EVALUATION OF BEEF CATTLE TEMPERAMENT USING INFRARED THERMOGRAPHY AND COMPUTER VISION IMAGING TECHNOLOGIES

A Thesis
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Sciences

By

William Paul Ogdahl

In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE

Major Department:
Animal Sciences

June 2022

Fargo, ND

North Dakota State University
Graduate School

Title

EVALUATION OF BEEF CATTLE TEMPERAMENT USING

INFRARED THERMOGRAPHY AND COMPUTER VISION IMAGING

TECHNOLOGIES

By

William Paul Ogdahl

The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

SUPERVISORY COMMITTEE:

Dr. Eric P. Berg
Co- Chair

Dr. Xin (Rex) Sun
Co-Chair

Dr. Lauren Hanna

Dr. Mark McCourt

Approved:

October 17th, 2022 — Date

Dr. Guillermo Scaglia — Department Chair

ABSTRACT

The aim of these studies are two-fold. The first, was to evaluate the use of infrared thermography (IRT) maximum, average, and minimum eye temperature (IRT_{MIN}, IRT_{AVG}, and IRT_{MAX}, respectively) and percentage of eye white area (EW) to predict beef cattle temperament by assessing the relationship between IRT and EW traits with 4 established subjective and objective temperament scoring methods (n = 16 traits total). The second was to verify the feasibility of Video Technology (VT) as a measure of beef cattle temperament with minimal equipment and personnel and assess the accuracy and reliability of the VT measurements by comparing those with Temperament Score (TS) and Docility Score (DS). These studies showed potential in using eye white and video technology to objectively predict beef cattle temperament.

ACKNOWLEDGEMENTS

First and foremost, I would like to express sincere appreciation for my committee chair, and Graduate Co-Advisor, Dr. Eric Berg. Over the course of my entire career at NDSU, Dr. Berg has been a tremendous friend and mentor to me. He has shown extraordinary generosity of his time and resources over the years by sharing his knowledge of animal and meat science with me and involving me in a plethora of on and off-campus agricultural educational community events, conferences, and graduate student opportunities. I will take the lessons learned, and adventures had, with me for the remainder of my life and will be forever grateful.

I also want to thank my other Co-Advisor and mentor Dr. Xin Sun for his same generosity and friendship. I am so blessed to have been part of your research and I cannot wait to see the great things you will continue to create in Agriculture technology advancement.

Thank you also to the remainder of my thesis committee: Dr. Lauren Hanna and Dr. Mark McCourt for their encouragement and guidance over the course of this process. Thank you to all my friends and faculty at NDSU over the years. I am proud to have been a small part of North Dakota State University and I plan to continue to represent NDSU Animal Sciences with great reverence as I move forward from this chapter. Thank you also to all the previous undergraduate and graduate students I had the privilege to work and with at NDSU. You all are deserving of the greatness in store for you and the accomplishments you have already achieved.

None of this would have been possible without the constant love and support from my wife, Abigail. Thank you for continually being by my side.

Thank you to my Family, for your faith and support for me in achieving my goals. Thank you also to the North Dakota Extension Service for funding areas of this research. And thank you to my heavenly Father and His blessings; all the glory to you!

TABLE OF CONTENTS

ABSTRACT ……………………………………………………………………………………..iii

ACKNOWLEDGEMENTS ………………………………………………………………...…iv

LIST OF TABLES ………………………..……………………………………………...……viii

LIST OF FIGURES ……………………………………………………….……………….....ix

LIST OF ABBREVIATIONS ………………………………………….……….……..…...x

CHAPTER 1. INTRODUCTION AND LITERATURE REVIEW ……………………...……1

1.1. Introduction……..1

1.2. Attributes of Temperament………...2

1.2.1. Reproductive Efficiency 4

1.2.2. Health ……………..………………..……….……………………….………….……5

1.2.3. Performance 6

1.2.4. Carcass Quality ……...…...……………………………...7

1.3. Temperament Measurement ...………..……..…………………...……………...…...9

1.3.1. Subjective Measurement Methods …………………..……………..……………..10

1.3.2. Objective Measurement Methods ….……...……………………..………………11

1.4. Literature Cited ………………..………………...………………………...…….…13

CHAPTER 2. EVALUATION OF BEEF CATTLE TEMPERAMENT BY EYE TEMPERATURE USING INFRARED THERMOGRAPHY TECHNOLOGY ………………16

2.1. Abstract …..……....……………..…………………...……………………………….16

2.2. Introduction ……....……………..…………………...……………………………….17

2.3. Materials and Methods ……….....……………………...………………………………19

2.3.1. Animals ………..…………………………………………………….....……19

2.3.2. General Procedures and Experimental Design ...…………..…………………...….20

2.3.3. Image Data Process 22
2.3.4. Statistical Analysis 24
2.4. Results 25
2.4.1. Summary Statistics 25
2.4.2. Relationship Through Correlation Coefficients 25
2.4.3. Relationship Through Modeling 29
2.5. Discussion 34
2.6. Conclusion 39
CHAPTER 3. EVALUATION OF BEEF CATTLE TEMPERAMENT USING VIDEO TECHNOLOGY 40
3.1. Abstract 40
3.2. Introduction 41
3.3. Materials and Methods 43
3.3.1. Animals 43
3.3.2. Subjective Temperament Assessment 44
3.3.3. Objective Temperament Measurement with Video Technology 45
3.3.3.1. Video Image Acquisition System 45
3.3.3.2. Video Clip Extraction 46
3.3.3.3. Image Capture 47
3.3.3.4. Video Technology Temperament Calculation 48
3.3.4. Statistical Analysis 49
3.4. Results 50
3.5. Discussion 51
3.6. Conclusion 55

3.7. Literature Cited ……...……………………………………………………………...…...56

CHAPTER 4. SUMMARY AND CONCLUSIONS ……………………………………………....63

LIST OF TABLES

Table Page

2.1. Breed, age, and weight summary of calves used in experiment …………………………....20

2.2. Descriptive statistics of temperament score (TS), docility score (DS) eye white percentage (EW), and eye temperature (ºC) for all cattle ……...………..…………….……27

2.3. Pearson ($\hat{\rho}$) and Spearman Rank ($\hat{r}$) correlation coefficients for infrared thermography (IRT) temperature and eye white percentage (EW) traits with other temperament scoring methods ………………………………………………………....…...28

2.4. Pearson (top diagonal) and Spearman Rank (bottom diagonal) correlation coefficients of infrared thermography (IRT) temperature and eye white percentage (EW) traits ………29

2.5. P-values, least square means, and standard errors for fixed effects included in the base Model for eye traits ……………………………………………………………………30

2.6. Distribution of calves and summary statistics per category for Qualitative Behavior Assessment (QBA) attributes and four-platform standing scale (FPSS) measures …....…..31

2.7. P-values when different categorical temperament traits were fitted independently of each other as fixed effects for eye traits ………..……………………………………..32

2.8. Least square means and standard errors based on docility (DS) and temperament (TS) score categories for the proportion of white of the eye measured on a calf ………………..33

2.9. Least square means and standard errors based on significant Qualitative Behavior Assessment attribute categories for thermal eye traits ……………………………………..34

3.1. Criteria of evaluation scales used for temperament evaluations ……………………………44

3.2. Description statistics of Maximum Movement Distance (MMD), Average Movement Distance (AMD), Moving Frequency (MF), Temperament Score (TS) and Docility Scores (DS) for all cattle in the study ……………………………………………………50

3.3. Pearson correlation coefficients for Maximum Movement Distance (MMD), Average Movement Distance (AMD), Moving Frequency (MF), Temperament Score (TS) and Docility Scores (DS), N=150 ……………………………………………………………50

