Mindy Brashears. PhD
Director of the International Center for Food Industry Excellence
Professor of Food Safety and Public Health
Texas Tech University
Testimony to the House Ag Committee
-Food Safety Research-
September 29, 2015

I would like to introduce myself as a Professor of Food Safety and Public Health and the Director of the International Center for Food Industry Excellence at Texas Tech University. I received my B.S. in Food Technology at Texas Tech University and my M.S. and PhD in Food Science with a specialization in food microbiology at Oklahoma State University. I began my career as an Assistant Professor of Food Safety at the University of Nebraska and moved to Texas Tech University where I have been conducting research and developing food safety and security educational programs for the past 14 years. Food safety and protecting public health has been the focus of my career. I currently serve as the Director of the International Center for Food Industry Excellence at Texas Tech University. My primary academic appointment involves research and outreach with an emphasis on food safety microbiology.

Contamination of food with pathogenic organisms creates an enormous social and economic burden on communities, industry, and health systems all over the world (Ajayi et al., 2011). In the United States alone, the Centers for Disease Control and Prevention (CDC) estimate that each year, one in six Americans suffers from foodborne illness attributed to one of 31 major pathogens transmitted through food (Scallan et al., 2011). The CDC estimate these pathogens are responsible for approximately 9.4 million foodborne disease episodes, 55,961 hospitalizations, and 1,351 deaths in the U.S. every year (Scallan et al., 2011). Non-typhoidal *Salmonella*, *Clostridium perfringens*, and *Campylobacter* appear in the top five most common bacterial pathogens, causing 11, 10 and 9% of illnesses, respectively (Scallan et al., 2011). Furthermore, O157 and non-O157 Shiga toxin-producing *Escherichia coli* (STEC) account for approximately 176,000 foodborne illness cases annually (Scallan et al., 2011).

Data from the Foodborne Disease Active Surveillance Network (FoodNet) show that in 2013 alone, 818 foodborne disease outbreaks were reported, resulting in 13,360 illnesses, 1,062 hospitalizations, 16 deaths, and 14 food recalls. Outbreaks caused by *Salmonella* increased 39% from 2012 (113) to 2013 (157). Outbreak-associated hospitalizations caused by *Salmonella* increased 38% from 2012 (454) to 2013 (628) (CDC, 2015). A study conducted by the U.S. Department of Agriculture Economic Research Service found that foodborne pathogens impose over $15.5 billion (2013 dollars) in economic burden on the U.S. public each year (Hoffmann et al., 2015). Eighty-four percent of the economic burden from pathogens is due to deaths. This reflects both the importance the public places on preventing deaths and the fact that the measure of economic burden used for nonfatal illnesses (medical costs + productivity loss) is a conservative measure of willingness to pay to prevent nonfatal illness.

At Texas Tech University we have assembled a team of research scientists to address global food safety issues. In addition to myself, the team includes the following faculty members: Dr. Guy Loneragan, Dr. Kendra Nightingale, Dr. Todd Brashears, Dr. Alejandro Echeverry, Dr. Leslie Thompson, Dr. Mark Miller, Dr. Chance Brooks, Dr. Marcos Sanchez and Dr. Henk Den-Bakker. Our team is a diverse group of scientists who have been strategically selected to address issues related to food safety and public health in the U.S. and around the world. Addressing food safety challenges involves a comprehensive farm-to-table proactive approach with regard to research and educational efforts. Our efforts do not stop in the laboratory or with a research publication. No research study will have impact

on reducing illnesses if the final results are not transferred to the end user and therefore, in our of our research efforts, we strive to connect with our stakeholders. Most of our research has focused on beef safety, but we have also expanded to other commodities.

It is important to note that federal funding was responsible for early funding for the International Center for Food Industry Excellence (ICFIE) and the research and educational activities involved in this center. Our faculty team within ICFIE was able to leverage this money each year for a 5:1 or greater research match on the funding from competitive USDA, industry, commodity and other government sources. The funding has had a tremendous impact on the overall safety of the food supply in the U.S. and was responsible in part for most of the studies I will discuss in this testimony.

Investment in food safety research over the past 20 years has saved lives. In the early 1990s, we were scrambling for solutions to *E. coli* O157 in ground beef. Federal investment in translational research delivered effective controls. The FSIS's testing shows that ground beef contamination has fallen more than 90%. The CDC reports that the human incidence has fallen in half and met the healthy people 2010 goals. Investment can now help solve other food safety challenges. *Campylobacter, Salmonella*, and other emerging pathogens continue to injure too many people. Moreover, Antimicrobial Resistance (AMR) makes it harder to treat some of these illnesses. Investing in federal research programs will provides solutions and reduces the number of people injured by these pathogens, but continued progress is threatened by reduced funding of transformative ideas.

Over the past several years, the availability of funds for food safety research at the federal level has decreased which leaves scientists scrambling for limited resources from industry, foundations and other sources. Recent outbreaks and emerging pathogens can be controlled and even stopped through funding and educational efforts. Centers such as ICFIE are well positioned to solve food safety problems given the proper resources. In recent years, federal funding has been awarded in large amounts to a small number of scientists limiting the application of the intellectual capacity that exists in the U.S. in the food safety arena. Additionally, the majority of food safety research addressed in the research conducted with these large funds has been directed towards STECs which are responsible for much fewer illnesses and deaths compared to *Salmonella* and *Campylobacter*. Salmonellosis has remained constant with little change and recent data indicate that *Campylobacter* is prevalent in many food products with increasing numbers of illnesses each year. We are unable to quickly react to emerging problems such as antibiotic resistance, *Campylobacter* and others due to the lack of funding available to address these problems. It is imperative that funding be available and even increased for food safety research and educational efforts in order to protect public health. I will highlight some of the research that has had a direct impact on improving the safety of the beef supply that has been conducted at Texas Tech University and with collaborating institutions.

