

## BACTERIOLOGICAL/CHEMICAL SAFETY: MEAT AS A FOOD (2000)

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### **Consumer Concerns About Food and Meat Safety**

Contamination of beef, pork and lamb with foodborne pathogens and with residues of undesirable chemicals has prompted social fears and global concerns, threatened world trade, caused economic losses, and generated challenges and opportunities in process control concepts.

Possible food-safety concerns about beef (Smith *et al.*, 1994b) include: (a) Presence on meat of foodborne pathogens (most important would be *Salmonella*, *Listeria monocytogenes*, *Campylobacter jejuni* and *Escherichia coli* O157:H7), (b) Residues, in meat, of pesticides (of either or both of the types--chlorinated hydrocarbons and organophosphates), (c) Antibiotics (fear of residues of the antibiotics, in meat, and/or of development and presence, on meat, of antibiotic-resistant strains of human pathogens because of continued exposure of human pathogens--that have livestock vectors--to feed-grade antibiotics) and (d) Residues of livestock growth-promoting compounds in meat; concern is about the presence, in beef, of residues of naturally occurring growth-promotants (the hormones--estrogen, testosterone, progesterone) as well as of the chemically synthesized growth-promotants (the xenobiotics--trenbolone acetate, melengestrol acetate, zeranol). To that list should be added: (e) Possibility that beef could be contaminated with the prions that cause Bovine Spongiform Encephalopathy (BSE—commonly called “Mad Cow Disease),” and (f) Risks/benefits associated with the potential use of ionizing radiation (commonly called “irradiation”) to destroy foodborne pathogens in/on beef. Supermarket shoppers (FMI, 1997) identified as greatest threats to food safety: (a) spoilage, 69%, ranked first, (b) bacteria/contamination/*E. coli*/germs, 17%, ranked fourth, (c) pesticides/residues/insecticides/herbicides, 10%, ranked sixth, (d) chemicals, 6%, ranked seventh, and (e) antibiotics/hormones, <1%, ranked fifteenth. Hart Research Associates reported that 75% of consumers are confident that U.S. beef is safe and wholesome (Food and Nutrition News, 1997). Supermarket shoppers (FMI, 2000) said food safety was “very important” (71%) or “somewhat important” (20%) and were “completely” (15%) or “mostly” (59%) confident that food in the supermarket is safe.

NCBA (2000) interviewed 1,030 consumers asking the extent of their concern (10=extremely concerned; 1=not at all concerned) about certain items; greatest concern was registered for “unsanitary conditions in packing plants” (7.5), followed by “possible contamination of ground beef with harmful *E. coli* bacteria” (7.2), “possible contamination of beef with *Salmonella* bacteria” (6.8), “using government-approved growth hormones to produce cattle with less fat” (6.2), “administering antibiotics to treat illness and make sure cattle are kept healthy” (6.0), “the possibility there might be Mad Cow Disease in the United States” (5.9) and “using cattle feed containing corn that has been genetically modified to resist insects” (5.2). When asked “How confident are you that (item) is safe to eat?”, percentages of those interviewed who were “strongly confident,” “somewhat confident,” “somewhat not confident” and “strongly not confident” about steaks and roasts were 46%, 30%, 15%

and 8%, respectively, and about ground beef and hamburger were 36%, 32%, 18% and 13%, respectively (NCBA, 2000). When asked “Why are you not confident that (item) is safe to eat?”, the top five reasons for steaks and roasts were “chemicals/hormones in meat” (18%), “packing plant problems” (15%), “news reports/media” (14%), “bacteria/*E. coli*/recalls” (13%) and “things they feed cattle” (10%) while the top five reasons for ground beef and hamburger were “packing plant problems” (29%), “bacteria/*E. coli*/recalls” (24%), “grinding and things mixed with meat” (7%), “news reports/media” (6%) and “don’t know where the beef comes from” (6%) (NCBA, 2000).

Farm Bureau and Philip Morris Company interviewed 1,002 adult consumers asking “What trade-off would you be willing to accept if chemicals were not used in food production?”, in response, 73% would accept biotechnology, 72% would accept seasonal availability of products, 68% would accept a smaller selection of products, 52% would accept pest damage on their food and 57% would pay more for their food (Dairy Herd Management, 2000). Additionally, 74% agreed that “any price” is worth knowing that the food has no pesticides or chemicals (Dairy Herd Management, 2000).

In the USA: (a) 80% of consumers are as concerned about food safety as they are about safe drinking water, crime and health, (b) 75% would alter their food consumption based on negative media stories, and (c) 88% are “Very Concerned” about bacteria like *Salmonella* (Drovers Journal, 2000). “Product Safety” is “Very Important” in food selection (FMI, 2000) ranking 4<sup>th</sup> in FMI TRENDS reports in 1992, 1993, 1994 and 1995, and 3<sup>rd</sup> in 1991, 1996, 1997, 1998, 1999 and 2000 (Smith, 2000a). De Becker (1997) reported that: (a) The 5<sup>th</sup> biggest fear of USA consumers was “Food Poisoning From Meat” (36% of respondents), (b) The 7<sup>th</sup> biggest fear was “Pesticides On Food” (34%), and (c) The 2<sup>nd</sup> most often cited “Precaution I have taken in the past year, for safety reasons” was “Avoiding Certain Foods” (35%). Of respondents to a Newsweek (1997) poll: (a) 44% thought the U.S. food supply was less safe than 10 years ago (19% thought it was more safe). (b) 45% thought the government was not ensuring food safety. (c) 62% thought the government should spend more on food inspection. Consumers who get a lot of food safety information from the following sources were: (a) 30%, news stores and programs, (b) 24% food labels or packaging, (c) 23%, cookbooks, (d) 13%, government sources, and (e) grocery store handouts (Food Processing, 1997). In 1997, 29% of consumers said foodborne illness caused by home cooking was “somewhat” common while 30% thought it was “not very” or “not at all” common; in 2000, 43% thought it was “somewhat” common and 21% thought it was “not very” or “not at all” common (FMI, 2000).

The International Beef Quality Audit, conducted by Colorado State University, surveyed beef purchasers in five regions of the world and observed that U.S. beef is the safest in the world; it has the world's highest microbiological quality and the world's lowest incidence of violative levels of chemical residues (Morgan *et al.*, 1995).

### **Costs Of Foodborne Illness In The USA**

Human foodborne disease causes 24 to 81 million cases and costs \$5 to \$17 billion each year (Oblinger, 1988). Pathogens associated with meat and poultry may cause, each year, 7 million

foodborne-illness cases and 7,000 deaths (FSIS, 1995a) or 5.35 million cases, 4,600 deaths (3,348 from *Salmonella*, 480 from *Campylobacter jejuni/coli*, 423 from *Listeria monocytogenes*, 349 from *E. coli* O157:H7) and cost \$4.8 billion (FSIS, 1995b). Broder (1997) quoted CDC as saying “Pathogens carried in food are responsible for 9,000 deaths a year.” Wilson (1998) questioned the “9,000 deaths” when he learned that CDC attributed 1,000 of those postulated deaths to trichinosis, when, in fact, CDC had reported only one death due to trichinosis in the USA in the preceding 10 years. Challenged with the Wilson (1998) report, a CDC spokesperson, admitted, “Until we do good analysis, I would say we don’t know for sure” (NMA, 1998). Nevertheless, Buzby *et al.* (1999) repeated that foodborne illness causes 9,000 deaths each year.

In the USA, government reaction to, and press coverage of, foodborne-illness incidents differ dramatically among foods. On August 13, 1997 and August 15, 1997, media reports described foodborne-illness incidents involving ground beef and 16 cases (Wheeler, 1997) and alfalfa sprouts and 70 cases (Associated Press, 1997), both caused by *E. coli* O157:H7. Extensive press coverage and unprecedented media coverage caused the offending beef company to go out of business; essentially no press coverage and no reported government action occurred in the case of the contaminated sprouts (Smith *et al.*, 1998).

#### **Cases Of Foodborne Pathogen Illness In The USA**

Reported cases (per 100,000 people) of *E. coli* O157:H7 infection were 2.7, 2.3 and 2.8 in 1996, 1997 and 1998, respectively (NMA, 1999c) while, from 1996 to 1998, cases of *Salmonella enteritidis*, other *Salmonella* spp. and *Campylobacter* dropped 44%, 13% and 15%, respectively. CDC attributed: (a) the increase in reports of *E. coli* O157:H7 outbreaks, to widespread use of PFGE by health departments to subtype strains and link them to outbreaks (NMA, 1999a) and (b) the decrease in reports of outbreaks of other foodborne pathogens, to new inspection and HACCP programs (NMA, 1999c). Case-rate (per 100,000 people) for the 9 disease-causing agents tracked by CDC was 51.2 in 1996 vs. 40.7 in 1999 while *Salmonella* infections rose from 12.3 in 1998 to 14.8 in 1999 because of outbreaks in 1999 linked to unpasteurized orange juice, mangoes and uncooked sprouts (Bachman, 2000). Case-rate of *Campylobacteriosis* (the most widespread cause of food poisoning) fell from 25.2 in 1997 to 17.3 in 1999; *Shigella* and *E. coli* O157:H7 cases dropped 44% and 22% from 1996 to 1999 (Bachman, 2000).

CDC attributed 22.2%, 21.5%, 4.3%, 6.7% and 10.7% of *E. coli* O157:H7 illnesses to beef in 1994, 1995, 1996, 1997 and 1998, respectively; the highest incidences of *E. coli* O157:H7 illnesses in 1996, 1997 and 1998 were attributed to apple juice (18.6%), alfalfa sprouts (36.2%) and cole slaw (22.5%), respectively (NMA, 1999a). Of foodborne illness outbreaks in the 1990s, CSPI traced 1 of 5 to meat and poultry; three-fourths of food poisoning outbreaks stemmed from food subject to inspection by the FDA (e.g., eggs, fruits, vegetables, seafood, wild game) and one-fourth from meat and poultry which are inspected by USDA (Maixner, 1999). CDC reported that illnesses caused by food contaminated with foodborne pathogens have declined 19% since 1997; Dr. Patricia Griffin (CDC) said “There have been mandated changes in meat and poultry processing plants causing industry to make lots of changes and there has also been increased attention to good agricultural practices on farms” (NMA, 2000a).

### **Source Of Food Safety Problems**

When asked “Where do you think food safety problems are most likely to occur?,” respondents (Food Processing, 1997) said: (a) Processing plants (37% of those interviewed), (b) Restaurants (22%), (c) Warehouses (13%), (d) Homes (10%), (e) Supermarkets (10%), and (f) Farms (3%). Percentages of consumers who thought the following are serious food safety problems were: (a) 36%, microorganisms, (b) 28%, pesticide residues, (c) 9%, food preservatives, (d) 8%, hormone residues, and (e) 6%, antibiotic residues (Food Processing, 1997). CDC (1994) discussed “Location Of Food Mishandling” in relation to outbreaks of foodborne illness, reporting that 77% of mistakes occur at food-service sites (including restaurants and delicatessens), 20% in the home, and 3% at processing plants. In response to the question “Where do you think food safety problems are most likely to occur?,” supermarket shoppers (FMI, 2000) replied: (a) Food Processors/ Manufacturers, 27%; (b) Restaurants, 24%; (c) At Home, 14%; (d) During Transport, 8%; (e) Supermarkets, 7%; (f) Other, 7%; (g) All, 5%; and (h) On Farm, 2%.

In answer to the question “As far as you are personally concerned, who do you rely on the most to be sure that the products you buy in your supermarket are safe?”, the shopping public (FMI, 2000) responded: (a) Yourself, As An Individual, 37%; (b) Manufacturers/Food Processors, 17%; (c) Food Stores, 22%; (d) Government Institutions Or Agencies, 21%; (e) Consumer Groups/Organizations, 7%; (f) All/Everybody, 7%; (g) Farmers, 4%; (h) Not Sure, 2%; and (i) No One, 1%. In response to the question “What do you think is the single most important source of food poisoning?,” supermarket shoppers (FMI, 2000) answered: (1) Mishandling, 27% (of which 18% was due to mishandling/improper handling, and 9% was because of poor sanitation/not washing hands/dirty silverware); (2) Spoiled Food/Expired Food, 19%; (3) Improperly Cooked Food, 18%; (4) Germs/Bacteria, 13% (of which non-specific bacteria was 7%, *Salmonella* was 4%, and *E. coli* was 2%); and (5) Specific Food, 7% (of which chicken was 3% and beef was 2%).

### **Industry Investment In Beef Safety Prior To The 1993 Outbreak Of *E. coli* O157:H7**

Morgan and Smith (1992) quantified the food-safety investment by the USA beef packing industry to prevent foodborne illness, in 1991 as \$1.1295 billion (\$4.34 per USA consumer; \$42.62 per beef carcass). Of that, \$553 million was for Packaging, \$12 million was for Carcass Rinsing, \$484 million was for Refrigeration, \$25 million was for In-House Quality Control Programs, \$39 million was for Third-Party Quality Control Programs, \$29 million was for Sanitation, and \$8 million was for Heating of Water for Cleaning and Sterilization. Interestingly, expenditures during that same period (calendar year 1991) by FSIS to police the safety of meat and poultry was \$.5 billion—less than half as much as was spent by the beef industry to keep its products safe. Cross and Smith (2000) reported that, prior to implementation of USDA-mandated HACCP programs, the cost in their packing plant for Quality Control/Quality Assurance Programs was \$0.40/carcass while now—in 2000—it is more than \$10.00/carcass.

### **Chronology Of Events: *E. coli* O157:H7**

The chronology of events related to an outbreak of *E. coli* O157:H7 in the USA is as follows: (a) An outbreak of foodborne illness in 1993, because of undercooking of ground beef patties that contained

*E. coli* O157:H7, caused hundreds of illnesses and four children died (Bell *et al.*, 1994). (b) Concern arose in 1993-1994 among those in the consuming public, media, and U.S. Congress that FSIS and industry were not satisfactorily monitoring status and minimizing pathogens microbiological counts on red meat and poultry (Savell and Smith, 1998). (c) FSIS first responded by strictly enforcing "Clean Meat Programs," including "Zero Tolerance" policy which required knife-trimming of all soil (fecal material, ingesta and udder contents) from beef carcasses prior to washing and chilling them (Smith *et al.*, 1994). (d) Beef packers interacted with those in government, universities and allied industries to develop/research decontamination techniques (e.g., steam/hot-water vacuuming) and microbiological-intervention treatments (e.g., spray-washing and/or rinsing treatments employing water of different temperatures, organic acids and steam) for use on carcasses (FSIS, 1996a). (e) USDA meat and poultry inspection was modernized (FSIS, 1996b) with passage (July, 1996) of the Pathogen Reduction; Hazard Analysis and Critical Control Point Systems; Final Rule (PR;HACCP;FR). Sanitation Standard Operating Procedures and Generic *E. coli* Testing, went into effect in all USA plants in January, 1997; Salmonella Testing and implementation of In-Plant HACCP Systems, had effective dates of January 1998, 1999 or 2000, respectively, for large, medium or small plants (Savell and Smith, 1998).

Five to ten years earlier, most USA beef packers had emphasized Pre-Requisite Programs, GMPs, and sanitation and operational SOPs to improve microbiological quality of their products and some USA beef packers had created and implemented "Scientific HACCP Programs." Following passage PR;HACCP;FR, packers developed "Regulatory HACCP Programs" to comply with new meat inspection regulations. As beef packing plants initiated efforts to comply with regulatory requirements in the PR;HACCP;FR, research studies, like those of Sofos *et al.* (1999a,b,c), proved beneficial to government officials and packing plant personnel, especially as they related to meeting *Salmonella* and *E. coli* testing criteria. Since implementation of the PR;HACCP;FR, packers have used HACCP, decontamination techniques and microbiological interventions to produce beef carcasses that are dramatically cleaner and safer than they were a decade ago (Smith, 1998).

During the first year after HACCP was implemented in the 312 largest processing plants in the USA, the prevalence of *Salmonella* went down almost 50% in broilers, more than one-third in ground beef, 27% in ground turkey and more than 25% in pork, and percentages of plants meeting "Performance Standards" for *Salmonella* were 96% for broilers, 71% for swine, 90% for ground beef, and 91% for ground turkey (Meat Processing, 1999a). In March 2000, FSIS-USDA reported that results of two years of testing in large plants under HACCP showed a nearly 50% decrease in *Salmonella* prevalence in chicken and swine carcasses (compared to pre-HACCP baseline results), more than 20% in ground beef and more than 30% in ground turkey (Food Technology, 2000). Results of one year of testing in small plants showed decreases in *Salmonella* prevalence of more than 40% in ground beef, nearly 20% in chicken carcasses, and 15% in cow and bull carcasses, but an increase in swine carcasses; since HACCP implementation, 90% of large plants and 84% of small plants have met *Salmonella* performance standards (Food Technology, 2000).

Elder *et al.* (2000) reported that: (a) Of lots, at least one EHEC O157 positive was found in 72% of fecal, 38% of hide, 87% of preevisceration, 57% of postvisceration and 17% of postprocessing

samples. (b) Prevalence of EHEC O157 in feces, hides, preevisceration, postevisceration and postprocessing samples was 28%, 11%, 43.4%, 17.8% and 1.8%, respectively. Reduction in prevalence from preevisceration to postprocessing suggests that plant sanitary procedures were effective. (c) EHEC O157 was recovered from 45.5% of carcasses. (d) Fecal and hide prevalence were significantly correlated with carcass contamination ( $P=0.001$ ), indicating a role for control of EHEC O157 in live cattle on the farm. The USDA scientists told Brasher (2000a) that calves can pick up the bacteria during the birth process while other cattle get it from manure and that changes in feeding methods and transportation can reduce the incidence, and told Lundeen (2000) that cross-contamination of carcasses may occur in plants through: (a) direct contact with personnel, knives or equipment. (b) Direct contact among carcasses. (c) Airborne and water-borne sources.

### **Minimizing Pathogens On Beef Using Singular Microbiological Interventions**

Scientists have investigated: (a) Sanitizing solutions (e.g., chlorinated water, organic acids, hydrogen peroxide, trisodium phosphate, ozonated water, etc.), (b) Spray-washing, (c) Hot water application, (d) Steam-vacuuming, and (e) Conventional knife-trimming plus washing, to determine their efficacy in decontamination of carcasses (Anderson *et al.*, 1977; Barkate *et al.*, 1993; Gorman *et al.*, 1995a,b; Hardin *et al.*, 1995; Kochevar *et al.*, 1997; Powell and Cain, 1987; Reagan *et al.*, 1996; Sofos and Smith, 1998). Dickson and Anderson (1992) and FSIS (1995c) believe a decontamination step during the slaughtering process can improve shelf-life and safety, and, thus, should be an essential part of the slaughtering/dressing process. In general, washing and sanitizing agents have been effective in reducing bacterial counts (1 to 3 logs) and presence of pathogens on carcasses (Reagan *et al.*, 1996; Gorman *et al.*, 1995a,b; Dickson and Anderson, 1992).

Smith *et al.* (1994) presented results of the “Wash/Trim Studies” (Gorman *et al.*, 1995a,b; Reagan *et al.*, 1996) at the Meat Industry Research Conference (San Francisco, California, USA) and, a month later, FSIS approved the commercial use of hot water (74 C) spray-washing of beef carcasses. Additional studies (Cabedo *et al.*, 1996, 1997; Gorman *et al.*, 1997; Graves Delmore *et al.*, 1997a) demonstrated efficacy of hot-water spray-washing for decontaminating beef carcasses. The largest beef packing plants in the USA use either hot-water spray-washing (thermal pasteurization) or steam pasteurization to improve microbiological quality of beef carcasses.

Gorman *et al.* (1995a,b) reported that spray-washing more effectively reduced bacterial counts and visible fecal contamination when pressure and temperature of the water were 16.89 bar and 74°C, respectively. Hot water applications result in 1 to 3 log reductions in microbiological counts (Acuff *et al.*, 1997; Barkate *et al.*, 1993; Gorman *et al.*, 1995a; Graves Delmore *et al.*, 1997; Powell and Cain, 1987; Reagan *et al.*, 1996). FSIS (1996a) approved use of solutions of acetic, lactic and citric acids at 1.5 to 2.5%, chlorinated water (20-50 ppm), trisodium phosphate (12%), hot water (>74°C) sprays and steam pasteurization (Dickson *et al.*, 1997; Dorsa, 1997; Dorsa *et al.*, 1997; Cutter *et al.*, 1997; Nutsch *et al.*, 1997; Phebus *et al.*, 1997; Sofos and Smith, 1997, 1998).

Steam (or hot water) vacuuming was approved by FSIS in 1996 based upon studies by IBP, Inc., Kochevar *et al.* (1997) and Dorsa (1997). Steam vacuuming is used in plants processing more than 80% of USA fed cattle, saving more than \$200 million a year in reduced trim losses (Beef Today,

1997). Steam pasteurization lowers bacterial counts on beef tissues (Phebus *et al.*, 1997) and beef carcasses (Nutsch *et al.*, 1997) and is used in several U.S. beef slaughter plants. Delmore *et al.* (1999, 2000) demonstrated efficacy of hot water and steam or solutions of acetic acid, lactic acid, or trisodium phosphate for decontaminating beef offals.

### **Minimizing Pathogens On Beef Using Sequential Microbiological Interventions**

Incidence of *E. coli* O157:H7 on beef carcasses (FSIS, 1994) was 0.2% (1 of 500) in 1993-1994. Doyle (1991) reported that 2 to 4% of ground beef contained *E. coli* O157:H7. Smith *et al.* (1995) and Sofos and Smith (1995) investigated sequential applications of microbiological “interventions” in “multiple hurdle” strategies, like those used for processed meat (Leistner, 1992; Leistner and Gorris, 1995), to lessen the odds of *E. coli* O157:H7 or other foodborne pathogens surviving slaughtering/dressing/chilling operations. Minimizing airborne and/or condensate contamination (Worfel *et al.*, 1995, 1996) might result in a ten-fold decrease (1 of 5,000) in odds of presence of *E. coli* O157:H7 on a finished beef carcass while chemical dehairing of cattle (post-stunning) (Bowling and Clayton, 1992; Schnell *et al.*, 1995; Castillo *et al.*, 1998) involves three bacteriostatic/bactericidal steps (sodium sulfide, hydrogen peroxide, lactic acid) which might further reduce the odds to 1 of 5,000,000. Add to those, interventions like pre-evisceration carcass washing (acetic acid), final carcass washing (74 C water) and spray-chilling of carcasses (chlorine dioxide) and—theoretically—the odds of finding *E. coli* O157:H7 on beef carcasses can be made practically zero, provided that no contamination is introduced at steps following slaughter (Smith *et al.*, 1995).

Combinations of antimicrobial treatments can more effectively reduce bacterial contamination on carcasses and cuts than individual treatments (Anderson *et al.*, 1977; Dickson and Anderson, 1992; Graves Delmore *et al.*, 1998; Hardin *et al.*, 1995; Phebus *et al.*, 1997; Castillo *et al.*, 1998). Graves Delmore *et al.* (1998) identified sequences of decontamination treatments (spray-washing/rinsing with warm water, acetic acid solution and/or hot water) that reduced *E. coli* counts of beef tissue (inoculated to 7.4 log CFU/cm<sup>2</sup>) by 4.3 logs and total coliform counts of beef tissue (inoculated to 3.7 log CFU/cm<sup>2</sup>) by 1.7 logs. ConAgra, Inc. used Graves-Delmore *et al.* (1998) results to devise a “Chain Of Beef Safety™” consisting of: (a) Steam-vacuuming; (b) Pre-evisceration washing (90°F water) and rinsing (2% acetic acid in 120°F water); (c) Thermal-pasteurization (165°F water), and; (d) Final-carcass washing (90°F water) and rinsing (2% acetic acid or lactic acid in 125°F water). Bacon *et al.* (1999) confirmed the effectiveness of the four-step, “Chain Of Beef Safety™” multiple-hurdle microbiological intervention sequence in the eight ConAgra, Inc. plants, achieving reductions of 4.5, 3.7 and 3.2 log CFU/cm<sup>2</sup>, respectively, in total plate counts, total coliform counts and *E. coli* counts, on chilled carcasses.

