Intervention Strategies to Improve the Safety of Pork

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▪ Introduction

During the last 8 years the safety of meat products has emerged as a major public health issue. Ensuring the safety of the pork supply has become a challenge for all those involved in the production of pork and will require a partnership among all participants. Each link in the production chain, from the producer to the consumer, needs to recognize that their practices and actions have the potential to affect the safety of the product on the plate. An error at any point in the system can negate the food safety efforts of subsequent links in the pork production chain.

For bacterial pathogens, it is safe to assume that good management, sanitation and biosecurity programs will reduce the public health risk of enteric pathogens. To date we don't have the data to show that effective preharvest pathogen reduction measures consistently reduce the incidence of pathogens in meat, thereby reducing foodborne disease. Ultimately, the responsibility for producing a safe food pork product rests with the industry as a whole. There is a need to identify and address the aspects of pork production, processing, distribution and retail sale that may constitute a risk to consumer health. Hazard analysis critical control point (HACCP) based programs can be used as a basis for reducing contamination at any point in the production chain. To complement HACCP programs, antimicrobial treatments or interventions are being suggested to interrupt the transmission of foodborne pathogens from the animal to the consumer.

This paper outlines selected concepts relative to intervention strategies and explores the application of novel intervention strategies to control foodborne pathogens in the production of pork.

▪ Sources of Foodborne Pathogens and Pork

There is no doubt that anyone handling pork and pork products needs to be concerned with the incidence of foodborne pathogens on pork. Data gathered from April 1995 to March 1996 by the United States Department of Agriculture Baseline Data Collection Program for Market Hogs indicates that pork is a source of potential foodborne pathogens (Table 1). *Yersinia enterocolitica* (Mafu et al., 1989; de Boer and Nouws, 1991; Saide-Albornoz et al., 1995) and *Arcobacter* spp. (Collins et al., 1996) have also been linked with pork products. Pork constitutes one of the most important sources of *Y. enterocolitica* (Nesbakken and Skjerve, 1996). An outbreak of yersiniosis was linked to pork chitterlings (Anon., 1990). The presence of these organisms on pork products presents a potential human health risk. There are several points in the production chain at which control measures can be taken to prevent the spread of pathogens from the hog to meat and ultimately to humans. Any intervention that will reduce the spread of pathogens will reduce the incidence of foodborne disease.

Table 1. Prevalence of selected foodborne pathogens on raw pork carcass surface samples (USDA, 1996)

Pathogen	***Percent Positive***
Clostridium perfringens	10.4
Staphylococcus aureus	16.0
Listeria monocytogenes	7.4
Campylobacter jejuni/coli	31.5
Escherichia coli	0.0
Salmonella	8.7

▪ Preharvest Interventions

The use of good manufacturing practices at the farm will help to reduce the chances that animals arriving at the slaughter plant are contaminated with pathogens. General approaches, such as pathogen-free feeds, regular cleaning and disinfection of equipment and barns, biosecurity controls, and training and hygienic conduct of employees will all contribute to reducing the level of contamination of the animal leaving the farm.

Feed Ingredients

Something in the order of 5 to 20% of livestock feeds contain detectable *Salmonella* contamination. A recent study of the incidence of Salmonella in swine feeds found that 2.8% of the feed and feed ingredient samples (n=1,264) tested positive for *Salmonella* (Harris et al., 1997). In a study of diary cattle feed, about one-third of feeds were contaminated with generic *E. coli* (Lynn et al., 1998). A direct link between contamination of animal feeds and human disease has not been established. However, the potential for transferring pathogens through feed exists. The use of foodstuffs that are free from pathogens will help reduce the risk of contamination of the animals.

Intestinal Microflora

Manipulation of the intestinal microflora of the pig gastrointestinal tract has a significant effect on growth rate and feed efficiency, and may also be a way to reduce the presence of pathogenic bacteria in the gastrointestinal tract of animals (Hays and Muir, 1979). Manipulation of intestinal microflora can be achieved with subtherapeutic levels of antibiotics in animal feeds. However, the emergence of antibiotic resistant bacteria within animals and the potential for transfer of antibiotic resistance genes to human pathogens has resulted in pressure to reduce, if not eliminate, the use of antibiotics as growth promoters in animal feeds. Probiotics have the potential to be used as an alternative strategy to control contamination of animals at the farm.

Probiotic microorganisms, including lactic acid bacteria (LAB) such as *Lactobacillus* and *Enterococcus* spp., are live microbial feed supplements that affect the host animal beneficially by improving intestinal microbial balance (Fuller, 1989). LAB inhibits the growth of various bacteria, including human pathogens, such as *Listeria monocytogenes, Staphylococcus* spp. and *Clostridium* spp. This inhibition may be related to the production of organic acids, hydrogen peroxide (under aerobic conditions), and bacteriocins.