Research Highlights from Texas Tech

<u>Pre-Harvest Food Safety</u>

Beef is a staple product in the American diet. The beef production chain begins on the farm, prior to harvest. Cattle can harbor food-borne pathogens such as *Salmonella* and Shiga-toxin producing *E. coli* (STEC) such as *E. coli* O157:H7 that can be transferred to the carcass during harvest and can potentially threaten public health. The cattle's hide is the primary source of contamination of the final product but the carcass can also be contaminated through the environment, the employees or direct contact with the contents of the gastrointestinal tract. Industry groups such as NCBA provide educational opportunities to producers on best practices to follow on the farm which create a clean and

healthy environment to raise cattle. Research at Texas Tech in the pre-harvest realm has targeted interventions that reduce pathogens prior to harvest.

Over the course of my career, a primary focus of my research has been on the development of a pre-harvest intervention that reduces foodborne pathogens in cattle prior to harvest. The intervention is a lactobacillus-based cattle direct-fed microbial (DFM) which is basically a cattle probiotic. The cattle feed additive containing the selected cultures has been commercialized and sold under the brand names of Bovamine and Bovamine Defend and has been widely implemented in the beef and dairy industries in the U.S. This product contains a specific strain of *Lactobacillus* (NP51) that has proven to be effective in reducing pathogens in the live animal prior to harvest in many research studies over the past 15 years. I have been involved in this work from the beginning and its initial development but the work has also been validated by other scientific groups. Funding for this work was provided by the Beef Checkoff and commodity groups such as NCBA and AMIF, direct industry support, the State of Nebraska, and funding from the federal government. I will summarize many of the studies and results of our work in this area.

The microbial flora is an important component of the gastrointestinal tract and certain bacteria have long been recognized for beneficial properties and good health. Mechanistically, beneficial bacteria can prevent harmful bacterial colonization by competitively excluding, producing antibacterial compounds, and/or promoting healthy immune function (Berry et al., 2010). DFM are live bacteria fed to a host to elicit a beneficial response, and are typically, but not limited to, *Lactobacillus* spp. strains. Numerous DFM have been identified and tested for efficacy against *E. col*i O157:H7 in cattle (Callaway et al., 2009; Loneragan and Brashears, 2005; Sargeant et al., 2007). The overall goal of our strategy was to identify bacteria that are competitive with, or antagonistic to, pathogenic bacteria that could be fed as a supplement to the cattle diet without having a detrimental impact on animal performance.

In one of the first large-scale, feedyard studies (Brashears et al. 2003), we evaluated 180 steers for shedding of *E. coli* O157:H7 on arrival at the feedlot, just before treatment with the DFM, and every 14 days until slaughter. The prevalence on hides and carcasses at slaughter was also evaluated. *Lactobacillus acidophilus* NP51 decreased the shedding of *E. coli* O157:H7 in the feces significantly during the feeding period. *E. coli* O157:H7 was approximately twice as likely to be detected in control animal samples as in samples from animals not receiving the supplement. In addition, DFM supplementation significantly decreased the number of *E. coli* O157:H7–positive hide samples at harvest and the number of pens testing positive for the pathogen. The results of this first study suggested that feeding a *Lactobacillus*-based DFM to cattle decreases, but not eliminates, fecal shedding of *E. coli* O157:H7, as well as contamination on hides.

Younts et al. (2004) described the prevalence of *E. coli* O157 in the feces and on the hides of finishing beef cattle fed a standard diet and those fed diets supplemented with a DFM. Two hundred forty steers received one of four treatments: (1) control: (2) HNP51: high dose of *L. acidophilus* strain NP51 (10^9 CFU per steer daily) and *P. freudenreichii* (10^9 CFU per steer daily); (3) HNP51145: high dose of NP51 (10^9 CFU per steer daily), *P. freudenreichii* (10^9 CFU per steer daily), and *L. acidophilus* NP45 (10^6 CFU per steer daily); or (5) LNP51145: low dose of NP51 (10^6 CFU per steer daily), *P. freudenreichii* (10^9 CFU per steer daily), and NP45 (10^6 CFU per steer daily). Samples were collected from each animal and analyzed for the presence of *E. coli* O157 on day 0 (feces), 7 days before harvest (feces), and at harvest (feces and hide). At the end of the feeding period, cattle receiving HNP51 were 57% less likely to shed detectable *E. coli* O157 in their feces than were the controls. Cattle supplemented with a high dose of NP51 had reduced *E. coli* O157 prevalence in both fecal and hide samples, again indicating that this treatment may be an efficacious pre-harvest intervention strategy.

A follow-up study by Younts et al. (2005) evaluated the effects of three doses of *L. acidophilus* strain NP51 and a combination treatment of strains NP51 and NP45 on prevalence of *E. coli* O157 in cattle. Three hundred steers were assigned randomly to 60 pens and received one of five treatments: (1) control; (2) HNP51, high dose of NP51 at 10^9 CFU per steer daily; (3) MNP51, NP51 at 10^8 CFU per steer daily; (4) LNP51, low dose of NP51 at 10^7 CFU per steer daily; and (5) NP51145, NP51 at 10^9 CFU per steer daily and NP45 at 10^6 CFU per steer daily. All DFM treatments included *P. freudenreichii* at 10^9 CFU per steer. Individual rectal fecal samples were collected on arrival and every 28 days throughout the feeding period. Cattle receiving HNP51, MNP51, and LNP51 had a lower prevalence of *E. coli* O157 throughout the feeding period compared with the controls, and the dose response for NP51 was a linear decrease in prevalence with increasing dose. No decrease in prevalence for cattle receiving the combination NP51145 was detected compared with controls. *E. coli* O157 prevalence values averaged across collection times were 23.9, 10.5, 9.9, 6.8, and 17.3% for cattle in the control, LNP51, MNP51, HNP51, and NP51145 groups, respectively. We concluded that the greatest decrease in *E. coli* O157 carriage was achieved using NP51 at 10^9 CFU per steer.

