Microbial Decontamination, Food Safety, and Antimicrobial Interventions

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General

After the 1993 Jack-in-the-Box outbreak, movements towards new and stricter food safety measures have been initiated to better protect the public health. In 1996, the United States Department of Agriculture's Food Safety and Inspection Service (USDA-FSIS) introduced the Pathogen Reduction and Hazard Analysis and Critical Control Points (HACCP) Rule, and required implementation of HACCP, depending on the size of the plant, in meat and poultry processing facilities. This aimed, in part, to verify that meat and poultry facilities are meeting certain food safety performance standards. As a result of this ruling, HACCP since has played an important role in modernization of USDA's meat and poultry inspection system that previously relied on the Meat Inspection Act passed in 1906 following Upton Sinclair's book "The Jungle." Implementation of a HACCP system assists in identification of critical points in the processing steps that can be controlled and monitored to prevent food safety hazards from occurring in the final product. This leads to realized wholesomeness of the product through minimizing the likelihood of hazards (e.g., chemical, physical, or biological) in the finished commodity.

To further enhance the safety of the food supply, a comprehensive food safety strategy is planned to address hazards at different points from farm-to-table. The food industry has been working on intervention methods for microbial decontamination and effective risk assessment techniques for better evaluation of risks, provision of information regarding hazard identification and characterization, occurrence frequency of a hazard, and risk control. However, protecting the food supply and ensuring the safety of the public remains a challenge; especially, with the ever-changing food processing operations and emerging foodborne pathogens. The demand by consumers for more varied and convenient food affects the food processing operations. This, in turn, has an effect on control measures for foodborne pathogens. Food manufacturing operations such as processing techniques, refrigeration, freezing, heating, and preservation treatments (chemical or physical) may induce stresses and increase resistance of pathogens. Other factors affecting emergence of resistant and pathogenic strains of microorganisms include microbial ecology, interaction of microbes with each other or with other living organisms, agricultural practices, farm management, animal husbandry, pre- and post-harvest practices, sanitation protocols, food type, food matrix, origin of food or food ingredient, water in food processing, meat processing, use of antimicrobials, and preparation of food (at home or restaurants).

Antimicrobial Interventions

To better understand the preventive antimicrobial interventions considered by the industry in their challenge to providing safe food for consumers, a review of intervention treatments is presented in the following sections. Although the emphasis will be placed on post-harvest interventions, it is worth mentioning that pre-harvest meat safety technologies also are on the rise. Pre-harvest issues to minimize microbial contamination of meat and meat products such as management factors affecting pathogens in farm animals, ecology of pathogens, and prevalence and detection of pathogens on the farm are being addressed. Examples include monitoring and comparison of farm management, and animal shedding patterns and frequencies for pathogens of interest (e.g., *E. coli* O157:H7), identifying pathogen reservoirs in the environment, and development or use of proper and accurate sampling and analytic procedures from agricultural or fecal samples. Post-harvest meat safety technologies, normally, should complement pre-harvest intervention efforts. Post-harvest antimicrobial interventions, in conjunction with proper sampling methods and microbiological analysis, can facilitate compliance with and implementation of proper HACCP systems. Brief descriptions of a number of post-harvest intervention treatments or techniques follow.

1. Sanitation

Normally, muscles of animals are sterile; however, microorganisms can be introduced to the meat during slaughter/dressing procedures (especially hide-pulling and bung-tying), fabrication, or further processing. Exposure of meat to contaminating materials during processing is unavoidable; therefore, preventive measures are important to minimize contamination and reduce the risk of public health hazards. Probably one of the most important means for providing safe food to consumers is sanitation. Even with a state-of-the-art intervention in place, contamination of a product can occur if proper hygienic and sanitary practices are not precisely implemented. Proper sanitary practices include applications of all measures necessary to produce meat with the lowest possible microbial contamination. It is important that sanitation programs address issues such personnel hygiene, hygienic work practices, employee education, and proper cleaning and sanitization protocols. Knives, gloves and aprons are among a number of pieces of equipment identified as potential reservoirs of bacteria if not cleaned or sanitized properly. This intervention technique should be appropriately implemented with all other techniques for proper control of contamination.

2. Trimming

Knife trimming, a standard procedure regulated by USDA-FSIS, has been in use for many years by meat processing facilities to remove any visible fecal matter on the surface of carcasses and minimize physical or microbial contamination. USDA-FSIS requires proper removal of fecal, ingesta and milk contamination from beef carcasses during slaughter (USDA-FSIS, 1996a,b). Trimming of the carcass surface is performed on the slaughter floor after the dehiding step, and before the final wash and carcass chilling. The knife trimming process may be effective for removal of visible physical contaminant such as soil or debris. However, this does not guarantee the successful removal of microscopic contaminants such as bacteria.