The pathogen control process to be used by Future Beef Operations in their first USA plant consists of eight steps [(1) Sodium sulfide dehairing, (2) Hydrogen peroxide neutralization of sodium sulfide, (3) Steam vacuuming, (4) Lactic acid rinsing, (5) Hot subcutaneous fat removal, (6) Thermal pasteurization, (7) Acetic acid rinsing, (8) Competitive exclusion, using *Lactobacillus delbrueckii*, on cuts and trimmings; Bowling (1999) says it will reduce the probability of a pathogen being present on a carcass from 1 in 55 to 1 in 2.75 billion.

### **Minimizing Pathogens On Pork**

Zerby *et al.* (1998a, 1999a) sampled hog carcasses in 12 U.S. packing plants and reported that Aerobic Plate Counts (APC), Total Coliform Counts (TCC) and *E. coli* Counts (ECC) were lower in winter than in summer and were lower for market hogs than for packer sows; application of organic acid spray on carcasses following final wash lowered APC. Incidence of *Campylobacter* spp. (7.9%), *Salmonella* spp. (4.6%) and *Yersinia enterocolitica* (0.9%) on carcasses was lower than that in the USDA Microbiological Baseline (31.5%, 8.7% and 7.4%, respectively) and incidence of *Listeria monocytogenes* in the packing plant environment was 5.0% (Zerby *et al.*, 1998a). At three packing plant locations—Pre-Wash, After Final Wash, After Chilling—APC decreased (in log CFU/cm<sup>2</sup>) from 3.7 to 3.3 to 2.9, respectively, TCC decreased from 2.5 to 2.3 to 1.0, respectively, and ECC decreased from 2.0 to 1.8 to 0.5, respectively (Zerby *et al.*, 1998a, 1999a).

Zerby *et al.* (1998b, 1999b) characterized microbiological populations on pork kidney, heart, cheek meat, head meat, tongue, salivary gland, feet, liver, stomach, bung, and chitterlings. For example, APC, TCC and ECC (log CFU/g) on pork tongue before chilling were 5.3, 3.0 and 2.5, respectively, and after chilling were 5.1, 2.2 and 1.9, respectively; pathogens occurred on pork tongues with incidences of 0.0% for *Campylobacter jejuni/coli*, 22% for *Salmonella* spp., 11% for *Listeria monocytogenes* and 0.0% for *Yersinia enterocolitica* (Zerby *et al.*, 1998b). Zerby *et al.* (1998c) investigated intervention strategies for reducing microbiological contamination on pork variety meats. For example, *Salmonella* spp. counts (log CFU/g) on inoculated pork stomachs were reduced by 2.1, 2.2, 2.3 and 2.3, respectively, when dipped 5 sec. in acetic acid, dipped 5 sec. in lactic acid, dipped 10 sec. in acetic acid and dipped 10 sec. in lactic acid.

### **Minimizing Pathogens On Lamb**

Kochevar *et al.* (1995; 1997b) compared visual fecal scores (VFS) and Aerobic Plate Counts (APC) for lamb carcasses that were trimmed/washed, trimmed/washed/organic-acid rinsed, washed only/60°F water, washed only/95°F water or washed only/165°F water. Visual fecal scores were best for lamb carcasses that were trimmed/washed, washed only/165°F water and trimmed/washed/organic-acid rinsed; APC (log CFU/cm<sup>2</sup>) were lowest for lamb carcasses that were trimmed/washed/organic-acid rinsed and second lowest for those washed only/165°F water (Kochevar *et al.*, 1995; 1997b). Duffy *et al.* (2000a) compared APC, TCC and ECC on lamb carcasses pre-evisceration, post-evisceration and after chilling in six U.S. lamb plants; APC decreased from 5.19, to 4.06 log<sub>10</sub> CFU/cm<sup>2</sup> from pre-evisceration to after chilling but neither TCC nor ECC changed from pre-evisceration to after chilling. Positive samples of *Campylobacter jejuni* were not present (0.0%) on lamb carcasses after chilling but 1.9% of those carcasses had *Salmonella* spp. (Duffy *et al.*, 2000a).

Colorado State University, Food Safety and Inspection Service of USDA and American Sheep Industry Association cooperated to establish baseline data for microbiological quality of lamb carcasses. In that study, APC, TCC and ECC mean values (log CFU/cm<sup>2</sup>) were 4.42, 1.18 and 0.70, respectively, and the incidence of positive samples for *Salmonella* spp. was 1.5% on carcasses in the cooler, after 24 hr chill (Duffy *et al.*, 2000b). Incidences of *Campylobacter jejuni/coli* were 0.5%, 0.6%, 0.0% and 0.0%, respectively, for lamb carcasses pre-evisceration, post-evisceration, after final wash and after 24 hr chill (Duffy *et al.* 2000b).

Duffy *et al.* (2000d) identified the Good Manufacturing Practices (GMPs) that could be used during harvest to improve microbiological quality of lamb carcasses. GMPs for which there were areas of opportunity to improve microbiological quality were: (a) Improved pre-harvest presentation status of live lambs, (b) More careful pelt removal, (c) Reduced time carcasses are held on the harvest floor, (d) Use of steam vacuuming technology, (e) Use of wash cabinets and (f) Improved spacing of carcasses in the chill cooler (Duffy *et al.*, 2000d).

### **Microbiological Testing**

Data collected by 12 packing plants (1 sample per 300 carcasses) and analyzed by Bacon *et al.* (2000) showed that *E. coli* O157:H7 was present on hides of 3.56% of 2,245 animals and on 0.44% of 2,248 carcasses after hide removal, but was not present (0.00%) on 2,248 carcasses or in 1,342 samples of trimmings for ground beef. AMIF (2000a), from these findings, concluded that: (a) Data support the efficacy of sanitary hide removal and carcass microbial treatments as effective means of reducing pathogens. (b) Testing for process control verification would be more effective if the testing were done before carcass fabrication and distribution. (c) If carcass testing was used, carcasses testing positive for pathogens could be removed from the raw beef food supply before reaching the consumer and appropriate process reviews could ensure that the food safety system is working effectively. USDA scientists have successfully tested an instrument that uses specific wavelengths or colors of light to electronically determine if fecal matter is present on a carcass; if so, the carcass is further sanitized (SMA, 2000a).

Microbiological testing for indicator bacteria can be used to validate or verify slaughter procedures (QC, HACCP programs, etc.) and/or carcass decontamination interventions for reducing/ eliminating meatborne pathogens, but planned testing for pathogens like *E. coli* O157:H7 that are of low, infrequent and non-random (unpredictable) incidence with the objective of process monitoring or product safety assurance or verification is not effective and is not recommended by AMSA (1999), AAM (1999), Bacon (2000) or Gill (2000). Smith De Waal (2000), on the contrary, believes that pathogen testing is an essential weapon in the government's arsenal against foodborne illness and that testing at many levels (USDA should add mandatory testing of carcasses and trimmings at slaughterhouses) and for more pathogens (*Listeria monocytogenes* and *Campylobacter jejuni/coli* should be added) is needed to maximize consumer and public health protections.

AMIF (2000c) reported that a new genetic fingerprinting method developed by Andy Benson (University of Nebraska) shows that there are two genetically distinct *E. coli* O157:H7 populations in cattle. One population appears to be associated with fatal foodborne illness in people while the other is not commonly isolated from foodborne disease cases; the population most commonly found in cattle is either incapable of causing disease or is not easily transmitted to humans (AMIF, 2000d) and these results help explain why only about 20,000 cases of human infection with *E. coli* O157:H7 are reported each year when you would expect a much higher number, given the number of cattle infected (Western Livestock Journal, 2000). Itoh *et al.* (1999)

reported that both Shiga toxin-producing *E. coli* O157:H7 and Shiga toxin-non-producing *E. coli* O157:H7 coexist in cattle. Acheson (2000) said the current policy in the USA is to examine ground beef for *E. coli* O157:H7 only, but restricting the focus to O157 will miss other important human Shiga toxin-producing *E. coli*. These three studies reinforce the futility of testing carcasses or beef for *E. coli* O157:H7.

Carcass contamination after application of decontamination treatments will depend on facility design, sanitation, hygiene, process control and Good Manufacturing Practices; without this foundation, even the best decontamination technologies will fail (Sofos and Smith, 1997). Because it is so difficult (and so extraordinarily expensive) to try to find foodborne pathogens on beef by use of microbiological sampling, and because not all carcass sampling protocols provide the same estimate of contamination (Krizner, 1998; Ware *et al.*, 1999; Gill, 2000), a more rational approach to lowering incidence of foodborne pathogens like *E. coli* O157:H7 on beef, is to use sequential, multiple-hurdle applications of bacteriostatic/bactericidal technologies (Smith *et al.*, 1995; Graves Delmore *et al.*, 1997b,c, 1998; Bowling, 1999; Bacon *et al.*, 1999, 2000) and to validate or verify (by testing for indicator bacteria) that the process is under control.

In 1999, after having USDA inspection pulled from its processing plant because of three consecutive failures to meet *Salmonella* performance standards, Supreme Beef (Dallas, Texas, USA) filed suit against USDA in U.S. District Court. At issue in the Supreme Beef case (NMA, 2000b) were whether: (a) FSIS can enforce its performance standard for *Salmonella* at a point where the processor has access to no control measures to comply with the standard. (b) FSIS enforcement of the *Salmonella* performance standard at beef grinding plants contradicts and undermines the basic principles and credibility of the HACCP program. (c) USDA has exceeded its authority under the law by the manner in which it has implemented the performance standard for *Salmonella* testing. (d) The standard fails to take into account geographical and temperature factors that affect the prevalence of *Salmonella* and the significant differences between results from USDA vs. third-party laboratories. On May 25, 2000, a federal judge in Texas struck down the USDA's inspection standards for meat-processing plants saying they do not fairly measure sanitary conditions, they measure the quality of the meat brought into a plant but not necessarily the conditions of the plant, and federal law did not give the government the authority to close a meat processing plant based on bacterial tests (Burros, 2000). The standards, and the laboratory tests used to enforce them, were the foundation of a four-year-old government effort to limit meat and poultry contamination by *Salmonella*; USDA Secretary Dan Glickman said the agency (FSIS) would take "whatever legal steps are necessary" to overturn the ruling (Burros, 2000).

### **Responsibility Of The Beef Preharvest Sector**

From 1993 through 1996, the National Cattlemen's Beef Association (NCBA) spent more than \$5 million on food safety research studies of *E. coli* O157:H7 and *Salmonella* (Beef Today, 1997) with most of those expenditures directed toward research in the harvest portion of the "farm-to-fork" sequence and with little effort to study the preharvest or postharvest sectors. *E. coli* O157:H7 was first recognized as a human pathogen in 1982 following major outbreaks of hemorrhagic colitis in Michigan and Oregon (Riley *et al.*, 1983) and while *E. coli* O157:H7 is not host-specific (Armstrong *et*

*et al.*, 1996; Besser *et al.*, 1997; Dargatz *et al.*, 1997; Kudva *et al.*, 1997a; Hancock *et al.*, 1998a) it is most frequently found in ruminants, particularly cattle (Reimann and Cliver, 1998). CAST (1994) stated "Pathogens or their toxins may be controlled by preventing their entry into the food, by reducing the amount present, or by destroying that which is present." Crider (1997), Clapp (1997) and Suther (1997) insisted that farm-to-table HACCP plus all the pathogen kill-steps that science can provide must be used to reduce incidence of *E. coli* O157:H7 on beef.

Sugarman (1997), Wheeler (1997), Labudde (1997) and Effertz (1997) believed recurring outbreaks of *E. coli* O157:H7 occurred because no one eliminated the source of contamination at the ranch, feedlot or packing plant. Maday (1995), AMSA/NCBA (1997), Meat Processing (1997a), Kester (1997), Bryan (1997), Suther (1997), Meat and Poultry (1997b) and Murphy (2000) believe control of *E. coli* O157:H7 contamination and on-farm prevention deserved the most attention because, if farmers and ranchers could: (a) identify and cull carriers, (b) investigate production/management practices which influence growth, shedding and spread of *E. coli* O157:H7 in the environment, (c) improve on-farm sanitation and develop manure management strategies, (d) prevent this bacteria from infecting live animals (perhaps, by use of antibacterial agents), and (e) minimize cattle entering the packing plant with *E. coli* O157:H7 on or in their bodies, it would help prevent its spread further into the food production chain.

### **Knowledge Base For Developing Beef Preharvest Microbiological Interventions**

Most cattle producers agree (Smith *et al.*, 1998) that: (a) We do not have an adequate base of research knowledge to mandate microbiological interventions in the preharvest sector. (b) If preharvest microbiological interventions are needed, they should start with Good Production Practices (GPPs) and then proceed to HACCP systems if preharvest Critical Control Points are ever identified. (c) Preharvest microbiological interventions should be incorporated into the voluntary NCBA, BQA programs rather than dictated through government regulations.

Research has documented the presence of *E. coli* O157:H7 in cattle feces; and, human illnesses due to this pathogen have not been traced to animals other than cattle (Dean-Nystrom *et al.*, 1997). Beef and dairy cattle are known reservoirs for *E. coli* O157:H7 (Borczyk *et al.*, 1987; Wells *et al.*, 1991; Chapman *et al.*, 1993, 1997; Hancock *et al.*, 1994a, 1997b; Zhao *et al.*, 1995; Besser *et al.*, 1997). Of 100 outbreaks of *E. coli* O157 since 1982, 52% were associated with foods from cattle (WHO, 1997). Chapman *et al.* (1997) detected *E. coli* O157:H7 in the feces of 14% of culled dairy cows and of 13% of pasture-reared youthful cattle. Based on fecal samples from 100 feedlots in the top 13 cattle feeding states: (a) 1.61% of the samples of fresh feces in the pens contained *E. coli* O157:H7 and that 63% of the feedlots had one or more positive samples (NAHMS 1995a; Dargatz *et al.*, 1997), and (b) 5.5% of the samples of fresh feces in the pens contained *Salmonella* and that 38% of the feedlots had one or more positive samples (NAHMS, 1995b).

NAHMS (1997), Dargatz *et al.* (1997) and Hancock *et al.* (1997a) reported that: (a) Pens of cattle on-feed less than 20 days were 3.39 times more likely to have a positive sample of *E. coli* O157:H7 than those on-feed for longer times. (b) Pens of cattle fed vs. not fed barley in their current diet were 2.75 times more likely to have a positive sample of *E. coli* O157:H7. (c) Pens of cattle with entry

weights of 700 lb or more were less likely to have positive samples of *E. coli* O157:H7. (d) Pens of at least 85% heifers were less likely to have positive samples of *E. coli* O157:H7. (e) Shedding of *E. coli* O157:H7 was not related to current feeding of antibiotics, coccidiostats, ionophores, probiotics, urea or other feed additives. (f) Shedding of *E. coli* O157:H7 was not associated with general health of the cattle in the pen or of animal density in the pen. (g) *E. coli* O157:H7 prevalence among USA feedlots was not different among geographical regions. NAHMS (1995b) concluded that (a) Cattle on-feed longer were more likely to shed *Salmonella*. (b) Sample prevalence of *Salmonella* within feedlots appeared to be highly variable and was very low to zero (not detectable) in about two-thirds of feedlots. (c) Shedding by cattle, of *Salmonella* spp. serotypes commonly associated with human illness occurred infrequently.

Hancock *et al.* (1994a,b; 1996; 1997a,b,c; 1998a,b), LeJuene *et al.* (1997), Garber *et al.* (1995a,b; 1999), Lynn *et al.* (1998), Besser *et al.* (1996, 1997) and Herrott *et al.* (1998) concluded that *E. coli* O157:H7: (a) exists—at least intermittently—on a majority of cattle farms, (b) is distributed across the USA in both dairy and beef cattle, (c) prevalence is not affected by the size of a cattle herd, (d) is detectable in the feces of less than 5% of cattle, (e) is found in feces from cattle, deer, sheep, dogs, horses, flies and birds, (f) if it has a long-term reservoir species, that species has not been identified, (g) colonizes in cattle in short duration (1 to 2 months) but long-term carriers have not been identified, (h) prevalence rates in cattle recently arrived in the feedlot are threefold higher than in those in the feedlot for several months, (i) is not associated with any recognizable disease in cattle, but instead appears to behave as transient *E. coli* “normal flora,” (j) can colonize a minority of cattle at low doses (<250 CFU) and these animals amplify the infection and transmit *E. coli* O157:H7 to other cattle, (k) is more prevalent in growing cattle (3 to 18 months of age) than in either younger (suckling) calves or adult cattle, (l) prevalence in a herd may (Hancock *et al.*, 1994b) or may not (Hancock *et al.*, 1997) be associated with manure application to grazing land, (m) prevalence in a herd is eight times as likely on dairy farms where alleyways are flushed with water as opposed to being cleaned by other methods, (n) sheds in a typical pattern in a herd followed over time as “epidemics of shedding” (mainly during warm weather) interspersed with longer periods with rare or no shedding animals, (o) can multiply prolifically in cattle feeds when moisture is added, as commonly occurs in mixed rations, (p) will not grow in total mixed rations containing a silage naturally high in propionic acid, (q) can replicate in a variety of feeds at temperatures found on farms during summer months, (r) has been found in water troughs on numerous farms and can persist at least 4 months in water-trough sediments (thus water troughs could be a long-term reservoir which maintains *E. coli* O157:H7 in herds during periods of low infection prevalence), (s) persists on particular farms as a specific strain for at least 2 years, and (t) is regionally transmitted, because indistinguishable strains have been found in herds less than 500 km apart.

*E. coli* O157:H7 occurs in all regions of the USA (Garber *et al.*, 1995a) and prevalence fluctuates, from undetectable to detectable, depending partially upon season (Hancock *et al.* 1997a,b,c, 1998b). Fecal shedding, risk of cattle contamination and risk of human outbreaks (Riley *et al.*, 1983; Rodrigue *et al.*, 1995) are highest in Spring and Summer (Hancock *et al.*, 1994a; Van Donkersgoed *et al.*, 1999; Chapman *et al.*, 1997). *E. coli* O157:H7 shedding is greater in cattle fasted before harvest (Rasmussen *et al.*, 1993). *E. coli* O157:H7 shedding was not related to rumen fill, body condition, type, gender or distance traveled to the packing plant, in a study of slaughter cattle by Van

Donkersgoed *et al.* (1999). Jordan and McEwen (1998) reported that an abrupt change in diet slightly reduced shedding of *E. coli* Biotype I in feedlot cattle while Kudva *et al.* (1995, 1997b) increased shedding of *E. coli* O157:H7 in feces of sheep by shifting their diet from grain to forage.

Buchanan and Doyle (1997), citing their work (Zhao *et al.*, 1995; Meng *et al.*, 1995; Brown *et al.*, 1997) and that of others detailing “Reservoirs and Sources of *E. coli* O157:H7” reported that: (a) Young animals carry *E. coli* O157:H7 more frequently than adults, (b) Prevalence of fecal excretion varies substantially among positive herds, (c) Reported incidence among cattle varies widely, in part because of differences in sensitivity of procedures used for detecting *E. coli* O157:H7, (d) Results of two major USA surveys indicated that 3.2% of dairy calves and 1.6 to 2.0% of feedlot cattle were positive for *E. coli* O157:H7. (e) *E. coli* O157:H7 in calf feces ranged from  $<10^2$  to  $10^5$  CFU/g, (f) Fecal shedding of *E. coli* O157:H7 frequently is intermittent and of short duration, i.e., several weeks to months, (g) Strains of *E. coli* O157:H7 with indistinguishable PFGE genomic DNA profiles can be isolated from calves in different states or farms, (h) More than one strain of *E. coli* O157:H7 can be isolated from feces of the same animal or different animals within the same herd, (i) *E. coli* O157:H7 is not pathogenic to calves; inoculation with  $10^{10}$  CFU did not induce significant clinical disease, (j) *E. coli* O157:H7 shed in feces decreased dramatically during the first 14 days postinoculation (e.g., from  $10^4$  to  $10^6$  CFU/g after 48 hr to  $5\text{-}10^2$  CFU/g at 14 days, (k) *E. coli* O157:H7 is confined to the gastrointestinal tract, with the forestomachs (rumen, omasum, reticulum) and distal sites (distal ileum, proximal cecum, spiral colon, descending colon) as principal sites of localization, (l) Fasting increases the levels of *E. coli* O157:H7 shed in the feces of some animals, but not in most, (m) *E. coli* O157:H7 did not form attaching and effacing lesions and did not colonize mucosal surfaces, and (n) The ability of *E. coli* O157:H7 to persist in and reinfect cattle that have a strong immune response is likely to contribute to the introduction and persistence of infection in herds.

*E. coli* O157:H7 has unusual tolerance to environmental stresses such as acidic and dry conditions (Arnold and Kaspar, 1995). *E. coli* O157:H7 survived in cattle manure for 79 days (Wang *et al.*, 1996) and in a manure pile for 21 months (Kudva *et al.*, 1998). A waiting period between manure application and allowing cattle to graze that field is recommended by Hancock *et al.* (1994b). Gunnerson (2000) reported that Cornell University scientists discovered that adding sodium carbonate plus sodium hydroxide to manure kills most of the *E. coli* bacteria. The worst outbreak of *E. coli* O157:H7 in North America (6 deaths in Ontario, Canada) was caused by contamination of the municipal water supply, perhaps because flooding from rains washed animal feces into the town water supply (Cohen, 2000). While house flies and fruit flies have been thought to be simply mechanical vectors of enterohemorrhagic *E. coli* O157, Iwasa *et al.* (1999), Kobayaski *et al.* (1999) and Janisiewicz *et al.* (1999) proved otherwise, demonstrating that the organism is ingested by flies, lives in their mouth and crop, is excreted for several days and, thus, is disseminated via their spittle. Smith *et al.* (2000) used combination of draining/refilling, brush-scrubbing and 15 min. exposure to a 1:32 (sodium hypochlorite:water) solution and concluded that routine cleaning or disinfection may not, by itself, reduce the likelihood of transmitting coliform bacteria to cattle through feedlot water tanks. Doyle (1992) considers *Campylobacter jejuni*, *Listeria monocytogenes*, and Enterohemorrhagic *E. coli* O157:H7 important foodborne

pathogens. Siragusa *et al.* (1993) reported incidences of *Listeria monocytogenes* in six studies of bovine feces of 0%, 19%, 52%, 11%, 7% and 18% (52% in mature cows) and of 1.0 to 1.3% in feces from healthy feedlot beef cattle.

### **Attempts To Manipulate The Gastrointestinal Tract Of Cattle To Control Pathogens**

Newman (1996), Stern *et al.* (1996), Spring (1995), Scheoni and Wong (1994), Miles (1993) and Scheoni and Doyle (1992) described nutritional or microbiological manipulation of the gastrointestinal tract to prevent colonization or eliminate pathogens in chickens and/or pigs; such manipulation, using oligosaccharides or bacteria (lactic acid bacteria, *Bacillus cereus* and competitive exclusion cultures), though not 100% effective, have been shown to decrease populations of *Salmonella* and *Campylobacter* (Newman, 1996). Cannell *et al.* (1997) administered a feed additive combining a mannanoligosaccharide plus lactic-acid secreting bacteria to growing dairy heifers for 28 days but found no differences in Total Coliform Counts or Generic *E. coli* Counts in the feces of control vs. treated cattle. NMA (1997) and Meyer (1997) reported that Michael Doyle (University of Georgia) had isolated 18 beneficial strains of bacteria from cattle gastrointestinal tracts and droppings which, when added to cattle feed, virtually eliminated *E. coli* O157:H7 in two or three weeks and that this discovery might lead to a product that eliminates the microorganism before cattle are sent to slaughter or keep *E. coli* O157:H7 from invading cattle that do not have it.

