DISSERTATION

NATIONAL BEEF QUALITY AUDIT 2016 FACE TO FACE INTERVIEWS AND VALIDATION OF HPP PATHOGEN DESTRUCTION FOR USE IN RAW PET FOOD

Submitted by

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ABSTRACT

NATIONAL BEEF QUALITY AUDIT-2016 FACE TO FACE INTERVIEWS AND VALIDATION OF HPP PATHOGEN DESTRUCTION FOR USE IN RAW PET FOOD

The two studies described in this dissertation (1) were The National Beef Quality Audit (NBQA) and (2) the Validation of HPP Pathogen Destruction for Use in Raw Pet Food. The NBQA is conducted every five years; the 2016 version face-to-face interviews gauged the status and progress of the live cattle production industry in improving overall quality and consistency of beef using the procedures of set forth in NBQA 2011.This was the first time that the audit of fed steers and heifers was combined with an audit of market cow and bull beef. Face-to-face interviews were designed to illicit definitions for beef quality, estimate willingness to pay (WTP) for quality attributes, establish relative importance (RI) rankings for important quality factors, and assess images, strengths, weaknesses, potential threats, (SWOT) and shifting trends in the beef industry since the 2011 audit. Individuals making purchasing decisions in five market sectors of the steer/heifer and cow/bull beef supply chain were interviewed, including packers (n = 36), retailers (including large and small supermarket companies and warehouse food sales companies; n = 35), food service operators (including quick-serve, full-service, and institutional establishments; n = 29), further processors (n = 64), and peripherally related government and trade organizations (GTO; n = 30). Face-to-face interviews were conducted across the U.S. between January and November of 2016 using a designed (by sequence) dynamic routing program designed on the Qualtrics software platform (Qualtrics 2016; Provo, UT, USA). Interviewers from three separate land-grant universities first correlated on the administration of

interviews in November of 2015 to standardize data collection. Definitions (as described by interviewees) for the seven pre-determined quality factors, including: (1) How and where the cattle were raised, (2) Lean, fat, and bone, (3) Weight and size, (4) Visual characteristics, (5) Food safety, (6) Eating satisfaction, and (7) Cattle genetics were recorded verbatim and categorized into similar responses for analysis. It was critical to understand how interviewees perceived the meaning of each of the seven quality factor groupings to interpret WTP and RI responses. As in NBQA-2011, "food safety" was the most important ($P < 0.05$) quality factor in RI scaling. Additionally, each sector that did not list "food safety" as a non-negotiable *must have* characteristic, but was willing to pay a premium for the trait, said that they would pay an average of 11.1% premium for a guarantee of their definition of "food safety" (likely overinflated). The "eating satisfaction" quality factor, primarily defined as "customer satisfaction" by all sectors, was ranked second ($P < 0.05$) by all marketing sectors except packers, who ranked "lean, fat, and bone" second. Compared to NBQA-2011, generally, a higher percentage of companies were willing to pay a premium for guaranteed quality attributes, but overall were willing to pay lower average premiums than the companies interviewed in 2011.

In the second part of this study, (2) non-pathogenic *E. coli* (ATCC BAA 1427-31), were used to validate the efficacy of High Pressure Processing (HPP) as a destruction tool for use in raw pet food. According to the American Pet Products Association (APPA), pet industry expenditures in the U.S. have grown more than 350% in the past 20 years. Monetarily, annual expenditures increased by approximately $2 billion dollars each year for the past 5 years. Furthermore, APPA estimates that 2016 U.S. pet industry expenditures will exceed $62 billion dollars. Raw pet food products are a rapidly growing sector of the pet food industry. While these formulations are increasingly attractive to pet owners, food safety has historically been a

concern. This concern, met with FDA regulations of "zero tolerance" for *Salmonella*, demands that raw pet food producers explore technologies for the elimination of pathogens in raw pet food products. Thus, the objective of this second experiment was to evaluate the effects of HPP and frozen storage on the destruction of surrogate pathogens in a raw pet food.

Approximately 18 kg of a raw beef pet food was inoculated to a target of 7 logs CFU/g with a 5 strain cocktail of non-pathogenic *Escherichia coli* (ATCC BAA 1427-31), which previously were validated as surrogates for STECs and *Salmonella* (Dickson, 2015). Inoculated product was packaged in 227 g individual roll-stock packages and shipped to a commercial HPP facility for HPP application. Inoculated samples were subjected to HPP at 87,000 psi for 480 seconds. After HPP processing, samples were transported on ice to Colorado State University for determination of remaining bacterial populations. Samples were assigned randomly to either a 24-hours post-processing (n = 10) or following 5-d of frozen storage at -23˚C (n = 10) evaluation times. Raw product samples were serially diluted in BPW and plated onto selective (Violet Red Bile Agar; VRBA; selective for coliforms) and non-selective (Tryptic Soy Agar; TSA) medias for enumeration. The TSA survivors totaled 5.36 and 4.6 log CFU/g 24 hours post-HPP and post-frozen storage, respectively. Data were analyzed using the mixed procedure of SAS (version 9.3; Cary, NC) and separated using the PDIFF statement with an α of 0.05.

These data suggested that HPP is an effective tool for destruction of foodborne pathogens in raw pet food diets, but that HPP alone is not sufficient to reduce pathogenic loads beyond detection limits. Additionally, these data suggest that a frozen storage period following HPP may also be an effective method for enhancing pathogen destruction. Additional research related to the safety of raw pet food is needed.

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McClure that has rang loud and clear ever since the first time I heard him say it. I truly hope that I have and will continue to live out those words to the best of my ability.

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CHAPTER I

INTRODUCTION

The National Beef Quality Audit was the first audit ever to benchmark beef quality for the industry on a national scale. Based on W. Edwards Deming's philosophy, quality is measured by two factors, 1) a conformance to standards 2) meeting the customers' wants and needs (Deming, 1986). The NBQA set forth to measure quality under both definitions in 1991 utilizing three different phases. Phase 1 face-to-face interviews were designed to document the beef industry's ability to meet the customers' wants and needs, while phase 2 identified the conformance to standards by conducting in-plant audits of the coolers and slaughter floors. Phase 3 of NBQA was a strategic workshop designed to reveal the results of both phases to leaders of the beef industry in order to develop a strategy, for the improvement of the industry(Smith et al., 1992). The phases of NBQA have adapted over time to more adequately measure their original goals of benchmarking quality across the entire beef industry.

For the second part of the study included in this dissertation, researchers designed 5 raw pet food diets in accordance with Association of American Feed Control Officials (AAFCO) requirements for maintenance. FDA regulation regards *Salmonella* as an adulterant in animal feed (FDA, 2016b). Multiple recalls associated with non-thermally processed Ready-to-Eat (RTE) pet foods (FDA, 2016a) have occurred, and researchers evaluated the use of High Pressure Processing (HPP) as a measure to effectively reduce *Salmonella* to an undetectable limit within the raw pet food matrices.

CHAPTER II

REVIEW OF LITERATURE

Rationale for National Beef Quality Audit

The goal of the National Beef Quality Audit (NBQA) in 1991 was, "to conduct a quality audit of the slaughter steers/heifers (their carcasses, cuts and dress-off/offal items) for the U.S. beef industry in 1991, establishing baselines for present quality shortfalls and identifying targets for desired quality levels by the year 2001" (Smith et al., 1992). The NBQA consists of three phases: phase 1 are was face-to -face interviews with those that make purchasing decisions in the beef supply chain, phase 2 included in-plant audits of the slaughter floor and the grading coolers, and phase 3 was a strategy workshop revealing the results of the first two phases to develop a strategy to improve the beef industry over the next five years. Phase 1 interviews were conducted to reflect the wants and desires of those making purchasing decisions in multiple market sectors representing the beef supply chain. Phase 2 audits included collection of defect data from slaughter floors and grading coolers in participating facilities across the nation during multiple seasons of the year. Phase 3 was a strategy workshop designed to develop a roadmap for the industry to improve beef value including industry leaders from each sector of the phase 1 interviews of the marketing chain, as well as cattlemen and women from across the country. During these workshops, participants discussed the findings from phases 1 and 2 of the audit while developing improvement strategies.

The concept for conducting the NBQAs arose from multiple origins of quality management and statistical process control theory, but primarily from those principles studied and developed from principles by W. Edwards Deming championed (Deming, 1986). Based on

Deming's principles, Rod Bowling, an executive at Monfort of Colorado during the late 1980's, made the first attempt to quantify the monetary costs associated with quality shortfalls. In 1989, Bowling estimated that quality defects cost the industry an estimated $107.32 per head on average due to management errors, insufficient yield, and quality deficiencies (Smith et al., 1992). Following Bowling's estimations, Chuck Lambert of the National Cattlemen's Association penned a paper titled "Lost Opportunities in Beef Production." Lambert's paper estimated that the beef industry was losing approximately $11.999 billion due to shortfalls in cattle management, or beef carcass defects. Identification of the quality shortfalls presented in each of these early studies, in combination with the unknown validity of these estimates across the entire industry, were the driving factors establishing the need for conducting the original NBQA-1991 (Smith et al., 1992).

In a letter to customers, William (Bill) Fielding, President of Excel Corporation in 1991, listed 4 absolutes to explain his company's stance on quality: "1) Quality is not 'goodness,' it is conformance to requirements. 2) Quality demands the prevention of problems. Discovery of and correction of, problems after the fact has nothing to do with quality. 3) The only acceptable standard of performance is zero defects. 4) Measurement of quality is the price of nonconformance; the cost of correcting mistakes." Fielding's letter was similar to the ideas and philosophies driven by W. Edward Deming that ultimately shaped the rationale for conducting the original NBQA-1991 (Smith et al., 1992).

Deming

W. Edwards Deming was an American statistician, author, professor, and business consultant. He received his undergraduate degree in engineering from the University of Wyoming. He completed a Master's degree in physics and mathematics from the University of

Colorado-Boulder. Additionally, he received his Ph.D. from Yale University in 1928 in mathematical physics. Before completing his Ph.D., Deming learned of Water A. Shewhart's statistical control chart. For the first time, Shewhart's charts used data and statistical methods to quantify effectiveness of process controls in a sequence of processes involved in manufacturing of products (Institute, 1991).

Following completion of his Ph.D., Deming worked for the U. S. Department of Agriculture (USDA) in Washington, DC, then became a lecturer for the USDA Graduate School. In 1935, he studied under a highly successful statisticians and developed an in depth understanding of statistics, particularly sampling statistics which had a major impact on the U.S. census. In 1940, Deming began work with the U.S. Census Bureau increasing the accuracy and lowering the cost of the census; this marked the first use of statistical methods of quality improvement on a large scale. In 1946, he made his first trip to Japan as a statistical consultant to General Douglas MacArthur, to study agricultural problems within a defeated country. In 1947, he went back to Japan in order to prepare a census and to identify issues with housing and nutrition in the country (Institute, 1991).

Deming was well received in Japan because he treated the Japanese with respect not previously awarded to them by Americans. In 1950, he was asked to speak to a large group of Japanese businessmen and taught them the applications of statistics for quality improvements (Haga, 1950). In 1951, the Japanese Union of Scientists and Engineers initiated the "Deming Prize" as a recognition to Deming, as he refused to accept royalties from the transcripts of his lectures (Blog, 2016).

Dr. Deming's methods to improve product quality helped to rebuild Japan following WWII, and his Total Quality Management philosophy improved Japanese manufacturing in such

a way that it surpassed U.S. manufacturing with respect to product quality (Deming, 1986). His philosophy suggested that, by focusing on quality and controlling each processing step to cause a measurable outcome, a company could save money by reducing re-work, and ultimately improve customer relationships. He explained that, as companies primarily focused on reducing costs, quality of products eventually declined and costs inevitably rose over time (Deming, 1986). In 1980, a documentary entitled "If Japan Can, Why Can't We?" aired nationally and garnered attention to Deming's theories in the U.S., thus, revolutionizing quality control in manufacturing (Institute, 1991).

The Ford Motor Company lost billions of dollars in the late 1970's and early '80's due to lost market share—primarily to Japanese auto manufacturers (e.g., Toyota)—before the newly appointed Corporate Quality Director sought Deming's advice. Deming attributed 85% of Ford's lack of quality in its cars to managerial actions. After revamping corporate culture, Ford developed a profitable line of cars (e.g., Taurus, etc.) and, by 1986, had overtaken General Motors as the most profitable American Auto Company (Walton, 1988).

In 1987, an award similar to the Deming Prize in Japan was established in the U.S. and named the Malcom Baldridge National Quality Award, named after an American businessmen and former U.S. Secretary of Commerce. The Baldridge award was the only formal recognition of quality performance excellence for U.S. private and public sector entities (Hernandez, 2015).

Deming's ideas about total quality management (TQM) have revolutionized the way companies focus on quality to improve their business models, and have evolved into multiple branches of quality management programs across the globe. His legacy of focusing on improving quality in order to reduce wastes and costs, therefore improving profitability, was the basis of the first National Beef Quality Audit in 1991 (Smith et al., 1992).

Total Quality Management

Total Quality Management is a system of controls that were the result of W. Edwards Deming's visions that can be implemented by companies to improve quality of manufactured products. The basic theory was that improved quality ultimately improved profitability by increasing satisfaction with consumer goods at retail, and by virtue of improved efficiencies, reduced costs of production, ultimately lowering the cost offered to consumers. Deming described quality from two different perspectives. Firstly, quality from a production-based standpoint was described as conformity with standards. Secondly, quality was defined as meeting consumers' wants and needs. The philosophy uultimately created constancy of purpose toward improvement of product and service, with the aim to become competitive, to stay in business and to provide jobs (Deming, 1986).

Deming listed 14 key principles that managers seeking TQM should adopt in order to effectively transform a business (Deming, 1986):

1. Adopt the new philosophy. We are in a new economic age. Western management must awaken to the challenge, must learn their responsibilities, and take on leadership for change.
2. Cease dependence on inspection to achieve quality. Eliminate the need for massive inspection by building quality into the product in the first place.
3. End the practice of awarding business on the basis of a price tag. Instead, minimize total cost. Move towards a single supplier for any one item, on a long-term relationship of loyalty and trust.
4. Improve constantly and forever the system of production and service, to improve quality and productivity, and thus constantly decrease costs.