LIST OF FIGURES

Figure Page

2.1. Eye white percentage calculation procedure …………………………………...…………..23

2.2. Infrared image and the areas used to obtain temperature measurements for beef cattle……24

3.1. Beef Cattle Temperament Video Image Acquisition System ………………………………46

3.2. Beef Cattle Temperament Video Image Collection Method ………………………………46

3.3. Example of captured images ………………………………………………………………..47

3.4. The distance (D*i*) over time reflecting the calf's movement frequency……………………49

3.5. Frequency distribution of (a) Docility Scores, (b) Temperament Score, (c) Maximum Movement Distance; as well as (d) Average Movement Distance and (e) Moving Frequency, N= 150 ..……………………………………………………………………..51

3.6. Relationships between Docility Score (DS)/Temperament Score (TS) and Maximum Movement Distance (MMD)/ Average Movement Distance (AMD)/ Moving Frequency (MF), N=150 ……….…………………………………….……………….……52

LIST OF ABBREVIATIONS

HPA ……………………………………………………………Hypothalamic-pituitary axis

ACTH …………………………………..………..…………Adrenocorticotropic hormone

BCS ………………………………..……………………………..Body condition score

ADG ………………………………………………………….………..Average daily gain

WBSF ………………………………………………………….…..Warner-Bratzler shear force

DS ……………………………………………………………………………...Docility score

TS ……………………………………………………………..………Temperament score

MMD…………………………..……………………………....Movement-measuring device

FPSS …………………………………………………………..….Four-platform standing scale

IRT ……………………………………………………………..…Infrared thermography

EW …………………………………………………………….………………Eye white area

QBA ………………………………………………………Qualitative behavioral assessment

FS………………………………………………………….……...………...…Flight speed

SSD …………………………………………………………………….……Standard deviation

CVSSD ……………………………………………………………Coefficient of variation

VT ……………………………………………………………………...…Video technology

MMD …………………………………………………………..….Maximum movement distance

AMD ………………………………………………………….…….Average movement distance

MF ……………………………………………………………………….….Movement frequency

CHAPTER 1. INTRODUCTION AND LITERATURE REVIEW

1.1. Introduction

Fordyce (1998) defined beef cattle temperament as the stress response characteristic when cattle are exposed to human handling. The activation of the hypothalamic-pituitary-adrenal (HPA) axis in response to an external stimulus is the survival mechanism which helps animals to maintain homeostasis (King, 2006). Kasimanickam et al. (2014) concluded that the temperament of a beef herd, or certain individuals within the herd, can impact many production parameters such as reproductive performance, growth performance, and carcass quality; all of which are important cattle traits that affect the profitability of the beef operation.

Stockmen/women evaluate cattle temperament as a primary herd trait selection criterion of commercial beef sire and dam production characteristics. Selection for an appropriate temperament initially began as a basic need for the safety of the handlers involved in the cattle operation, and to extend the longevity of equipment. These almost unconscious culling criteria evolved over time into a scientific understanding of the influence of temperament on the productivity of the commercial beef operation. Beginning in the 20th century, researchers observed that less excitable cattle performed better in a production setting. Cattle with a mild temperament were safer to handle, more productive throughout their lifetime, had greater carcass merit, and were less prone to disease (King et al., 2006; Montanholi et al., 2009; Kasimanickam et al., 2017) Because all these traits impact beef production on an economic basis, the evaluation of cattle temperament became a production trait of importance for cattle producers.

The objective of this study was to discover an automated, simple, objective method to measure beef cattle temperament by means of infrared thermography, eye area measurements, and video imaging. We hypothesize that cattle temperament can be measured objectively and accurately using computer vision technologies, removing the need for an individual to subjectively score each animal. It is worth noting that subjective methods of temperament scoring have been shown to produce accurate findings.

1.2. Attributes of Temperament

Beef cattle temperament is the way in which animals respond to human handling. A good temperament generally means a calmer animal that possesses a lower threshold for excitability, while a bad, or temperamental animal can be easily excited and cause harm to themselves or handlers (BIF, 2011). A more excitable temperament is of concern to beef producers because of the negative effects on productivity and operational efficiency as well as the overall welfare of the animals, facilities, and the humans around them (Kasimanickam et al., 2017).

On a physiological level, beef cattle temperament is a function of the sympathetic nervous system that is activated in response to an external stimulus (King, 2006). This response is activated from the animals biological "flight or fight" response in a necessity for the animal's need for energy to deal with stimulus. The amygdala is the emotional center of the brain responsible for this "flight or fight" response. Anatomically, the sympathetic nervous system is composed of the hypothalamic-pituitary-adrenal axis (HPA) which, when activated, initiates an involuntary survival mechanism (King, 2006). The centromedian nucleus of the amygdala sends a signal to the ventromedial nucleus of the hypothalamus, which then tells the pituitary gland to release adrenocorticoid-releasing hormone. The adrenal gland releases glucocorticoids which are all major components of the function of the HPA axis. When the HPA is activated, it increases the synthesis and circulation of adrenocorticotropic hormone (ACTH), cortisol (released from the adrenal cortex), and epinephrine (released from the adrenal medulla).

Epinephrine induces smooth muscle contraction throughout the body, thus increasing heart rate concurrently. This increases blood flow carrying more oxygen and energy to points in the body to enhance the physiological response to the stressor. The physiological response to stress also increases body temperature to positively affect chemo-mechanical coupling of contractile proteins for more efficient and immediate smooth and skeletal muscle contractions. Expansion of the airways takes place to increase oxygen uptake to oxygenate the blood to sustain muscle contractions called upon to flee or fight. Other, less physical actions are also activated such as the dilation of the pupils for improved vision for a faster response to a perceived threat.

Cattle with a more excitable temperament possess a lower threshold for activation of a stress response which can be triggered by an actual or perceived threat. These cattle have an increased response to the stimulus resulting in higher basal levels of glucocorticoids (Curley, 2004). As observed in Kasimanickam et al., (2017), serum cortisol concentrations were elevated in excitable cows compared to their calmer, more docile cohorts. The hyperactivation of the HPA axis is likely a combination of learned experience (classic conditioning) and genetic instinct. Either way, it can be regulated within a herd by good management decisions regarding animal handling and animal breeding. Cooke et al. (2017) calculated temperament score by averaging how cows behaved in the working chute and how fast they exited the chute. Exit score was calculated by assigning cows a score from 1 to 5 where 1 represented the slowest cows spanning to 5 which represented the fastest cow. Cooke et al. (2017) observed that cattle with higher baseline plasma cortisol concentrations had a more aggressive temperament (excitable temperament, temperament score > 3) when compared with a more adequate temperament (adequate temperament, temperament ≤ 3.

1.2.1. Reproductive Efficiency

Profitability of a beef cow-calf operation is dependent upon pounds of calf weaned per cow exposed for breeding. Cows becoming pregnant early in the breeding season and maintaining that pregnancy to achieve successful parturition are two crucial factors affecting annual calf crop (Rae 2006, Mathis and Sawyer 2010). Hastened puberty of beef heifers and fertility in beef cows is essential to the overall profitability of the operation. Beef cows with excitable temperaments had decreased rates of pregnancy when compared to cohorts of adequate temperament (Cooke, 2017). The decreased pregnancy rates were attributed to an increased circulating cortisol concentration in females observed with a more excitable temperament (Cooke, 2014). This physiological response is because cortisol negatively effects fertility and the physical ability to maintain pregnancies (Dobson et al., 2001). Temperament may also indirectly affect beef female pregnancy rates because of reduced feed intake or increased energy needs (Kasimanickam et al., 2016). As observed in Wettemann and Bossis (2000), the more excitable females had increased feed requirements in order to reestablish homeostasis, impaired from a perceived threat. Furthermore, the more temperamental animals may have spent less time grazing or eating because of a heightened sympathetic nervous system response due to the perceived or actual threat/stress. With the increased cortisol circulation, it has also been observed to cause decreased feeding behavior and appetite suppression (Dobson and Smith, 1995).

