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Review

Overview of current meat hygiene and safety risks and summary of recent studies on biofilms, and control of *Escherichia coli* O157:H7 in nonintact, and *Listeria monocytogenes* in ready-to-eat, meat products

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ABSTRACT

As meat consumption is increasing around the world, so do concerns and challenges to meat hygiene and safety. These concerns are mostly of a biological nature and include bacterial pathogens, such as *Escherichia coli* O157:H7, *Salmonella* and *Campylobacter* in raw meat and poultry, and *Listeria monocytogenes* in ready-to-eat processed products, while viral pathogens are of major concern at foodservice. A major goal of scientists, industry, public health and regulatory authorities is to control pathogenic microorganisms and improve meat product hygiene and safety within a country and internationally. This paper is not a comprehensive or critical review of the scientific literature on the broad area of meat hygiene and safety, but it provides an overview of major current meat hygiene and safety issues, and then a summary of studies on biofilm formation by pathogens, control of *E. coli* O157:H7 in nonintact meat products, and control of *L. monocytogenes* in ready-to-eat meat products, conducted at the Center for Meat Safety & Quality and Food Safety Cluster of Colorado State University in recent years.

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1. Introduction

This paper is the basis for an invited presentation on meat hygiene and safety at the 56th International Congress of Meat Science and Technology, held on 15–20 August 2010 in Jeju, South Korea. As the subject of meat hygiene and safety is very broad and cannot be covered in a single lecture or paper, the presentation, and consequently the paper, were designed to provide a brief overview of major meat hygiene and safety issues, and then to concentrate on three timely meat hygiene and safety topics, namely biofilm formation by pathogens in meat processing and foodservice environments, control of *Escherichia coli* O157:H7 in nonintact meat products, and control of *Listeria monocytogenes* in ready-to-eat (RTE) meat products. Since these topics are also broad, the material presented is not comprehensive or a critical literature review, but rather summaries of related major research activities undertaken at the Center for Meat Safety & Quality and Food Safety Cluster of Colorado State University in recent years. It should be noted that in addition to the overall introduction of meat hygiene and safety issues, the initial part of each of the specific topics covered includes an overview of that topic. It is acknowledged that numerous other scientists have conducted important studies related to the topics examined. However, due to space limitations only key pertinent literature reviews of such studies have been cited.

Current challenges and concerns related to consumption of meat products may be divided into those associated with microbial pathogens and into other meat safety issues. Major challenges related to microbial pathogens include foodborne illness outbreaks, associated product recalls, regulatory compliance, and issues related to pathogen control. Other issues are the emergence of pathogens with increased virulence and low infectious doses, pathogen resistance to antibiotics or food-related stresses, cross-contamination of foods other than meat products, as well as water, with enteric pathogens, animal manure disposal issues, and potential for implementation of food safety programs at the farm. In the category of other meat safety concerns we may include food additives, chemical residues, animal identification and traceability issues, the safety and quality of organic and natural products, the need for and development of improved and rapid testing and pathogen detection methodologies, regulatory harmonization issues at the national and international levels, products of food biotechnology or genetically modified organisms (GMO), and intentional bioterrorism concerns. These issues have been presented in some detail in recent publications (Doyle & Erickson, 2006; Sofos, 2008a, 2009a).

Sofos (2008a, 2009a) also indicated that potential reasons for the increasing food safety concerns of recent and future years include changes in animal production, product processing and distribution practices; increased international food trade; consumer expectations for minimally processed and convenient food products; projected increases in worldwide meat consumption; higher numbers of consumers at-risk for infection; emerging pathogens and microbial pathogen changes which may be associated with increased virulence and resistance to control or clinical treatment; advances in microbial detection methodologies; inadequate food-handler and consumer education and training in proper food handling; and, increased interest, awareness and scrutiny of food safety issues by consumers, news media, and activist groups.