Diez-Gonzales *et al.* (1998) reported that: (a) The gastric stomach of humans is a barrier to foodborne pathogens, but *Escherichia coli* can survive at pH 2.0 if it is grown under mildly acidic conditions. (b) Cattle are a natural reservoir for pathogenic *E. coli*, and cattle fed mostly grain had lower colonic pH and more acid-resistant *E. coli* than cattle fed only hay. (c) On the basis of numbers and survival after acid shock, cattle that were fed grain had 10<sup>6</sup>-fold more acid-resistant *E. coli* than cattle fed hay; but, a brief period of hay feeding decreased the acid-resistant count substantially. (d) Cattle could be given hay for a brief period immediately before slaughter to significantly reduce the risk of foodborne *E. coli* infection. Keen *et al.* (1999) determined that an abrupt ration change from a corn-based concentrate to 100% alfalfa hay greatly decreased fecal EHEC O157 shedding from 50% to 18% within 7 days of ration change (vs. no change for grain-fed cattle); however, hay-fed cattle lost about 0.8 lb per day (vs. 2.6 lb per day gain in grain-fed cattle). Scott *et al.* (2000) manipulated finishing diets of cattle by limit-feeding, altering dietary ingredients in a finishing ration and feeding alfalfa hay *ad libitum* for five days. Manipulation of finishing diets did not reduce shedding of acid-resistant *E. coli* in feces; however, short duration hay feeding reduced acid-resistant *E. coli* shedding in the feces (Scott *et al.*, 2000).

### **Programs For Preharvest Microbiological Interventions In Livestock**

Campbell *et al.* (1982, 1984) and Mallinson *et al.* (1995) reported that risk of *Salmonella* contamination on processed turkey and broiler carcasses is reduced when the carcasses originate from farms with lower levels of *Salmonella*. The *Salmonella enteritidis* Pilot Project (SEPP) started in 1992 and evolved into the Pennsylvania Egg Quality Assurance Program (PEQAP) in 1994; included in both programs were microbiological interventions (chick/pullet testing, rodent control, cleaning/disinfection between flocks occupying the houses) that could be implemented by producers. White *et al.* (1997) concluded that the on-farm risk-reduction management practices of SEPP and

PEQAP had reduced *Salmonella enteritidis* infections.

To assure safety of ruminant-animal foods, Gangarosa *et al.* (1994) recommended that: (a) Each segment of the food chain identify its responsibilities (based on risk, and implemented by HACCP) for the maintenance of food safety and product quality assurance. (b) Quality Assurance Programs of commodity organizations should encompass considerations of fecal contamination of feed, water and hair coats; pathogen-free feeds; control of birds and rodents; potential chlorination of water and pasteurization of feedstuffs; and, minimizing animal stress to reduce shedding rates of pathogens. (c) Research be conducted on ecology/epidemiology of foodborne pathogens to establish appropriate critical controls in on-farm HACCP programs. (d) Preharvest food safety education programs are needed for producers, farm laborers and veterinarians. (e) A system of food safety data-bases should be developed. (f) Total Quality Management programs should be implemented that include general on-farm sanitation, cleaning/disinfecting of transport vehicles and handling of animals with minimal stress. (g) A unique animal identification system that is electronically-based should be established. (h) A traceback system should be considered but—with foodborne pathogens—a traceback system to the source, with the intent of eliminating risk at the source, is unlikely to work. (i) Specialized slaughter facilities producing only a cooked product should be established to accommodate animals identified as having a foodborne pathogen.

Grandin (1994), Hancock and Dargatz (1995) and Besser (1995) discussed potential methods of preharvest control of *Salmonella*, *Campylobacter* and *Listeria* in livestock: (a) *Trace-back* is not realistic because about 70 to 80% of farms, ranches and feedlots have cattle that are shedding *E. coli* O157:H7 and the organism is also shed by sheep and deer. (b) *Universal-testing* of all cattle going to slaughter is not realistic because about 1 in 40 slaughter cattle have *E. coli* O157:H7 in their gastrointestinal tract and many more (perhaps 10 times as many) cattle carry the organism on their hair than actually shed it in their feces. (c) *Farm visits* by FSIS or APHIS officials is not realistic inasmuch as not enough is known to allow government personnel to provide meaningful advice. (d) *Vaccination* is being studied but with not much promise of success. (e) *Preslaughter measures* such as elimination of preslaughter fasting, dietary measures to minimize colonization levels (prevalence and dose) and washing of live animals to remove feces and soil may prove efficacious for lowering the odds of finding pathogens on the outside of cattle. (f) *Ecological measures, competitive exclusion or niche engineering* by modifying nutritional and/or environmental variables found to be important in susceptibility to colonization, level of exposure, or maintenance of the reservoir in the herd, reduced feed contamination (5 to 20% of livestock feeds contain *Salmonella*; one-third of feeds may contain Generic *E. coli*) and using probiotics in the feed and/or inoculating the rumen with “good” bacteria that will compete with pathogens—is probably the best approach for lessening occurrence of *E. coli* O157:H7 and other pathogens in and on slaughter cattle.

Archer (1995) suggested that: (a) Soil protozoa could act as Trojan Horses for pathogenic bacteria, shielding them from disinfectants, facilitating their travel, and influencing their virulence in humans. (b) Microbial ecology at the farm level must be elucidated. (c) Potential sources and niches for *E. coli* O157:H7 at the feedlot must be identified. (d) Pathogens try to survive under the adverse conditions of the farm or feedlot and develop resistances as well as niches (e.g., water troughs, standing water) for

their survival. (e) A potential decrease in the acidity of the rumen, as well as protection by protozoa, may allow survival of *E. coli* O157:H7.

Labudde (1997) recommended the following GMPs as solutions to preventing *E. coli* O157:H7 contamination on beef: (a) Cattlemen can test herds for the presence of *E. coli* O157:H7 and forego selling positive animals to packers. (b) Ranchers and feeders should wash manure off animals before sending them to market; USDA inspectors should reject unclean animals before they enter a packing plant. (c) Ranchers, feeders and packers should withhold feed from animals between 8 to 16 hr before slaughter because a two-fold to ten-fold reduction in contamination can be accomplished by withholding feed as the gut will not become bloated and burst as easily during evisceration. Crider (1997) suggested producers use these GMPs: (a) Maintain stored feeds free of bird and rodent contamination; bird feces commonly contains *Salmonella* and also has *E. coli* O157:H7; rodents commonly carry *Salmonella* and other pathogens. (b) Manage feed bunks so that refusal is minimized and residue removed frequently; *E. coli* O157:H7 and *Salmonella* can grow to very high levels in some mixed feeds. (c) Clean water troughs frequently enough to prevent visible accumulation of sediments and biofilms, or slimy scum, because pathogenic bacteria, including *E. coli* O157:H7 and *Salmonella*, live there.

Targeted research to reduce pathogens on cattle and carcasses (Smith, 1996, 2000b; Sofos *et al.*, 1998; Smith *et al.*, 1998) should include: (a) Ecology/epidemiology of pathogens on the farm, including reservoirs and life cycles. *E. coli* O157:H7 are found in deer, antelope, elk and flies and *Salmonella* is found in birds; the role of wildlife, flies, birds and rodents as reservoirs and in the life cycle of pathogens must be determined. (b) Determination of how pathogens reproduce in livestock and how/why they move into the feces. Research is needed to determine if production/management practices, stress during handling and long transportation and holding times increase shedding and transmission of *E. coli* O157:H7 and *Salmonella* from the gastrointestinal tracts of slaughter cattle. (c) Identification of potentials for changing feedstuffs or manipulating the flora in the gastrointestinal tract for decreasing pathogens in feces or for changing acid-resistance of pathogens that are shed. Competitive exclusion or inhibition should be investigated as means for enabling non-harmful bacteria to out-compete, and reduce incidence of, pathogenic bacteria like *E. coli* O157:H7 and *Salmonella*. Changing forage:concentrate ratios in the diet to make the *E. coli* O157:H7 that are shed less resistant to acid (making them less apt to survive the acidic conditions of the stomachs of humans who ingest them). (d) Evaluation of cattle cleaning systems and chemical dehairing, immediately prior to hide removal, during harvest. Most contamination comes from the hair or skin of cattle; removing the hair of cattle and cleaning them before they proceed to dehide and dressing may be the most comprehensive and effective approach to reducing risk of contaminating meat with pathogenic bacteria. The packing plant is the first “point of concentration” for all slaughter cattle; cattle cleaning or chemical dehairing is a more practical method for reducing contamination on slaughter cattle than would be development of HACCP plans for every farm, ranch, auction market or feedlot that sends a bovine animal to a packing plant. (e) Determination of sources of farm-to-carcass contamination via conduction of longitudinal studies (replicated seasonally and geographically). Samples of bird droppings, old fecal pats, feed rations from bunks, water in troughs, fresh fecal pats, dung-locks at feedlots and auction markets, trucks (sideboards) before (at the feedlot) and after (at the packing plant)

use for transportation of cattle, gastrointestinal tract feces, dung-locks at packing plants and chilled carcass surfaces should be collected, tested for *Salmonella* and *E. coli* O157:H7, and, if present, DNA fingerprinted (via RFLP analysis and profiles by PFGE or Ribotyping) for strain identification and clustering of isolates to trace sources and/or vehicles of infection of cattle with pathogens. (f) Using information from research conducted in parts “a” through “e,” above, evaluate implementation of Good Production Practices (e.g., water ozonation, on-farm truck cleaning, pen scraping/bedding, bird and rodent control, diet manipulation, stress reduction) for reducing contamination in and on slaughter cattle.

Hussein (2000) summarized the present status of on-farm factors that can decrease risk of *E. coli* contamination as follows: (a) In the past 20 years, *E. coli* O157:H7 has surfaced as an emerging foodborne pathogen causing illness in humans. (b) The pathogen has been traced, in most cases, to the consumption of contaminated cattle products that are raw (i.e., milk) or undercooked (i.e., beef). (c) Research has identified methods to decrease post-harvest contamination of beef with *E. coli* O157:H7; a combination of these methods and preharvest (on-farm) control methods would be effective in reducing the risk of *E. coli* O157:H7 contamination of beef. (d) Preharvest control measures are based on manipulation of cattle management practices, manure handling, drinking water and dietary ingredients to decrease fecal shedding of the pathogen. (e) Although recent research addressing these control measures has shown promise, the on-farm factors associated with the carriage and shedding of *E. coli* O157:H7 by cattle remain to be elucidated.

Duffy *et al.* (2000c) investigated pre-harvest management practices (PHMP) and microbiological quality of lamb carcasses. There were no advantages in APC, TCC or ECC on chilled lamb carcasses that were related to shearing lambs prior to harvest, bedding sheep prior to slaughter or keeping lambs dry before harvest. Duffy *et al.* (2000c) concluded that the greatest control over carcass contamination is exerted within the packing plant via use of GMPs and use of in-plant multiple-hurdle microbiological interventions; pre-harvest management practices can make a positive contribution to meat safety of lamb carcasses but cannot be relied upon, by themselves, to control contamination (Duffy *et al.*, 2000c).

### **Attempts To Characterize Farm-To-Fork Microbiological Interventions**

FSIS (1993) presented a “Farm-To-Table Continuum Of Responsibility For Food Safety” that consisted of the following discussion points: (a) Producers should provide “healthy” animals (via: probiotics, GMPs, QA/QC, recordkeeping, trace-back, education); “healthy” means free of human pathogens, drugs, environmental contaminants and pesticides, (b) Transporters of cattle must minimize contamination and stress, (c) Slaughterers must use education, “process control” and/or HACCP, (d) Food-service should develop and use training and HACCP, (e) Consumers should be better educated (via: schools, television, print media) and better informed (via: “safe handling” labels); but, the consumer must not be assigned all or even most of the responsibility of safe meat, and (f) Government’s role should be HACCP verification, process-control oversight, compliance guarantees and consumer education.

National Live Stock and Meat Board (1994) developed a blueprint for industry action for solving the

*E. coli* O157:H7 problem that included: (a) Preharvest—Research on host:pathogen relationships; reservoirs; ecology; interventions, (b) Carcass Conversion—Clean hide before removal; use antimicrobial washes (use HACCP), (c) Carcass Break-Up; Trim Generation—Prevent recontamination and temperature abuse (use HACCP), (d) Ground Beef Processing—Prevent pathogen growth; use interventions (use HACCP), (e) Food Service—Require suppliers to use HACCP and train employees. (f) Retail—Require suppliers to use HACCP and train employees, (g) Public Health/Consumer Education—conduct a national consumer awareness campaign, (h) Intervention Strategies—Research irradiation and other strategies, and (i) Regulatory Opportunities/ Challenges—Move to risk-based analyses and verify HACCP.

### **Postharvest Microbiological Interventions**

There are microbiological interventions that should occur during distribution and storage (Smith *et al.*, 1998). Meat & Poultry (1997a) described “Transportation and storage critical control points,” of FSIS-USDA (Transportation Analysis Group) as follows: (a) Inspect the truck and trailer before loading, (b) Ensure the temperature of the product to be loaded is not above 40°F, (c) Properly configure the load, (d) Ensure maintenance of 40°F temperature while awaiting additional product to be loaded, (e) Maintain proper temperature of the food during transit, and (f) Maintain inside temperature of the food during unloading and movement to storage.

There are microbiological interventions that could be used at supermarkets (Smith *et al.*, 1998). Sofos and Smith (1994) said retail meat markets need Sanitation Standard Operating Procedures, time/temperature controls, avoidance of cross-contamination and at least two Critical Control Points: (a) CCP1—Receiving at the warehouse; check temperature and condition of incoming product, and (b) CCP2—In the cutting room, assure pre-operation sanitation, personal hygiene, temperature, time and condition of wholesale/retail cuts are within accepted tolerances. Peter Rojack (A&P Stores) said supermarkets should: (1) Buy Safe Food (via buying specifications); (2) Maintain The Cold-Chain (via HACCP checks); (3) Eliminate Cross-Contamination (via training/controls and in-store discipline); (4) Assure Effective Sanitation (A&P does this via their “Sparkle” program); and (5) Partner With The Customer (via consumer education in special kiosks in stores) (Smith and Morgan, 1999). Nancy Donley (Safe Tables Our Priority) described things that supermarkets should do to help prevent consumer illness due to foodborne pathogens on meat and poultry, as: (1) Have HACCP programs in all stores. (2) Build microbiological control into supplier agreements. (3) Conduct unannounced visits to suppliers to assure that their sanitation standards are met. (4) Maintain species-specific areas for cutting and grinding. (5) Stop using rework. (6) Sell meat/poultry thermometers and educate people in their use. (7) Double-wrap all meat cuts to minimize contamination from drip. (8) Have plastic gloves or bags at meat counters to prevent consumer cross-contamination of other foods. (9) Separately bag meat/poultry at the checkout counter. (10) Incorporate pictures of the faces of previous innocent victims of food poisoning in numerous places to increase employee awareness of the problem in relation to their own children’s vulnerability (Smith and Morgan, 1999).

Microbiological interventions have been described by fast-food companies (Smith *et al.*, 1998). Salvage (1996) characterized food-safety activities of fast-food companies as follows: (a) Jack In The

Box—HACCP-based program; *E. coli* O157:H7 control program; ServSafe training program (with National Restaurant Association); HACCP system in restaurants. (b) Arbys—HACCP-based program covering each element of receiving, manufacturing, storage, distribution, product cooking and restaurant/sandwich preparation. Burger King—HACCP-based program; unannounced audits of raw-material suppliers and meat processors; HACCP system in restaurants. AMS-USDA may require all ground beef suppliers for the National School Lunch Program to operate under a HACCP program, to have microbiological intervention steps, to test end-product for pathogens, and to test uncooked product for *E. coli* O157:H7 (Meat Processing, 1997b). FSIS-USDA may expand its efforts beyond slaughtering and processing plants to include: (a) Monitoring of retail food stores, restaurants, commercial kitchens, hotels and other institutions, and (b) Random reviews of distributors, warehouses, retail stores, restaurants/caterers, animal food processors, transporters and renderers (Smith and Morgan, 1999).

Kain *et al.* (1999) studied microbial counts on beef carcasses, wholesale cuts and retail cuts to assist those in the fabrication, distribution and retailing sectors to deliver safe beef to retail consumers. Beef at six packing plants was followed to six retail stores and bacterial counts and incidences of *Salmonella* spp., *Listeria* spp. and *Listeria monocytogenes* were determined; counts/incidences of bacteria/pathogens were higher on wholesale and retail cuts than on the carcasses from which they originated in 3 to 5, of 6, comparisons. A study of a multiple-hurdle microbiological intervention sequence for use during fabrication of beef carcasses into subprimal cuts and beef trimmings (Smith *et al.*, 1999) will be completed in late 2000. Kain *et al.* (1999) reported that more than 9% of consumers intercepted at supermarkets took more than 2 hr. to refrigerate or freeze beef purchases in the home.

A “U.S. Cold Temperature Evaluation” survey (AMIF, 2000b) revealed that product temperatures rose 8 to 10°F during the typical summer shopping excursion, and 15 to 20°F for the worst 5% of shopping conditions. Percentages of household refrigerators above 41°F (the maximum recommended by FDA’s Food Code), 45°F and 50°F were 27, 8 and 2, respectively; comparable percentages, in retail cases, were 27, 9 and 1 for fresh meat, 71, 42 and 14 for deli meats and 60, 34 and 11 for pre-packaged lunch meat. To help keep food cold, American Meat Institute Foundation (2000b) recommended that consumers: (1) Ask grocery store staff to pack cold foods together in paper, not plastic, bags. (2) Take foods home from the grocery store promptly. (3) Place perishable foods in the car near the air conditioning vents or use a cooler or ice packs between store and home. (4) Keep home refrigerators and freezers at or below 41°F and 0°F, respectively.

### **Microbiological Quality Of Retail Pork**

Duffy *et al.* (1999) characterized the microbiological quality of Whole-Muscle/Store-Packaged Pork, Whole-Muscle/Enhanced Pork, Store-Ground Pork and Pre-Packaged Ground Pork, obtained in U.S. retail stores, reporting incidences of 8.3%, 10.4%, 7.3% and 12.5%, respectively, positive for *Salmonella* spp., 1.0%, 1.0%, 0.0% and 3.1%, respectively, positive for *Campylobacter jejuni/coli*, 14.6%, 14.6%, 22.9% and 27.1%, respectively, positive for *Listeria monocytogenes*, 19.8%, 5.2%, 11.5% and 1.0%, respectively, positive for *Yersinia enterocolitica* and 28.1%, 25.0%, 61.5% and 53.1%, respectively, positive for *Listeria* spp. Percentages of ground pork samples originating from

each of three plant-types—Hot-Boning Sow/Boar, Slaughter/Fabrication and Further-Processing—that were positive for *Salmonella* spp. were 10.0, 7.5 and 0.0, respectively, for *Campylobacter jejuni/coli* were 12.5, 0.0 and 7.5, respectively, for *Listeria monocytogenes* were 12.5, 32.5 and 35.0, respectively, and for *Yersinia enterocolitica* were 0.0, 7.5 and 2.5, respectively (Duffy *et al.*, 1999).

### **A Recent *Listeria monocytogenes* Outbreak In The USA**

In August 1998, CDC observed deaths and illnesses related to a rare strain of *Listeria monocytogenes*; the contaminated product (hot dog and deli meat products) was traced to a specific processing plant (Meat Marketing & Technology, 1999b). By March 1, 1999, 20 deaths—14 adults and six miscarriages/stillbirths—and at least 97 illnesses had been traced to the products (Meat Marketing & Technology, 1999b). Although turkey meat in contaminated hot dogs and deli products was originally believed to be the source of the *Listeria monocytogenes* (serotype 4b), FSIS-USDA since identified construction dust entering the plant through an air conditioning system as the source of the foodborne pathogen that was introduced after the products had been pasteurized (Meat Marketing & Technology, 1999c).

Recalls of processed meat products are soaring (Associated Press, 2000) because of: (a) stepped-up government testing for *Listeria monocytogenes*, and (b) refusal of processors to delay shipments of products until the results of the tests are known; 23 recalls were issued between October 1, 1999 and May 15, 2000, for hot dogs, deli meats and products that may be contaminated with *Listeria monocytogenes*. The National Advisory committee on Meat and Poultry Inspection recommended that FSIS officials include *Listeria* for finished product testing as part of the HACCP verification program and that FSIS explore use of existing and new, developmental methods of post-packaging pasteurization for ready-to-eat products (SMA, 2000b). President Bill Clinton announced on May 6, 2000 that the USA government will propose (by August 2000) requiring that companies that produce hot dogs, deli meats and cold cuts test for *Listeria monocytogenes* and related bacteria on equipment, floors and other areas of their plants; such tests will be designed to warn of sanitation problems that could lead to meat contamination and are intended to reduce illnesses caused by *Listeria monocytogenes* by one-half over five years (Brasher, 2000b).

### **Microbiological Interventions Through Consumer Education**

Researchers at FDA and CDC have found that consumers could benefit from food safety education (NMA, 1999b). Based on a survey of almost 20,000 adults, it was found that 25% of men and 14% of women do not routinely wash their hands with soap after handling raw meat or poultry; half of the respondents reported eating undercooked eggs during the previous year. And, overall, when it comes to handling and eating food safely: (a) men take more risks than women, (b) younger people take more risks than older ones; (c) whites take more risks than blacks, and; (d) those with higher incomes are not as careful as those with lower incomes.

The most probable cause (Sofos and Smith, 1993) of the 1993 outbreak of hemorrhagic colitis caused by *E. coli* O157:H7 was undercooking of ground beef. In 1995, an FSIS spokesperson said, "Perhaps we've done too good a job of convincing U.S. consumers that we have the safest food supply in the world, because now they abuse it with temperature" (Smith, 1995). To minimize occurrence of foodborne pathogen illness (Smith, 1995) government, industry and university personnel must

emphasize consumer education. Osterholm (1997) said that well-publicized outbreaks represent only a very small part of the problem nationwide, *E. coli* O157:H7 infections have been traced to: (a) Undercooked hamburger, (b) Consumption of unpasteurized milk, (c) Contact with farm animals, (d) Transmission in day-care settings, and (e) Fruits and vegetables. “The Hudson Foods recall unfortunately reinforces the impression that government can fully protect us against contamination of our food supply and that when problems do occur, they’ll be quickly fixed, while the truth is quite the opposite!” (Osterholm, 1997).

At food-service sites and in the home, the biggest problems of food mishandling are: (a) Cross-contamination, (b) Temperature abuse, and (c) Undercooking (CDC, 1994). CDC (1996): (a) Identified “where the mishandled food that caused a foodborne illness was eaten” as restaurant/deli (33%), home/residence (20%), camp/picnic/church (6%), unknown (5%), school (4%) and all other (32%), (b) Determined that the largest number of foodborne illness outbreaks are linked to improper handling of foods at the point of preparation, and (c) Concluded that 97% of foodborne illnesses could be prevented with basic hygiene and improved food handling practices. Three simple means for minimizing foodborne illness include: (a) Thoroughly cook foods to destroy foodborne pathogens, (b) Keep raw and cooked foods separate and (c) Refrigerate cooked foods promptly in shallow containers (Sofos *et al.*, 1993). For fresh beef sold at supermarkets, consumers must be educated to: (a) Cook ground beef to 71°C (measured with a thermometer or t-stick) and (b) Refrigerate or freeze beef as soon after purchase as possible. While ground beef should be cooked to an internal temperature of 71°C, steaks and roasts can be safely served if cooked “medium rare” (63°C internal) because surface bacteria will be destroyed (Food and Nutrition News, 1997).

