THESIS

SURVEY OF MANAGEMENT AND MARKETING PRACTICES ON U.S. COW-CALF OPERATIONS AND EVALUATION OF DIFFERENT CAPTIVE BOLT LENGTHS IN A COMMERCIAL SLAUGHTER PLANT

Submitted by

Miriam Sharon Martin

Department of Animal Sciences

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Master's Committee:

Advisor: M. Temple Grandin
Co-Advisor: Lily Edwards-Callaway

Lynn Delmore
Bernard Rollin

ABSTRACT

SURVEY OF MANAGEMENT AND MARKETING PRACTICES ON U.S. COW-CALF OPERATIONS AND EVALUATION OF DIFFERENT CAPTIVE BOLT LENGTHS IN A COMMERCIAL SLAUGHTER PLANT

Finding ways to objectively measure welfare within different sectors of the beef industry is necessary to continually improve cattle welfare from birth to slaughter. The first objective of Study 1 was to benchmark cow-calf producer perspectives on management strategies and challenges that ultimately affect cattle welfare on ranches in the United States. The second objective of Study 1 was to quantify how producers are marketing their calf crop, their priorities when selecting replacements, and if producers saw value in handling and care guidelines. A total of 1,414 responses from cow-calf producers in 44 states were collected through a survey done in partnership with *BEEF* Magazine. Thirty questions were asked of producers to gather demographic information, producers' current handling and health management practices, and how they prioritized industry challenges. As well as establish at what age and through what avenue producers are marketing their calf crop, and gauge producer perspectives on a quality assessment outlining handling and care guidelines.

After analyses of producer responses, it was concluded that the frequency of management methods and decisions are impacted by age, operation size, location, and BQA certification [P-values ≤ 0.009]. A higher percentage of respondents who were BQA certified used electronic eartags, followed by freeze branding [P-value = 0.009]. A higher percentage of respondents not BQA certified used basic eartags and hot branding. 74.5% of respondents were preconditioning

their calf crop. A higher percentage of respondents were preconditioning their calf crop that were BQA certified, than those who were not BQA certified [P-value < 0.001]. The most important beef industry challenge identified was cow-calf health and the biggest challenge to producer's own operation was identified as land availability/price. The most important animal health issues on producers' operations were identified as Bovine Respiratory Disease, flies, Pinkeye, and reproductive health. Health challenge responses varied significantly by producer age, beef cow inventory, and region of the United States [P-values < 0.001]. By producer age, calf/neonate health was identified as the biggest challenge for respondents under the age of 30 [P-value < 0.001]. Respondents age 55-70 responded that Veterinary Feed Directive (VFD)/regulations was more of a challenge than any other age group. The percentage of respondents who marketed their calf crop at certain ages varied by herd size [P-value < 0.001]. Respondents with 50 head or less or more than 1,000 head more frequently retained their calf crop through finishing and respondents with 51 to 200 head and 201 head to 500 head more frequently backgrounded and then sold their calf crop. Respondents' top priorities when selecting bulls were calving ease, followed by growth and feed efficiency traits. When selecting females, top priorities were reproductive efficiency, followed by mothering ability. The percentage of respondents using pain management differed by whether or not a vet had offered to administer a drug for pain management [P-value < 0.001]. 13.5% of respondents answered yes, a veterinarian had offered to administer a drug for pain management when castrating or dehorning. Of those 13.5% who responded yes pain management had been offered, 54.55% of respondents chose to use a pain relief method. A higher percentage of producers that precondition also indicated that they use a pain relief method when castrating or dehorning more frequently, though it was still a low percentage [P-value = 0.006]. Overall, 46.3% of respondents saw value in handling and care

guidelines and 54.9% of respondents saw value in a program including source and age verification, a vaccination plan, and handling and care guidelines. Respondents who were BQA certified, had a beef cow inventory of 501 to 1,000 head, who preconditioned their calves and backgrounded them before selling, and who lived in the West more frequently saw value in a quality assessment outlining handling and care guidelines [P- values ≤ 0.015].

The objective of Study 2 was to examine the effects of captive bolt length and breed type on post-stun leg activity in cattle. A total of 2,850 Holstein (HOL) and non-Holstein British/Continental bred (NHOL) steers and heifers were observed post-stunning at a large commercial slaughter facility. A penetrating pneumatic captive bolt stunner was used with three different bolt lengths: CON, 15.24 cm; MED, 16.51 cm; and LON, 17.78 cm. Hind limb kicking, forelimb activity, take away belt stops, carcass swing and number of knife sticks during exsanguination were recorded for each animal from video recording. Hind limb and forelimb kicks observed ranged from 0 to 25 and 0 to 8, respectively. A significant main effect of treatment [$P < 0.001$], breed type [$P < 0.001$] and an interaction between treatment and breed type [$P < 0.001$] on hind limb activity was found. Analysis of post-stun hind limb and forelimb activity indicated that increasing pneumatic captive bolt length does not decrease post-stun leg activity but alternatively can increase kicking when using the longest bolt tested in particular types of cattle, i.e. Holsteins. Other parameters associated with the shackling and hoisting process were impacted by breed type as well. There was a higher percentage of cattle experiencing take away belt stops and carcass swing in HOL as compared with NHOL.

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CHAPTER I

INTRODUCTION

Livestock producers are encountering increased pressure from regulations and market movements to alter how they raise animals (Olynk, 2012). Today producers face the challenge of effectively addressing consumer concerns while remaining competitive in the marketplace (Verbeke and Viaene, 2000). Consumer concerns extend beyond the realm of food safety and include animal well-being (Verbeke and Viaene, 2000). Consumer views on animal handling techniques, production practices, housing, manure management, and social impacts of livestock production all play into consumer buying preferences (Olynk, 2012). With measures to better improve animal welfare comes an associated cost, and questions surrounding how the cost will be paid and by whom begin to surface (Olynk, 2012).

The United States beef industry has responded to this movement through the implementation of welfare assessment programs at beef processing plants and feedlots (American Meat Institute Animal Welfare Committee, 2010; National Cattlemens Beef Association, 2017). Through Beef Quality Assurance (BQA) training, the Beef Checkoff is educating the cow-calf producer sector of the beef industry about proper animal handling and welfare (Beef Checkoff, 2017a). The BQA Cow-Calf Assessment is an educational tool that focuses on animals, records, and best management practices, along with facilities and equipment (Beef Quality Assurance, 2017). However, a third-party verified, value-added, practical welfare assessment program does not exist for the cow-calf sector of the beef industry in the United States. Traceability becomes more challenging, operation facilities are more diverse in nature,

and management styles vary greatly within the cow-calf sector (Simon et al., 2016a). All of these factors make a cow-calf assessment program more challenging to develop than the standardized assessments currently used for feedyards and processing facilities. Further investigation into current management practices, cow-calf welfare issues, and marketing strategies is needed to create a program that increases consumer confidence and provides value to the cow-calf producer.

Many measures already exist to improve cow-calf operation welfare such as developing a good veterinary-client-patient relationship, preconditioning, and using pain management when performing painful procedures such as castrating and dehorning. Cow-calf operations vary in their use of veterinary services and veterinarian-client-patient-relationships are not well established on every cow-calf operation in the United States. Use of herd-health related veterinary services has been found to increase with herd size (Waldner et al., 2013). Producers with more than 220 breeding females were more likely to seek veterinary advice in regards to treating sick calves than producers with less than 85 breeding females (Waldner et al., 2013). Bovine Respiratory Disease (BRD) accounts for over 50% of all cattle treated for sickness (Krehbiel et al., 2016). Good management practices for weaned calves such as vaccination, castration, dehorning, and adapting them to a feed bunk are collectively called preconditioning and help lower the risk of cattle encountering health problems (Krehbiel et al., 2016). Calves who encounter more stress and are sold through an auction market, spending more time in the marketing chain than calves transported directly from the ranch of origin to the feedlot, are at higher risk of developing clinical BRD (Krehbiel et al., 2016). Cattle are routinely castrated and dehorned on ranches in the United States either prior to weaning or as part of a preconditioning program. Physical castration is the most common method practiced in the United States

(Coetzee, 2013). There are currently no analgesic drugs specifically approved for pain relief in livestock during castration or dehorning by the United States Food and Drug Administration (Coetzee, 2013). However, a veterinarian can administer a local anesthetic which will greatly reduce the calf's cortisol response, or a combination of a local anesthetic and a non-steroidal anti-inflammatory drug which will also eliminate pain up to 12 hours post-castration (Stafford and Mellor, 2005), via extra-label-drug-use (Smith et al., 2008). Management practices that reduce stress such as pain management, vaccination programs, and preconditioning give producers who make the extra effort, the opportunity to enroll their calves in third-party verified programs. These third-party programs help ensure that regardless of market fluctuations, the opportunity for added value exists.

It is estimated that verification of vaccinated calves adds $1.44/cwt and the value of weaning, vaccinating, and certification can add from $2.39 to $5.74/cwt (Williams et al., 2012). Export markets requiring source and age verification, demand for non-hormone treated cattle, and naturally raised cattle all present profit opportunities for cow-calf producers (Zimmerman et al., 2012). These market opportunities only exist for calves who are enrolled in verified programs with strict parameters for weaning, preconditioning, and health care practices. Many value-added certifications bundle certain management practices and better information is needed to study the value of these individual impacts on calf prices (Zimmerman et al., 2012). Part of this shift in the market towards rewarding cow-calf producers for calves enrolled in value-added verification programs, is due to calves no longer solely being marketed through traditional livestock auctions.

Farming operations in the United States are very diverse, with beef cattle being the most common specialization on small farms (Hoppe and Banker, 2006). As livestock are raised in increasingly complex systems, with cattle moving from the ranch of origin, to the auction

market, to a backgrounding operation, and then to a feedlot oftentimes, communicating how those animals were raised throughout those different locations and time periods becomes an increasingly difficult task (Olynk, 2012). Labeling schemes to relay information to consumers are only as valuable as the verification systems employed to ensure consumer trust and substantiate value (Olynk, 2012). Finding the biological optimal for each animal that maximizes yield, while ensuring the welfare needs of the animal are being met is necessary for producers and consumers to come to a consensus in the marketplace (Olynk, 2012).

Benchmarking cow-calf producer perspectives on management strategies and industry challenges can provide insight into how producers are altering their production systems to meet consumer demands, while still remaining profitable. On-farm cow-calf production practices are as a whole, privately-held information that is difficult to observe and verify by the rest of the beef industry (Williams et al., 2012). Several studies have begun investigations into cow-calf producer perspectives on management and marketing. Simon and colleagues benchmarked health and handling practices, along with producer perspectives on 30 California ranches, and created an assessment designed around those findings (Simon et al., 2016a). The Iowa Beef Center surveyed Iowa cow-calf producers by region in 2014 to gain insight into their current operation, future plans, and greatest obstacles (Schulz, 2014). In 2017, the United States Department of Agriculture's National Animal Health Monitoring System (NAHMS) surveyed cow-calf producers nationwide on health, management, and identification practices (APHIS, 2016).

Ensuring that high animal welfare standards are met begins at the ranch and continues up until the time that animal is slaughtered. Captive bolt stunning is the primary method used in US commercial beef processing plants to render cattle unconscious prior to slaughter (Daly et al., 1987; Algers and Atkinson, 2007; Oliveira et al., 2017). The purpose of captive bolt stunning is

to cause a deep and irreversible form of concussion (Gregory et al., 2007). Captive bolt stunning when performed properly, ensures that the animal is unconscious during exsanguination and subsequent dressing procedures until the heart beat ceases and death occurs (Gregory et al., 2007; Atkinson et al., 2013). Penetrating pneumatic captive bolt stunning causes trauma to the skull, brain, and associated blood vessels that results in hemorrhaging (Atkinson et al., 2013), and a phase of tonic convulsion, followed by clonic convulsion (Oliveira et al., 2017). Tonic convulsion is a rigid extension or contraction of the legs (Oliveira et al., 2017). The tonic phase transitions into a stage of clonic convulsion, which is often characterized by uncoordinated hind limb and forelimb movements (Gregory and Shaw, 2000). These movements can continue up until three minutes after the start of exsanguination (Terlouw et al., 2015). The circuits that generate reciprocal leg movements for walking are located in the spinal cord which communicates with the brainstem (Grillner, 2011). When this line of communication is disrupted by stunning, the walking circuit becomes overactive which causes involuntary leg activity patterns (Grandin, 2013).Variation in the physical expression of clonic convulsion exists depending on stun placement, stun depth, and at what velocity and kinetic energy the penetrating captive bolt meets the skull (Atkinson et al., 2013).

There is an industry perception that Holstein cattle exhibit more post-stun limb movement compared to *Bos taurus* beef breeds. Whether or not this is an accurate perception, and the influence of maturity and sex warrants further research. Post-stun leg activity poses a potential safety risk for employees in some slaughter facilities during exsanguination and subsequent processing steps (Grandin, 2002). Uncoordinated limb movements while the animal is being exsanguinated create a potentially unsafe environment for employees working near the stunned animals. In large U.S. slaughter plants, employees in these positions wear extensive

protective equipment to help protect them from these unpredictable leg movements. Finding a method to reduce post-stun leg activity would be beneficial to worker safety. Some abattoirs routinely administer a second captive bolt stun immediately following the first, referred to as a "security knock", which is anecdotally thought to possibly reduce post-stun leg activity by causing additional damage to the brain and more hemorrhaging. Although a security knock can be applied, to remain within regulations set forth within the Humane Slaughter Act enforced by the United States Department of Agriculture (USDA) Food Safety Inspection Service (FSIS USDA, 1958), the initial stun must render the animal insensible (FSIS USDA, 2013).

Another approach the beef industry has used to increase brain trauma and hemorrhaging, and potentially reduce post-stun kicking, is a longer penetrating captive bolt in the stunner. The majority of U.S. commercial beef slaughter plants use a standard-length bolt of 15.24 cm in the Jarvis pneumatic captive bolt stunner. Three different captive bolt lengths are commercially available for the Jarvis pneumatic penetrating stunner.

CHAPTER II

LITERATURE REVIEW

BEEF COW AND CALF WELFARE

Dr. Temple Grandin defines our responsibility to animals with the statement, “I think using animals for food is an ethical thing to do, but we've got to do it right. We've got to give those animals a decent life and we've got to give them a painless death. We owe the animal respect” (Grandin, 2006). Welfare can be defined as multidimensional, comprising things such as health, comfort, and the animal’s ability to express natural behaviors (Botreau et al., 2007). The World Organization for Animal Health (OIE) defines welfare as how an animal is coping with the conditions in which it lives (OIE, 2018a). The Brambell Commission’s Five Freedoms include (1) freedom from hunger and thirst, (2) freedom from physical and thermal discomfort, (3) freedom from pain, injury and disease, (4) freedom from fear and distress and (5) freedom to express normal behavior (FAWC, 1979; Rowan, 1993). Another welfare framework, designed by Fraser includes the four guiding principles of maintaining basic health, reducing pain and distress, accommodating natural behaviors and affective states, and accounting for natural elements in the environment (Fraser, 2008). Welfare ultimately relates to an animal’s ability to cope with its external environment, other animals, and its internal environment (Phillips, 2008). The OIE has developed guiding principles for animal welfare that identify the critical relationship between animal health and animal welfare and state that improvements to welfare can often improve productivity and lead to economic benefits (OIE, 2018b). The OIE outlines

principles to consider in livestock production systems that include genetic selection that takes into account health and welfare, animals must be able to adapt to the new environments they are introduced to, pain should be managed during painful procedures, handling of animals should foster a positive relationship between animals and humans, and owners and handlers should have sufficient skill and knowledge to treat animals according to these principles (OIE, 2018b). The criteria to assess welfare should be exhaustive in nature, have the minimal number of requirements necessary, and be agreed upon by stakeholders (Botreau et al., 2007). Ideally an assessment would take into account cattle's genetic predisposition, their recent experiences, their environment, and anticipation of any future events such as feeding (Phillips, 2008). By developing ways to quantify welfare effectively, an animal's quality of life can be objectively assessed from the time of birth up until when death occurs.

COW-CALF WELFARE ASSESSMENT

Livestock producers are facing increased pressure through market movements to reconsider or alter how livestock are raised. Consumer concern surrounding animal handling, livestock housing, and welfare is influencing purchasing decisions (Olynk, 2012).The United States beef industry has responded to this movement through the implementation of welfare assessment programs at beef processing plants and feedlots (American Meat Institute Animal Welfare Committee, 2010; National Cattlemens Beef Association, 2017). Through Beef Quality Assurance training, the Beef Checkoff is educating the cow/calf producer sector of the beef industry about proper animal handling and welfare (Beef Checkoff, 2017a). A welfare assessment program does not exist for the cow/calf sector of the beef industry in the United

States. Traceability becomes more challenging, operation facilities are more diverse in nature, and management styles vary greatly within the cow/calf sector (Simon et al., 2016a). All of these factors make a cow/calf assessment program more challenging to develop than the standardized assessments currently used for feedyards and processing facilities.

Further investigation into current management practices, cow/calf welfare issues, and marketing strategies is needed to create a program that increases consumer confidence and provides value to the cow/calf producer. Several studies have begun these investigations. (Simon et al., 2016a) benchmarked health and handling practices, along with producer perspectives on 30 California ranches, and created an assessment designed around those findings. The Iowa Beef Center surveyed Iowa cow/calf producers by region in 2014 to gain insight into their current operation, future plans, and greatest obstacles (Schulz, 2014). In 2017, the United States Department of Agriculture's National Animal Health Monitoring System (NAHMS) surveyed cow/calf producers nationwide on health, management, and identification practices (APHIS, 2016).

MANAGEMENT PRACTICES

Handling. With the invention of mechanized restraint devices known as squeeze chutes, animal welfare has improved and labor requirements have been reduced (Grandin, 2014). The lariat is more skill dependent and a high skill level must be employed in order to maintain an acceptable level of welfare. Hydraulically activated squeeze chutes are becoming more popular, and when pressure is properly adjusted, are safer for both people and cattle (Grandin, 2014). Hydraulic chutes are quieter when set properly, due to the absence of a loud, banging head gate

and safer because the long, protruding lever arms of the manual squeeze chute are eliminated. Bruises directly attributable to the squeeze chute occur in 2-4% of cattle from rough handling and carelessness (Grandin, 2014). Hydraulic chutes can lead to increased vocalizations, most likely as a result of more pressure being applied to the animal (Simon et al., 2016b). This is a problem that feedlot managers have corrected for, as (Woiwode et al., 2016) found much lower vocalization scores in feedlots using hydraulic chutes than (Simon et al., 2016b) found on ranches. Cattle exit speed from the squeeze chute is a good way to evaluate cattle handling. Cattle who ran out at a high speed grew more slowly (Hoppe et al., 2010).

Simple corral modifications such as blocking the animal's ability to see workers inside their flight zone and eliminating shadows, along with workers remaining calm, and eliminating electric prod use reduces stress in cattle (Lima, 2016). Beef Quality Assurance trained stockpersons led to improved cow cleanliness and less mis-catching in the restraint device (Simon et al., 2016b). Certain principles apply to extensively raised animals that interact with humans less and spend more time on large expanses of land, when handling such as the flight zone and point of balance. Workers should operate on the edge of the animal's flight zone, which is their personal space. The flight zone can vary from 0 to 50 m from a person, and when a person steps into the flight zone, the animal will move away (Grandin, 2015). Three things determine the size of the flight zone; the amount of contact with people, the quality of contact with people (calm versus shouting), and the animal's genetics (Grandin, 2015). The point of balance exists at an animal's shoulder. When a person quickly walks past the point of balance, animals will move in the opposite direction. Proper utilization of the point of balance can speed up herd movement. When groups of cattle are moved with the handler being some distance

away, the point of balance moves forward from the shoulder to just behind the eye (Grandin, 2015).