Two further subsequent studies demonstrated the effectiveness of NP51 in the control of *E. coli* O157:H7 shedding in cattle. In a study conducted by Stephens et al. (2007), 500 yearling steers were housed in pens of 10 animals each. Upon arrival, steers were randomly allocated to one of five cohorts. Four of the cohorts were fed various strains and dosages of *Lactobacillus*-based DFM throughout the feeding period. Fecal samples were collected from the rectum of each animal immediately prior to shipment to the abattoir. The prevalence in the controls (26.3%) was significantly greater than that in cattle supplemented with *L. acidophilus* strains NP51, NP28, or NP51-NP35 (13.0, 11.0, and 11.0%, respectively). The greatest *E. coli* O157 concentration was observed in the controls (3.2 log most probable number, MPN/g of feces); this concentration was significantly greater than that observed in positive animals receiving NP51, NP28, or NP51-NP35 (0.9, 1.1, 1.7 log MPN/g of feces, respectively). We demonstrated that specific strains of *Lactobacillus*-based DFMs effectively reduced the prevalence and concentration of *E. coli* O157 in harvest-ready cattle. Another subsequent study we conducted (Stephens et al. 2007b) evaluated the effectiveness of DFM in reducing *E. coli* O157 and *Salmonella* in beef cattle. Steers (n =240) received one of four treatment concentrations: control (lactose carrier only); low (10^7 CFU per steer daily *Lactobacillus acidophilus* NP51); medium (10^8 CFU per steer daily *L. acidophilus* NP51); and high (10^9 CFU per steer daily *L. acidophilus* NP51). All diets included 10^9 CFU per steer *Propionibacterium freudenreichii* NP24. Feces were collected from each animal at allocation of treatment and found to have no variation between cohorts concerning *E. coli* O157 recovery. No significant dosing effects were detected for *E. coli* O157 recovery from feces at the medium dose or from hides at the medium and high doses. *E. coli* O157 was 74% and 69% less likely to be recovered in feces from animals receiving the high and low diets, respectively, compared with controls. Compared with controls, *E. coli* O157 was 74% less likely to be isolated on hides of cattle receiving the low dose. No significant dosing effects were detected for *Salmonella* recovery from feces at the medium and low doses or from hides at any doses. Compared with controls, *Salmonella* was 48% less likely to be shed in feces of cattle receiving the high dose.

Finally, Pond and Brashears (2013, unpublished data) evaluated the effect of feeding *L. animalis* strain NP51 on the prevalence and concentration of non-O157 STEC serogroups O26, O45, O103, O111, O121, and O145. In one study, conducted in a commercial feedlot, approximately 1,800 cattle were randomized upon arrival into treatment and control pens. The control pens were fed routine feedlot diets whereas treatment pens received a diet that only differed by the daily supplementation of 10^9 CFU

of NP51 and 10^9 CFU of *Propionibacterium* NP24. Twenty-five fecal pats were taken from each pen (n = 600 samples) prior to transport to a regional abattoir for slaughter. A second study was conducted in a research-dedicated feedlot. One-hundred twelve cattle were blocked by weight and randomized into treatment or control pens at a research feedlot. Fecal grabs were collected from the rectum of each animal prior to transport to a regional abattoir for slaughter. In the commercial feedlot, *E. coli* O157 was detected in 45% fewer fecal pats compared to the contemporaneous control cohort. Within positive samples, the concentration of *E. coli* O157 was 1.23 $\log_{10}$ CFU/g lower among treated animals compared to controls ($P = 0.02$). Genes encoding serogroups O26, O45, O103 and O121 were detected 53.2% ($P = 0.01$), 41.2% ($P < 0.01$), 34.6% ($P = 0.03$) and 47.4% ($P = 0.02$), respectively, less frequently among treated animals compared to controls. In the research feedlot, *E. coli* O157 was recovered from 75% fewer treated cattle compared to controls. However, no differences were detected for the non-O157 serogroups evaluated. The results of this study show promising evidence that the use of DFM may be effective in reducing the prevalence and concentration of non-O157 STEC, along with a proven effectiveness for the reduction of STEC O157 and *Salmonella* in the feces and lymph nodes of beef cattle.

As previously stated, many other research groups have evaluated the efficacy of NP51 in reducing pathogens in the gastrointestinal tract of cattle. In a recent study published in *Zoonosis and Public Health* (Wisener et al, 2015), they conducted a Meta-analysis of 16 independent research studies related to pathogen reduction in cattle when fed NP51. From the 16 studies, they concluded that the NP51 significantly reduced *E. coli* O157:H7 prevalence and when used in cattle feeding systems could prevent human illnesses from beef products.