5. Institute training on the job.
6. Institute leadership. The aim of supervision should be to help people and machines and gadgets do a better job. Supervision of management is in need of overhaul, as well as supervision of production workers.
7. Drive out fear, so that everyone may work effectively for the company.
8. Break down barriers between departments. People in research, design, sales, and production must work as a team, in order to foresee problems of production and usage that may be encountered with the product or service.
9. Eliminate slogans, exhortations, and targets for the work force asking for zero defects and new levels of productivity. Such exhortations only create adversarial relationships, as the bulk of the causes of low quality and low productivity belong to the system and thus lie beyond the power of the work force.
10. Eliminate work standards (quotas) on the factory floor. Substitute with leadership.
11. Eliminate management by objective. Eliminate management by numbers and numerical goals. Instead substitute with leadership.
12. Remove barriers that rob the hourly worker of his right to pride of workmanship. The responsibility of supervisors must be changed from sheer numbers to quality.
13. Remove barriers that rob people in management and in engineering of their right to pride of workmanship. This means, abolishment of the annual or merit rating and of management by objectives. Institute a vigorous program of education and self-improvement.
14. Put everybody in the company to work to accomplish the transformation. The transformation is everybody's job.

Application of Deming's principles are widespread. Japanese industry leaders were the first to widely adopt the principles of TQM to wide success. During the reconstruction of Japanese industry following WWII, Japanese products had the reputation of being low quality and cheaply made. Shewart and Deming first describe principles associated with statistical controls associated with manufacturing in their book Statistical Method from the Viewpoint of Quality Control in 1939 (Shewhart and Deming, 1939). Shewart and Deming's book outlined the need for system controls outside the traditions of inspection, in order to build systems that built quality into the production line and removed need for quality inspections. Identifying the removal of quality deficiencies from the system as a cost reduction method began during the industrial revolution and was further built upon by Shewart and his statistical control chart (Shewhart and Deming, 1939). The reduction of process variation was a key element in Deming's teachings (Haga, 1950) and was a philosophy he continued to build upon during his career. The combination of removing production variance and empowering the production employee to identify system improvements are centerpieces to TQM (Deming, 1986). Implementation of TQM requires upfront costs to an industry, however full implementation has been shown to increase business growth and profitability (Hendricks and Singhal, 1997). Bagur-Fermenias (2015) identified a positive relationship between increased competitiveness when investments in quality were made in travel companies in Spain. The true measurement of the effectiveness of TQM has been hard to analyze as multiple different analytic approaches have been used (Kaynak, 2003). Researchers have analyzed TQM as a single construct affecting a firm's success (Douglas and Judge, 2001) while others have focused on TQM as a multidimensional program (Samson and Terziovski, 1999) with differing results as to the effectiveness of implementation. Samson (1999) identified executive commitment, open culture, and employee empowerment as more accurate predictors of

firm success than TQM specifically, nevertheless, those factors of are all key features listed in TQM principles. Implementation of TQM for improvement of competitiveness in business is widely supported in literature (Kaynak, 2003), especially when employees are encouraged to participate in quality improvement (Germain and Spears, 1999).

Application of TQM principles in the beef industry originated from a quote that has often been credited to Deming, but cannot be identified as his, stating, "You cannot manage what you cannot measure." The beef industry realized it had never measured quality factors as an aggregate, triggering the need for the NBQA-1991. Total Quality Management is an approach that places the responsibility for an organization's processes in the hands of those who know the processes best. Measuring quality from Deming's principles included measuring the wants and needs of the customers (Phase 1), as well as identifying conformance issues for production (Phase 2).

History of NBQA Face-to-Face Interviews

Phase 1 of the NBQA has historically been an interview process including companies and organizations that are directly or indirectly involved in the beef industry. The purpose of the interview is to illicit top of mind responses without prompting the interviewee with visual aids such as multiple-choice options. The questions are not provided in advance and, historically, have been asked in a semi structured interview to combat response bias.

In NBQA-1991, beef supply chain market sectors interviewed included retailers, purveyors, restaurateurs, and beef packers. Common areas of "Producer-Controllable Concerns About the 'Quality' of Beef" included excess external fat, too high of an incidence of injection-site blemishes, too large of cuts, low overall uniformity, and too many dark cutters (Smith et al., 1992). In 1995, the same supply chain market sectors were interviewed and, although some of

the issues that were identified were consistent, there also were multiple changes from the 1991 audit. Some of the major concerns impacting the beef industry were excessive external fat, too large of cuts and low uniformity across multiple sectors. However, findings just as important were traits that were no longer considered top ten concerns or that had moved down lists in importance. The quality defect that had the largest decrease in occurrence was needle injection-site blemishes; this defect either made substantial moves down the list of importance, or did not appear at all during the NBQA-1995 (Smith et al., 1995). The non-appearance or shift of needle injection-site blemishes in the NBQA-1995 signified a positive improvement from NBQA-1991.

The NBQA-2000 shifted focus from face-to-face interviews to online questionnaires sent to further processors, retailers, and restaurants. The greatest challenges reported were "insufficient marbling" and "a lack of uniformity in cuts" (Roeber et al., 2002). Seed-stock, cow/calf producers, stockers, and feeders were also sent questionnaires in NBQA-2000, with the "Greatest Quality Challenges" reported as "inadequate tenderness of beef" and "a lack of uniformity in beef". Also in NBQA-2000, packers felt that the "lack of uniformity in live cattle" was the "Greatest Quality Challenge", followed closely by "carcass weights too high". Similar to previous audits, one of the greatest challenges reported as plaguing the cattle industry was "the lack of uniformity within the cow herd" (Roeber et al., 2002).

Nevertheless, improvements in some characteristics also were reported when comparisons of data were made to previous audits. Producers rated the most significant changes since NBQA-1991 as a "change in injection-site location" and the "change in the genetic types of their cattle". More improvements, especially in the packing industry, were identified as the addition of food safety interventions. In NBQA-2000, 100% of the packers reported to be using steam vacuums, while greater than 80% of packers reported they were using pre-evisceration

washes and steam pasteurization, respectively. The most impressive reported quality improvement from purveyors, retailers, and restauranteurs, was the low incidence of injection-site blemishes. No purveyors, and less than 1% of restaurateurs, reported injection-site blemishes as a quality challenge; less than 3% of retailers cited it as a concern, a substantial improvement going back to the NBQA-1991 (Roeber et al., 2002).

The NBQA-2005 also utilized a survey instead of face-to-face interviews. The institutions surveyed include Seed-stock and Cow/Calf producers, Feeders, Packers, retailers, further processors, and restauranteurs. Beef producers again cited lack of uniformity in the cattle herd as the greatest quality challenge, along with insufficient beef tenderness. There were so few respondents from beef merchandisers in NBQA-2005 that comparisons to previous audits were hard to justify. Responses from only 6 packers, 8 further processors, 6 retailers, and 12 restaurants were included in the data (Shook et al., 2008). Nevertheless, 2 of the 6 packers agreed that cuts were becoming more uniform and that the incidences of bruises had improved. In addition, at least 3 merchandisers also agreed that cut uniformity had improved (Shook et al., 2008).

The NBQA-2011 abandoned the survey method of data collection and renewed use of face-to-face interviews during data collection. However, unlike previous audits that had included face-to-face interviews, the new system was able to utilize dynamic routing software and designed question sequencing to improve metrics associated with interview data. Additionally, the interview format changed and included willingness to pay estimates and a best/worst ranking systems for seven pre-determined quality categories (Igo et al., 2013).

Market Cow and Bull Audits

Data collection via face-to-face interviews also occurred during each market cow and bull beef audit (NMCBQA) conducted in 1994, 1999, and 2007. Consistent themes amongst the three market cow and bull audits was a need for more timely culling of animals, reduced bruising, and concerns regarding prevalence of birdshot and other physical contamination in beef. The NMCBQA-1994 advised producers to market cows and bulls more expeditiously to lessen downers, reduce cancer eyes and emaciation. Reduction of bruises and branding defects were also important pieces of advice that consumers wanted to give producers (Smith et al., 1994). Phase-1 of the NBMCQA-1999 concluded that carcass bruises and arthritic joints were the largest concerns from packers, and auction barn owners felt that more appropriate timeliness of culling would increase quality of market cows and bulls. Government and affiliated organizations felt that incidences defects could be reduced if packers would delay payment until after the cattle suspected of arthritic joints and residue violations could be processed (Roeber et al., 2000). The NMCBQA-2007 reported that top quality challenges included food safety, animal welfare/handling, poor condition, antibiotic residues and bruises. The downer rule instituted by USDA was cited to have been a large contributor to reduced numbers of downers and dead cattle being delivered to slaughter facilities (Hale et al., 2007).

Interviews

Since the first NBQA in 1991, one phase of each audit has historically included collection of data from professionals within the industry. Generally, these data were collected via face-to-face interviews, often considered the gold standard (Opdenakker, 2006) while NBQA-1999 and NBQA-2005 employed email questionnaires. The NBQA-2011 returned to using face-

to-face interviews utilizing a computer based routing software that allowed the interview to shift based on previous answers.

Semi-structured interviews are defined as interviews in which each participant is asked pre-determined questions in the same order, using the same wording across the study, but the interviewer is free to seek clarification to questions depending on need (Doody and Noonan, 2013). Utilization of the semi-structured interview allowed researchers flexibility while gathering qualitative data. Quantitative questions are most often closed questions such as with demographic data or WTP questions while qualitative questions are more open-ended as with the definitions, strengths, weaknesses, and potential threat questions (Doody and Noonan, 2013).

Within the NBQA, separation of financial data and quality data was key to the identification of certain quality factors that are often intertwined with finances. In general, it is best to start interviews off with questions that respondents feel very comfortable answering, then slowly transition into more difficult or thought provoking questions (Bryman and Cassell, 2006). Within 2011-NBQA and 2016-NBQA, researchers structured the interview so that quantitative questions regarding demographic and WTP questions were at the beginning of the interview and ended with the qualitative questions. Some of the qualitative questions required follow up questions in order to develop a further understanding of the interviewees responses; such procedure is known as a prompt or probe (Holloway and Galvin, 2016).

Avoiding bias is paramount when conducting survey or interview-based research and can be addressed with proper experimental design. Target audience, question type, interview style, response recording style, comfortability of the respondent, clarity of the question, and objectivity of the question are all factors of the interview process that need to be considered before proceeding. In order to provide as broad of an experimental base as possible, respondents need to

be randomly sampled across all potential levels of bias (Cohen and Neira, 2003). Levels of potential audience bias could be age, income, education, sex, race, or religion, and if interviewer's desire is to gain access to all potential information, equal distribution of the interview is critical. Additionally, questions can be worded in ways that are designed to register a specific response with the respondent and specific focus should be made to insure that the question is objective and not leading (Doody and Noonan, 2013). Interview style also has a large impact on the answers received, some people respond better to in-person interviews, while others respond equally to, or more truthfully with, an anonymous computer based survey (Sturges and Hanrahan, 2004).

Best-Worst Scaling

The identification of 7 pre-determined quality factors associated with meat quality for use in a national audit began with Murphy et al. (2010) and was built upon by Igo et al. (2013). Pre-determined quality factors were identified by researchers prior to interviews to encompass a wide range of quality attributes associated to a specific industry in order to test a null hypothesis. Utilizing pre-determined categories offered the opportunity for respondents to rank quality categories using a method known as best-worst scaling. Multiple other methods such as approve/disapprove (Kastens and Goodwin, 1994) or Likert-scale models (Allen and Seaman, 2007) identify preferences of specific factors or scenarios. However, these models do not allow for ordinal ranking of quality factors, and often provide very little tangible information as respondents can indicate that all options are important or preferred (Lusk and Briggeman, 2009). In order to develop ordinal best-worst rankings, it is imperative that respondents are forced to choose between pairs that reflect the maximum difference within a certain scenario (Louviere, 1993).

Willingness to Pay

A major shortcoming of the NBQAs before 2011 was the inability to objectively measure the importance of multiple value added practices within the beef industry. Multiple methods have been employed throughout the years in an attempt to measure WTP attributes for multiple factors ranging from environmental to medical to food (Klaus Wertenbroch and Skiera, 2002; Plott and Zeiler, 2005).

There are a variety of methods utilized by researchers to determine a consumer's WTP, Marbeau (1987) focused on two specific tests; monadic or competitive. In general, there are two types of experiments used to determine a customer's WTP, laboratory experiments and field experiments. Although lab experiments offer immediate results, certain biases often occur as the subjects know that they are under review and may make more rational, thought-out decisions (Hanna and Dodge, 1995) or may not spend realistically as they know they are not spending their own money. Although field experiments are immune to some of the biases affiliated with lab experiments, other drawbacks include expense, data collection, and extended time periods. In the NBQA model, researchers used theoretical expenditures to ascertain WTP estimates. A theoretical expenditure model utilizes a hypothetical purchasing transaction via a question to determine a respondents WTP for a given attribute or service. The majority of theoretical expenditure models used to estimate WTP in the literature, stem from environmental studies or policy adoption from a consumer point of view (Zapata and Carpio, 2014). Nevertheless, Lusk et al. (2004) describes multiple applications of utilizing WTP estimators in the agribusiness sector. One issue with theoretical expenditures is the opportunity for respondents to overestimate their WTP due to the hypothetical nature of the question, versus real time payment, estimations have concluded that some responses could be up to three times more than actual (List and Gallet,

2001). However, this estimation bias can be overcome with proper interview techniques such as described by Lusk et al. (2003).

CHAPTER III

PART 1-PHASE 1 NATIONAL BEEF QUALITY AUDIT FACE-TO-FACE INTERVIEWS

Background Information

National Beef Quality Audits (NBQA) initially were conducted based on rationale derived from Total Quality Management principles of W. Edwards Deming. Those same principles leading to the original audit in 1991 hold true for today's beef industry. In NBQA-1991, authors stated that, "The U.S. cattle industry cannot expect improvements in prices for its products/byproducts when "quality" doesn't warrant such a price increase." Deming described quality from two different perspectives. The first perspective was from a production stand point; identifying quality as "conformance to standards" through the prevention of problems. Deming understood that the correction of problems after the fact has nothing to do with quality. He described a second perspective of the consumer as "meeting consumer wants and needs." Phase 1 of the NBQA historically focused on the wants and needs of consumers by interviewing employees that make purchasing decisions for companies that are positioned in the beef marketing chain.

Since 1991, and throughout the history of the audits, multiple areas of concerns have arisen, shifted, and sometimes plagued the industry throughout each audit. The objective of NBQA face-to-face interviews is to identify producer related beef quality shortfalls from the perspective of packers, retailers, food service, further processors, and GTO's, and to ascertain WTP estimates, best/worst scaling, and views of the industry.

