

SAFETY OF FOOD OF RUMINANT ORIGIN

G.C. Smith, J.N. Sofos, K.E. Belk, J.A. Scanga and J.D. Tatum

Colorado State University, Fort Collins, Colorado USA

Abstract

Uruguay and the USA must assure that food of ruminant origin, for domestic and international consumers, is chemically and bacteriologically safe. International rules for food safety, under the World Trade Organization's Sanitary-Phytosanitary Agreement, use science-based risk assessment and standards set by Codex Alimentarius. Protection of USA consumers from unsafe meat is provided via government regulation and producer/processor self-regulation. Government food-safety regulations involve Environmental Protection Agency (EPA), Food and Drug Administration (FDA) and U.S. Department of Agriculture (USDA). USDA residue monitoring program minimizes chemical residues in meat, and meat inspection program assures bacteriological safety. "Quality Assurance" programs unite producers and packers to meet consumer expectations about meat quality, wholesomeness and safety; in the USA, 98% of feedlot cattle and 90% of cull cattle come from states with Beef Quality Assurance (BQA) programs. National audits (e.g., Injection-Site Lesion Audits, annually since 1991; National Fed Beef Quality Audits, 1991, 1995, 2000; Strategic Alliance Field Study, 1993; National Veal Quality Audit, 1998; National Market Cow And Bull Audits, 1994, 1999) and the International Beef Quality Audit (1994) provide assessments of quality and safety of beef. USDA meat inspection regulations (PR; HACCP; Final Rule, 1996) augmented by packer/processor Pre-Requisite Programs, GMPs, QA/QC Programs and Multiple-Hurdle Decontamination Interventions help assure microbiological safety. Public health is protected at end-user level by FDA (through its Food Code), USDA (by retail microbiological testing), associations (National Restaurant Association's "ServSafe" program) and company HACCP programs (Kroger, Sysco and Burger King). Combined efforts of producers, packers, processors and retailers are essential to assure chemical and bacteriological safety of food of ruminant origin.

Introduction

Countries like Uruguay and the USA are obliged to assure that food of ruminant origin, sold to domestic and international consumers, is chemically and bacteriologically safe. International rules for food safety, under the World Trade Organization's Sanitary-Phytosanitary Agreement, rely upon science-based risk assessment and scientific standards set by Codex Alimentarius. In the USA, protection of consumers from unsafe milk and meat (foods of ruminant origin) is provided via government regulation and producer/processor self-regulation. Government food-safety regulations involve activities of the Environmental Protection Agency (EPA), the Food and Drug Administration (FDA) and the U.S. Department of Agriculture (USDA). USDA administers monitoring and surveillance programs to minimize chemical residues in meat, and inspection programs to assure wholesomeness and bacteriological safety of meat. "Quality Assurance" programs unite animal scientists, veterinarians, feed suppliers, animal health companies, packers and retailers with livestock producers to meet consumer expectations about meat quality, wholesomeness and safety.

Chemical Safety

Livestock may be exposed, during their life-cycle, to: (1) Pesticides (directly applied or when treated crops become components of animal feed), (2) Drugs (used to treat disease, to prevent illness or to enhance production or performance) and (3) Environmental Contaminants (chlorinated hydrocarbons, chlorinated organophosphates, heavy metals, aflatoxins—not given or fed). Producers in the USA are allowed to use approved drugs, vaccines and chemical compounds so long as there are residue controls and residue monitoring programs. Federal mechanics of food safety regulation in the USA are these: (1) EPA—approves pesticides and chemicals and sets tolerances for residues, (2) FDA—approves animal drugs and sets tolerances for residues, and (3) USDA—administers the meat and poultry inspection program and enforces tolerances for residues, set by EPA and FDA, in meat and poultry products (Smith *et al.*, 2000a).

The federal food safety apparatus for pesticides in foods consists of EPA registering pesticides and setting tolerances (based upon FIFRA—Federal Insecticide, Fungicide and Rodenticide Act—and FFDCa—Federal Food, Drug and Cosmetic Act) with FDA in charge of monitoring/enforcement in all foods except fresh meat and poultry and USDA in charge of monitoring/enforcement in fresh meat and poultry (Smith *et al.*, 2000a). FDA administers the Pesticide Residue Monitoring Program conducting Animal Feed Pesticide Residue Monitoring plus the All Foods Study and the Total Diet Study on an annual basis. In addition, FDA approves animal drugs, specifies their use, sets tolerances for their residues in food and monitors levels of antibiotic residue in food-producing animals' tissue (through the FDA Center for Veterinary Medicine).

Residues of animal drugs, pesticides and environmental contaminants in fresh meat and poultry are monitored by Food Safety and Inspection Services (FSIS) of USDA through its National Residue Program (NRP). The NRP is designed to detect, with 95% confidence, residue problems if they occur at a frequency of more than 1% in one or more of a major species or production-class group (FSIS-USDA, 1997). Results of the monitoring function of the NRP in 1979 revealed that 3.2% (1 in 31) of tissue-samples from livestock and 0.7% (1 in 143) of tissue-samples from poultry contained violative chemical residues; by 1990, 0.3% (1 in 333) and 0.2% (1 in 500) of tissue-samples from meat and poultry, respectively, collected and tested in the National Residue Program, contained violative chemical residues (FSIS-USDA, 1979, 1990).

Results of the NRP are reported in FSIS-USDA publications entitled “Domestic Residue Data Book, National Residue Program (year data were collected)” (e.g., FSIS-USDA, 1997) and details of what is to be done in the NRP during a given year reported in FSIS-USDA publications entitled “National Residue Program Plan (year in which data are to be collected) (e.g., FSIS-USDA, 1999).” For the first years of the existence of the NRP, FSIS-USDA was quite punctual in releasing results of each annual NRP, usually within six to nine months after the close of the previous calendar year (Smith *et al.*, 2000a). Since 1994, perhaps because interest at FSIS-USDA shifted toward bacteriological safety and away from chemical-residue monitoring, annual NRP results have not been released during the next calendar year (e.g., 1994 results were released in 1996; 1995 results were released in 1997; 1996 results were released in 1998; 1997 results were released in 1999). Neither NRP results for 1998 nor NRP results for 1999 had been released on May 15, 2000; so, results discussed here will focus on 1996 and 1997 NRP results. National Cattlemen's Beef Association, at its annual convention in 1999, passed a resolution

asking that FSIS-USDA issue results of the NRP on a more punctual basis (Smith *et al.*, 2000a). Quality Assurance programs of the NCBA and of states that have QA programs use results of the NRP to develop educational programs for cattlemen, dairymen and veal producers and must have current information to do that.

Results of the FSIS-USDA National Residue Program for combined meat and poultry samples (FSIS-USDA, 1991, 1992, 1993, 1994, 1995, 1996, 1997) revealed that, among monitoring samples in 1991, 0.26% showed violative concentrations of chemical residues; comparable data for 1992 (0.29%), 1993 (0.26%), 1994 (0.18%), 1995 (0.21%), 1996 (0.16%) and 1997 (0.27%) suggest that the average annual incidence, during this decade, of violative chemical residues in meat and poultry tissues is about 0.23% (1 in 435).

Focusing on NRP results for 1996 and 1997 (the last two years for which data are available), these are summaries of the findings from the National Residue Program: (a) The 1996 NRP results (FSIS-USDA, 1996) involved 31,748 monitoring sample units tested for 51 chemical compounds; 50 sample units (0.16% incidence) had violative residues. Of violative residues, 17 were sulfonamides, 14 were antibiotics, 7 were chlorinated hydrocarbon or chlorinated organophosphate pesticides, 6 were ivermectin and 6 were arsenic. (b) The 1997 NRP results (FSIS-USDA, 1997) involved 26,626 monitoring sample units tested for 57 chemical compounds; 72 sample units (0.27% incidence) had violative residues. Of violative residues, 20 were sulfonamides, 32 were antibiotics, 9 were chlorinated hydrocarbon or chlorinated organophosphate pesticides, 6 were ivermectin and 5 were arsenic.

Further detail regarding the FSIS-USDA Domestic Residue Monitoring Program Results for 1996 and 1997 (FSIS-USDA, 1996, 1997) is provided in Tables 1 and 2, respectively. In 1996, there were no violative chemical residues in tissue-samples from market beef cows or heifers but some tissue-samples from both market bulls and market dairy cows had violative residues of ivermectin and some tissue-samples from steers had violative residues of chlorinated hydrocarbons (Table 1). In 1997, there were violative residues of chlorinated hydrocarbon and/or chlorinated organophosphate pesticides in tissue-samples from market bulls, of antibiotics in tissue-samples from market beef cows, of antibiotics and sulfonamides in tissue-samples from market dairy cows, and of sulfonamides in tissue-samples from heifers but there were no violative residues of any kind in tissue-samples from steers (Table 2).