While pathogen contamination in the GI tract is a concern, we have also generated significant data in recent years indicating that *Salmonella* can be harbored in the lymph nodes of the animals and can be incorporated into ground beef thus posing a public health risk. During the past three years, several studies have been conducted in the Food Safety Laboratories at Texas Tech University to evaluate the effect of DFM on the prevalence and concentration of *Salmonella* and STEC in bovine feces and lymph nodes. A study conducted in our lab (Vipham et al, 2015) evaluated a total of 112 steers blocked by weight in a research feedlot with 14 pens/treatment and 4 steers/pen. Cattle were randomized to either a control group or a treatment group with 10^9/head/day *L. animalis* NP51 supplementation. Immediately after slaughter, LN were acquired from the steers (n=107). *Salmonella* prevalence in bovine subiliac LN from control cattle was found to be 34.0%. A significant reduction in *Salmonella* prevalence of 88.0 % was observed between control cattle and cattle fed NP51. *Salmonella* concentration in treatment cattle were more likely to be low (at 1 log CFU/g or below the level of detection) while higher (4 log CFU/g) concentrations were more likely to be found in control samples. The results from this study indicated that supplementation with 10^9/head/day NP51 as a pre-harvest intervention will successfully reduce both the prevalence and concentration of *Salmonella* in bovine lymph nodes.

Guillen and Brashears (2015, unpublished data) evaluated the effect of *L. acidophilus* NP51 at a rate of 10^9/head/day (NP51) on the reduction of *Salmonella* prevalence in cattle lymph nodes. Approximately 1,800 cattle were randomized into two treatments in a commercial feedlot with 12 pens/treatment and 75 head/pen. Subiliac lymph nodes were obtained from approximately 25 animals/pen (n= 600) at the slaughter facility. *Salmonella* was recovered from 25% fewer LN for cattle fed NP51 when compared to controls. Quantitatively the NP51 cattle had significantly less *Salmonella* in lymph nodes (3.1 vs 4.2 $\log_{10}$ cfu/lymph node) and per gram of lymph nodes (1.9 vs. 2.9 log10 cfu/g).

Control samples were more likely to have a higher concentration of *Salmonella* in lymph nodes with 10.4% vs. 11.7% between 3 and 4 $\log_{10}$ cfu/g; 13.7% vs. 6.4% between 4 and 5 $\log_{10}$ cfu/g, and 7.5% vs. 2.1% greater than 5 $\log_{10}$ cfu/g. The results of this study indicated that supplementation with NP51 is an effective pre-harvest intervention to reduce the prevalence of *Salmonella* in cattle lymph nodes, which may lead to a decrease in the *Salmonella* prevalence if ground beef.

Recently, a study was conducted to examine the efficacy of using *Lactobacillus animalis* and *Propionibacterium freudenreichii* (NP24) to control *Salmonella* within PLNs of feedlot cattle (Gragg et al., 2013). Cattle were randomly allocated into either control or DFM treatment groups. Diets of treated cattle were supplemented with 10^9 CFU/head/day of the DFM, while control groups received no DFM supplementation. During slaughter, one subiliac lymph node (SLN) per carcass was collected from 627 carcasses from one study and 99 carcasses from a second study. In the first study, effects of DFM supplementation varied across slaughter days. On the first and second slaughter days, the prevalence of *Salmonella* was significantly reduced by 50% and 31%, respectively. In the second study, *Salmonella* was 82% less likely (p=0.008) to be recovered from SLNs of treatment cattle. While a greater relative risk reduction was observed in the latter study, absolute risk reductions were similar across studies. Once again, the results indicated that NP51 and NP24 supplementation may aid in reducing the prevalence and concentration of *Salmonella* in SLNs and, therefore, serve as an effective control measure to reduce *Salmonella* in ground beef products.

Post-Harvest Food Safety

At Texas Tech University we have a very specialized set up to evaluate processes in simulated industry settings. More than 100 food processes have been validated in our pathogen processing area in which results are proprietary to protect specific companies. This validation service is offered for companies with a need to determine if their processes result in adequate reduction of pathogens during processing. In general, we have validated safe procedures for the production of cooked products, fresh products and even pet foods. We have also utilized this research laboratory space to a conduct research that addresses food safety issues to generate data that are directly applicable to the industry and can be used to make process decisions to produce safe food products.

We have generated data on reducing the food safety risks of needle tenderized beef products. In one study, we evaluated 3 different intervention strategies (lactic acid, lactic acid bacteria, and acidified sodium chlorite) to control *E. coli* O157:H7 and *Salmonella* in mechanically tenderized and brine-enhanced beef strip loins when applied to the steaks prior to packaging and shipment for processing. After tenderization, lactic acid bacteria reduced internal *E. coli* O157:H7 loads 1.2 to 2.2 log cycles, while the acidified sodium chlorite and lactic acid reduced them between 0.8 and 3.0 log, respectively. *Salmonella* was also reduced internally after application of all interventions between 0.9 and 2.2 log. The application of antimicrobials to the steaks prior to packaging and shipment on day 0 was effective in reducing internalization of both pathogens in non-intact beef products. (Echeverry et al, 2009) In a similar study, our aim was to validate the use of lactic acid bacteria (LAB), acidified sodium chlorite (ASC), and lactic acid (LA) sprays when applied under a simulated purveyor setting as effective interventions to control and reduce *E. coli* O157:H7 and *Salmonella* prior to tenderization. LAB and LA reduced internal *E. coli* O157:H7 loads up to 3.0 log, while ASC reduced the pathogen 1.4 to 2.3 log more than the control ($P < 0.05$), respectively. *Salmonella* Typhimurium DT 104 was also reduced internally 1.3 to 2.8, 1.0 to 2.3, and 1.4 to 1.8 log after application of LAB, LA, and ASC, respectively. (Echeverry et al, 2010)