Health Issues. Murray et al., (2016) conducted a survey investigating herd-level morbidity and calf mortality prior to weaning and found it to be dependent upon calving time and colostrum management, and resulting from pre-weaning calf diarrhea, Bovine Respiratory Disease, and stillbirths. Mortality from 1 to 7 days old was 1.1% and mortality from 7 days to weaning was 1.4%. Colostrum management having a significant impact on mortality from day 1 to 7, and calving season having a significant impact on mortality from day 7 to weaning (Murray et al., 2016). Calves born in April had a lower mortality rate than those born in January and February (Murray et al., 2016). Management plays a large role in which health issues cow/calf operations encounter and the level of mortality as a result.

The livestock-wildlife interface also plays a role in animal health and disease threats today. Of the 86 avian, ruminant. swine, and poultry diseases reportable to the World Organization for Animal Health (OIE), 53 are found in the United States (Miller et al., 2013). 42 of those 53 diseases are associated with either wildlife transmission, maintenance, or life cycle of the pathogen (Miller et al., 2013). Six of these diseases have a wildlife reservoir that is impeding eradication in domestic animal populations, thus highlighting the need to better understand the role of livestock-wildlife interactions and how to manage them.

Cow/calf operations vary in their use of veterinary services and veterinarian-client-patient-relationships are not well established on every cow/calf operation in the United States. Use of herd-health related veterinary services has been found to increase with herd size, along with neonatal diarrhea and clostridial vaccine usage (Waldner et al., 2013). Producers with more

than 220 breeding females were more likely to seek veterinary advice in regards to treating sick calves than producers with less than 85 breeding females (Waldner et al., 2013).

Bovine Respiratory Disease accounts for over 50% of all cattle treated for sickness (Krehbiel et al., 2016). Good management practices for weaned calves such as vaccination, castration, dehorning, and adapting them to a feed bunk are collectively called preconditioning and help lower the risk of cattle encountering health problems (Krehbiel et al., 2016). Calves who encounter more stress and are sold through an auction market, spending more time in the marketing chain than calves transported directly from the ranch of origin to the feedlot, are at higher risk of developing clinical Bovine Respiratory Disease (Krehbiel et al., 2016).

Preconditioning. Preconditioning programs for feeder calves include both health and management practices that help calves transition from being weaned at the ranch to either a backgrounding or feedlot environment (Stuttgen and Halfman, 2013). Calves who have been through well-managed preconditioning programs are less likely to get sick, which results in better feedlot performance and improved carcass quality (Stuttgen and Halfman, 2013). Preconditioning also reduces morbidity and mortality of calves as they transition through the beef production system (Machen and Gill, 2016). The primary reason that calf morbidity and mortality decreases is that preconditioned calves are at less risk of acquiring bovine respiratory disease (Hilton, 2015). A lack of preconditioning calves induces a higher level of stress on the animals that are weaned and shipped to a feedlot on the same day. Ultimately calves who are preconditioned have improved health, gain, feed efficiency, and better welfare (Hilton, 2015). Preconditioning calves began in the 1960's, but it has not always been profitable for the producer to invest extra time and inputs into weaned calves. Today buyers are willing to pay more for calves if their likelihood of profitability increases (Hilton, 2015). With the advent of antibiotic-

free and natural programs, calves who are less likely to become sick hold even more value. The factors within the control of the producer that determine the level of profitability when preconditioning calves include; weight gain of calves, length of preconditioning period, and marketing strategies (Hilton, 2015).

Pain Relief. Cattle are routinely castrated and dehorned on ranches in the United States either prior to weaning or as part of a preconditioning program. Physical castration is the most common method practiced in the United States (Coetzee, 2013). Castration reduces mounting behavior and aggression, making animals safer for people to be in contact with. Dehorning also reduces the risk of injury for people, as well as other animals (Stock et al., 2013). Castration and dehorning can cause physiological and behavioral changes that are associated with pain and distress (Sutherland et al., 2013). Combining castration and dehorning procedures seems to exacerbate the calf's physiological response (Sutherland et al., 2013). There are currently no analgesic drugs specifically approved for pain relief in livestock by the United States Food and Drug Administration (Coetzee, 2013). Administering a local anesthetic alone mitigates acute distress during the process of castration but the integrated cortisol response is only modestly reduced (Coetzee, 2013). Behavioral and physiological changes caused by castration and dehorning suggest that calves are experiencing acute pain and distress for the first 30 minutes, followed by an inflammatory pain response for at least 6 to 8 hours after the procedure (Stock et al., 2013; Sutherland et al., 2013). Combining a local anesthetic with a nonsteroidal anti-inflammatory drug significantly reduces peak serum cortisol concentrations, suggesting that a multimodal approach is the most effective at pain mitigation (Coetzee, 2013).

Traceability. In 2003, when a dairy a cow from the state of Washington was diagnosed with *Bovine Spongiform Encephalopathy*, U.S. beef export markets were drastically affected in a

negative way (Bailey and Slade, 2004). This caused the U.S. beef industry to move towards a more sophisticated animal traceability system. The National Animal Identification System (NAIS) includes information regarding premises registration, animal identification and animal tracing, and is designed to help producers and animal health officials quickly respond to disease events (Schulz and Tonsor, 2010). In order to effectively trace animal movements, premises registration, and individual animal identification, cow/calf producers must voluntarily register their premises and willingly participate. Less than 35% of producers have registered their premises (Schulz and Tonsor, 2010). More private traceability programs have surfaced in recent years, driven by export markets, and have created a landscape of different traceability programs with differing claims. When cow/calf producers were surveyed in 2010, it was found that a traceability program requiring less additional information from producers was preferred, and a system that added value to the cattle they market was also a deciding factor in producers volunteering to participate in such a program (Schulz and Tonsor, 2010).

Today concerns about animal health, bio-terrorism, and foreign animal disease threats such as Foot and Mouth Disease reaching the U.S. have created an environment where international markets are motivating the development of animal identification systems (Tonsor and Schroeder, 2006). Economic incentives exist for improving animal health management and rapid disease response systems. Brazil, one of the world's largest beef exporters, implemented a bovine traceability system that requires the producer to report how the animal was bred, its principal diet, vaccination, and birth date (Schroeder and Tonsor, 2012). Producer operations are inspected every six months. A key driver in developing the system was to better control Foot and Mouth Disease (Schroeder and Tonsor, 2012). The traceability system was originally designed to require participation by all producers supplying cattle for export, with the function to certify,

individually identify, and register animals on farms as a full traceability system requiring reporting for any incoming or outcoming animals or animal deaths (Schroeder and Tonsor, 2012). Australia, another one of the world's largest beef exporters, through the National Livestock Identification System has implemented traceability (Tonsor and Schroeder, 2006). Some distinct differences exist between the Australian and U.S. cattle sector, with the U.S. having ten times the number of cow/calf producers and exporting a much smaller percentage of beef produced (Tonsor and Schroeder, 2006). The challenge of educating many more producers and achieving voluntary participation, along with less incentive due to a smaller percentage of beef being sold through the export market, has created a less progressive movement towards traceability in the U.S.

The United States Department of Agriculture's National Animal Health Monitoring System launched its fourth national study of cow/calf operations in 2017 to provide the industry with new and valuable information regarding animal health and management trends (APHIS, 2016). In 2013, The United States Department of Agriculture published a final ruling on improved traceability and livestock moving between states. Cattle must be officially identified through brands, tattoos, backtags, or eartags and accompanied with a certificate of veterinary inspection or other documentation such as owner-shipper statements or brand certificates when crossing state lines (USDA-APHIS, 2017).

Grass Management. Nutrition-related costs make up a significant portion and sometimes the majority of cash costs on a cow/calf operation and forages are often the most cost-effective way to supply cattle with the nutrients they require (Parish et al., 2016). Stocking density is the number of animals per unit of available forage and stocking rate is the number of animals per unit of land (Parish et al., 2016). Good forage management includes finding the optimum

stocking rate-depending upon pasture productivity, measuring rainfall, and understanding growing seasons, which forages are adapted to the area, and what variety of forages is ideal. Grazing systems are defined as a combination of animal, plant, soil and other environmental factors all integrated, along with the grazing methods employed to achieve a specific goal (Parish et al., 2016). If given the choice, cattle will only eat the most palatable and highest quality forages in a pasture. This creates a need for a grazing management system with the basis of controlling the number of animals and how long they are on a certain pasture (Rinehart, 2008). Rotational grazing is stocking cattle at a high density for a short period of time. This helps build soil organic matter and decreases grazing selectivity. When the proper timing, intensity of grazing, residue plant height, and duration of rest are achieved, pastures become highly productive, dense and resilient (Rinehart, 2008). Different grazing methods such as continuous stocking, rotational stocking, strip grazing, creep grazing, and limit grazing all have advantages and disadvantages. Finding the best fit grazing system for an operation is highly dependent upon region, amount of rainfall, labor availability, and cow inventory. By planning a nutritional program based around a forage system management plan, efficient and effective feeding programs can be accomplished (Parish et al., 2016).

Water Resources and Quality. Cattle water requirements are influenced by rate of gain, pregnancy, lactation, activity, diet, feed intake, and environmental temperature (Lardy et al., 2009). These water requirements are met from water sources such as wells or ponds, and moisture in feedstuffs. Cattle who drink from water sources where they may also defecate and urinate in the water, can cause the water source to have added nutrients but reduced palatability (Willms et al., 2002). Limiting water intake can depress cattle performance more quickly and significantly than any other nutrient deficiency (Lardy et al., 2009). Weather conditions greatly

affect water intake, with cold weather reducing intake. Water systems that allow water to get too hot or to freeze are not ideal; Drinkable water is between 40 and 65 degrees Fahrenheit (Lardy et al., 2009). Insulated waterers are a good solution to reducing problems with waterers freezing in colder regions of the United States.

Cows who are given free access to water produce more milk and butterfat than cows allowed to drink twice a day (Lardy et al., 2009). Cattle that have access to clean water spend more time grazing and less time resting than those drinking pond water (Willms et al., 2002). Reduced water consumption is a sign of sickness and stress. Newly arrived animals take time to adapt to new water sources. Water quality and quantity affect feed consumption and health of the animal (Lardy et al., 2009). Water troughs should be cleaned regularly as dirty water is a host for disease. Rapid disease spread between animals drinking from the same trough is possible. Water quality is determined by many different factors including salinity, nitrates, sulfates, cyanobacteria, pH and other minerals and chemicals (Lardy et al., 2009). Water testing should be a common practice to ensure that livestock are reaching optimum productivity.

MARKETING STRATEGIES

Value-Added. On-farm cow/calf production practices are as a whole, privately-held information that is difficult to observe and verify by the rest of the beef industry (Williams et al., 2012). Third-party verification can ensure that good management practices have been used and add value to calves in the marketplace. It is estimated that verification of vaccinated calves adds $1.44/cwt and the value of weaning, vaccinating, and certification can add from $2.39 to $5.74/cwt (Williams et al., 2012). Export markets requiring source and age verification, demand

for non-hormone treated cattle, and naturally raised cattle all present profit opportunities for cow/calf producers (Zimmerman et al., 2012). These market opportunities only exist for calves who are enrolled in verified programs with strict parameters for weaning, preconditioning, and health care practices. Many value-added certifications bundle certain management practices and better information is needed to study the value of these individual impacts on calf prices (Zimmerman et al., 2012).

Part of the shift in the market towards rewarding cow/calf producers for calves enrolled in value-added verification programs, is due to calves no longer solely being marketed through traditional livestock auctions. The largest auction market in the United States today is Superior Livestock Auction (SLA) (Zimmerman et al., 2012). Cattle are marketed through SLA via video auction, internet auction, or private-treaty internet listings. A SLA representative videos the cattle on the ranch and the majority of sales are cash-forward contracts sold for future delivery. SLA markets large lots of cattle, with catalog and on-screen information displayed outlining vaccination programs, source and age verification, preconditioning, natural, and hormone-free certifications. While the value of these programs is dependent upon the nature of the market and fluctuates, steers who are certified weaned are worth on average $3 to $5 more per cwt, certified health programs add an additional $3/cwt, and source and age verification is worth another $2/cwt (Zimmerman et al., 2012). The opportunity exists for cow/calf producers to profit from adopting additional management and marketing practices. Integrating a welfare assessment into this value-added marketing framework already in place has the possibility of adding additional value for cow/calf producers. Gaining a better understanding of current management practices is the first step in that process.

With the advent of beef alliances, value-added programs, branding, and quality and process assurance programs, marketing feeder calves based on verified third-party certifications has become common in the U. S. beef industry (Bulut and Lawrence, 2007). What are known as "good management practices" encompassing dehorning, castration, bunk training, and vaccinations has become defined by the term "preconditioning". The purpose of preconditioning was originally to boost the immune system of cattle arriving at feedlots (Bulut and Lawrence, 2007). Controversy over economic incentives for producers to precondition calves has long existed, accompanied by contradictory research, with the value of preconditioning changing amidst market conditions (Bulut and Lawrence, 2007). Today there seems to be general agreement that beef industry trends show potential for increased interest and value in preconditioning programs.

Handling and Welfare Guidelines. Consumers expectation for their food to be produced with respect for the welfare of the animals has resulted in private and public standards designed to assure good animal husbandry (Webster, 2009). Animal welfare is increasing in its importance to international trade, and through government-led initiatives, efforts by the World Organization for Animal Health (OIE), private welfare standards, and food retailers putting pressure on suppliers, production welfare standards are becoming more prevalent (Rushen et al., 2011). Whether or not private standards complement or conflict with legislation is an emerging issue (Rushen et al., 2011).

> Rushen et al. (2011) states that, "Successful integration of best animal care practices into the farming community begins with a set of well-researched, scientifically and ethically valid, and practical set of standards that meet the approval of producers and expectations of the public, and it ends with accurate characterization and reporting of on-farm compliance".

The challenge arises when research gives a clear answer regarding a welfare practice, but science cannot define whether or not the practice is acceptable, whether it is ethical (Rushen et al., 2011). Other hurdles when coming to a consensus on welfare standards include scientific uncertainty and how to communicate that to the public, people defining welfare differently, management-based vs. animal-based standards, and the challenges of auditing for compliance including auditor training (Rushen et al., 2011).

Transporting cattle is an unavoidable and essential element of raising cattle extensively. Transporting livestock can be divided into three categories to evaluate welfare. Handling and loading, withdrawal of feed and water, and thermal and physical conditions of the vehicle and journey (Fisher et al., 2009). Stress response during loading and unloading can be minimized by careful handling, proper facility design, appropriate driving techniques and stocking densities (Fisher et al., 2009). Many factors determine an animal's ability to cope with feed and water withdrawal including their age, physiological state, and access to feed and water prior to transport. Very cold and hot conditions during transport, and vehicles containing sharp, protruding objects, along with noise and poor ventilation can all induce stress that is avoidable (Fisher et al., 2009).

Source and Age Verified. The USDA Agricultural Marketing Service (AMS) has a set of voluntary beef export verification and certification programs that exist for producers exporting beef to countries requiring animal age and ranch-of-origin to be verified (Schroeder and Tonsor, 2012). Challenges exist within source and age verification programs. To take advantage of the added-value of exporting beef, the entire vertical supply chain from the cow/calf producer at the ranch-of-origin all the way up to the exporter, must be close to vertically aligned in order to participate in the full extent of the verification program (Schroeder and Tonsor, 2012). Beef is

exported in carcass portions, such as shoulder clods or livers, so a large number of producers must participate in a source and age verification program to have a sufficient volume of product to meet international export demands (Schroeder and Tonsor, 2012).

SELECTION

Conformation/Feed and Leg Structural Soundness. Breed associations in the United States and Australia acknowledge that structural conformation is an ongoing challenge for cow/calf producers, and it is the responsibility of seedstock producers to make selection decisions that improve structural conformation (American Angus Association; Ashwood, 2011; Bertz, 2016). Structural conformation is a moderately to highly heritable trait and includes claw set, pastern angle, shoulder structure and angle, and hip and hock structure and angles (American Angus Association; Ashwood, 2011; Bertz, 2016). Sound bulls produce steers that spend less time lame and grow faster, and sound replacement heifers stay in the herd longer (Bertz, 2016). An ongoing project to develop an Expected Progeny Difference (EPD) for a range of feet and leg conformation traits is underway, with the hope of aiding producers in selecting sires that produce sounder progeny (Bertz, 2016). The American Angus Association has developed foot scoring guidelines for pastern angle and claw set, with values ranging from 1-9 and 5 being ideal; along with clear pictures describing each value to aid producers in selecting for better feet and leg conformation (American Angus Association). Lameness can be attributed to genetics, infection, nutrition, and the environment (Ashwood, 2011). The first step in correcting lameness problems, whether the problem may be in the breeding herd or finished cattle, is genetic selection for improved feet and leg conformation when selecting sires and replacement females.

Replacement Selection. Establishing a sound breeding program that includes the prediction of animal performance in relation to economically important traits is necessary for breeding herds to be profitable (Garrick and Golden, 2009). Selection emphasis is heavily placed on production traits such as live weights due to the nature of feeder calves being marketed on a live weight basis. Less emphasis is placed upon reproduction, animal health, and energy requirements as a consequence (Garrick and Golden, 2009). Production evaluations are centered around breed associations, and have resulted in a lack of across-breed genetic evaluations that allow for crossbred bulls' performance and economic merit to be compared with that of purebred bulls (Garrick and Golden, 2009). Purebred bulls of different breeds also cannot be easily assessed for the same performance and economic parameters. Due to the nature of different genetic evaluations based upon breed, along with different marketing endpoints, an array of selection strategies and pressures are employed when deciding upon replacement heifers and bulls.

Replacement Selection: Heifer Selection. Replacement heifers reflect the future profitability and genetic improvement of the cow herd (Houghton, 2009). Heifer selection criteria should include pregnancy at 12-15 months of age, wean a calf, rebreed, and serve as a source of genetic improvement to the collective herd (Comerford, 2011). Genetic improvement can be based around selection for maternal traits, growth traits, or carcass traits, depending on the goals of the operation (Houghton, 2009). By selecting the biggest heifers at weaning, this will identify the heifers born earlier in the breeding season (Comerford, 2011). Use of genetic prediction tools to match traits that fit the specific environment heifers live in, along with selection of heifers that are not overly fat at weaning (overly fat heifers may have reduced milk

production), and selecting docile females that will produce progeny who will perform well in the feedlot setting are all standards of proper replacement female selection (Comerford, 2011).

Heifers should undergo a reproductive soundness exam that includes reproductive tract scoring, body condition scoring, pelvic measurements, body weight, frame score, and a functional soundness evaluation 35 to 45 days prior to being bred (Houghton, 2009). Longevity has relatively low heritability, thus management strategies such as a good heifer development program have greater potential for impacting cow retention in the herd (Endecott et al., 2013). Heifer development has long been recognized as a management practice with lasting impacts on herd retention rate and profitability, greatly influencing lifetime production efficiency (Endecott et al., 2013). A complete heifer development program includes genetic consultation, an estrus synchronization and heat detection program, a total AI and/or embryo transfer program, selection pressure on fertility via nutrition program and length of breeding season, and helping the producer meet their goals for genetic improvement (Houghton, 2009). Selection of replacement heifers raised on the operation should be largely based upon which females fit well into the heifer development system employed. If purchasing replacement females, what heifer development program they have been a part of along with goals for genetic improvement should be considered.

Replacement Selection: Bull Selection. Bull selection is comprised of many factors including breed, whether females will be retained, goals for growth and carcass traits, and temperament (Kirkpatrick, 2015). Bulls should be selected that complement the cow herd, are physically sound, and exhibit reproductive potential (Gadberry et al., 2016). Expected Progeny Differences (EPD) provide predictions of genetic merit for specific traits and are a valuable selection tool (Gadberry et al., 2016). Accuracy values give an indication of the reliability of

EPDs and typically increase as the bull sires more calves whose performance records are reported; heavily utilized sires via artificial insemination often achieve the highest accuracy scores (Gadberry et al., 2016). Post-weaning nutritional programs determine future effectiveness of sires, with younger bulls requiring higher protein percentages and having less dry matter intake relative to older bulls who are experiencing less rapid lean muscle growth (Gadberry et al., 2016). Bull age is another selection consideration. Yearling bulls have the advantage of lowering the generation interval and speeding up genetic improvement, but are at more risk of losing a significant amount of weight during the breeding season (Gadberry et al., 2016). Bull body condition score should be evaluated going into the breeding season and managed throughout the breeding season, with the target of a two-year-old bull weighing 75% of his expected mature weight (Gadberry et al., 2016).