The benefits of artificial insemination continue to be proven profitable for the beef cattle industry impacting earlier estrus response in heifers and improved weaning weights of offspring. An increase in artificial insemination rates has been shown to occur in less temperamental females (Kasimanickam et al., 2017). When examining the heifer or cows' capability of estrus expression early in puberty or the breeding season, it is important to explore multiple factors that can be associated with temperament and how that can contribute to economically important traits. It is important to note that Kasimanickam et al. (2014) found that body condition score (BCS) of heifers did not have an impact on first estrus breeding, however their excitability did impact days to first estrus. This could imply that temperamental heifers will struggle to carry an early pregnancy.

1.2.2. Health

How animals are raised is becoming just as important as how the meat tastes when it comes to consumers making their purchase decisions. In the mind of the consumer, production practices have a direct impact on the “happiness” and overall health of the animals (Jorquera-Chavez et al., 2019). Health is not only important for the survivability of the animals, but also for the profitability of the ranch. Animal stewardship and the production environment are at the front of many American minds when it comes to purchasing and eating beef. There are various beef cattle production systems where the animal’s health plays a pivotal role to the overall profitability of the operation (Burrow and Dillon, 1997).

In a cow-calf production system the producer concentrates their efforts on maintaining cattle that will raise and wean a calf to be sold. In this system the dam lives her whole life involved by the ability to get pregnant every year, raise a calf (every year), and stay healthy and productive for as long as possible. Feedlot systems are different in that many of the cattle involved in the system come from different herds, different stages of life, and are from different locations which can cause many opportunities for health complications early in their time in the feedlot. If feedlot animals are not healthy, they will not eat, grow, or even survive, which all three are crucial to the success of the feedlot cattle system (Kasimanickam et al. 2014). Finishing systems are similar to the feedlot in that they are fed, mostly in confinement, a high grain diet and then are sold directly to a packing facility to be processed into boxed beef or consumer cuts. Health is extremely important to the finishing feedlot because if the animal is not healthy, it will be condemned and not able to be used for human consumption, resulting in a large economic and ethical loss. Hine (2019) expressed that more excitable beef calves tend to be far more susceptible to diseases caused by the animal's inability to cope with induced stressors, inhibiting their ability to mount an appropriate immune response. Calves that are more susceptible to disease require necessary medical (medicine) treatment and additional labor to treat the sick animal, as well as the ever present potential that the animal may succumbed to loss of life.

1.2.3. Performance

Improving the overall status of the beef herd requires application of trait specific genetic selection to achieve the herd-specific production goals. Genetics for temperament are moderately heritable, indicating that there is a moderate chance that the progeny will carry on their sire or dam's temperament (Hine, 2019). Therefore, livestock managers who sires for a more agreeable temperament and simultaneously cull the temperamental dams, can make genetic progress with the docility of the herd. There have been private companies that offer genetic marker testing for bovine docility such as IGENITY® (Merial Ltd., Duluth, GA) and GenSTAR (Zoetis, Kalamazoo, MI). While these new genetic technologies have reduced the length of time for making genetic progress in a herd, it is important to remember to not go too far with single trait selection. Most of the beef cattle in the United States will give birth to their calves while out on pasture and many will do so without the watchful eye of a herdsman. By over-selecting for moderate temperament, we may be selecting against a heightened fight or flight response. Although, there is literature lacking on this topic, the author argues t could be that an active and healthy fight or flight response is part of the physiological response necessary for protecting the young, vulnerable offspring. These cows still need to possess a healthy mothering ability and more temperamental dams that possess a heightened fight or flight instinct may be better able to defend against predation.

Turner et al. (2013) observed an increase in average daily gain (ADG) of calves from cows that calmly approached a handler during calf tagging, these calves also took less time to stand after calving. This phenomenon may be explained by the fact that a calmer, more curious mother cow raised a less temperamental calf and had a greater transfer of heritable traits (Cooke et al,. 2012).

1.2.4. Carcass Quality

In the beef cattle production cycle, whether the animal is a bull, steer, cow, or heifer, it will ultimately end up as a meat product destined for a consumer. Because of this fact, it is very important for cattle managers all along this market chain to keep the palatability of the carcass in mind. This implies that marketability of the final meat product either will (or won't) be purchased for consumption based on the perceived palatability of the retail product. Based upon recent consumer preferences, tenderness is the number one factor that consumers attribute to beef quality followed closely by the presence of intra-muscular fat (marbling). According to King (2006), a more temperamental beef calf is more likely to produce a less tender ribeye than a calmer animal. To put this in perspective, temperamental animals possess a more active fight or flight response and are more likely to be in a more hyper-vigilant state; they are "stressed." A natural physiological response to stress is tense (contracted) muscles. In human terms, we may develop "knots" in our shoulders after a long stressful drive on an icy road. To explain these "knots" in the terms of myofibrillar anatomy, the prolonged (and unconscious) contraction results in hyper-shortening of the sarcomere and maximum overlapping of the thick and thin myofilaments. This similar response happens in animals and will be exacerbated when the animal is in a strange environment such as lairage at the packing plant. The stress manifested in living muscle is transferred to the conversion of muscle to meat and can negatively impact beef tenderness. The increase in steak toughness obtained from more temperamental slaughter calves could be attributed to the shorter sarcomere lengths in muscles. The shortened sarcomere possesses maximum overlap of the contractile proteins which results in a tougher bite of cooked steak (King, 2006). Specifically, King (2006) found that animals classified as excitable (based on the experiment temperament index calculated as [exit velocity + pen score]/2), produced longissimus lumborum (strip) steaks with higher Warner-Bratzler shear force values (WBSF). These measures of beef cattle temperament will be explained in greater detail in the subsequent section. Briefly, exit velocity is a measurement of how fast (seconds/meter) an animal spans 1.83 meters when released from the scale or restraining chute. Pen score is a subjective indication of how close a human can get to an animal while both are confined in a holding pen. Warner-Bratzler shear force is the mechanical toughness of meat measured in kg of pressure to shear through a 1.3 cm diameter core of cooked steak. It is an important factor to note that this research sited was pertaining to Bos Taurus breeds of cattle; different findings may be prevalent for Bos Indicus breeds of livestock.

It has also been observed that cattle behavior and temperament in a working chute and their subsequent exit velocity can influence the quality of the meat. Hall (2008) found that steers with faster exit velocities produced a higher proportion of tougher meat. Additionally, steers with faster exit velocities were less likely to deposit intramuscular or perirenal fat. This phenomenon is explained by the inability for a more temperamental steer to achieve a level of homeostasis and 'allow' for the storage of energy in the form of fat deposition as observed in Hall et al., (2008). In other words, temperamental animals with a more heightened fight or flight response utilize more energy to maintain this hyper-vigilant metabolism with little energy remaining for positive attributes such as fattening. Achieving a desirable USDA quality grade is very economically important to the cattle producer because, depending on the time of year, there can be as much as $25/cwt premium for a USDA choice grade carcass versus a USDA select (National Daily Cattle & Beef Summary, USDA AMS, 2022).. This equals a $200 profit on an 800-pound choice vs. select carcass. It is important to note that at the time of this publication, the choice/select spread was $12.15 (National Daily Cattle & Beef Summary, USDA AMS, 2022).

1.3. Temperament Measurement

The true nature of animal temperament is best observed when that animal is in its most familiar environment or what will be its most frequently utilized environment such as the production site pen or handling facility, depending of course on the production system being utilized, which the author speculates is on pasture or fed in a pen (Lanier, Grandin, Green, Avery, & McGee, 2000). Adequately designed handling equipment will not put additional stress on the animals. There are many documented means for measurement of temperament, some more invasive than others, requiring equipment and computer monitoring, while other methods simply require a trained human eye. That said, many of the easiest ways to measure temperament are highly subjective and can vary from evaluator to evaluator, to geological/environmental location regarding evaluators baseline perceived animal temperament, even across breeds of cattle.