We also evaluated the impact of various interventions on the reduction of pathogens during ground beef production. These data are important to inform producers on the proper use of interventions in industry settings. We conducted a study to determine if acidified sodium chlorite (1,200 ppm) and acetic and lactic acids (2 and 4%) were effective in reducing foodborne pathogens in beef trim prior to grinding in a simulated processing environment. The reduction of *Salmonella* Typhimurium and *Escherichia coli* O157:H7 at high (4.0 log CFU/g) and low (1.0 log CFU/g) inoculation doses was evaluated. All antimicrobial treatments reduced the pathogens on the trim inoculated with the lower inoculation dose to non-detectable numbers in the trim and in the ground beef. There were significant reductions of both pathogens in the trim and in the ground beef inoculated with the high inoculation doses. On the trim itself, *E. coli* O157:H7 and *Salmonella* Typhimurium were reduced by 1.5 to 2.0 log cycles, with no differences among all treatments. In the ground beef, the organic acids were more effective in reducing both pathogens than the acidified sodium chlorite immediately after grinding, but after 1 day of storage, there were no differences among treatments. Overall, in the ground beef, there was a 2.5-log reduction of *E. coli* O157:H7 and a 1.5-log reduction of *Salmonella* Typhimurium that was sustained over time in refrigerated and frozen storage. Very few sensory differences between the control samples and the treated samples were detected by a consumer panel. (Harris, 2006)

In a similar study we compared the effectiveness of two application methods (dip versus spray) of 4.4% lactic acid for reducing pathogens on inoculated beef trim and in ground beef. Beef trim inoculated with cocktail mixtures of *E. coli* O157:H7, non-O157 Shiga toxigenic *E. coli* (STEC), or *Salmonella* (10^5 to 10^6 CFU/g) at separate times was subjected to five treatments: lactic acid spray (LS), lactic acid dip (LD), water spray (WS), water dip (WD), and untreated control (CTL). The dip treatment reduced all pathogens significantly ($P < 0.05$); *E. coli* O157:H7 was reduced by 0.91 to 1.41 log CFU/g on beef trim and ground beef, non-O157 STEC by 0.48 to 0.82 log CFU/g, and *Salmonella* by 0.51 to 0.81 log CFU/g. (Wulf et al, 2012)

While the use of interventions is prevalent in the beef industry, mechanical interventions are also valuable. I have also been involved in the development of a spin-off company of Texas Tech University, MicroZap which is a technology company which has several U.S. and international patents on a process that utilizes the use of microwaves in unique configurations to solve a number of world problems including killing of MRSA (Methicillin resistant *Staphlococcus aureus*) (Laury et al, 2011), pasteurizing eggs (Lakins et al, 2008, 2009), improving water safety for third world countries and extending the shelf-life of bread by eliminating the molds thus decreasing food waste (Lakins et al 2008). The current goal of the use of the MicroZap system is to kill *Salmonella* in peanut butter. Overall, the microwave technology uses radio waves in the microwave spectrum in a novel and controlled process to reduce pathogens in foods without damaging the food. Pathogens and other microorganisms are killed without cooking the food when the microwaves are properly applied because in addition to the killing action of the temperature itself, the energy generated from the microwaves also cause a non-thermal killing effect which allows treatment at lower temperatures than simply using temperature alone.

The MicroZap system kills of *Salmonella* on peanuts (Laury et al, 2011) and we found that 99% of the *Salmonella* was killed on the surface of the raw peanuts after treatment in the MicroZap chamber. We can also achieve a 3 log reduction (99.5%) of *Salmonella* in peanut butter in the jars. The use of the MicroZap system was highlighted by the BBC in 2012 and there are many potential applications of the technology with the reduction of *Salmonella* in peanut butter being at the top of the list. The specific production parameters of the technology must be optimized to kill pathogens and also to preserve the quality of the food itself.

Safety of Imported Products and Food Security

Much food safety research in our program has focused on improving food safety and security in Latin America and the Caribbean. Foodborne diarrheal illness is the number one cause of death in children under five in Mexico. This is a preventable problem as the key need is education. We do not need a new technology, we need to educate the industry and consumers on proper food handing. Currently we have active projects in Mexico, Honduras, Nicaragua, Costa Rica, Panama, Colombia, Bahamas, the Dominican Republic and Haiti. The bulk of the work is in Mexico, Honduras and the Bahamas. In our international program efforts, we have developed relationships and partnerships to improve food safety, security and public health through research and education. Our goals are to improve technical knowledge, share research innovations across borders, invest in international development of 3rd world countries and to increase market access for U.S. industries.

Of key importance is the validation of the safety of products from plants that export to product to the U.S. We have conducted validation studies in beef slaughter plants in Mexico, Honduras, Nicaragua and Costa Rica to validate the efficacy of the process with regard to *Salmonella* and STEC contamination. This was of key importance to the U.S. industry and to the company. In a Honduran beef plant that exported product to the U.S., the total *Salmonella* detected on hides was 17.5%, pre-evisceration carcasses contained 6.7% samples that were positive while there were none found on the final carcass (Maradiaga et al., 2015). In Mexico, we evaluated both *Salmonella* and *E. coli* O157:H7 prevalence during beef harvest. With regards to *Salmonella*, the hides were 80% positive, the pre-evisceration carcasses had 15% of the samples positive for *Salmonella* while none of the samples from the cooler were positive. In the same facility in Mexico, 6% of the hides were positive for *E. coli* O157:H7 while none of the carcass samples at any sampling point were positive. The study was repeated in Nicaragua where 90% of the hide samples tested positive for *Salmonella* and none of the carcass samples were positive for the pathogen. We tested the prevalence of the non-O157:H7 O groups from the hide samples in Honduras and Nicaragua and found the majority were O26, O131 and O45. A similar trend was found in plants that export product to the U.S. in Costa Rica. The focus of this study was non-O157:H7 STECS. The hides were up to 96% positive, but very little pathogen contamination was found on the final carcasses with only 2 of 90 testing positive. The prevalent O groups were O103 and O45. In all inspected facilities that export beef to the U.S. and are overseen by FSIS oversight, the prevalence of pathogens is very low and equivalent to the U.S. pathogen baselines. The FSIS oversight in these countries is working to prevent public health hazards.

