.W., Griffin, D.B., Dill, C.W., Acuff, G.R. and Vanderzant, C. 1986. Effect of film oxygen transmission rate on lean color and microbiological characteristics of vacuum-packaged beef knuckles. J. Food Prot. 49(11):917.
- Schaefer-Seidler, C.E., Judge, M.D., Cousin, M.A. and Aberle E.D. 1984. Microbiological contamination and primal cut yields of skinned and scalded pork carcasses. J. Food Sci. 49:356.

- Schmidt, G.R. 1986. Processing and fabrication. In "Muscle as Food." Bechtel, P.J. ed. p. 218. Academic Press, Inc., Orlando.
- Schmidt, G.R., Moore, S.L., Gildemeister, B.D. and Sofos, J.N. 1988. The effect of injected soy protein concentrate on restructured beef. Proc. 34th Int. Congress Meat Sci. Technol. p. 413.
- Schwartz, W.C. and Mandigo, R.W. 1976. Effect of salt, sodium tripolyphosphate and storage on restructured pork. J. Food Sci. 41:1266.
- Secrist, J.L. 1982. Long-term research needs and goals. Proc. Int. Symp. Meat Sci. Technol. p. 299. National Live Stock and Meat Board, Chicago.
- Secrist, J.L. 1987. Restructured meats-the past and present. In "Advances in Meat Research; Vol 3: Restructured Meat and Poultry Products." Pearson, A.M. and Dutson, T.R. eds. p. 1. Van Nostrand Reinhold Co., New York.
- Seideman, S.C. 1982. Utilization of meat and non-meat replacements in restructured products. In "Meat Science and Technology; International Symposium Proc." Franklin, K.R. and Cross, H.R. eds. National Live stock and Meat Board, Chicago.
- Seideman, S.C., Smith, G.C., Carpenter, Z.L., Dutson, T.R. and Dill, C.W. 1979. Modified gas atmospheres and changes in beef during storage. J. Food Sci. 44:1036.
- Shelof, L.A. 1977. Effect of glucose on the bacterial spoilage of beef. J. Food Sci. 42(5):1172
- Siegel, D.G. and Schmidt, G.R. 1979. Crude myosin fractions as meat binders. J. Food Sci. 44:1129.
- Simunovic, J., Oblinger, J.L. and Adams, J.P. 1985. Potential for growth of nonproteolytic types of Clostridium botulinum in pasteurized restructured meat products: a review. J. Food Prot. 48(3):265.
- Smith, M.G. 1988. Decontamination of beef carcasses with hot water. Proc. 34th Int. Congress Meat Sci. Technol. p.646.
- Smulders, F.J.M. and Woolthuis, C.H.J. 1983. Influence of two levels of hygiene on the microbiological condition

- of veal as a product of two slaughtering/processing sequences. J. Food Prot. 46(12):1032.
- Sofos, J.N., Maga, J.A. and Boyle, D.L. 1988. Effect of ether extracts from condensed wood smokes on the growth of Aeromonas hydrophila and Staphylococcus aureus. J. Food Sci. 53(6):1840.
- Stern, N.J., Smoot, L.A. and Pierson, M.D. 1979. Inhibition of Staphylococcus aureus growth by combinations of butylated hydroxyanisole, sodium chloride, and pH. J. Food Sci. 44:710.
- Stern, N.J., Pierson, M.D. and Kotula, A.W. 1980. Effects of pH and sodium chloride on Yersinia enterocolitica growth at room and refrigeration temperatures. J. Food Sci. 45:64.
- Stern, N.J. 1980. Effect of boning, electrical stimulation and medicated diet on the microbiological quality of lamb cuts. J. Food Sci. 45:1749.
- Stern, N.J. 1981. Recovery rate of Campylobacter fetus ssp. jejuni on eviscerated pork, lamb and beef carcasses. J. Food Sci. 46:1291.
- Stern, N.J. and Custer, C.S. 1985. Salmonella growth in cooked beef at selected cooling rates. J. Food Prot. 48(12):1046.
- Stites, C.R., McKeith, F.K., Bechtel, P.J. and Carr, T.C. 1989. Palatability and storage characteristics of precooked beef roasts. J. Food Sci. 54(1):3.
- Stringer, W.C., Bilskie, M.E. and Naumann, H.D. 1969. Microbial profiles of fresh beef. Food Technol. 23(1):97.
- Stringer, W.C. 1976. Microbiology of carcasses. Proc. Meat Ind. Res. Conf. p. 87. Amer. Meat Inst. Foundation, Washington, D.C.
- Stringer, W.C. 1982. Removing microbes from meat surfaces. Proc. Meat Ind. Res. Conf. p. 81. Amer. Meat Inst. Foundation, Washington, D.C.
- Szabo, R.A., Todd, E.C.D. and Jean, A. 1986. Method to isolate Escherichia coli 0157:H7 from food. J. Food Prot. 49(10):768.