Materials and Methods

Face-to-face interviews were administered across the U.S. from January through November 2016 using a designed, dynamic-routing software system. Interviews targeted individuals that make purchasing decisions, individuals very knowledgeable about purchasing requirements within U.S. beef companies, or technical personnel employed by peripherally related government and trade organizations (GTO). Five sectors of the U.S. beef supply chain for steers and heifers and market cows and bulls were interviewed: packers (n = 36), retailers (n = 35), food service (n = 29), further processors (n = 64), and peripherally related GTOs (n = 30).

Computer-Assisted Interview Software

A dynamic-routing, computer-assisted interview program was developed using the Qualtrics software platform (Qualtrics 2016; Provo, UT, USA). The computer program standardized administration of the interview such that the order of questions was "designed" to prevent "leading" interviewees to answers by those administering the interview. Additionally, the program allowed for routing of questions based on responses and provided sliding scales to interpret a respondent's WTP once it was established that they were, in fact, willing to pay a premium for a given quality attribute. Subtle changes in contrast with NBQA-2011 (Igo et al., 2013) were adapted to improve the interview process.

Interview Overview

Interviews began with demographic questions designed to briefly characterize interviewee's companies. Demographic questions also allowed dynamic routing of subsequent questions. Sectors of the industry not associated with purchasing, such as GTO, did not answer financial questions. Likewise, companies purchasing only steers and heifers or only cows and bulls were routed such that they answered questions only associated with that portion of the

audit, while companies purchasing both types of beef answered questions from both perspectives.

Economic questions followed demographic questions closely. Respondents (except those in the GTO sector) were asked to list financial considerations affecting their purchasing decisions. The goal of asking financial questions before asking quality questions was to separate the influence of such factors on purchasing from those associated with quality in the mind of respondents.

Willingness to pay (WTP) questions immediately followed, and were broken into two separate categories. To accurately determine a respondents WTP for a quality attribute, it was key to first identify non-negotiable quality traits that a company "*must have*" before continuing with a business transaction. Respondents were asked to list all attributes of cattle or beef products that they absolutely *must have* before purchasing the product. Responses were categorized into one of the seven predetermined quality factors by trained interviewers and were then asked: if that trait could not be guaranteed, would they still purchase the product at a discounted price? If the respondent agreed to purchase the product for a discount, then that quality trait was deemed not absolutely necessary to purchase, and was therefore removed from the *must have* responses during analysis. For every quality factor that was not determined to truly be a *must have* requirement, a WTP a question was asked: "If your definition of the trait could be guaranteed, would you be willing to pay a premium?" If the respondent answered no, the interviewer moved to the next question. If the answer was yes, a follow up question was asked to determine the percentage premium that the respondent was willing to pay for a specific quality category.

Questions to determine best-worst scaling of quality factors followed questions associated with WTP. Eight questions were asked for each type of beef (fed steers/heifers vs cows/bulls) such that seven of the questions included a triad of quality categories, while the eighth question included all of seven quality categories; this procedure previously described by Louivere, (2008). Respondents were asked to select the most important and least important quality factor during each round of ranking.

Questions to elicit the perceived definitions for quality factors followed. Questions were phrased as, "What does the [quality factor] mean to your company?" Interviewers recorded entire responses into blank textboxes or into checkboxes populated with common potential answers such as "tenderness" or "flavor". How an interviewee defined each quality factor was critical to extracting meaning from the WTP estimates and the relative importance responses administered in preceding questions.

Images, strengths, weaknesses, potential threats, and changes since the last NBQA audit were the last questions asked; all allowed open-ended responses. Entire responses were recorded verbatim into text boxes within survey software and were categorized into groups of similar responses for analysis.

Some interviewees offered multiple responses for each question. In cases of multiple responses from a single individual, each response was counted individually. For instance, if a respondent stated that weight and size meant, "how large the individual muscles were," and "how consistent they were in size" the analysis was conducted so that the statements were counted as two separate responses.

Data Collection

Research institutions involved in conducting face-to-face interviews included Colorado State University, Oklahoma State University, and Texas A&M University. Following previous NBQA precedent (Igo et al., 2013), teams of two trained interviewers conducted each face-to-face interview. One individual would conduct the interview and record responses into the Qualtrics dynamic routing pre-programed system, while the other individual would manually record responses on a written copy of the interview template for quality control. Interviews were conducted at company headquarters and trade meetings January-November 2016. The number of interviews conducted by market sector included: packers (n = 36), retailers (n = 35), food service (n = 29), further processors (n = 64), and peripherally related GTO (n = 30). Companies represented in the interview sample accounted for greater than 92% of the packing sector market share in 2016, greater than 55% of the retail market, and greater than 25% of the food service industry. Total market coverage of the further processing sector was unclear.

Statistical Analysis

A binary logit model using the Glimmix procedure of SAS (SAS Institute Inc., Cary, NC) was used to estimate statistical probabilities that a respondent would select a quality category as a *must have*, if the quality category was indeed a *must have*, and the WTP a premium for a guarantee that they would receive the desired quality category. Probabilities were calculated and mean separations were computed with $\alpha = 0.05$.

An ANOVA using MIXED procedure of SAS using market sector as the fixed effect was used to estimate the average percentage premium that respondents were reportedly willing to pay for each quality category given that the category was not a *must have*. Least squares means were calculated and mean separations were computed with $\alpha = 0.05$.

Best-worst scaling analytics were based on the methods utilized by (Wolf, 2013) to determine policy preferences within the U.S. Dairy industry. To calculate shares of preference for each category, the respondent's best-worst scaling survey results were estimated using a multinomial logit model (Greene, 2003) within SAS (SAS Institute Inc., Cary, NC). After utilizing the multinomial logit model, estimated coefficients were used to calculate the share of preference for each category following procedures of (Lusk and Briggeman, 2009). In order to test whether the shares of preference statistically differed, a distribution of each estimated parameter was generated using a Monte Carlo procedure within Simetar (Richardson and Outlaw, 2008). In this application, probabilities generated a cardinal ranking system of relative importance. Mean separations of the calculated shares of preference were compared via ANOVA using the Mixed model of SAS ($\alpha = 0.05$; SAS Institute Inc., Cary, NC) with quality factor serving as the fixed effects of the model. This system can be used to identify magnitudinal differences between quality factors. For example, if a share has a value twice as large as another, one may conclude that one share is twice as important as the other.

Because the steer and heifer audit was conducted simultaneously in 2016 with the market cow and bull audit for the first time, it was essential to separate steer and heifer answers from cow and bull answers when possible. However, multiple companies participate in both markets. When a company participated in both markets, answers to perspective questions were analyzed separately as if the responses came from two individual institutions.

Results and Discussion

Industry-wide, there appeared to be a substantial increase in numbers of dairy cattle harvested as a replacement for shortened supplies of native beef animals compared to 2011 (Igo et al., 2013). Additionally, the average number of branded beef items increased from 2011 (Igo

et al., 2013) in the marketplace, coinciding with concerns expressed about size inconsistencies in beef boxes. Researchers also found that the penetration of Beef Quality Assurance (BQA) in the market place was severely lacking. When companies were asked if they required their suppliers to source cattle that were raised using live animal quality assurance programs, less than 5% of companies reported that they mandated BQA in their responses.

Steer and Heifer Packers

Relative importance of the seven quality factors (established by the research team) was estimated using methods provided by Louviere (Louviere, 2008). "Food safety" (36.7% shares of preference; Table 1) was most important and was preferred more than twice as often as "Lean, fat, and bone" (13.7%; Table 1), which was the second most important. Twenty-nine percent of packers identified "food safety" as a *must have* and, when they didn't identify it as a *must have,* 69% were willing to pay an average premium of 11.1% (Table 3). When asked to define what the term "Food safety" meant to their company, 40% (Table 2) defined it as a "critical" part of business and when pressed further for a definition, 29% (Table 2) responded with "pathogen free." "Lean, fat, and bone" was defined by packers as "yield" (36%; Table 2) and "lean to fat ratio" (26%; Table 2). Furthermore, 19% (Table 3) of packers required a guaranteed "lean, fat, and bone" before purchasing cattle.

The third most important factor for packers was "how and where the cattle were raised" (11.37%; Table 1), which they defined as "source location" (38%; Table 2) (the geographic region the cattle were raised in) or "welfare/handling" (28%; Table 2). "How and where the cattle were raised" was tied ($P > 0.05$) with "food safety" as the most frequently ($P < 0.05$) identified as *must have* (32.5%; Table 3), but generated the lowest premium (4.9%; Table 3). "Eating satisfaction" (11.17%; Table 1) was the fourth most important category. Curiously,

"eating satisfaction" ranked much lower than the previous audit (Igo et al., 2013), which could potentially be linked directly to economic fluctuations in 2015 and 2016. Not a single packer listed "eating satisfaction" as a *must have*, but 55% were willing to pay an average premium of 10% (Table 3) to guarantee it, which they primarily described as "customer satisfaction" (29%; Table 2) driven by "tenderness" (17%; Table 2) and "flavor" (14%; Table 2). "Cattle genetics" (10.97%; Table 1), defined as "breeds", (39%; Table 2) was more important to packers than "weight and size" (9.3%; Table 1), defined as "cattle size", (40%; Table 2).

The quality category of least importance to steer and heifer packers was "visual characteristics" (6.8%; Table 1), which they defined primarily as "live cattle composition" (45% Table 2). One packer told of his experiences buying cattle primarily by visual characteristics, stating that "Anybody buying cattle knows that you want them to look good, but that you can never really tell what their carcass will look like when they're alive."

Packers indicated a larger number of quality factors as *must haves* and were more willing to pay a premium for quality guarantees, but were willing to pay less for those guarantees than in NBQA-2011 (Igo et al., 2013). Best-worst rankings for market cow and bull packers are presented in Table 4. "Food safety" again dominated relative importance rankings at 56.3%, with the second most important factor of "lean, fat, and bone" at 13.4%. Following the two most important quality factors of "food safety" and "lean, fat and bone", the remaining quality factors had comparatively low shares of preferences when compared to the steer and heifer packers.

Retailers

For retailers, "food safety" (44.0%; Table 1) was the most important quality category, which, similarly to 2011-NBQA, retailers primarily defined as being "produced within a safe environment" (25%; Table 2). Food safety also was described as "critical to business" and as "an

obligation to consumers" (23% and 18%, respectively; Table 2). Twenty-six percent of retailers determined that "Food safety" was *must have,* but of the companies not describing "Food safety" as *must have,* 47% said they were willing to pay an average premium of 12.3% (Table 3).

"Eating satisfaction", primarily defined as "customer satisfaction" (Table 2), was the second most important factor ($P < 0.05$) (23.6%; Table 1) and was more than twice as important as "visual characteristics" (Table 1). When describing "eating satisfaction", one retailer stated that "It is very important, if it [the product] doesn't taste good and isn't tender, people won't come back and buy it." "Customer satisfaction" was the primary definition of "eating satisfaction" followed by "tenderness" and "flavor" (20% and 13%, respectively; Table 2). During the interviews, it was apparent that retailers fundamentally understand their consumers' purchasing patterns and complaints. Similar to studies performed by Platter et al. (2005) and Huffman et al. (1996), retailers were very aware of the impact that "eating satisfaction" has on maintaining repeat customers, as 29% of retailers required guaranteed "eating satisfaction" as a *must have* (Table 3). Of retailers not requiring "eating satisfaction" as a *must have,* 85% were willing to pay an average premium of 13.2% (Table 3) for guaranteed "eating satisfaction".

"Visual characteristics," primarily described as "color" by 34% of respondents (Table 2), was another category related to customer purchasing. Despite the knowledge that color does not necessarily affect eating satisfaction (Carpenter et al., 2001), color is a primary driver for beef purchases (Smith et al., 2000; Font-i-Furnols and Guerrero, 2014; Holman et al., 2016). retailers know how important color is to their bottom line and, although only 6% require "visual characteristics" as a *must have,* 63% were willing to pay an average premium of 6.6% to guarantee it (Table 3). Following the three most important factors, differences between quality categories narrowed considerably with "lean, fat, and bone" identified as "Yield" and "lean to fat

ratio" (27% and 22%, respectively; Table 2) rating as the least important factor to retailers. Tighter windows on company-specific cutting specifications could be the reason that "lean, fat, and bone" guarantees ranked so lowly in importance, as there are already mechanisms in place to control this quality category.

Very few retailers claimed to participate in the market cow and bull industry, with only 7 of the 35 companies interviewed stating that they purchase beef from market cows and bulls. Nevertheless, the cardinal ranking of quality factor importance can be found in Table 4. It should be noted that, of retailers stating that they purchased beef from market cows and bulls, they answered the majority of questions from the perspective of ground beef. "Food safety" (52.3%), followed by "visual characteristics" (21.2%) and "eating satisfaction" (15.9%), were the quality categories that dominated best-worst rankings with "cattle genetics" (1.1%; Table 4) as the least important quality factor ($P < 0.05$). Retailers were the only market sector that did not rank "visual characteristics" towards the bottom of the best-worst ranking system. Considering the business models for the marketing sectors, this discrepancy fit expectations. Retail meat purchasing decisions are influenced by color more than any other quality factor because consumers most often associate color with freshness (Mancini and Hunt, 2005)

Food Service

"Food safety", "eating satisfaction", and "lean, fat, and bone" (46.3%, 18.5%, and 9.3%, respectively; Table 1) were the three most important quality factors to food service providers with "cattle genetics" (5.1%) ranked the least important ($P < 0.05$). According to food service companies, the term "food safety" was described equally as the "top priority", "wholesome", or "pathogen free" 19% of the time (Table 2). "Food safety" was more than twice as important ($P < 0.05$) as "eating satisfaction" and, before 2011, had never even been listed as a top 10 quality

concern (Smith et al., 1992; Smith et al., 1995; Smith et al., 2006). Fifty percent of food service respondents cited "food safety" as a *must have* category, and 51% of companies not listing it as a *must have* category were willing to pay an average of 15.6% (Table 3) premium for "food safety" guarantees.