In contrast, we also observed facilities and products from facilities that were not subjected to U.S. equivalency rules. These facilities are in desperate need of educational efforts. *Salmonella* prevalence in some of the facilities was up to 100% and poor dressing procedures were observed. These numbers correlated to high *Salmonella* prevalence in market samples with 80% being positive. Unfortunately, these markets serve the poorest, most vulnerable populations and there is a need to protect public health in these areas.

Communication and Outreach to Industry

Capacity Building

In the fall of 2012, we received a capacity building grant from the USDA-NIFA Non-Land Grant Capacity Building (NLGCB) program in the amount of $690,000. This money was leveraged for an equipment donation from the Pall Corporation for an additional $150,000. The title of this project is "Building Laboratory and Intellectual Capacity in order to Effectively Detect and Reduce *Salmonella* in

the Food Supply." While much attention and funding has been directed at STEC detection and reduction in recent years, universities along the southwest corridor are severely lacking in the equipment, knowledge and human capacity to effectively detect and mitigate *Salmonella* in foods, especially in the small ruminants and fresh fruits and vegetables that account for much of Hispanic diet in this region of the U.S.

This program was built on three underlying needs. First, non-land grant universities such as Texas Tech have limited resources available to build research and educational capacity. Second, teams of scientists who can work to solve this issue must have the scientific skills to work in the laboratory and field, but must also have the relational skills to work effectively within multidisciplinary teams, and third, faculty teaching must constantly evolve and improve to meet the changing needs of the industry. In order to effectively address these three needs, our team proposed a multidisciplinary approach to efficiently meet four objectives.

Our first objective deals with our ability to build human capital in all STEM fields related to this problem of detecting and mitigating Salmonella in the food supply. In order to identify high-ability undergraduate students who would work in the U.S. and in Latin America, we created the SOWER Scholar program. SOWER stands for Sustaining our World through Education and Research. The concept is to recruit, train and return students to countries where their academic preparation and directly affect food production. In conjunction with partnering universities, we have hosted 35 students from Zamorano University in Honduras. This USAID agricultural school recruits the best undergraduates from Latin American countries and trains them in agriculture. During their final year, they are required to complete an internship. We take 10-20 students each spring and match them with a faculty member for an intense 4-month program. They range from food safety, meat science, soil and plant science, communications, economics and human nutrition. This program is design to improve English speaking and writing, research skills, laboratory skills as well as identify which of these students are best equipped to return in for graduate programs. We currently have nine graduate students who have come through this program and it continues to grow as we hosted 30 undergraduate interns this summer and have another 35 coming this fall for short-term experiences.

Our second objective focuses on developing those graduate students to be change agents by equipping them with the knowledge, skills and abilities to dramatically impact the region from a food security perspective. While technical skills are a necessity and can be provided in many universities, we wanted to go beyond the traditional technical training to produce students with the ability and the passion to have positive impacts in agriculture. We exceeded our grant activities of providing limited distance resources and created a graduate certificate in Global Food Security that can be delivered on campus or at a distance. This certificate includes two all-new introductory courses in food security and four tracks that allow a student to specialize their educational experience. These tracks align with the U.N.'s Pillars of Food Security: Access, Availability, Stability and Utilization. Our track areas within these pillars include Production, Food Safety, Human Nutrition and Program Development and Analysis. This graduate certificate has been approved at all levels at Texas Tech and is waiting on approval from the Texas Higher Education Coordinating Board, which we expect in October. When this program launches in January, we expect 30+ graduate students from Texas Tech University, San Angelo State and California State University – Fresno to make up the first cohort.

In addition to our two southwest regional partners, we have formed relationships with multiple universities and industry groups throughout the U.S. and Latin America. Our faculty continues to expand their knowledge and understanding of their role in improving food safety through training and

professional development opportunities. Through the course of installing new equipment in laboratories at San Angelo State and CSU – Fresno, we have trained multiple faculty members and students on proper sampling and testing techniques. These training opportunities have also led to the expansion of our understanding of the breadth of the problem within the small ruminant population. Over a 14-month period samples were collected to determine a microbial prevalence for sheep and goats. Fecal samples were collected from the Bahamas, Mexico, Texas, New Mexico and California from abattoirs and farm locations. Fecal samples from small-ruminants were found to have 14.02% *Salmonella* prevalence (N=535), 15.30% *Escherichia coli* O157 prevalence (N=477) and 80.68% *Campylobacter* prevalence (N=176). Retail samples collected from the Bahamas and U.S. were found to have a *Salmonella* prevalence of 16.98% (N=106). This analysis was conducted and completed by students and faculty using skills and equipment that only exist as a result of this grant project.

Finally, this project has helped forge permanent collaborative partnerships at two levels. We have created horizontal connections focused on research, education and international experiences between the three universities in the southwest U.S. and better equipped them to detect and reduce *Salmonella* in the U.S. food supply. We have also created a wealth of vertical connections between our faculty and international partners in universities, government agencies and industry. The U.S. food supply is safer today because of the actions of this grant project that it would have been otherwise, but far more work is needed to protect consumers as markets continue to expand and globalize.