1.3.1. Subjective Measurement Methods

A very commonly used means of assessing subjective temperament score (TS) was modified and developed by renowned animal behaviorist Temple Grandin (1993). The Grandin TS is a system where the observer awards a numeric score of 1, 2, 4, or 5. A score of three is not allowed so the evaluator is forced to score the animal as temperamental, 4 or 5, or calm, 1 or 2. The scoring using this system takes place in a small to medium sized pen where the observer can monitor how the animal reacts to them by paying close attention to the animal's flight zone and/or aggressiveness.

Another popular subjective temperament scoring system is Docility Score (DS). According to the Beef Improvement Federation (2010), DS is scored on integers ranging from 1 to 6, with 1 being the most docile, and 6 being the most aggressive while the animal is restrained in a working chute. Docility score differs from TS, because when recording the TS, the animal is free to move about a pen, rather than restrained in a head gate. Further, docility score is an index of 1 to 6 with 1 being docile and 6 being very aggressive. This scoring system was designed to subjectively evaluate differences in disposition when animals are processed through a holding chute. This method is commonly used by beef breed associations. Temperament score was adapted from the breeding program of Agropecuária Jacarezinho® (Conexao Delta, 2011). The TS is determined when an animal leaves the holding chute, enters a working pen, and interacts with a human handler. The range of the TS scale is from 1 (calm) to 5 (excitable). To avoid the tendency of observers to concentrate their grades on an intermediary level (TS = 3), this score was eliminated from the scale and animals were scored as 1, 2, 4, or 5 according to the criteria of Sant'Anna and Paranhos da Costa (2013). Both TS and DS observation methods have proven to be an efficient means at determining temperament but are limited by their subjective nature.

1.3.2. Objective Measurement Methods

Exit velocity (EV) is one of the most widely used objective measurements of beef cattle temperament. Described by Burrow et al. (1988), EV was measured by two infrared motion sensors (FarmTek, Inc., Wylie, TX), one placed at the “start” and the other at the “finish.” The sensor locations were approximately one-half meter away from the exit end of the head gate and the second was 1.82m away from the first. Thus, the exit velocity was recorded as the amount of time it took each animal to travel the 1.82m upon being released from the working chute. It has been suggested that the more rapid speed which the animal exits the chute, the more excitable the animal (as indicated in Burrow et al., 1988). The EV is calculated by dividing the predetermined 1.82m distance by the time in seconds necessary to cover the distance. This technology is quantitative and removes the need for human observers, therefore, eliminates the variation associated with subjective observation. That said, specialized equipment is required and some training on proper use may be necessary, however this has been used as a just indicator of temperament scoring.

A movement-measuring device (MMD) is an electronic scale that uses voltage readings obtained from load cells that objectively quantify an animals’ natural instinct to move to evade a threat. The MMD records voltage changes for a set period of time while the animal is on the scale. The frequency or forcefulness of the animal’s movements are expressed as deviation in voltage readings. Those animals that remain still generate less voltage measured variations, therefore it is proven that calmer animals have lower MMD scores (Waynert et al., 1999). The four-platform standing scale (FPSS) is a form of MMD scale first observed by Yu et al. (2020), that positions four individual load cells under each leg of the animal. The scale is placed at the end of a working chute. The animal will stand on the FPSS unrestrained for a pre-determined amount of time and allowed to shift its weight between all legs causing a fluctuation of recorded weights for the predetermined length of time. The resulting temperament product is a measurement of perceived stress of the animal while it is unrestrained but stopped in a chute. The standard deviation between the shifted weights across the four legs and the four load cells is calculated and assigned to the animal as a temperament score. The greater the standard deviation, the more excitable the animal.

Computer vision technologies for measuring stress may be more practical and possibly less invasive than previous, more common methods (Jorquera et al., 2019). Aside from physiological indicators that may need multiple subjective observers or equipment, non-invasive technological temperament measurements may be possible through infrared thermography, remote sensing, and video imaging (Tattersall, 2016). Core et al. (2009) used a color video camera (Panasonic WV-CP240, Panasonic Canada Inc., Mississauga, Ontario, Canada) to capture eye images of heifers, bulls, and steers to be analyzed for pupil dilation that has been consistent with the natural physiological dilation response exhibited by animals with a keener fight or flight response (more temperamental animals) (Sandem et al., 2002). Furthermore, video recording and computer analyses of eye white percentage proved to be an accurate and repeatable means of identifying beef cattle temperament (Core et al., 2009). There have been tremendous advancements in technology of picture resolution that can now measure the most minute details that were previously undetectable by outdated technologies. By example, near infrared temperature analysis can now be recorded and possesses the ability to detect miniscule changes in body temperatures that may be indicative of changes in peripheral blood flow (Tattersall, 2016).

These electronic technologies that have been described to quantify beef cattle temperament are subject to updates and improvements in software that often times make the systems obsolete before real world applications can be applied, these issues could pose problems for "real-world" application (such as increased costs passed on to producers) if not addressed. Therefore, it is necessary to publish research that details the capability of these monitoring technologies as soon as possible. To date, no research has been done using objective, noninvasive video technology to evaluate cattle temperament. Thus, the main hypothesis of this research is the use of video technology for measurement of eye white percentage and animal movement in stressful environments may accurately and repeatably be able to measure beef cattle temperament and will facilitate the temperament score measurements. Therefore, the objectives of this study were to (1) verify the feasibility of video technology as a measure of beef cattle temperament, and (2) assess the accuracy and reliability of the video technology measurements by comparing those with temperament and docility scores.

1.4. Literature Cited

Burrow, H. M., and R. D. Dillon. 1997. Relationships between temperament and growth in a feedlot and commercial carcass traits of Bos indicus crossbreds. Australian Journal of Experimental Agriculture. 37:407-411.

Burrow, H. M., Seifert, G., Corbet, N., 1988. A new technique for measuring temperament in cattle. Proceedings of the Australian Society of Animal Production. Vol 17, 155.

Cooke, R.F., Bohnert, D.W., Cappellozza, B.I., Mueller, C.J., DelCurto, T., 2012. Effects of temperament and acclimation to handling on reproductive performance of Bos Taurus beef females. Animal Science. 90, 3547-3555.

Cooke, R.F., Schubach, K.M., Marques, R.S., Peres, R.F.G., Silva, L.G.T., Carvalho, R.S., Cipriano, R.S., Bohnert, D.W., Pires, A.V., Vasconcelos, J.L.M., 2017. Effects of temperament on physiological, productive, and reproductive responses in Bos Indicus beef cows. Animal Science. 95, 1-8.

Core, S., Widowski, T., Mason, G., Miller, S., 2009. Eye white percentage as a predictor of temperament in beef cattle. Journal of Animal Science. 87, 2168-2174.

Grandin, T., 1993. Behavioral agitation during handling of cattle is persistent over time. Applied Animal Behavior Science. 36, 1-9.

Hall, N. L., Buchanan, D. S., Anderson, V. L., Ilse, B. R., Carlin, K. R., & Berg, E. P. 2011. Working chute behavior of feedlot cattle can be an indication of cattle temperament and beef carcass composition and quality. Meat Science, *89*(1), 52-57.

Hine, B.C., Bell, A.M., Niemeyer, D.D.O., Duff, C.J., Butcher, N.M., Dominik, S., Ingham, A.B., Colditz, I.G., 2019. Immune competence traits assessed during the stress of weaning are heritable and favorably genetically correlated with temperament traits in angus cattle. Animal Science 4053-4065.