The NRP helps prevent the marketing of animals containing violative residues of pesticides, animal drugs or potentially hazardous chemicals through its monitoring and enforcement, sample collection and testing activities (Smith *et al.*, 2000a). In 1996, 31,748 sample units were analyzed in monitoring national incidence of violative chemical residues and 235,495 sample units were analyzed in enforcement (based on clinical signs and previous herd-history) activities involving in-plant testing (rapid screening) plus laboratory testing for violative chemical residues (Table 3). Results of enforcement testing of cattle tissue-samples during 1996 (FSIS-USDA, 1996) revealed that 266 of 35,177 Swab Test On Premises (STOP) were positive, 1,022 of 154,727 Fast Antimicrobial Screen Test (FAST) were positive, 8 of 65 cattle tissue-samples tested in the laboratory for antibiotics were positive and 12 of 18 cattle tissue-samples tested in the laboratory for sulfonamides were positive (Table 3). In 1997, 26,626 sample units were analyzed in monitoring national incidence of violative chemical residues and 165,328 sample

units were analyzed in enforcement activities involving in-plant testing (rapid screening) plus laboratory testing for violative chemical residues (Table 4). Results of enforcement testing of cattle samples during 1997 (FSIS-USDA, 1997) revealed that 135 of 27,107 STOP were positive, 384 of 90,487 FAST were positive, 5 of 71 cattle tissue-samples tested in the laboratory for antibiotics and 3 of 13 cattle tissue-samples tested in the laboratory for sulfonamides were positive (Table 4).

Rank of violative residues of antibiotics and sulfonamides from NRP enforcement testing in 1996 (Smith *et al.*, 2000a) is presented in Table 5. Penicillin, oxytetracycline, tetracycline, streptomycin and gentamicin were the problematic antibiotics while sulfamethazine, sulfadimethoxine, sulfadiazine, sulfamethoxazole and sulfathiazole were the most frequently misused sulfonamides in 1996. Rank of violative residues of antibiotics and sulfonamides from NRP enforcement testing is presented in Table 6. Penicillin, gentamicin, oxytetracycline, streptomycin and tetracycline were again (though in a different rank order) the five most problematic antibiotics while sulfadimethoxine, sulfamethazine, sulfathiazole and sulfamethoxazole were the most prevalent sulfonamides found in tissue-samples at violative levels in 1997 (Table 6).

Numbers of total (monitoring plus enforcement samples) violative residues of antibiotics and sulfonamides from results of the 1996 and 1997 NRP (Smith *et al.*, 2000a) are presented in Table 7. For all cattle combined in 1996, the highest incidences of violative residues for antibiotics were for penicillin, oxytetracycline, streptomycin, tetracycline and gentamicin and for sulfonamides were for sulfadimethoxine, sulfamethazine, sulfamethoxazole and sulfathiazole (Table 6). In 1997, most of the violative residues for antibiotics and sulfonamides occurred in tissue-samples from dairy cows; beef cow tissue-samples had the second highest incidences of violative residues of antibiotics and were tied for second, with tissue-samples from steers, in incidence of violative residues of sulfonamides. As was the case in 1996, violative residues of antibiotics in 1997 were highest for penicillin, gentamicin, oxytetracycline, streptomycin and tetracycline and the highest incidences of violative residues for sulfonamides were for sulfadimethoxine and sulfamethazine (Table 7).

According to Food Regulation Weekly (1999), FSIS-USDA is toughening its testing procedures for antibiotic residues in cattle. Previously, animals were selected for testing based on pre-slaughter evaluation only (“down,” disabled, recent surgery). Craig Shultz, DVM, undertook surveillance of cattle with high-risk, postmortem pathology; dramatically higher number of antibiotic residues were found (Food Regulation Weekly, 1999). He also found extreme variations in residue surveillance among geographical regions. As a result, effective August 9, 1999, field veterinarians were instructed to check for residues in animals, after slaughter, with the following twelve conditions (Food Regulation Weekly, 1999): (1) downers, (2) suspects, (3) mastitis, (4) pneumonia, (5) body-cavity lining inflammation, (6) heart sac lining inflammation, (7) skin inflammation, (8) twisted stomach disease, (9) septicemia, (10) pyemia, (11) injection sites, and (12) uterine infection.

In March 1991, a producer of “natural” beef launched a 12-week advertising campaign in the Boston Globe (1991) promoting the idea that “natural” beef is “pure” as opposed to the “adulterated kind” raised by cattlemen who use antibiotics or hormones, and that cattle which

have been exposed to antibiotics and hormones should be labeled as “chemical cattle” (Smith *et al.*, 1994b). The primary problem with such ads is that they have the potential to raise questions in consumers’ minds regarding the safety and wholesomeness of the generic beef supply (Wilkinson, 1991). In 1982, the USDA approved use of the term “natural” for beef that is minimally processed and that contains no additives—a definition that allows all conventionally prepared fresh beef to bear the “natural” label (USDA, 1982).

In efforts, though, to position “natural” beef uniquely in the marketplace, overzealous marketers (Smith *et al.*, 1994b), have argued that the term connotes beef from cattle raised in specific geographic locations (e.g., “up high in the mountains, way up at the head of the creek, where the water is clean and pure,” Boston Globe, 1991), on uncontaminated land (e.g., “on rangeland untainted by pesticides or fertilizers,” Boston Globe, 1991), never treated for disease or illness (e.g., “kept off drugs,” Boston Globe, 1991), containing no additives (e.g., “totally free of chemical additives,” Boston Globe, 1991), with a unique taste (e.g., “it tastes clean, like all beef would taste if man hadn’t come along and messed with it,” Boston Globe, 1991) and produced differently during finishing (e.g., not given “growth hormones, not unlike the steroids employed by athletes”; not given “antibiotics to prevent illness or to treat it”; “chemical cattle” gain faster but “a large proportion of that is just fat, which you don’t want anyway,” Boston Globe, 1991).

A memorandum (ECD No. 90-22-ECC), sent by FSIS/USDA on March 29, 1990 to slaughter plants in the U.S. that were approved for export by the European Economic Community (EEC), detailed guidelines involved with the 1990 EEC Residue Testing Program for meat, and described “an expanded Residue Testing Program” consisting of five requirements; requirement number four identified 10 “residue compounds” (compounds/compound classes/elements) for which residue levels must be determined for meat to be exported to EEC countries (Fetzner, 1990). For dairy/beef breeding cows, the “residue compounds” were listed as; (a) diethylstilbestrol, (b) zeranol, (c) thyrostat(s), (d) trenbolone acetate, (e) melengestrol acetate, (f) tranquilizer(s), (g) beta-blocker(s), (h) lead, (i) cadmium and (j) clenbuterol; for “nontreated beef” (presumably feedlot steers and heifers that had not been given growth-promotants or heat-suppressants), no analyses were required for items a, b, d, or e, above (Fetzner, 1990).

The Center for Red Meat Safety at Colorado State University has conducted three studies to determine the safety of U.S. beef relative to presence/absence of violative chemical residues as defined by the EU and/or by the EPA, FDA or USDA of the USA. Smith *et al.* (1994c) studied muscle, fat, kidney and liver tissues collected from steers, heifers and cows at eight packing plants in four states from “organic,” “natural,” “conventional,” “realizer” (chronically ill) and “cull cow” cattle. Results of that study (Smith *et al.*, 1994c) are presented in Table 8. There were 3 sets of samples (muscle, fat, liver and kidney) from “organic” steers and heifers, 3 sets of samples from “natural” steers and heifers, 8 sets of samples from “conventional” steers and heifers, 3 sets of samples from “realizer” (chronically ill) steers and heifers and 3 sets of samples from “cull cow” (both beef and dairy) cattle. Analyses revealed no violative residues of anabolic steroids/xenobiotics (diethylstilbestrol, zeranol, trenbolone acetate, melengestrol acetate, clenbuterol), heavy metals (lead, cadmium), stress reducers (carazolol, azaperone, propiopromazine), thyrostats/sulfa-drugs (sulfamethazine, sulfadimethoxine, sulfabromomethazine, sulfaethoxyipyridazine, sulfachloropyridazine, sulfamethoxyipyridazine) and chlorinated hydrocarbon and organophosphate pesticides (hexachlorobenzene, lindane,

heptachlor, aldrin, 4,4'-DDT, 4,4'-DDD, 4,4'-DDE, endrin, mirex, ethyl parathion, methyl parathion, pirimiphos-methyl, alpha-BHC, beta-BHC, delta-BHC, heptachlor epoxide, methoxychlor, ethion, chlorpyrifos, malathion, ronnel, trithion, dieldrin, diazinon, disyston).

The second study (Smith *et al.*, 1997a) involved muscle, fat, kidney and liver; the tissues were collected from steers and heifers at 8 packing plants, 4 retail markets and 1 mail-order meat business in the USA and included “organic,” “natural” and “conventional” beef. Results of that study are presented in Table 9. There were 24 muscle, 20 fat, 13 liver and 6 kidney samples of “organic” beef; 20 muscle, 20 fat, 13 liver and 10 kidney samples of “natural” beef; and, 20 muscle, 20 fat, 10 liver and 10 kidney samples of “conventional” beef. Analyses (Smith *et al.*, 1997a) revealed no violative residues of anabolic steroids (estradiol, testosterone, progesterone) xenobiotics (zeranol, melengestrol acetate, trenbolone acetate), beta-lactam antibiotics (penicillin, tylosin, erythromycin), sulfa-drugs (sulfathiazole, sulfamethazine, sulfadimethoxine, sulfaquinoxaline), tetracycline antibiotics (tetracycline, oxytetracycline, chlortetracycline) and chlorinated hydrocarbon and organophosphate pesticides (lindane, heptachlor, aldrin, 4,4'-DDT, 4,4'-DDD, 4,4'-DDE, ethyl parathion, methyl parathion, pirimiphos-methyl, alpha-BHC, beta-BHC, delta-BHC, heptachlor epoxide, methoxychlor, ethion, chlorpyrifos, malathion, ronnel, trithion, dieldrin, disyston). There were 6 violative residues of pesticides in livers from “organic” beef (3 of hexachlorobenzene; 3 of diazinon), 6 violative residues of pesticides in livers from “natural” beef (2 of hexachlorobenzene; 1 of endrin, 3 of diazinon) and 3 violative residues of pesticides in livers from “conventional” beef (2 of hexachlorobenzene; 1 of mirex).