CHALLENGES

Hall et al., (2003) identified beef producers' primary risk management concerns for their operations as severe drought, cattle price variability, cold weather, and disease. Challenges such as succession planning, and land availability also impact beef operations in the United States.

Producer Challenges. Livestock producers today face the challenge of effectively addressing consumer concerns while remaining competitive in the marketplace (Verbeke and Viaene, 2000). Consumer concerns extend beyond the realm of food safety and include animal well-being (Verbeke and Viaene, 2000). As a result, livestock producers are facing increased pressure to reconsider livestock production practices (Olynk, 2012). Consumer views on animal handling techniques, production practices, housing, manure management, and social impacts of

livestock production all play into consumer buying preferences (Olynk, 2012). With measures to better improve animal welfare comes an associated cost, and questions surrounding how the cost will be paid and by whom begin to surface (Olynk, 2012).

Ninety-eight percent of the farms in the United States in 2003 were family farms (Hoppe and Banker, 2006). Farms in the United States are very diverse, with beef cattle being the most common specialization on small farms (Hoppe and Banker, 2006). An aging farm population, along with the high cost associated with purchasing land and cattle to enter the livestock business present real challenges to the United States beef industry. Twenty-seven percent of farm operators are reported to be over the age of 65, and only 6% are under the age of 35 (Hoppe and Banker, 2006). Renting land is no longer considered to be a primary method for entering into the farming business, creating the necessity for start-up capital in order to purchase land (Hoppe and Banker, 2006).

As farm size increases, operators are more likely to be educated (Hoppe and Banker, 2006). The diversity of production practices on cow/calf operations becomes more understood when the range of farm size, operator age and education level, market access, and consumer demands are considered. As livestock are raised in increasingly complex systems, with cattle moving from the ranch of origin, to the auction market, to a backgrounding operation, and then to a feedlot oftentimes, communicating how those animals were raised throughout those different locations and time periods becomes an increasingly difficult task (Olynk, 2012). Labeling schemes to relay information to consumers are only as valuable as the verification systems employed to ensure consumer trust and substantiate value (Olynk, 2012). Finding the biological optimal for each animal that maximizes yield, while ensuring the welfare needs of the animal are

being met is necessary for producers and consumers to come to a consensus in the marketplace (Olynk, 2012).

Succession Planning. Farming is a largely inherited occupation with intergenerational succession also being intrafamilial (Lobley et al., 2016). Succession is the process of transferring the management of business assets, often linked with retirement whether partial or full, and the legal transfer of ownership known as inheritance (Lobley et al., 2016). The combination of farmers increasing in age and reluctance to transfer management to the successor generation has created a lack of succession planning on beef cow/calf operations. Parents desire to allow children to first make career decisions, fear of straining relationships, and the current owner's wishes to keep control of the operation and not give up decision making power have all been shown to be underlying causes of why succession planning does not occur (Kaplan et al., 2009). Failure to plan a succession can lead to the farm being inherited by multiple heirs along with the possibility of inheritance taxes and fees crippling the new owners (Kaplan et al., 2009). Succession decisions are impacted by government farm policy, and wealth, age, and education of farm operators (Mishra and El-Osta, 2008). Farm ownership, educational attainment, and marital status of the farm operator all increase the likelihood of a family succession to occur (Mishra and El-Osta, 2008). Including younger generations in decision making about the future of the farm and individuals sharing their goals for the operation can be beneficial to proper succession planning (Kaplan et al., 2009).

SLAUGHTER WELFARE

With the number of animal welfare audits increasing in slaughter plants along with greater enforcement of the Humane Slaughter Act, awareness surrounding captive bolt stunning and the need to better assess and ensure that animals are rendered insensible prior to slaughter has changed over the past twenty years (Grandin, 2002).

CAPTIVE BOLT STUNNING

Captive bolt stunning is the primary method used in US commercial beef processing plants to render cattle unconscious prior to slaughter (Daly et al., 1987; Algers and Atkinson, 2007; Oliveira et al., 2017). The purpose of captive bolt stunning is to cause a deep and irreversible form of concussion (Gregory et al., 2007). Captive bolt stunning when performed properly, ensures that the animal is unconscious during exsanguination and subsequent dressing procedures until the heart beat ceases and death occurs (Gregory et al., 2007; Atkinson et al., 2013).

POST-STUN ACTIVITY

Penetrating pneumatic captive bolt stunning causes trauma to the skull, brain, and associated blood vessels that results in hemorrhaging (Atkinson et al., 2013), and a phase of tonic convulsion, followed by clonic convulsion (Oliveira et al., 2017). Tonic convulsion is a rigid extension or contraction of the legs (Oliveira et al., 2017). The tonic phase transitions into a

stage of clonic convulsion, which is often characterized by uncoordinated hind limb and forelimb movements (Gregory and Shaw, 2000). These movements can continue up until three minutes after the start of exsanguination (Terlouw et al., 2015). The circuits that generate reciprocal leg movements for walking are located in the spinal cord which communicates with the brainstem (Grillner, 2011). When this line of communication is disrupted by stunning, the walking circuit becomes overactive which causes involuntary leg activity patterns (Grandin, 2013).Variation in the physical expression of clonic convulsion exists depending on stun placement, stun depth, and at what velocity and kinetic energy the penetrating captive bolt meets the skull (Atkinson et al., 2013).

Additionally, substantial animal-to-animal variation exists in hind limb and forelimb movements during the clonic phase of death (Bate-Smith and Bendall, 1949). These uncoordinated leg movements will be referred to as post-stun hind limb and forelimb activity. This variation exists in part due to factors influencing depth of unconsciousness (Oliveira et al., 2017) which is a result of consciousness not being an all-or-none phenomenon (Gregory and Shaw, 2000). The location of specific brain structures, along with their resistance to anoxia may explain the order in which different functions are lost (Terlouw et al., 2016). Clonic convulsions and leg movements appear in properly stunned cattle. Corneal reflex, spontaneous eye blinking, rhythmic breathing, and righting reflex are all considered signs that the animal is starting the process of returning to consciousness or has fully regained consciousness (Terlouw et al., 2016). If any of these indicators are displayed, the animal should be immediately re-stunned (Gregory and Shaw, 2000; AVMA et al., 2013; Grandin, 2017).

One industry perception of this animal-to-animal variation is that Holstein cattle exhibit more post-stun limb movement compared to *Bos taurus* beef breeds. Whether or not this is an

accurate perception, and the influence of maturity and sex warrants further research. Post-stun leg activity poses a potential safety risk for employees in some slaughter facilities during exsanguination and subsequent processing steps (Grandin, 2002). Uncoordinated limb movements while the animal is being exsanguinated create a potentially unsafe environment for employees working near the stunned animals. In large U.S. slaughter plants, employees in these positions wear extensive protective equipment to help protect them from these unpredictable leg movements.

Finding a method to reduce post-stun leg activity would be beneficial to worker safety. Some abattoirs routinely administer a second captive bolt stun immediately following the first, referred to as a "security knock", which is anecdotally thought to possibly reduce post-stun leg activity by causing additional damage to the brain and more hemorrhaging. Although a security knock can be applied, to remain within regulations set forth within the Humane Slaughter Act enforced by the United States Department of Agriculture (USDA) Food Safety Inspection Service (FSIS USDA, 1958), the initial stun must render the animal insensible (FSIS USDA, 2013).

Another approach the beef industry has used to increase brain trauma and hemorrhaging, and potentially reduce post-stun kicking, is a longer penetrating captive bolt in the stunner. The majority of U.S. commercial beef slaughter plants use a standard-length bolt of 15.24 cm in the Jarvis pneumatic captive bolt stunner. Three different captive bolt lengths are commercially available for the Jarvis pneumatic penetrating stunner.

Wagner et al. (2017) found a greater amount of brain damage caused by longer captive bolt length (Wagner et al., 2017). Sagittal and dorsal brain damage was found to be greater for cattle stunned with the medium and long length bolts compared to the control length (Wagner et

al., 2017). More brain damage with increasing bolt length could lead to more disruption of the deep parts of the brain that control movement, whether that be the basal ganglia which helps control coordination and movement (American Association of Neurological Surgeons, 2017), or the cerebellum that inhibits involuntary movement and receives proprioceptive input from the spinal cord (McCaffrey, 1997). At the core of the spinal cord motor system are interneurons that make up networks called central pattern generators which control motor output (Grillner and Jessell, 2009). The lumbar spinal cord contains neuronal elements that determine the timing and activation of hind limb muscles used for locomotion and the cervical region of the spinal cord controls forelimb locomotion (Kiehn, 2006). Synaptic interactions across these different pathways form core neural circuits which create the intersection between higher brain function and executive spinal circuits (Capelli et al., 2017). V2a neurons in the brainstem project to the ventral spinal cord and these "stop neurons" depress locomotor rhythm generation and inhibit locomotion that is of episodic nature, i.e. bursts of locomotor movement (Bouvier et al., 2015). When V2a neurons are activated in the rostral medulla they stop locomotion by inhibiting premotor networks in the spinal cord (Bouvier et al., 2015). It is speculated that when this network communication is disrupted by the effects of stunning, these neurons no longer inhibit locomotor networks in the spinal cord and post-stun leg activity occurs. It was found that when the spinal cord was completely severed immediately post-stunning that paddling movements were still prevalent (Terlouw et al., 2015), further reinforcing the idea that disrupting neural network communication between the brain stem and spinal cord perpetuates this post-stun activity. The bursts of leg activity and speed at which the unconscious animal kicks are also influenced by damage to these neural networks.

Wagner et al. (2017) found that pneumatic captive bolt stunning in a commercial slaughter plant was not causing brain stem disruption based on visual damage from the bolt tract. However, there are two types of brain injury that occur via penetrating captive bolt stunning. The first is laceration and crushing of the tissue due to penetration of the captive bolt (Finnie, 1993) or bone crush from pieces of the skull plate being forced into the brain cavity by the captive bolt; this type of trauma is what was identified in the Wagner et al. study (Wagner et al., 2017). Secondly, stretch injury can occur which ruptures blood vessels and nerve fibers at some distance from the bolt tract of damage, which when a captive bolt enters the brain cavity at a high velocity, oftentimes due to the inelasticity of the brain, this secondary damage is more altering than the localized bolt tract damage (Finnie, 1993). Even though the longest captive bolt did not visually disrupt the brain stem based on damage from the bolt tract (Wagner et al., 2017), the secondary effects from the damage could have disrupted brain stem function, as a result, altering the neural network connections discussed previously that control involuntary limb movements. Future studies examining the amount of primary bolt tract damage and secondary blood vessel and nerve fiber damage in relation to the amount of post-stun kicking that cattle exhibit would be beneficial.

REFLEXES

Forelimb kicking could potentially have a relationship with the sticking process. It has been observed that in reaction to the skin being cut and the animal exsanguinated, some animals will show a nociceptive withdrawal reflex (Terlouw et al., 2015). This occurs due to a reflex arc from the stimulus of the stick causing receptors to be excited. By exciting an afferent nerve, one or more interneurons in the central nervous system, and an efferent neuron this reflex arc can occur through communication with only the spinal cord and not the brain (Brittanica, 2018). Reflexes are actions that do not involve consciousness and are automatic (Verhoeven et al., 2015). Another variable that could influence forelimb activity is nociception, which is how the central nervous system processes noxious stimuli such as a knife incision. The neck cut creates an area of incision that has a high density of pain receptors (Von Holleben et al., 2010). Even if the animal is rendered fully unconscious the kicking reaction could be influenced by the nociception receptors still communicating with the central nervous system.

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CHAPTER III

SURVEY OF COW CALF PRODUCER PERSPECTIVES ON MANAGEMENT STRATEGIES AND INDUSTRY CHALLENGES PART 1: HANDLING PRACTICES AND HEALTH AND INDUSTRY CHALLENGES

SUMMARY

The objective of this study was to benchmark cow-calf producer perspectives on management strategies and beef industry challenges within the cow-calf sector. A total of 1,414 responses from cow-calf producers in 44 states were collected through a survey conducted in partnership with BEEF, a producer focused magazine designed to help readers build more efficient and profitable beef operations. Survey recipients were asked 30 questions to gather demographic information, producers' current handling and health management practices, and how they prioritized industry challenges. After analyses of producer responses, it was concluded that the frequency of management methods and decisions are impacted by age, operation size, location, and BQA (Beef Quality Assurance) certification [P-values ≤ 0.009]. Percentage of respondents who were using different methods of animal identification differed by BQA certification status [P-value = 0.009]. A higher percentage of respondents not BQA certified used basic eartags and hot branding. 74.5% of respondents overall were preconditioning their calf crop. Percentage of respondents preconditioning differed by BQA certification status [P-value < 0.001]. A higher percentage of producers were preconditioning their calf crop that were BQA certified, than those who were not BQA certified. The most important beef industry challenge identified was cow-calf health and the biggest challenge to producer's own operation was identified as land

availability/price. The most important animal health issues on producers' operations were identified as Bovine Respiratory Disease, flies, Pinkeye, and reproductive health. Health challenge responses varied significantly by producer age, beef cow inventory, and region of the United States [P-values < 0.001]. By producer age, calf/neonate health was most frequently identified as the biggest challenge for respondents under the age of 30 [P-value < 0.001]. Producers age 55-70 most frequently responded that VFD/regulations were more of a challenge than any other age group.
Key Words: Beef Quality Assurance; Cattle; Value-Added Marketing

INTRODUCTION

Livestock producers are encountering increased pressure from regulations and market movements to alter how they raise animals (Olynk, 2012). Today producers face the challenge of effectively addressing consumer concerns that extend beyond the realm of food safety and include animal well-being (Verbeke and Viaene, 2000). There often comes a cost associated with measures to better improve animal welfare, and questions surrounding how the cost will be paid and by whom begin to surface (Olynk, 2012). From the cow-calf producer's perspective, the expected benefit from a production practice must outweigh the expected added cost of implementation (Ward et al., 2008).

Benchmarking cow-calf producer perspectives on management strategies and industry challenges can provide insight into how producers are altering their production systems to meet consumer demands, while still remaining profitable. On-farm cow-calf production practices are as a whole, privately-held information that is difficult to observe and verify by the rest of the beef industry (Williams et al., 2012). Several studies have begun to investigate cow-calf

producer perspectives on management and marketing. Simon et al. (2016) benchmarked health and handling practices, along with producer perspectives on 30 California ranches, and created multivariable models based on those management predictors. These models used management predictors to examine relationships with cattle health and behavior outcomes such as lameness or balking (Simon et al., 2016b). The Iowa Beef Center surveyed Iowa cow-calf producers by region in 2014 to gain insight into producers' current operations, future plans, and greatest obstacles to succession planning (Schulz, 2014). Obstacles such as labor and capital availability, salary and tax policy were included in the survey. Expansion of crop acres and animal care/handling regulations were identified as major obstacles (Schulz, 2014). In 2017, the United States Department of Agriculture's (USDA) National Animal Health Monitoring System (NAHMS) surveyed cow-calf producers nationwide on health, management, and identification practices (APHIS, 2016) to benchmark current practices. Prior to launching the survey, a needs assessment was used to determine gaps in management practices. Management issues were prioritized with cow and calf health, along with animal welfare being high ranking priorities in the needs assessment (APHIS, 2016).

The way in which cow-calf producers manage production risks through planning, preventative management practices, and measuring the outcomes of their risk management efforts ultimately impacts the well-being of their cattle and the profitability of their operation. Preventing calf hood diseases has a major impact on the economic viability of beef operations and is dependent upon nutritional management of gestating females, maternity facility design and cleanliness and calving supervision (Lorenz et al., 2011). Management practices such as preconditioning can add on average $14 per head more value to calves sold 45 days post-weaning, but returns associated with preconditioned calves in the feedlot are $40 to $60 per

head, indicating that premiums could increase as preconditioning programs become more well-documented and are third-party verified (Dhuyvetter et al., 2005). Larger producers, who rely on cattle for a greater percentage of their household income, along with younger cow-calf producers were found to be more likely to adopt management practices recommended by university extension agents (Ward et al., 2008) indicating that herd size and age does play a role in adoption of certain management practices.

The purpose of this study was to explore the decisions producers are making in regards to basic management practices that are reducing the likelihood of adverse events such as stress and disease on cow-calf operations.

MATERIALS AND METHODS

General. Survey questions regarding current management and marketing practices on United States cow-calf operations were developed by Colorado State University in partnership with Penton Research (Penton, New York, NY, USA). The survey was constructed for electronic dissemination using Qualtrics survey software (Qualtrics, Provo, Utah, USA). Methodology, data collection and analysis were performed by Colorado State University and Penton Research, the research branch of Penton (Penton, New York, NY, USA). Penton was the parent company of *BEEF*, and *BEEF* has since been acquired by Informa (Informa, London, UK). *BEEF* Magazine serves as a source for business management and production information for the U.S. beef cattle industry, with subscribers in all fifty states with varying cow inventories and management styles. *BEEF* Magazine's purpose is to help readers build more efficient and profitable cattle production businesses with a focus on quality and the preservation of natural resources (BEEF, 2018). As a

result, BEEF subscribers are likely to be cattle producers who are engaged in new industry practices and are more focused on improving their herd management than the industry as a whole. Due to this survey being distributed via email, cow calf producers who only receive *BEEF* Magazine in print were excluded from the survey distribution. This survey was examined by the Institutional Review Board (IRB) at Colorado State University and deemed exempt from full IRB review (CSU IRB #122-18H).

On July 26, 2017, Penton Research emailed invitations to participate in an online survey to 41,191 *BEEF* subscribers who within the *BEEF* database had previously reported having any beef cows in inventory. By August 14, 2017 Penton Research received 1,414 completed surveys and the survey was closed to respondents on that date. To encourage prompt response and increase the response rate overall, the following marketing research techniques were used: a live link was included in the e-mail invitation to route respondents directly to the online survey, reminder emails were sent to non-respondents on August 1, 2017, and the invitations and survey were branded with the property name and logo of *BEEF* in an effort to capitalize on subscriber brand affinity.

The survey response rate was 3.43%. The survey consisted of 30 questions divided into sections which included: respondent demographic information, handling, management, marketing, selection practices, and challenges. Respondents could opt out of answering any of the questions, and the option to provide an answer labeled as "other" was included where applicable if respondents did not identify with any of the responses listed. Respondents could cease filling out the survey at any time, but only completed surveys were included in the analyses. The survey questions regarding respondent demographic information, handling and management practices, and challenges are outlined here (Table 3.1).

The first section of the survey collected demographic information including beef cow inventory, what state the respondent's cows predominantly occupy, what role the respondent fills on the cattle operation, if the respondent would describe his/her operation as seedstock, commercial, or both, respondent age, and whether or not the respondent had achieved Beef Quality Assurance (BQA) certification. Handling questions included squeeze chute type and the primary method of herding cattle. Management questions included the most important health issue facing the respondent's operation, does the respondent's calf crop receive vaccinations, is castration performed while under his/her ownership, do respondents wean and vaccinate (precondition) their calf crop 45 to 60 days prior to them leaving the operation, and the main method of animal identification. Industry challenge questions included what respondents saw as the top five industry challenges, whether or not they had a succession plan in place, their level of concern with succession planning, and how they would rate a list of challenges to the success of their operation (Table 3.1).