Ten common food safety mistakes identified by Food and Nutrition News (1997) are: (1) Countertop thawing, (2) Leftovers left on the counter, (3) Unclean cutting board, (4) Room-temperature marinating, (5) Store-to-refrigerator lag time, (6) Same platter for raw and cooked meat, (7) Restaurant “doggie-bag” delay, (8) Stirring-and-tasting spoon, (9) Shared knife for raw meat and vegetables, and (10) Hide-and-eat Easter eggs. Morganthau (1997) presented the following guidelines for “Making The Kitchen Safe”: (a) Wash your hands (20 seconds); (b) Wash the dishes (within 2 hours); then air-dry; (c) Clean dish-rags and sponges (use bleach); (d) Clean the counter (bleach, not detergent); (e) Clean the cutting board (after each use); (f) Pop it in the fridge (within 2 hours after cooking); (g) Keep the fridge cold (40°F or colder); (h) Defrost in the fridge, microwave or cold water (30 minute changes of the water); (i) Don’t eat the batter or raw eggs; and (j) Cook the red out (71°C in the center) (Morganthau, 1997).

Partnership For Food Safety Education (a coalition of industry, government and consumer groups) developed a “Fight Bac™” campaign (FMI, 1998) with four key principles: (a) Wash Hands And Surfaces Often, (b) Prevent Cross-contamination, (c) Cook Foods To Proper Temperatures, and (d) Refrigerate Promptly. “Fight Bac™” addresses critical points in everyday food handling where improper practices can lead to foodborne illness and educates the public because consumers are the last line of defense in the food safety chain (FMI, 1998). USDA has launched a new food safety education campaign to promote the use of food thermometers in cooking meat, egg and poultry dishes; the

campaign theme “It’s safe to bite when the temperature is right!” is spouted by a cartoon food thermometer named “Thermy™” (SMA, 2000c).

Consumers were willing to pay a modest price increase for measures associated with beef safety—including irradiation, steam pasteurization and hot-water rinsing—in a Kansas State University (1999) study. Survey participants would pay 34 cents per pound premium for steam-pasteurized beef if it was 99% free of *E. coli* and 29 cents per pound premium for hot-water rinsed beef if it was 90% free of *E. coli*. If the price for beef treated with interventions was equal, the majority of respondents chose the irradiation option (Kansas State University, 1999).

In response to the question “What are the most important things you do in your kitchen to be sure food you prepare is safe from germs?”, supermarket shoppers said: (1) Wash Hands/Surfaces, 60%; (2) Wash Vegetables/Clean Food, 36%; (3) Cook Properly, 17%; (4) Refrigerate Promptly, 13%; (5) Use Antibacterial Soap, 9%; (6) Keep Counters/Utensils/Dishes Clean, 7%, (7) Keep Foods Separate, 6%; (8) Use Fresh/Non-Expired Food, 6% and (9) Other, 7% (Food Marketing Institute, 2000); (7) Use Fresh/Non-Expired Food, 6%; and (8) Other, 9%. Reasons consumers gave (Food Marketing Institute, 1998) for safe food-handling measures were; (a) Keep Germs/Bacteria From Spreading, 57%; (b) Stay Safe, 37%; (c) To Kill Bacteria, 19%; and (d) Keep Juices Separate, 3%. In answer to the question “How common do you think it is for people in the United States to become sick because of the way food is handled or prepared in their homes?”, the shopping public replied: (a) Very Common, 17%; (b) Fairly Common, 15%; (c) Somewhat Common, 43%; (d) Not Very Common, 18%; and (e) Not At All Common, 3% (Food Marketing Institute, 2000).

### **Will Irradiation Be Used To Destroy Foodborne Pathogens In USA Ground Beef?**

Use of irradiation (more appropriately termed “electronic pasteurization”) on fresh pork, poultry and beef for sale to consumers has been approved by both the FDA and USDA (most recently, for beef, on February 13, 1999 by USDA) but there are concerns (Smith and Morgan, 1997) with use of irradiation that may delay its adoption by the beef industry. These concerns include: (1) Expense—Application of this technology is costly because of the expense to construct or access irradiation facilities and the comparatively high costs for special packaging materials. (2) Consumer Acceptance—Many end-users, especially those in foreign markets, are reluctant to purchase and consume or sell to consumers, meat or poultry that has been exposed to radiation; intentional exposure of a food to radiation seems incongruous to many food purchasers. (3) Incidence Of Odd Odor/Flavor—To some people, and in certain instances, irradiation generates “odd,” “off” or “undesirable” tastes and smells in end-products.

Colorado Boxed Beef, IBP, Inc. and Excel, Inc. (Meat Processing, 1999b; Associated Press, 1999) were the first meat companies in the USA to commercially use irradiation technology. In March 1999, McDonald’s Corporation announced that it has suspended testing of ground beef treated with irradiation because “the irradiated meat did not measure up to the chain’s organoleptic standards” (Meat Marketing and Technology, 1999a). The first irradiated hamburgers, sold in the USA (Minneapolis/St. Paul; May 2000) sold so fast that distributors immediately expanded sales into four other states (Manning, 2000). The burgers were irradiated using electronic pasteurization after the beef was processed, formed as patties, wrapped, frozen and packaged; electronic beam

pasteurization (Surebeam; Titan Corporation) is more acceptable to consumers than processes that expose food to radioactive material such as cobalt<sup>60</sup> (Manning, 2000).

Of supermarket shoppers asked the question “How Likely Would You Be To Buy Food Products Like Strawberries, Poultry, Pork Or Beef If They Had Been Irradiated to Kill Germs And Keep It Safe?”, 38% said they were “Very Likely” or “Somewhat Likely”—down substantially from the 69% in 1996 and from the 56% in 1999 who said that, while 36% replied “Not Very Likely” and 20% said “Not At All Likely.” Interestingly, more women than men, those with a high school education or less and single persons (rather than those with families) are more likely to say they would purchase irradiated products (FMI, 2000). Frenzen *et al.* (2000) reported results of a survey by the Foodborne Diseases Active Surveillance Network (FoodNet) indicating that: (a) only half of the adult residents of FoodNet sites were willing to buy irradiated ground beef or chicken, (b) only a fourth of these consumers were willing to pay a premium for irradiated products, and (c) the impact of food irradiation on public health will be limited unless consumer preferences change, perhaps in response to educational messages about the safety and benefits of food irradiation.

### **Pesticides And Other Chemicals In U.S. Food And Red-Meat**

According to Smith (1995), Dr. Dixie Lee Ray (former Governor of the State of Washington) said, in *Priorities* magazine in 1989, "Most of the public believes that cancer is caused by toxic substances created by industry. Why? Because they listen to the wrong spokesmen. National television has raised 'risk-assessment by the media' and 'sob-sister journalism' to a new dramatic high, with emotional, heartrending stories about cases of childhood leukemia and other individual or family tragedies as if they were epidemic. The EPA has admitted, with remarkable candor, 'Our priorities...in regulating carcinogens appear....to be more closely aligned with public opinion than with our estimated risks'--and with scientific evidence" (Smith, 1995). “There are, though, genuine concerns about over-exposure to pesticides. An article in *The Denver Post* (1997b) reported results of a study published in the *American Journal of Industrial Medicine* that showed that females who worked in farm-related professions were from twice to 20 times as likely to experience infertility. And, *Associated Press* (1994) concluded that there was a disturbing link between pesticides and breast cancer because pesticides (especially DDT and other chlorine-containing pesticides) appear to raise levels of a harmful (“bad”) form of estrogen (by three-fold to four-fold amounts). In that same report (*Associated Press*, 1994), researchers found that women who eat cruciferous vegetables—broccoli, cauliflower, brussels sprouts and cabbage—appear to counteract the harmful effects of “bad estrogen generating pesticides” because such vegetables contain an anticancer substance (indole-3-carbinol) that increases the ratio of “good estrogen” to “bad estrogen.”

"Americans for Safe Food," a campaign of the Center for Science in the Public Interest, has issued publications, according to Smith (1995), identifying naturally occurring carcinogens in virtually every food that we eat (e.g., trifluralin, parathion and linuron -- in carrots). American Council for Science and Health counters by saying, "Yes, there are natural carcinogens in foods, but the dose makes the poison. A toxic dose of caffeine requires 96 cups of coffee, and 3.8 tons of turkey would be needed to deliver a toxic dose of malonaldehyde" (Smith, 1995).

Dr. Bruce Ames and Dr. Lois Swirsky-Gold (Ames and Swirsky-Gold, 1990) say that, of the pesticides in the human diet, 99.99% (by weight) are natural pesticides (chemicals that plants produce to defend themselves) and 0.01% are synthetic pesticides (added by man to plants or animals). Average intake by humans of 27 of these natural pesticides that are rodent carcinogens is about 1500 milligrams per day; average human intake per day of residues of 100 synthetic pesticides is 0.09 milligrams per person per day. But, they conclude, neither exposure is a major human carcinogenicity risk (Brody, 1994).

Abelson (1990) said "The principal method of determining potential carcinogenicity of substances is based on studies of daily administration of huge doses of chemicals to inbred rodents for a lifetime. Then by questionable models, which include large safety factors, the results are extrapolated to effects of minuscule doses in humans. Resultant stringent regulations and attendant frightening publicity have led to public anxiety and chemophobia. If current ill-based regulatory levels continue to be imposed, the cost of cleaning up phantom hazards will be in the hundreds of billions of dollars with minimal benefit to human health. The standard carcinogen tests that use rodents are an obsolescent relic of the ignorance of past decades." "As a defense against predators and parasites, plants have evolved a large number of chemicals that have pathological effects on their attackers...plant foods contain 5,000 to 10,000 natural pesticides; compared to the amount of synthetic pesticides we consume, we eat about 10,000 times more of the plant pesticides" (Abelson, 1990).

Feeding toxic chemicals to rats and mice may not be an accurate way to determine the substance's potential to cause cancer in humans because: (a) High doses, in and of themselves, cause most of the cancers, and (b) There is no evidence that chemicals that are carcinogenic to rodents in high doses, cause cancer in humans in low doses (Ames *et al.*, 1990).

Scheuplein (1990) estimated that the risk of fatal cancer from food-borne carcinogens to an individual U.S. citizen is 1 in 13 or 7.7000%. Scheuplein (1990) then subdivided and apportioned the 7.7000% risk as follows: 7.6100% of it is from the natural toxins that occur in traditional foods, 0.0757% from the carcinogens in spices and flavorings, 0.0122% from indirect sources such as industrial chemicals, 0.0007% from synthetic pesticides and environmental contaminants in our food supply, 0.0007% from antibiotics, hormones and drugs in our food supply, 0.0007% from mutagens formed in food by charring during cooking, and less than 0.0001% from mycotoxins.

National Academy of Sciences (1987) in "Regulating Pesticides in Foods: The Delaney Paradox," determined the risk for a U.S. citizen of contracting any type (not just fatal, but in any form) of cancer to be 1 in 4 (on an individual U.S. citizen basis, 25.0000%). National Academy of Sciences (1987) then computed the upper-bound estimate (using worst-case scenarios regarding presence of residues of pesticides in foods consumed at maximum tolerance levels for periods of 74 consecutive years; etc.) of dietary oncogenic risk from consuming foods containing the 28 oncogenic pesticides and said the increased risk of cancer to the individual citizen is 0.5840 (thus the risk of contracting cancer increases from 25.0000 to 25.5840) if all of the assumptions that they used are correct. National Academy of Sciences (1987) made similar estimates of increased risk of contracting any type of cancer from consuming beef containing residues of the 28 oncogenic pesticides (the risk changes from 25.0000 to 25.0649 for beef, if the assumptions are correct).

Results of residue monitoring by Food and Drug Administration (1994) revealed the following: (a) In the ALL FOODS STUDY for FY 1993, enforcing EPA tolerances, 12,751 samples from all 50 of the States and from 107 countries were tested; there were no detectable residues in 64% of the foods, and, less than 1% of foods had residues over allowable tolerances. Food and Drug Administration (FDA) concluded that "Our findings from the ALL FOODS STUDY in 1993 showed that only a small percentage (less than 1%) of the food samples we analyzed contained pesticide residues that exceeded the tolerances set by the Environmental Protection Agency (EPA). When pesticide residues were found, they were--in almost all instances--only a fraction of EPA tolerances (Food and Drug Administration, 1994). (b) In the TOTAL DIET STUDY, testing 1,566 food items during the periods of FY 1991, FY 1992 and FY 1993 for 300 pesticides, the conclusion was that "Residue levels were very low; the data for 1991 through 1993 continue to indicate that consumer exposure to pesticide residues from food is very low." FDA further concluded that "Over the years, the TOTAL DIET STUDY which assays food items representing the diets of U.S. consumers and which measures our daily intake of pesticide residues from foods prepared table-ready, demonstrates that intakes of pesticides are manyfold lower than the intakes of pesticides established as 'acceptable' by the World Health Organization" (Food and Drug Administration, 1994).

Smith (1995) reported that Dr. Catherine Adams, then of FSIS/USDA, described the National Residue Monitoring Program and said "Each year, more than 300,000 tests were made, involving 400 chemicals; less than 1% exceeded FDA tolerances, and FDA tolerances have a 100-fold margin of safety." Dr. Sanford Miller of the University of Texas Health Sciences Center in San Antonio has, according to Smith (1995), said, "There simply is no public health problem with pesticide residues. The real risks in the food supply are microbiological hazards; actuarial risk for illness from microbes, is 1 in 100, while risk of illness from pesticides is 1 in 1,000,000." Dr. Frank Young, then Commissioner of the FDA, said in a 1989 interview, "Pesticides are perceived by many people as the most dangerous health issue but contamination with microbes is much more important than are chemical/toxic residues" (Smith, 1995).

Smith *et al.* (1992; 1994a; 1997) and Heaton *et al.* (1993a) assayed adipose tissue from "conventional" steers/heifers, "natural" steers/heifers, "organic" steers/heifers, chronically ill ("realizer") steers/heifers and "cull beef/dairy cows" for residues of 15 chlorinated-hydrocarbon and 10 organophosphate pesticides and reported that--in 500 tests-- they did not detect a single violative residue of pesticides in muscle, fat, liver or kidney tissues from these animals.

Smith *et al.* (1993), Heaton *et al.* (1993b, 1996) completed a study on residues of 15 chlorinated-hydrocarbon pesticides and 10 organophosphate pesticides in pork carcass tissues obtained at packing plants in four States (Kentucky, Iowa, Missouri and Minnesota) and in pork products (cured ham and fresh pork sausage) obtained at grocery stores (in response to criticism by Steinman, 1990) in three sections of the U.S. (Eastern, Central, Western). In 1,905 assays for chlorinated hydrocarbons, 1,886 tests detected no residues, 19 tests found detectable--but not violative--amounts of residues and no tests found violative amounts of chlorinated-hydrocarbon residues; in 1,270 assays for

organophosphates, 1,269 tests detected no residues while 1 test found detectable--but not violative--amounts of organophosphate residues (Heaton *et al.*, 1996).

In results of the National Residue Monitoring Program for 1994 (USDA, 1996), there were no violative residues of 22 chlorinated hydrocarbon or chlorinated organophosphates in samples of beef from steers, heifers, beef cows, dairy cows or bulls.

Schnell *et al.* (1995a; 1997) studied pesticide residues in beef tissues from cattle fed fruits, vegetables and their byproducts. Muscle, adipose, liver and kidney tissue samples were collected from cattle fed potato processing residue, apple pomace, pear pomace, cannery corn waste, cotton gin trash, tomato pomace plus almond hulls, dried grape solids or dried citrus pulp as well as from control cattle which were not fed fruits, vegetables or their byproducts. All adipose tissue samples (n=143), representative samples of the above feeds (n=24) and representative samples of muscle (n=35), liver (n=35) and kidney (n=35) tissues were assayed for acephate, benomyl, captafol, cypermethrin, folpet, azinphos-methyl, captan, chlorothalonil, ethyl parathion, and permethrin. In 2,720 tests for the aforementioned oncogenic pesticides, eight tests were positive, but no residue amount that would be considered violative was detected. The only pesticide detected was benomyl and it was detected at nonviolative levels in the adipose tissue of cattle that had been fed either apple pomace or pear pomace.

Biondo (1997) reported that from now to the year 2006, the Environmental Protection Agency will restudy 300 pesticides, looking for residues that cause cancer, nerve damage, hormone disruption and birth defects in humans of all ages but paying strict attention to setting new standards for children's safety.

Hebert (1999) reported that a National Academy of Sciences research panel concluded that low-level exposure to chemicals that disrupt hormones won't necessarily lead to additional cancers or infertility. Environmentalists and numerous health experts have argued that there is growing evidence that synthetic chemicals affect estrogen levels and even at low doses may lead to cancers, neurological problems and infertility; these chemicals called "endocrine disrupters" are the subject of a massive screening process directed by the Environmental Protection Agency with as many as 15,000 chemicals to be tested (Hebert, 1990). The National Academy of Sciences panel report said "The current literature does not support an association between exposure to low levels of these chemicals and breast cancer or a variety of other hormonally sensitive cancers," and "The data on the effects of these chemicals on human nervous system development at levels in the environment is insufficient to make a conclusion" (Hebert, 1999).

### **Antibiotics And The Red-Meat Supply**

For many years, antibiotics (tetracyclines--like Oxytetracycline and Chlortetracycline) were fed to cattle in feedlots at "sub-therapeutic" ("therapeutic" is the amount needed to treat an animal that is sick or diseased; "subtherapeutic" is much less than that) doses. Chlortetracycline fed in the ration of a steer or heifer at a level of 70 milligrams per day: (a) promotes growth, (b) improves feed efficiency, and (c) aids in prevention of liver abscesses, foot rot and bacterial diarrhea (Smith, 1995). If, because of such feeding, there were residues of Chlortetracycline in the beef from those animals, and if humans who are

sensitized to Chlortetracycline ate that beef, presence of that antibiotic in their food would endanger their health. Smith (1995) reported that the Harvard Medical School Newsletter in an article "Antibiotics and Livestock: Feeding a Controversy" discussed the fear of some scientists that long-term exposure of human pathogens to antibiotics (such as would occur with subtherapeutic feeding of antibiotics to cattle) could create strains of bacteria-- potentially pathogenic to humans -- that would be resistant to that antibiotic. Such occurrence would endanger the public health because rampant growth of such antibiotic-resistant pathogens in humans could not be stopped by usual means--treatment with the antibiotic (Smith, 1995).

Because of public concern over this issue, then-President of the National Cattlemen's Association--Jo Ann Smith--urged U.S. cattle feeders to stop feeding subtherapeutic-levels of antibiotics (Smith, 1995). And, they did (97 to 99% of them by industry estimates). Four studies--commissioned by the Animal Health Institute--two by Dr. Edward Kass (of Harvard Medical School), one by Dr. Harvey Elder (of Loma Linda University) and one by Dr. Thomas O'Brien (of Harvard University)--reaffirmed the safety of routinely adding antibiotics to animal feeds and strengthened the conclusion that the practice of feeding low level antibiotics to livestock doesn't endanger human lives (Beef, 1987). National Academy of Sciences (1989) issued a report on subtherapeutic use of antibiotics in animal feed stating that "there is no direct evidence (this practice) creates an excess risk of disease or death in humans" and "The study (made at the request of FDA) was unable to find data directly implicating the subtherapeutic use of feed antimicrobials (antibiotics) in human illness." Nevertheless, according to Smith (1995), the nation's cattle feeders have not resumed the practice of automatically feeding low levels of antibiotics in cattle rations.

Studies by Fagerberg and Quarles (1986) and Center For Veterinary Medicine (1993) as well as status-reports like those of Price (1995) confirm the safety of use of antibiotics in livestock feeding with regard to potential dangers to consumers. Price (1995) states that "National Academy of Sciences (NAS) concluded in 1989, that no definitive reason to ban the use could be shown. Indeed, the NAS study found that the people most at risk are not the public, but rather you and I--those who actually handle livestock. The NAS study (and virtually every other study) found that the public is infinitely more likely to encounter resistant bacteria by visiting a hospital or otherwise come into contact with resistant bacteria created through human use of antibiotics. Analysis of sewage from hospitals has universally shown enormous levels of resistant bacteria that are so frightening as to discredit worry over animal use of antibiotics as frivolous in comparison" (Price, 1995).

Smith *et al.* (1994c; 1997) assayed muscle, adipose tissue, kidney and liver from "conventional" steers/heifers, "natural" steers/ heifers and "organic" steers/heifers for residues of ten kinds of antimicrobials/antibiotics (3 beta-lactams, 4 sulfonamides and 3 tetracyclines) and reported that--in 1,890 tests--they did not detect a single violative residue.

In results of the National Residue Monitoring Program for 1994 (USDA, 1996) there were no violative residues of antibiotics in samples from steers, heifers, dairy cows or bulls and very low levels of violative residues of antibiotics in samples from beef cows (0.20%). Violative residues of sulfonamides in results from the 1994 National Residue Monitoring Program revealed 0.0% in steers, 0.0% in

heifers, 0.2% in beef cows, 0.5% in dairy cows and 0.0% in bulls (USDA, 1996); all of these levels are considered very low by world health authorities.

Food and Nutrition News (1997) reports that: (a) In caring for their cattle, cattlemen use government-approved antibiotics to prevent and treat diseases—just as antibiotics are used therapeutically in humans. (b) There is no evidence that antibiotic-treated beef causes human illness due to the transfer of antibiotic-resistant bacteria. In fact, many of the antibiotics used with cattle are not used in human medicine. (c) The cattle industry's Beef Quality Assurance program works with veterinarians and feedlot managers to ensure that proper withdrawal times are followed when antibiotics are administered. (d) Monitoring by USDA shows that there are no violative residues of antibiotics in beef from treated cattle.

USA TODAY (1999) reported that mankind has dangerously miscalculated the threat posed by bacteria and viruses to millions of lives, national security and world economic development. In the decades since the advent of antibiotics led to premature claims of victory, infectious diseases (according to the World Health Organization) are still killing 13 million people a year, half in prosperous countries (in 1998, 180,000 people died of infections in the USA). Just six ailments—AIDS, tuberculosis, malaria, measles, diarrheal disease and pneumonia—killed 90% of those who died before their 44<sup>th</sup> birthday. Resistance to antibiotics is adding to that toll; most germs learn to thrive in the presence of mankind's deadliest antibiotics. That trend will continue until better antibiotics are made and existing antibiotics are used more wisely (USA TODAY, 1999).

### **Anabolic Steroids/Hormones And The Red-Meat Supply**

There are people who are greatly concerned about use of growth promotants in the feeding of cattle. Beef animals of different genotypes differ quite markedly in size/height/weight at a given point in chronological age. Differences in genetic size are caused by differences in the amount (and/or timing) of release of Growth Releasing Factor (GRF) from the hypothalamus. GRF causes the pituitary gland to release differing amounts of Growth Hormone (depending upon the amount of GRF signal received by the pituitary). Increases in Growth Hormone (GH) cause (a) stature to increase, (b) muscle growth to be enhanced, and (c) fat deposition to be lessened (delayed, chronologically).