The objectives of this paper are to: (i) provide a brief overview of meat hygiene and safety issues and challenges, especially those associated with microbial pathogens and their control; and (ii) summarize selected Colorado State University Center for Meat Safety & Quality and Food Safety Cluster recent research activities on the potential for pathogen biofilm formation in processing and foodservice environments, control of *E. coli* O157:H7 in nonintact meat products, and control of *L. monocytogenes* in RTE meat products.

2. Meat hygiene and safety challenges

Major pathogens that need to be controlled in fresh meat include *Salmonella, Campylobacter,* and enterohaemorrhagic *E. coli* O157:H7. Even though progress is being made in their control, some of these pathogens will continue to be of concern well into the future (Bacon & Sofos, 2003). *L. monocytogenes* will also continue to be the number one target for control in RTE meat and poultry products, considering its ubiquitous presence, potential to contaminate products after processing, and the ability to multiply even at cold temperatures (FDA/FSIS (Food and Drug Administration/Food Safety & Inspection Service), 2003; ILSI (International Life Sciences Institute) Research Foundation/Risk Science Institute, 2005; Ryser & Marth, 2007; Tompkin, 2002). The main cause of concern for foodborne illness caused by agents introduced into the food at foodservice will remain to be viruses, such as Norovirus, which presently are considered as the biggest cause of foodborne illness in the United States (www.cdc.gov/). Additional pathogens may emerge and become of concern in meat products in the future (Sofos, 2008a) and include non-O157 shigatoxin producing *E. coli* serotypes, *Mycobacterium avium* subsp. *paratuberculosis*, *Escherichia albertii*, *Clostridium difficile*, etc. Emergence of pathogens should not be a surprise as approximately 60–70% of outbreaks and 40–50% of reported cases of foodborne illness are of unknown etiologic agent (www.cdc.gov/). Therefore, progress in detection methodologies and associated progress in knowledge of the ecology of additional pathogens should lead to elucidation of their role in the safety of foods (Sofos, 2008a, 2009a).

3. Improving the safety of meat products

3.1. Pathogen control

As indicated by Sofos (2008a, 2009a), control of meatborne pathogens will continue to be one of our major goals well into the future. The best strategy for improving the safety of meat is by applying proper hygiene and antimicrobial intervention technologies that (Sofos, 2008a, 2009a): (i) reduce contamination on live animals; (ii) minimize access and transfer of microorganisms to carcasses and meat; (iii) reduce, through decontamination, microbial levels on carcasses or meat; (iv) reduce or eliminate, by killing, microbial contamination on products; (v) avoid or minimize cross-contamination; and (vi) inhibit growth of surviving microorganisms (Juneja & Sofos, 2002, 2009; Sofos, 1994, 2002, 2005; Stopforth & Sofos, 2006). Thus, foodborne pathogen control requires application of interventions at pre-harvest, post-harvest, processing, storage, distribution, merchandizing, preparation, foodservice, and consumption.

3.1.1. Pre-harvest pathogen control

Pre-harvest pathogen control should aim at minimizing sources, levels, access and transfer of contamination to the animal (Koutsoumanis & Sofos, 2004; Koutsoumanis, Geornaras & Sofos, 2006; Samelis & Sofos, 2003a,b; Sofos, 2005; Stopforth & Sofos, 2006). Pathogen reduction programs at the farm level contribute to food safety by decreasing the probability of pathogen presence in animals and associated foods and by reducing water and produce contamination, as well as direct animal-to-human pathogen transmission (Sofos, 2008a). Proposed or used on-farm interventions include diet manipulation, use of feed additives or supplements, antibiotics, bacteriophage therapy, administration of vaccines or immunization, competitive exclusion, prebiotics or probiotics, and proper animal management practices such as pen management, clean feed, clean and chlorinated water, and clean and unstressful transportation (Huffman, 2002; LeJeune & Wetzel, 2007; Sofos, 2004a,b, 2005; Stopforth & Sofos, 2006). In addition, it is important to apply proper animal manure treatment and disposal procedures in order to limit spreading of pathogens in the environment, water and other food crops. Overall,