Consumer Education through the Media

There is a strong effort to communicate our findings to our stakeholders, we hold food safety workshops for stakeholders (cattle producers, food industry, consumers), have a website (www.icfie.co) and participate in dozens of industry conferences each year. It is important for scientists like myself and our team to help consumers understand the safeguards in place and their role in food safety. I'm finding more scientists like myself engaging with social media to provide clarity to consumers. I personally have a site on social media (The Food Doctor) which can be found on Facebook where I provide science-based information for the public. I recently appeared on the Today Show to negate negative information that was conveyed in a Consumer Reports article about the beef industry. It is important for consumers to have a readily-available science-based source of information in order to make informed decisions about agriculture.

In summary, investments in research and education save lives. There is a need to address food safety issues in the U.S. and globally to improve the quality of life and protect public health for our population. Funding is the key to develop new technologies to control emerging pathogens and to communicate science-based information to the consumer.

REFERENCES:

1. Ajayi, O., L. L. Williams, J. Oluwoy, J.U. Johnson, F. Okafor, O-G. Sanders, and T. Wilson. 2011. Epidemiological Approaches to Food Safety. Food Protection Trends. 31, 560-568.
2. Berrry, E. and J.E. Wells. 2010. *Escherichia coli* O157:H7: Recent Advances in Research on Occurrence, Transmission, and Control in Cattle and the Production Environment. Advances in Food and Nutrition Research. 60, 67-117.
3. Brashears, M.M., M.L. Galyean, G.H. Loneragan, J.E., Mann, and K. Killinger-Mann. 2003. Prevalence of Escherichia coli O157:H7 and performance by beef feedlot cattle given Lactobacillus direct-fed microbials. Journal of Food Protection. 66, 748-754.
4. Callaway, T.R., M.A. Carr, T.S. Edrington, R.C. Anderson, D.J. Nesbit. 2009. Diet, *Escherichia coli* O157:H7, and Cattle: A Review After 10 Years. Current Issues in Molecular Biology. 11, 67-80.
5. Centers for Disease Control and Prevention (CDC). 2015. Surveillance for Foodborne Disease Outbreaks, United States, 2013, Annual Report. Available online at http://www.cdc.gov/foodsafety/pdfs/foodborne-disease-outbreaks-annual-report-2013-508c.pdf. Accessed on 09/23/2015
6. Chaves, B.D., A. Echeverry, L.G. Garcia, M.T. Brashears, M.F. Miller, and M.M. Brashears. 2015. Seasonal prevalence of potentially positive non-O157 Shiga toxin-producing Escherichia coli (STEC) bovine hides and carcasses in Costa Rica. Meat Science. 110, 196-200.
7. Chaves, B.D., M.F. Miller, M. Maradiaga, M.A. Calle, L. Thompson, S.P. Jackson, T. Jackson, L.G. Garcia, A. Echeverry, H. Ruiz, and M.M. Brashears. 2013. Evaluation of process control to prevent contamination of beef with non-O157 Shiga toxin-producing *Escherichia coli* (STEC) in U.S. export abattoirs in Honduras and Nicaragua. Food Protection Trends, 33(4):224–230.
8. Crim, S, M. Iwamoto, J.Y. Huang, P.M. Griffin, D. Gilliss, A.B. Cronquist, M. Cartter, M. Tobin-D'Angelo, D. Blythe, K. Smith, et al. 2014. Incidence and Trends of Infection with Pathogens Transmitted Commonly Through Food — Foodborne Diseases Active Surveillance Network, 10 U.S. Sites, 2006–2013. MMWR. 63, 328-332.
9. Doores, S. 1999. Food Safety: Current Status and Future Needs. American Academy of Microbiology. Washington D.C. On-line version accessed on 03.06.15 at http://academy.asm.org/index.php/food-microbiology/437-food-safety-current-status-and-future-needs
10. Echeverry, A., J. C. Brooks, M. F. Miller, J.A. Collins, G. H. Loneragan, and M. M. Brashears. 2009. Validation of Intervention Strategies to Control Escherichia coli O157:H7 and Salmonella Typhimurium DT 104 in Mechanically Tenderized and Brine Enhanced Beef. Journal of Food Protection. 72, 1616-1623.
11. Echeverry, J. C. Brooks, M. F. Miller, J. A. Collins, G. H. Loneragan, and M. M. Brashears. 2010. Validation Of Lactic Acid Bacteria, Lactic Acid, And Acidified Sodium Chlorite As Decontaminating Interventions To Control Escherichia coli O157:H7 And Salmonella Typhimurium DT 104 In Mechanically Tenderized And Brine Enhanced (Non - Intact) Beef At The Purveyor. Journal of Food Protection. 73, 2169- 2179.
12. Gragg, S.E., G. H. Loneragan, M. M. Brashears, T. M. Arthur, J.M. Bosilevac, N. Kalchayanand, R. Wang, J.W. Schmidt, J. C. Brooks, S.D. Shackelford, T.L. Wheeler, T.R. Brown, T.S. Edrington, and D. M. Brichta-Harhay. 2013. Cross-sectional Study Examining *Salmonella enterica* Carriage in Subiliac Lymph Nodes of Cull and Feedlot Cattle at Harvest. Foodborne Pathogens and Disease. 10, 368-374.