A Canadian study by 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. And, Potthast (1993) concluded, based upon studies of beef and pork from the European Union, that: (a) residues of environmental contaminants (i.e., lead, mercury, cadmium) were hardly ever found, (b) pesticides were at concentrations considerably below established limits such that complaints about pesticide contamination are becoming more and more rare, (c) toxic dioxins, which arise mostly from combustion processes, have not—so far—been detected in red meat, and (d) random sampling and residue testing for drugs, antibiotics, anabolics and thyreostats effectively protect the consumer and assure that chemical residues in meat will not be harmful to the public health.

In the third study conducted at Colorado State University (Schnell *et al.*, 1997), muscle, adipose, liver and kidney tissue samples were collected from cattle fed potato processing residue (n=20), apple pomace (n=20), pear pomace (n=10), cannery corn waste (n=20), cotton gin trash (n=20), tomato pomace plus almond hulls (n=16), dried grape solids (n=10) or dried citrus pulp (n=6) as well as from control cattle which were not fed fruits, vegetables or their byproducts (n=21). 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 (Schnell *et al.*, 1997).

Quality Assurance Programs

The NCBA's Beef Quality Assurance (BQA) program started in 1986 "to address the growing issue of consumer concern about the safety and wholesomeness of beef" (Smith *et al.*, 1997b); in its Consensus Points, the BQA statement of purpose says "Because consumer concerns about drug and chemical residues are a threat to the cattle industry, the industry must do something substantive about it and must develop a Quality Assurance program; industry organizations (e.g., NCBA) can help but actions by individuals within the industry are key." As it is presently constituted, Beef Quality Assurance: (a) Is the beef industry's voluntary "Quality Control" program. (b) Focuses on producer awareness and educational training. (c) Addresses the day-to-day management practices that influence the safety, quality and wholesomeness of beef and beef products. (d) Focuses on residue avoidance, prudent use of animal health products, correcting quality non-conformance and utilization of science-based "Best Management Practices" (Cowman, 2000).

Quality Assurance programs must know (in near-real-time) what residue problems are occurring (thus, FSIS-USDA must be more punctual in reporting the findings of the National Residue Program) and must do their best to educate cattlemen and dairymen about honoring withdrawal times, about not using off-label drugs and about using Best Management Practices to minimize the potential for occurrence of violative chemical residues in tissue-samples from meat animals (Smith *et al.*, 2000a).

National Cattlemen's Beef Association (1999b) has "National Guidelines for Beef Quality Assurance" which include sections covering:

- (A) **Feedstuffs:** (a) Maintain records of any pesticide/herbicide use on pasture or crops that could potentially lead to violative residues in grazing cattle or feedlot cattle. (b) Adequate quality control program(s) are in place for incoming feedstuffs. Program should be designed to eliminate contamination from molds, mycotoxins or chemicals of incoming feed ingredients. Supplier assurance of feed ingredient quality is recommended. (c) Suspect feedstuffs should be analyzed prior to use. (d) Ruminant-derived protein sources cannot be fed per FDA regulations. (e) Feeding by-products ingredients should be supported with sound science.
- (B) **Feed Additives and Medications:** (a) Only FDA approved medicated feed additives will be used in rations. (b) Medicated feed additives will be used in accordance with the FDA Good Manufacturing Practices (GMP) regulation. (c) Extra-label use of feed additives is illegal and strictly prohibited. (d) To avoid violative residues—withdrawal times must be strictly adhered to. (e) Where applicable, complete records must be kept when formulating or feeding medicated feed rations. (f) Records are to be kept a minimum of two years. (g) Operator will assure that all additives are withdrawn at the proper time to avoid violative residues.
- (C) **Processing/Treatment and Records:** (a) Following all FDA/USDA/EPA guidelines for product(s) utilized. (b) All products are to be used per label directions. (c) Extra-label drug use shall be kept to a minimum, and used only when prescribed by a veterinarian

working under a valid Veterinary Client Patient Relationship (VCPR). (d) Strict adherence to extended withdrawal periods (as determined by the veterinarian within the context of a valid VCPR) shall be employed. (e) Treatment records will be maintained with the following recorded: (1) Individual animal or group identification. (2) Date treated. (3) Product administered and manufacturer's lot/serial number. (4) Dosage used. (5) Route and location of administration. (6) Earliest date animal will have cleared withdrawal period. (f) When cattle are processed as a group, all cattle within the group shall be identified as such, and the following information recorded: (1) Group or lot identification. (2) Date treated. (3) Product administered and manufacturer's lot/serial number. (4) Dosage used. (5) Route and location of administration. (6) Earliest date animal will have cleared withdrawal period. (g) All cattle (fed and non-fed) shipped to slaughter will be checked by appropriate personnel to assure that animals that have been treated meet or exceed label or prescription withdrawal times for all animal health products administered. (h) All processing and treatment records should be transferred with the cattle to next production level. Prospective buyers must be informed of any cattle that have not met withdrawal times.

- (D) **Injectable Animal Health Products:** (a) All products labeled for subcutaneous (SQ) administration shall be administered SQ ahead of the point of the shoulder. (b) All products labeled for intramuscular (IM) use shall be given in the neck region only (no exceptions, regardless of age). (c) All products cause tissue damage when injected IM. Therefore all IM use should be avoided if possible. (d) Products cleared for SQ, IV or oral administration are recommended. (e) Products with low dosage rates are recommended and proper spacing practiced. (f) No more than 10 cc of product is administered per IM injection site.
- (E) **Care and Husbandry Practices:** (a) All cattle will be handled/transported in such a fashion to minimize stress, injury and/or bruising. (b) Facilities (fences, corrals, load-outs, etc.) should be inspected regularly to ensure proper care and ease of handling. (c) Strive to keep feed and water handling equipment clean. (d) Provide appropriate nutritional and feedstuffs management. (e) Strive to maintain a clean environment appropriate to the production setting (National Cattlemen's Beef Association, 1999b).

In the USA, 98% of feedlot cattle (steers and heifers) and 90% of salvage cattle (market cows and bulls) come from states (like Texas, Nebraska and Colorado) with Beef Quality Assurance programs. American families expect quality beef and USA beef producers work to provide it through programs like the Beef Quality Assurance (BQA) program (National Cattlemen's Beef Association, 1999a). Created in 1986 by the National Cattlemen's Beef Association, BQA brings together beef producers with one key goal: To produce safe, wholesome beef that provides a great eating experience every time. The BQA program's mission is to maximize consumer confidence in, and acceptance of, beef by focusing the industry's attention on Beef Quality Assurance through the use of science, research and education initiatives (National Cattlemen's Beef Association, 1999a). BQA participants are made constantly aware of problems/potentials to improve the safety and quality of their products through conduction of National Audits.

The first of the National Audits, conducted by universities for the BQA program of NCBA, was “Incidence Of Injection-Site Damage In Top Sirloin Butts From Fed Cattle” in 1990; those audits have continued through the year 2000. National Audits were initiated in 1994 for injection-site damage in round steaks from fed cattle and for injection-site damage in round steaks from market cows and bulls (Smith *et al.*, 1999). Because the results of these Audits were widely disseminated by the BQA program (Smith *et al.*, 1999), incredible progress has been made in reducing incidence of injection-site lesions (Table 10). Research sponsored by the beef checkoff program of the USA Cattlemen’s Beef Promotion and Research Board has contributed to recognition of the significance of injection-site damage in beef by cattlemen and scientists; scientific papers on this subject include those of Dexter *et al.* (1994) and George *et al.* (1995a,b, 1996, 1997).

The National Beef Quality Audit—1991 (Smith *et al.*, 1992; Lorenzen *et al.*, 1993) was “A quality audit of slaughter steers/heifers (their carcasses, cuts and dress-off/offal items) for the USA beef industry in 1991, establishing baselines for present quality shortfalls and identifying targets for desired quality levels by the year 2001.” The NBQA—1991 concluded that—To Increase The Consistency And Competitiveness Of Fed Beef—those in the industry need to (a) Attack Waste, (b) Enhance Taste, (c) Improve Management, and (d) Control Weight. Because of quality defects, \$279.82 was being lost for every steer and heifer slaughtered in the USA in 1991. The \$279.82 represents potential revenue gains if all steers and heifers had no defects, and—of that—\$219.25 was due to Excess Waste, \$28.81 was because of Inadequate Taste, \$27.26 was due to Improper Management, and \$4.50 was because of Inappropriate Weight (Smith *et al.*, 1992).

There were four targeted objectives resulting from the National Beef Quality Audit—1991 (Smith *et al.*, 1992); of those, substantial progress was made in the Strategic Alliance Field Study (National Cattlemen’s Association, 1993; Eilers *et al.*, 1993), in “Attacking Waste” (\$31.25 savings), “Improving Management” (\$8.66 savings) and “Controlling Weight” (\$3.66 savings) without losing sight of the need to “Enhance Taste.” There was also a \$20.29 credit per head for improved retail sales and caselife due to Vitamin E supplementation to the cattle while they were in the feedlot (Sanders *et al.*, 1993). But, the genius of the Strategic Alliance Field Study was not in demonstrating the means for recovery of \$63.79 of the \$279.82 loss per steer/heifer due to quality defects. The genius was that—just in time—those people who are in the beef industry proved that by working together, nothing is impossible. Quality losses due to problems with management practices were lessened in the Strategic Alliance Field Study (as compared to those in the NBQA—1991) because of decreases in quality losses associated with carcass pathology, liver pathology, tongue infection, injection-site lesions, bruises, dark-cutters and grubs/blood-splash/calloused-ribeyes/yellow fat. By working together—and doing things right—the beef industry can reduce nonconformities and gain a competitive advantage.