Jorquera-Chavez, M., Fuentes, S., Dunshea, F.R., Jongman, E.C., 2019. Computer vision and remote sensing to assess physiological responses of cattle to pre-slaughter stress, and its impact on beef quality: a review. Meat Science, 156,11-22.

Kasimanickam, R., Asay, M., Schroeder, S., Kasimanickam, V., Gay, J.M., Kastelic, J.P., Hall, J.B., Whittier, W.D., 2014. Calm temperament improves reproductive performance of beef cows. Reproduction in Domestic Animals 49, 1063-1067.

Kasimanickam, V.R., Abdel Aziz, R.L., Williams, H.M., Kasimanickam, R.K., 2017. Predictors of beef calf temperament at weaning and its impact on temperament at breeding and reproductive performance. Reproduction in Domestic Animals, 53: 484-494.

King, D., Pfeiffer, C.S., Randel, R., Welsh Jr, T., Oliphint, R., Baird, B., Curley Jr, K., Vann, R., Hale, D., Savell, J., 2006. Influence of animal temperament and stress responsiveness on the carcass quality and beef tenderness of feedlot cattle. Meat Science 74, 546-556.

Magolski, J.D., Berg, E.P., Hall, N.L., Anderson, V.L., Keller, W.L., Jeske, T.M., Maddock Carlin, K.R., 2013. Evaluation of feedlot cattle working chute behavior relative to temperament, tenderness, and postmortem proteolysis. Meat Science, 95 92-97

Montanholi, Y.R., Swanson K.C., Palme, R., Schenkel, F.S., McBride, B.W., Lu, D., Miller, S.P., 2009. Assessing feed efficiency in beef steers through feeding behavior, infrared thermography and glucocorticoids. The Animal Consortium 2009, 4:5 692-701.

Sandem, A., Braastad, B., Bøe, K., 2002. Eye white may indicate emotional state on a frustration–contentedness axis in dairy cows. Applied Animal Behaviour Science 79, 1-10.

Tattersdall, G. J., 2016. Infrared thermography: A non-invsive window into thermal physiology. Comparative Biochemistry and Physiology 202, 78-98.

Turner, S.P., Jack, M.C., Lawrence, A.B., 2013. Precalving temperament and maternal defensiveness are independent traits but precalving fear may impact calf growth. Animal Science 2013.91:4417-4425.

Waynert, D. F., J. M. Stookey, K. S. Schwartzkoph-Fenswein, J. M. Watts, and C. S. Waltz. 1999. The response of beef cattle to noise during handling. Appl. Anim. Behav. Sci. 62:27-42.

CHAPTER 2. EVALUATION OF BEEF CATTLE TEMPERAMENT BY EYE TEMPERATURE USING INFRARED THERMOGRAPHY TECHNOLOGY[1]

2.1. Abstract

Beef cattle temperament can impact animal performance and meat quality in cattle. The aim of this study was to evaluate the use of infrared thermography (IRT) maximum, average, and minimum eye temperature (IRT_{MIN}, IRT_{AVG}, IRT_{MAX}) and percentage of the eye with the sclera visible in a digital image (eye white percentage, EW) to predict beef cattle temperament by (1) assessing the relationship between IRT and EW traits with 4 established subjective and objective temperament scoring methods (n = 16 traits total) and (2) identify behavioral characteristics that IRT and EW traits are predicting. Traits were measured on Angus- and Hereford-influenced steers (n = 203; age 183.00 ± 15.80 days; BW 264.50 ± 30.84 kg) and heifers (n = 200; age 186.60 ± 15.18 days; BW 251.90 ± 28.77 kg). Computer vision and image processing technologies were used to extract IRT_{MIN}, IRT_{AVG}, IRT_{MAX}, and EW features. Temperament scores (TS), docility scores (DS), four-platform standing scale (FPSS), Qualitative Behavioral Assessment (QBA) attributes were measured to compare with the imagery methods. Results showed there were no statistically significant relationships of IRT_{MIN}, IRT_{AVG}, IRT_{MAX} for TS, DS, FPSS and QBA. The correlations value between EW and DS and between EW and TS were also low but correlated at a certain level (0.258 and 0.179 at $P < 0.0001$). This study found thermal and eye white area to objectively predict beef cattle temperament, yet more cattle sample numbers should be further investigated to validate the hypothesis.

[1] The adapted material in this chapter was co-authored by William Ogdahl, Xiaoming Chen, Lauren Hanna, Eric Berg and Xin Sun. William Ogdahl had primary responsibility for collecting beef cattle thermal and eye imagery data. William Ogdahl, Eric Berg and Xin Sun were the primary developer of the project idea that is advanced here. William Ogdahl also was the primary responsibility for data input and initial analysis in this chapter.

2.2. Introduction

Temperament is defined as an animal's behavioral responses to handling by humans and novel environments (Burrow, 1997). It is economically important to producers (Petherick et al., 2002) because a more docile temperament is favorably correlated with improved production traits such as feedlot growth rate (Cafe et al., 2011b), meat quality (King et al., 2006), immune function (Fell et al., 1999) and stress responsiveness (Cafe et al., 2011a). Sant'Anna and Paranhos da Costa (2013) suggested that temperament is a complex trait formed by an animal's consistent reaction to its environment stating that fear, reactivity, and activity play a part in forming an animal's measurable temperament. Common methods for determining beef cattle temperament include subjective and objective methods. Subjective methods, such as temperament scores (**TS**) (Valente et al., 2015), docility scores (**DS**) (BIF, 2010), and Qualitative Behavioral Assessment (**QBA**) (Sant'Anna and Paranhos da Costa, 2013; Wemelsfelder et al., 2000) are methods evaluated by human observers. Valente et al. (2015) describe TS as scores scaled for each animals' reaction after leaving the holding chute and entering a corral pen. BIF (2010) define DS as scores evaluating differences in disposition when animals are processed through the holding chute. Wemelsfelder et al. (2000) define QBA as method to summarize the different aspects of an animal's dynamic style of interaction with the environment, it could be used to discriminate different behavioral profiles and has already been used to obtain accurate interpretations of behavioral reactions (Stockman et al., 2011; Yu et al., 2020). Objective methods, such as eye white percentage (**EW**)(Sandem et al., 2006), flight speeds (**FS**) (Burrow et al., 1988), and four-platform standing scale (**FPSS**) (Yu, 2016) do not depend on human interpretation of animals. Sandem et al. (2006) identified EW, as measured by the percentage of revealed eye white as being associated with some means of temperament. The result showed the percentage of white in the eye increased significantly after the calf was taken out of the pen, with a peak at 4 min. When the calf was put back in the pen, the eye-white percentage significantly decreased during the first 4 min. Burrow et al. (1988) define FS as a speed an animal passes a set distance after leaving a confined area. Yu (2016) identified FPSS as measured using a four-platform standing scale which can record an animal’s weight shift and degree of weight shift over time. To date, studies have compared cattle temperament evaluation methods and found a great deal of variation among methods (Burrow and Corbet, 2000; Kilgour et al., 2006; Petherick et al., 2003). Comparison across studies is often difficult because evaluation methods test different aspects of temperament (Jones, 2013; Sant’Anna and Paranhos da Costa, 2013). Therefore, identification of consistent, cost-effective, temperament evaluation methods could be used as an assessment tool to better understand the relationship between beef quality and behavior performance. Further, the assessment of animal temperament can be used to monitor positive or negative changes in animal welfare that would allow producers to recognize the situation and adapt the animal environment accordingly.