Analysis. Data were entered into a spreadsheet (Microsoft Excel, 2017, Microsoft Corporation, Redmond, WA) and results from partially completed surveys were removed from that specific question analysis. Data describing respondent demographic information, handling and management practices, and challenges were generated using means and frequency tables. Data were analyzed as the number of respondents within each category and as the percentage of the total number of survey respondents (N = 1,414). Comparisons were performed using contingency tables with significance tested by chi-square analysis using R software (R Core Team, Vienna, Austria). Statistical significance was designated *a priori* as p-values less than or equal to 0.05.

RESULTS AND DISSCUSSION

Demographics. Respondents with cows in 44 states responded to the survey. Respondents' cow herds predominantly occupied the Midwest region, followed by the Southeast and Southwest, the West, and finally the Northeast (Figure 3.1), with regions defined using the O'Connor 2012 U.S. regions map (O'Connor, 2012). The percentage of respondents from each region was consist with the overall *BEEF* Magazine readership. The overall readership consists of 58.2% of readers in the Midwest, 13.2% in the Southeast, 13.1% in the West, 12.1% in the Southwest, and 1.8% in the Northeast. Respondents' cow herds predominantly occupied the states of Texas, Missouri, Nebraska, Iowa, Oklahoma, Kansas and California (136; 9.6%, 100;7.1%, 96;6.8%, 78;5.5%, 71;5.0%, 64;4.5% and 51;3.6%, respectively). As of January 1, 2017 the top states that raised cattle and calves were Texas, Nebraska, Kansas, California, Oklahoma and Missouri (Livestock Marketing Information Center, 2017). Relative to a national study performed in 2016 by the USDA National Animal Health Monitoring Service, the Midwest region had a higher representation of respondents and the Northeast region had a lower representation of respondents in this study (USDA-APHIS-NAHMS, 2016).

Survey respondents predominantly had 51 to 200 head of beef cows (604), followed by 50 head or less (479), 201 to 500 head (232), 501 to 1,000 head (64), and finally more than 1,000 head (36) (Table 3.2). The average beef cow herd in the United States is 40 head, but operations with 100 head or more beef cow inventories make up 51% of the overall U.S. beef cow inventory (USDA-ERS, 2018). A higher percentage of respondents with 50 head or less were from the Northeast region (29) relative to other regions, and a higher percentage of respondents with 201 head up to more than 1,000 head were from the West (105). The majority of survey respondents

were age 55-70 (749), followed by 30-54 (351), then over 70 (272), and the smallest age group of respondents was under 30 (37) (Figure 3.2). In the 2012 Ag Census, 16% of beef cattle operation respondents were under age 45, 49% were 45-64 years of age, and 35% were 65 years and older (USDA-NASS, 2012). The current study age demographic results are similar in that a high percentage of cow-calf respondents are over the age of 45, and a much higher proportion of respondents are over the age of 70 relative to under 30.

39.8% (552) of respondents self-identified as Beef Quality Assurance (BQA) certified. As age decreased, the percentage of respondents that indicated that they were BQA certified increased; 45.9% of respondents under 30 claimed to be certified (17), and only 36% of respondents over 70 answered that they were certified (98). The survey question simply asked respondents to self-identify if they were BQA certified; researchers were not able to verify the certification of respondents. Therefore, it is not known if respondents self-identifying as BQA certified were currently certified or had received BQA training at some point but their certification had expired. The purpose of the BQA program is to demonstrate the beef industry's commitment to food safety and quality, enhance profitability through better management, and uphold consumer confidence in valuable beef products (Beef Checkoff, 2017b). BQA certification is a measurable way to identify producer willingness to make learning about good management practices a priority. Whether or not BQA certified producers more frequently make different management decisions than producers who are not certified was investigated in this study.

Handling. When asked what type of squeeze chute respondents used, 75.2% of respondents used a manual chute (1,062), 9.5% used a hydraulic chute (134), and 7.9% did not use a squeeze chute (112). Woiwode et al. (2016) found that in 28 western feedyards 50% were

using generic scissor type squeeze chutes and 50% were using Silencer hydraulic chutes (Woiwode et al., 2016). A lower percentage of cow-calf operations seem to be utilizing hydraulic chutes, likely due to cost and smaller animal numbers being regularly processed through the working facility. With land availability and price being identified by respondents as the biggest challenge to their operation, the need for portable systems that allow respondents to move handling facilities from site to site, and still have a good option for handling cattle on rented land without making permanent improvements is evident. 41.4% of respondents are primarily herding cattle with an ATV (All-Terrain Vehicle) or four-wheeler (583), 32.7% are herding on foot (461), 16.6% on horseback (234), 7.2% via pickup truck (101), and 2.1% are primarily using dogs (30). The advancing average age of beef producers may be partially attributable to why such a high percentage of respondents are using an ATV or four-wheeler (Hoppe and Banker, 2006) as they allow for less physical exertion than walking and are easier to get in and out of than some other vehicles. The high percentage of ATV and four-wheeler use and low percentage of horseback use may be attributable to 42.9% of respondents having cows located in the Midwest (607) and only 16.1% of respondents having cows located in the West (228). Horseback being a more prevalently used herding method in the West.

Management. Respondents' main method of identification was basic ear tag (967;69.3%), followed by hot iron branding (314;22.5%), tattoo (42;3.0%), electronic ear tag (40;2.9%), and freeze branding (32;2.3%). The percentage of respondents using the various methods of animal identification differed by BQA certification status [*P*-value = 0.009] (Table 3.3). Respondents not BQA certified more frequently indicated that their primary methods of identification were basic eartags and hot iron branding (Table 3.3). BQA certified producers seem to be using more technologically advanced identification methods such as electronic

eartags that can be used for traceability purposes. When choosing a type of animal identification, producers likely consider the stress of restraint, how often the animal is handled, cattle temperament, how quickly and effectively the means of identification can be applied, and what other procedures take place concurrently which all impact the stress response of the calf and how soon that response diminishes (Lay Jr et al., 1992; Grandin, 2014). Whether or not respondent's cows occupied states with brand inspection requirements likely also impacted which identification methods they chose to utilize. Respondents who were BQA certified had received some education about restraint and good handling, which may have bene influencing what methods of identification they chose.

Per survey results, 74.5% of respondents are preconditioning their calf crop (1,045). In the survey, preconditioning was defined as weaning and vaccinating calves 45 to 60 days prior to them leaving the cow-calf operation. Percentage of respondents preconditioning their calf crop differed by BQA certification status [P-value < 0.001]. Respondents who were BQA certified more frequently preconditioned their calf crop (449;81.49%) as compared with those who were not BQA certified (582;70.4%). However, regardless of BQA certification status, the number of respondents preconditioning their calves was high. In the past, premiums have existed for preconditioning but not necessarily great enough premiums to result in increased net profit for the producer (Thrift and Thrift, 2011). The high number of respondents preconditioning calves in this survey may be a sign that premiums are resulting in a net profit for producers that makes preconditioning financially justifiable, or producers are preconditioning for reasons other than profit such as long-term improved cattle health and welfare. Preconditioning programs help calves transition from being weaned at the ranch to either a backgrounding or feedlot environment (Stuttgen and Halfman, 2013). Calves who have been through well-managed

preconditioning programs are less likely to get sick, which results in better feedlot performance and improved carcass quality (Stuttgen and Halfman, 2013). Preconditioning also reduces morbidity and mortality of calves as they transition through the beef production system (Machen and Gill, 2016). The primary reason that calf morbidity and mortality decreases is that preconditioned calves are at less risk of acquiring Bovine Respiratory Disease (Hilton, 2015). Animals that are weaned and shipped within a relatively short time period, sometimes on the same day, will experience higher levels of stress. Ultimately calves who are preconditioned have improved health, gain, feed efficiency, and better welfare (Hilton, 2015). Preconditioning is a form of risk management; whether the benefit of preconditioning as a disease prevention practice is passed on to the backgrounder or the feedlot, or whether the respondent retains ownership to capitalize on that value determines who reaps the benefit of that mitigated risk. Today cattle buyers are willing to pay more for calves if their likelihood of profitability increases as a result of lowered risk (Hilton, 2015). With the advent of antibiotic-free and natural programs, calves who are less likely to become sick hold even more value because they are less likely to require treatment and have to be removed from those special programs.

Challenges. Another risk management tool that can be employed by beef producers to mitigate long-term operation risk is succession planning. When asked if succession planning was of great, minimal, or no concern to their operation 40.5 % of respondents answered it was of great concern (557), 46.2% of respondents indicated it was of minimal concern (636), and 13.3% of respondents indicated it was of no concern (183). The percentage of respondents with and without a succession plan varied by age group [P-value < 0.001]. Survey respondents under the age of 30 less frequently had a succession plan in place for their operation; 45.7% of respondents under 30 said they did not have a succession plan and that they had not planned a transition (13).

Only 12.6% of respondents over the age of 70 had not planned a transition (33). Fifty percent of the respondents over the age of 70 who did have a succession plan, indicated that their plan was to have the next generation take over (131). 13.4% of respondents over the age of 70 said yes, they had planned a transition, the cattle will be sold and the land still used for agricultural purposes (35). Overall, 43.0% of respondents planned a transition for the next generation to take over (593), with 11.3% saying no, there was no opportunity for a transition to occur (156). With land availability and price being an obstacle for young people entering the cow-calf business, succession is a solution that greatly reduces the amount of capital required to enter the business. With 11.3% of producers not having the opportunity for a transition to occur, that land will likely be purchased by an established producer or used for non-agriculture purposes, thus discouraging young people from entering the cow-calf business. Succession decisions are impacted by government farm policy, wealth, age, and education of farm operators (Mishra and El-Osta, 2008). This survey suggests that as age increases, respondent's concern with succession planning and their likelihood to have a succession plan increases. Studies have found that outside of age, farm ownership, educational attainment, and marital status of the farm operator have also been found to increase the likelihood of a family succession occurring (Mishra and El-Osta, 2008), questions that were not asked in this survey.

Hall et al. (2003) identified beef producers' primary risk management concerns for their operations as severe drought, cattle price variability, cold weather, and disease. These findings are consistent with respondents' answers in the current survey when asked what the most important health challenge on their operation was (Figure 3.3). Responses were typed into a comment box by respondents and then broken down into nineteen categories for analysis. Categories included Bovine Respiratory Disease (BRD)/Pneumonia, Flies, Pinkeye,

Reproductive, Internal Parasites, Scours/Diarrhea, Lameness/Foot Rot, Lice/External Parasites, Nutritional, Anaplasmosis, Calf/Neonate Health, Veterinary Feed Directive (VFD)/Regulations, Drought, Heat Stress, Endophyte, Clostridials, Predators, Other and None. Management challenges that increase disease risk such as drought, heat stress, flies, and nutritional shortcomings were all identified as relevant challenges, along with specific disease outbreaks such as BRD and Anaplasmosis. The percentage of respondents who identified certain health challenges differed by region [P-value < 0.001]. By region, respondents' most important health challenges surfaced as BRD being identified as a challenge more frequently in the West (42;19.18%) and less frequently identified as a problem in the Southeast (27;9.4%) and Northeast (3;7.3%) (Table 3.4). Reproductive problems were also identified as a challenge more frequently in the West (26;11.9%) and Northeast (5;12.2%) as compared with other regions. With endemic herd health challenges such as Bovine viral diarrhea virus and *Leptospira spp.* being common pathogenic organisms that cause substantial reproductive losses that include low conception rates and abortions (Grooms, 2006), it is not surprising that reproductive challenges were a big concern for respondents. Scours were identified as a challenge more frequently in the Midwest (32;5.6%) and the West (18;8.2%). Environmental factors and management practices play a big role in calf hood diarrhea (Cho and Yoon, 2014). Large temperature swings in these regions may be partial contributors to this problem, along with the need for improved management practices such as better hygiene in calving areas. Predator problems were identified as a challenge more frequently in the West (5;2.3%), this being a low percentage likely due to only 16.1% of respondents having cows located in the West. The VFD and/or other regulations were identified most often in the Midwest (17;3.0%) as significant challenges. Internal parasites were most prevalently identified in the Southeast (26;9.0%) and Southwest (26;12.4%) as

challenges. Nutritional problems were most identified as challenges in the Northeast (5;12.2%). Endophyte was a problem in the Midwest (8;1.4%) and Southeast (2;0.7%); where fescue is most prevalent. Flies were most frequently identified in the Midwest (78;13.6%) and Southeast (53;18.4%). With the timing of this survey running parallel to the warmest part of the year, the most humid regions of the U.S. reporting flies as a challenge was expected. Lameness/foot rot was most identified as a top challenge in the Northeast (3;7.3%). Pinkeye was identified in the Midwest (90;15.7%) and Southeast (51;17.7%). Lice were identified more frequently as a problem in the Southwest (20;9.5%). Many of these regional challenges identified are linked to management practices and are a result of environmental factors not being managed ideally. Most are either a result of a lack of management, such as poor hygiene or a nutritional shortcoming, or can be solved by more intensive management, such as a more aggressive vaccination protocol. Understanding the biggest health challenges in their specific region would be beneficial to producers in order to focus their efforts on better managing the risks associated with those disease challenges. Preventative practices and being prepared for inclement weather are two solutions to better managing the regional challenges identified. Hall et al. (2003) found that low stocking density and stockpiling hay were two effective risk management tools that cow-calf producers could employ (Hall et al., 2003). Through better managing inclement weather by meeting animal's nutritional needs, improved long-term health and welfare outcomes can be achieved.

The frequency by which particular challenges were indicated by respondents as important to their operations varied by herd size [P-value < 0.001]. Respondents with larger herd sizes identified BRD and scours more frequently as significant challenges. Attention to individual calf health may have become more of a challenge as herd size increased. Internal parasites, flies,

pinkeye, and lice were more frequently identified as problematic as herd size decreased. Use of herd-health related veterinary services has been found to increase with herd size (Waldner et al., 2013). So this may be attributable to smaller herd sizes being less likely to have a good relationship with a veterinarian. By respondent age, calf/neonate health was identified as the biggest challenge for respondents under the age of 30 (7;.7%). A lack of experience in younger producers or less developed husbandry skills may be contributing to this challenge. Calf health is influenced by factors such as cleanliness of the calving area and whether or not the calf receives colostrum which can be very dependent upon management. Lameness/Foot Rot (3;7.1%) and Clostridials (2;4.8%) were also identified as more prevalent problems for those under the age of 30. Respondents age 55-70 responded that VFD/regulations was more of a challenge than any other age group (17;2.4%). Younger producers likely transitioned into operating under the VFD as of January 1, 2017 more smoothly than more age advanced producers. Having a good working relationship with a veterinarian who understands the needs of the producer's herd, as well as being willing to go through the process of securing a VFD may be a change that younger producers better adapted to. Those over the age of 70 more frequently responded that they had no major health challenges on their operation (35;12.1%) relative to other age groups. These findings are consistent with the idea that as respondents get older, their likelihood to see value in herd health education and to make new decisions to further manage health risks becomes marginalized (Hall et al., 2003). Yet overall, Hall et al. found that one in two respondents expresses strong interest in additional information and education on how to better manage herd health (Hall et al., 2003). Through improved veterinary-client-patient relationships and the development of teaching materials that are relevant to younger producers, better herd health management protocols can be put into place. BQA certification seems to be having a positive

influence on implementing good management practices based on the results from this study. BQA certification is a practical education tool that is part of the solution to better equipping producers with relevant information for better managing their operations.

The most important health challenges respondents identified overall were BRD/pneumonia (202), flies (179), Pinkeye (172), and reproductive challenges (112) (Figure 3.3). These are disease challenges that the beef industry has struggled to find good solutions to for a long time. Sick animals can potentially create a need for antibiotics and a negative welfare situation that leads to consumer concern. Continuing to explore preventive ways to mitigate the risk of disease such as BRD through preconditioning and effective vaccination programs will help solve these challenges. Respondent's answers showed that more intensive management of cow-calf operations does not seem to be a priority for producers, but rather decreasing management requirements seemed to be the cause of many of the health challenges identified. With many small producers having other sources of off-farm income, this may be part of the reason that less intensive management styles seem to prevalent in smaller herd sizes. When asked to choose what they viewed as the cow-calf industry's top five challenges, respondents identified cow-calf health as the top challenge (787;57.4%), followed by reproductive health (670;48.9%), the export market (585;42.7%), pasture availability (579;42.2%), and biosecurity/disease prevention (492;35.9%) (Figure 3.5). With three of the top five challenges identified relating to herd health, that seemed to be the biggest challenge facing producers overall. Similar priorities were identified by producers in 2016 when cow and calf health were identified as top management issues, followed by animal welfare, nutritional management, and biosecurity in a USDA NAHMS study (USDA-APHIS-NAHMS, 2016). Managing herd health is an important part of risk management; when disease outbreaks occur, they can be very

detrimental to producers' bottom line with long term repercussions. A need is apparent to better educate producers about the impact of management practices on health outcomes due to many of the challenges identified being a result of lack of management. The export market was ranked third by respondents which may be linked to the desire to be more competitive with other protein exports such as pork and chicken, as well as other countries such as Australia who export a much higher percentage of the beef they produce (Tonsor and Schroeder, 2006). The lack of a widely accepted and implemented traceability system for U.S. beef is a hindrance to export market access and may be contributing to why respondent's identified export markets as a concern.

When asked to rate challenges to the success of their own operation, respondents first chose land availability/price (752;55.8%), followed by lack of market predictability (702;51.9%), and access to reliable labor (502;37.1%) (Table 3.5). More financial challenges were identified when producers were asked about their own operation instead of the beef industry in general. Land availability was identified as a personal operation challenge and pasture availability was ranked within the top five industry challenges. Access to land seemed to be at the forefront of producer's minds when identifying challenges. This challenge was identified by a high percentage of respondents likely due to there being a 42.9% of respondents having cows located in the Midwest, where pasture availability is low and land prices are high.

CONCLUSIONS AND FUTURE RESEARCH

Further studies investigating how a lack of pasture availability is influencing producer's management decisions would be beneficial. The differences in management styles between producers who have off-farm income, those who have other sources of on-farm income, and

those who solely rely on their beef cow herd as their source of income should be investigated. The need for more veterinary advice and involvement in cow-calf operations is apparent. With specific health challenges identified by region and herd size, veterinarians can be a better resource to producers by targeting specific gaps in management and health protocols that negatively impact cow-calf welfare.

Table 3.1 Survey question categories and question topics.

Survey Question Category	Survey Question Topics
Producer Demographics	• Producer age • Producer BQA certification • Seedstock or commercial producer • Role of producer on operation • Beef cow inventory • Beef cow location
Handling	• Squeeze chute type • Herding method
Management	• Preconditioning • Animal identification method
Challenges	• Most important herd health challenge • Top 5 industry challenges • Top challenges to producer's operation • Succession planning

Table 3.2 Respondents' beef cow inventory as a percentage of overall respondents (N = 1,414).

Beef Cow Inventory	**Respondent Percentage**
50 head or less	33.9%
51 to 200 head	42.7%
201 to 500 head	16.4%
501 to 1,000 head	4.5%
More than 1,000 cows	2.5%
Respondent Count[1]	**1,414**
Base = All Respondents	

[1]The number of respondents who answered the question in the survey

Table 3.3 Respondents' primary method of animal identification with responses divided by the percentage of yes/no response to Beef Quality Assurance (BQA) certification status (N = 1,396).

	Overall Method Use	**Divided by BQA Certification**	
Method of Identification		**No**	**Yes**
Basic ear tag	69.3%	61.2%	38.8%
Electronic ear tag	2.9%	38.5%	61.5%
Freeze branding	2.3%	40.6%	59.4%
Hot branding	22.5%	60.6%	39.4%
Tattoo	3.0%	55.0%	45.0%
Respondent Count[1]	**1,396**		
Base = All Respondents			

[1]The number of respondents who answered the question in the survey

Table 3.4 Percentage of respondents who identified the most important animal health issue facing their operation by region (N = 1,377).