The International Beef Quality Audit was conducted by Colorado State University (Morgan *et al.*, 1995; Smith *et al.*, 1995) and involved interviews of 275 traders/wholesalers, retail operators, hotel and restaurant managers/chefs in 20 countries. The principle reasons foreign beef importers purchase USA beef are as follows: (1) Excellent Product Availability. Foreign customers can purchase large volumes of individual beef cuts. This means they can order the cuts they want and in the volumes they want without having to buy the “full set,” or the entire beef carcass. (2) Outstanding Tenderness and Flavor. USA beef is considered to have excellent tenderness and

flavor. These two attributes, along with juiciness, are the main components of overall eating satisfaction. USA beef far surpassed its competition in this category. Ninety-seven percent of end-users were more than satisfied with the eating quality of USA beef. This contrasts markedly with satisfaction levels of 86% and 83% for New Zealand and Australian beef, respectively. (3) High Perceived Value. Export customers feel the price they pay for high-quality USA beef is justified by the value of the product they receive. In Japan, for example, U.S. Prime and U.S. Choice beef is priced at one-third the cost of domestically produced Wagyu beef, yet receives very acceptable comparisons in palatability. (4) Good Overall Product Quality. As a general response, end-users included many different characteristics of beef. Key among these traits was appearance, with 97% of end-users being satisfied with the appearance of USA beef, compared to 81% for beef from other countries. (5 tie) Positive Image of the United States of America and the USDA Quality Grading System. Foreign customers view the quality grading system used by the USA as the benchmark for beef quality and palatability. The “U.S. Choice” designation was termed the “international yardstick for palatability” by many in the study. Export markets also exist, however, for quality grades of USA beef other than U.S. Choice. For example, while customers in the Philippines prefer beef from the Upper Two-Thirds of U.S. Choice, Japanese customers prefer beef of U.S. Prime quality, and customers in Europe and Israel indicated a market for U.S. Select and U.S. Standard grades. (5 tie) Confidence In Product Safety. Recognized around the world, USDA’s Food Safety and Inspection Service and its Residue Monitoring Program have helped assure customers in other countries that USA beef is safe (Morgan *et al.*, 1995; Smith *et al.*, 1995).

There were, though, some areas in which USA beef exporters needed to improve (Morgan *et al.*, 1995; Smith *et al.*, 1995): (1 tie) Excessive External Fat Compared To Purchase Specifications. (1 tie) Boxes and Whole-Muscle Cuts Too Heavy. (3) Insufficient Customer Service. (4) Excessive Seam Fat. (5) Inadequate Shelf Life. (6) Excessive Purge. (7) Torn/Crushed Boxes. (8) Leaks In Vacuum Packaging. (9) Poor Overall Workmanship. (10) Inadequate Labeling (Morgan *et al.*, 1995; Smith *et al.*, 1995).

Colorado State University (Smith *et al.*, 1994) conducted the National Non-Fed (Market Cow and Bull) Beef Quality Audit. Included among the costs of non-conformance in non-fed market cows and bulls were: whole cattle and/or carcass condemnation (\$11.99), brands (\$4.56), bruises (\$3.91), latent-defects/insect-damage to hides (\$2.36), yellow carcass fat (\$2.27), carcasses passed with parts removed (\$2.13), carcass weight lost to "zero tolerance" standards (\$1.87), condemnation of edible offal (\$3.99), handling of disabled cattle (\$0.78), injection-site lesions (\$0.66), dark-cutters (\$0.06) and carcasses passed for cooking (\$0.03). Many of those problems can be alleviated or solved with herd-health programs and most of these errors in management practices could be corrected by providing sound advice to cattlepersons—otherwise, these problems persist, resulting in increases in the price of beef and making it less competitive with pork and poultry (Smith, 1997). As a means for recovering such lost opportunities, participants in the Strategy Workshop of the National Non-Fed Beef Quality Audit (Smith *et al.*, 1994) made three general recommendations. The industry, they said, should: (1) Manage non-fed cattle to minimize defects and quality deficiencies; (2) Monitor the health and condition of non-fed cattle; and (3) Market non-fed cattle in a timely manner. Of the total quality loss of \$69.90 for each non-fed animal harvested in 1994, \$14.60 per head could have been saved if the cattle were managed properly, \$27.65 per head could have been recaptured if the cattle were monitored correctly, and \$27.65 per head could have been salvaged if the cattle were marketed appropriately (Smith *et al.*, 1994).

In the National Beef Quality Audit—1995 (Smith *et al.*, 1995b; Boleman *et al.*, 1998), it was determined that \$137.82 in "Quality Losses" could be recovered if efforts were made to: (1) Increase Red Meat Yield (Total=\$47.76) which includes \$27.42 for Excessive External, Seam and Beef-Trim Fat and \$20.34 for Incorrect Muscling And Muscle:Bone (either too much or too little); (2) Enhance Taste And Tenderness (Total=\$38.30) which includes \$7.64 for Inadequate Overall Palatability (especially inconsistent tenderness and also inadequate flavor), \$28.41 for Insufficient Marbling (the extent to which the present consist of USDA Quality Grades fails to conform to the desired consist of 7% Prime, 21% Upper Two-Thirds of Choice, 34% Low Choice, 38% Select and 0% Standard and lower Grades), \$1.35 for Maturity Problems (carcasses that are "hard-boned"; i.e., not eligible for the Prime, Choice, Select or Standard Grades because of advanced, older than B+, Maturity) and \$0.90 for Gender Problems (uncastrated males classified as "Bullocks" by USDA Graders); (3) Improve Management (Total=\$47.10) which includes \$24.30 for Hide Defects, \$0.46 for Carcass Pathology, \$3.44 for Offal Condemnations (condemnations of lungs, livers, tripe, heads and tongues), \$7.05 for Injection-Site Lesions (loss of product in and around the site plus increased toughness at sites several inches away from, and surrounding, the site), \$4.03 for Bruises, \$6.08 for Dark Cutters and \$1.74 for Grubs, Blood Splash, Callouses and Yellow Fat; and (4) Control Weight (Total=\$4.66) which includes \$4.66 for Carcasses Weighing Less Than 550 Pounds Or More Than 950 Pounds (Smith *et al.*, 1995b).

The Response/Reaction/Consensus Panel, at the close of the Strategy Workshop of the National Beef Quality Audit—1995 (Smith *et al.*, 1995b), concluded that estimated Quality Losses in 1991 had encouraged the beef industry to attempt to reach "zero" fat production, and that such expectations were unrealistic. It was feared that the estimated Quality Losses due to excess fat production in 1991 (\$189.78) were so much of the Total Overall Quality Losses (\$279.82) that producers over-emphasized fat reduction and did not work to correct any of the taste, management or weight problems identified in 1991. Consequentially, those problems were even larger in 1995. In addition, members of the Panel felt that we now have much more detailed, specific information concerning other areas of quality shortfall. Therefore, to make future comparisons with data from the National Beef Quality Audit—1995, the Panelists established "mid-course" corrections for estimated Quality Losses. Corrections entailed adjustment of losses due to inadequacies in Red Meat Yield to a standardized target of 16.5% of carcass weight as fat, 15.0% of carcass weight as bone and 68.5% of carcass weight as Red Meat Yield. Additionally, a targeted USDA Quality Grade mixture of 7% Prime, 21% Upper Two-Thirds Choice, 34% Low Choice and 38% Select was established. Based upon data analyses and use of 1995 logic/prices the Quality Losses Per Steer/Heifer from the National Beef Quality Audit—1995 (Smith *et al.*, 1995b) totaled \$137.82 of which 34.7% could be recovered by Increasing Red Meat Yield (\$47.76), 27.8% might be recaptured by Enhancing Taste And Tenderness (\$38.30), 34.1% was recoverable by Improving Management (\$47.10) and 3.4% was recapturable by Controlling Weight (\$4.66).

The National Veal Quality Audit—1998 (Henning *et al.*, 1998) demonstrated that veal quality defects cost the industry \$15.7 million in 1998, or \$20.92 for every veal calf marketed. Of the \$20.92, \$2.94 was due to light weight, \$10.29 was because of muscle color problems, \$2.72 was due to condemnations, \$2.20 was because of death during transportation, \$1.84 was due to bottom round blemishes and bruises, \$0.65 was from sweetbreads weight-nonconformity, \$0.14 was from scratch and parasite defects in hides, \$0.11 was due to carcass contamination and \$0.03 was because

calves had pneumonia. The message of the National Veal Quality Audit—1998 (Henning *et al.*, 1998) was that the information gathered would allow the veal industry to fine-tune and focus its efforts to make further product improvements to increase market-share and to ensure profitability and sustainability.