Maximum eye temperature measured using the technique of infrared thermography (**IRT**) has been utilized to assess level of animal stress in previous studies (Bartolomé et al., 2013; McGreevy et al., 2012; Schwartzkopf-Genswein et al., 2012a; Stewart et al., 2005). The concept of IRT is based on photography of the external animals’ surfaces with an infrared camera. The method is a passive, remote, and noninvasive means of measuring surface temperatures. The commonly used temperament evaluations, such as DS, TS, FS and EW, involve the use of a restraining head gate and (or) holding chute which could be considered a stressful condition (Grandin, 1993; Sant’Anna and Paranhos da Costa, 2013). Observations of maximum eye temperature are not previously described as an evaluation parameter of beef cattle temperament.

Obtaining eye temperature in the head gate/holding chute situation may be a parameter that could evaluate animal's temperament.

The aim of this study was to evaluate the use of infrared thermography maximum, average, and minimum eye temperature (IRT_{MIN}, IRT_{AVG}, IRT_{MAX}) and percentage of the eye with the sclera visible in a digital image (eye white percentage, EW) to predict beef cattle temperament by (1) assessing the relationship between IRT and EW traits with TS, DS, FPSS, and QBA attributes (n = 16 traits total) and (2) identify behavioral characteristics IRT and EW traits are predicting.

2.3. Materials and Methods

All cattle used in this research were managed according to the Federation of Animal Science Guide for the Care and Use of Agricultural Animals in Agriculture Research and Teaching (FASS, 2010). All procedures were reviewed and approved by the Institutional Animal Care and Use Committee of North Dakota State University (protocol A18005).

2.3.1. Animals

Four hundred and three weaning-age calves were used in this study, which included 203 steers and 200 heifers (Table 2.1). All calves were part of the production herd at the North Dakota State University Central Grasslands Research Extension Center and were produced from crossing Angus or Hereford sires with Angus or Hereford crossbred cows, previously described by Yu et al. (2020).

Table 2.1. Breed, age, and weight summary of calves used in experiment

Primary breed[1]	Sex	N[2]	Age (SD), d	Weight (SD), kg
Angus	Heifers	163	185.6 (16.6)	248.4 (29.6)
	Steers	150	181.2 (17.8)	261.5 (32.6)
Hereford	Heifers	37	190.8 (3.3)	267.1 (18.8)
	Steers	53	188.0 (5.3)	273.0 (23.4)

[1]Primary breed refers to the breed of that calf that is 50% or greater based on known pedigree.
[2]Number (N) of calves in that grouping.

2.3.2. General Procedures and Experimental Design

Beef cattle image data and temperament measurement were conducted over two consecutive days in October of 2017. The handling facility and collection procedure were previously described in Hulsman Hanna et al. (2019) and Yu et al. (2020), the facility temperature and humidity were within a consistent range since there was no significant weather change during the data collection period. The cattle were moved from their home pens to a handling facility connected to a raceway leading to a silencer chute (Moly Manufacturing Inc., 101 Lorraine, KS). Individual cattle were moved through the raceway and their head was restrained by a head gate for approximately one minute. Docility scores and images for determining EW were collected as well as eye temperature were obtained while the animal was restrained by the holding chute. The cattle were then moved to the four-platform standing scale (FPSS; Pacific Industrial Scale, British Columbia, Canada) and data was collected on each quadrant of the scale. Following FPSS, cattle were released to a working pen for TS and QBA evaluation. For each subjective scoring method (DS, TS, QBA attributes), 4 evaluators scored each animal. The average across those evaluators per method were used in this study to reduce the influence of evaluator's experience, stress of evaluating individually, and personal bias.

Docility score, an index of 1 to 6 with 1 being docile and 6 being very aggressive, was designed to subjectively evaluate differences in disposition when animals are processed through a holding chute. This method is commonly used by beef breed associations. Temperament score was adapted from the breeding program of Agropecuária Jacarezinho® (Conexao Delta, 2011). The TS is determined when an animal leaves the holding chute, enters a working pen, and interacts with a human handler. The range of the TS scale is from 1 (calm) to 5 (excitable). To avoid the tendency of observers to concentrate their grades on an intermediary level (TS = 3), this score was eliminated from the scale and animals were scored as 1, 2, 4, or 5 according to the criteria of Sant'Anna and Paranhos da Costa (2013).

Qualitative behavior assessment followed the procedures of Sant'Anna and Paranhos da Costa (2013). Twelve attribute descriptors (active, relaxed, fearful, agitated, calm, attentive, positively occupied, curious, irritated, apathetic, happy, and distressed) were evaluated while a single human handler calmly interacted with the calf. These attributes were scored on a 136 mm visual analog line. The level of attribute expression was considered from left (no expression) to right (highest level of expression). Scores were obtained by the distance, in millimeters, measured from the left edge of the visual analog line to the evaluator's mark.

The four-platform standing scale is a novel cattle temperament assessing method. The principle and procedures of this method was described by Yu et al. (2020). Briefly FPSS had scales in each quadrant of working area to record the weight shifts of each foot of the animal. The scales were connected to a computer which could recorded the weight of each scale approximately 15 records per second for at least 45 seconds after starting the recording software. The standard deviation of FPSS measurements (SSD) and the coefficient of variation of the SSD (CVSSD = SSD divided by mean) were used as temperament scores for subsequent analyses. More weight shifting within and between platforms indicated a more temperamental calf.

Eye white percentage was collected using a modified near-infrared (NIR) camera (Powershot A520, Canon U.S.A., Inc). The EW image data was collected from the right eye of each animal after the neck was restrained by the hydraulic chute system. The resolution of EW images was 3648×2736.

The IRT images of the animal's head were acquired by industrial infrared camera (TiS40, Fluke Corporation, Everett, WA). The temperature measurement range of the camera was from -20 °C to 350 °C, the accuracy of the camera was ± 2 °C, and thermal sensitivity was 0.09 °C. The resolution of IRT images was 160×120 (19,200 pixels). The camera was positioned approximate 1 meter from the head of the animal. Before recording, the camera was calibrated to ambient temperature and humidity to achieve accurate measurements (Macmillan et al., 2019). Wind speed has been reported to impact eye temperature (Church et al., 2014). Wind speed was not measured in the present study because all IRT images were taken indoors, sheltered from wind. Likewise, there was no direct sunlight to impact the radiant thermal heating of the cattle. The IRT images of the cattle's left eye were taken after the cattle were restrained for approximately 10s.

2.3.3. Image Data Process

The EW images were analyzed according to the procedure used by Core et al. (2009) and Jones (2013). One clear image was selected for each calf based on being representative of the estimated average EW of the animal, ensuring the head of the animal was perpendicular to the camera, and without head and eye movements. The technician responsible for the image selection had no prior knowledge of any other temperament assessment results. An EW was calculated from the selected image for each animal using the computing program Image J (U.S. National Institutes of Health, Bethesda, Maryland, USA) which evaluates the area of an image in pixels. This method has been used before to analyze morphometrics (Doube et al., 2010; Schneider et al., 2012). The areas of total eye and iris were traced and measured, then EW was calculated using the following formula: EW = (1- [area of the iris/area of the total eye]) × 100%. Figure 2.1 shows the steps of procedure.