	Region									
Health Category	**Midwest n**	**Midwest**	**Northeast n**	**Northeast**	**Southeast n**	**Southeast**	**Southwest n**	**Southwest**	**West n**	**West**
BRD/Pneumonia	96	16.72%	3	7.32%	27	9.38%	33	15.71%	42	19.18%
Repro	36	6.27%	5	12.20%	18	6.25%	8	3.81%	26	11.87%
Calf/Neonate Health	15	2.61%	0	0.00%	4	1.39%	3	1.43%	5	2.28%
Scours/Diarrhea	32	5.57%	0	0.00%	7	2.43%	7	3.33%	18	8.22%
Predators	1	0.17%	0	0.00%	2	0.69%	1	0.48%	5	2.28%
VFD/Regulations	17	2.96%	0	0.00%	3	1.04%	3	1.43%	1	0.46%
Internal Parasites	13	2.26%	3	7.32%	26	9.03%	26	12.38%	4	1.83%
Drought	6	1.05%	0	0.00%	1	0.35%	4	1.90%	3	1.37%
Nutritional	15	2.61%	5	12.20%	9	3.13%	11	5.24%	11	5.02%
Endophyte	8	1.39%	0	0.00%	2	0.69%	0	0.00%	0	0.00%
Flies	78	13.59%	4	9.76%	53	18.40%	25	11.90%	18	8.22%
Lameness/Foot Rot	23	4.01%	3	7.32%	13	4.51%	9	4.29%	14	6.39%
Heat Stress	7	1.22%	0	0.00%	5	1.74%	3	1.43%	3	1.37%
Pinkeye	90	15.68%	4	9.76%	51	17.71%	7	3.33%	20	9.13%
Lice/External Parasites	15	2.61%	2	2.44%	4	1.39%	20	9.52%	6	2.74%
Clostridials	6	1.05%	0	0.00%	2	0.69%	2	0.95%	1	0.46%
Anaplasmosis	15	2.61%	0	0.00%	9	3.13%	6	2.86%	1	0.46%
Other[1]	63	10.98%	6	14.63%	24	8.33%	32	15.24%	29	13.24%
None	38	6.62%	7	17.07%	28	9.72%	10	4.76%	12	5.48%
Total	574	100.00%	41	100.00%	288	100.00%	210	100.00%	219	100.00%

[1]Health Challenges that did not fit into a category were placed into other

Table 3.5 Percent of respondents ranking the listed challenges as the top two challenges to their operation. Respondents were asked to rank the list of challenges and table values represent the combined percentages of producer's top two choices.

Challenge	**Top Two Values % Total**	**Respondent Count[1]**
Land availability/Price	55.8%	1,348
Lack of market predictability	51.9%	1,352
Access to reliable labor	37.1%	1,353
Lack of market access/Marketing options	21.7%	1,353
Wildlife predation	16.9%	1,348
Sickness/Disease	14.5%	1,348
Stress from transport/Handling	6.8%	1,345
Base = All respondents		

[1]The number of respondents who rated that particular challenge in the survey

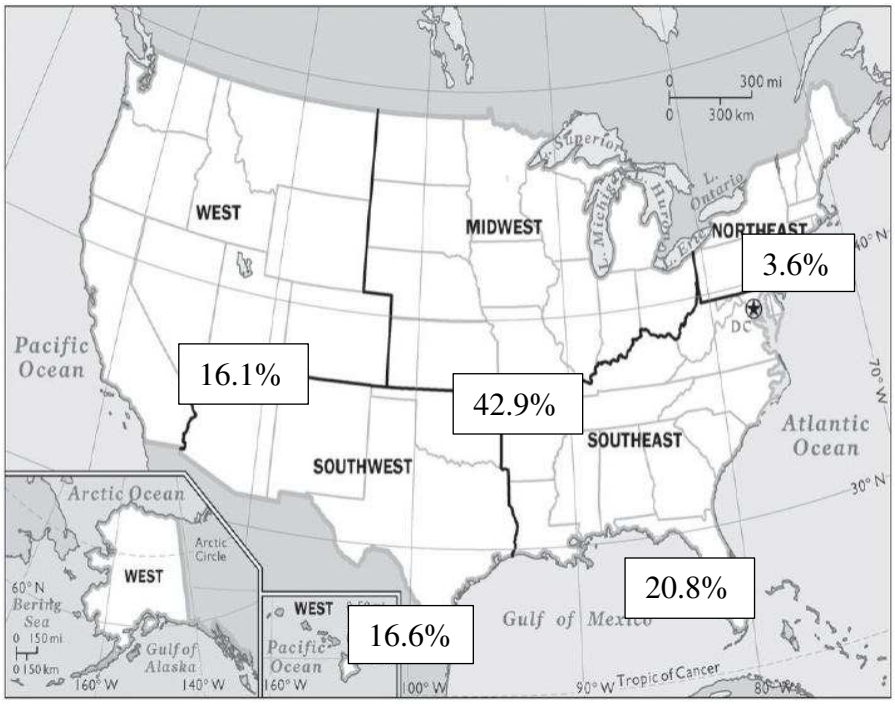

Figure 3.1 Percentage of respondents by region of the United States (N = 1,414).

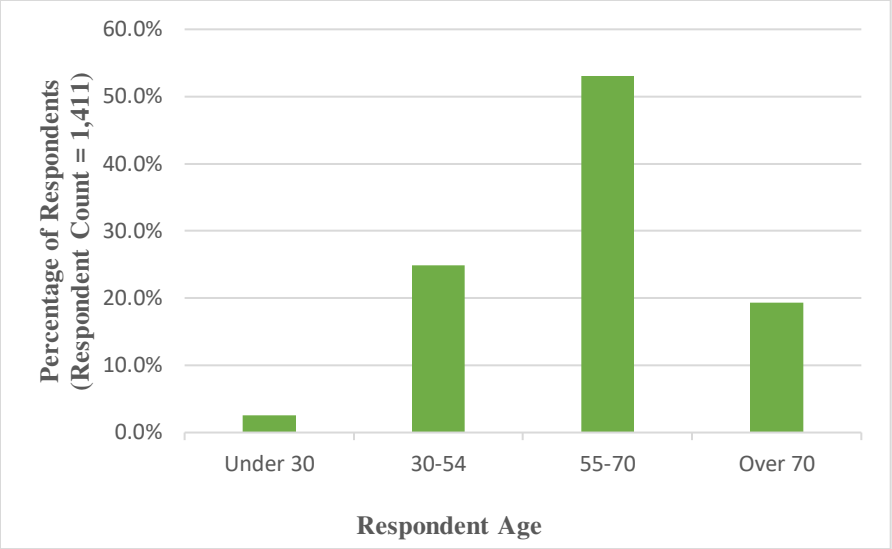

Figure 3.2 Producer age as a percentage of overall respondents (N = 1,411).

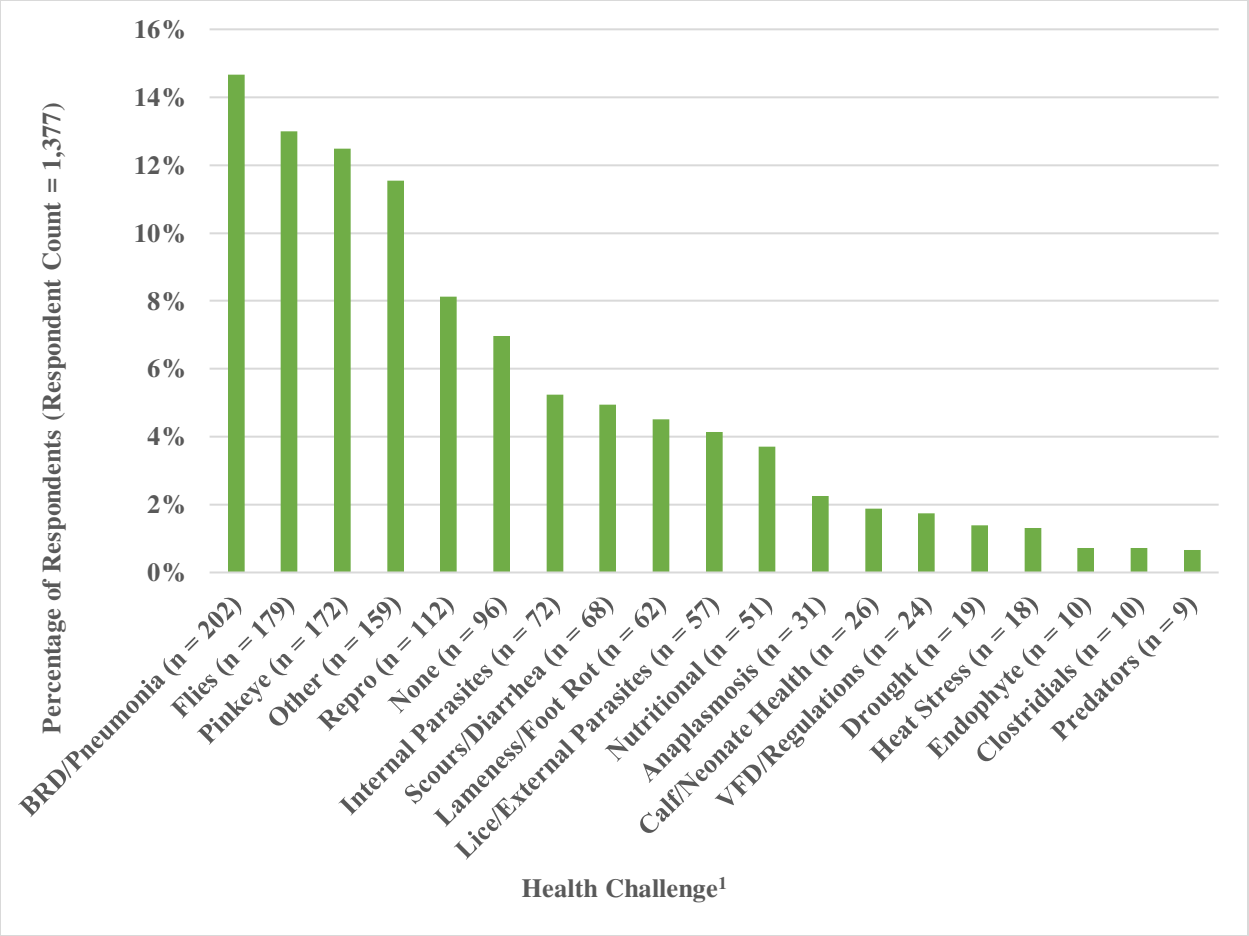

Figure 3.3 Figure 3. Percentage of respondents who identified the most important animal health issue facing their operation by health category (N = 1,377).

[1]Health Challenges that did not fit into a category were placed into other

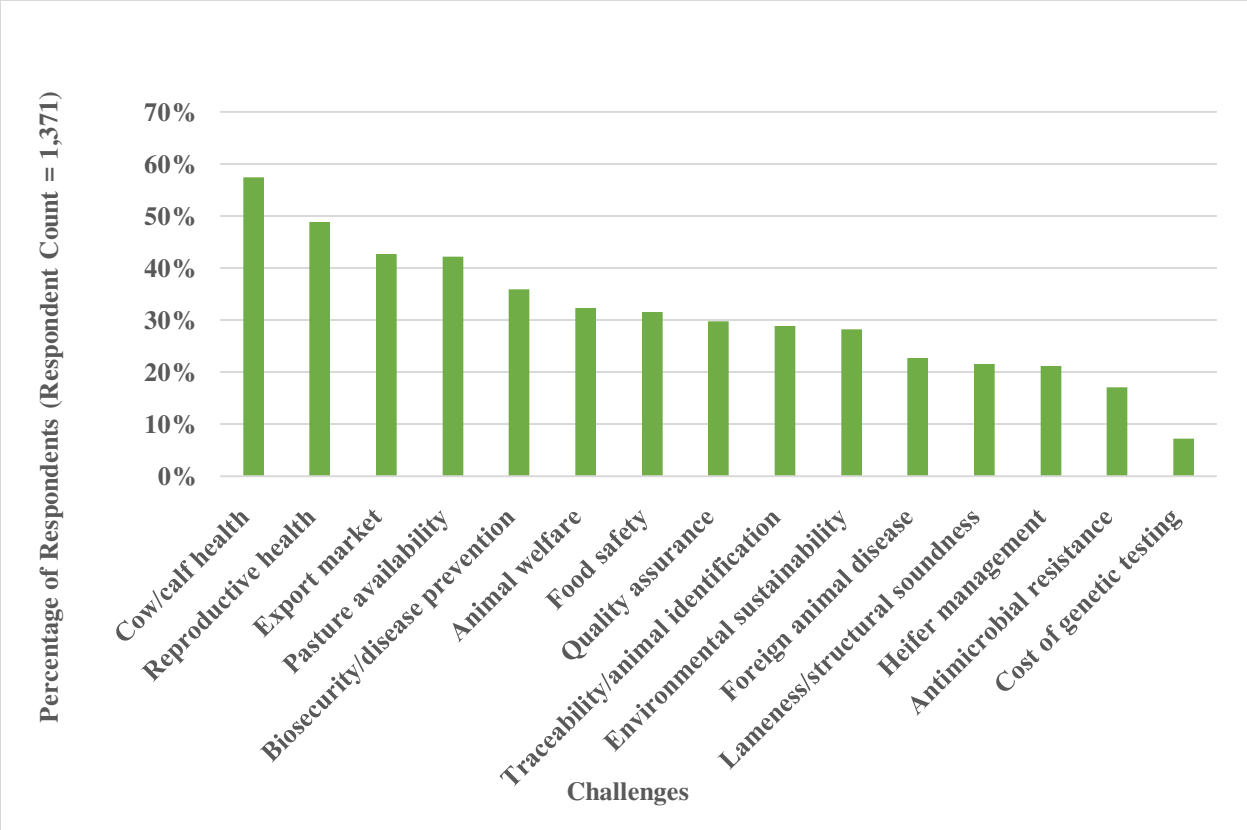

Figure 3.4 Challenges expressed as a percentage of respondents that selected what they perceive to be the cow-calf industry's top five challenges from a predetermined list (N = 1, 371).

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CHAPTER IV

SURVEY OF COW CALF PRODUCER PERSPECTIVES ON MANAGEMENT STRATEGIES AND INDUSTRY CHALLENGES PART 2: MARKETING AND SELECTION DECISIONS

SUMMARY

The objective of this study was to benchmark how cow-calf producers were marketing their calf crop, their priorities when selecting replacements, and if producers saw value in a quality assessment focusing on animal handling and care. A total of 1,414 responses from cow-calf producers in 44 states were collected through a survey done in partnership with *BEEF* Magazine. Thirty questions were asked of respondents to gather demographic information, establish at what age and through what avenue respondents were marketing their calf crop, and gauge respondent perspectives on a quality assessment outlining handling and care guidelines. The percentage of respondents who marketed their calf crop at certain ages varied by herd size [*P*-value < 0.001]. Respondents with 50 head or less or more than 1,000 head more frequently retained their calf crop through finishing and respondents with 51 to 200 head and 201 head to 500 head more frequently backgrounded and then sold their calf crop. Respondents' top priorities when selecting bulls were calving ease, followed by growth and feed efficiency traits. When selecting females, top priorities were reproductive efficiency, followed by mothering ability. The percentage of respondents using pain management differed by whether or not a veterinarian had offered to administer a drug for pain management [*P*-value < 0.001]. 13.5% of respondents answered yes, a veterinarian had offered to administer a drug for pain management when

castrating or dehorning. Of those 13.5% who responded yes pain management had been offered, 54.55% of respondents chose to use a pain relief method. A higher percentage of respondents that precondition also more frequently indicated that they used a pain relief method when castrating or dehorning, though it was still a low percentage (12.2%) [*P*-value = 0.006]. Overall, 46.3% of respondents saw value in handling and care guidelines and 54.9% of respondents saw value in a program including source and age verification, a vaccination plan, and handling and care guidelines. Respondents who were Beef Quality Assurance (BQA) certified, had a beef cow inventory of 501 to 1,000 head, who preconditioned their calves and backgrounded them before selling, and who lived in the West more frequently saw value in a quality assessment outlining handling and care guidelines [*P*- values $\leq$ 0.015].
Key words: Beef Quality Assurance; Cattle; Value-Added Marketing

INTRODUCTION

Livestock producers are facing increased pressure through regulations and market movements to reconsider or alter how livestock are raised. Consumer concern surrounding animal handling, livestock housing, and welfare is influencing meat purchasing decisions (Olynk, 2012).The United States beef industry has responded to this movement through the implementation of welfare assessment programs primarily at beef processing plants and feedlots (American Meat Institute Animal Welfare Committee, 2010; National Cattlemens Beef Association, 2017). Through Beef Quality Assurance (BQA) training, the Beef Checkoff provides educational materials to multiple sectors of the cattle industry, including the cow-calf sector, on proper animal handling and welfare (Beef Checkoff, 2017a). The BQA Cow-Calf

Assessment is an educational tool that focuses on health and production records and best management practices, along with facilities and equipment (Beef Quality Assurance, 2017). This BQA Assessment tool is valuable for benchmarking handling practices and can be used by cow-calf producers to measure improvement over time. However, a third-party verified, practical, value-added cow-calf welfare assessment program that producers are willing to implement on a large scale is not established in the U.S. Global Animal Partnership (GAP) Certification and Niman Ranch All-Natural Beef are two programs that have integrated welfare standards such as humane handling and environmental enrichment into cow-calf operations (Global Animal Partnership, 2018; Niman Ranch, 2018). However, these programs are not implemented on a large scale in the United States cow-calf industry. Traceability becomes more challenging, operation facilities are more diverse in nature, and management styles vary greatly within the cow-calf sector as compared with feedlot operations (Simon et al., 2016a). All of these factors make a cow-calf assessment program more challenging to develop than the standardized assessments currently used for feedyards and processing facilities. Further investigation into current management practices, cow-calf welfare issues, and marketing strategies is needed to create a program that increases consumer confidence in how cattle are raised throughout the supply chain while simultaneously providing value to the cow-calf producer.

It is estimated that providing verification that calves have been vaccinated at the time of sale adds $1.44/cwt and the value of weaning, vaccinating, and vaccination certification can add from $2.39 to $5.74/cwt (Williams et al., 2012). Export markets requiring source and age verification, demand for non-hormone treated cattle, and naturally raised cattle all present profit opportunities for cow-calf producers (Zimmerman et al., 2012). These market opportunities only exist for calves who are enrolled in verified programs with strict parameters for weaning,

preconditioning, and health care practices. Many value-added certifications bundle certain management practices and better information is needed to study the value of these individual impacts on calf prices (Zimmerman et al., 2012). The purpose of this survey was to quantify producer willingness to market their calf crop via non-traditional avenues and their perspective on value-added programs. It was hypothesized that demographics such as producer age, cow inventory, and location did not play a role in marketing decisions.

MATERIALS AND METHODS

General. As referenced in (Martin et al., 2018), survey questions regarding current management and marketing practices on United States cow-calf operations were developed by Colorado State University in partnership with Penton Research (Penton, New York, NY, USA). The survey was constructed for electronic dissemination using Qualtrics survey software (Qualtrics, Provo, Utah, USA). Methodology, data collection and analysis were performed by Colorado State University and Penton Research, the research arm of Penton (Penton, New York, NY, USA). Penton was the parent company of *BEEF*, and *BEEF* has since been acquired by Informa (Informa, London, UK). *BEEF* Magazine serves as a source for business management and production information for the U.S. beef cattle industry, with subscribers in all fifty states with varying cow inventories and management styles. *BEEF* Magazine's purpose is to help readers build more efficient and profitable cattle production businesses with a focus on quality and the preservation of natural resources (BEEF, 2018). As a result, BEEF subscribers are likely to be cattle producers who are engaged in new industry practices and are more focused on

improving their herd management than the industry as a whole. Due to this survey being distributed via email, cow-calf producers who only receive *BEEF* Magazine in print were excluded from the survey distribution. This survey was examined by the Institutional Review Board (IRB) at Colorado State University and deemed exempt from full IRB review (CSU IRB #122-18H).