The National Market Cow and Bull Beef Quality Audit—1999 was the sequel to the National Non-Fed (Market Cow and Bull) Beef Quality Audit—1994. Packer interviews (Roeber *et al.*, 2000) revealed that their most frequent problems were bruises, antibiotic residues, birdshot/buckshot, arthritic joints, yields (dressing percentage and cutability), condition/leanness and condemnation rate. Value loss for each market cow or bull was: \$4.14 for condemnations of cattle and carcasses; \$4.49 for condemnations of edible offal; \$0.56 for disabled cattle; \$3.10 for hide-value loss due to hot-iron branding; \$3.17 for hide-value loss from latent injury or insect damage; \$9.72 for trim loss due to arthritic joints; \$2.24 for trim loss due to bruises; \$0.46 for trim loss due to “zero tolerance” compliance; \$0.52 for trim loss due to birdshot/buckshot; \$1.46 for trim loss due to injection-site lesions; \$6.48 due to yellow external fat; \$1.41 due to dark-cutting muscle; \$18.70 for inadequate muscling, \$10.17 for excess external fat, \$1.28 for light weight carcasses, and; \$0.92 for antibiotic residues. Of the \$68.82 per head value loss it was determined that better management could have recaptured \$13.82, improved monitoring could have decreased value losses \$27.50 and more timely marketing could have increased market value per head \$27.50. At the Strategy Workshop for the National Market Cow and Bull Beef Quality Audit—2000 (Roeber *et al.*, 2000), four Primary Directives were developed for improving the quality and value of market cows and bulls; they included: (1) Recognize and maximize the value of your market cows and bulls, (2) Be proactive to ensure the safety and integrity of your product, (3) Use appropriate management and handling practices to prevent quality defects, and (4) Closely monitor herd health and market cull cattle timely and appropriately. To facilitate implementation of the four Primary Directives, a Quality Assurance Marketing Code of Ethics was developed for use by cattlemen, dairymen and packers. It states: “I will only participate in marketing cattle that: (a) Do not pose a known public health threat, (b) Have cleared proper withdrawal times, (c) Do not have a terminal condition (including advanced lymphosarcoma, septicemia, etc.), (d) Are not disabled, (e) Are not severely emaciated, (f) Do not have uterine/vaginal prolapses with visible fetal membrane, (g) Do not have advanced eye lesions, and (h) Do not have advanced Lumpy Jaw. Furthermore, I will: Do everything possible to humanely gather, handle and transport cattle in accordance with accepted animal husbandry practices. Finally, I will: Humanely euthanize cattle when necessary to prevent suffering and to protect public health” (Roeber *et al.*, 2000).

The National Beef Quality Audit—2000 (Smith *et al.*, 2000b) is underway and its results will be announced to the USA beef industry in 2001.

Reducing Microbial Contamination in Packing Plants: Implementing HACCP and Technological Alternatives

To improve the safety of beef for domestic and global marketplaces (Smith, 1998), the federal government—initially, in response to the 1993 Jack-In-The-Box outbreak of *E. coli* O157:H7 in the Pacific Northwest—(a) Made mandatory the use of Clean Meat Programs (“Zero Tolerance”). (b) Approved use of decontamination techniques that were developed/researched by people in government, university and/or industry. (c) Approved use of microbiological

interventions that were developed/researched by people in government, university and/or industry. (d) Updated meat inspection regulations by passage of the Pathogen Reduction; Hazard Analysis Critical Control Point System; Final Rule (PR;HACCP;FR). During that same period, the beef packing industry: (a) Emphasized Good Manufacturing Practices, Clean Meat Programs and Standard Operating Procedures For Sanitation/Operation to improve microbiological quality of their products. (b) Interacted with people in government, university and/or industry to develop/research decontamination techniques (e.g., steam vacuuming). (c) Interacted with people in government, university and/or industry to develop/research microbiological interventions (e.g., hot-water washing, organic acid rinsing, steam pasteurization). (d) Created and implemented “Scientific HACCP Programs,” beginning five to ten years before the government mandated development and meat inspection regulations. Since implementation of the Pathogen Reduction; Hazard Analysis Critical Control Point System; Final Rule (PR;HACCP;FR) as an FSIS/USDA regulation, in 312 plants, all industry innovations and most of their Scientific HACCP Programs have remained in place and—as a result—beef carcasses are many-fold cleaner and safer than they were a decade ago (Smith, 1998).

To comply with the Pathogen Reduction; Hazard Analysis Critical Control Point System; Final Rule: (1) All plants must adopt HACCP; HACCP is defined as “a system of process controls to prevent food safety hazards.” (2) To verify that HACCP systems are effective in reducing contamination with harmful bacteria, FSIS/USDA has set pathogen reduction performance standards for *Salmonella*. (3) To verify that process control systems are working, slaughter plants must conduct microbial testing for generic *E. coli*. (4) FSIS/USDA has required that all plants adopt and follow, written Standard Operating Procedures for Sanitation, to reduce the likelihood that harmful bacteria are on finished product.

As implementation of the Pathogen Reduction; HACCP Systems; Final Rule occurred, in January 1998, FSIS/USDA—though vowing originally to give up “command and control—continued to monitor “Zero Tolerance” at the final inspection rail (prior to final washing) and continued to monitor “Acceptable Quality Levels” after final washing of carcasses (Smith, 1998). Upon implementation of the PR; HACCP; Final Rule, industry’s “Scientific HACCP Programs” were modified to drop back from 6 or 7 Critical Control Points (CCPs) to 1, 2 or 3 CCPs in the government’s “Regulatory HACCP Programs”; to meet vendor specifications/expectations, industry often kept remaining CCPs but redesignated them as “Process Control Points” (PCPs) or just “Control Points” (CPs). Examples of CCPs used by beef packers after PR; HACCP; Final Rule implementation in January 1998 include: CCP#1—Acceptable Quality Level inspection by plant personnel, CCP#2—steam pasteurization, CCP#3—hot-water washing and CCP#4—internal temperature of the round, after chilling (Smith, 1998).

Since 1993, personnel in industry, government and universities have developed and researched beef carcass decontamination techniques and microbiological interventions (Smith, 1998). As parts of the FSIS/USDA “Clean Meat Programs” (Zero Tolerance), packers implemented protocols/procedures including (a) knife-trimming, (b) hock blow-off, (c) film draping, (d) toweling, (e) use of hide spring-holders, (f) bung bagging, (e) steam-vacuuming and (f) hot-water vacuuming, as decontamination techniques. In addition, packers have used the following new technologies as decontamination techniques and/or as microbiological interventions, to assist in

complying with FSIS/USDA microbiological “standards” and “criteria” as well as in meeting customer/consumer expectations: (a) Carcass washing/rinsing (at pre-evisceration, near-final or final washing) with water alone (at ambient, warm, hot or very hot temperatures) or with solutions (containing organic acids or other bactericides/bacteriostats), (b) Chemical dehairing (the best of the new technologies, but awaiting industry implementation because of problems with excess sodium in the waste water), (c) Steam or thermal pasteurization (of sides, after final washing) and (d) Multiple-hurdle, microbiological intervention systems (Smith, 1998).

Smith (1999) outlined the chronology—as “Points Of Progress: 1993 to 1999”—of the great strides made by industry in identifying potential entry points for product contamination and establishing “interventions,” or microbial pathogen roadblocks, for reducing the incidence of *E. coli* O157:H7 and other foodborne pathogens in the USA beef supply, as follows: 1993: Organic Acid Rinsing. Actually begun in 1991, this four-year study determined whether using natural food acids (acetic, lactic, citric) could be helpful in removing pathogenic microorganisms from beef carcasses. The beef industry worked closely with the USDA to develop and test rinses that might be effective. 1994: Methods For Sampling Fresh Meat Products For Analysis. Interventions for pathogens are only as good as the investigative tactics used to find them. 1994: Investigation Of Cooking Procedures To Destroy *E. coli* O157:H7. Research helped determine the chances *E. coli* O157:H7 might survive the cooking process on whole muscle cuts. 1994: Methods For Sampling Fresh Meat For Analysis. To assure that samples taken from fresh meat are accurate and representative, sampling procedures were developed that are being used nationwide. 1994: Washing Vs. Trimming. More than 25 different interventions were evaluated for effectiveness in reducing pathogens on beef carcasses. This research led to use of some of these individual processes, singularly, and to use of several of these processes, collectively—in combination—by the packing industry. 1995: Hot Water Or Steam Vacuuming. Five universities shared in the research that led to development and implementation of this technology, which is now being used in virtually every major packing plant in the USA. In fact, more than 90% of USA fed cattle are treated with the process. 1995: Microbial Mapping I: Used to identify Critical Entry Points (CEPs) for pathogens, the first phase of this study helped extend and improve HACCP systems in the harvesting process. The data derived from this field study was crucial in development of the government’s HACCP regulations, and helped determine how much contamination was coming from outside the actual production chain. 1996: Microbial Mapping II. The second phase of the Microbial Mapping study series helped assess where microbes can enter the rest of the chain (fabrication, transportation, distribution, retail cutting and display). Mapping data is used, for instance, to determine the prevalence of pathogens in different seasons, and at different points in the processing sequence. 1996: Hot Water Pasteurization. A hot water wash/rinse (160°F) process serves as a kill step in the elimination of pathogens. Often, this pasteurization is followed by rinsing with cold water to assure optimum color and quality. 1997: Irradiation. All avenues for removing potential microbial contamination are being studied, including irradiation of the product. The process was approved by the Food and Drug Administration for use with red meat in December 1997, and is expected to be in application by some processors in 1999. (The process is, in fact, presently being applied to fresh beef and irradiated beef is being offered for sale in USA retail stores in May 2000). 1997: Pre-Evisceration Wash. Adding another hurdle that microbes must cross is pre-evisceration washing/rinsing of the carcasses. This helps eliminate microbes that might remain after the hide has been removed and assists in preventing the attachment of bacteria as carcasses

are processed. 1998: Microbial Mapping III. Developing mapping techniques for raw materials destined for ground beef helps add potential sites for impeding the entry of microbial pathogens into the beef system. 1999: Microbial Mapping IV. Multiple Hurdles System. Investigating how effective each hurdle is—and how effective they are, together, in a system is helping to determine the relative value of individual processes in overall beef safety (Smith, 1999). In that brochure (Smith, 1999), Warren Mirtsching (Monfort/ConAgra, Inc.) was quoted as saying “Technology has improved over the last six years, allowing more detailed investigation and evaluation of each food safety incident. Thanks to that technology, the industry has been able to create interventions—such as steam vacuuming, organic acid rinsing, thermal pasteurization—that can prevent occurrences. Good Manufacturing Practices and Standard Sanitation Operating Procedures have improved, with results proven in longer shelflife of the finished products due to lessened microbial activity” (Smith, 1999).