Food service providers defined "eating Satisfaction" as "customer satisfaction" 29% of the time, 18% described the term as "flavor", and 11% as "tenderness" (Table 2). Food service providers required "eating satisfaction" 39% of the time while 61% of remaining companies were willing to pay an average premium of 8.9% (Table 3) for guaranteed "eating Satisfaction". "Eating satisfaction" was tied with "food safety" ($P > 0.05$) for the most likely quality factor to be required before purchasing and ($P > 0.05$) as the trait companies were most willing to pay a premium for (Table 3). Following previous consumer research (Huffman et al., 1996; Boleman, 1997; Miller et al., 2001; Platter et al., 2003), it is widely known that consumers are willing to pay a premium for positive eating experiences and can differentiate multiple levels of known sensory differences within steaks. The ability to provide a consistent, positive eating experience generates more exposure for the restaurant to new customers and increases rates of returning customers. It was apparent during interviews how passionate restauranteurs were about "eating satisfaction" and the impact it could have on their business. One operator stated "Customer satisfaction: it's all about eating satisfaction and the consumer telling their friend about their experience."

"Lean to fat ratio" was used to define the "lean, fat, and bone" quality category by 33% of the respondents (Table 2) with 18% of respondents defining it as "yield" and 13% referring to the presence of "bones" within the product. CattleFax estimates that ground beef consumption today has grown to between 55 and 60% of total beef consumption. Therefore, it is logical that

foodservice companies would place emphasis on a specific "lean to fat ratio" within their ground beef blends. Although companies have tight specifications already in place for "lean, fat, and bone" percentages, 34% of companies were willing to pay an additional 7.6% (Table 3) premium for increased guarantees of agreed upon lean percentages. One restauranteur mentioned "Ensuring proper ratios will entice more business between a supplier and customer, and will also play key roles in the guests' experience and if they would be willing to repeat the purchase of that menu item." Food service companies stated that 43.5% of their beef purchases were subprimals to be cut in the back of the stores; "yield" and the amount of trimming required to reach serving specifications was critical because there is rarely an outlet for trimmings in large food service companies and it is widely considered waste. "Cattle genetics", predominantly defined as "breed" by 43% (Table 2) of respondents, ranked last ($P < 0.05$) in relative importance and only 4% (Table 3) of companies considered "cattle genetics" a *must have* for purchase.

Of the 29 food service companies, 10 claimed to participate in the market cow and bull market and best-worst rankings for quality categories can be found in (Table 6). "Food safety" dominated rankings with six times the shares of preferences (66.4%) than the second most important quality category "lean, fat, and bone" (11.1%). Again, like retailers, most companies only focused on beef from the cow and bull market as trimmings or ground beef and, for the clear majority, were not answering questions from the perspective of whole muscle cuts.

Further Processors

Companies classified as "further processors" consisted of grinding operations, purveyors, cookers, and distributors and represented a much broader perspective than other, more narrowly focused sectors. Nevertheless, "food safety" ranked the highest ($P < 0.05$) of the 7 quality

categories, generating 46.5% of the shares of preference (Table 1). “Food safety” was most frequently described as “critically important” (32%) or as products being “produced in a safe environment” (19%) and “pathogen free” (9%) (Table 2). Additionally, 33% (Table 3) of companies required a guarantee of “food safety” before completing the purchase. Of the companies not identifying “food safety” as a *must have* category, 41% were prepared to pay a premium of 11.3% (Table 3). The level of attention paid to food safety from the further processing sector was made very clear by the clear majority of the respondents, “Food safety is what the industry is based upon. Number one factor in our production and for consumers buying our product.”

Similar to all other sectors dealing directly with end consumers, “eating satisfaction” ranked second ($P < 0.05$) to “food safety”, with 15.96% of the shares of preference (Table 1). “Eating satisfaction” again was defined as “customer satisfaction” by 35% of companies interviewed, with “tenderness” and “flavor” reflecting 13% and 10% of how this category was defined, respectively (Table 2). Curiously, though, only 9% of the further processors required guaranteed “eating satisfaction”, but more than half (57%) were willing to pay a premium for guaranteed “eating satisfaction” of 8.9% (Table 3).

“Weight and size” was the third most important quality category for further processors and was defined as “cut Sizes” (25%), “subprimal size” (21%), “consistency” (10%) and “unimportant” (10%). With so many further processors buying steaks and roasts, increasing cattle sizes are causing issues with respect to meeting customer specifications for thicknesses and weights. Therefore, it was not surprising that 66% (Table 3) of further processors would be willing to pay a premium for a guaranteed weight and size. While discussing a customer, one steak purveyor said: “White table cloths want smaller subprimals to control the portion and

thickness of steaks." Other companies simply want the products they purchase to be more consistently sorted before reaching their facility, and other companies only grind, so weight and size of raw trimmings they buy don't matter to them or were "unimportant".

Best-worst rankings by companies participating in the market cow and bull beef industry can be found in (Table 4). Rankings of further processors for market cows and bulls very closely mirrored rankings of food service providers. As with all rankings, "food safety" was most important ($P < 0.05$), garnering 62.7% of the shares of preference, while "lean, fat, and bone" represented 11.7% as the second most important quality category (Table 4).

Government and Trade Organizations

Although GTO's do not purchase beef and were not subjected to WTP questions of the interview, it was important to understand their perspective on the industry and to provide guidance as to the issues that are likely to be discussed in future policy, trade, and developing sciences. All GTO's were asked questions pertaining to both the fed cattle and market cow and bull portions of the beef industry. Best-worst rankings for each sector differed except in relation to the ranking for "food safety", which was most important for both industries (Tables 1, 4). "Food safety" was defined by GTO's as "obligation to consumers" by 19%, "trade impacts" by 14%, "residues" by 12%, "crucial to business" by 12%, and 12% reported "food safety" as meaning "pathogen free" (Table 2). One GTO respondent said: "(It's the) baseline for being in the meat business. Without food safety, nothing else matters."

Government and trade organizations ranked "eating satisfaction" as the second most important quality category ($P < 0.05$; Table 1) for steers and heifers and described it as "customer satisfaction" 16%, "customer experiences" 16%, "flavor" 12%, and "tenderness" 12%. For market cows and bulls, the second most important factor was "lean, fat, and bone" ($P < 0.05$;

Table 4) with 27% of interviewees defining that category as “yield” (Table 2), with the addition of multiple references to actual yield grades. The second most offered response included the impact that particular “drug administration” can have on the specific tissues (17%; Table 2). Third, ($P < 0.05$) was the “Lean to fat ratio” presented within the product, primarily from the perspective of trimmings produced by market cows and bulls.

For GTO’s, “How and where the cattle were raised” was the third most important fed beef quality category ($P < 0.05$; Table 1), with the predominant definition described as “production practices” (32%; Table 2), followed by “geography” (20%) and “marketing” (10%). When discussing “production practices,” respondents were primarily concerned about marketing claims and how to classify the animals produced under the premise of potential branding opportunities. “Geography” meant the location within the country that animals were raised, while “marketing” definitions primarily pertained to the ability to sell products within certain markets, e.g., exports or local vs non-local. “Eating satisfaction” was listed as the third most important factor ($P < 0.05$) for market cows and bulls (Table 4).

Not captured with the questions of the formal interview, but an important factor that should be noted when interviews were completed with GTO, was emergence of novel genetic technologies and the potential implications those technologies could have on the future of the beef industry. Use of clustered regularly spaced palindromic repeat (CRISPR) sequences and Cas (CRISPR-associated) proteins to modify genomes were one of the largest topics that policy makers were concerned with. The CRISPR-Cas9 is a technology advancing at an exponential rate utilizing an organisms’ natural virus defense system to specifically target genes within a piece of DNA. Following the targeting of a specific gene, scientists can either delete (knock out) the gene, or replace that gene with a new, more preferred alternative. Since CRISPR-Cas9

systems do not introduce genetic code from outside organisms, the method is currently legislated differently than for genetically modified organisms (GMOs; i.e., transgenic organisms) as shown by a letter from USDA Animal and Plant Health Inspection Service (APHIS, 2016) to Dr. Yang of Pennsylvania State University. Since Dr. Yang's mushrooms, created using CRISPR, did not utilize genetic sequences from separate organisms such as with GMOs, CRISPR falls outside of the realm of GMO labeling and legislation. The USDA Agricultural Marketing Service defines GMOs as: "The term 'bioengineering', and any similar term as determined by the Secretary (USDA Secretary of Agriculture) with respect to a food, refers to a food (A) that contains genetic material that has been modified through in vitro recombinant deoxyribonucleic acid (DNA) techniques; and (B) for which the modification could not otherwise be obtained through conventional breeding or found in nature"(AMS, 2016). Although the CRISPR/Cas9 technology is still gaining traction in the applied sciences, the implications on trade and policy are a new frontier going forward.

Images, Strengths, Weaknesses, Potential Threats, Changes from Previous Audits

Open-ended questions regarding the image, strengths, weaknesses, potential threats, and changes from the previous audits for the beef industry were asked. The question "what does your company/organization believe the image of the steer and heifer industry/market cow and bull industry is?" generated polarizing opinions. Companies predominately purchasing steer and heifer beef suggested that the image is mostly positive; however, respondents suggesting a negative image were represented in every sector except food service (Table 5). The image of the beef industry to those predominately purchasing market cow and bull beef was less "positive" when compared to that reported for the steer and heifer beef industry (Table 6). About 25% of retailers and 16.6% of food service companies believed that the image of the market cow and

bull sector was either the “same as fed” or “unknown to customers”, revealing the lack of consumer knowledge relative to sources of beef items in the marketplace.

When asked about the strengths of the two industries it, was obvious that companies involved in the industry are proud of the products being produced. The “product quality” was reported as a strength of the steer and heifer industry by all market sectors (Table 7). Market cow and bull packers, as well as further processors, believed that “product quality” was the biggest strength, while most retailers and GTO focused on the “value” and the positive “economics” of the products. Furthermore, 30.8% of food service companies said they import the majority of their market cow and bull product (Table 8).

Retailers and food service companies reported that “marketing” was the greatest weakness within the steer and heifer industry, with “consumer communication” as the second most frequently reported weakness among packers (Table 9). Multiple quotes from retailers and food service companies suggested that the beef industry has lacked progress towards addressing consumers’ wants and needs with respect to specific production practices and process transparency. Weaknesses identified by the market cow and bull industry focused more on the “animal welfare” perspective than did the steer and heifer industry. Twenty-five percent of cow and bull packers believed the “producers” were the largest weakness, with special attention directed at the timeliness of marketing their animals. Food service, further processors, and GTO all cited “animal welfare” either first or second as the largest weakness of the market cow and bull sector (Table 10). Management of slaughter endpoints and timeliness of culling seemed to be the root of animal welfare concerns from companies that seemingly understood that older, less mobile animals were the primary targets of animal welfare complaints.

Potential threats reported within the steer and heifer industry were closely related to the weaknesses, as "poor marketing" has evidently translated into "public perception" being the most cited potential threat by retailers, food service, and further processing companies (Table 11). "Animal Disease" was another concern that was consistently expressed across all sectors of the industry except GTO and, with the memories of Porcine Epidemic Diarrhea Virus and Avian Influenza, companies expressed concern that they did not believe the beef industry could survive similar outbreaks. Multiple government agencies discussed discrepancies between beef, pork, and poultry relative to the development of vaccine banks for known viral and bacterial zoonotic pathogens, and the concern that they had for the beef industry if more resources were not allocated to developing a vaccine bank. Respondents from the market cow and bull beef industry listed a multitude of factors as potential threats, with "residues" and "food safety" as the only truly common themes throughout the sectors (Table 12).

When asked about changes that companies had witnessed since the NBQA-2011, more than 30% of food service and further processors stated "nothing" had changed, while packers cited "grading" and "business expansion" as the primary changes. Retailers responded with "economics" and "nothing", while 13.7% of GTO said they had seen an "improvement" in the industry and another 13.7% said that "trade" has increased (Table 13). When asked what had changed since the NMCBQA-2007, 50% of retailers and 44.4% of further processors said that "nothing" had changed (Table 14). Packers believed that "supply" (19.5%) had decreased, but "animal welfare" (19.5%) had improved, while 23.1% of food service companies believed that "Food safety" had improved and 35.7% of GTO stated that there was a better "understanding of production" (Table 14).

Conclusions

Companies across all sectors of both industries ranked "food safety" as the highest priority (P <0.05), often garnering more than twice as many shares of preference as the second most important factor (Table 1). "Eating satisfaction" (Table 1), described primarily as "customer satisfaction" (Table 2), was the second most important factor ($P < 0.05$) to all steer and heifer industry sectors except for packers. Therefore, producing a safe product that meets consumer demands for eating quality are the primary factors that companies involved in the steer and heifer industry are concerned with. When companies were asked about the market cow and bull industry, they were primarily answering questions related to beef trimmings generated from those products and not whole muscle cuts. Partially due to the perspective in which the companies were answering the questions, "lean, fat, and bone" was the second ($P < 0.05$) most important factor, and was described as "lean to fat ratio" by multiple sectors, except for retailers, who stated "visual characteristics" was the second ($P < 0.05$) most important quality factor (Table 4). When compared to NBQA-2011, more companies required guarantees of "food safety" across the board and 50% of food service companies stated they required some guarantee of "food safety" before conducting business. Responses also showed that more companies were willing to pay premiums for guaranteed quality factors than in 2011, but that they were willing to pay less for those guarantees, on average (Table 3) (Igo et al., 2013). Companies believed that the image of the steer and heifer industry is polarizing, with the majority believing beef is still viewed as "Positive" (Table 5) with the primary strength being "product quality" (Table 7). Nevertheless, multiple companies believe the image is "negative" with one of the largest weaknesses as "marketing" (Table 9) and one of the largest threats "public perception. The market cow and bull sector is a less visible and is a less popular industry compared to the steer

and heifer industry. Additionally, the market cow and bull industry is often misunderstood by the general consumer. Furthermore, purchasing agents within the retail and food service industry were often unfamiliar with the sources of trimmings or grinds they are buying. The market cow and bull beef industry is viewed as a high "value", high "quality" (Table 8) product that delivers beef as a more economical alternative to steers and heifers. One of the largest weaknesses that continues to plague the industry are "animal welfare" (Table 10) concerns linked to producers holding cows and bulls past their optimal culling period. The largest potential threats to the industry varied across sectors with "animal welfare", "food safety", and "animal activists" rising as common themes throughout the responses (Table 12). "Nothing" was most often cited as the change from the 2007 NMCBBQA with "increased food safety initiatives" also mentioned (Table 14).

As consumer demands shift, it is paramount for the U.S. beef industry to also shift to maintain viability. "The U.S. cattle industry cannot expect improvements in prices for its products/byproducts when 'quality' doesn't warrant such increases." Identification of the relative importance of quality factors and estimation of the industries WTP for those quality factors has provided targets of improvement to increased profitability within the beef industry. In general, companies are willing to pay for additional quality guarantees, providing the industry and opportunity to increase value to each of the marketing sectors.