- Taylor, A.A. 1982. Retail packaging systems for fresh meat. Proc. Int. Symp. Meat Sci. Technol. p. 353. National Live Stock and Meat Board, Chicago.
- Thomas, D.J. and Wagner, M.K. 1987. Effect of sodium acid pyrophosphate and/or potassium sorbate on Staphylococcus aureus FRI-100 growth and toxin production. J. Food Sci. 52(3):793.
- Thompson, S.G., Ockerman, H.W., Cahill, V.R. and Plimpton, R.F. 1978. Effect of soy protein flakes and added water on microbial growth (total counts, coliforms, proteolytics, Staphylococci) and rancidity in fresh ground beef. J. Food Sci. 43:289.
- Toth, L. and Potthast, K. 1984. Chemical aspects of the smoking of meat and meat products. Adv. Food Res. 29:87.
- Trout, G.R. and Schmidt, G.R. 1987. Nonprotein additives. In "Advances in Meat Research; Vol 3: Restructured Meat and Poultry Products. Pearson, A.M. and Dutson, T.R. eds. p.307. Van Nostrand Reinhold Co., New York.
- Vanderzant, C., Hanna, M.O., Ehlers, J.G., Savell, J.W., Smith, G.C., Griffin, D.B., Terrell, R.N., Lind, K.D. and Galloway, D.E. 1982. Centralized packaging of beef loin steaks with different oxygen-barrier films: Microbiological characteristics. J. Food Sci. 47:1070.
- Wagner, M.K. and Busta, F.F. 1984. Inhibition of Clostridium botulinum growth from spore inocula in media containing sodium acid pyrophosphate and potassium sorbate with or without added sodium chloride. J. Food Sci. 49:1588.
- Weiffenbach, S.T., Johnson, D.D. and West, R.L. 1988. Evaluation of an accelerated processing system for precooked beef products. J. Food Sci. 53(4):1051.
- Wendorff, W.L. 1981. Antioxidant and bacteriostatic properties of liquid smoke. Proc. Red Arrow 20th Smoke Symposium, Manitowoc, WI. p. 73.
- West, R.L. 1983. Functional characteristics of hot-boned meat. Food Technol. 37(6):57.
- Williams, S.K., Oblinger, J.L. and West, R.L. 1978. Evaluation of a calcium alginate film for use on beef cuts. J. Food Sci. 43:292.

- Wright-Rudolph, L., Walker, H.W. and Parrish, F.C.Jr. 1986. Survival of Clostridium perfringens and aerobic bacteria in ground beef patties during microwave and conventional cookery. J. Food Prot. 49(3):203.
- Zamora, M.C. and Zaritzky, N.E. 1987. Antimicrobial activity of undissociated sorbic acid in vacuum packaged beef. J. Food Sci. 52(6):1449.
- Zessin, K.G. and Shelef, L.A. 1988. Sensitivity of Pseudomonas strains to polyphosphates in media systems. J. Food Sci. 53(2):669.

FACTORS INFLUENCING THE
MICROBIAL CHARACTERISTICS OF UNCURED
RESTRUCTURED MEAT PRODUCTS

by

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Meat restructuring allows utilization of lower value meat cuts and co-products to produce convenient, cost competitive, palatable, wholesome products. Therefore, the microbial condition of restructured product is of central concern. Restructuring meat consists of mixing meat particles which are formed, then frozen or cooked. Restructured products can be marketed fresh or frozen and partially or fully cooked.

In the healthy animal, the muscle interior is essentially sterile. Many bacteria are transferred to the surface of meat during slaughter. Subsequent handling and processing techniques can enhance or inhibit the growth of bacteria. Various carcass wash solutions have been used to decrease surface contamination, with acetic acid being the most common.

Ingredients can affect restructured product microbial quality. Bacterial counts of Grade A milk products are governed by regulation. Soy proteins normally do not add to microbial counts, but enhance bacterial growth rates. Mechanically deboned meat frequently has high microbial counts and significantly increases the restructured product's microbial counts.

Natural spices are a source of Bacillus cereus contamination which can be eliminated with use of spice extracts. Addition of sweeteners has been shown to extend product shelf life by causing a shift in substrate utilization by bacteria and delaying the onset of

characteristic spoilage off odors and slime. Traditional hardwood and liquid smoke have varied antimicrobial qualities due to aldehydes, phenols and/or organic acids present in the wood smoke or extract. Effects depend on the kind of smoke and the microorganisms present.

Antimicrobial activity of salt depends on concentrations used and organisms present. Phosphate antimicrobial action is limited, depending upon concentration and product pH. Phenolic antioxidants have varied inhibitory action and are synergistic with other compounds. Parabens are more effective against gram-negative than gram-positive bacteria. Potassium sorbate is inhibitory towards C. botulinum, Y. enterocolitica and Salmonella, but only slightly restricts S. aureus growth. Acetic and lactic acid antimicrobial action increases as pH decreases.

Cooking (63°C) destroys vegetative cells but does not affect bacterial spores or S. aureus enterotoxin. Cook-in-the-bag systems prevent post-cooking contamination. Vacuum packaging alters product microflora depending upon oxygen permeability of the package. Modified atmosphere packaging (MAP) appears more effective in inhibiting bacterial growth when at least 20% CO₂ is present. Cooking and packaging (vacuum or MAP) alter the product environment to one possibly allowing C. botulinum and/or pathogen growth. Refrigeration slows microbial spoilage, but does not inhibit

growth of the 'new emerging' pathogens and non-proteolytic strains of C. botulinum.