Microbiological interventions, like hot-water washing, organic-acid solution rinsing, steam vacuuming and steam pasteurization were originally perceived to be singular technologies for use at, or as, Critical Control Points (Smith, 1998). At present, most microbiological interventions [with notable exceptions of: (a) steam pasteurization, in at least one plant, used as a CCP, and (b) hot-water washing, by at least one company, being considered for a potential CCP] are perceived as parts (components) of a “multiple-hurdle, microbiological intervention system.” And, as such, the components are monitored as CPs or PCPs, but not as CCPs, for compliance with FSIS/USDA regulations. It stands to reason that if a single technological intervention reduces carcass contamination, multiple-hurdle microbiological intervention systems may yield additional (additive or accumulative) decontaminating effects. The multiple-hurdle approach should result in microbiologically cleaner carcasses and should assist plants in meeting FSIS regulatory requirements. Both HACCP and decontamination treatments can be useful in reducing unnoticed contamination, especially of fecal origin, that may harbor pathogens. However, the microbiological status of the meat that reaches the consumer will also depend on exposure to contamination during subsequent processing, handling, distribution and preparation for consumption. All of the decontamination techniques and microbiological interventions are, though, applied to a product (meat) that is still not safe to eat...until it is cooked...and cooked properly (Smith, 1998).

Further protection of public health is afforded through food-safety efforts at the end-user at the level by FDA (through its Food Code), USDA (by microbiological testing at retail establishments), groups (National Restaurant Association’s “Serve Safe” program) and companies (Kroger, Sysco and Burger King, for example, have self-imposed HACCP programs). *Drovers Journal* (2000) reported that beef checkoff dollars help ensure the continued safety of the U.S. food supply by supporting the “ServSafe®,” Serving Safe Food training program, which is the national industry standard in food safety training; to date, the program has certified 1.13 million restaurant and supermarket employees. Smith *et al.* (1998) described procedures/processes/programs being used by Jack-In-The-Box, Arby’s and Burger King to minimize risk of foodborne illness for their patrons. Combined efforts of producers, packers, processors and retailers are essential to assuring the chemical and bacteriological safety of food of ruminant origin.

In a report to the Agricultural Committee of the United States Senate, Smith (1999) said “Consumer confidence...American agriculture depends on it in the day-to-day production of food. The 1989 Alar apple scare is a good, but extreme, example of what can happen when consumer confidence in a food is compromised. Many consumers destroyed and avoided apples, applesauce and apple juice. Apple producers lost millions of dollars, not necessarily because their products were defective but because consumers had lost confidence in their ability to enjoy them safely. At that point, the producers had the responsibility not only of producing safe apples, but of assuring consumers that the apples being produced were safe. Assuring such confidence goes far beyond the innate desire of food producers to do everything they can to make foods as safe as possible. To assure that consumers can feel confident about the safety of beef, those in every sector of cattle/beef production should pledge that all possible precautions are being taken to reduce contamination and to prevent other potential safety problems with beef as a food” (Smith, 1999). Because tens of millions of pounds of beef are sold in the USA every day, each sector in the industry, and each segment of the beef production and marketing chain has an enormous responsibility to consumers. This responsibility includes not just a direct role in producing safe food, but in providing the assurances to consumers that this role is taken seriously.

Table 1. Domestic Residue Monitoring Program Results For 1996.

	Bull	Steer	Beef Cow	Dairy Cow	Heifer	All Cattle	Market Cows/Bulls	Steers/ Heifers
Antibiotics	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00
Chlorinated Hydrocarbons (CHCs)	0.0	0.6	0.0	0.0	0.0	0.06	0.00	0.03
Chlorinated Organophosphates (COPs)	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00
Ivermectin	0.3	0.0	0.0	0.6	0.0	0.18	0.26	0.00
Levamisole	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00
Sulfonamides	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00
Clenbuterol	---	0.0*	---	---	---	0.00**	---	---

SOURCE: FSIS-USDA (1996) (Released in 1998)

*324, mostly show steers

**499, cattle

Table 2. Domestic Residue Monitoring Program Results For 1997.

	Bull	Steer	Beef Cow	Dairy Cow	Heifer	All Cattle	Market Cows/Bulls	Steers/ Heifers
Antibiotics	0.0	0.0	0.2	0.2	0.0	0.10	0.16	0.00
CHCs/COPs	0.4	0.0	0.0	0.0	0.0	0.07	0.12	0.00
Ivermectin	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00
Carbadox	---	0.0	---	---	0.0	0.00	---	0.00
Sulfonamides	0.0	0.0	0.0	0.3	0.4	0.13	0.10	0.20
Arsenic	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00
Clenbuterol	---	0.0*	---	---	---	0.00**	---	---

SOURCE: FSIS-USDA (1997) (Released in 1999)

*80, steers

**84, cattle

Table 3. National Residue Program, Enforcement Testing Results For 1996.

National Residue Program: To help prevent the marketing of animals containing violative residues of pesticides, animal drugs or potentially hazardous chemicals.

- I) 31,748 sample units analyzed in monitoring national incidence.
- II) 235,495 sample units analyzed in enforcement (clinical signs; herd-history testing). In-plant tests (rapid screening) include:
 SOS (Sulfa-On-Site); CAST (Calf Antibiotic and Sulfonamide Test);
 STOP (Swab Test On Premises); FAST (Fast Antimicrobial Screen Test)

Enforcement Testing: observed, rapid-tested, held, chemically tested:

Cattle STOP 266 of 35,177
 Cattle FAST 1,022 of 154,727
 Cattle Antibiotic Tested 8 of 65
 Cattle Sulfonamide Tested 12 of 18

(1 of 216, pesticide; 0 of 16, ivermectin; 0 of 508, trace metal; 0 of 190, clenbuterol)

SOURCE: FSIS-USDA (1996) (Released in 1998).

Table 4. National Residue Program, Enforcement Testing Results For 1997.

National Residue Program: To help prevent the marketing of animals containing violative residues of pesticides, animal drugs or potentially hazardous chemicals.

- I) 26,626 sample units analyzed in monitoring national incidence.
- II) 165,328 sample units analyzed in enforcement (clinical signs; herd-history testing). In-plant tests (rapid screening) include:
 SOS (Sulfa-On-Site); CAST (Calf Antibiotic and Sulfonamide Test);
 STOP (Swab Test On Premises); FAST (Fast Antimicrobial Screen Test)

Enforcement Testing: observed, rapid-tested, held, chemically tested:

Cattle STOP	135 of 27,107
Cattle FAST	384 of 90,487
Cattle Antibiotic Tested	5 of 71
Cattle Sulfonamide Tested	3 of 13

(1 of 11, pesticide; 0 of 11, ivermectin; 0 of 3, trace metal; 0 of 84, clenbuterol)

SOURCE: FSIS-USDA (1997) (Released in 1999).

Table 5. Rank Of Violative Residues Of Antibiotics And Sulfonamides From NRP Enforcement Testing In 1996.

Antibiotic	Cattle Enforcement	Cattle STOP	Cattle FAST	Sulfonamide	Cattle Enforcement	Cattle STOP	Cattle FAST
Oxytetracycline	1	2	2	Sulfamethazine	1	1	2
Penicillin	1	1	1	Sulfadimethoxine	2	2	1
Chlortetracycline	1	6	8	Sulfadiazine	3	---	---
Gentamicin	2	5	5	Sulfamethoxazole	---	---	3
Tetracycline	2	3	4	Sulfathiazole	---	---	4
Erythromycin	2	8	7	Sulfachlorpyridazine	---	---	5
Neomycin	---	6	6				
Streptomycin	---	4	3				
Tylosin	---	---	9				

SOURCE: FSIS-USDA (1996) (Released in 1998).

Table 6. Rank Of Violative Residues Of Antibiotics And Sulfonamides From NRP Enforcement Testing In 1997.