Table 1. Shares of Preference (± SE) For Relative Importance of Quality Factors for Steer and Heifer Beef

Quality Category	Packer	Retailer	Food Service	Further Processor	GTO
How and Where Cattle were Raised	11.4[c] (0.05)[1]	6.3[d] (0.03)	6.1[e] (0.03)	5.3[f] (0.02)	12.2[c] (0.05)
Lean Fat and Bone	13.7[b] (0.06)	4.7[f] (0.03)	9.3[c] (0.05)	9.2[d] (0.03)	10.7[d] (0.05)
Weight and Size	9.3[f] (0.04)	6.1[e] (0.09)	9.0[d] (0.04)	10.2[c] (0.03)	8.9[e] (0.04)
Visual Characteristics	6.8[g] (0.03)	9.3[c] (0.03)	5.7[f] (0.03)	7.4[e] (0.02)	11.3[d] (0.05)
Food Safety	36.7[a] (0.13)	44.0[a] (0.04)	46.3[a] (0.15)	46.5[a] (0.10)	30.2[a] (0.12)
Eating Satisfaction	11.2[d] (0.05)	23.6[b] (0.14)	18.5[b] (0.08)	16.0[b] (0.05)	17.6[b] (0.07)
Cattle Genetics	11.0[e] (0.05)	6.0[e] (0.02)	5.1[g] (0.03)	5.4[f] (0.02)	9.1[e] (0.04)

[a-c] Percentages within each column without a common superscript differ ($P < 0.05$)

SEM[1] Standard Error of the Mean

Table 2. Categorized responses from interviewed companies for explaining what the pre-identified quality categories mean to their company as it relates to all beef products

	Packer		Retailer		Food Service		Further Processors		GTO	
	Most freq.[1]	Definition	Most freq.	Definition	Most freq.	Definition	Most freq.	Definition	Most freq.	Definition
How and where the cattle were raised	38%	Source Location	47%	Geography	27%	Animal Welfare	29%	Geography	32%	Production Practices
	28%	Welfare/Handling	18%	Animal Well-Being	22%	Local/COOL	19%	Production Practices	20%	Geography
	13%	Feed	16%	Other	14%	Feed	10%	Welfare	10%	Marketing
Cattle Genetics	39%	Breeds	37%	Breed	43%	Breeds	48%	Breeds	26%	Breeds
	27%	Quality	26%	Quality	17%	Ability to Guarantee Quality	20%	Unimportant	19%	Improvements
	11%	Nothing*	13%	Bloodline	17%	Product Improvements	17%	Quality Improvement	16%	Eating Quality
Weight and Size	40%	Cattle Size	27%	Uniformity in Cuts	46%	Cut Sizes	25%	Cut Sizes	33%	Carcass Weights
	26%	Cut Sizes	24%	Cut Sizes	20%	Yield	21%	Size of the Subprimal	15%	Dosage Size
	22%	Carcass Weight	18%	Subprimal Weights	12%	Unimportant	10%	Consistency	15%	Cut Sizes
Visual Characteristics	45%	Live Cattle Composition	34%	Color	32%	Quality of the Product	23%	Appropriate Product Color	27%	Live Animal
	17%	Other	18%	Marbling	18%	Eye Appeal	16%	Lean/Trimmed Product	20%	Other
	13%	Animal Health	15%	Eye Appeal	16%	Nothing	12%	Marbling	17%	Hide Color
							11%	Unimportant		
Food Safety	40%	Critical	25%	Produced in a Safe Environment	19%	Top Priority	32%	Critically Important	19%	Obligation to Consumer
	29%	Pathogen Free	23%	Critical to Business	19%	Wholesomeness	19%	Produced in a Safe Environment	14%	Trade
	13%	Obligation to Consumer	18%	Obligation to Consumer	19%	Pathogen Testing	9%	Free of Pathogens	12%	Residues
					9%	Brand Protection	9%	Compliance	12%	Crucial to Business
					9%	Supplier Assurance			12%	Pathogen Free
Lean, Fat, and Bone	36%	Yield	27%	Yield	33%	Lean to Fat Ratio	21%	Lean to Fat Ratio	27%	Yields
	26%	Lean to Fat Ratio	22%	Lean to Fat Ratio	18%	Yield	20%	Boneless	17%	Drug Administration
	13%	Fat Thickness	14%	Lean to Bone	13%	Bones	14%	Yields	17%	Lean to Fat Ratio
							13%	Specifications		
Eating Satisfaction	29%	Customer Satisfaction	23%	Customer Satisfaction	26%	Customer Satisfaction	35%	Customer Satisfaction	16%	Customer Satisfaction
	17%	Tenderness	20%	Tenderness	18%	Flavor	13%	Tenderness	16%	Experiences
	14%	Flavor	13%	Flavor	11%	Tenderness	10%	Flavor	12%	Flavor
					11%	Quality	6%	Quality	12%	Tenderness
									9%	Returning Customers

[1]Most freq. = Top 3 most freq. and ties. responses. Response data were evaluated as the number of times that interviewees in each market sector identified the attribute as a definition or description of the given category divided by the total number of responses

Table 3. Least Squares Means (Confidence Limits) for Probabilities of "must haves", paying premiums, and the average values (%) of paying premiums

Sector	WTP[1]	How and Where Cattle were Raised	Lean, Fat, and Bone	Weight and Size	Visual Characteristics	Food Safety	Eating Satisfaction	Cattle Genetics
Packers	Must Have[1]	0.31[a]	0.17[ab]	0.09[b]	0.11[b]	0.31[a]	None[4]	0.11[b]
		(0.18-0.49)	(0.08-0.33)	(0.03-0.23)	(0.04-0.27)	(0.18-0.49)		(0.04-0.27)
	Premium[2]	0.42[ab]	0.65[ab]	0.47[ab]	0.39[b]	0.71[a]	0.55[ab]	0.45[ab]
		(0.23-0.64)	(0.44-0.82)	(0.30-0.64)	(0.23-0.57)	(0.50-0.85)	(0.38-0.71)	(0.28-0.63)
	Premium %[3]	5.28	7.43	10.77	5.17	11.13	10.06	9.85
Retailers	Must Have	0.30[a]	0.18[ab]	0.06[b]	0.09[b]	0.24[a]	0.36[a]	0.18[ab]
		(0.17-0.48)	(0.08-0.35)	(0.02-0.21)	(0.03-0.25)	(0.12-0.42)	(0.22-0.54)	(0.08-0.35)
	Premium	0.38[b]	0.54[b]	0.65[ab]	0.61[ab]	0.46[b]	0.84[a]	0.59[ab]
		(0.20-0.60)	(0.35-0.73)	(0.47-0.79)	(0.42-0.77)	(0.27-0.65)	(0.61-0.95)	(0.38-0.77)
	Premium %	3.30	6.50	6.5	6.71	9.36	12.59	10.15
Food Service	Must Have	0.08[bc]	0.19[abc]	0.11[bc]	0.15[bc]	0.42[a]	0.35[ab]	None
		(0.02-0.26)	(0.08-0.39)	(0.04-0.30)	(0.06-0.35)	(0.25-0.62)	(0.19-0.55)	
	Premium	0.45[a]	0.39[ab]	0.55[a]	0.15[b]	0.50[a]	0.56[a]	0.29[ab]
		(0.26-0.66)	(0.20-0.62)	(0.34-0.74)	0.05-0.38	(0.26-0.74)	(0.32-0.78)	(0.15-0.50)
	Premium %	11.78[a]	3.3[b]	7.5[a]	6.67[ab]	3.3[b]	8.75[a]	7.29[a]
Further Processors	Must Have	0.09[b]	0.32[a]	0.11[b]	0.08[b]	0.33[a]	0.14[b]	0.06[b]
		(0.04-0.19)	(0.22-0.45)	(0.05-0.21)	(0.03-0.17)	(0.23-0.47)	(0.07-0.25)	(0.02-0.15)
	Premium	0.47[b]	0.46[b]	0.67[a]	0.36[b]	0.41[b]	0.57[ab]	0.39[b]
		(0.35-0.60)	(0.30-0.62)	(0.53-0.78)	(0.24-0.49)	(0.28-0.57)	(0.44-0.69)	(0.27-0.52)
	Premium %	6.17	8.14	7.03	7.26	10.0	5.55	6.90

[a-c] Means within a row for each sector without a common superscript differ ($P < 0.05$)

[1] *Must have* = odds of a category identified as a *must have*, [2]Premium = odds a sector would be willing-to-pay a premium WTP for guarantee of their definition of each quality factor.

[3]Premium % = average percent premium respondents were willing to pay for guarantee of their definition of each quality factor.

[4] No probabilities were calculated for the sector with 0 observations for this attribute.

Table 4. Shares of Preference (± SE) For Relative Importance of Quality Factors in Cow and Bull Beef Market

Quality Category	Packer	Retailer	Food Service	Further Processor	GTO
How and Where Cattle were Raised	7.8[d] (0.05)[1]	1.5[e] (0.06)	2.9[f] (0.04)	4.4[f] (0.03)	10.6[d] (0.07)
Lean Fat and Bone	13.4[b] (0.08)	6.1[d] (0.23)	11.1[b] (0.12)	11.7[b] (0.07)	14.0[b] (0.08)
Weight and Size	8.4[c] (0.05)	1.8[e] (0.07)	4.9[d] (0.06)	5.3[d] (0.04)	7.1[f] (0.04)
Visual Characteristics	4.5[f] (0.03)	21.2[b] (0.74)	4.2[e] (0.05)	4.9[e] (0.03)	9.2[e] (0.06)
Food Safety	56.3[a] (0.20)	52.3[a] (1.58)	66.4[a] (0.29)	62.7[a] (0.18)	39.0[a] (0.20)
Eating Satisfaction	5.4[e] (0.04)	15.9[c] (0.57)	8.4[c] (0.09)	8.2[c] (0.05)	13.0[c] (0.08)
Cattle Genetics	4.1[g] (0.03)	1.1[e] (0.05)	2.1[g] (0.03)	2.7[g] (0.02)	7.2[f] (0.05)

[a-c] Percentages within each column without a common superscript differ ($P < 0.05$)

[1] Standard Error of Mean

Table 5. Categorized responses from interviewed companies explaining what they believed the image of steer and heifer beef industry is

Packer		Retail		Food Service		Further Processing		GTO	
Most freq[1]	Response	Most freq.	Response	Most freq.	Response	Most freq.	Response	Most freq.	Response
33.0 %	Good Image	75.0%	Positive	55.2 %	Positive Image	39.1 %	Positive Image	51.5%	Positive Image
12.5 %	Unknown	9.4%	Improving Image	10.3 %	Uneducated Customers	27.5 %	Negative	27.3%	Negative
12.5 %	Improving Image	9.4%	Negative	10.3 %	Improving Image	13.0 %	Improving Image	6.1%	No Opinion
12.5 %	Negative			10.3 %	No position			6.1%	Family Farms and Old West

[1]Most freq. = Top 3 most freq. responses and ties. Response data were evaluated as the number of times that interviewees in each market sector identified the attribute as a definition or description of the given category divided by the total number of responses.

Table 6. Categorized responses from interviewed companies explaining what they believed the image of market cow and bull beef industry is

Packer		Retail		Food Service		Further Processing		GTO	
Most freq.[1]	Responses	Most freq.	Responses	Most freq.	Responses	Most freq.	Responses	Most freq.	Responses
26.1%	Negative	50.0%	Positive Image	25.0%	Unknown	33.3%	Positive	35.7%	Positive Image
26.1%	Positive	25.0%	Same as Fed	16.6%	Good Image	13.3%	Negative	35.7%	Negative
21.7%	Improving Image	12.5%	Negative	16.6%	Unknown to Consumers	13.3%	No Image	21.4%	No Image
		12.5%	Improving Image	16.6%	Decreasing in Competition	6.7%	Unknown to Consumers		

[1]Most freq. = Top 3 most freq. responses and ties. Response data were evaluated as the number of times that interviewees in each market sector identified the attribute as a definition or description of the given category divided by the total number of responses.

Table 7. Categorized responses from interviewed companies explaining what they believed the strengths of the steer and heifer beef industry are

Packer		Retail		Food Service		Further Processor		GTO	
Most freq.[1]	Response	Most freq.	Response	Most freq.	Response	Most freq.	Response	Most freq.	Response
28.5%	Quality	26.9%	Product Quality	39.6%	Product Quality	28.6%	Product Quality	28.3%	Product Quality
11.9%	Taste	13.5%	Nutrition	14.6%	Food Safety	18.1%	Food Safety	19.6%	Production Practices
11.9%	Story	11.5%	Sustainability	8.3%	Supply	8.6%	Supply	15.2%	Marketing
11.9%	Food Safety	9.6%	Food Safety	8.3%	Market	6.7%	Animal Welfare		
						6.7%	Consistency		

[1]Most freq. = Top 3 most freq. responses and ties. Response data were evaluated as the number of times that interviewees in each market sector identified the attribute as a definition or description of the given category divided by the total number of responses.

Table 8. Categorized responses from interviewed companies explaining what they believed the strengths of the market cow and bull beef industry are

Packer		Retail		Food Service		Further Processor		GTO	
Most freq.[1]	Response	Most freq.	Response	Most freq.	Response	Most freq.	Response	Most freq.	Response
37.0%	Product Quality	33.3%	Value	30.8%	Don't Buy US	31.3%	Product Quality	30.0%	Economics
18.5%	Source	22.2%	Product	15.4%	Sustainability	18.8%	Supply	30.0%	Value
18.5%	Value	11.1%	Taste	15.4%	Food Safety	12.5%	Food Safety	10.0%	Tradition
								10.0%	Product Production
								10.0%	Cost

[1]Most freq. = Top 3 most freq. responses and ties. Response data were evaluated as the number of times that interviewees in each market sector identified the attribute as a definition or description of the given category divided by the total number of responses.