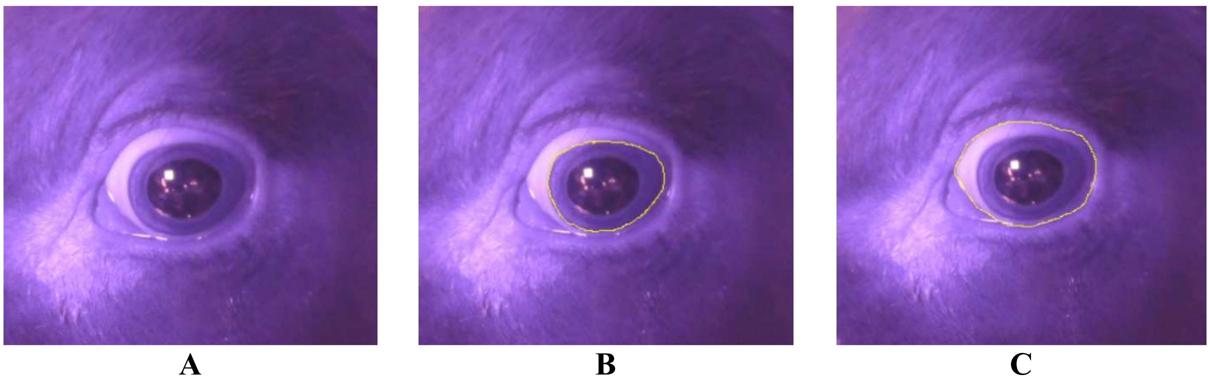

Figure. 2.1. Eye white percentage calculation procedure. (A) original image; (B) traced area of the iris; (C) traced area of total eye. EW was than calculated using: EW = (1- [area of the iris/area of the total eye]) × 100.

The eye temperature was measured from IRT images using Fluke SmartView v4.3 (Fluke Process Instruments INC, Plymouth, MN, UK). Temperatures were measured within an oval area covering the entire eye and approximately 1 cm around the eyelids (Stewart et al., 2008; Stewart et al., 2005). Figure 2.2 illustrates the areas used to obtain temperature measurement. The maximum eye temperature (IRT_{MAX}), minimum eye temperature (IRT_{MIN}), and average eye temperature (IRT_{AVG}) were extracted from the measuring area.

Eye white percentage and IRT images that were out of focus or cattle had their head oblique to the image were removed from the analysis.

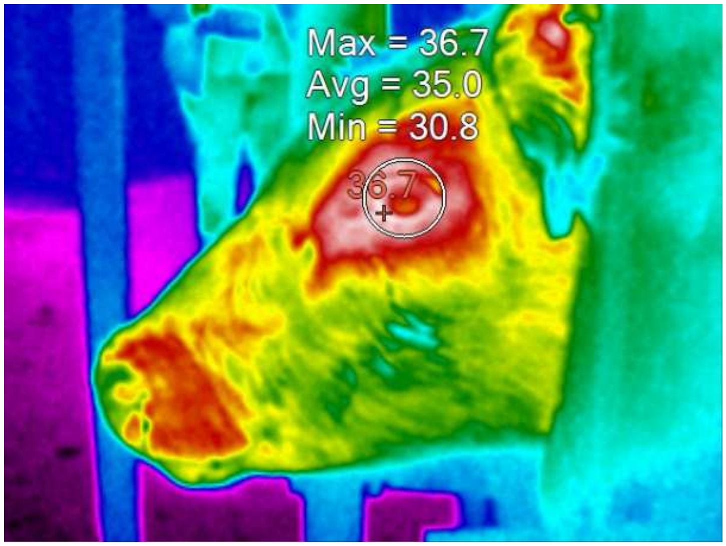

Figure. 2.2 Infrared image and the areas used to obtain temperature measurements for beef cattle.

2.3.4. Statistical Analysis

All data were analyzed using SAS 9.4 (SAS Institute, Inc., Cary, NC) and results were considered statistically significant at $P < 0.05$. Summary statistics were generated using the MEANS procedure to identify potential outliers and overall statistics of each eye trait (n = 4), which included grouping based on date of evaluation (n = 2), primary breed (n = 2; the fraction of that breed in a calf that was 50% or greater based on known pedigree), sex (n = 2), and period of day (morning, afternoon, evening) nested within date of evaluation (n = 5). Pearson and Spearman correlation coefficients were generated using the CORR procedure for eye traits with other subjective (DS, TS, QBA) and objective (FPSS) temperament measures (n = 16). Furthermore, relationships of other subjective (DS, TS, QBA) and objective (FPSS) temperament measures with ET and IRW traits were assessed using the MIXED procedure that included a base model of fixed effects of primary breed, sex, and period nested within date of evaluation and random effect of animal for each IRT and EW trait. Normality of models were confirmed using residual diagnostic panels. Thermal eye (IRT) traits also supported the inclusion of age at evaluation as a fixed covariate. To this base model, categorical groupings of temperament scores from DS, TS, QBA, and FPSS were fitted independently to determine significant association. Creating categories for each subjective and objective temperament measure outside of eye traits were either based on the original scale (e.g., DS was grouped based on the 1 to 6 scale), clear separation of scores (e.g., TS was grouped into 2 categories based on non-temperamental scores of 1 and 2 and temperamental scores of anything greater than 2), or quartile breakdown of that trait (e.g., QBA each had 4 categories). Significant effects had least square means generated and pairwise comparisons were adjusted using Tukey-Kramer method to control experiment-wise error.

2.4. Results

2.4.1. Summary Statistics

The mean, SD, minimum, median and maximum for TS, DS, EW, IRT_{MIN}, IRT_{AVG}, IRT_{MAX}, QBA attributes and SSD, CVSSD are presented in Table 2.2. Pearson and Spearman correlation coefficients between eye traits (EW, IRT_{MIN}, IRT_{AVG}, IRT_{MAX}) and other temperament evaluation methods can be found in Table 2.3. Pearson and Spearman correlation coefficients within eye traits (EW, IRT_{MIN}, IRT_{AVG}, IRT_{MAX}) are presented in Table 2.4.

2.4.2. Relationships Through Correlation Coefficients

Relationship of DS, TS, QBA attributes, and FPSS measures were previously described by Yu et al. (2020). Low to moderate ($r > 0.01$, $r < 0.30$) significant correlation coefficients were observed between IRT temperament and EW traits with other subjective and objective temperament scoring methods (Table 2.3). For example, a positive moderate correlation between EW and DS was observed ($P \leq 0.0001$), indicating that as DS increased (i.e., animal became more agitated or aggressive), so too did EW ($P \leq 0.0001$). When focusing on QBA attributes, consistent positive correlation coefficients (r = 0.10 to r = 0.17) were found between active, agitated, distressed, fearful, and irritated. Likewise, both TS and SSD has similar positive correlation coefficients with EW as QBA attributes ($P \leq 0.0001$). Of the three IRT traits, IRT_{MAX} had the greatest number of significant correlation coefficients with other temperament scoring systems. Measure of IRT_{MAX} had opposite relationships to QBA than EW. For example, consistent negative correlation coefficients (r = -0.11 to r = -0.12) were found between IRT_{MAX} and active, distressed, and fearful. All correlation coefficients between IRT traits and EW and among IRT were significant ($P \leq 0.0001$). The lower correlation coefficients between EW and IRT traits support the different relationships observed with other temperament scoring methods ($P \leq 0.0001$).

Table 2.2. Descriptive statistics of temperament score (TS), docility score (DS) eye white percentage (EW), and eye temperature (ºC) for all cattle

Variable	n	Mean	SD	Median	Minimum	Maximum
EW	393	0.34	0.057	0.34	0.20	0.50
IRT_{MIN}	391	28.44	2.744	28.70	20.70	35.80
IRT_{AVG}	393	33.49	1.259	33.50	30.30	36.70
IRT_{MAX}	393	36.30	0.935	36.30	33.80	39.20
DS	403	1.38	0.490	1.25	1	4
TS	403	1.78	0.782	1.67	1	5
Active	403	49.30	26.358	46.48	2.75	121.49
Relaxed	403	74.24	34.642	80.75	3.89	131.30
Fearful	403	22.46	15.820	18.31	2.84	100.53
Agitated	403	26.88	23.156	19.05	2.59	119.99
Calm	403	48.33	35.675	85.28	2.20	131.11
Attentive	403	48.31	18.705	48.28	4.34	98.55
Positively Occupied	403	28.76	17.688	26.18	2.08	73.11
Curious	403	24.42	15.869	21.50	2.53	75.04
Irritated	403	22.17	19.528	15.96	2.16	117.63
Apathetic	403	49.47	31.400	16.95	2.50	133.83
Happy	403	34.66	23.519	33.39	1.63	102.88
Distressed	403	7.24	8.481	3.90	0.62	60.79
SSD	398	37.11	17.871	35.03	3.73	123.26
CVSSD	398	0.068	0.0333	0.064	0.007	0.211