Antibiotic	Cattle Enforcement	Cattle STOP	Cattle FAST	Sulfonamide	Cattle Enforcement	Cattle STOP	Cattle FAST
Gentamicin	1	3	2	Sulfadimethoxine	1	1	1
Oxytetracycline	2	2	4	Sulfamethoxazole	1	---	---
Streptomycin	2	4	3	Sulfamethazine	---	2	2
Penicillin	2	1	1	Sulfathiazole	---	---	3
Tetracycline	---	4	6				
Erythromycin	---	6	7				
Neomycin	---	---	5				
Chlortetracycline	---	---	7				
Tylosin	---	---	7				

SOURCE: FSIS-USDA (1997) (Released in 1999)

Table 7. Number Of Total (Monitoring Plus Enforcement Samples) Violative Residues Of Antibiotics And Sulfonamides (NRP, 1996 and 1997).

	1996 Cattle	1997				
		Dairy Cows	Beef Cows	Bulls	Steers	Heifers
Penicillin	442	210	41	1	3	3
Oxytetracycline	247	29	12	2	3	2
Streptomycin	166	40	2	---	1	---
Tetracycline	163	6	3	---	---	---
Gentamicin	128	59	11	---	1	---
Neomycin	57	9	---	---	---	---
Erythromycin	31	4	---	---	---	---
Chlortetracycline	27	1	---	---	---	---
Tylosin	2	1	---	---	---	---
Sulfadimethoxine	162	55	4	1	---	---
Sulfamethazine	117	8	4	1	7	4
Sulfamethoxazole	22	---	---	---	1	---
Sulfathiazole	19	1	---	---	---	---
Sulfachlorpyridazine	7	---	---	---	---	---
Sulfadiazine	1	---	---	---	---	---

SOURCE: FSIS-USDA (1996 and 1997) (Released in 1998 and 1999).

*Combined totals, all tests.

Table 8. Aggregated Results Of Testing Samples Of Muscle, Fat, Liver And Kidney From Cattle Of Five Types/Kinds For Residues Of Five Classes Of Chemicals.

Types/Kinds of Beef (Cattle Source)	Samples with Violative Residues, of, Total Tests Performed				
	Anabolic Steroids (N=5)	Heavy Metals (N=2)	Stress Reducers (N=3)	Thyrostats; Sulfa-drugs (N=6)	Chlorinated Hydrocarbon & Organo-Phosphate Pesticides (N=25)
Organic ^a	0 of 60	0 of 24	0 of 36	0 of 72	0 of 75
Natural ^b	0 of 60	0 of 24	0 of 36	0 of 72	0 of 75
Conventional ^c	0 of 160	0 of 64	0 of 96	0 of 192	0 of 200
Realizer ^d	0 of 60	0 of 24	0 of 36	0 of 72	0 of 75
Cull Cow ^e	0 of 60	0 of 24	0 of 36	0 of 72	0 of 75
Total	0 of 400	0 of 160	0 of 240	0 of 480	0 of 500

^aSteers/heifers raised with no health/performance aids; no pesticides used on land or livestock.

^bSteers/heifers raised with no health/performance aids; pesticides can be used on land and livestock.

^cSteers/heifers raised with use of health/performance aids; pesticides can be used on land and livestock.

^dSteers/heifers raised with use of health/performance aids; pesticides can be used on land and livestock; slaughtered earlier than planned because they are chronically ill or not gaining weight in the feedlot.

^eMature cows raised/maintained with use of health/performance aids; pesticides can be used on land and livestock; includes both beef and dairy cows.

SOURCE: Smith *et al.* (1994c).

Table 9. Aggregated Results Of Testing Samples Of Muscle, Fat, Liver And Kidney From Cattle Of Three Kinds For Residues Of Six Classes Of Chemicals.

Kind of beef (cattle source)	Samples with Volative Residues, of, Total Tests Performed					
	Anabolic Steroids (N=3)	Xeno-biotics (N=3)	Beta-lactams (N=3)	Sulfa-drugs (N=4)	Tetra-cyclines (N=3)	C.H.C. & O.P. Pesticides (N=25)
Organic ^a	0 of 189	0 of 189	0 of 189	0 of 252	0 of 189	6 of 1575
Natural ^b	0 of 189	0 of 189	0 of 189	0 of 252	0 of 189	6 of 1575
Conventional ^c	0 of 180	0 of 180	0 of 180	0 of 240	0 of 180	3 of 1500
Total	0 of 558	0 of 558	0 of 558	0 of 744	0 of 558	15 of 4650

^aSteers/heifers raised with no health/performance aids; no pesticides used on land or livestock.

^bSteers/heifers raised with no health/performance aids; pesticides can be used on land and livestock.

^cSteers/heifers raised with health/performance aids; pesticides can be used on land and livestock.

SOURCE: Smith *et al.* (1997a).

Table 10. Summary Of Results Of The Eleven Audit Periods For Top Sirloin Butts From Slaughter Steers/Heifers.

Year of Audit	Incidence of Lesions	Average Trim Per Lesion	Average Fluid-Filled Lesions (of Total Lesions)
1990	21.6%	8.0 oz	“many”
1991	19.3%	10.0 oz	6.5%
1992	12.5%	4.9 oz	0.2%
1993	11.5%	3.9 oz	0.5%
1994	13.6%	5.1 oz	0.4%
1995	10.5%	6.0 oz	0.6%
1996	9.2%	6.4 oz	0.5%
1997	6.2%	9.8 oz	0.7%
1998	5.1%	5.6 oz	1.6%
1999	4.0%	9.0 oz	0.7%
2000*	3.0%*	10.4 oz*	0.5%*

SOURCE: Smith *et al.* (1999)

*Through March, 2000 only (Personal Communication; Deb Roeber, CSU)

References

Boleman, S.L., S.J. Boleman, W.W. Morgan, D.S. Hale, D.B. Griffin, J.W. Savell, R.P. Ames, M.T. Smith, J.D. Tatum, T.G. Field, G.C. Smith, B.A. Gardner, J.B. Morgan, S.L. Northcutt, H.G. Dolezal, D.R. Gill and F.K. Ray. 1998. National Beef Quality Audit—1995: Survey of producer-related defects and carcass quality and quantity attributes. *J. Anim. Sci.* 76:96-103.

Boston Globe. 1991. “We’re So Sure You’ll Think Our Beef Is Better, We Bet The Ranch On It.” *Boston Globe Newspaper*. (March 15, 1991 Issue) page 32. Boston, Massachusetts, USA.

Cowman, G.L. 2000. What is Beef Quality Assurance? Presented at the Annual Meeting of the Arby’s Restaurant Group (Fort Lauderdale, Florida, USA).

Dexter, D.R., G.L. Cowman, J.B. Morgan, R.P. Clayton, J.D. Tatum, J.N. Sofos, G.R. Schmidt, R.D. Glock and G.C. Smith. 1994. Incidence of injection-site blemishes in beef top sirloin butts. *J. Anim. Sci.* 72:824-827.

Drovers Journal. 2000. Checkoff Dollars Educate Food Handlers About Food Safety. (May Issue) page 48 (Insert).

Eilers, J.D., J.D. Tatum, J.B. Morgan, and G.C. Smith. 1993. Quality Losses—Due To Producer-Related Problems—From Cattle In The Strategic Alliance Field Study. Final Report of the Colorado State University Portion of the Strategic Alliance Field Study. Meat Science Program, Colorado State University, Fort Collins, Colorado, USA.

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. FSIS-USDA, March 29, 1990.

Food Regulation Weekly. 1999. FSIS toughens antibiotic-residue testing for cattle. (August 30 Issue) page 39. Food Regulation Weekly, Washington, DC, USA.

FSIS-USDA. 1979. Domestic Residue Data Book; National Residue Program 1979. Office of Public Health and Science, Food Safety and Inspection Service, U.S. Department of Agriculture, Washington, DC, USA.

FSIS-USDA. 1990. Domestic Residue Data Book; National Residue Program 1990. Office of Public Health and Science, Food Safety and Inspection Service, U.S. Department of Agriculture, Washington, DC, USA.

FSIS-USDA. 1991. Domestic Residue Data Book; National Residue Program 1991. Office of Public Health and Science, Food Safety and Inspection Service, U.S. Department of Agriculture, Washington, DC, USA.

FSIS-USDA. 1992. Domestic Residue Data Book; National Residue Program 1992. Office of Public Health and Science, Food Safety and Inspection Service, U.S. Department of Agriculture, Washington, DC, USA.

FSIS-USDA. 1993. Domestic Residue Data Book; National Residue Program 1993. Office of Public Health and Science, Food Safety and Inspection Service, U.S. Department of Agriculture, Washington, DC, USA.

FSIS-USDA. 1994. Domestic Residue Data Book; National Residue Program 1994. Office of Public Health and Science, Food Safety and Inspection Service, U.S. Department of Agriculture, Washington, DC, USA. (Released in 1996)

FSIS-USDA. 1995. Domestic Residue Data Book; National Residue Program 1995. Office of Public Health and Science, Food Safety and Inspection Service, U.S. Department of Agriculture, Washington, DC, USA. (Released in 1997)

FSIS-USDA. 1996. Domestic Residue Data Book; National Residue Program 1996. Office of Public Health and Science, Food Safety and Inspection Service, U.S. Department of Agriculture, Washington, DC, USA. (Released in 1998)

FSIS-USDA. 1997. Domestic Residue Data Book; National Residue Program 1997. Office of Public Health and Science, Food Safety and Inspection Service, U.S. Department of Agriculture, Washington, DC, USA. (Released in 1999)

FSIS-USDA. 1999. 1999 FSIS National Residue Program. Office of Public Health and Science, Food Safety and Inspection Service, U.S. Department of Agriculture, Washington, DC, USA.