Research, conducted beginning nearly 40 years ago, revealed that minute doses of natural hormones (like estrogen, progesterone and testosterone) and of artificially synthesized growth promotants--called xenobiotics (like zeranol, trenbolone acetate and melengestrol acetate) caused growth and composition changes in cattle that were remarkably similar to those attributed to Growth Hormone (Smith, 1995). In the 1980s, Dr. Bill Tanner and Dr. Tom Welsh of Texas A&M University discovered that administration of estrogen "tricked" (in much the same way that a vaccine tricks the animal into developing immunity to a disease) the animal's pituitary-- making it believe it was receiving more GRF signal--into releasing more Growth Hormone (Smith, 1995). Other growth promotants act in another way that is not related to Growth Hormone; trenbolone acetate, for example, is believed to act by decreasing protein turnover so that more muscle accretion per unit of time takes place (Smith, 1995).

"Implanting"--introduction into the animal's ear of a tiny rubber silastic cylinder that contains about 36 milligrams of estrogen, for example--causes the animal (during the 90 or so days it takes for the estrogen to be absorbed and to enter the animal's bloodstream) to repartition its use of what it eats. It has now been amply demonstrated that implanted animals produce more muscle and less fat (all other things being equal) than do non-implanted animals.

Concern is registered by a few people who have observed that there is 58% more estrogen in a serving of beef steak, for example, from an animal implanted with estrogen than in a steak of equal size from an animal that was not implanted (3-ounce portions contain 1.9 nanograms of estrogen if from an implanted animal and 1.2 nanograms of estrogen if from a non-implanted animal). Such concerns disappear when it is realized that the normal daily *in vivo* (within the person's body) production of estrogen by an average male is 136,000 nanograms and by a normal non-pregnant female is 480,000 nanograms. Experts conclude that there would be no physiological effect on humans caused by the difference (1.9 billionths of a gram) between 480,001.9 and 480,001.2 or 480,000.0 nanograms in daily estrogen supply (Smith, 1995).

Balter (1999) reported that some researchers argue that the levels of hormone residues in beef are so low compared to normal concentrations in the human body that they pose no danger to most sectors of the population. "At certain times of the month, women are just bathed in estradiol," says John Herrman, a WHO toxicologist and JECFA member. And, according to Balter (1999), Gary Smith, a meat biochemist at Colorado State University in Fort Collins, says that many other foods have higher levels of various estrogenic substances than beef. "The estrogen activity in peas, butter, ice cream, wheat germ, and soybean oil can be thousands of times that of beef from cattle implanted with estrogen," he says (Balter, 1999).

Present consumer fear of use of growth promotants in beef production arose when the European Economic Community (EEC) banned importation of beef from the U.S. on grounds of our use of anabolic steroid hormones. In truth, the EEC -- drowning at the time in excess beef -- used the hormone issue to create a non-tariff trade barrier to preclude importation of our beef into those 12 countries. According to Smith (1995), since imposition of the "EEC Hormone Ban," (a) a committee of scientists appointed by the EEC (and chaired by Dr. Eric Lamming of the United Kingdom), (b) Codex Alimentarius, and (c) the Food and Agriculture Organization of the World Health Organization, have all gone on record as stating "there is no risk to the public health or well-being as a result of properly administered growth-promoting, anabolic steroid hormones to beef cattle."

Smith (1992), in a position paper prepared for the U.S. Meat Export Federation, stated "If the EC agrees to accept the Joint FAO/WHO Expert Committee Report of 1988 and the EC Scientific Advisory Committee Report by Lamming in 1987 confirming no risk to human health from proper use of anabolic and xenobiotic agents and if the EC will change the wording in EC Council Directives from "residues" to "violative residues" (as delineated by FDA, FSIS or the JECFA of FAO/WHO)....then, the U.S.A. will request of FSIS/USDA that it test beef for presence of residues of diethylstilbestrol, estradiol-17B, estradiol benzoate, testosterone propionate, progesterone, zeranol, melengestrol acetate and trenbolone acetate, on a continual, annual basis." According to Smith (1995), Dr. H. Russell

Cross, then Administrator of FSIS/USDA, agreed to implement the latter process--as a part of the National Residue Program; EC officials agreed on July 7, 1992 to consider the proposal presented in the position paper, and there is still hope (in 1995) that the EC will rescind its ban on importation of beef and beef products from cattle that were administered natural or artificial growth-promotants.

U.S. beef producers are trying very hard to produce leaner beef. As they proceed from flagrantly fat, to sensibly slim, beef, attempting to reduce the amounts of external and seam fat, on and in beef cuts, use of growth promotants that repartition consumed nutrients--toward muscle and away from fat--is a vital tool for accomplishing desired modifications in body composition. To lose the use of these immensely valuable chemical compounds, especially if on trumped-up charges and greatly exaggerated consequences, would be a setback to recent success in "the leaning of the U.S. beef supply."

According to Food and Nutrition News (1997): (a) Hormones are naturally occurring compounds in humans, as well as in animals and in plants. (b) The human body naturally produces hormones in quantities substantially greater than would ever be consumed by eating beef or any other foods. (c) Compared to many other foods, beef is very low in hormone content, regardless of whether hormones are used as growth promotants. (d) Growth-promoting hormones are implanted in an estimated 63% of cattle in the U.S. These hormones have been used safely and successfully for more than 30 years, to increase growth of muscle tissue and decrease deposition of fat. (e) When cattle are implanted with growth promotants, they have more lean meat and less fat; in addition, with growth promotant use, the amount of feed necessary to produce each pound of edible lean meat is reduced. (f) Use of growth implants is estimated to reduce the total cost of beef production by \$50 to \$80 per animal or by \$.20 to \$.30 per pound of retail beef. (g) Without growth-promoting hormones, the supply of beef would be smaller and the average retail price of beef would increase by 10 to 15%.

Although the scientific community may be divided over the safety of hormone implants, the EU has yet another piece of ammunition in its battle to maintain the ban (Balter, 1999). According to an as yet unpublished draft report, a spot check last year of 258 meat samples from the Hormone Free Cattle program, which is run jointly by the beef industry and the USDA, indicated that 12% of the samples had detectable levels of hormones—even though they had been certified to be from cattle raised without hormones and thus eligible for import into the EU. European officials cite this as evidence that use of the substances is poorly regulated and that consumers might be exposed to higher than allowed concentrations if the ban were lifted. These revelations are embarrassing for U.S. officials. "If there are deficiencies in our system, we want to work with the EU to correct them," says Tim Galvin, administrator of the USDA's Foreign Agricultural Service (Balter, 1999). Unfortunately, though, in July 1999, officials in Switzerland found residues of trenbolone acetate, melengestrol acetate and diethylstilbestrol in U.S. beef, causing FSIS-USDA to suspend the Hormone Free Cattle Program. Obviously, something is amiss with this program and it must be corrected.

### **Chemical Residues In "Conventional," "Natural" And "Organic" Beef**

There are some marketers who have tried to position "natural" or "organic" beef as superior to "conventional" beef in terms of safety (National Live Stock and Meat Board, 1995). There is some confusion in the marketplace as to what the terms "natural" and "organic" mean when applied to red

meat. Both terms imply a difference from "conventional" beef. "Natural" beef (according to FSIS/USDA) has been minimally processed and contains no artificial flavoring, coloring, chemical preservatives or other synthetic ingredients--a definition that allows all conventionally prepared fresh beef to be labeled "natural" (USDA, 1982). After the future implementation of a USDA National Organic Program (which is supposed to occur in 1995) the "organic" meat label will have official meaning (as opposed to the present definitions applied by those who market beef as "organic") and--according to knowledgeable sources--will indicate those products that are derived from animals raised on certified organic farms and processed by certified handlers in ways that minimally impact the environment (Kinsman, 1994). In efforts, though, to position "natural" beef uniquely in the marketplace, some marketers have argued that the term connotes beef from cattle raised in specific geographic locations on uncontaminated land, never treated for disease or illness, containing no additives, with a unique taste, and produced differently during finishing; all of this is from an advertising campaign sponsored by a natural beef marketer in the Boston Globe (1991). The primary problem with such advertisements is that they have the potential to raise consumer questions regarding the safety and wholesomeness of the generic beef supply (Wilkinson, 1991).

FSIS/USDA (USDA, 1993, 1994) does not report separately the residue monitoring results for samples from cattle raised under different management systems (i.e., "conventional," "natural," "organic"). The Cattlemen's Beef Promotion and Research Board provided funds for determining the incidence of chemical residues in beef tissues to the National Live Stock & Meat Board, who awarded funding to conduct two such studies to the Center For Red Meat Safety at Colorado State University. Results of the two studies conducted by the Center For Red Meat Safety (Smith *et al.* 1992; 1994c) confirm that beef is safe relative to the exceptionally low incidence of violative chemical residues. One of those studies (Smith *et al.*, 1994a) involving 80 samples of muscle, fat, liver and kidney from "conventional," "natural," "organic" and "realizer" (chronically ill) steers and heifers as well as "cull (beef/dairy) cows," detected no violative residues of five anabolic steroids, two heavy metals, three stress reducers, six thyrostats/sulfa-drugs and 25 chlorinated hydrocarbon and organophosphate pesticides. A second study (Smith *et al.*, 1997) of muscle, fat, liver and kidney samples from "conventional," "natural" and "organic" steers and heifers detected zero violative residues in 558 tests for three anabolic steroids, zero violative residues in 558 tests for three xenobiotics, zero violative residues in 1,860 tests of 10 sulfa-drugs/antibiotics and 15 violative residues (three in "conventional" beef; six in "natural" beef; six in "organic" beef; all in liver samples and none in muscle, fat or kidney samples) in 4,650 tests for 25 chlorinated hydrocarbon and organophosphate pesticides.

Data from the two studies conducted by the Center For Red Meat Safety reveal exceptionally low incidence of violative chemical residues in U.S. beef produced under "conventional" production/management conditions (Smith *et al.*, 1992; 1994a; 1994c; 1997). There were no violative residues of anabolic steroids (estrus suppressants; growth promotants), xenobiotics (growth promotants), heavy metals (environmental contaminants), stress reducers (tranquilizers), thyrostats/sulfa-drugs (growth promotants; health aids), beta-lactams (health aids), or tetracyclines (health aids). In one of the CSU studies in which violative residues occurred, the residues were of pesticides, and the highest incidence was in livers from beef cattle produced under "natural" (six of 1,575 tests; 0.38%) and "organic" (six of 1,575 tests; 0.38%) management conditions. The only

violative residues of any chemical found in these two studies were in livers and not in meat, *per se* (Smith *et al.*, 1997).

Results of the two studies conducted by the Center For Red Meat Safety reveal that it is highly unlikely that there is any difference in presence of harmful chemical residues of vaccines, pesticides, drugs, antibiotics and/or growth promotants in "conventional," "natural" and "organic" beef (National Live Stock and Meat Board, 1995). Beef companies that attempt to position a "natural" or "organic" product as safer or less dangerous to personal or public health by claiming that "conventional" beef contains violative chemical residues must be held accountable for conducting research studies of the type conducted by the Center For Red Meat Safety, to document their claims. To the best of our knowledge they have never done so (National Live Stock and Meat Board, 1995).

Smith and Morgan (1999) reported that, because 77%, 55% and 33%, respectively, of supermarket shoppers in the Food Marketing Institute TRENDS—1999 report say they “seek out and purchase” products “low in fat,” “natural” and “organic,” there is need to make such beef available in supermarkets. Maverick Ranch Beef (Denver, Colorado) has successfully merchandised “Natural Lite Beef” to satisfy demand for such product. Some, but not all, beef must meet the needs of consumers who seek beef that is lean to very lean, and low to very low in calories, fat, saturated fat and cholesterol, because of concerns about diet/health/nutrition as well as beef that can be defined as “Natural” or “Organic.” It is easy to accomplish leanness, especially in ground products, but harder to do this in solid-muscle cuts while simultaneously assuring satisfactory palatability. It can best be done for solid-muscle cuts by using raw materials from carcasses that can be source-verified (as originating from genetically superior—in palatability, especially tenderness—lines of cattle that have been produced/managed to minimize production of excess fat). Healthful ground beef can originate from the trimmings from commodity cattle; healthful steaks/roasts should come, exclusively, from source-verified, branded beef programs. And, “Natural” and “Organic” beef—by definition—must come from source-verified, production practice-verified and—perhaps—USDA process-verified programs (Smith and Morgan, 1999).

On April 12, 1999, FSIS-USDA announced the availability of a guidance document providing information on the use of the claim “certified organic by (a certifying entity)” labeling of meat and poultry products (Hostetler, 1999). In order to use the claim “certified organic by (a certified entity)” on the labeling of a meat or poultry product, processors will have to submit the labeling to FSIS for approval; the statement “certified organic by (a certified entity)” must be followed by the name of the certifying entity but the guidance document does not provide a definition of “organic” (Hostetler, 1999).

### **Test Of Chemical Residues In Red Meat In Other Countries**

Usborne (1994) compared "natural" and "conventional" beef, purchased as such in retail supermarkets in Canada, and reported no violative residues of sulfa-drugs, antibiotics, heavy metals, polychlorinated biphenyls, growth promotants, parasiticides, pentachlorophenol (a wood fungicide) or pesticides in either kind of beef. Potthast (1993), of the German Meat Research Institute in Kulmbach, concluded--based upon studies of beef and pork from the European Union--that: (a) environmental residue

contaminants (i.e., lead, mercury, cadmium) were hardly ever found, (b) pesticides had concentrations considerably below established limits such that complaints about pesticide contamination are becoming more and more rare, (c) toxic dioxines, which arise mostly from combustion processes have not--so far--been detected in meat, and (d) random sampling and residue testing for antibiotics, drugs, anabolics and thyrostats effectively protect the consumer and assure that chemical residues in meat will not be harmful to the public health.

### **Could U.S. Beef Be Contaminated With The Prions That Cause Bovine Spongiform Encephalopathy?**

The outbreak of Bovine Spongiform Encephalopathy (BSE or, the so-called “Mad Cow Disease”) has wreaked havoc on the cattle/beef industry in the United Kingdom (Smith and Morgan, 1999). Industry personnel and government officials in the USA have worked diligently to detect BSE if it exists in this country (so far it does not) and to take extraordinary precautions to minimize spread of the prion (a unique kind of protein) if it happens to be here and we just haven’t yet discovered it. The Food and Drug Administration issued a ban in 1997 on feeding mammalian byproducts (like meat scraps, meat and bone meal or tankage) to ruminants. In 1998, it was reported that there has been 100% compliance with the mammalian byproduct rendering ban by the U.S. renderers (Caparella, 1998). Both FSIS and industry personnel have investigated potential that spinal cord is contained in the products generated by use of Advanced or Automated Meat Recovery Systems or Mechanical Deboning Machines—just in case we have the disease and don’t know it, and inasmuch as the tissues/organs most likely to contain the prion include brain and spinal cord—that are used in ground or comminuted meat products. Research has also been conducted to investigate the potential for certain kinds of stunning equipment to cause brain or spinal tissue to enter the circulatory system of improperly stunned animals. Based upon results of the latter studies (Schmidt, 1999) industry has been advised to change or replace certain stunning equipment or devices that present risk of spreading nervous tissue into meat. Industry has responded quickly and completely to such recommendations.

From January 1994 through October 1998, the number of BSE cases in cattle (Office International Des Epizooties, 1999) declined in United Kingdom (24,436 to 1,728) and Switzerland (64 to 14) but increased in Portugal (12 to 104), Ireland (19 to 69), France (4 to 18), Belgium (0 to 6) and Netherlands (0 to 1). Harald Niemann, President of the European Union Renderers Association informed the audience at the National Renderers Association Annual Convention in November 1998 that “The bovine spongiform encephalopathy (BSE) crisis has been settled; the number of infected animals is declining” (Caparella, 1999). Daley (2000) reported that, in France, 6 cases of BSE were discovered in 1997, 18 in 1998 and 30 in 1999; so far (through April 2000) 16 cases have been detected in 2000.

Fox (1999) reported that researchers have documented how the agent (a “prion”) that causes Mad Cow Disease gets from food to the brain (it travels from the digestive tract, into the lymphatic system and from there into the brain) in primates (the family that includes human beings); 39 people are known to have died from a human version of Mad Cow Disease (known as “new variant Creutzfeldt-Jacob Disease,” nvCJD) and cause of nvCJD is blamed on human consumption of beef infected with Mad

Cow Disease. Dairy, Food and Environmental Sanitation (2000) described a study that demonstrated that the particular strain of prion implicated in Mad Cow Disease in cows is the same strain that causes nvCJD in humans, and that inoculation of mice with prions from human cases of nvCJD produced the same incubation period and pattern of damage as had inoculation with prions from diseased cows. The March 30, 1999 issue of the Proceedings of the National Academy of Sciences describes an explosion of Bovine Spongiform Encephalopathy (BSE) in primates in French zoos apparently acquired from BSE-tainted feed supplements and said that these findings suggest very strongly that that nvCJD epidemic will indeed be a “plague of biblical proportions” (World Wide Web, 1999). Evans (2000) said it will be at least a year or two before scientists can predict whether the variant of Creutzfeldt-Jacob Disease, the human equivalent of BSE will be come widespread in the United Kingdom population. Daley (2000) said estimates of how many people are likely to be infected with new variant CJD range widely; some British scientists have speculated that 75 more people will die of the disease in the next 20 years while others say 80,000 depending on the incubation period and how the infection is passed from animal to human.

A report by an official European Union (EU) scientific committee (Associated Press, 2000a) suggests that meat and byproducts from one cow infested with Mad Cow Disease could contaminate 116 tons of ground beef and infect as many as 400,000 people. The report notes that infected cattle still enter the food chain in the EU, along with organs known to pose a particular risk including the brain, intestines and spinal cord; several EU countries, including the United Kingdom and France, remove those “specified risk” tissues, but other don’t. Roughly 50 people have developed the human version of Mad Cow Disease, called new variant Creutzfeldt-Jakob disease (nvCJD); most cases have occurred in the United Kingdom (Associated Press, 2000a).

At present, we do not believe the disease exists in the USA but the potential that it might and the reported linkage of BSE in cattle, prions in beef and occurrence of new variant Creutzfeldt-Jakob Disease (nvCJD) in humans mandates continued vigilance and precautions.

### **Will Irradiation Be Used to Destroy Foodborne Pathogens In U.S. Ground Beef?**

A better term for this process, likening it to what is done to kill bacteria in milk, is “electronic pasteurization”; and, the latter term would be more readily acceptable to consumers as well as more easily explained to those who fear the process because of association of the term “radiation” that has been used so often in discussions of nuclear warfare. Bacteria exposed to ionizing radiation are almost always killed. Many people believe that we should convert all carcasses into table-ready consumer products in very strong and reliable packages that can—just prior to reaching retail outlets—be irradiated to make them microbiologically sterile (and thus free of foodborne pathogens). Use of irradiation on fresh pork, poultry and beef for sale to consumers has been approved by both the FDA and USDA (most recently, for beef, on February 13, 1999 by USDA) but there are concerns (Smith and Morgan, 1997) with use of irradiation that may delay its adoption by the meat and poultry industries. These concerns include: (1) Expense. Application of this technology is costly because of the expense to construct or access irradiation facilities and the comparatively high costs for special packaging materials. (2) Consumer Acceptance. Many end-users, especially those in foreign markets, are reluctant to purchase and consume or sell to consumers, meat or poultry that has been exposed to

radiation. In addition, consequences of use of atomic bombs in World War II, of the Chernobyl disaster in the USSR and widespread media coverage of the Three Mile Island nuclear reactor incident in Pennsylvania continue to generate concern among domestic consumers about use of this technology.

Intentional exposure of a food to radiation seems incongruous to many food purchasers. (3) Incidence Of Odd Odor/Flavor. To some people, and in certain instances, irradiation generates “odd,” “off” or “undesirable” tastes and smells in end-products. Unless and until odor/flavor irregularities are solved, it is not likely that this technology will engender widespread acceptance and application.

Colorado Boxed Beef (Auburndale, FL) announced in April 1999 that it plans to be among the first meat firms to use irradiation technology to kill life-threatening bacteria such as *E. coli* O157:H7 (Meat Processing, 1999b). IBP, Inc. and Excel, Inc. announced in April 1999 that they will test-market beef irradiated by use of electron-beam technology in late 1999 or in early 2000 (Associated Press, 1999). In March 1999, McDonald’s Corporation announced that it has suspended testing of ground beef treated with irradiation because “the irradiated meat did not measure up to the chain’s organoleptic standards” (Meat Marketing and Technology, 1999a).

According to results of the most recent survey published in “TRENDS in the United States—Consumer Attitudes And The Supermarket 2000” (Food Marketing Institute, 2000), supermarket shoppers asked the question “How Likely Would You Be To Buy Food Products Like Strawberries, Poultry, Pork Or Beef If They Had Been Irradiated to Kill Germs And Keep It Safe?”, 38% said they were “Very Likely” (19%) or “Somewhat Likely” (19%)—down substantially from the 69%, 60%, 56% and 56% in 1996, 1997, 1998 and 1999, respectively, who said that, while 36% replied “Not Very Likely” and 20% said “Not At All Likely.” Interestingly, more women than men, those with high school or less education and those in single-person households are more likely to say they would purchase irradiated products (Food Marketing Institute, 2000). If the wording of the question was changed to eliminate reference to the word “irradiation” and stated as “How likely Would You Be To Buy Food Like Strawberries, Poultry, Pork Or Beef If It Had Been Treated To Kill Germs And Keep It Safe?”, only 28% of respondents said they would be “Very” or “Somewhat” Likely to purchase it, while 43% were “Not Too” Likely and 25% were “Not At All” Likely to purchase such product (FMI, 2000).

### **Present Status Of Meat And Poultry Safety In The U.S.**

Smith and Morgan (1999) reported that several pork packers announced in late 1998 that they would buy hogs for slaughter only from swine producers who qualify for NPPC, Pork Quality Assurance Level III (the most stringent of NPPC’s on-farm pork safety standards). The largest supermarket chain in Australia announced in April, 1998 that they would now purchase beef only from farms/ranches that qualify for the “Cattle-Care” farm safety designation. It seems highly probable that similar things will happen in the U.S. beef industry. Both the NPPC, Pork Quality Assurance program and the NCBA, Beef Quality Assurance program have served us well but may eventually move from an industry-oversight status, to one of a gate-to-plate pork/beef safety verification overseers, as customers (retailers and food-service operators) search for ways to reduce risk (and avoid litigation) of food-safety hazards and to allay fears and concerns of consumers (end-users) about food safety (Smith and Morgan, 1999).

Each year, the National Residue Program of the Food Safety and Inspection Service of the U.S. Department of Agriculture releases results of its nationwide residue monitoring efforts in U.S. meat and poultry (Carnevale, 1991). The National Residue Program for 1994 (USDA, 1996) tested for 42 chemicals in 12 classes of animal drug and pesticide compounds. FSIS/USDA, in announcing results for FY-1994 (in August, 1996), said, "Only 0.18% of the 38,894 samples of livestock and poultry meats tested in 1994 by FSIS/USDA during our domestic routine residue-monitoring program showed illegal levels (violative concentrations) of pesticide, hormone, antibiotic, drug and other chemical residues, down from 0.26% in the 1991 samples, 0.29% in the 1992 samples and 0.26% in the 1993 samples" (USDA, 1996). Nevertheless, producers, processors, wholesalers, retailers, scientists and agents of Federal/State governments must be constantly vigilant and do all that is possible to maintain or improve the safety of our food supply (Smith, 1995).