Table 9. Categorized responses from interviewed companies explaining what they believed the weaknesses of the steer and heifer beef industry are

Packer		Retail		Food Service		Further Processor		GTO	
Most freq.[1]	Response	Most freq.	Response	Most freq.	Response	Most freq.	Response	Most freq.	Response
29.4%	Market	18.6%	Poor Marketing	21.2%	Marketing	19.7%	Economics	23.5%	Production Practices
17.6%	Consumer Communication	11.6%	Supply	18.2%	Production Practices	15.5%	Cut Sizes	20.6%	Marketing
14.7%	Consistency	11.6%	Size	18.2%	Economics	9.9%	Supply	14.7%	Product Quality
		9.3%	Food Safety	12.1%	Too Fragmented	8.5%	Too Few Companies	8.8%	Public Perception
		9.3%	Environment	12.1%	Supply	7.0%	Too Fragmented	8.8%	Traceability

[1]Most freq. = Top 3 most freq. responses and ties. Response data were evaluated as the number of times that interviewees in each market sector identified the attribute as a definition or description of the given category divided by the total number of responses.

Table 10. Categorized responses from interviewed companies explaining what they believed the weaknesses of the market cow and bull beef industry are

Packer		Retail		Food Service		Further Processor		GTO	
Most freq.[1]	Response	Most freq.	Response	Most freq.	Response	Most freq.	Response	Most freq.	Response
25.0%	Producers	20.0%	Product	19.0%	Animal Welfare	21.4%	Supply	22.2%	Animal Welfare
22.2%	Supply	20.0%	Food Safety	14.3%	Too Fragmented	14.3%	Product Quality	16.7%	Residues
13.9%	Cost	20.0%	Media	14.3%	Residues	14.3%	Economics	16.7%	Traceability
				14.3%	Controversies	14.3%	Animal Welfare	16.7%	Quality
								16.7%	Supply

[1]Most freq. = Top 3 most freq. responses and ties. Response data were evaluated as the number of times that interviewees in each market sector identified the attribute as a definition or description of the given category divided by the total number of responses

Table 11. Categorized responses from interviewed companies explaining what they believed the potential threats for the steer and heifer beef industry are

Packer		Retail		Food Service		Further Processor		GTO	
Most freq.[1]	Response	Most freq.	Response	Most freq.	Response	Most freq.	Response	Most freq.	Response
22.0%	Market	21.1%	Public Perception	17.8%	Public Relations	15.7%	Public Perceptions	20.4%	Activist Groups
15.9%	Animal Rights Activists	19.3%	Food Safety	16.1%	Animal Diseases	15.7%	Food Safety	14.3%	Regulations
13.6%	Animal Disease	12.3%	Media	16.1%	Economics	10.2%	Animal Disease	12.2%	Uninformed Consumer
13.6%	Food Safety	12.3%	Animal Disease	16.1%	Production Practices	9.3%	Economics	12.2%	Exports
13.6%	Resources					8.3%	Activist Groups	10.2%	Media

[1]Most freq. = Top 3 most freq. responses and ties. Response data were evaluated as the number of times that interviewees in each market sector identified the attribute as a definition or description of the given category divided by the total number of responses

Table 12. Categorized responses from interviewed companies explaining what they believed the potential threats of the market cow and bull beef industry are

Packer		Retail		Food Service		Further Processor		GTO	
Most freq. [1]	Response	Most freq.	Response	Most freq.	Response	Most freq.	Response	Most freq.	Response
22.2%	Business	41.7%	Food Safety	17.6%	Animal Welfare	18.9%	Animal Disease	18.8%	Trade Issues
16.7%	Residues	16.7%	Public Perception	17.6%	Meat from Alternative Sources	10.8%	Activist Groups	18.8%	Policy
13.8%	Uneducated Consumers	8.3%	Activist Groups	11.8%	Media	10.8%	Economics	12.5%	Cost
11.1%	Animal Disease	8.3%	Animal Welfare	11.8%	Food Safety	10.8%	Food Safety	12.5%	Residues
				5.9%	Animal Rights Activists	8.1%	Federal Regulations		
				5.9%	Cost	8.1%	Nature		
				5.9%	Too Fragmented				
				5.9%	Environmental				

[1]Most freq. = Top 3 most freq. responses and ties. Response data were evaluated as the number of times that interviewees in each market sector identified the attribute as a definition or description of the given category divided by the total number of responses.

Table 13. Categorized responses from interviewed companies explaining what they believed has changed since the 2011 NBQA

Packer		Retail		Food Service		Further Processor		GTO	
Most freq.[1]	Response	Most freq.	Response	Most freq.	Response	Most freq.	Response	Most freq.	Response
17.5%	Grading	22.4%	Economics	31.4%	Nothing	36.5%	Nothing	13.7%	Improvement
17.5%	Business Expansion	18.4%	Nothing	22.9%	Economics	15.9%	Products	13.7%	Trade
12.5%	Supply	14.3%	Improved Quality	11.4%	Consumer Demands/Perceptions	12.7%	Increased Food Safety Initiatives	11.8%	Cattle Size
12.5%	Nothing	8.1%	Consumer Awareness					7.8%	Competition
								7.8%	Nothing
								5.9%	Antibiotics
								5.9%	Alignment
								5.9%	Increased Food Safety Initiatives

[1]Most freq. = Top 3 most freq. responses and ties. Response data were evaluated as the number of times that interviewees in each market sector identified the attribute as a definition or description of the given category divided by the total number of responses.

Table 14. Categorized responses from interviewed companies explaining what they believed has changed since the 2007 NMCBBQA

Packer		Retail		Food Service		Further Processor		GTO	
Most freq.[1]	Response	Most freq.	Response	Most freq.	Response	Most freq.	Response	Most freq.	Response
19.5%	Supply	50.0%	Nothing	23.1%	Increased Food Safety Initiatives	44.4%	Nothing	35.7%	Understanding Production
19.5%	Animal Welfare	25.0%	Supply	15.4%	Marketing	18.5%	Increased Food Safety Initiatives	28.6%	Antibiotics
12.2%	Costs	12.5%	Improvements	15.4%	Improvement in Quality	11.1%	Economics	14.3%	Supply
12.2%	Food Safety	12.5%	Increased Food Safety Initiatives	7.7%	Animal Welfare				

[1]Most freq. = Top 3 most freq. responses and ties. Response data were evaluated as the number of times that interviewees in each market sector identified the attribute as a definition or description of the given category divided by the total number of responses.

CHAPTER IV

PART 2-LITERATURE REVIEW

History of Dogs and Man

The exact origin of the modern dog's genetic lineage is currently unknown. Nevertheless, multiple studies link the genomes of dogs with gray wolves and the tamyr wolves originating around 27,00 to 40,000 years ago (Skoglund et al., 2015). These dates pre-date agriculture and suggest that dogs originated during the times of human hunter gatherers. Molecular dating suggests that dogs were first domesticated by Eastern Asian populations around 15,000 years ago while the Europeans began domesticating them around 18,800 to 32,100 years ago. These data suggest that it was early human hunter-gatherer tribes that began domesticating canids that have eventually morphed into the modern dog (Thalmann et al., 2013). The majority of the modern dogs are more closely related to their European ancestors than their Asian ones, with the exception of Artic breeds (Skoglund et al., 2015).

The exact mechanism and history of domestication is foggy. However, hypotheses suggest hunter gatherers stumbled across wolf pups and began training the pups for specific uses within the human groups. The breeding adults were artificially selected for docility as an overly aggressive adult wolf would have been a safety issue. Through generations of interbreeding for specific traits the evolutionary changes were more rapid. Through trade and commerce, it was suggested that multiple blood lines could be drawn from for specific purposes: hunting, tracking, retrieving and companionship. These early traits mapped the artificial selection criteria from which the modern dog breeds have now developed (Wayne and vonHoldt, 2012; Thalmann et al.,

2013; Alchin, 2015). Through this human and dog connection, canines began to become a part of the family and were often thought of as pets and companions as time passed between the species.

Dog Food

People have been sharing their food with dogs almost since the beginning of canine domestication. Virgil, a Roman writer, first mentioned feeding Spartan hounds and Mastiffs whey in 37 BC in his novel Bucolics (Virgil, 1880). Feeding of the dogs is absent in Roman literature until again in 70 AD when Columella, the famous Roman agricultural writer, discusses multiple rations for dogs including whey, spent grains, warm broth from cooked beans and bread, all being acceptable victuals for dog consumption (Columella, 70 AD). In 200-600 CE the Avesta, an ancient collection of texts from Zoroastrianism, people were advised to bring the dogs milk, fat, and meat (Scholars, 1880). This documentation shows a transition from a diet supplemented with plants to animal proteins. In 18th century France the word patee` began to appear. The word patee` was first used to describe feed made for poultry but evolved into a word that was defined as a mixture of bread, crumbs and meat that was given to pets(Denis Diderot, 1751). As time passed, dog handlers were more in tune with the animals they were caring for and this is evident by the increased depth of documentation of how to feed the animals. Michael Lawrence was the first to document that dogs were omnivores in his book for British sportsmen "dogs are not wholly carnivorous or herbivorous but of a mixed kind"(Lawrence, 1883).

Although people had been preparing foods for dogs for centuries, the first commercially formulated and manufactured dog food was not available until James Spratt invented it in the late 1880's. His idea came from watching sailors feeding dry biscuits to dogs in London. His first product involved wheat meals, vegetables and meat and production started in the US in 1890 under the name of "Spratt's Patent Limited." Canned horsemeat for dogs became commercially

available following World War I and canned cat food was introduced in the 1930's (Institute, 2016). During the 1950's multiple dry foods were made available through the introduction of breakfast cereal technology into the pet food industry. Extrusion increased the ability of pet food manufacturers to make consistently sized dry pet foods faster and cheaper than before. During the 1960's a variety of products were available to pet owners and the National Research Council developed the first of several nutrient profiles based on university research called the "Nutrient Requirements of Dogs and Cats" (NRC, 2006).

The treatment of pets has changed in dramatic fashion since the early days of commercial pet food production. The most measurable example of changes in handling are consumer expenditures on their pets. Pet expenditures have continued to rise for decades and have increased by 25% since 2010 (APPA, 2016a). Americans spent approximately $62.75 billion on their pets in 2015, with approximately $23.05 billion of those expenditure on pet food (APPA, 2016a).

There are multiple types of commercially available dog food that consumers can choose from, including kibble, canned, wet food, fully cooked chubbed food, fresh raw and frozen raw. Not only do the types of pet food vary, the ingredients can also be extremely variable; however, all stem from one of the basic groups including: protein, carbohydrates, vitamins and minerals, fats and preservatives. Although tremendous variablilty exists in pet food diet, all ingredients and labelling are regulated by the Food and Drug Adminstration (FDA).

Protein

The Magendie Commission was appointed in 1815 to study purified proteins and their effects on the diet. In 1847, the Magendie Commission report indicated that dogs could not be maintained when fed only purified proteins; rather, dogs need a balance of amino acids from a

high quality protein source. Micronutrient knowledge was lacking at the turn of the 20th century; nevertheless, it was noted that the quality of protein in a dog's diet was crucial to proper maintenance (Chittenden, 1904). Some of the first commercial dog foods were made in Germany using protein hydrolysates but they were never successful in formulating a diet solely using amino acids as the only nitrogen source (Abderhalden, 1912). It wasn't until 1935 when Rose and McCoy isolated and characterized threonine as the last essential amino acid (R.H. McCoy, 1935) that a satisfactory diet could be developed using amino acids as the sole nitrogen source.

Dietary protein is required for two primary reasons. The first reason is that dietary protein provides essential amino acids that dogs and cats cannot synthesize but are required for successful metabolic function. The second reason is that protein provides dispensable amino acids that are paramount for maintenance, growth, gestation and lactation. Currently there are 10 known essential amino acids in dogs: arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. The removal of one of these essential amino acids has been shown to reduce to food intake in omnivores (Gietzen, 1993). Nevertheless, omnivores have been shown to avoid diets that are deficient in one or more amino acid as rats will avoid diets that contain less than $0.1 g \cdot kg^{-1}$ in an essential amino acid (Hrupka et al., 1999).

Dogs have been shown to consume three to four times the minimum amount of protein than needed for maintenance. Although there is no known toxicity for protein overconsumption in dogs, the ability of the dog to utilize all of the amino acids within the diet is not possible at those levels. The measurement of the utilization or protein digestibility is defined as the difference between ingested protein and excreted protein as measured with nitrogen. Nitrogen balance has been the preferred method to determine the amino acid requirements for any life

stage of dog or cat. The crude protein requirements for growing puppies and kittens have primarily been determined using weight and nitrogen balance. The most common variables for adult dogs and cats at various life stages is weight gain and nitrogen balance. It has been shown that limiting the intake of energy and protein while still meeting the minimum requirements has increased longevity in some breeds of dogs and due to a delay in the onset of chronic diseases (R. D. Kealy, 2002). Satisfactory maintenance and maximum growth can be achieved using a multitude of diets. However, these maintenance and growth requirements can only be met when the adequate level of essential amino acids are present, without the 10 essential amino acids multiple health issues arise and the level of food intake diminishes. The health issues found in conjunction with amino acid deficiencies are often non-life threatening in the short term, but if not addressed can cause chronic health problems or death. There are few reports on amino acid imbalances but according to Harper (A.E. Harper, 1970) omnivores are only more sensitive to diets with un proportional levels of amino acids when fed diets low in protein. Feeding dogs a diet that is high in protein while offering a balanced set of the essential amino acids is crucial to sufficient maintenance and growth of the individual dog.

Carbohydrates

Dietary carbohydrates include low and high molecular weight sugars, starches, and various cell wall and storage non-starch polysaccharides or dietary fibers produced by plants during photosynthesis (Bach-Knudsen, 1997). Carbohydrates are the primary energy source for omnivores and can be broken down into four primary groups depending on their degree of polymerization and digestibility. The four types of carbohydrates are absorbable carbohydrates, digestible carbohydrates, fermentable carbohydrates, and non-fermentable carbohydrates.

Absorbable carbohydrates include monosaccharides and sugar alcohols (Whistler., 1996). These compounds can be absorbed directly into the bloodstream without the need for hydrolysis by gastric enzymes. Glucose and Fructose are the most commonly available monosaccharides found in pet foods in the forms of cereal and legume grains and their by-products. As in humans there is most likely a minimum glucose threshold for certain organs like the brain to properly function. In the absence of adequate levels of glucose in the diet the body's metabolic mechanisms can create glucose using protein through the gluconeogenesis. However, the cost of long term gluconeogenesis is the development of increased levels of ketone bodies that eventually create ketosis and or fatty liver disease which can be fatal.