Bacteriocins are antibacterial peptides that are active against species closely related to the producer organism. LAB that exert antagonism against undesired intestinal bacteria may interact to stabilize or control the intestinal microflora. Bacteriocins generally have a narrow spectrum of antibacterial activity such that usually they are only active against closely related bacteria, e.g., lactobacilli are generally active against other lactobacilli. At best, bacteriocins of gram-positive bacteria are active against a broad spectrum of gram-positive bacteria; not against gram-negative bacteria such as *E. coli* and *Salmonella* spp. This limits their efficacy as probiotics for control of gram-negative pathogens, such as *E. coli* or *Salmonella*.

Bacteriocins from gram-negative organisms, such as *E. coli,* could be used to target pathogenic *E. coli* in the hog intestine; however, a delivery system for *in* *situ* production of the bacteriocin from the gram-negative organism is necessary. A possible approach to controlling *E. coli* and other *Enterobacteriaceae* in the intestine of the hog is the use of bacteriocins delivered by natural bacteria of the GI tract, such as LAB. Researchers in the Food Microbiology Laboratory at the University of Alberta and CanBiocin Inc. have developed genetically improved lactic acid bacteria for use as a probiotic delivery system for *in situ* production of bacteriocins that are known inhibitors of pathogenic *E. coli* and *Salmonella* spp. (McCormick et al., 1999). This system allows bacteriocins to be produced against target pathogens in a method that is environmentally safe, because the vector plasmid will not contain antibiotic resistant markers and will not transfer between bacterial genera.

The use of bacteriocin-producing bacteria as probiotics will provide benefits to the hog producer by reducing the incidence of infections and animal death. In addition, the use of probiotics may reduce pathogens on carcasses, thereby reducing the risk of foodborne infections from the consumption of pork products.

▪ Interventions During Processing

As long as animals contaminated with pathogens enter the processing plant for slaughter, there will be transmission of pathogens to the consumer. The slaughter of hogs is an open process with many opportunities for the contamination of the pork carcass with pathogenic bacteria. The major contamination points during pig slaughter are related to the contamination of the skin during dehairing (Berends et al., 1997; Gill and Bryant, 1997), and contamination of the carcass with pathogens from the throat and mouth and with faecal material during removal of the anus (Andersen, 1988; Nesbakken, 1988; Gill and Jones, 1997, 1998).

Intervention strategies during slaughter can help to reduce the risk that pathogens will be transferred to meat products; however, they cannot be a substitute for good manufacturing practices that include good sanitation procedures. The implementation of the Pathogen Reduction/HACCP Proposal in the United States requires that slaughter establishments be required to meet pathogen reduction standards. Recent data from the USDA indicates that the implementation of HACCP with sound sanitation and hygienic standards in processing facilities has reduced the incidence of salmonella on hog carcasses (Table 2). The requirement to meet pathogen reduction performance standards may increase the need to implement intervention strategies to reduce pathogens on meat products.

Table 2. Incidence[1] of *Salmonella* on hog carcasses before and after implementation of HACCP (USDA, 1999).

Incidence Before HACCP (%)	Incidence After HACCP (%)
8.7[2]	6.5[2]

[1]Based on preliminary data from 17 federally inspected swine slaughter plants.
[2]*Salmonella* performance standard as set by the USA Pathogen Reduction and HACCP legislation [9 CFR §310.25(b)].

Pasteurization of hog carcasses has been shown to reduce the contamination of the skin after dehairing by about two orders of magnitude (Gill et al., 1997) and is currently in use in an Alberta hog processing facility. Pasteurization of the carcass after dressing cannot be done without surface discoloration (Gill and Badoni, 1997) thus it cannot be used as an intervention strategy for hogs. Reduction of contamination from faecal material can be achieved by sealing off the rectum with a plastic bag during slaughter and is in use in slaughter facilities in the Europe to reduce carcass contamination with *Y. enterocolitica* (Nesbakken et al., 1994). A substantial reduction (25%) in the incidence of yersiniosis occurred after this technique was introduced in Norway (Nesbakken and Skjerve, 1996).

Acid washes after evisceration have been identified as possible antimicrobial treatments that could be incorporated into HACCP plans. The use of organic acids for reduction of pathogens on meats has recently been reviewed by Smulders and Greer (1998). Dilute (2 to 3%) lactic or acetic acids have been used in studies designed to determine the reduction in numbers of specific pathogens on carcass surfaces. *Salmonella enterica* serovar Typhimurium can be reduced to below detectable levels on the surface of a pork carcass with a 30 sec treatment with 2% lactic acid (van Netten et al., 1995).