13. Harris, K., M.F. Miller, G.H. Loneragan, and M.M. Brashears. 2006. Validation of the Use of Organic Acids and Acidifed Sodium Chlorite To Reduce *Escherichia coli* O157 and *Salmonella* Typhimurium in Beef Trim and Ground Beef in a Simulated Processing Environment. Journal of Food Protection. 69,1802-1807.
14. Hoffmann, S. B. Maculloch, and M. Batz. 2015. Economic Burden of Major Foodborne Illnesses Acquired in the United States. United States Department of Agriculture Economic Research Service. Available online at http://www.ers.usda.gov/media/1837791/eib140.pdf. Accessed on 09/23/2015.
15. Lakins, D., A. Echeverry, C.Z. Alvarado, J.C. Brooks, M.T. Brashears, and M.M. Brashears 2008. Quality and Mold Growth on White Enriched Bread for Military Rations Following Directional Microwave Treatment. Journal of Food Science. 73,99-103.
16. Lakins, D., C.Z. Alvarado, L.D. Thompson, M.T. Brashears, J.C. Brooks, and M.M. Brashears. 2008. Reduction of *Salmonella* Enteritidis in Shell Eggs Using Directional Microwave Technology. Poultry Science. 87, 985-991.
17. Laury A.M., K. Fermin, D. Stull, A. Neuber, J.C. Brooks, M.T. Brashears, C. Alvarado, and M.M. Brashears. 2011. Reduction of Methicillin-resistant Staphylococcus aureus (MRSA) on towels utilizing targeted directional microwave technology. 111th General Meeting of the American Society for Microbiology, May 21-24, New Orleans, LA.
18. Laury A.M., K. Fermin, D. Stull, A. Neuber, J.C. Brooks, M.T. Brashears, C. Alvarado, and M.M. Brashears. 2011. Re-distribution of Methicillin-resistant Staphylococcus aureus (MRSA) during the laundering of cotton towels. 111th General Meeting of the American Society for Microbiology, May 21-24, New Orleans, LA.
19. Loneragan, G.H. and M.M. Brashears. 2005. Pre-harvest interventions to reduce carriage of *E. coli* O157 by harvest-ready feedlot cattle. Meat Science. 71, 72-78.
20. Mangen, M-J., M. B. Batz, A. Kasboher, T. Hald, J.G. Morris, M. Taylor, A. Havelaar. I2010. Integrated Approaches for the Public Health Prioritization of Foodborne and Zoonotic Pathogens. Risk Analysis. 30, 782-787.
21. Maradiaga, M., M.F. Miller, L. Thompson, A. Pond, S.E. Gragg, A. Echeverry, L.G. Garcia, G.H. Loneragan, and M.M. Brashears. 2013. Salmonella in Retail Beef and Produce from Honduras and Mexico. Submitted to the *International Journal of Food Microbiology* (In Review).Journal of Food Protection. 3, 498-502.
22. Narvaez-Bravo, C., M. F. Miller, T. Jackson, S. Jackson, A. Rodas-Gonzalez, K. Pond, A. Echeverry, And M. M. Brashears. 2013. *Salmonella* and *Escherichia coli* O157:H7 Prevalence in Cattle and on Carcasses in a Vertically Integrated Feedlot and Harvest Plant in Mexico. Journal of Food Protection. 76, 786–795.
23. Sargeant, J. M., M. R. Amezcua, A. Rajic and L. Waddell. 2007. Pre-harvest interventions to reduce the shedding of *E. coli* O157 in the faeces of weaned domestic ruminants: a systematic review. Zoonoses and Public Health. 54, 260-277.
24. Scallan E, Hoekstra RM, Angulo FJ, Tauxe RV, Widdowson M-A, Roy SL, et al. 2011. Foodborne illness acquired in the United States—major pathogens. Emerging Infectious Diseases. 17, 7-15.
25. Stephens, T.P., G.H. Loneragan, E. Karunasena, and M.M. Brashears. 2007a. Reduction of *Escherichia coli* O157 and *Salmonella* in feces and on hides of feedlot cattle using various doses of a direct-fed microbial. Journal of Food Protection. 70, 2386-2391.

26. Stephens, T.P., G.H. Loneragan, L.M. Chichester, and M.M. Brashears. 2007b. Prevalence and enumeration of *Escherichia coli* O157 in steers receiving various strains of *Lactobacillus*-based direct-fed microbials. Journal of Food Protection. 70, 1252-1255.
27. Vipham, J.L., G.H. Loneragan, L.M. Guillen, J.C. Brooks, B.J. Johnson, A. Pond, N. Pond, and M.M. Brashears. 2015. Reduced Burden of *Salmonella enterica* in Bovine Subiliac Lymph Nodes Associated with Administration of a Direct-fed Microbial. Zoonoses and Public Health. Article first published online: 17 MAR 2015. DOI: 10.1111/zph.12187
28. Wolf, M.J., M.F. Miller, A.R. Parks, G.H. Loneragan, A.J. Garmyn, L.D. Thompson, A. Echeverry, and M.M. Brashears. 2012. Validation Comparing the Effectiveness of a Lactic Acid Dip with a Lactic Acid Spray for Reducing Escherichia coli O157:H7, Salmonella, and Non-O157 Shiga Toxigenic Escherichia coli on Beef Trim and Ground Beef. Journal of Food Protection. 75, 1968–1973.
29. Younts-Dahl, S.M., G.D. Osborn, M.L. Galyean, D.J. Rivera, G.H. Loneragan, and M.M. Brashears. 2005. Reduction of Escherichia coli O157 in finishing beef cattle by various doses of Lactobacillus. Journal of Food Protection. 68, 6-10.
30. Younts-Dahl, S.M., M.L. Galyean, G.H. Loneragan, N.A., Elam, and M.M. Brashears. 2004. Dietary supplementation with *Lactobacillus*- and *Propionibacterium*-based direct-fed microbials and prevalence of Escherichia coli O157 in beef feedlot cattle and on hides at harvest. Journal of Food Protection. 67, 889-893.