On July 26, 2017, Penton Research emailed invitations to participate in an online survey to 41,191 *BEEF* subscribers who within the *BEEF* database had previously reported having any beef cows in inventory. By August 14, 2017 Penton Research received 1,414 completed surveys and the survey was closed to respondents on that date. To encourage prompt response and increase the response rate overall, the following marketing research techniques were used: a live link was included in the e-mail invitation to route respondents directly to the online survey, reminder emails were sent to non-respondents on August 1, 2017, and the invitations and survey were branded with the property name and logo of *BEEF* in an effort to capitalize on subscriber brand affinity.

The survey response rate was 3.43%. The survey consisted of 30 questions divided into sections which included: respondent demographic information, handling, management, marketing, and selection practices, and challenges. Respondents could opt out of answering any of the questions, and the option to provide an answer labeled as "other" was included where applicable if respondents did not identify with any of the responses listed. Respondents could cease filling out the survey at any time, but only completed surveys were included in the analyses. The survey questions regarding respondent demographic information, selection and marketing decisions will be outlined here (Table 4.1).

The first section of the survey collected demographic information including beef cow inventory, what state the respondent's cows predominantly occupy, what role the respondent fills on the cattle operation, if the respondent would describe his/her operation as seedstock, commercial, or both, respondent age, and whether or not the respondent had achieved Beef Quality Assurance (BQA) certification. Marketing questions included how respondents market their calf crop, through what avenue and if that avenue is a special sale, what that special sale is specified for. Respondents were asked if enrolling calves in a quality assessment that provides guidelines for handling and care would add value to their program, and whether or not a program including source and age verification, a vaccination plan, and a quality assessment would add value to their program. Selection questions included how respondents felt about their breeding herd's feet and leg conformation, and their top priorities when selecting bulls and replacement females (Table 4.1).

Analysis. Data were entered into a spreadsheet (Microsoft Excel, 2017, Microsoft Corporation, Redmond, WA) and results from partially completed surveys were removed from that specific analysis. Data describing producer demographic information, selection and marketing decisions were generated using means and frequency tables. Data were analyzed as the number of respondents within each category and as the percentage of the total number of survey respondents (1,414). Comparisons were performed using contingency tables with significance tested by chi-square analysis using R software (R Core Team, Vienna, Austria). Statistical significance was designated *a priori* as p-values less than or equal to 0.05.

RESULTS AND DISCUSSION

Demographics. Respondents with cows in 44 states responded to the survey. Respondents' cow herds predominantly occupied the Midwest region, followed by the Southeast and Southwest, the West, and finally the Northeast (Figure 3.1), with regions defined using the O'Connor 2012 U.S. regions map (O'Connor, 2012). Respondents' cow herds predominantly occupied the states of Texas, Missouri, Nebraska, Iowa, Oklahoma, Kansas and California (136; 9.6%, 100;7.1%, 96;6.8%, 78;5.5%, 71;5.0%, 64;4.5% and 51;3.6%, respectively). As of January 1, 2017 the top states that raised cattle and calves were Texas, Nebraska, Kansas, California, Oklahoma and Missouri (Livestock Marketing Information Center, 2017). Relative to a national study performed in 2016 by the USDA National Animal Health Monitoring Service, the Midwest region had a higher representation of respondents and the Northeast region had a lower representation of respondents in this study (USDA-APHIS-NAHMS, 2016).

Survey respondents predominantly had 51 to 200 head of beef cows (604), followed by 50 head or less (479), 201 to 500 head (232), 501 to 1,000 head (64), and finally more than 1,000 head (36) (Table 3.2). The average beef cow herd in the United States is 40 head, but operations with 100 head or more beef cow inventories make up 51% of the overall U.S. beef cow inventory (USDA-ERS, 2018). A higher percentage of respondents with 50 head or less were from the Northeast region (29) relative to other regions, and a higher percentage of respondents with 201 head up to more than 1,000 head were from the West (105). The majority of survey respondents were age 55-70 (749), followed by 30-54 (351), then over 70 (272), and the smallest age group of respondents was under 30 (37) (Figure 3.2). In the 2012 Ag Census, 16% of beef cattle operation respondents were under age 45, 49% were 45-64 years of age, and 35% were 65 years and older (USDA-NASS, 2012). The current study age demographic results are similar in that a

high percentage of cow-calf respondents are over the age of 45, and a much higher proportion of respondents are over the age of 70 relative to under 30.

39.8% (552) of respondents self-identified as Beef Quality Assurance (BQA) certified. As age decreased, the percentage of respondents that indicated that they were BQA certified increased; 45.9% of respondents under 30 claimed to be certified (17), and only 36% of respondents over 70 answered that they were certified (98). The survey question simply asked respondents to self-identify if they were BQA certified; researchers were not able to verify the certification of respondents. Therefore, it is not known if respondents self-identifying as BQA certified were currently certified or had received BQA training at some point but their certification had expired. The purpose of the BQA program is to demonstrate the beef industry's commitment to food safety and quality, enhance profitability through better management, and uphold consumer confidence in valuable beef products (Beef Checkoff, 2017b). BQA certification is a measurable way to identify producer willingness to make learning about good management practices a priority. Whether or not BQA certified producers more frequently make different management decisions than producers who are not certified was investigated in this study.

Marketing. The percentage of respondents who marketed their calf crop at certain production points varied by herd size [P-value < 0.001]. Respondents with 50 head or less or more than 1,000 head more frequently retained their calf crop through finishing than other herd sizes (142;23.7% and 14;31.8%, respectively). Respondents with small herd sizes may be using niche marketing avenues or directly selling beef products in order to retain their cattle through finishing. Respondents with more than 1,000 head also more frequently sold their calf crop at weaning (7;15.9%) and were less likely to background and then sell relative to respondents with

smaller cow inventories. Respondents with 51 to 200 head and 201 head to 500 head more frequently backgrounded and then sold their calf crop (332;40.4% and 140;41.5%, respectively). At what stage in the cattle's life cycle respondents market their calf crop depends on marketing options and the level of risk they are willing take on. Respondents with smaller calf crops have less direct and video marketing options than those with larger groups of calves due to how cattle are purchased and transported in the U.S. via a pot load weighing 19,000-23,500 kilograms which is approximately 72 yearling calves. If producers cannot offer enough calves to fill a pot load, those calves must be mingled with others and typically direct marketing and video auction buyers do not purchase lots smaller than those large enough to fill a pot load. If producers choose to retain ownership they take on more price variability risk (Hall et al., 2003) due to changing market prices and input costs, which requires producers to surpass receiving a large part of their annual income upon weaning their calf crop, and continue to pay for expenses longer into the life of their calf crop.

Overall, more respondents were backgrounding their calf crop post-weaning and then selling the calves (702;50.3%), followed by marketing at weaning (498;35.7%), with selling replacements and retaining through finishing (both 343;24.6%) being less frequent marketing strategies (Table 4.2). A study done by the National Animal Health Monitoring System (NAHMS) in 2016 indicated that more producers were selling their calves at weaning (41%) and less were retaining ownership post-weaning (21%) (USDA-APHIS-NAHMS, 2016). The NAHMS Study had a much higher percentage of producers with more than 200 cows, and less small producers which could explain why more producers were selling their calves at weaning. Risk aversion is an important factor in deciding whether cow-calf producers sell calves at weaning or retain ownership. The most risk averse producers have more than a 60% probability

of selling calves at weaning, relative to the most risk tolerant producers having less than a 20% probability of marketing their calf-crop at weaning (Pope et al., 2011). Producers who retain ownership of their cattle through the finishing process receive valuable feedback regarding yield grade and carcass quality parameters, this allows them to make production decisions that will ultimately improve carcass characteristics (Gillespie et al., 2004).

When asked through which avenues they market their calves, respondents indicated that they were predominantly marketing their calf crop through local auction markets (1,129;80.9%), followed by direct marketing (505;36.2%) and video auctions (112;8.0%) (Table 4.3). Marketing avenue varied significantly by herd size [*P*-value < 0.001]. Respondents with 50 cows or less (293;50.8%) more frequently responded that they market through normal sales at auction markets than larger herd sizes. Respondents with 201 to 500 head (65;19.3%) more frequently indicated that they market through special sales as local auction markets than other herd sizes. Respondents with 501 to 1,000 head and more than 1,000 head were more likely to direct market (28;29.8% and 17;36.2%, respectively) and market via video auction (26;27.7% and 11;23.4%, respectively) than smaller herd sizes. Direct marketing and selling via video auction are options that oftentimes result in less stress on calves from spending less time in the marketing chain, however they seem to be options that smaller producers have less access to. Of those who responded that they market their calf crop through a special sale, preconditioning was what most special sales were specified for (200;65.8%), followed by vaccination programs (131;43.1%), source and age verification (103;33.9%), breed specific sales (75;24.7%), and finally natural (38;12.5%) and hormone-free (26;8.6%) programs.

Part of the shift in the market towards rewarding cow-calf producers for calves enrolled in value-added verification programs, is due to calves no longer solely being marketed through

traditional livestock auctions. The largest auction market in the United States today is Superior Livestock Auction (SLA) (Zimmerman et al., 2012). Cattle are marketed non-traditionally through SLA via video auction, internet auction, or private-treaty internet listings. SLA markets large lots of cattle, with catalog and on-screen information displayed outlining vaccination programs, source and age verification, preconditioning, natural, and hormone-free certifications. Video auction marketing creates the opportunity for cow-calf producers to profit from adopting additional management practices. Some drawbacks to conventional livestock auctions include a limited number of bidders, added value that is not visually verifiable such as specific vaccinations are less likely to bring a premium, commission fees, transportation costs to the auction market, and significant shrink from the calves being hauled and held prior to sale at the auction market (Gillespie et al., 2004). Some of these good management practices that are not visually verifiable include developing a good veterinary-client-patient relationship, preconditioning calves, and using pain management when performing painful procedures such as castrating and dehorning.

Respondents identified in this study that cow-calf operations varied in their use of veterinary services and veterinarian-client-patient-relationships are not well established on every cow-calf operation in the United States. Use of herd-health related veterinary services has been found to increase with herd size (Waldner et al., 2013). In a study performed by Waldner et al. (2013) producers with more than 220 breeding females were more likely to seek veterinary advice in regards to treating sick calves than producers with less than 85 breeding females. Bovine Respiratory Disease (BRD) accounts for over 50% of all cattle treated for sickness (Krehbiel et al., 2016). Management practices for weaned calves such as vaccination, castration, dehorning, and adapting them to a feed bunk are collectively called preconditioning and help

lower the risk of cattle encountering health problems (Krehbiel et al., 2016). If these practices are performed before the calves leave the ranch of origin, as opposed to when the calves enter the feedlot, the calves are likely to encounter less stress while adapting to the new feedlot setting. Calves who are sold through an auction market, who spend more time in the marketing chain and are likely experiencing more stress than calves transported directly from the ranch of origin to the feedlot, are at higher risk of developing clinical BRD (Krehbiel et al., 2016).

Selection. Respondents indicated more frequently that their herd's feet and leg conformation was worsening as herd size increased [*P*-value < 0.001] (when asked if conformation was improving, worsening, or staying the same); 6.5% of respondents with more than 1,000 head thought their herd's feet and leg conformation was worsening (62); there was no time period associated with this question. Respondents with 50 head or less or 51 to 200 head more frequently indicated their herd's feet and leg conformation was not changing (267;56.5% and 319;53.2%, respectively). However, respondents with 501 to 1,000 head also frequently indicated that their herd's feet and leg conformation was improving (36;58.1%), with a much lower percentage indicating that their herd's conformation was not changing. Respondents with larger herd sizes seem to be showing clear improvement or decline in their herd's conformation, with a lower percentage indicating that feet and leg conformation is not changing. Larger producers are likely using a larger bull battery and as a result introducing more genetic variation into their herd, as opposed to a smaller scale producer who keeps the same herd bull for a longer time period, thus being more likely to see slower change in herd conformation.

Respondent perception of herd conformation varied by operation type [*P*-value < 0.001]; seedstock producers more frequently indicated that their herd's conformation was improving (70;62.5%) relative to commercial producers (394;40.7%). Likely seedstock producers are

making conformation more of a priority than commercial producers and seeing more improvement as a result. Commercial producers most frequently indicated that their herd's conformation was not changing (552;57.0%). Respondent perception of herd conformation differed by age [*P*-value = 0.006]. Respondents under the age of thirty more frequently indicated that their herd's feet and leg conformation was improving than other age groups (26;72.2%). Younger respondents may be more focused on traits such as feet and leg conformation that relate to how long animals will stay in the herd as opposed to older producers who may be less focused on long term herd improvement due to them being closer to retirement. Respondents over the age of 70 more frequently indicated that their herd's conformation was not changing (153;57.5%). Breed associations in the United States and Australia acknowledge that structural conformation is an ongoing challenge for cow-calf producers, and it is the responsibility of seedstock producers to make selection decisions that improve structural conformation (American Angus Association; Ashwood, 2011; Bertz, 2016). Structural conformation is a moderately to highly heritable trait and includes claw set, pastern angle, shoulder structure and angle, and hip and hock structure and angles (American Angus Association; Ashwood, 2011; Bertz, 2016). Sound bulls produce steers that spend less time lame and grow faster, and sound replacement heifers stay in the herd longer (Bertz, 2016). The American Angus Association began collecting feet and leg scores in 2014 and projects are ongoing to develop an Expected Progeny Difference (EPD) for a range of feet and leg conformation traits, with the hope of aiding producers in selecting sires that produce sounder progeny (Bertz, 2016; American Angus Association, 2017).

When prioritizing parameters for selecting which bulls to utilize in their herd, respondents ranked calving ease first, followed by growth and feed efficiency traits, physical appearance/phenotype, and feet and leg conformation (Figure 4.1). Selection emphasis is heavily

placed on production traits such as live weights due to feeder calves being marketed on a live weight basis. In the past, less emphasis has been placed upon reproduction, animal health, and energy requirements as a consequence of selecting for growth when making selection decisions (Garrick and Golden, 2009).When choosing priorities for selecting females, reproductive efficiency was the top priority, followed by mothering ability, calving ease, and longevity (Figure 4.2). These traits all being maternal in nature, come as no surprise when selecting females. Respondents seem to be identifying traits that lead to less intensive management such as calving ease. Carcass trait selection that could improve upon the value of their calf crop further down the supply chain seemed to be much less of a priority. Milk was also further down the list of priorities when selecting females which may be a result of producers having heavily selected for that trait in the past, and with less than ideal weather conditions and a lower plane of nutrition, the need for lower maintenance females has become evident.

Management. Cattle are routinely castrated and dehorned on ranches in the United States either prior to weaning or as part of a preconditioning program. Physical castration is the most common method practiced in the United States (Coetzee, 2013). Pain mitigation during castration and dehorning is not something that has become commonplace on U.S. cow-calf operations but could become more prevalent in the future with increasing consumer concern with animal welfare. 13.5% of respondents answered yes, a veterinarian had offered to administer a drug for pain management when castrating or dehorning (186), and 10.5% of respondents said yes, they did use a pain relief method when castrating or dehorning (147). Of those who had never had a veterinarian offer to administer pain relief, 96.4% had never used any method of pain relief (1,152). Of those who had a veterinarian offer to administer a drug for pain management during castrating or dehorning, 54.6% of respondents chose to use a pain relief method (102);

meaning that if a veterinarian offered a drug for pain management, 1 in 2 respondents chose to use pain management during castration or dehorning. There are currently no analgesic drugs specifically approved for pain relief in livestock for pain associated with castration or dehorning by the United States Food and Drug Administration (Coetzee, 2013). (Flunixin transdermal solution is approved for control of pain associated with foot rot and pyrexia associated with BRD (Merck Animal Health, 2018)). However, a veterinarian can administer a local anesthetic, or a combination of a local anesthetic and a non-steroidal anti-inflammatory drug which will also eliminate pain up to 12 hours post-castration (Stafford and Mellor, 2005), via extra-label-drug-use covered under the Animal Medicinal Drug Use Clarification Act (AMDUCA) (Smith et al., 2008).

The percentage of respondents who used a pain relief method when castrating or dehorning differed by herd size [*P*-value = 0.004]. Those with 50 head or less (65;13.8%) or more than 1,000 head (6;17.6%) most frequently indicated that they used pain management. Those with 501 to 1,000 head most frequently indicated that they did not use pain management (1;1.6%). Smaller producers may be less impacted by the additional time required during castration and dehorning to use pain management, and the largest producers may be willing to make that time sacrifice because they see production benefits to using pain management.

The percentage of respondents who use a pain relief method when castrating or dehorning differed by whether or not respondents precondition [*P*-value = 0.006]; of the respondents who precondition, 12.2% indicated that they are using pain mitigation (127). Producers who have BQA training and precondition their cattle are already making good management practices a priority. Management practices that reduce stress and add value such as pain management, vaccination programs, and preconditioning give producers who make the

extra effort, the opportunity to enroll their calves in third-party verified programs. Some practices such as castration and dehorning are visually verifiable by cattle buyers and are still the most frequently used value-added practices since they do not require third-party verification to be verified (Williams et al., 2012). However, using pain management, vaccinating and/or bunk training are attributes that are not visually verifiable by observing the cattle (Williams et al., 2012). One method of ensuring that producers can receive a premium for these attributes is through third-party verification of production practices.

Value-Added Programs. Two survey questions served to measure respondent willingness to enroll in a third-party verified program that outlined handling and care guidelines and could possibly be integrated into a source and age verification and vaccination program. Overall, 46.3% of respondents saw value in a quality assessment outlining handling and care guidelines (643) and 54.9% of respondents saw value in a program including source and age verification, a vaccination plan, and handling and care guidelines (764). The percentage of respondents who saw value in a quality assessment outlining handling and care guidelines differed by BQA certification [P-value < 0.001]. Those who are BQA certified more frequently indicated that yes, a quality assessment outlining handling and care guidelines would add value to their program (301;55.1%). Percentage of respondents who saw value in a quality assessment outlining handling and care guidelines differed by herd size [P-value = 0.006]. Those with cow inventories of 501 to 1,000 more frequently indicated yes, a quality assessment would add value (41;66.1%) and those with more than 1,000 head more frequently answered no, to whether or not a quality assessment would add value to their program (20;60.6%). Respondents with larger cattle inventories likely had more marketing options which could allow for more leverage in gleaning a premium for calves enrolled in a quality assessment. Percentage of respondents that found value

in a quality assessment varied by the age at which they sold their calf crop [*P*-value < 0.001]. Respondents who backgrounded and then sold their calf crop more frequently found value in a quality assessment (357;51.8%) than those who retained their calf crop through finishing (126;37.1%). Respondents who sell their cattle after backgrounding are more likely to profit from a value-added program such as a quality assessment than those who retain through finishing and are focused on carcass characteristic premiums. Percentage of respondents who saw value in a quality assessment differed by whether or not they precondition [*P*-value = 0.002]. Those who precondition their calf crop more frequently saw value in a quality assessment outlining handling and care guidelines (593;48.9%) than those who do not precondition (136;39.0%). Those who preconditioned are already adding value to their calf crop and would be more likely to see the value in a program that highlights those good management practices. The percentage of respondents who saw value in a quality assessment varied by region [*P*-value = 0.015]. Respondents in the West and Southeast more frequently saw value in a quality assessment (120;53.6% and 147;51.4% respectively). This may be linked to midrange and larger cow inventories in these regions giving producers more opportunities to capitalize on a quality assessment through selling larger lots of calves.

The percentage of respondents who saw value in a program including source and age verification, a vaccination plan, and a quality assessment differed by BQA certification [*P*-value < 0.001], with 63.7% of those BQA certified answering yes, such a program would add value to their marketing plan (349). Percentage of respondents who saw value in the total assessment outlined above differed by herd size [*P*-value < 0.001]. Respondents with 201 to 500 head and 501 to 1,000 head more frequently answered yes, the all-inclusive program outlined above would add value (142;62.0% and 51;81.0%, respectively). The largest producers are likely selling at a

premium due to size and enrolling their calf crop in such a program could be a large undertaking. The smallest producers would likely have difficulty finding a marketing avenue that would pay a premium for a small group of calves enrolled in such a program.