According to Smith and Morgan (1999), results of the National Residue Monitoring Program for 1996 (released by FSIS-USDA in December 1998), revealed that the percentage incidence of violative residues of antibiotics, sulfa-drugs, pesticides (chlorinated hydrocarbons and organophosphates) and parasiticides, respectively, were: (a) 0.0, 0.0, 0.0 and 0.0 in steer/heifer beef, (b) 1.2, 0.3, 0.0 and 0.2 in market hog pork, and (c) 0.5, 0.0, 0.0 and 0.2 in market lamb. "Positives" for violative residues in samples from Steers/Heifers, Bulls/Cows, Market Hogs, Boars/Sows, Market Lambs and Rams/Ewes (FSIS, 1999) were 0.0%, 0.1%, 1.2%, 0.5%, 0.5% and 0.5%, respectively, for antibiotics, 0.0%, 0.2%, 0.3%, 1.0%, 0.0% and 0.0%, respectively, for sulfonamides, 0.0%, 0.0%, 0.0%, 0.3%, 0.0% and 0%, respectively, for chlorinated hydrocarbon and organophosphate pesticides, 0.0%, 0.3%, 0.0%, 0.0%, 0.0% and 0.0%, respectively, for ivermectin and 0.0%, 0.1%, 0.3%, 0.2%, 0.3% and 0.7%, respectively, for levamisole.

Sofos *et al.* (1992) and Kukay *et al.* (1996) conducted a study of residues of heavy metals (lead; cadmium), hormones (zeranol; melengestrol acetate), antibiotic (tetracycline), sulfa drugs (six specific sulfonamides) and pesticides (15 chlorinated hydrocarbons and 10 organophosphates) and did not find a single violative residue in Canadian bacon, Chorizo sausage, ham, bacon, beef trim or pork trim. The latter study, "National Extension Service--HACCP for Small- and Medium-Size Meat Plants," concluded that there were no problematic or violative residues of heavy metals, hormones, antibiotics or pesticides in samples of six kinds of meat products (Sofos *et al.*, 1992; Kukay *et al.*, 1996).

Another study (Smith *et al.*, 1994a) determined that "tests prescribed by European Economic Community import-statutes confirm that U.S. beef does not contain violative or problematic residues of anabolic steroids, thyrostat, tranquilizers, beta-blocker, beta-agonist, heavy metals, sulfa-drugs, chlorinated hydrocarbons, or organophosphate pesticides."

Finally, in summarizing results of all of the studies conducted between 1990 and 1995 by the Center For Red Meat Safety at Colorado State University, Smith *et al.* (1994b) at the Reciprocal Meat Conference of the American Meat Science Association said, "Data of these five studies reveal that the incidence of violative chemical residues in U.S. beef and pork produced under 'conventional' production/management conditions is exceptionally low; beef and pork are 'safe' relative to absence of violative chemical residues."

## Conclusions

Why do we continue to use all these chemicals? Smith (1995) reported that Dr. Lowell Schake (of the University of Connecticut) said in September 1990, "Had humankind remained hunters and gatherers, the maximum human population that could have been sustained on planet Earth would be 30 million. As of this date, we have 5 billion people on Earth, and, we expect to have another 5 billion here in the early part of the 21st century. We can and will feed all of those people because we have developed and used science and technology for food production" (Smith, 1995).

The United States of America has the most abundant, the cheapest, and the safest food supply in the world. According to Smith (1995), Dr. Dixie Lee Ray (then, a scientist at the University of Washington and former Governor of Washington, said, in *Priorities* magazine in 1989, "Despite all the evidence of our physical well-being, beyond the dreams of all previous generations, we seem to have become a nation of easily frightened people--the healthiest hypochondriacs in the world."

## REFERENCES

- AAM. 1999. Food safety: Current status and future needs. Report based on an AAM colloquium (August, 1998; Nashville, TN). Ed. Stephanie Doores. American Academy of Microbiology, Washington, DC.
- Abelson, P. 1990. Natural Plant Pesticides In Food. *Science*. Volume 249, Number 4975 (September Issue).
- Acheson, D.W.K. 2000. How does *Escherichia coli* O157:H7 testing in meat compare with what we are seeing clinically? *J. Food Prot.* 63:819-821.
- Acuff, G.R., A. Castillo and J.W. Savell. 1997. Hot water rinses. *Proc. Recipr. Meat Conf.*, 49:125-128.
- Ames, B.N. and L. Swirsky-Gold. 1990. Human Consumption of Carcinogens In The Food Supply. *The Daily Yomiuri* (Tokyo, Japan) (September 5 Issue).
- Ames, B.N., L. Swirsky-Gold, S. Cohen and L. Ellwein. 1990. Of Mice and Men: Rodent Cancer Tests Are Inaccurate. *Science* (August Issue) and *Proceedings of the National Academy of Sciences* (September Issue).
- AMIF. 2000a. AMIF study shows pathogen interventions in beef plants are effective against *E. coli* O157:H7. *American Meat Institute Foundation News*. (March Issue) Volume 2, Issue 1, pages 1-6.
- AMIF. 2000b. AMIF survey shows foods often kept too warm to ensure food safety. *American Meat Institute Foundation News*. (March Issue) Volume 2, Issue 1, pages 1-5.

AMIF. 2000c. DNA fingerprinting of *E. coli* O157:H7. American Meat Institute Foundation News. (March Issue) Volume 2, Issue 1, page 5.

AMSA. 1999. The role of microbiological testing in beef food safety programs: The scientific perspective. AMSA Symposium (January 1999; Chicago, IL). Co-Chairs: C.R. Calkins and M. Koohmaraie. American Meat Science Association, Kansas City, MO.

AMSA/NCBA. 1997. Beef safety symposium. Emerging beef pathogens. American Meat Science Association and National Cattlemen's Beef Association. (December 3-4; Chicago, IL) National Cattlemen's Beef Association, Englewood, CO.

Anderson, M.E., R.T. Marshall, W.C. Stringer and H.D. Naumann. 1977. Combined and individual effects of washing and sanitizing on bacterial counts of meat—A model system. *J. Food Prot.* 40:688-670.

Archer, D. 1995. The Food Microbiology Division Lecture. Institute of Food Technologists Annual Meeting (Anaheim, CA). IFT Book of Abstracts: 34.1.

Armstrong, G.L., J. Hollingsworth and J.G. Morris, Jr. 1996. Emerging foodborne pathogens: *E. coli* O157:H7 as a model of entry of a new pathogen into the food supply of the developed world. *Epidemiol. Rev.* 18:29-51.

Arnold, K.W. and C.W. Kaspar. 1995. Starvation and stationary-phase-induced acid tolerance of *E. coli* O157:H7. *Appl. Environ. Microbiol.* 59:2364-2368.

Associated Press. 2000a. Mad-cow burgers. *The Denver Post* (January 23 Issue) page 13.

Associated Press. 2000b. Heightened testing hikes meat recalls. (May 15 Release).

Associated Press. 1999. IBP, Excel to test-market irradiated hamburger meat. *Dow Jones News* (April 13 Issue) page 14.

Associated Press. 1997. Sprouts tainted by *E. coli*. *The Denver Post* (August 15 Issue) page 23.

Associated Press. 1994. Study: Pesticides Raise Breast Cancer Risk By Increasing Bad Estrogen. *Star-Tribune* (Kansas City, MO) (October 4 Issue).

Bachman, J. 2000. Foodborne diseases. Associated Press. (March 17 Release).

Bacon, R.T., J.N. Sofos, K.E. Belk and G.C. Smith. 2000. Incidence of *Escherichia coli* O157:H7 on beef animal hides, carcasses and trimmings in twelve commercial slaughtering facilities. *Dairy, Food and Environmental Sanitation* (Submitted for publication).

- Bacon, R.T., J.N. Sofos, K.E. Belk, J.O. Reagan and G.C. Smith. 1999. Commercial evaluation of multiple-sequential interventions for decontamination of beef carcasses. Annual Meeting, International Association of Milk, Food and Environmental Sanitarians, 86:T3.
- Balter, M. 1999. Scientific cross-claims fly in continuing beef war. *Science* 284:1453-1455.
- Barkate, M.L., G.R. Acuff, L. Lucia and D.S. Hale. 1993. Hot water decontamination of beef carcasses for reduction of initial bacterial numbers. *Meat Science* 35:397-401.
- Bean, N.H., J.S. Goulding, M.T. Daniels and F.J. Angulo. 1997. Surveillance for foodborne disease outbreaks—United States, 1988-1992. *J. Food Protection* 60:1265-1286.
- Beef. 1987. Four Studies Reaffirm Safety Of Antibiotics In Feed. *Beef* (Overland Park, KS) (September Issue).
- Beef Business Bulletin. 1998. *E. coli* update from CDC. (July 19 Issue) page 1.
- Beef Today. 1997. Safe Food “From Farm To Fork.” *Beef Today* (April Issue) page 34.
- Bell, B.P., M. Goldoft, P.M. Griffin, M.A. Davis, D.C. Gordon, P.I. Tarr, C.A. Bartleson, J.H. Lewis, T.J. Barrett, J.G. Wells, R. Baron and J. Kobayaski. 1994. A multistate outbreak of *Escherichia coli* O157:H7—Associated bloody diarrhea and hemolytic uremic syndrome from hamburgers. The Washington Experience. *JAMA* 272:1349-1353.
- Besser, T.E. 1995. Means for lessening/preventing occurrence of *E. coli* O157:H7 in cattle populations. Proc. Conf. On New Technol. To Improve Food Safety (April 12, 1995; Chicago, IL) Food Safety and Inspection Service, USDA, Washington, DC.
- Besser, T.E., D.D. Hancock, L.C. Pritchett, E.M. McRae, D.H. Rice and P.I. Tarr. 1997. Duration of detection of fecal excretion of *Escherichia coli* O157:H7 in cattle. *J. Infect. Dis.* 175:726-729.
- Besser, T.E., D.H. Rice, D.D. Hancock and B. Richards. 1996. Colonization of calves with *Escherichia coli* O157:H7: Infectious dose and direct contact transmission. *App. Environ. Microbiol.* 60:1328-1335.
- Biondo, B. 1997. Is there poison in your produce? *USA Weekend* (August 17 Issue) page 21.
- Black, Baxter. 1998. Organic foods’ labels open can of worms. *Western Livestock Journal* (June 8 Issue) page 12.
- Borczyk, A.A., M.A. Karmali, H. Lior and L.M.C. Duncan. 1987. Bovine reservoir for verotoxin-producing *E. coli* O157:H7. *Lancet* 1:98.

- Boston Globe. 1991. "We're So Sure You'll Think Our Beef Is Better, We Bet The Ranch On It." Boston Globe (Boston, MA) (March 15 Issue).
- Bowling, R.A. 1999. Future Beef Operations: A farm-to-fork beef supply chain. Presented at the Rosenthal Lecture Series, Texas A&M University (College Station, TX).
- Bowling, R.A. and R.P. Clayton. 1992. Method for dehairing animals. U.S. Patent 5,149,295.
- Brasher, P. 2000a. Study: *E. coli* rates in cattle higher; USDA considering tighter controls. Associated Press. The Denver Post. (March 1 Issue) page A-9.
- Brasher, P. 2000b. Clinton targets *Listeria* in latest food-safety plan. Associated Press. The Coloradoan. (May 7 Issue) page 5.
- Broder, J.M. 1997. Food safety push on tap. The Denver Post. (December 28 Issue) page 13A.
- Brody, Jane E. 1994. Scientists Say Chemicals Aren't Cancer Causers. Bangor Daily News (Bangor, ME) (July 5 Issue).
- Brown, C.A., B.G. Harmon, T. Zhao and M.P. Doyle. 1995. Experimental *Escherichia coli* O157:H7 carriage in calves. Appl. Environ. Microbiol. 63:27-32.
- Bryan, J. 1997. The war against a pathogen. Farm Journal. (October Issue) page 34.
- Buchanan, R.L. and M.P. Doyle. 1997. Foodborne disease significance of *Escherichia coli* O157:H7 and other Enterohemorrhagic *E. coli*. Food Technology 51:69-76.
- Burros, M. 2000. Meat plant standards struck down. The Denver Post. (May 26 Issue) page 29.
- Buzby, J.C., T. Roberts, C.T. Jordan, C.T. Lin and J.M. MacDonald. 1999. Bacterial foodborne disease, medical costs and productivity losses. Agricultural Economic Report No. 741. Economic Research Service, U.S. Department of Agriculture, Washington, DC.
- Cabedo, L., J.N. Sofos and G.C. Smith. 1997. Attachment of *Escherichia coli* and other bacterial cells grown in two media to beef adipose and muscle tissues. J. Food Protection 60:102-106.
- Cabedo, L., J.N. Sofos and G.C. Smith. 1996. Removal of bacteria from beef tissue by spray-washing after different times of exposure to fecal material. J. Food Protection 59:1284-1287.
- Campbell, D.F., R.W. Johnston, M.W. Wheeler, K.V. Nagaraja, C.D. Szymanski and B.S. Pomeroy. 1984. Effects of evisceration and cooling processes on the incidence of *Salmonella* in fresh dressed turkeys grown under *Salmonella*-controlled and -uncontrolled environments. Poultry Science

63:1069-1072.

Campbell, D.F., S.S. Green, C.S. Custer and R.W. Johnston. 1982. Incidence of *Salmonella* in fresh dressed turkeys raised under *Salmonella*-controlled and -uncontrolled environments. *Poultry Science* 61:1962-1967.

Cannell, R.C., J.H. Killen, J.N. Sofos, T.P. Karnezos, R.L. Lewis and G.C. Smith. 1997. Use of lactic-acid secreting bacteria and mannanoligosaccharide to reduce pathogens in cattle preharvest. Final Report to Alltech, Inc. Colorado State University, Fort Collins, CO.

Caparella, T. 1999. Global issues addressed at 65<sup>th</sup> annual convention. *Render* (February Issue) page 9.

Caparella, T. 1998. One year later—An update on the enforcement of FDA's ruminant feed ban. *Render* (December Issue) page 17.

Carnevale, R. 1991. Residues In Tissues From Livestock and Poultry Collected In The National Residue Monitoring Program. *Food Processing* (September Issue).

CAST. 1994. *Foodborne Pathogens: Risks And Consequences*. September, 1994. Des Moines, IA.

Castillo, A., J.S. Dickson, R.P. Clayton, L.M. Lucia and G.R. Acuff. 1998a. Chemical dehairing of bovine skin to reduce pathogenic bacteria and bacteria of fecal origin. *J. Food Prot.* 61:623-625.

Castillo, A., L.M. Lucia, K.J. Goodson, J.W. Savell and G.R. Acuff. 1998b. Comparison of water wash, trimming and combined hot water and lactic acid treatments for reducing bacteria of fecal origin on beef carcasses. *J. Food Prot.* 61:823-828.

CDC. 1996. Foodborne illness outbreaks by location—Where the mishandled food was eaten. *Morbidity and Mortality Weekly Reports (MMWR)*, (October 25 Issue). Centers For Disease Control, U.S. Department of Health and Human Services, Atlanta, GA.

CDC. 1994. Location of Food Mishandling. *Morbidity and Mortality Weekly Reports (MMWR)*, (November 1 Issue). Centers For Disease Control, U.S. Department of Health and Human Services, Atlanta, GA.

Center For Veterinary Medicine. 1993. *Antibiotics In Animal Feed:Information For Consumers*. Food and Drug Administration (July Issue). Washington, DC.

Chapman, P.A., C.A. Siddons, A.T. Cerdan Malo and M.A. Harkin. 1997. A 1-year study of *E. coli* O157:H7 in cattle, sheep, pigs and poultry. *Epidemiol. Infect.* 119:245-250.

Chapman, P.A., C.A. Siddons, D.J. Wright, P. Norman, J. Fox and E. Crick. 1993. Cattle as a

possible source of verocytotoxin-producing *E. coli* O157:H7 infections in man. *Epidemiol. Infect.* 111:439-447.

Clapp, S. 1997. Speakers note HACCP limits. *Meat & Poultry*. (November Issue) page 10.

Cohen, T. 2000. Canada water plant knew about *E. coli* bacteria. Associated Press. *The Denver Post* (May 26 Issue) page 6.

Crider, J. 1997. No longer just a packer problem. *Drovers Journal*. (October Issue) pages 24-26.

Cross, J. and B. Smith. 2000. Personal communication. (Cross and Smith own Lone Star Packing Company, San Angelo, TX).

Cutter, C.N., W.J. Dorsa and G.R. Siragusa. 1997. Parameters affecting the efficacy of spray washes against *Escherichia coli* O157:H7 and fecal contamination of beef. *J. Food Protection* 60:614-618.

Dairy Herd Management. 2000. Survey suggests consumers will pay for food safety. (July Issue) page 13.

Dairy, Food and Environmental Sanitation. 2000. New data establish link between “Mad Cow Disease” and fatal brain damage in humans. (February Issue) page 136.

Daley, S. 2000. France’s mad-cow incidence increases. *The New York Times*. *The Denver Post* (May 7 Issue) page 32.

D'Aoust, J.Y., A.M. Sewell, E. Daley and P. Greco. 1992. Antibiotic resistance of agricultural and foodborne *Salmonella* isolates in Canada: 1986-1989. *Journal of Food Protection* 55:428-434.

Dargatz, D.A., S.J. Wells, L.A. Thomas, D.D. Hancock and L.P. Garber. 1997. Factors associated with the presence of *Escherichia coli* O157:H7 in feces of feedlot cattle. *J. Food Protection* 60:466-470.

Dean-Nystrom, E.A., B.T. Bosworth, W.C. Cray and H.W. Moon. 1997. Pathogenicity of *E. coli* O157:H7 in the intestines of neonatal calves. *Infect. Immun.* 65:1842-1848.

De Becker, G. 1997. Conquering what scares us. *USA Weekend* magazine (August 24 Issue) Report of “What Americans Fear/Taking Precautions”) pages 4-6.

Delmore, Jr., R.J., J.N. Sofos, G.R. Schmidt, K.E. Belk, W.R. Lloyd and G.C. Smith. 2000. Interventions to reduce microbiological contamination of beef variety meats. *J. Food Prot.* 63:44-50.

- Delmore, Jr., R.J., J.N. Sofos, K.E. Belk, W.R. Lloyd, G.L. Bellinger, G.R. Schmidt and G.C. Smith. 1999. Good manufacturing practices for the improvement of the microbiological quality of beef variety meats. *Dairy Food and Environmental Sanitation* 19:472-752.
- Dickson, J.S. and M.E. Anderson. 1992. Microbiological decontamination of food animal carcasses by washing and sanitizing systems. A review. *J. Food Protection* 55:133-140.
- Dickson, J.S. and M.E. Anderson. 1991. Control of *Salmonella* on beef tissue surfaces in a model system by pre- and post-evisceration washing and sanitizing, with and without spray chilling. *J. Food Protection* 54:514-518.
- Dickson, J.S., M.D. Hardin and G.R. Acuff. 1997. Organic acid rinses. *Proc. Recipr. Meat Conf., American Meat Science Association, Chicago, IL* 49:129-131.
- Diez-Gonzalez, F., T.R. Callaway, M.G. Zizoulis and J.B. Russell. 1998. Grain feeding and the dissemination of acid-resistant *Escherichia coli* from cattle. *Science* 281:1666-1668.
- Dorsa, W.J. 1997. New and established carcass decontamination procedures commonly used in the beef-processing industry. *J. Food Protection* 60:1146-1151.
- Dorsa, W.J., C.N. Cutter and G.R. Siragusa. 1997. Effects of acetic acid, lactic acid and trisodium phosphate on the microflora of refrigerated beef carcass surface tissue inoculated with *Escherichia coli* O157:H7, *Listeria innocua*, and *Clostridium sporogenes*. *J. Food Protection* 60:619-624.
- Doyle, M.P. 1992. A new generation of foodborne pathogens. *Dairy, Food and Environmental Sanitarian* 12:490-492.
- Doyle, M.P. 1991. *E. coli* O157:H7 and its significance in foods. *Int. J. Food Microbiol.* 12:289-302.
- Drovers Journal. 2000. Consumers prioritize food safety. (January Issue) page 18.
- Duffy, E.A., S.B. LeValley, K.E. Belk, J.D. Tatum, C.V. Kimberling, J.N. Sofos and G.C. Smith. 2000a. Sheep Pathogen Reduction Intervention And Animal Production Food Safety Practices. Final Report to Animal and Plant Health Inspection Service and American Sheep Industry Association. Center for Red Meat Safety, Colorado State University, Fort Collins, CO.
- Duffy, E.A., S.B. LeValley, M.L. Kain, K.E. Belk, J.D. Tatum, J.N. Sofos, G.C. Smith and C.V. Kimberling. 2000b. Microbial Contamination On Lamb Carcasses Processed In The United States. Final Report to Food Safety and Inspection Service of USDA and American Sheep Industry Association. Center for Red Meat Safety, Colorado State University, Fort Collins, CO.
- Duffy, E.A., S.B. LeValley, M.L. Kain, K.E. Belk, J.D. Tatum, J.N. Sofos, G.C. Smith and C.V. Kimberling. 2000c. Preharvest Management Practices And Microbiological Quality Of Lamb

Carcasses. Final Report to Animal and Plant Health Inspection Service and American Sheep Industry Association. Center for Red Meat Safety, Colorado State University, Fort Collins, CO.

Duffy, E.A., S.B. LeValley, M.L. Kain, K.E. Belk, J.D. Tatum, J.N. Sofos, G.C. Smith and C.V. Kimberling. 2000d. Good Manufacturing Practices During Harvest And Microbiological Quality Of Lamb Carcasses. Final Report to Animal and Plant Health Inspection Service and American Sheep Industry Association. Center for Red Meat Safety, Colorado State University, Fort Collins, CO.

Duffy, E.A., K.E. Belk, J.N. Sofos, G.R. Bellinger and G.C. Smith. 1999. United States Retail Pork Microbiological Baseline. Final Report to the National Pork Producers Council. Center for Red Meat Safety, Colorado State University, Fort Collins, CO.

Effertz, N. 1997. What to do about beef's bad bug. Beef Today. (October Issue) pages 8-9.

Elder, R.O., J.E. Keen, G.R. Siragusa, G.A. Barkocy-Gallagher, M. Koohmaraie and W.W. Laegreid. 2000. Correlation of enterohemorrhagic *Escherichia coli* O157 prevalence in feces, hides and carcasses of beef cattle during processing. PNAS 97:2999-3003.

Evans, A. 2000. UK prepares public for more bad news on human mad cow epidemic. (April 6 Issue) pages 1-2. [www.purefood.org/Meat/ukmadcow.cfm](http://www.purefood.org/Meat/ukmadcow.cfm).

Fagerberg, D.J. and C.L. Quarles. 1986. Antibiotic Feeding, Resistance and Alternatives. American Hoescht Corporation, Somerville, NJ.

Fetzner, R. 1990. Memorandum to: All Plants That Are Currently EEC Approved for the Slaughter of Swine, Lamb, Horse, non-treated Beef, and Veal. Subject: Participation in EEC Residue Testing Program. USDA-FSIS, (March 29 Issue).

Food and Drug Administration. 1994. Food and Drug Administration Pesticide Program Residue Monitoring. Journal of the Association of Official Analytical Chemists International (September Issue).

Food and Drug Administration. 1991. Residues in Foods. Journal of the Association of Official Analytical Chemists, 74:121A-135A.

Food and Nutrition News. 1997. Food safety perspectives. National Cattlemen's Beef Association. Volume 69, Number 1, (Spring Issue). Chicago, IL.

FMI. 2000. TRENDS IN THE UNITED STATES--Consumer Attitudes & The Supermarket 2000. Food Marketing Institute, Washington, DC.