The risk of recontamination of meat during carcass breaking and further processing cannot be ignored. Research done at the Lacombe Research Centre has shown that some contamination of meat takes place during the carcass breaking process (Colin Gill, 1999, Lacombe Research Station, personal communication). The use of organic acids on pork cuts just prior to packaging may be an effective intervention. Organic acid washes will reduce populations of *L. monocytogenes* by 2 logs on fresh pork (Greer and Dilts, 1995). However, irreversible changes in the colour of retail cuts subjected to treatment with organic acids has limited the application of organic acids at this point in the processing line.

Protective cultures or "biopreservation" can be used on fresh meats to control the growth of pathogens (McMullen and Stiles, 1996). The incidence of *Listeria* *monocytogenes* on fresh pork, and the recent link of this pathogen to 21 deaths in the United States as a result of the contamination of wieners, has increased the need to introduce steps to reduce this pathogen on meat and meat products. This psychrotrophic pathogen will survive and grow at refrigeration temperatures on vacuum packaged meats, increasing the need for control measures. Bacteriocin-producing lactic acid bacteria have been shown to effectively control the growth of *Listeria* spp. on fresh (Figure 1; Panayach et al., 1998) and processed meat products (Stiles and McMullen, unpublished data).

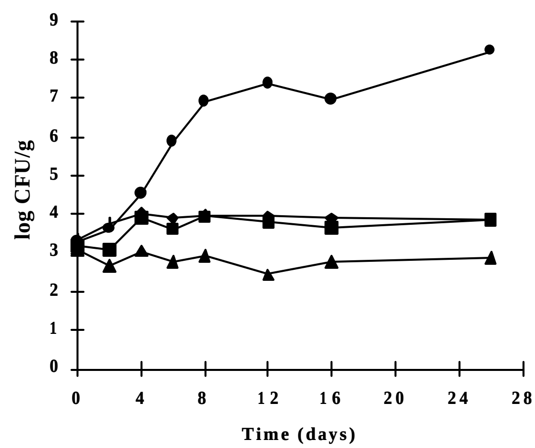

Figure 1. Growth and inhibition of *L. monocytogenes* in vacuum-packaged ground beef stored at 5°C with the following treatments: *L. monocytogenes* alone (●); and when *L. monocytogenes* was co-inoculated with *Leuconostoc gelidum* UAL187-13 (◆); *Leuc. gelidum* UAL187 (▲); and *Leuconostoc* sp. UAL280 (■). *Leuconostoc* inoculation levels were 5 log CFU/g and *L. monocytogenes* log 3 CFU/g. Each data point is the mean of four samples.

▪ Interventions During Storage and in the Retail Sector

The primary control point for pathogen growth during product storage and in the retail sector is temperature control. Maintenance of the proper temperature from the processor to the retailer and during retail display is important to control the growth of foodborne pathogens. Anytime that temperature control is compromised, the risk of foodborne disease from the consumption of pork products increases. Psychrotrophic pathogens such *as L. monocytogenes* and *Y. enterocolitica* have been shown to have a higher prevalence on vacuum packaged pork after storage than the freshly prepared product (Saide-Albornoz et al., 1995). During display in the retail case, it is possible that pork will be exposed to temperatures that are abusive. An evaluation of the temperatures in a commercial meat display case indicated that meat is subjected to temperatures between 6 and 10°C in a display case (Greer et al., 1994). Data provided by Gill et al. (1998) indicate that temperature fluctuations above 9°C allowed *E. coli* to grow on lean pork muscle after 4 days of aerobic storage. It will be necessary to control temperatures and storage times during storage to limit the risk from the growth of pathogens during storage.

▪ Consumer Education

Despite the best scientifically-based programs to ensure the safety of pork products from the producer to the packer, education of the consumer is a necessary link in the chain. We cannot assume that fresh pork can ever be free of risk of contamination with pathogens but we can manage the level of risk with adequate consumer education. The consumer is the last critical control point to eliminate foodborne disease hazards. Proper storage and handling procedures must be used by the consumer to reduce the risk of foodborne disease. The Fightbac™ Campaign is intended to educate consumers about safe food handling practices. At this time it is too early to gauge the impact that this consumer education campaign may have on the incidence of foodborne disease.

▪ Conclusion

The impact of “farm to fork” or “gate to plate” food safety systems has yet to be realized. Good manufacturing practices are the basis for any pathogen control program and supplementary interventions at any stage of the production system from the producer to the consumer have the potential to reduce the incidence of foodborne disease.

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