The percentage of respondents who saw value in an all-inclusive program showed a trend towards differing by producer age [*P*-value = 0.064]. As respondent age decreased, a trend towards significance showed producers more frequently saw value in an all-inclusive program, with respondents under the age of 30 finding the most value (26;70.3%). Younger producers are likely more open to trying new programs than older, more established producers. Percentage of respondents who saw value in a total assessment also differed by whether or not they precondition [*P*-value < 0.001]. Respondents who precondition their cattle more frequently saw value in such a program (606;58.7%) relative to those who do not precondition (156;44.6%). If respondents are already adding value to their calf crop through preconditioning, adding value through a total assessment would likely fit into their marketing strategy. With many different value-added programs available to enroll feeder calves in, a total assessment might make enrollment simpler for producers who are currently using multiple programs. Percentage of respondents who saw value in a total assessment also differed by region [*P*-value = 0.010]. Respondents in the West more frequently answered yes, an all-inclusive program would add value (144;64.6%), and producers in the Northeast more frequently answered no (28;54.9%). Western respondents more frequently indicated that they had larger herd sizes relative to other regions, and Northeastern respondents had proportionally smaller herd sizes than any other region. This could explain why respondents in the West saw more value in an all-inclusive assessment than respondents in the Northeast, who likely had less marketing avenues available as a result of a smaller calf crop offering and their distance from western feedyards. Respondents

with mid-level cattle inventories, who were young, and already preconditioning their cattle saw the most value in an all-inclusive type of program.

Cow-calf producers use less risk mitigation tools such as forward contracting and hedging than crop producers, which could be attributed to beef producers finding risk mitigation tools inadequate, or that producers lack the training to use the tools effectively, or the motivation to adopt them (Hall et al., 2003). This survey established that value-added marketing is a risk mitigation tool that a certain demographic of producers are open to adopting. Ensuring that this tool adequately provides value for the producers who utilize it and that producers have the training to use the tool properly is something the beef industry must continue to improve upon. A need for a value-added welfare program in the cow-calf sector exists for producers to better account for risk. Consumers' expectation for their food to be produced with respect for the welfare of the animals has resulted in private and public standards designed to assure good animal husbandry (Webster, 2009). Rushen et al. (2011) describes how to successfully develop standards for handling and care, and then implement those standards into production in the following statement:

> "Successful integration of best animal care practices into the farming community begins with a set of well-researched, scientifically and ethically valid, and practical set of standards that meet the approval of producers and expectations of the public, and it ends with accurate characterization and reporting of on-farm compliance" (Rushen et al., 2011).

CONCLUSIONS AND FURTHER RESEARCH

Further research is needed to develop a quality assessment for handling and care guidelines on cow-calf operations that is approved by producers and meets consumer expectations. BQA certification is one education tool that needs to be more widely implemented

across the U.S. with producer certification that is up to date. The combination of certified producers, verified calves who are enrolled in a program outlining handling and care, and a well-accepted traceability program has the opportunity to improve the demand for U.S. beef. Many countries such as Australia have already implemented a traceability system that gives them more access to export markets as a result (Tonsor and Schroeder, 2006). A growing beef export market provides assurance for producers that their product is valuable. Producers are willing to implement the steps needed to ensure that the U.S. will remain competitive in the global marketplace, but without the certification, verification, and traceability programs in place for producers to implement, the U.S. beef industry will not realize its potential. Producer willingness to become better educated and implement management practices such as pain management is evident, but the resources to reward producers with different herd sizes and marketing options for value-added practices needs to be further developed.

Table 4.1 Survey question categories and question topics.

Survey Question Category	Survey Question Topics
Producer Demographics	• Producer age • Producer BQA certification • Seedstock or Commercial producer • Beef cow inventory • Beef cow location
Management	• Preconditioning • Pain relief during castration/dehorning
Marketing	• What age calf crop is marketed at • What avenue calf crop is marketed through • If sold through special sale, sale specifications • Openness to quality assessment for handling and care • Openness to total assessment for source and age verification, vaccination plan, and handling and care
Selection	• Feet and leg conformation • Priorities when selecting bulls • Priorities when selection replacement females

Table 4.2 Percentage of respondents indicating at what age they market their calf crop. Respondents were permitted to select more than one answer if applicable (N = 1,396).

Marketing Age	**Respondent Percentage[2]**
Background post-weaning, then sell	50.3%
At weaning	35.7%
As replacements	24.6%
Retain through finishing	24.6%
Respondent Count[1]	**1,396**
Base = All Respondents	

[1]The number of respondents who answered the question in the survey

[2] Percents may reflect multiple answers

Table 4.3 Percentage of respondents indicating through what avenue they market their calf crop. Respondents were permitted to select more than one answer if applicable (N = 1,395).

Marketing Avenue	**Respondent Percentage[2]**
Local auction – normal sale	58.7%
Direct marketing	36.2%
Local auction – special sale	22.2%
Video auction	8.0%
Other	8.0%
Respondent Count[1]	**1,395**
Base = All respondents Percents may reflect multiple answers	

[1]The number of respondents who answered the question in the survey
[2]Percents may reflect multiple answers

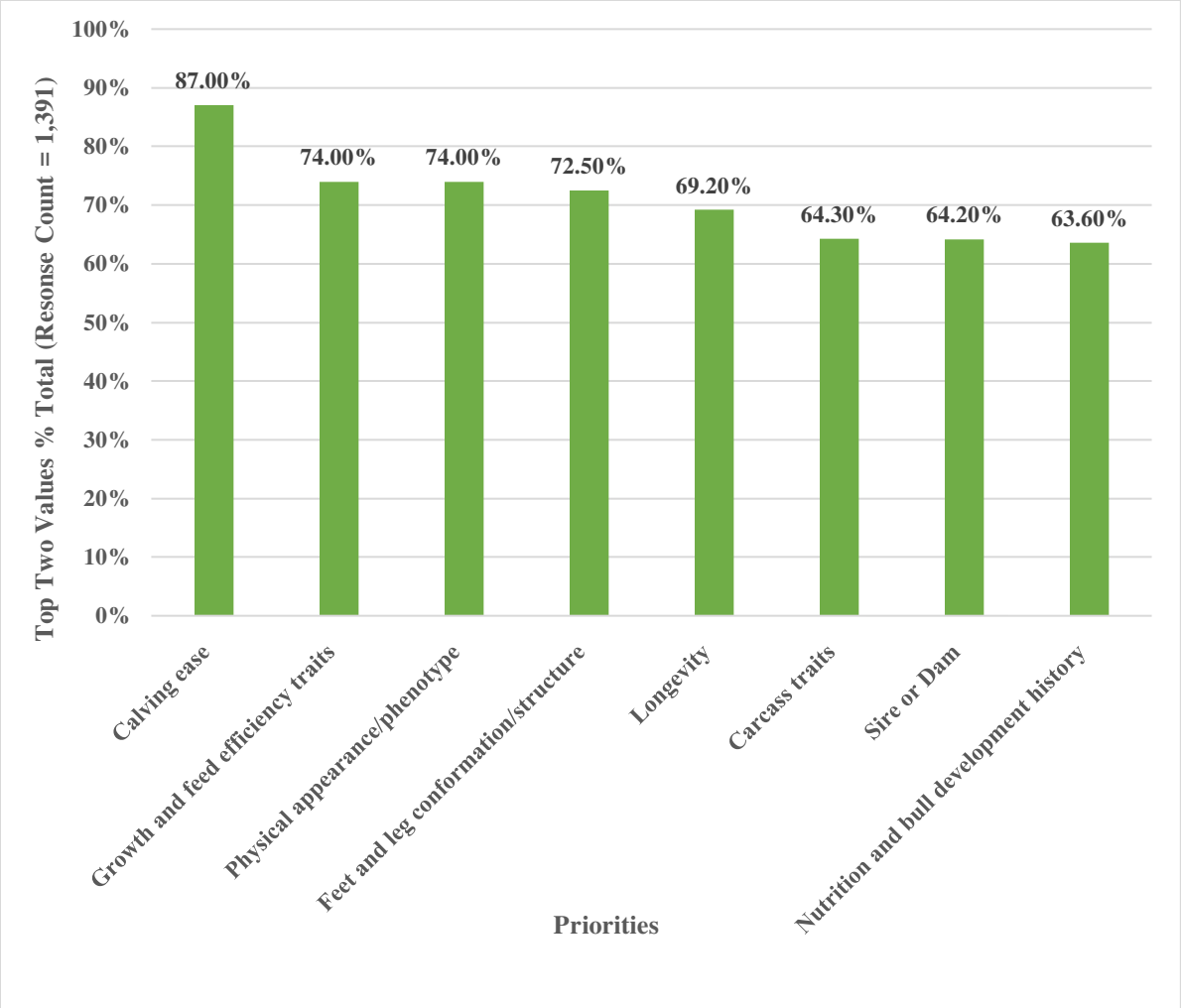

Figure 4.1 Priorities expressed as a percentage when respondents rated these priorities as very important or extremely important when selecting which bulls to utilize in their herd.

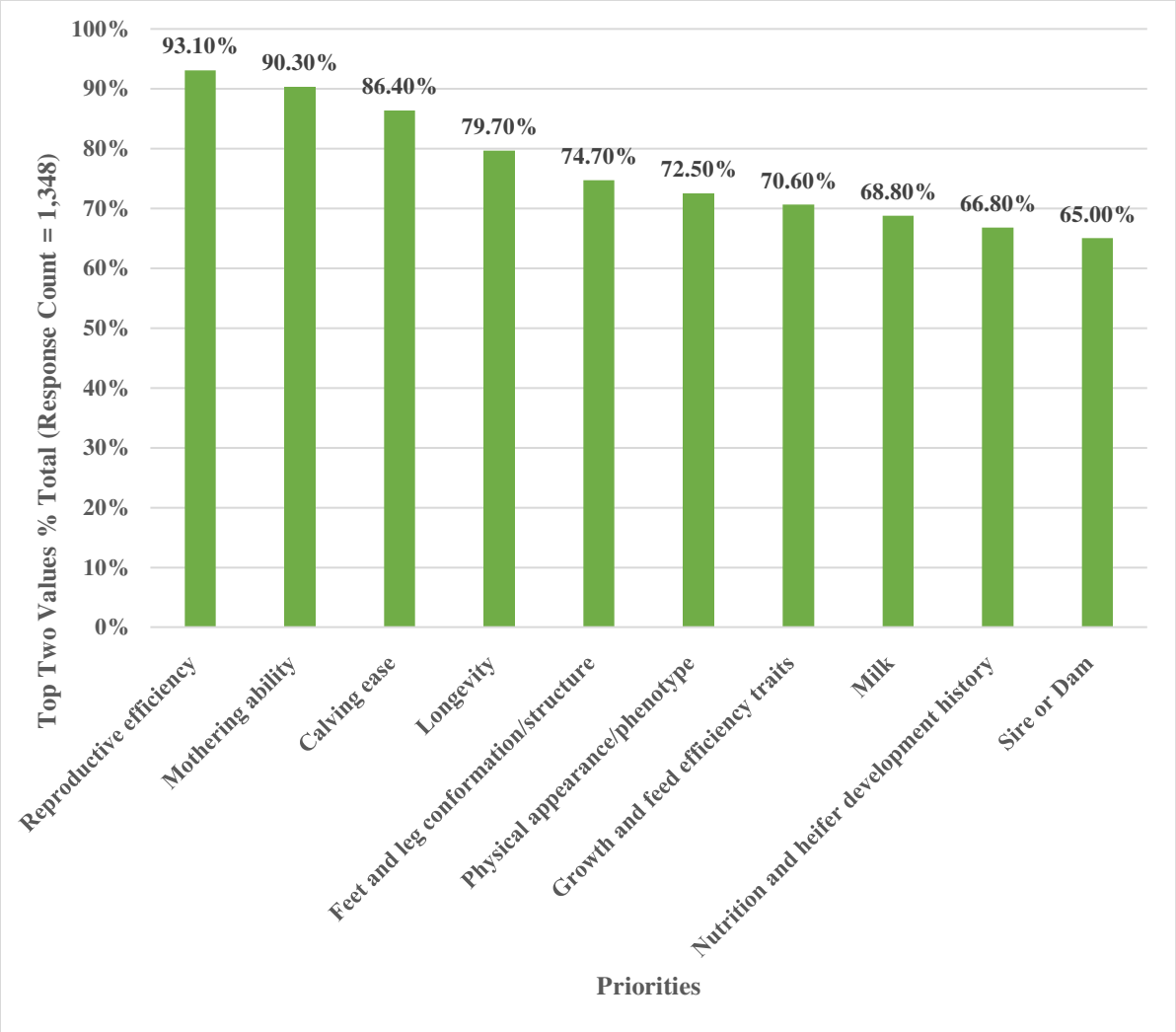

Figure 4.2 Priorities expressed as a percentage when respondents rated these priorities as very important or extremely important when selecting which replacement females to utilize in their herd.

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CHAPTER V

EVALUATION OF DIFFERENT CAPTIVE BOLT LENGTHS AND BREED INFLUENCE UPON POST-STUN HIND LIMB AND FORELIMB ACTIVITY IN FED CATTLE AT A COMMERCIAL SLAUGHTER FACILITY

SUMMARY

The objective of this study was to assess the effects of captive bolt length and breed type on post-stun leg activity in cattle. A total of 2,850 Holstein (HOL) and non-Holstein British/Continental bred (NHOL) steers and heifers were observed post-stunning at a large commercial slaughter facility. A penetrating pneumatic captive bolt stunner was used with three different bolt lengths: CON, 15.24 cm; MED, 16.51 cm; and LON, 17.78 cm. Hind limb kicking, forelimb activity, take away belt stops, carcass swing and number of knife sticks during exsanguination were recorded for each animal from video recording. Hind limb and forelimb kicks observed ranged from 0 to 25 and 0 to 8, respectively. Analysis of post-stun hind limb and forelimb activity indicated that increasing pneumatic captive bolt length does not decrease post-stun leg activity. There was a higher percentage of cattle experiencing take away belt stops and carcass swing in HOL as compared with NHOL.

Key words: captive bolt; stunning; leg activity; abattoir

INTRODUCTION

Captive bolt stunning is the primary method used in US commercial beef processing plants to render cattle unconscious prior to slaughter (Daly et al., 1987; Algers and Atkinson, 2007; Oliveira et al., 2017). The purpose of captive bolt stunning is to cause a deep and irreversible form of concussion (Gregory et al., 2007). Captive bolt stunning when performed properly, ensures that the animal is unconscious during exsanguination and subsequent dressing procedures until the heart beat ceases and death occurs (Gregory et al., 2007; Atkinson et al., 2013). Penetrating pneumatic captive bolt stunning causes trauma to the skull, brain, and associated blood vessels that results in hemorrhaging (Atkinson et al., 2013), and a phase of tonic convulsion, followed by clonic convulsion (Oliveira et al., 2017). Tonic convulsion is a rigid extension or contraction of the legs (Oliveira et al., 2017). The tonic phase transitions into a stage of clonic convulsion, which is often characterized by uncoordinated hind limb and forelimb movements (Gregory and Shaw, 2000). These movements can continue up until three minutes after the start of exsanguination (Terlouw et al., 2015). The circuits that generate reciprocal leg movements for walking are located in the spinal cord which communicates with the brainstem (Grillner, 2011). When this line of communication is disrupted by stunning, the walking circuit becomes overactive which causes involuntary leg activity patterns (Grandin, 2013).Variation in the physical expression of clonic convulsion exists depending on stun placement, stun depth, and at what velocity and kinetic energy the penetrating captive bolt meets the skull (Atkinson et al., 2013).

Additionally, substantial animal-to-animal variation exists in hind limb and forelimb movements during the clonic phase of death which are probably a reflection of differences in the

residual functionality of the nervous system post-stun (Bate-Smith and Bendall, 1949; Terlouw et al., 2015). These uncoordinated leg movements will be referred to as post-stun hind limb and forelimb activity. This variation exists in part due to factors influencing depth of unconsciousness (Oliveira et al., 2017) which is a result of consciousness not being an all-or-none phenomenon (Gregory and Shaw, 2000). The location of specific brain structures, along with their resistance to anoxia may explain the order in which different functions are lost (Terlouw et al., 2016). Clonic convulsions and leg movements appear in properly stunned cattle. Corneal reflex, spontaneous eye blinking, rhythmic breathing, and righting reflex are all considered signs that the animal is starting the process of returning to consciousness or has fully regained consciousness (Terlouw et al., 2016). If any of these indicators are displayed, the animal should be immediately re-stunned (Gregory and Shaw, 2000; AVMA et al., 2013; Grandin, 2017).

There is an industry perception that Holstein cattle exhibit more post-stun limb movement compared to *Bos taurus* beef breeds. Whether or not this is an accurate perception, and the influence of maturity and sex warrants further research. Post-stun leg activity poses a potential safety risk for employees in some slaughter facilities during exsanguination and subsequent processing steps (Grandin, 2002). Uncoordinated limb movements while the animal is being exsanguinated create a potentially unsafe environment for employees working near the stunned animals. In large U.S. slaughter plants, employees in these positions wear extensive protective equipment to help protect them from these unpredictable leg movements. Finding a method to reduce post-stun leg activity would be beneficial to worker safety. Some abattoirs routinely administer a second captive bolt stun immediately following the first, referred to as a "security knock", which is anecdotally thought to possibly reduce post-stun leg activity by

causing additional damage to the brain and more hemorrhaging. Although a security knock can be applied, to remain within regulations set forth within the Humane Slaughter Act enforced by the United States Department of Agriculture (USDA) Food Safety Inspection Service (FSIS USDA, 1958), the initial stun must render the animal insensible (FSIS USDA, 2013).

Another approach the beef industry has used to increase brain trauma and hemorrhaging, and potentially reduce post-stun kicking, is a longer penetrating captive bolt in the stunner. The majority of U.S. commercial beef slaughter plants use a standard-length bolt of 15.24 cm typically in the USSS-1 Jarvis pneumatic captive bolt stunner. Three different captive bolt lengths are commercially available for the Jarvis pneumatic penetrating stunner. The objective of this study was to evaluate if different captive bolt lengths effect the level of post-stun leg activity of cattle in a commercial slaughter plant. The purpose of the study was to evaluate the effect of both cattle breed type and bolt length on post-stun leg activity in fed cattle at a commercial slaughter facility.

MATERIALS AND METHODS

Animals, Handling, Facility, and Slaughter Process. Since all animal observations occurred post-stunning in a commercial slaughter plant, an exemption was filed and granted from the Colorado State University Institutional Animal Care and Use Committee. The study took place in the fall of 2016 in a large fed beef slaughter facility in the United States. The slaughter facility was a double shift plant operating two eight-hour shifts (A and B shift), slaughtering a total of approximately 5,000 cattle per day at approximately 360 head per hour. Cattle arrived at the abattoir directly from feedlots. They were held in lairage and quietly moved up through the lead-up alley and onto a center track conveyor restrainer. Animals were stunned with a

pneumatic penetrating captive bolt gun while on the conveyor restrainer, shackled post-stunning on the left hind limb and then released onto a take away conveyor belt. An inclined conveyor lifted up the shackled animal onto the bleed rail. All cattle included in the study were under 30 months of age, as determined by assessing dentition which was performed by plant employees. Experimental cattle were randomly selected from different sources (i.e. producers) on both A and B shifts during the three data collection days. A total of 2,850 cattle, 397 Holstein and 2,453 non-Holstein (British/Continental) cattle were sampled randomly throughout A and B shifts in groups of approximately 50 to 150 head which varied depending on lot size, plant breaks, and line speed.