FMI. 1999. TRENDS IN THE UNITED STATES--Consumer Attitudes & The Supermarket 1999. Food Marketing Institute, Washington, DC.

- FMI. 1998. TRENDS IN THE UNITED STATES--Consumer Attitudes & The Supermarket 1998. Food Marketing Institute, Washington, DC.
- FMI. 1997. TRENDS IN THE UNITED STATES--Consumer Attitudes & The Supermarket 1997. Food Marketing Institute, Washington, DC.
- FMI. 1996. TRENDS IN THE UNITED STATES--Consumer Attitudes & The Supermarket 1996. Food Marketing Institute, Washington, DC.
- FMI. 1995. TRENDS IN THE UNITED STATES--Consumer Attitudes & The Supermarket 1995. Food Marketing Institute, Washington, DC.
- FMI. 1994. TRENDS IN THE UNITED STATES--Consumer Attitudes & The Supermarket 1994. Food Marketing Institute, Washington, DC.
- FMI. 1993. TRENDS IN THE UNITED STATES--Consumer Attitudes & The Supermarket 1993. Food Marketing Institute, Washington, DC.
- FMI. 1992. TRENDS IN THE UNITED STATES--Consumer Attitudes & The Supermarket 1992. Food Marketing Institute, Washington, DC.
- FMI. 1991. TRENDS IN THE UNITED STATES--Consumer Attitudes & The Supermarket 1991. Food Marketing Institute, Washington, DC.
- FMI. 1988. TRENDS IN THE UNITED STATES--Consumer Attitudes & The Supermarket 1988. Food Marketing Institute, Washington, DC.
- Food Processing. 1997. Safety measures. (Report of an FDA/USDA consumer survey) Food Processing magazine (June Issue) 58:88.
- Food Technology. 2000. HACCP programs result in substantial reductions in *Salmonella*. 54(5):30.
- Fox, M. 1999. Study shows how mad cow disease gets to brain. Reuters (March 30 Report) pages 36-37.
- Frenzen, P.D., A. Majchrowicz, J.C. Buzby and B. Imhoff. 2000. Consumer acceptance of irradiated meat and poultry products. Issues In Food Safety Economics, Agriculture Information Bulletin No. 757 (August Issue) pages 1-8. ERS-USDA, Washington, DC.
- FSIS. 1999. National Residue Monitoring Program Results—1996. Food Safety and Inspection Service, United States Department of Agriculture, Washington, DC.
- FSIS. 1996a. Achieving the zero tolerance performance standard for beef carcasses by knife trimming

and vacuuming with hot water and steam; Use of acceptable carcass interventions for reducing carcass contamination without prior agency approval. Notice of Policy Change. Federal Register 61:15024-15027.

FSIS. 1996b. Pathogen Reduction; Hazard Analysis and Critical Control Point (HACCP) systems: Final Rule. Federal Register 61:38805-38989.

FSIS. 1995a. Backgrounder:FSIS Pathogen Reduction/HACCP Proposal. (February Issue) page 2. FSIS-USDA, Washington, DC.

FSIS. 1995b. Pathogen Reduction; Hazard Analysis and Critical Control Point (HACCP) Systems. Code of Federal Regulations 9:308-381. FSIS-USDA, Washington, DC.

FSIS. 1995c. Comparison of methods for achieving the zero tolerance standard for fecal, ingesta and milk contamination of beef carcasses; Notice of conference. Federal Register 60:49553-49564.

FSIS. 1994. Nationwide beef microbiological baseline data collection program: Steers and heifers—October 1992 to September 1993. FSIS-USDA. Washington, DC.

FSIS. 1993. Discussion points—continuum of responsibility (farm-to-table). Proceedings of the FSIS Conference on the Regulatory Program of the Future (November; College Station, TX), FSIS-USDA, Washington, DC.

Gangarosa, E.J., C.V. Kimberling, G.A. Mitchell, B.I. Osburn, M.E. Potter, G.C. Smith, P.H. Sparling, H.F. Troutt and J.C. Whittier. 1994. Final Report, Ruminant Animal Production TAG for USDA, FSIS and APHIS. Information Data Systems. Silver Spring, MD.

Garber, L., S. Wells, L. Schroeder-Tucker and K. Ferris. 1999. Factors associated with fecal shedding of verotoxin-producing *E. coli* O157 on dairy farms. J. Food Prot. 62:307-312.

Garber, L.P., S.J. Wells, D.D. Hancock, M.P. Doyle, J.A. Shere and T. Zhao. 1995a. *E. coli* O157:H7 in dairy heifers: Results of a case-control study. J. Am. Vet. Med. Assoc. 207:46-47.

Garber, L.P., S.J. Wells, D.D. Hancock, J. Tuttle, J.A. Shere and T. Zhao. 1995b. Public veterinary medicine: Food safety and handling—Risk factors for fecal shedding of *E. coli* O157:H7 in dairy calves. J. Am. Vet. Med. Assoc. 207:48-49.

Gill, C. 2000. Microbiological testing and safety of beef: Summary of the Task Force's conclusions. pages 1-4. International Livestock Congress (Houston, TX).

Glausiusz, J. 1997. The good bugs on our tongues. Discover magazine (October Issue) pages 32-33.

Grandin, T. 1994. Preharvest pathogen control. Meat & Poultry. (January Issue) pages 62-64.

Graves Delmore, L.R., J.N. Sofos, G.R. Schmidt and G.C. Smith. 1998. Decontamination of inoculated beef with sequential spraying treatments. *J. Food Science* 63:890-893.

Graves Delmore, L.R., J.N. Sofos, J.O. Reagan and G.C. Smith. 1997a. Hot-water rinsing and trimming/washing of beef carcasses to reduce physical and microbiological contamination. *J. Food Sci.* 62:373-376.

Graves Delmore, L.R., J.N. Sofos, G.R. Schmidt and G.C. Smith. 1997b. Inactivation of pathogenic bacteria by the chemical dehairing process proposed for use on beef carcasses during slaughter. Proceedings of the 50<sup>th</sup> Annual Reciprocal Meat Conference, American Meat Science Association, Chicago, IL.

Graves Delmore, L.R., J.N. Sofos, G.R. Schmidt and G.C. Smith. 1997c. Evaluation of multiple hurdles for beef carcass decontamination. Proceedings of the 50<sup>th</sup> Annual Reciprocal Meat Conference, American Meat Science Association, Chicago, IL.

Gorman, B.M., S.L. Kochevar, J.N. Sofos, J.B. Morgan, G.R. Schmidt and G.C. Smith. 1997. Changes on beef adipose tissue following decontamination with chemical solutions or water of 35C or 74C. *J. Muscle Foods* 8:185-197.

Gorman, B.M., J.B. Morgan, J.N. Sofos and G.C. Smith. 1995a. Microbiological and visual effects of trimming and/or spray-washing for removal of fecal material from beef. *Journal of Food Protection* 58:984-992.

Gorman, B.M., J.N. Sofos, J.B. Morgan, G.R. Schmidt and G.C. Smith. 1995b. Evaluation of hand-trimming, various sanitizing agents and hot water spray-washing as decontamination interventions for beef brisket adipose tissue. *Journal of Food Protection* 58:899-907.

Gunnerson, T. 2000. Carbonating cow manure kills *E. coli* bacteria. Reuters Limited. Citing a study by Diez-Gonzalez *et al.* (2000); *Environ. Sci. and Research* 34:1275-1278. [http://dailynews.yahoo.com/h/nm/20000428/hlmanure\\_1.html](http://dailynews.yahoo.com/h/nm/20000428/hlmanure_1.html).

Hancock, D. and D. Dargatz. 1995. Implementation of HACCP on the farm. Presented at the HACCP Symposium of the 75<sup>th</sup> Annual Meeting of the Conference of Research Workers in Animal Diseases (November 12; Chicago, IL) pages 1-6.

Hancock, D.D., T.E. Besser, D.H. Rice, E.D. Ebel, D.E. Herriott and L.V. Carpenter. 1998a. Multiple sources of *E. coli* O157:H7 in feedlots and dairy farms in the Northwestern USA. *Prev. Vet. Med.* 35:11-19.

Hancock, D.D., T.E. Besser and D.E. Rice. 1998b. Ecology of *E. coli* O157:H7 in cattle and impact of management practices. pages 85-91: In: *E. coli* O157:H7 And Other Shiga-Toxin Producing *E. coli*

Strains (Eds. J.B. Kaper and A.B.O'Brien) ASM Press, Washington, DC.

Hancock, D.D., D.H. Rice, L.A. Thomas, D.A. Dargatz and T.E. Besser. 1997a. Epidemiology of *Escherichia coli* O157:H7 in feedlot cattle. *J. Food Protection* 60:462-465.

Hancock, D.D., D.H. Rice, D.E. Herriott, T.E. Besser, E.D. Ebel and L.V. Carpenter. 1997b. Effects of farm manure handling practices on *Escherichia coli* O157:H7 prevalence in cattle. *J. Food Protection* 60:363-366.

Hancock, D.D., T.E. Besser, D.H. Rice, D.E. Herriott and P.I. Tarr. 1997c. Longitudinal study of *E. coli* O157:H7 in 14 cattle herds. *Epidemiol. Infect.* 118:193-195.

Hancock, D.D., T.E. Besser, D.H. Rice, D.E. Herriott and P.I. Tarr. 1996. Longitudinal study of *Escherichia coli* O157:H7 in fourteen cattle herds. *Epidemiol. Infect.* 118:193-195.

Hancock, D.D., T.E. Besser, M.L. Kinsel, P.I. Tarr, D.H. Rice and M.G. Paros. 1994a. The prevalence of *Escherichia coli* O157:H7 in dairy and beef cattle in Washington State. *Epidemiol. Infect.* 113:119-207.

Hancock, D.D., T.E. Besser and D.H. Rice. 1994b. Identification of management factors influencing farm prevalence of *E. coli* O157:H7. Proceedings of the 8<sup>th</sup> International Congress of Animal Hygiene. pages PB1-PB4. St. Paul, MN.

Hardin, M.D., G.R. Acuff, L.M. Lucia, J.S. Oman and J.W. Savell. 1995. Comparison of methods for decontamination from beef carcass surfaces. *J. Food Protection* 58:368-374.

Heaton, K.L., G.C. Smith, J.N. Sofos, M.J. Aaronson and D.K. Jones. 1996. Analysis of pork products for chemical residues. *J. Muscle Foods* 7:213-224.

Heaton, K.L., G.C. Smith, M.J. Aaronson, J.N. Sofos and R.P. Clayton. 1993a. Residues of Antibiotics, Hormones and Pesticides in Conventional, Natural and Organic Beef. Final Report to the National Live Stock and Meat Board. Center for Red Meat Safety, Department of Animal Sciences, Colorado State University, Fort Collins, CO.

Heaton, K.L., G.C. Smith, J.B. Morgan, J.N. Sofos, D.K. Jones, M.J. Aaronson, R.P. Clayton, J.D. Tatum and G.R. Schmidt. 1993b. Determination of Extent of Compliance of U.S. Pork With USDA-FSIS-ECD No. 90-22-EEC Residue Testing Requirements For 1990. Final Report to the National Live Stock and Meat Board. Center For Red Meat Safety, Department of Animal Sciences, Colorado State University, Fort Collins, CO.

Hebert, H.J. 1999. Brush with chemicals not linked to cancer. Associated Press (In: The Denver Post. August 4 Issue) page 10A.

- Herriott, D.E., D.D. Hancock, E.D. Ebel, L.V. Carpenter, D.H. Rice and T.E. Besser. 1998. Association of herd management factors with colonization of dairy cattle by Shiga Toxin-positive *E. coli* O157. *J. Food Prot.* 61:802-807.
- Hostetler, M.S. 1999. "Certified Organic." Memorandum to clients and companies under USDA/FDA regulation (April 12, 1999). Herzog, Crebs & McGhee, LLP, Attorneys At Law, St. Louis, MO.
- Hussein, H.S. 2000. On-farm factors can decrease risk of *E. coli* contamination. *Feedstuffs.* (March 13 Issue) pages 18-23.
- Itoh, Y., N. Hayashi, M. Katoh, A. Yamamoto, S. Hayashi, S. Maeda and T. Ezaki. 1999. The characterization of Shiga toxin-non-producing *Escherichia coli* serotype O157:H7 isolated from carcasses of cattle at a slaughter house. *Microbiol. Immunol.* 43:699-703.
- Iwasa, M., S.I. Makino, H. Asakura, H. Kobori and Y. Morimoto. 1999. Detection of *Escherichia coli* O157:H7 from *Musca domestica* (Piptera; Muscidae) at a cattle farm in Japan. *J. Med. Entomol.* 36:108-115.
- Janisiewicz, W.J., W.S. Conway, M.W. Brown, G.M. Sapers, P. Fratamico and R.L. Buchanan. 1999. Fate of *Escherichia coli* O157:H7 on fresh-cut apple tissue and its potential for transmission by fruit flies. *Appl. Environ. Microbiol.* 65:1-9.
- Jordan, D. and S.A. McEwen. 1998. Effect of duration of fasting and a short-term, high-roughage ration on the concentration of *E. coli* Biotype I in cattle feces. *J. Food Prot.* 61:531-534.
- Kain, M.L., J.N. Sofos, K.E. Belk, J.O. Reagan, G.C. Smith, D.R. Buege, W.P. Henning, J.B. Morgan, T.P. Ringkob and G.R. Belling. 1999. Microbiological contamination baselines of beef carcasses, wholesale cuts and retail cuts. Annual Meeting, International Association of Milk, Food and Environmental Sanitarians, 86:P44.
- Kansas State University. 1999. Consumers will pay for beef safety. Kansas Livestock Association, News and Market Report. (In: Beef. July Issue) page 40.
- Keen, J.E., G.A. Uhlich and R.O. Elder. 1999. Effects of hay- and grain-based diets on fecal shedding of naturally-acquired enterohemorrhagic *E. coli* (EHEC) O157 in beef feedlot cattle. Proceedings of the Conference for Research Workers on Animal Diseases. Abstract No. 86 (Chicago, IL).
- Kester, W. 1997. Food safety: An issue on the hot seat. *Beef magazine* (August Issue) pages 26-28.
- Kinsman, D., 1994. USDA National Organic Standards Board. (Dr. Kinsman worked at University of Connecticut, Storrs) Personal Correspondence.

- Kobayashi, M., T. Sasaki, K. Tamura, K. Suzuki, H. Watanabe and N. Agui. 1999. Houseflies not simple mechanical vectors of enterohemorrhagic *Escherichia coli* O157:H7. *Am. J. Trop. Med. Hyg.* 61:625-629
- Kochevar, S.L., J.N. Sofos, R.R. Bolin, J.O. Reagan and G.C. Smith. 1997a. Steam vacuuming as a pre-evisceration intervention to decontaminate beef carcasses. *J. Food Protection* 60:107-113.
- Kochevar, S.L. J.N. Sofos, S.B. LeValley and G.C. Smith. 1997b. Effect of water temperature, pressure and chemical solution on removal of fecal material and bacteria from lamb adipose tissue by spray-washing. *Meat Science* 45:377-388.
- Kochevar, S.L., B.M. Gorman, J.N. Sofos, S.B. LeValley, J.B. Morgan, J.D. Tatum, G.C. Smith and W.E. Cunningham. 1995. Preliminary Final Report On The Efficacy Of Spray-Washing For The Removal Of Physical And Bacterial Contamination From Lamb Adipose Tissue. Center For Red Meat Safety, Department of Animal Sciences, Colorado State University, Fort Collins, CO.
- Krizner, K. 1998. Incongruities in testing lead to inconsistent results. *Meat Marketing & Technology*. (December Issue) page 60.
- Kudva, I.T., K. Blanch and C.J. Hovde. 1998. Analysis of *E. coli* O157:H7 survival in ovine or bovine manure and manure slurry. *Appl. Environ. Microbiol.* 64:3166-3174.
- Kudva, I.T., P.G. Hatfield and C.J. Hovde. 1997a. Characterization of *E. coli* O157:H7 and other Shiga toxin-producing *E. coli* serotypes isolated from sheep. *J. Clin. Microbiol.* 35:892-899.
- Kudva, I.T., C.W. Hunt, C.J. Williams, U.M. Nance and C.J. Hovde. 1997b. Evaluation of dietary influences on *E. coli* O157:H7 shedding by sheep. *Appl. Environ. Microbiol.* 63:3878-3886.
- Kudva, I.T., P.G. Hatfield and C.J. Hovde. 1995. Effect of diet on the shedding of *E. coli* O157:H7 in a sheep model. *Appl. Environ. Microbiol.* 61:1363-1370.
- Kukay, C.C., L.H. Holcomb, J.N. Sofos, J.B. Morgan, J.D. Tatum, R.P. Clayton and G.C. Smith. 1996. Application of HACCP by small-scale and medium-scale meat processors. *Dairy, Food and Environmental Sanitation* 16:14-20.
- Labudde, R. 1997. The facts about Hudson Foods and *E. coli* O157:H7. *Meat & Poultry*. (October Issue) pages 12-15.
- Lean Trimmings. 1997. Hamburger recall update. *National Meat Association Newsletter* (August 25 Issue) page 1.

Leistner, L.E.E. 1992. Linkage Of Hurdle-Technology With HACCP. Proceedings of the Reciprocal Meat Conference, American Meat Science Association, Chicago, IL.

Leistner, L. and L.G.M. Gorris. 1995. Food preservation by hurdle technology. Trends In Food Science and Technology 6:41-46.

LeJuene, J., D.D. Hancock and T.E. Besser. 1997. *E. coli* O157:H7 in cattle water troughs: A possible on-farm reservoir. Proceedings of the 5<sup>th</sup> Annual Food Safety, Farm To Table Conference. Northwest Food Safety Consortium (Moscow, ID).

Lundeen, T. 2000. Prevalence of *E. coli* greater in summer; lower after processing. Feedstuffs. (April 10 Issue) page 9.

Lynn, T.V., D.D. Hancock, T.E. Besser, J.H. Harrison, D.H. Rice, N.T. Stewart and L.L. Rowan. 1998. The occurrence and replication of *E. coli* in cattle feeds. J. Dairy Sci. 81:1102-1108.

Maday, J. 1995. Searching for pathogen control points. Drovers Journal. (June Issue) pages 17-20.

Maixner, E. 1999. Meat, poultry cause minority of food poisonings. Feedstuffs. (September 6 Issue) page 8.

Mallinson, E.T., L.E. Carr, G.W. Malone, C.J. Wabeck, D.H. Palmer, E.P. Pusey, E. Russek-Cohen and S.W. Joseph. 1995. Lower Water Activity In Broiler Litter And The Reduction of *Salmonella* On Farms And Processed Carcasses. Cooperative Extension Service Bulletin 348, University of Delaware and University of Maryland, College Park, MD.

Manning, A. 2000. Fallout of irradiated burgers: Red-hot sales, rapid expansion. USA Today. (May 25 Issue) page D-6.

Meat & Poultry. 1997a. Transportation and storage critical control points. (August Issue) page 43.

Meat & Poultry. 1997b. Beef Safety Symposium advocates preharvest research. (December Issue) page 3.

Meat Marketing & Technology. 1999a. The Scoop: No irradiation for Ronald? (March Issue) page 19.

Meat Marketing & Technology. 1999b. *Listeria*: Government and industry take aim at a silent killer. (April Issue) page S3.

Meat Marketing & Technology. 1999c. Turkey not the culprit. (April Issue) page 11.

Meat Processing. 1999a. *Salmonella* down in HACCP plants. (April Issue) page 10.

- Meat Processing. 1999b. Colorado Boxed Beef to irradiate meat. (April Issue) page 12.
- Meat Processing. 1997a. Prevention is critical in *E. coli* situations. (December Issue) page 16.
- Meat Processing. 1997b. HACCP coming for school lunch suppliers? (December Issue) page 8.
- Meng, J., S. Zhao, T. Zhao and M.P. Doyle. 1995. Molecular characterization of *Escherichia coli* O157:H7 isolates from raw milk, ground beef and calf feces using pulsed field gel electrophoresis and plasmid DNA analysis. *J. Med. Microbiol.* 42:258-263.
- Meyer, T. 1997. Germ that kills *E. coli* found. *The Denver Post*. (October 13 Issue) page 13.
- Miles, R.D. 1993. Manipulation of the microflora of the gastrointestinal tract; Natural ways to prevent colonization by pathogens. Proceedings of the 9<sup>th</sup> Annual Symposium on Biotechnology in the Feed Industry. pages 133-138. Alltech's Technical Publications, Nicholasville, KY.
- Morgan, J.B. and G.C. Smith. 1992. 1991 Beef Investments To Prevent Food-Borne Illness. *Meat Minutes* (April Issue). Meat Science Group, Department of Animal Sciences, Colorado State University, Fort Collins, CO.
- Morgan, J.B., G.C. Smith, J.A. Sherbeck, S.K. Fitzgerald and C.C. Kukay. 1995. A Foreign Market Audit of U.S. Beef. The Final Report of the International Beef Quality Audit--1994. Meat Science Program, Department of Animal Sciences, Colorado State University, Fort Collins, CO.
- Morganthau, T. 1997. *E. coli* alert. *Newsweek* magazine (September 1 Issue) pages 26-32.
- Murphy, D. 2000. Food safety: The next stage; down on the farm. *Meat Marketing & Technology*. (April Issue) pages 52-55.
- NAHMS. 1997. Factors Associated With *Escherichia coli* O157:H7 In Feces Of Feedlot Cattle. National Animal Health Monitoring System, VS/APHIS, U.S. Department of Agriculture, Fort Collins, CO.
- NAHMS. 1995a. *Escherichia coli* O157:H7 Shedding By Feedlot Cattle. National Animal Health Monitoring System, VS/APHIS, U.S. Department of Agriculture, Fort Collins, CO.
- NAHMS. 1995b. *Salmonella* Shedding By Feedlot Cattle. National Animal Health Monitoring System, VS/APHIS, U.S. Department of Agriculture, Fort Collins, CO.
- National Academy of Sciences. 1989. Report On The Subtherapeutic Use of Antibiotics In Animal Feed. Board on Agriculture, National Research Council. National Academy Press. Washington, DC.

- National Academy of Sciences. 1987. Regulating Pesticides in Food--The Delaney Paradox. Board on Agriculture, National Research Council. National Academy Press, Washington, DC.
- NCBA. 2000. Beef safety consumer survey. National Cattlemen's Beef Association, Englewood, CO.
- NCBA. 1997. Thought-Leader Survey: Confidence In Beef Safety Increases. The Beef Brief (March Issue). National Cattlemen's Beef Association, Englewood, CO.
- NCBA. 1995. Thought-Leader Survey: Cattlemen Are Given Good Grades. The Beef Brief (April Issue). National Cattlemen's Beef Association, Englewood, CO.
- National Live Stock and Meat Board. 1995. "Conventional," "Natural" and "Organic" Beef: No Scientific Differences. Facts From The Meat Board: Product Technology. Series FS/PT 007. Chicago, IL.
- National Live Stock and Meat Board. 1994. Solving the *E. coli* O157:H7 problem. A blueprint for industry action. Blue Ribbon Task Force (July). National Cattlemen's Beef Association, Englewood, CO.
- National Meat Association. 1999b. Risky food handling behaviors commonplace. Lean Trimmings newsletter (April 12 Issue) page 1.
- National Meat Association. 1999c. Cases of infection. Lean Trimmings newsletter (April 12 Issue) page 2.
- National Meat Association. 1998. Article questions USDA statistics. Herd On The Hill newsletter (June 15 Issue) page 1.
- Newman, K.E. 1996. Nutritional manipulation of the gastrointestinal tract to eliminate *Salmonella* and other pathogens. Proceedings of the 12<sup>th</sup> Annual Symposium on Biotechnology in the Feed Industry. pages 37-46. Nottingham University Press, Nottingham, UK.
- Newsweek. 1997. Poll, Princeton Survey Associates. (September 1 Issue) pages 26-32.
- NMA. 2000a. Foodborne illness numbers decrease. Herd On The Hill. (March 30 Issue) page 3.
- NMA. 2000b. At issue in the Supreme Beef case. Lean Trimmings. (January 10 Issue) page 1.
- NMA. 1999a. CDC *E. coli* O157:H7 illness data for 1998. Lean Trimmings. (April 12 Issue) page 1.
- NMA. 1999b. Risky food handling behaviors commonplace. Lean Trimmings. (April 12 Issue) page 1.