Digestibility or absorption of monosaccharides is influenced by carbohydrate fraction and processing conditions as well as the other dietary components and the physiological state of the animal (Bach-Knudsen, 1997). As doses of monosaccharides in the diet become too high to absorb in the small intestine, they can then be fermented within the cecum of the large intestine. As a result of the ease of absorption of monosaccharides and the length of time that absorption can occur throughout the entire digestive system as well as in the large intestine almost 100% of the ingested monosaccharides are absorbed by the dog. Dogs consuming carbohydrate free diets exhibit low glucose utilization rates suggesting that dogs can alter their metabolic fuel sources but still possess a minimum metabolic requirement for glucose regardless of diet composition. The nutritive value of monosaccharides is dependent on digestibility, absorption rate and availability. Once absorbed, one glucose molecule can be anaerobically metabolized through glycolysis into two moles of Adenosine Tri Phosphate (ATP) or aerobically metabolized into 38 ATP via the electron transport chain. Dietary glucose results in large increases in blood sugar and can utilized for up to 62.3% of the total dietary energy required by dogs.

Digestible carbohydrates or disaccharides have two monomeric residues and include lactose, sucrose, maltose, and trehalose. Starch is another digestible carbohydrate and the most abundant carbohydrate found in cereal grains (Bach-Knudsen, 1997) Lactose, maltose and sucrose are the most common forms of disaccharides found in pet food with the main sources of legumes, cereal grains and other plant materials. Disaccharides must be degraded into their respective monomers before absorption can occur and the jejunum is the primary source of disaccharide absorption. The nutritive value of starch is dependent on the ability to degrade the macromolecules amylose and amylopectin to glucose before absorption (P. Colonna, 1992). Additionally, the glycemic response especially in regards to blood glucose and insulin, vary greatly with the starch source and the amount of processing prior to ingestion (K. N. Englyst, 1999)

Fermentable carbohydrates or oligosaccharides are carbohydrates consisting of three to ten monosaccharide residues combined through glycosidic bonds (Pazur, 1970). These types of carbohydrates resist being hydrolyzed in the small intestine but are fermented by microbes indigenous in the lower part of the gastro intestinal tract of dogs. Wheat, barley and soybeans are common sources of fermentable carbohydrates typically found in a pet's food. The molecular structures of the linkages between the monosaccharides of an oligosaccharide determine the solubility and fermentabilty of the feed. Although soluble plant sources are easier to digest than insoluble, extrusion technologies reduce the molecular weight of the starches and can decrease the ratio of insoluble to soluble fibers, increasing the ability of the dog to digest (Krumar, 1990). The energy available from these carbohydrates is directly related to the dog's microbes' ability to ferment them in the hindgut and primarily cecum generating usable glucose that can then be

absorbed by the animal. Without the necessary microbes the dog would not be able to utilize these feeds as a nutrition source.

Non-fermentable carbohydrates are dietary fibers that are not readily digestible by the bacteria normally found in dogs and cats. Cellulose and wheat bran are common examples of non-fermentable carbohydrates often found in the diets of dogs and cats. Lignin is also linked in with these types of carbohydrates and due to the inability of the animal to extract nutritive value these compounds directly contribute to fecal bulking. Unfortunately, cellulose is the most abundant carbohydrate on the planet and it accounts for 15-30% of all plant cell walls (M. Mcneil, 1984). Although these carbohydrates provide little to no nutritive value they are a large benefit to the healthy movement of material through the digestive tract.

Although the recommended amount of carbohydrates differs based on the amount of food consumed, caloric density of the food and the energy requirement of the dog. It is nevertheless important to mingle multiple types of carbohydrates within the diet in order to supply the animal with enough digestible energy while also not restricting the amount of non-digestible fiber in the diet. When considering which combination of digestible and non-digestible carbohydrates it is essential to carefully analyze all of the unique characteristics of the carbohydrates added.

Minerals

Minerals serve a variety of physiological roles within the body and must be consumed within the diet in order to provide proper maintenance and growth throughout the animal's life. Calcium (Ca) and Phosphorous (P) aid in rigidity of teeth and bones while Ca, Magnesium (Mg), Potassium (K), and Sodium (Na) are essential for nervous system impulse and muscle contraction. In addition to the importance of P in the skeletal system, P is crucial to energy metabolism due to its role in ATP. The primary roles of trace minerals are in metalloenzymes

where they function in a multitude of enzymatic actions. Deficiencies in minerals may cause need for clinical observation and are very common in ill-prepared home diets.

When preparing diets for companion animals it is paramount that the minimum amounts of essential minerals are present in the diet (NRC, 2006).

Vitamins

Vitamins are organic compounds that are essential at low concentrations in the diet, because either dogs cannot synthesize them through precursors or they are produced at suboptimal levels (NRC, 2006). When diets are inadequately filled with vitamins a variety of clinical abnormalities results and depending on the severity of the deficiency symptoms can be troublesome to diagnose. Vitamin deficiencies were first noticed approximately 85 years ago and dogs played a substantial role in identifying the differences between vitamins A and D. Vitamins have been divided into two subclasses, water soluble and fat soluble. Water soluble vitamins primarily aid in energy metabolism and antioxidant effects whereas fat soluble vitamins maintain a variety of roles throughout the body including blood clotting and aiding in the absorption of calcium. Although processing steps have relatively minor effects on protein, carbohydrates and fats, processing can have major ramifications to the vitamins in the diet, especially if they are purified or added as concentrates. The inactivation of vitamins that occurs is primarily related temperature and duration of the processes (NRC, 2006)

Fats

Fats are an important component of companion animal diets. Dietary fats provide a concentrated source of energy for storage and utilization and supply the essential fatty acids EFA that are not otherwise synthesized (NRC, 2006). Fats belong to a broader group of compounds known as lipids that can be glycerol or non-glycerol based. Glycerol based lipids include triglycerides,

phospholipids and glycolipids. Non-glycerol based lipids include cholesterol and its fatty acid esters such as waxes and other various sterols. The materials of which most of the dietary fats originate are from land and sea mammals as well as seed oils of numerous different plants. Other sources of dietary fats for dogs and cats include eggs, muscle, and offal. Dietary fat provides the most concentrated source of energy in the diet, accounting for approximately 2.25 times the metabolizable energy as protein or carbohydrates. Digestion and absorption of dietary fat is a multistep process requiring intrinsic coordination of three recognized stages in the gastrointestinal tract (I.E. Masklell, 1993) luminal, mucosal and secretory. The digestibility of crude fat is high in dogs varying from approximately 85-95% when mixed with acylglycerols (Meyer, 1984). Diets with a wide variety of fats are considered healthy for dogs as long as the correct ratios of protein, vitamins and minerals can be assured.

Types of Pet Foods and Processes

Pet food can generally be divided into two main categories of dry and wet. Dry food can be further divided into multiple different categories but it is sufficient to keep the two separate with the generic terms. The vast majority of dry pet foods marketed today are produced via the extrusion process. Modern extrusion methods manipulate the food mash pre extrusion via steam and hot water. Following preconditioning, the mix is transferred to the extrusion barrel where it is potentially mixed with a meat slurry and while further heated using steam and hot water. The mash is then corkscrewed through the barrel while heat from friction and in-direct steam increases the heat within the mash to sterilize the product from a pathogenic standpoint (Huber, 1994). Also, during the extrusion process the meal is cooked at such high temperatures that the starches gelatinize (Mercier, 1975), increasing the digestibility of these foods by making the starches more available for utilization by the upper gut.

The frictional heat is created when the mash is forced through the large barrel exiting by way of a die and a cutter substantially smaller than the barrel. The combinations of dies and cutters are nearly endless, giving the manufacturers almost limitless shaping options for desired markets. At the exit of the extruder the product returns to atmospheric pressure which is considerably lower than the pressures exhibited throughout the extrusion processes which instantly increases the size of the food. Following extrusion, moisture content can range from 22-28% but because of shelf life requirements needs to be reduced to 10-12% (NRC, 2006). The moisture reduction of extruded pet food occurs in a variety of ways but most commonly occurs via continuous dryers using dry heat and high airflow. Following drying liquefied fat may be added to the pieces to increase the fat percentages and to add flavorings to kibbles.

Wet food is a different process entirely and does not include extrusion methods in any form. Wet foods often contain much higher percentages of fresh and frozen meat products combined with multiple dry ingredients formulated to precise dietary needs. After formulation, the ingredients are placed in containers that can withstand retort methods. Although the wet food market predominantly consists of canned foods, newer technologies have allowed for alternative packaging capable of withstanding the temperatures and pressures of retort. Additionally, a new sector of wet dog food is appearing in the marketplace and gaining considerable market share. Raw pet food has increased over 40% year over end since 2012 with estimated expenditures of $52 million in 2015 (Lange, 2016).

Raw pet food is pet food that has undergone no heat treatment or cooking. The push for the addition of this type of diet into the companion animal market can be traced to Dr. Pitcairn's Complete Guide to Natural Health for Dogs and Cats in 1982. In his books, Dr. Pitcairn advises his readers to steer away from commercially available feeds and treats and to substitute the diet

with more “natural” food sources often prepared in the home. Home prepared diets often follow recommended recipes easily found on the internet or within specific recipe books. These recipes can produce food that either over or under provides essential vitamins and minerals. A German study found that greater than 60% of the bone and raw food diets were severely unbalanced in one or more vitamin or mineral and the other 40% were at least slightly unbalanced (Dillitzer et al., 2011). In 2005, scientists and veterinarians from the University of Tennessee tested 85 home cook pet food diets published within 6 different books. Of these diets, 55% were inadequate in protein, 62% were inadequate in vitamins and 86% were inadequate in minerals (Lauten et al., 2005). The imbalances in vitamins and minerals can cause illnesses such as rickets, rubber jaw syndrome, or hyperparathyroidism. The importance of properly balanced vitamins and minerals in the diets of pets are well documented (NRC, 2006; Baldwin et al., 2010). The Association of American Feed Control Officials AAFCO provide lists of minimum requirements to be considered a balanced diet. For a diet to fit this requirement samples must be sent to an approved chemical laboratory for sampling and those samples must then be submitted to AAFCO for approval. Utilizing feeding recipes or feeds that do not fit or have not been tested to meet the minimum requirements set forth by AAFCO could result in deficiencies or the overabundance of vitamins and minerals.

The most cited advantages of raw based diets are the increases in digestibility the only studies found only involved felids and at the time of writing there were no comparisons of raw foods and kibble in relation to canines. The felid studies have corroborated the theories of supporters of raw diets that raw diets are more digestible (Kerr et al., 2012) (Vester et al., 2010). Vester also suggested that although raw diets increased digestibility they did not increase enough

to warrant a change from high protein kibble. Each of these articles cite the risks of potential pathogenic contamination often associated with raw meat as real and concerning.

Food Safety

Common pathogenic microorganisms associated with raw meat include *Salmonella, Listeria monocytogenes, Campylobacter* spp., and pathogenic strains of *Escherichia coli.* The two pathogens that are generally of the most concern for raw pet food are *Salmonella* and *Listeria monocytogenes*. *Salmonella* and *Listeria monocytogenes* make up the majority of pet food recalls (FDA, 2016f). *Salmonella* contamination is well documented in raw meats associated with raw pet foods (Chengappa et al., 1993; Weese et al., 2005; Finley et al., 2007b; Nemser et al., 2014; Philbey et al., 2014). *Salmonella* is a genus of a rod shaped gram negative bacterium of the Enterobacteriaceae family (Tortora, 2008). Although dogs can often be asymptomatic carriers of *Salmonella* they have been shown to harbor and shed *Salmonella* for up to 6 weeks (Finley et al., 2007a; Leonard et al., 2011). Salmonellosis is the disease that occurs from a *Salmonella* infection in either dogs or humans and is especially concerning when the patient is immune-compromised. Symptoms of salmonellosis are often characterized as abdominal distress including pain, diarrhea and vomiting. Most cases of salmonellosis do not require medical attention and subside within a week of infection. However, complications can arise when immune compromised patients are exposed including humans and dogs and complications can lead to prolonged need of medical care or even death. Listeriosis primarily affects older adults, pregnant women or other people who are immunocompromised. *Listeria monocytogenes* is a ubiquitous pathogen that most commonly causes infections through oral ingestion of contaminated food products such as raw meat or uncooked vegetables. *Listeria monocytogenes* primarily causes infections of the central nervous system in

immunocompromised individuals and gastroenteridis in otherwise healthy patients. Listeriosis is of primary concern due to the relatively high risk of death associated with infection; approximately 20% of listeriosis infections result in death(CDC, 2013).

The reduction of pathogens from raw meat is essential to the safety of the ready to eat (RTE) pet foods and treats commercially available for purchase. There are multiple interventions commercially available to reduce the pathogenic bacterial load within a meat product. Based on work performed at Colorado State University it is common to see multiple interventions applied in line with each other in a synergistic manner to increase efficacy (Delmore et al., 1998). Common commercially available interventions include hot water, organic acids, chlorine, steam pasteurization or heat pasteurization and high pressure processing (HPP). It is well documented that commercially available interventions work to reduce pathogenic bacteria from carcasses and fresh meat (Belk, 2005; Sofos, 2005; Skandamis et al., 2008). However, the focus of this project was to determine the efficacy of HPP to reduce a non-pathogenic cocktail of *Eschericia coli* ATCC BAA 1427-1431 within raw pet food. *Eschericia coli* ATCC BAA 1427-1431 have been utilized and validated as surrogate organisms for *Salmonella* in order to validate in-plant food safety systems (Niebuhr et al., 2008; Keeling et al., 2009; Dickson, 2015). Surrogate organisms have been validated to be more tolerant to the intervention than the actual pathogen, allowing the non-pathogenic bacteria to be viable indicators as to whether the intervention is an effective tool to reduce the bacteria. Based on the validation method, it can be assumed that a more intervention tolerant, non-pathogenic surrogate, will mimic the efficacy of the intervention without introducing a potential pathogenic bacterium into the food system. Dr. James Dickson of Iowa State University validated ATCC BAA 1427-1431 against Non-typhoidal *Salmonella* and *E. coli* 0157:H7 and the non-0157 STECS for HPP(Dickson, 2015).