Treatments and Study Design. All captive bolt stunning was performed with a Jarvis USSS-1 [Jarvis Products Corp., Middletown, Connecticut, USA] penetrating pneumatic captive bolt gun [CBG] and associated Jarvis captive bolts. The CBG was tested at the beginning of each collection period using house air pressure in the maintenance shop between 60-90 PSI following standard plant protocol to ensure proper functioning and to test bolt velocity. A Jarvis Model AST-101 [Jarvis Products Corp., Middletown, Connecticut, USA] test stand for the Jarvis Model USSS-1 pneumatic stunner was used. For all three bolt lengths, the CBG was operated at a pressure of 200-210 PSI. All CBG maintenance, cleaning, and adjustments were made in accordance with the slaughter facility's standard operating procedures and Jarvis recommendations.

Three captive bolt lengths were evaluated in the study: the control [CON] treatment was the standard length of 15.24 cm, the medium [MED] treatment was 1.27 cm longer than the CON, and the long treatment [LON] was 2.54 cm longer than the CON. Treatments were blocked by day; one bolt treatment was used per day for three days. On each day, the specified

bolt treatment was used on both A and B shift. A total of 2,850 cattle were sampled (CON, n = 399; MED, n = 1157; LON, n = 1294). Within the 2,850 cattle sample, 398 were Holstein and 2,452 were non-Holstein (British/Continental) cattle. The only determining factor for animal selection was hide, in order to capture breed differences between Holstein and Non-Holstein (British/Continental) cattle. Breed type was recorded as Holstein [HOL] or non-Holstein [NHOL]. Black and white hided steers and heifers who appeared to have dairy influence (based on head shape, muscle and bone conformation) were designated as Holstein. All other cattle were designated as non-Holstein; no *Bos indicus* influence was observed at the commercial slaughter facility on the designated collection days. Fewer Holstein cattle were sampled than non-Holstein as a result of the number slaughtered at the plant each day. The same stunner operator worked on A shift and the same stunner operator worked on B shift each day, and different shacklers rotated throughout shifts with two shacklers working at all times.

Data Collection. GoPro Hero4 (GoPro, San Mateo, CA, USA) cameras were placed in the slaughter facility to record forelimb and hind limb post-stun activity. A single camera was clamped to a steel bar that was part of the facility structure overlooking the area from the take away belt up to the bleed rail stack line. After stunning, hind limb activity was recorded from the time the carcass was freely hanging up until the carcass reached the stack line (line of stunned animals awaiting exsanguination) which was approximately 17 seconds. A single camera was clamped to a steel bar that was part of the surrounding facility structure above the area where exsanguination occurred to capture forelimb activity. Forelimb activity was recorded when the dewlap was cut open up to the thoracic method of exsanguination which was approximately 5 seconds. One employee opened the dewlap and a second employee made the thoracic incision. Battery pack extenders were utilized to increase the amount of footage that each camera could

capture. Data was recorded for approximately three-hour time periods. SanDisk (Western Digital Technologies, Inc., Milpitas, CA, USA) micro SD cards were used to store GoPro footage on the cameras, with each camera having a designated SD card. Footage was downloaded from the camera SD cards at the end of each shift onto a laptop. Camera footage was analyzed at a later date by an observer trained to score post-stun activity, who was blinded to the bolt treatments.

Post-stun Hind Limb Activity Scoring. Post-stun hind limb activity was scored by a trained observer from the camera footage collected during the study. The trained observer recorded: day number, assigned an animal identification number, breed, and number of hind limb kicks (Table 5.1). In the facility, there was a metal bar immediately prior to the start of the stack line (i.e. the row of carcasses as they approach the exsanguination area); the observer stopped counting kicks when the carcass reached this bar. The total time observed per animal prior to reaching the stack was approximately ten to twenty seconds.

Post-stun Forelimb Activity Scoring. Forelimb data recorded included: slaughter date, previously assigned animal identification number, hide color, and number of forelimb kicks (Table 5.1). Forelimb kicks during sticking were counted by the observer from the time that the incision was made to open the dewlap over the brisket, up to immediately after the animal was stuck with a knife to be exsanguinated. The time that elapsed was approximately eight to ten seconds per animal.

Additional Post-Stun Activity Assessment. Additionally, the observer recording kicks also scored take away belt stops, carcass swing, and whether or not a righting reflex was observed during hind limb kick assessment (Table 5.1). Take away belt stops and carcass swing were recorded as yes or no. Take away belt stops occurred due to the stack line being filled, cattle kicking too violently to be quickly shackled, or from the shackle being kicked off by the

animal. However, the reason that the take away belt stopped was not recorded. During forelimb kick assessment, the number of sticks, and whether or not a righting reflex was observed was also recorded.

Statistical Analysis. For all analyses, animal was the experimental unit. Count variables (hind limb and forelimb kicks) were not normally distributed and were analyzed with a Poisson regression accounting for over-dispersion in the GLIMMIX procedure of SAS Version 9.3 (Institute, 2008). The number of sticks (NO = not more than 1 stick; YES = greater than 1 stick), take away belt stops (NO = no stops; YES = belt did stop) and carcass swing (NO = no swing; YES = carcass did swing) were analyzed with a binary logistic regression using the GLIMMIX procedure in SAS (Institute, 2008). Breed type (HOL and NHOL) and treatment (CON, MED, LON) were the main effects in the model, and an interaction of breed type and treatment was also included. For all analyses, pairwise comparisons were performed using a Tukey-Kramer adjustment. Statistical significance was designated *a priori* as *P*-values less than or equal to 0.05. If the take away belt did stop, the animal likely began the clonic stage of convulsions while on the belt. Data from the 173 cattle that experienced take away belt stops were removed from the kicks analysis as the time and activity associated with the stop could have influenced the final kick count. Data from two cattle were removed from the analysis of carcass swing, take away belt stops, and sticks due to recording errors.

RESULTS AND DISCUSSION

Hind Limb Activity. Experimental cattle exhibited a range of 0 to 25 hind limb kicks during the time period assessed. A significant main effect of treatment [$P < 0.001$], breed type [*P*

< 0.001] and an interaction between treatment and breed type [$P < 0.001$] on hind limb activity was found (Table 5.2). Holstein (HOL) cattle in the LON treatment group exhibited significantly greater hind limb kicks [$P < 0.001$] than all other treatment combinations except for the cattle in the HOL MED group. HOL cattle exhibited significantly more kicks than NHOL, with 6.6 $\pm$ 0.05 kicks and 5.7 $\pm$ 0.03 kicks respectively [$P = 0.0102$].

Forelimb Activity. Experimental cattle exhibited a range of 0 to 8 forelimb kicks during the time period assessed. The main effects of captive bolt treatment [$P < 0.001$] and breed type [$P = 0.0002$] were significant; the interaction between the two factors was not significant [$P = 0.8060$] (Table 5.2). Cattle in the CON treatment group exhibited significantly fewer forelimb kicks than the MED and LON treatment groups [0.4 $\pm$ 0.04 kicks, 0.80 $\pm$ 0.09 kicks, and 0.7 $\pm$ 0.08 kicks, respectively; $P < 0.001$] (Table 2). HOL cattle exhibited fewer kicks than NHOL cattle, 0.5 $\pm$ 0.10 kicks and 0.7 $\pm$ 0.04 kicks respectively [$P = 0.0002$].

Additional Post-Stun Activity Assessment. Captive bolt treatment, breed type and the interaction of breed type did not have a significant effect on the number of sticks (1 or >1 stick; $P = 0.3189$, 0.9482, and 0.6890, respectively) (Table 5.3).

There was a significant main effect of treatment [$P < 0.0001$] and breed type [$P = 0.0009$] on carcass swing, but not a significant interaction between treatment and type [$P = 0.4101$]. The CON treatment had a higher percentage of animals with a carcass swing [16.54% $\pm$ 14.00%] than the MED [3.59% $\pm$ 23.30%] and LON [4.78% $\pm$ 19.70%] treatments [$P < 0.001$] (Table 3). HOL [9.44% $\pm$ 19.60%] had a significantly greater amount of carcass swing than NHOL [4.72% $\pm$ 10.80%] [$P = 0.0009$].

There was a significant main effect of bolt length treatment and breed type [$P < 0.001$] on take away belt stops [$P < 0.001$]; the interaction was not significant [$P = 0.9234$]. The CON

treatment had a higher percentage of take away belt stops [17.55% ± 13.78%] than the MED [6.18% ± 17.80%] and LON [6.24% ± 15.81%] treatments [$P < 0.001$] (Table 5.3). HOL [14.59% ± 15.28%] had significantly more take away belt stops than NHOL [5.29% ± 10.15%] [$P < 0.001$]. Righting reflex was observed in 1 CON treatment animal, 2 MED treatment animals, and 1 LON treatment animal.

Analysis of post-stun forelimb and hind limb activity indicated that in this study increasing pneumatic captive bolt length does not decrease post-stun leg activity. If a longer bolt length was used, cattle showed increased forelimb kicking (although all treatments indicated less than one forelimb kick per animal) and in Holsteins, increased hind limb kicking is seen with the longer bolt lengths. This could be attributable to a greater amount of brain damage caused by the longer bolts (Wagner et al., 2017). Sagittal and dorsal brain damage was found to be greater for cattle stunned with the MED and LON length bolts compared to the CON (Wagner et al., 2017). More brain damage with increasing bolt length could lead to more disruption of the deep parts of the brain that control movement, whether that be the basal ganglia which helps control coordination and movement (American Association of Neurological Surgeons, 2017), or the cerebellum that inhibits involuntary movement and receives proprioceptive input from the spinal cord (McCaffrey, 1997). At the core of the spinal cord motor system are interneurons that make up networks called central pattern generators which control motor output (Grillner and Jessell, 2009). The lumbar spinal cord contains neuronal elements that determine the timing and activation of hind limb muscles used for locomotion and the cervical region of the spinal cord controls forelimb locomotion (Kiehn, 2006). Synaptic interactions across these different pathways form core neural circuits which create the intersection between higher brain function and executive spinal circuits (Capelli et al., 2017). V2a neurons in the brainstem project to the

ventral spinal cord and these "stop neurons" depress locomotor rhythm generation and inhibit locomotion that is of episodic nature, i.e. bursts of locomotor movement (Bouvier et al., 2015). When V2a neurons are activated in the rostral medulla they stop locomotion by inhibiting premotor networks in the spinal cord (Bouvier et al., 2015). It is speculated that when this network communication is disrupted by the effects of stunning, these neurons no longer inhibit locomotor networks in the spinal cord and post-stun leg activity occurs. It was found that when the spinal cord was completely severed immediately post-stunning that paddling movements were still prevalent (Terlouw et al., 2015), further reinforcing the idea that disrupting neural network communication between the brain stem and spinal cord perpetuates this post-stun activity. The bursts of leg activity and speed at which the animal kicks are also influenced by damage to these neural networks.

Wagner et al. (2017) found that pneumatic captive bolt stunning in a commercial slaughter plant was not causing brain stem disruption based on visual damage from the bolt tract. However, there are two types of brain injury that occur via penetrating captive bolt stunning. The first is laceration and crushing of the tissue due to penetration of the captive bolt (Finnie, 1993) or bone crush from pieces of the skull plate being forced into the brain cavity by the captive bolt; this type of trauma is what was identified in the Wagner et al. study (Wagner et al., 2017). Secondly, stretch injury can occur which ruptures blood vessels and nerve fibers at some distance from the bolt tract of damage, which when a captive bolt enters the brain cavity at a high velocity, oftentimes due to the inelasticity of the brain, this secondary damage is more altering than the localized bolt tract damage (Finnie, 1993). Even though the longest captive bolt did not visually disrupt the brain stem based on damage from the bolt tract, the secondary effects from the damage could have disrupted brain stem function, as a result, altering the neural

network connections discussed previously that control involuntary limb movements. This could explain why Holstein cattle stunned with the LON bolt exhibited the most hind limb kicks. Future studies examining the amount of primary bolt tract damage and secondary blood vessel and nerve fiber damage in relation to the amount of post-stun kicking that cattle exhibit would be beneficial.

Forelimb kicking was observed and recorded immediately post-stick and likely had a relationship with the sticking process. It has been observed that in reaction to the skin being cut and the animal being stuck, some animals will show a nociceptive withdrawal reflex (Terlouw et al., 2015). This occurs due to a reflex arc from the stimulus of the stick causing receptors to be excited. By exciting an afferent nerve, one or more interneurons in the central nervous system, and an efferent neuron this reflex arc can occur through communication with only the spinal cord and not the brain (Brittanica, 2018). Reflexes are actions that do not involve consciousness and are automatic (Verhoeven et al., 2015). Nociception is how the central nervous system processes noxious stimuli such as a knife incision. The neck cut creates an area of incision that has a high density of pain receptors (Von Holleben et al., 2010). Even if the animal is rendered fully unconscious the kicking reaction could be influenced by the nociception receptors still communicating with the central nervous system.

A great amount of animal to animal kicking variation exists, with number of forelimb kicks ranging from 0 to 8 and the number of hind limb kicks ranging from 0 to 25 in the time span that the cattle were observed in this study. This time span was approximately 17 seconds post-shackling for hind limb and 5 seconds post-sticking for forelimb. Studies examining post-stun activity for longer periods of time could provide important information regarding the impact that time has on post-stun involuntary movements like kicking. In commercial slaughter

facilities, the time between stun to exsanguination and exsanguination to carcass dressing is variable. Understanding how stunning procedures and exsanguination procedures impact post-stun kicking behavior could help improve worker safety. Leg activity poses potential risk to employees performing tasks associated with exsanguination and sometimes carcass dressing. Where employees are positioned along the line, chain speed, and the design of the plant all influence whether post-stun activity will compromise the safety of employees.

Anecdotally, it has been noted that Holstein cattle kick more than non-Holstein cattle and potentially slow down plant production by increased take away belt stops due to the impact post-stun kicking has on the shackling process. In this study, there was a greater frequency of take away belt stops and carcass swing in Holstein cattle. Take away belt stops have the potential to slow down production efficiency, depending on the reason and duration of the stoppage. More Holstein cattle were harvested on B shift at this facility, so the impact of shift on production efficiency would be beneficial to examine in future studies. The take away belt may be stopped for a number of reasons other than kicking having to do with the stack line filling up and stops further down the line, which should be examined in future studies. If the belt is stopped due to hind limb kicking, this could also be a potential safety risk for the shacklers who need to re-shackle the limb. Depending on the design of the slaughter plant, carcass swing could pose a safety risk. Often times the area between stunning and exsanguination is limited in space and therefore more carcass movement could pose a threat to employees moving through the area; though it should be noted that those areas do not usually have high employee traffic.

CONCLUSIONS AND FURTHER RESEARCH

The purpose of this study was to evaluate how different captive bolt lengths influence post-stun leg activity and whether or not breed type plays a role in these differences in a commercial fed beef slaughter facility. There was industry speculation that longer captive bolts could potentially cause increased brain damage and thus decrease the occurrence of post-stun limb movement in cattle. This study identified that increasing captive bolt length does not reduce post-stun limb activity but alternatively can increase kicking when using the longest bolt tested in particular types of cattle, i.e. Holsteins. This study did not explore differences in brain damage. Other parameters associated with the shackling and hoisting process were impacted by breed type as well. Holstein cattle had more take away belt stops and carcass swing than non-Holstein cattle. How these parameters may impact production efficiency, along with the relationship between brain damage, post-stun limb activity and stun-to-stick interval warrants further investigation.

Table 5.1 Definitions of parameters measured post-stunning to capture hind limb and forelimb activity.

Hind Limb Kicks	Number of kicks from the unshackled hind leg counted from when the animal's spine was vertical as it was hoisted onto the rail, to just prior to the animal reaching the stack line
Forelimb Kicks	Number of kicks from both forelimbs, counting beginning at the opening of the dewlap, and ending when the bleed knife is removed
Take Away Belt Stop	Recorded when the shackle conveyor belt stopped while the animal was resting on the belt
Carcass Swing	Lateral carcass movement (from side to side) and lateral head movement
Righting Reflex	Arching of the back in an attempt to raise the head to regain a lateral position with the floor (sign of sensibility/consciousness) (Bartz et al., 2015; Grandin, 2002)
Sticks	The number of times the animal was stuck with a knife to be exsanguinated

Table 5.2 Effects of breed type (TYPE) and captive bolt length treatment (TRT) on post-stun leg activity in Holsteins and British/Continental cattle at a commercial slaughter facility.[1, 2, 3, 4]

										P-values for main effects and interaction		
Measurement	N		CON[2]		MED[2]		LON[2]		SEM	TRT	TYPE	TRT*TYPE
	HOL	NHOL	HOL	NHOL	HOL	NHOL	HOL	NHOL				
Hind limb KCKS (# of kicks)										< 0.001	< 0.001	< 0.001
	397	2,453	5.8[a]	6.0[a]	6.0[a, b]	5.3[a]	8.2[b]	5.6[a]	0.07			
Forelimb KCKS (# of kicks)										0.0002[5]	< 0.001[6]	0.8060
	382	2,261	0.3	0.5	0.7	0.9	0.6	0.9	0.12			

[1] Least squares means

[2] There were two breed TYPEs: HOL represents Holstein breed type and NHOL represents British/Continental breed type

[3] There were three captive bolt TRTs: CON denotes the standard bolt length, MED is 1.27 cm extended in length, and LON is 2.54 cm extended in length

[4] Means with different superscripts (a, b) differ ($P < 0.05$).

[5] CON (0.41 ± 0.11) vs MED (0.80 ± 0.09) $P < 0.001$; CON (0.41 ± 0.11) vs LON (0.72 ± 0.08) $P < 0.001$; MED (0.80 ± 0.09) vs LON (0.72 ± 0.08) $P = 0.3462$

[6] HOL (0.51 ± 0.10) vs NHOL (0.75 ± 0.04) $P = 0.0002$

Table 5.3 Effects of breed type (TYPE) and captive bolt length treatment (TRT) on post-stun events in Holsteins and British/Continental cattle at a commercial slaughter facility.[1, 2]

										P-values for main effects and interaction		
Measurement	N		CON (%[3])		MED (%[3])		LON (%[3])		SEM	TRT	TYPE	TRT*TYPE
	HOL	NHOL	HOL	NHOL	HOL	NHOL	HOL	NHOL				
STCKS										0.3189	0.9482	0.6890
	380	2,261	10.00	10.04	10.84	9.01	6.57	8.22	0.23			
CRCS SWING										< 0.001[4]	0.0009[5]	0.4101
	397	2,451	24.83	10.63	5.36	2.39	5.71	3.99	0.26			
BELT STOPS										< 0.001[6]	< 0.001[7]	0.9234
	397	2,451	27.59	10.63	9.82	3.83	10.71	3.56	0.22			

[1] TYPE = HOL represents Holstein breed type, NHOL represents British/Continental breed type

[2] TRT = Bolt treatment CON denotes the standard bolt length, MED is 1.27 cm extended in length, and LON is 2.54 cm extended in length

[3] Table values are expressed as a percentage of "yes" responses to more than one stick (STCKS), if the carcass did swing (CRCS SWING), and if the take away belt did stop (BELT STOPS)

[4] CON (16.54% ± 14.00%) vs MED (3.59% ± 23.30%) $P < 0.001$; CON (16.54% ± 14.00%) vs LON (4.78% ± 19.70%) $P < 0.001$; MED (3.59% ± 23.0%) vs LON (4.78% ± 19.70%) $P = 0.3278$

[5] HOL (9.44% ± 19.60%) vs NHOL (4.72% ± 10.80%) P = 0.0009

[6] CON (17.55% ± 13.78%) vs MED (6.18% ± 17.80%) $P < 0.001$; CON (17.55% ± 13.78%) vs LON (6.23% ± 15.81%) $P < 0.001$; MED (6.18% ± 17.80%) vs LON (6.23% ± 15.81%) $P = 0.9642$

[7] HOL (14.59% ± 15.28%) vs NHOL (5.29% ± 10.15%) $P < 0.001$

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