- NMA. 1999c. Cases of infection. Lean Trimmings. (April 12 Issue) page 2.
- NMA. 1998. Article questions USDA statistics. Herd On The Hill. (June 15 Issue) page 1.
- NMA. 1997. Search for methods of destroying *E. coli* O157:H7 continue. Lean Trimmings. (September 2 Issue) page 1.
- Nutsch, A.L., R.K. Phebus, M.J. Riemann, D.E. Schaefer, J.E. Boyer, R.C. Wilson, J.D. Leising and C.L. Kastner. 1997. Evaluation of a steam pasteurization process in a commercial beef processing facility. *J. Food Protection* 60:485-492.
- Oblinger, J.L. 1988. Bacteria associated with foodborne diseases. *Food Technology* 42:181-200.
- Office International Des Epizooties. 1999. Confirmed number of Bovine Spongiform Encephalopathy (BSE) cases in Europe (1994-1998). *Render* (February Issue) page 23.
- Osterholm, M.T. 1997. No magic bullet. *Newsweek* magazine (September 1 Issue) page 33.
- Phebus, R.K., A.L. Nutsch, D.E. Schaefer, R.C. Wilson, M.J. Riemann, J.D. Leising, C.L. Kastner, J.R. Wolf and R.K. Prasai. 1997. Comparison of steam pasteurization and other methods for reduction of pathogens on surfaces of freshly slaughtered beef. *J. Food Protection* 60:476:484.
- Potthast, K. 1993. Residues in meat and meat products. *Fleischwirtschaft International* 4:26.
- Powell, V.H. and B.P. Cain. 1987. A hot water decontamination system for beef sides. *CSIRO Food Research Quarterly*. CSIRO Division Of Food Research, Cannon Hill, Queensland 47:79-84.
- Price, D.P. 1995. Low-Level Antibiotics. *Beef Magazine* (April Issue).
- Rasmussen, M.A., W.C. Cray, T.A. Casey and S.C. Whipp. 1993. Rumen contents as a reservoir of Enterohemorrhagic *E. coli*. *FEMS Microbiol. Letters* 114:79-84.
- Reagan, J.O., G.R. Acuff, D.R. Buege, M.J. Buyck, J.S. Dickson, C.L. Kastner, J.L. Marsden, J.B. Morgan, R. Nickelson II, G.C. Smith and J.N. Sofos. 1996. Trimming and washing of beef carcasses as a method of improving the microbiological quality of meat. *Journal of Food Protection* 59:751-756.
- Riemann, H.P. and D.O. Cliver. 1998. *E. coli* O157:H7. pages 41-48. In: *The Veterinary Clinics Of North American Food Animal Practice: Microbial Food Borne Pathogens* (Ed. L. Tollefson). W.B. Saunders Company, Philadelphia, PA.
- Riley, L.W., R.S. Remis, S.D. Helgerson, H.B. McGee, J.G. Weil, B.R. Davis, R.J. Hebert, E.S. Olcott, L.M. Johnson, N.T. Hargrett, P.A. Blake and M.L. Cohen. 1983. Hemorrhagic colitis

associated with a rare *E. coli* serotype. *New Engl. J. Med.* 308:681-685.

Rodrique, D.C., E.E. Mast, R.D. Greene, J.P. Davis, M.A. Hutchinson, J.G. Wells, T.J. Barrett and P.M. Griffin. 1995. A university outbreak of *E. coli* O157:H7 infections associated with roast beef and an unusually benign clinical course. *J. Infect. Dis.* 172:1122-1125.

Salvage, B. 1996. Tales from the fast-food front. *Meat Marketing & Technology.* (February Issue) pages 58-60.

Savell, J.W. and G.C. Smith. 1998. *Laboratory Manual For Meat Science.* (Sixth Edition) pages 8-9. American Press, Boston, MA.

Scheoni, J.L. and A.C.L. Wong. 1994. Inhibition of *Campylobacter jejuni* colonization in chicks by defined CE bacteria. *Appl. Environ. Microbiol.* 60:1191-1197.

Scheoni, J.L. and M.P. Doyle. 1992. Reduction of *Campylobacter jejuni* colonization of chicks by cecum-colonizing bacteria producing anti-*C. jejuni* metabolites. *Appl. Environ. Microbiol.* 58:664-670.

Scheuplein, R.J. 1990. *Food-Borne Carcinogenic Risk.* (August Mimeograph) Food and Drug Administration, Washington, DC.

Schmidt, G.R. 1999. Detection of central nervous system tissue in beef cattle after disruption by different types of captive bolt stunners. *Proceedings of AMI Stunning/Handling Conference,* (Kansas City, MO) pages 1-3.

Schnell, T.D., J.N. Sofos, J.B. Morgan, M.J. Aaronson, J.D. Tatum and G.C. Smith. 1997. Pesticide residues in beef tissues from cattle fed fruits, vegetables and their byproducts. *J. Muscle Foods* 8:173-183.

Schnell, T.D., G.C. Smith, M.J. Aaronson, J.N. Sofos, J.D. Tatum and J.B. Morgan. 1995a. No Significant Pesticide Residues By Feeding Fruits, Vegetables To Cattle. *Meat Science Research Update.* (February/March Issue) Volume 2, Number 1) National Livestock and Meat Board, Chicago, IL.

Schnell, T.D., J.N. Sofos, V.G. Littlefield, J.B. Morgan, B.M. Gorman, R.P. Clayton and G.C. Smith. 1995b. Effects of postexsanguination dehairing on the microbial load and visual cleanliness of beef carcasses. *J. Food Protection* 58:1297-1302.

Scott, T., C. Wilson, D. Bailey, T. Klopfenstein, T. Milton, R. Moxley, D. Smith, J. Gray and L. Hungerford. 2000. Influence of diet on total and acid resistant *E. coli* and colonic pH. 2000 Nebraska Beef Report. pages 39-41. University of Nebraska, Lincoln, NE.

- Siragusa, G.R., J.S. Dickson and E.K. Daniels. 1993. Isolation of *Listeria* spp. from feces of feedlot cattle. *J. Food Protection* 56:102-105, 109.
- SMA. 2000a. Prototype provides instant *E. coli* detection. *InfoMeat*. (June 12 Issue) page 3.
- SMA. 2000b. Advisory committee recommends *Listeria* testing. *Info Meat*. (May 30 Issue) page 1.
- SMA. 2000c. USDA launches new food safety education campaign. *Info Meat*. (May 30 Issue) page 2.
- Smith, D., T. Milton, R. Moxley, J. Gray, L. Hungerford, D. Bailey, T. Scott and T. Klopfenstein. 2000. Cleaning coliform bacteria from feedlot water tanks. 2000 Nebraska Beef Report. pages 77-79. University of Nebraska, Lincoln, NE.
- Smith DeWaal, C. 2000. FSIS policy on *E. coli* O157:H7: Reviewing the role of pathogen testing in HACCP. pages 1-9. Center for Science in the Public Interest, Washington, DC.
- Smith, G.C. 2000a. Bacteriological/Chemical Safety: Meat As A Food (2000). Presented at the Minnesota Dietetics Association Annual Conference (Minneapolis, MN).
- Smith, G.C. 2000b. Meat scientist urges research that could improve food safety on farms and feedlots. *Western Livestock Journal, North American Bull Guide—Section II*, pages 102-103.
- Smith, G.C. 1998. Reducing microbial contamination in the plant: Implementing HACCP and technological alternatives. *Proceedings of the 1998 World Food and Sustainable Agriculture Symposium*, University of Illinois, Urbana, IL.
- Smith, G.C. 1997. Consumer acceptance—domestically and internationally—of beef from cattle produced with use of growth promotant implants. *Proc. Symposium Impact of Implants on Performance and Carcass Value of Beef Cattle*. P-957, pages 182-192. Oklahoma State University, Stillwater, OK.
- Smith, G.C. 1996. The role of bovine practitioners in assuring the safety of beef. *American Association of Bovine Practitioners, The Bovine Proceedings*. pages 3-9.
- Smith, G.C. 1995. Food Safety. *Meat Minutes* (January Issue). Meat Science Group, Department of Animal Sciences, Colorado State University, Fort Collins, CO.
- Smith, G.C. 1992. Position of the USA Regarding Acceptability of Proper Administration of Certain Specific Anabolic and Xenobiotic Agents To Beef Cattle and Relative To The Safety Of Muscle/Organ Meats, From Such Animals, For Human Consumption. Prepared for presentation by officials of the U.S. Meat Export Federation to officials of the European Economic Community (EEC) in London, England on July 6, 1992. Center For Red Meat Safety, Colorado State University, Fort Collins, CO.

- Smith, M.G. 1992. Destruction of bacteria on fresh meat by hot water. *Epidemiol. Infect.* 109:491-496.
- Smith, G.C. and J.B. Morgan. 1999. Understanding today's customers and marketing to their needs; Industry trends and projections for the future; Current and future food safety issues—Staying ahead (1998-1999). Wakefern Food Corporation Seminar, Edison, NJ (September 14-15, 1999).
- Smith, G.C. and J.B. Morgan. 1997. Technology: Changing the meat you sell. Proceedings of the AMI/FMI/FDI/NGA Meat Marketing Conference (Nashville, TN) pages 34-52.
- Smith, G.C. and J.N. Sofos. 1994. The scientist in the meat department and building a HACCP program. AMI/FMI Meat Marketing Conference (April 19; Boston, MA), American Meat Institute, Arlington, VA.
- Smith, G.C., K.E. Belk and J.N. Sofos. 1999. Microbial Mapping III. Determining microbiological counts on beef cuts and trimmings during/following fabrication, with and without microbiological interventions. Colorado State University for National Cattlemen's Beef Association. Center for Red Meat Safety, Colorado State University, Fort Collins, CO.
- Smith, G.C., J.N. Sofos and K.E. Belk. 1998. Interventions from the farm or feedlot to the food store: Minimizing microbiological food safety risks. Proceedings of All-Tech's Fourteenth Annual Symposium on Biotechnology In The Food Industry. Nottingham University Press, Nottingham, UK.
- Smith, G.C., K.L. Heaton, J.N. Sofos, J.D. Tatum, M.J. Aaronson and R.P. Clayton. 1997. Residues of antibiotics, hormones and pesticides in conventional, natural and organic beef. *Journal of Muscle Foods* 8:157-172.
- Smith, G.C., J.N. Sofos, J.B. Morgan, J.O. Reagan, G.R. Acuff, D.R. Buege, J.S. Dickson, C.L. Kastner and R. Nickelson, II. 1995. Fecal-Material Removal and Bacterial-Count Reduction by Trimming and/or Spray-Washing of Beef External-Fat Surfaces. Proceedings of the Conference On New Technology to Improve Food Safety (April 12, 1995; Chicago IL) Food Safety and Inspection Service, U.S. Department of Agriculture, Washington, DC.
- Smith, G.C., J.N. Sofos, M.J. Aaronson, J.B. Morgan, J.D. Tatum and G.R. Schmidt. 1994a. Incidence of pesticide residues and residues of chemicals specified for testing in U.S. beef by the European Community. *Journal of Muscle Foods* 5:271-284.
- Smith, G.C., J.N. Sofos, J.B. Morgan, M.J. Aaronson, R.P. Clayton, D.K. Jones, J.D. Tatum and G.R. Schmidt. 1994b. Ensuring the Safety of the Meat Supply. Proceedings of the Reciprocal Meat Conference. pp. 1-13. American Meat Science Association, Chicago, IL.

Smith, G.C., J.N. Sofos, J.B. Morgan, M.J. Aaronson, R.P. Clayton, D.K. Jones, J.D. Tatum and G.R. Schmidt. 1994c. Ensuring the safety of the meat supply--chemical residues in "conventional," "natural" and "organic" beef. Final Report to the National Live Stock and Meat Board, Center for Red Meat Safety, Department of Animal Sciences, Colorado State University, Fort Collins, CO and Warren Analytical Laboratory and Product Integrity and Food Safety Division, ConAgra Red Meat Companies, Inc., Greeley, CO.

Smith, G.C., J.N. Sofos, J.B. Morgan, J.O. Reagan, G.R. Acuff, D.R. Buege, J.S. Dickson, C.L. Kastner and R. Nickelson, II. 1994d. Fecal-Material Removal and Bacterial-Count Reduction by Trimming and/or Spray-Washing of Beef External-Fat Surfaces. Proceedings of the Meat Industry Research Conference. pp. 1-17. American Meat Institute, Washington, DC.

Smith, G.C., K.L. Heaton, J.N. Sofos, M.J. Aaronson, J.B. Morgan, J.D. Tatum and R.P. Clayton. 1993. Characterization and Quantification of Chlorinated Hydrocarbons and Organophosphate Pesticides in Pork Products Produced and Sold in the USA. Final Report to the National Live Stock and Meat Board. Center For Red Meat Safety, Department of Animal Sciences, Colorado State University, Fort Collins, CO.

Smith, G.C., J.N. Sofos, M.J. Aaronson, J.B. Morgan, J.D. Tatum and G.R. Schmidt. 1992. Incidence of Pesticide Residues and of Residues of Chemicals Specified For Testing in U.S. Beef by the European Community. Final Report to the National Live Stock and Meat Board. Center For Red Meat Safety, Department of Animal Sciences, Colorado State University, Fort Collins, CO.

Sofos, J.N. 1994. Microbial growth and its control in meat, poultry and fish. pages 359-403. *In* Quality Attributes and Their Measurement in Meat, Poultry and Fish Products. A.M. Pearson and T.R. Dutson (Eds.) Blackie Academic and Professional, Glasgow.

Sofos, J.N. 1993. The HACCP system in meat processing and inspection in the United States. *Meat Focus International* 2:217-225.

Sofos, J.N. and G.C. Smith. 1998. Nonacid meat decontamination technologies: Model studies and commercial applications. *Int. J. Food Microbiol.* 44(3):171-188.

Sofos, J.N. and G.C. Smith. 1997. Meat decontamination technologies: Model studies and commercial applications. *Proceedings of the World Congress on Food Hygiene.* page 269. The Hague, Netherlands.

Sofos, J.N. and G.C. Smith. 1995. Preliminary Studies To Initiate Development Of A Model With Multiple Hurdles For The Reduction Of The Probability Of Contamination Of Beef Carcasses With Bacterial Pathogens. A Research Project being conducted by Center For Red Meat Safety, Colorado State University, Fort Collins, CO.

Sofos, J.N. and G.C. Smith. 1993. The new headache of the U.S. meat industry: *E. coli* O157:H7. *Meat Focus International* 2:317-325.

Sofos, J.N., K.E. Belk and G.C. Smith. 1998. Minimizing microbiological food safety risks: Potential for preslaughter (preharvest) interventions. A White Paper prepared for the National Cattlemen's Beef Association by Center for Red Meat Safety, Colorado State University, Fort Collins, CO

Sofos, J.N., J.B. Morgan and G.C. Smith. 1993. Meat Safety Facts and Guide. *Meat Minutes* (September Issue). Meat Science Group, Department of Animal Sciences, Colorado State University, Fort Collins, CO.

Sofos, J.N., L. Holcomb, J.D. Tatum, R.P. Clayton, J.B. Morgan, S. Sanders, J.D. Eilers, M.J. Aaronson and G.C. Smith. 1992. Model H.A.C.C.P. Plans For Smaller Meat Plants. Technical Bulletin No. CRMS-7. Center For Red Meat Safety, Department of Animal Sciences, Colorado State University, Fort Collins, CO.

Sofos, J.N., S.L. Kochevar, G.R. Bellinger, D.R. Buege, D.D. Hancock, S.C. Ingham, J.B. Morgan, J.O. Reagan and G.C. Smith. 1999a. Sources and extent of microbiological contamination in seven U.S. slaughtering plants. *J. Food Prot.* 62:140-145.

Sofos, J.N., S.L. Kochevar, J.O. Reagan and G.C. Smith. 1999b. Extent of beef carcass contamination with *Escherichia coli* and probabilities of passing United States regulatory criteria. *J. Food Prot.* 62:234-238.

Sofos, J.N., S.L. Kochevar, J.O. Reagan and G.C. Smith. 1999c. Incidence of *Salmonella* on beef carcasses relating to the U.S. Meat and Poultry Inspection regulations. *J. Food Prot.* 62:467-473.

Spring, P. 1995. Competitive exclusion of *Salmonella* using bacterial cultures and oligosaccharides. Proceedings of the 11<sup>th</sup> Annual Symposium on Biotechnology in the Feed Industry. pages 383-388. Nottingham University Press, Nottingham, UK.

Steinman, D. 1990. *Diet For A Poisoned Planet*. Harmony Books, Crown Publishers, Inc. New York, NY.

Stern, N.J., J.S. Bailey and N.A. Cox. 1996. MCE to control *Campylobacter* in turkeys and broiler chickens. *Southern Poultry Science Society* 17:4(Abstract).

Sugarman, Carole. 1997. Building a safer burger. Critics question cattlemen's role. *The Washington Post*. (September 3 Issue) pages E1-E10.

Suther, S. 1997. The *E. coli* buck stops at your gate. *Beef Today*. (September Issue) page 3.

- The Denver Post. 1997a. Mind-Body Link Strong As Ever. The Denver Post (Denver, CO) (May 1 Issue).
- The Denver Post. 1997b. Farming May Reap Fertility Problems. The Denver Post (Denver, CO) (April 27 Issue).
- The Florida Cattleman. 1997. Consumers, Influencers View Cattlemen Positively. The Florida Cattlemen. (Kissimmee, FL) (February Issue).
- Todd, E.C.D. 1989. Preliminary Estimates of Costs of Foodborne Disease in the United States. Journal of Food Protection. 52:595-601.
- Usborne, W.R. 1994. Natural vs. Regular Beef. Mimeographed Report from the University of Guelph. Guelph, Ontario, Canada.
- USA TODAY. 1999. Mankind has dangerously miscalculated the threat posed by bacteria and viruses. (June 20 Issue) page D-1.
- USDA. 1996. Domestic Residue Program Results--1994. USDA-FSIS, Washington, DC.
- USDA. 1994. Domestic Residue Program Results--1993. USDA-FSIS, Washington, DC.
- USDA. 1993. Compound Evaluation and Analytical Capability--National Residue Program Plan. USDA-FSIS, Washington, DC.
- USDA. 1982. Policy Memo 055:Natural Claims, USDA-FSIS, Washington, DC.
- Van Donkersgoed, J., T. Graham and V. Gannon. 1999. The prevalence of verotoxins, *E. coli* O157:H7 and *Salmonella* in the feces and rumen of cattle at processing. Canadian Vet. J. 40:332-338.
- Wang, G.D., T. Zhao and M.P. Doyle. 1996. Fate of Enterohemorrhagic *E. coli* O157:H7 in bovine feces. Appl. Environ. Microbiol. 62:2567-2570.
- Ware, L.M., M.L. Kain, J.N. Sofos, K.E. Belk and G.C. Smith. 1999. Comparison of sponging and excising as sampling procedures for microbiological analysis of fresh beef-carcass tissue. J. Food. Prot. 62:1255-1259.
- Wells, J.G., L.D. Shipman, K.D. Greene, E.G. Sowers, J.H. Green, D.N. Cameron, F.P. Downes, M.L. Martin, P.M. Griffin and S.M. Ostroff. 1991. Isolation of *E. coli* serotype O157:H7 and other Shiga-like toxin-producing *E. coli* from dairy cattle. J. Clin. Microbiol. 29:985-989.
- Western Livestock Journal. 1999. Research reveals surprises about *E. coli* O157:H7. (December 6 Issue) page 4.

Wheeler, S.R. 1997. *E. coli* triggers meat recall. The Denver Post (August 13 Issue) page B-1.

White, P.L., W. Schlosser, C.E. Benson, C. Maddox and A.Hogue. 1997. Environmental survey by manure drag sampling for *Salmonella enteritidis* in chicken layer houses. J. Food Protection 60:1189-1193.

WHO. 1997. Prevention and control of enterohemorrhagic *Escherichia coli* (EHEC) infections. Food Safety Unit, Programme of Food Safety and Food Aid. World Health Organization, Geneva, Switzerland.

Wilkinson, B. 1991. Coleman Advertising Campaign in Boston. National Cattlemen's Association, Issue Update. (May Issue) page 5.

Wilson, D. 1998. Factoid watch: Food poisonings phony figure. Columbia Journalism Review. (May/June Issue) pages 47-61.

Worfel, R.C., J.N. Sofos, G.C. Smith, J.B. Morgan and G.R. Schmidt. 1995. Microbial contamination of condensates formed on superstructures of wood and other materials in meat plants. Dairy, Food and Environmental Sanitation 15:430-434.

Worfel, R.C., J.N. Sofos, G.C. Smith and G.R. Schmidt. 1996. Airborne contamination in beef slaughtering-dressing plants with different layouts. Dairy, Food and Environmental Sanitation 16:440-443.

World Wide Web. 1999. French primate disaster. From the March 30, 1999 Proceedings of the National Academy of Sciences and Webmaster Opinion.

Zerby, H.N., K.E. Belk, M. Hardin, J.N. Sofos and G.C. Smith. 1999a. Levels of microbiological contamination of pork carcasses during slaughter. Annual Meeting, International Association of Milk, Food and Environmental Sanitarians, 86:T11.

Zerby, H.N., K.E. Belk, M. Hardin, W. Lloyd, J.N. Sofos and G.C. Smith. 1999b. Extent of microbiological contamination on pork variety meats. Annual Meeting, International Association of Milk, Food and Environmental Sanitarians, 86:T12.

Zerby, H.N., K.E. Belk, J.N. Sofos, G.R. Schmidt, G.R. Bellinger, A.A. Pape, M.W. Hardin, W.L. Lloyd and G.C. Smith. 1998a. Microbiological Sampling Of Hog Carcasses. Final Report to the National Pork Producers Council. Center for Red Meat Safety, Colorado State University, Fort Collins, CO.

Zerby, H.N., R.J. Delmore, K.E. Belk, J.N. Sofos, G.R. Schmidt, G.R. Bellinger, A.A. Pape, M.W. Hardin, W.L. Lloyd and G.C. Smith. 1998b. Microbiological Profile Of Pork Variety

Meats. Final Report to the U.S. Meat Export Federation and to the National Pork Producers Council. Center for Red Meat Safety, Colorado State University, Fort Collins, CO.

Zerby, H.N., R. Murphree, K.E. Belk, J.N. Sofos, G.R. Schmidt, M.W. Hardin, W.L. Lloyd and G.C. Smith. 1998c. Intervention Strategies For Reducing Microbiological Contamination On Pork Variety Meats. Final Report to the U.S. Meat Export Federation and to the National Pork Producers Council. Center for Red Meat Safety, Colorado State University, Fort Collins, CO.

Zhao, T., M.P. Doyle, J. Shere and L. Garber. 1995. Prevalence of Enterohemorrhagic *Escherichia coli* O157:H7 in a survey of dairy herds. Appl. Environ. Microbiol. 61:1290-1293.