The first reported usage of high pressure to extend the shelf life of food came in 1899 and occurred with milk (Hite, 1899). Hite was searching for a compromise between effective reduction in pathogenic and spoilage organisms through a method that eliminated the need for heat treatments. Since Hite, multiple applications of HPP have arisen as a minimal processing step to increase shelf life and reduce pathogens. Foods such as lunch meats, salsas, dips, and juices have been the primary applications of HPP. High pressures are shown to destroy or critically injure the cell membrane of bacterial cells reducing or eliminating the cells ability to maintain normal metabolic function (Huang et al., 2014). Coupling HPP with mild heat (Ates et al., 2016) or decreased pH (Bayındırlı et al., 2006) increases the effectiveness of the bacterial reduction and eliminates the potential of bacterial rebound that often follows HPP (Black et al., 2010). Despite the effectiveness, discoloration associated with the utilization of HPP has limited its acceptance for use in fresh meat(Carlez et al., 1995; Morales et al., 2008). Implementing HPP into a food safety system has been shown to be an effective measure that can reduce bacterial loads (Cheftel and Culioli, 1997; Huang et al., 2014; Sheen et al., 2015).

Food Safety Modernization Act

Pet foods are regulated by the Food and Drug Administration as required by the Food, Drug, and Cosmetic Act (FFDCA). The FFDCA requires that, "All animal foods, like human foods, be safe to eat, produced under sanitary conditions, contain no harmful substances, and be truthfully labeled"(FDA, 2016e). In 1958, congress amended the FFDCA to require FDA to review and approve any food additives before they can be marketed unless that additive can be considered Generally Recognized as Safe (GRAS). It is illegal to use an unapproved feed additive in human or animal food and the use of any unapproved additive renders the food unsafe and adulterated. Generally, there are two methods for determining whether or not a food item can

be considered GRAS. First is based on experience that the additive has been commonly used in food with a lengthy and known history with a significant number of animals consuming the food. The second method is through scientific procedures, the results must be published in scientific literature and be of the same quality and quantity of scientific data for FDA to approve a food additive petition(FDA, 2016c).

The Food Safety Modernization Act (FSMA) increased the regulatory focus placed on the production of pet foods and treats. Key requirements of the new regulation include the use of Current Good Manufacturing Practices (CGMP) established for animal food operations and the analysis of potential hazards and risk based preventative controls within a food safety plan. The recommendations for establishing complete CGMP's can be found in Title 21 part 110 of the CFR (Regulations, 2016). Recommendations for a complete food safety plan in order to comply with subpart C are included within Part 117 "FSMA Final Rulemaking for Current Good Manufacturing Practice and Hazard Analysis and Risk-Based Preventative Controls for Human Food" (FDA, 2016d). The determination to treat pet foods with the same standards as human food stems from the fear that pet food can present a human health risk to "at risk" populations, especially children. According to Compliance Policy Guide 690.800, *Salmonella* in Food for Animals FDA enforcement efforts should focus on *Salmonella* as FDA maintains a zero tolerance approach to any *Salmonella* serotypes (FDA, 2013). Any article of pet food will be considered adulterated when introduced into and while in commerce if *Salmonella* of any serotype is discovered in one or more sub samples of the pet food or pet food ingredients (FDA, 2013). The FDA's decision to consider *Salmonella* an adulterant in pet food has increased the focus on food safety within the industry and has increased the numbers of recalls associated with

pet food. Recalls associated with *Salmonella* have become common place within the pet food industry with multiple recalls within the last 24 months (FDA, 2016a).

Identifying new and effective methods to reduce the incidences of *Salmonella* and *Listeria monocytogenes* within RTE pet foods is an essential step to guaranteeing the prosperity of pet food companies. The pet food industry continues to grow into a considerable industry, and the increased focus that the FSMA has placed on the improvement of food safety calls for the implementation of novel approaches to food safety. As research, has shown HPP can be an effective tool to accommodate the needs of producers of minimally processed pet foods in the reduction of pathogenic and spoilage organisms within the final package of pet food products. Further research is still needed to guarantee sterility of the products, but the use of HPP as a critical step within a food safety plan has been documented through prior literature and current experiments.

CHAPTER V

PART 2- VALIDATION OF HPP IN THE DESTRUCTION OF PATHOGEN FOR RAW PET DIETS

Introduction

The humanization of American pets has steadily increased since domestication. As the attachment to the family pet has increased, so has the amount of money that families spend to care for and pamper pets; the APPA estimates that American pet owners will spend over $62 billion on their pets in 2016 (APPA, 2016b), with the majority of these expenditures on pet food. Raw pet foods are an emerging sector of the pet food industry. Feeders and producers of raw pet diets cite multiple beneficial aspects of feeding raw diets despite no peer-reviewed literature in canines. Despite the absence of peer-reviewed literature there is a plethora of online testimonials and blogs touting the oral, gastrointestinal and epidermal advantages to raw diets over commercial diets. Although raw diets are inherently associated with food safety risks, proponents continue efforts to increase offerings for minimally processed pet food items. Although the food industry has multiple heat related reduction methods, heat treatments for raw commercial diets have been removed as a processing step. The removal of heat treatment is a concern, as heat treatment is a well-documented processing step for removing *Salmonella* in meat (Juneja et al., 2001). Pets that consume foods contaminated with *Salmonella* may not develop clinical signs of salmonellosis but may shed the bacteria from 1-7 d (Finley et al., 2007b). From April, 2015-April 2016 the FDA reported 18 different recalls involving the potential contamination of pet foods or treats (FDA, 2016f). The risk for pet foods to be adulterated with *Salmonella* is

unfortunately high whether the diet is kibble or raw. In a study evaluating commercial diets, up to 53% of diets purchased from retail were adulterated with non-type specific *Escherichia coli*, *Salmonella*, or *Campylobacter spp* and 5.9% of the samples were positive for *Salmonella* which were all derived from raw meat diets. (Strohmeyer et al., 2006).High pressure processing (HPP) is a reasonable compromise to minimal processing without sacrificing food safety. However, few, if any studies, regarding HPP utilization in raw pet foods currently exist. Nonetheless, based on evidence of potential *Salmonella* contamination in raw pet food and the risk to the pets and the humans feeding raw pet food, more research aimed at ensuring the safety of these products is imperative. The goal of this experiment was to benchmark the efficacy of HPP in reducing non-pathogenic surrogates for *Escherichia coli* and *Salmonella enterica* in raw pet food diets.

Materials and Methods

Eighteen kg of a raw beef diet (mixed ration of ground beef, whole vegetables and fish oils) was inoculated with a five-strain mixture of non-pathogenic *E. coli* (ATCC BAA-1427, ATCC BAA-1428, ATCC BAA-1429, ATCC BAA-1430, ATCC BAA-1431) that are considered surrogates for pathogenic *E. coli* and *Salmonella enterica* (Dickson, 2015; FSIS, 2015). The strains were individually cultured and sub-cultured (35°C, 24±2 h) in 10 ml of tryptic soy broth (Becton, Dikinson and Company, Sparks, MD). Broth cultures (10 ml) of all five strains were then combined and cells harvested by centrifugation (15min, 4°C, 5590 x *g*, J2-MC Centrifuge, Beckman Instruments, Inc., Palo Alto, CA). Cell pellets were washed with 10 ml phosphate-buffered saline (PBS, pH 7.4; Sigma, St. Louis, MO), re-centrifuged, and the washed pellet re-suspended in 100 ml of PBS to obtain a concentration of approximately 8 to 9 log CFU/ml.

Product Inoculation

The prepared inoculum mixture (100 ml) was added to the 18 kg batch of product and mixed (5 min) using a 45.36 kg mechanical mixer (Hobart, Troy Ohio). The target inoculation level was 7 log CFU/g. Following a 15-min cell attachment period, 10, 50 g samples were collected and placed into individual Whirl-Pak filter bags (Nasco, Modesto CA) for microbial analysis

Packaging, High Pressure Processing, and Frozen Storage

Immediately following inoculation and collection of samples for 0-h microbial analysis ("Before HPP"), the raw product was bulk-packaged and shipped overnight on ice to a packaging facility in South Carolina to be individually packaged into 27-g packages (130 x 95 cm). Packages were vacuum sealed in a roll stock machine (Mutlivac, Kansas City, MO) under 19 mbar of vacuum. All individual packages were then shipped overnight on ice to Nebraska for HPP application. High pressure processing was carried out by placing samples into a HPP vessel (350 liter Avure Quintus® QFP 350L-600) and subjected to 87,000 psi for 480 s. The water temperature within the chamber was 0˚C for the duration of the treatment. Twelve packages did not receive the HPP treatment and were designated as shipping controls. More specifically, the shipping controls were used to assess whether microbial loads had changed from the time of inoculation to when the HPP treatment was applied. Following HPP, all samples were placed on ice and transported (7 h) to Colorado State University (Fort Collins, CO). Upon arrival at Colorado State University, 10 samples were set aside for microbial analysis ("24 h Post HPP"), and the remaining samples were stored at -23.3˚C for 5 d. Following the 5-d storage period, 10 samples were subjected to microbial testing ("After HPP and Freezing").

Microbiological Analysis

Maximum recovery diluent (Acumedia-Neogen, Lansing, MI) was added to each sample at a 1:2 ratio (sample weight to volume of diluent) followed by pummeling for 2 min (Masticator, IUL Instruments, Barcelona, Spain). Sample homogenates were serially diluted in 0.1% buffered peptone water (Difco, Becton Dickinson, Sparks, MD) and appropriate dilutions were spread-plated in duplicate onto tryptic soy agar (TSA; Acumedia-Neogen), for enumeration of total bacterial populations (Aerobic Plate Count; APC), and Violet Red Bile Agar (VRBA; Becton, Dickinson and Company Sparks, MD) for enumeration of total coliforms. TSA plates were incubated for 72 h at 25˚C and VRBA plates were incubated for 24 h at 35˚C.

Objective Color

. Objective color measurements (*L*, a*, b**) were taken for each package using a portable spectrophotometer (MiniScan® EZ; Hunter Association Laboratory Inc., Reston, VA, USA) 24 h post HPP. Color measurements were taken through the packaging film and the spectrophotometer was standardized using identical packaging material.

Statistical Methods:

Treatment means were compared using an ANOVA within the mixed procedure of SAS (version 9.3; Cary, NC) and separated using the PDIFF statement with an α of 0.05. Levels of HPP treatments served as the fixed effects of the model. Bacterial counts were log(10) transformed prior to analysis.

Results and Discussion

High pressure processing was an effective mode for reducing inoculated bacterial populations (P <0.05; Table 15) but did not reduce surrogate bacteria below detection limits. Additionally, the exposure to high pressures also elicited a color change, as post HPP product

presented a lighter, paler colored product (P <0.05) as shown in Table 16. Similar results have been shown in multiple ground beef studies (Carlez et al., 1995; Cheftel and Culioli, 1997).

The FDA has labeled *Salmonella* species adulterants in animal feed and therefore all animal feed must comply with a zero-tolerance statute set forth by FDA (FDA, 2016b). In samples tested 24 h post-HPP, surviving populations totaled 1.8 log CFU/g (4.9 log CFU/g reduction) and 4.8 log CFU/g (2.1 log CFU/g reduction) on VRBA and TSA, respectively. Twenty-four-hour post HPP and frozen storage 5d at -23.3˚C, surviving colonies on VRBA totaled 0.48 log CFU/g (6.2 log CFU/g reduction) with 90% of all samples under the detection limit and TSA colonies totaled 4.6 log CFU/g (2.3 log CFU/g reduction). The utilization of freezing as a mechanism for further reduction of surrogate bacterial populations has been previously demonstrated (Black et al., 2010). We hypothesize that freezing post HPP inhibited the cells' ability to recover from the cellular wall damage sustained during exposure to high pressure, thus resulting in an increased reduction.

Results on selective agars were similar to those found within other studies utilizing non-thermally processed meat matrices (Porto-Fett et al., 2010). However, viable bacterial counts on TSA were substantially greater than expected and the observed morphology of colonies differed from microbiological expectations. Specifically, numerous, smaller colonies were noted on the TSA plates following incubation. Because of these observations of differing sizes and morphologies, representative colonies from each differing morphology were isolated and re-streaked on a selective media (VRBA) to elucidate additional information. The smallest colonies identified and isolated from TSA plates were the only colonies to flourish when streak plated onto VRBA. Following the recovery time on the TSA agar during incubation, the cells could fully recover and grow on the VRBA, suggesting the VRBA was too harsh of an environment for

the potentially sub-lethally injured cells to recover, generating an incomplete count of coliform bacteria. Through this discovery, we believe that previous literature may over-estimate the efficacy of HPP if only plated on selective media, and that given the proper opportunity, sub-lethally injured bacteria can remain viable.

High pressure processing is an effective mode of reducing pathogens ($P<0.05$) in raw pet foods. However, these results suggest that utilization of HPP alone is not sufficient to reduce pathogen populations to an acceptable level. Nonetheless, these data suggest that HPP use in pet food processing may be an effective piece to a multi-hurdle process. The results of this experiment confirm the previously published literature in regards to the efficacy of HPP in a non-thermally processed meat matrices on selective media (Porto-Fett et al., 2010) . However, the ability of organisms to recover during incubation on TSA plates and then grow and colonize on VRBA while not originally growing on VRBA suggests that previous literature may have over-estimated the reduction efficacy of HPP. Further research is needed in order to validate a processing system utilized to reduce *Salmonella* to the "zero tolerance" level required for FDA.

Part 2 Tables

Table 15: Aerobic plate counts[1] (APC; log CFU/ml) of beef maintenance diet before inoculation of (ATCC BAA-1427, ATCC BAA-1428, ATCC BAA-1429, ATCC BAA-1430, ATCC BAA-1431), after inoculation, after high pressure processing (HPP), after combination of HPP and freezing (-23.3˚C) for 5 days.

Sampling Time	Microbial Populations			
	APC	% BDL[2]	VRBA	% BDL[2]
Before HPP[1]	6.91[a]	0	6.73[a]	0
24 h After HPP	5.36[b]	0	1.78[b]	0
After HPP & Freezing	4.60[c]	0	0.48[c]	90
SEM	0.036		0.338	

[1] Data are reported as least squares means
[2] BDL: below detection limit (-0.6 log CFU/cm^2).
[a, c] Means with different superscripts within column are different ($P < 0.05$).

Table 16. The influence of high pressure processing on the color (L^*, a^*, b^*) of raw pet food without exposure to high pressure processing and 24 hours post high pressure processing.

Color Value	*Treatment (n=10)*		Standard Error	*P* Value
	Control	HPP		
L^*	50.32[b]	52.53[a]	0.60	0.0177
a^*	16.64[a]	14.84[b]	0.28	0.0003
b^*	17.75[b]	19.27[a]	0.45	0.0308

Data are reported as least squares means
[a-b] Means with different superscripts within column are different ($P < 0.05$).

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