George, M.H., P.E. Heinrich, D.R. Dexter, J.B. Morgan, K.G. Odde, R.D. Glock, J.D. Tatum, G.L. Cowman and G.C. Smith. 1995a. Injection-site lesions in carcasses of cattle receiving injections at branding and at weaning. *J. Anim. Sci.* 73:3235-3240.

George, M.H., J.B. Morgan, R.D. Glock, J.D. Tatum, G.R. Schmidt, J.N. Sofos, G.L. Cowman and G.C. Smith. 1995b. Injection-site lesions: Incidence, tissue histology, collagen concentration, and muscle tenderness in beef rounds. *J. Anim. Sci.* 73:3510-3518.

George, M.H., G.L. Cowman, J.D. Tatum and G.C. Smith. 1996. Incidence and sensory evaluation of injection-site lesions in beef top sirloin butts. *J. Anim. Sci.* 74:2095-2103.

George, M.H., J.D. Tatum, G.C. Smith and G.L. Cowman. 1997. Injection-site lesions in beef subprimals: Incidence, palatability consequences and economic impact. *Comp. Food Anim. Medicine & Management* 19(2):S84-S93.

Henning, W., E. Mills, J. Grim, B. Coe, D. Ivan and A. Kroutch. 1998. The National Veal Quality Audit. Final Report of the 1998 National Veal Quality Audit to the National Cattlemen's Beef Association. Department of Animal Science, Pennsylvania State University, State College, Pennsylvania, USA.

Lorenzen, C.L., D.S. Hale, D.B. Griffin, J.W. Savell, K.E. Belk, T.L. Frederick, M.F. Miller, T.H. Montgomery and G.C. Smith. 1993. National Beef Quality Audit: Survey of producer-related defects and carcass quality and quantity attributes. *J. Anim. Sci.* 71:1495-1502.

Morgan, J.B., G.C. Smith, J.A. Sherbeck, S.K. Fitzgerald, C.C. Kukay, S.W. Neel and K.E. Belk. 1995. A Foreign Market Audit of U.S. Beef—The Final Report of the International Beef Quality Audit—1994. Final Report to the U.S. Meat Export Federation and Agricultural Marketing Service of USDA. Meat Science Program, Colorado State University, Fort Collins, Colorado, USA.

National Cattlemen's Association. 1993. Executive Summary: Strategic Alliances Field Study, Managed by the National Cattlemen's Association, in coordination with Colorado State University and Texas A&M University—1993. National Cattlemen's Association. Englewood, Colorado, USA.

National Cattlemen's Beef Association. 1999a. Beef Quality Assurance: A Commitment To Consumers. National Cattlemen's Beef Association, Englewood, Colorado, USA.

National Cattlemen's Beef Association. 1999b. Beef Quality Assurance—National Guidelines. (Revised July 1999). National Cattlemen's Beef Association, Englewood, Colorado, USA.

Potthast, K. 1993. Residues in meat and meat products. *Fleischwirtschaft International* 4:26-31.

Roeber, D.L., K.E. Belk, G.C. Smith, J.D. Tatum, T.G. Field, J.A. Scanga, C.D. Smith, P.D. Mies, H.A. Foster, T.K. Kennedy, B.R. Moore and S.G. Hodge. 2000. Improving The Consistency And Competitiveness Of Market Cow And Bull Beef; And, Improving The Value

Of Market Cows And Bulls—The Final Report of the National Market Cow and Bull Beef Quality Audit—1999. Meat Science Program, Department of Animal Sciences, Colorado State University, Fort Collins, Colorado, USA.

Sanders, S.K., J.B. Morgan, J.D. Tatum and G.C. Smith. 1993. Quality Gains—Due To Vitamin E Supplementation—From Cattle In The Strategic Alliance Field Study. Final Report of the Colorado State University Portion of the Strategic Alliance Field Study. Meat Science Program, Colorado State University, Fort Collins, Colorado, USA.

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.

Smith, G.C. 1997. National and international audits for fed and/or non-fed beef quality. Presented at the 59th Annual Conference for Veterinarians, College of Veterinary Medicine, Kansas State University (Manhattan, Kansas, USA).

Smith, G.C. 1998. Reducing microbial contamination in the plants: Implementing HACCP and technological alternatives. Presented at the 1998 World Food and Sustainable Agriculture Symposium (Urbana, Illinois, USA).

Smith, G.C. 1999. Progress In Food Safety: Toward A Safer Beef Supply. Report to the Agricultural Committee of the United States Senate (presented verbally and distributed as a six-page brochure), March 1999 in Washington, DC, USA. Brochure printed and distributed by the National Cattlemen's Beef Association, Englewood, Colorado, USA.

Smith, G.C., J.W. Savell, R.P. Clayton, T.G. Field, D.B. Griffin, D.S. Hale, M.F. Miller, T.H. Montgomery, J.B. Morgan, J.D. Tatum, J.W. Wise, D.L. Wilkes and C. Lambert. 1992. Improving The Consistency And Competitiveness Of Beef—A Blueprint For Total Quality Management In The Fed-Beef Industry—The Final Report of the National Beef Quality Audit-1991. Final Report to the National Cattlemen's Association. Colorado State University, Fort Collins, Colorado, USA and Texas A&M University, College Station, Texas, USA.

Smith, G.C., J.B. Morgan, J.D. Tatum, C.C. Kukay, M.T. Smith, T.D. Schnell, G.G. Hilton, C. Lambert, G. Cowman and B. Lloyd. 1994a. Improving The Consistency And Competitiveness Of Non-Fed Beef; And, Improving The Salvage Value Of Cull Cows And Bulls—The Final Report of the National Non-Fed Quality Audit—1994. Final Report to the National Cattlemen's Association. Meat Science Program, Colorado State University, Fort Collins, Colorado, USA.

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. *Proc. Reciprocal Meat Conference* (State College, Pennsylvania, USA) 47:31-36.

Smith, G.C., J.N. Sofos, M.J. Aaronson, J.B. Morgan, J.D. Tatum and G.R. Schmidt. 1994c. Incidence of pesticide residues and residues of chemicals specified for testing in U.S. beef by the European Community. *J. Muscle Foods* 5:271-284.

Smith, G.C., J.B. Morgan, S.W. Neel and K.E. Belk. 1995a. The International Beef Quality Audit. Proceedings of the 1995 International Livestock Congress (Houston, Texas, USA) Session III, pages 62-68.

Smith, G.C., J.W. Savell, H.G. Dolezal, T.G. Field, D.R. Gill, D.B. Griffin, D.S. Hale, J.B. Morgan, S.L. Northcutt, J.D. Tatum, R. Ames, S. Boleman, S. Boleman, B. Gardner, W. Morgan and M. Smith. 1995b. Improving The Quality, Consistency, Competitiveness And Market-Share Of Beef—The Final Report Of The Second Blueprint For Total Quality Management In The Fed-Beef (Slaughter Steer/Heifer) Industry. National Beef Quality Audit—1995. Final Report to the National Cattlemen's Beef Association. Meat Science Program, Department of Animal Sciences, Colorado State University, Fort Collins, Colorado, USA.

Smith, G.C., K.L. Heaton, J.N. Sofos, J.D. Tatum, M.J. Aaronson and R.P. Clayton. 1997a. Residues of antibiotics, hormones and pesticides in conventional, natural and organic beef. *J. Muscle Foods* 8:157-172.

Smith, G.C., K.E. Belk, R.C. Cannell, J.N. Sofos and J.D. Tatum. 1997b. Beef Quality Assurance: Past, Present And Future. Presented at The Range Beef Cow Symposium (Rapid City, South Dakota, USA).

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. Pages 323-350. In: *Passport To The Year 2000: Biotechnology In The Feed Industry* (Eds. T.P. Lyons and K.A. Jacques) Nottingham University Press, Nottingham, United Kingdom.

Smith, G.C., R.C. Cannell, K.E. Belk, J.D. Tatum, J.N. Sofos and G.R. Schmidt. 1999. Beef Quality Assurance Audits: Incidence of Injection-Site Damage In Top Sirloin Butts And In Muscles Of The Round. Final Report to the National Cattlemen's Beef Association. Center for Red Meat Safety, Department of Animal Sciences, Colorado State University, Fort Collins, Colorado, USA.

Smith, G.C., D.L. Roeber, K.E. Belk, T.G. Field and J.D. Tatum. 2000a. Incidence of violative residues in tissues from market cows and bulls; Results of the National Residue Program. Pages 138-146. In: *Improving The Consistency And Competitiveness Of Market Cow And Bull Beef; And, Improving The Value Of Market Cows And Bulls—The Final Report of the National Market Cow and Bull Beef Quality Audit—1999*. National Cattlemen's Beef Association, Englewood, Colorado, USA.

Smith, G.C., J.W. Savell, J.B. Morgan and T.H. Montgomery. 2000b. National Beef Quality Audit—2000. A proposal to the National Cattlemen's Beef Association by Colorado State University, Texas A&M University, Oklahoma State University and West Texas A&M University.

Usborne, W.R. 1994. Natural vs. Regular Beef. Mimeograph Report from the University of Guelph, Guelph, Ontario, Canada.

USDA. 1982. Policy Memo 055: Natural Claims. USDA-FSIS. Washington, DC, USA.

Wilkinson, B. 1991. Coleman Advertising Campaign in Boston. National Cattlemen's Association, Issue Update. (May 1991 Issue) pages 5-7. National Cattlemen's Association, Denver, Colorado, USA.