3. Washing

(a) *Water Washing*:

Since bacteria are not necessarily removed by trimming of visible contamination on the affected area of the carcasses, alternative methods such as carcass washing with water or sanitizing agents are considered. Normally, carcasses are washed with water on the slaughter floor, under pressure, after weighing and before chilling to minimize physical or microbial contaminants. Several studies suggested showering or spraying the carcass or meat cuts with water as a physical method for microbial decontamination.

(b) *Hot Water Washing (HWW)*:

Hot water washing of carcasses before chilling is an alternative to ambient water washes, and is used by about 90% of beef processing facilities (AMI, 2000). Researchers in this area found that hot water temperature/time combinations were found effective in removing bacteria without permanently impairing the appearance of the treated meat, especially color.

4. Organic Acids

Over the years several organic acids have been used in an attempt to reduce the microbial flora of animal carcasses and subprimals. These include lactic, acetic, citric, propionic, ascorbic, formic, and peracetic acid. Similar to knife trimming and water washing, organic acid sprays also are approved by FSIS (USDA-FSIS, 1996a). Acetic, lactic, and citric acid solutions at 1.5-2.5% are approved by USDA-FSIS as acceptable interventions for reducing carcass contamination (USDAFSIS, 1996a). Acetic and lactic acids are the most commonly used sanitizers, and both are generally recognized as safe (GRAS; Food and Drug Administration, 1982) compounds. The AMI (2000) estimated that misting carcasses with organic acids is used in about 15% of beef processing plants.

5. Steam Pasteurization™ System (SPS)

The technology of steam pasteurization (developed jointly by Kansas State University, Frigoscandia and Cargill Co.) uses superheated steam, from potable water which is a natural and non-toxic substance, to decontaminate the outside exposed surface of animal carcasses or meat trimmings. This process is an online treatment where a controlled treatment of saturated steam is applied to surface of carcasses, instantaneously raising the surface temperature of the product to 190˚F (88˚C) for 10 sec. Immediately following treatment, the carcasses or trimmings are chilled using cold water as it enters the cooler. Two steam pasteurization systems are commercially available on the market, SPS 400 and SPS 60, with the former allowing treatment of up to 400 carcasses/h while the latter can accommodate 60 carcasses/h.

6. Irradiation Pasteurization

Although irradiation pasteurization (IP) has been approved for red meat by the USDA, work is currently in progress to establish proper rules regarding adequate application of the process and labeling requirements (AMI, 2000). The process of IP involves emission of an intense pulse of energy from a gamma radiation source (e.g., Cobalt 60) or from an electrical source (e.g., electron beam accelerator such as SureBeam®) that penetrates the meat and destroys the microorganisms (AMI, 2000).

Other pasteurization technologies for reducing microorganisms on muscle foods include pulsed light or PureBright®™, infra-red irradiation and ultraviolet light or Select UV®.

7. Ozonation

Ozone (O_3) is a soluble and unstable blue gas commercially produced by passing electric charges or ionizing radiation through air or oxygen. It is a powerful compound used to inactivate bacteria through its oxidizing properties, and was the first oxidizing agent to be used for disinfection of water. Ozonation was found to be effective for the inactivation of bacteria (e.g., *E. coli* O157:H7, *S. typhimurium*, *Pseudomonas fluorescens*) on several muscle foods and fish.

8. Hydrogen Peroxide

Hydrogen peroxide (H_2O_2), is a strong oxidizing agent that can rapidly kill microorganisms if used in adequate concentrations. Although it inactivates microorganisms, H_2O_2 is not permitted for use as a food additive in many countries because it has a bleaching effect and can oxidize food constituents. Scientists studied the antimicrobial activity of H_2O_2 (5%) and ozone (0.5%) as meat decontaminant, and found that these sanitizers reduce bacterial counts by more than 2.5 $\log_{10}$ CFU/cm^2.

9. Cetylpyridinium Chloride

Cetylpyridinium chloride (CPC) is a water soluble, colorless and odorless compound with a neutral pH that has been found effective as an antimicrobial agent. This compound has been used for many years as an oral hygiene product because it reduces bacterial attachment and plaque formation on the tooth surface. Recent research studies indicated that CPC is effective against *E. coli* O157:H7, *S. typhimurium*, *C. jejuni* and *L. monocytogenes* inoculated on meat.

10. Sodium Chloride (NaCl)

Sodium chloride (NaCl), is generally recognized as safe (GRAS) antimicrobial and a non-intentional food additive. Numerous studies examining NaCl as an antimicrobial agent indicated its effectiveness in reducing or inhibiting the growth of a number microorganisms. Generally, foodborne pathogenic bacteria are inhibited at 13% (w/v) NaCl (equivalent to water activity, a_w, of 0.92 or less) with the exception of *S. aureus*. In fermented meat products, NaCl restricts the growth of spoilage microorganisms and allows growth of lactic acid bacteria. Growth of lactic acid bacteria in fermented meats inhibits proliferation of foodborne pathogens such as staphylococci. Bacteria have different levels of tolerance to salt depending on their inherent properties and intrinsic and extrinsic growth factors such as nutrients, water activity, pH, oxygen availability, and temperature. Overall, *Salmonella* spp. can survive in salty environment with NaCl concentration as high as 3.25.3% , *C. perfringens* 8.0%, *L. monocytogenes* 8.0-12%, *C. botulinum* 11-12%, and *S. aureus*, 1820%, respectively (Stein, 2000). The preservation mode of NaCl as an antimicrobial agent can be attributed to a number of factors including (i) dehydration, (ii) direct effect of chloride ion, (iii) removal of oxygen from the medium, (iv) sensitization of microorganisms to carbon dioxide (CO_2), and (v) interference of NaCl with the rapid action of proteolytic enzymes.

11. Acidified Sodium Chlorite (Sanova® Process)

Chlorite stabilized in acids (e.g., acidified sodium chlorite, ASC, or $NaClO_2$) has been shown to provide an excellent method of carcass decontamination resulting from a combination of antimicrobial effect due to the acid content (low pH) of the spray, and the anti-microbial properties of chlorine. ASC is formed from the reaction of sodium chlorite with citric acid, and it is a powerful oxidant. ASC solutions, including the commercial antimicrobial compounds of Sanova®, are approved by the Food and Drug Administration as a direct food additive to be used for decontamination of poultry and red meat carcasses (CFR, 1998).

Sodium chlorite (as a topical application on udder and teats) has been widely used to prevent and reduce incidence of intramammary infections in dairy herds. Other applications include bleaching of fruits and vegetables, altering cecal *Salmonella* colonization in broiler chickens, and chicken skin decontamination. ASC was found effective against *S. typhimurium* and *E. coli* O157:H7 on beef surfaces.

12. Chlorine Washes

Chlorinated water solutions have been used as carcass rinses during the chilling process of carcasses to reduce or prevent proliferation of any remaining bacteria on the surface of carcasses. Chlorinated water at 200 ppm was found to reduce total aerobic bacteria (APC), and greater reductions were obtained after 24 h of treatment. Calcium hypochlorite ($CaCl_2O_2$) and chlorine dioxide (ClO_2) also reduced contamination on beef forequarters. Chlorinated water also has been used to disinfect seeds for sprouting. Unfortunately, the rapid inactivation of chlorine in an organic system such as meat is a disadvantage for this treatment.

13. Trisodium Phosphate (TSP)

TSP application as an antimicrobial treatment for beef carcasses before chilling (24 to 48 h before fabrication) is a method approved by USDA-FSIS (USDA, 1996a). The ability of TSP to inactivate pathogenic and nonpathogenic bacteria, and to minimize microorganisms from adhering to carcasses or meat trimmings has been extensively studied. A 1.6-1.8 log_{10} reduction of *Salmonella* per carcass was reported when post-chilled chicken were dipped in 10% TSP at 50˚C for 15 sec. TSP reduced the population of artificially inoculated pathogens on lean and adipose tissue with greater reductions observed in gram negative (e.g., *E. coli* and *Salmonella* spp.) than gram positive (e.g., *L. monocytogenes*) microorganisms.

14. Lactates

Sodium and potassium lactates that normally are used as humectants or flavor enhancers in meat and poultry products, have been reported as an effective agents in controlling growth of aerobes and anaerobes in meats, and in antibotulinal and antilisterial activities. Scientists found that sodium lactate delayed *Clostridium botulinum* toxin production in cook-in-bag turkey products; sodium, potassium, and calcium lactates exerted antilisterial activity, and the effect of calcium salt was greater than sodium or potassium salt.

15. Packing Innovations

These technologies are applied to packed meat only, and are more applicable to meat trimmings than to whole carcasses. These technologies include oxygen (O_2) adsorption method, modified atmosphere packaging (MAP), and vacuum technology (AMI, 2000). Oxygen adsorption involves including an O_2 scavenger (e.g., potassium permanganate) in a small pouch within the meat package where the O_2 binds with scavenger instead of the meat. This extends the shelf life of meat products as the unavailability of O_2 prevents the meat color from turning into brown, and renders proliferation conditions difficult for aerobic microorganisms. When the MAP technology is used, the red meat in a barrier package is flushed with an O_2 (80%) and carbon dioxide (CO_2; 20%) mixture. Oxygen in the package allows the meat to remain red in color while CO_2 delays microbial growth. Thus, by modifying the atmosphere in the package, the shelf life of red meat cuts can be extended for an additional 7-12 days (AMI, 2000). Finally, vacuum technology uses a high barrier packaging material and removes the atmosphere within the package. This extends the shelf life of the product to 21 days or more; however, the meat does not bloom or turn red inside the vacuum package (AMI, 2000). Additional packaging innovations under progress include development of biosensors that detect chemicals, indicators of decomposition, and packaging that can detect changes in temperature (AMI, 2000).

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