Table 2.3. Pearson ($\hat{\rho}$) and Spearman Rank ($\hat{r}$) correlation coefficients for infrared thermography (IRT) temperature and eye white percentage (EW) traits with other temperament scoring methods[1]

Temperament Trait[2]	Correlation	EW	IRT_{MIN}	IRT_{AVG}	IRT_{MAX}
DS	$\hat{\rho}$	0.258***	-0.045	-0.039	-0.023
	$\hat{r}$	0.250***	0.004	-0.003	0.015
TS	$\hat{\rho}$	0.179**	0.043	-0.048	-0.064
	$\hat{r}$	0.141**	0.069	-0.042	-0.051
Active	$\hat{\rho}$	0.120**	0.045	-0.058	-0.112**
	$\hat{r}$	0.096*	0.045	-0.056	-0.095*
Relaxed	$\hat{\rho}$	-0.077	-0.030	0.081	0.105**
	$\hat{r}$	-0.057	-0.030	0.076	0.083
Fearful	$\hat{\rho}$	0.130**	0.036	-0.068	-0.110**
	$\hat{r}$	0.104**	0.060	-0.062	-0.110**
Agitated	$\hat{\rho}$	0.158**	0.114**	0.034	-0.009
	$\hat{r}$	0.142**	0.104**	0.019	-0.010
Calm	$\hat{\rho}$	-0.094*	-0.046	0.067	0.101**
	$\hat{r}$	-0.076	-0.037	0.068	0.079
Attentive	$\hat{\rho}$	0.025	0.149**	0.123**	0.042
	$\hat{r}$	0.019	0.179**	0.149**	0.062
Positively Occupied	$\hat{\rho}$	-0.019	-0.019	0.054	0.065
	$\hat{r}$	-0.023	-0.005	0.070	0.060
Curious	$\hat{\rho}$	0.063	0.103**	0.149**	0.129**
	$\hat{r}$	0.061	0.104**	0.142**	0.123**
Irritated	$\hat{\rho}$	0.166**	0.037	-0.036	-0.050
	$\hat{r}$	0.105**	0.093*	0.006	-0.012
Apathetic	$\hat{\rho}$	-0.176**	-0.142**	-0.037	0.008
	$\hat{r}$	-0.166**	-0.152**	-0.037	-0.005
Happy	$\hat{\rho}$	-0.062	-0.050	0.078	0.115**
	$\hat{r}$	-0.039	-0.051	0.081	0.101**
Distressed	$\hat{\rho}$	0.148**	-0.016	-0.066	-0.058
	$\hat{r}$	0.076	-0.018	-0.119**	-0.116**
SSD	$\hat{\rho}$	0.113**	0.010	-0.037	-0.086*
	$\hat{r}$	0.096*	0.004	-0.058	-0.092*
CVSSD	$\hat{\rho}$	0.079	0.041	-0.033	-0.091*
	$\hat{r}$	0.064	0.040	-0.039	0.090*

[1]Highly significant ($P < 0.0001$) are indicated as ***, significant ($P < 0.05$) are indicated as **, and tendency ($P < 0.10$) are indicated as *.

[2]Temperament traits include docility score (DS), temperament score (TS), positive and negative oriented Qualitative Behavior Assessment attributes, and weight data from the four-platform standing scale.

Table 2.4. Pearson (top diagonal) and Spearman Rank (bottom diagonal) correlation coefficients of infrared thermography (IRT) temperature and eye white percentage (EW) traits.[1]

	EW	IRT_{MIN}	IRT_{AVG}	IRT_{MAX}
EW		0.106**	0.185***	0.292***
IRT_{MIN}	0.121**		0.777***	0.485***
IRT_{AVG}	0.198***	0.796***		0.824***
IRT_{MAX}	0.302***	0.529***	0.822***	

[1]Highly significant (P < 0.0001) are indicated as ***, significant (P < 0.05) are indicated as **, and tendency (P < 0.10) are indicated as *.

2.4.3. Relationship Through Modeling

All models were found normal through residual QQ plots and histograms. The base model per eye trait included fixed effects of primary breed, sex, and period of day within date of evaluation. Although all of these fixed effects were not significant for all traits, they are common systematic effects included in statistical models for temperament traits (e.g., Yu et al., 2020). Investigation of model fit criteria (e.g., AIC and BIC) for each of these fixed effects when estimation method was set to maximum likelihood showed that the model was not hindered or improved dramatically by fitting these fixed effects, therefore they were included for consistency across studies. The same outcome was shown when testing animal as a random effect using restricted maximum likelihood estimation for model fit criteria. Furthermore, thermal eye traits (IRT_{MIN}, IRT_{AVG}, IRT_{MAX}) showed improvement in model fit statistics when including the fixed covariate of age at evaluation. Least square means and standard errors are reported in Table 2.5 for all base model effects. Only period nested within date of evaluation was significant for all traits, where values were typically numerically or significantly higher in afternoon periods than other periods (P < 0.05) (Table 2.5).

Table 2.5. P-values, least square means, and standard errors for fixed effects included in the base model for eye traits[1]

Model Effect	EW	IRT_{MIN}	IRT_{AVG}	IRT_{MAX}
Primary Breed	0.448	0.163	0.901	0.957
Angus	0.345 + 0.003	28.25 + 0.13	33.35 + 0.06	36.22 + 0.05
Hereford	0.340 + 0.006	27.86 + 0.24	33.34 + 0.11	36.22 + 0.09
Sex	0.051	0.782	0.305	0.226
Heifer	0.337 + 0.005	28.02 + 0.18	33.29 + 0.08	36.17 + 0.07
Steer	0.348 + 0.004	28.09 + 0.17	33.40 + 0.08	36.27 + 0.07
Period(Day)	0.0002	<0.0001	<0.0001	<0.0001
Day 1, Morning	0.365 + 0.006^{a}	25.91 + 0.33^{d}	32.44 + 0.15^{d}	35.92 + 0.13^{d}
Day 1, Afternoon	0.356 + 0.006^{a,b}	30.61 + 0.24^{a}	34.52 + 0.11^{a}	36.88 + 0.09^{a}
Day 1, Evening	0.334 + 0.007^{b,c}	27.18 + 0.28^{c}	33.27 + 0.13^{c}	36.28 + 0.11^{b,c}
Day 2, Morning	0.327 + 0.006^{c}	27.17 + 0.26^{c}	32.68 + 0.12^{d}	35.75 + 0.10^{c,d}
Day 2, Afternoon	0.337 + 0.006^{b,c}	29.25 + 0.25^{b}	33.87 + 0.11^{b}	36.41 + 0.10^{b}
Age, days	--	0.045	0.206	0.419

^{a,b,c,d}Supercripts that differ within a column and within a model effect differ ($P < 0.05$).
[1]P-values are reported per eye trait on the main line for that particular model effect. Eye traits include proportion of white of the eye measured (EW) and the minimum, average, and maximum thermal eye temperature (IRT_{MIN}, IRT_{AVG}, IRT_{MAX}, respectively, □).

To create discrete categories per temperament trait for DS and TS, their original scales were used to group individual calf scores. For DS, individuals that scored, on average across 3 to 4 evaluators, with a 0.75 increment were rounded up to the next score. Otherwise, their whole number was used (e.g., 1.50 was scored as a 1). This resulted in only 4 of 6 categories with group sizes of 313, 70, 10 and 2 for scores of 1 to 4, respectively. For TS, the natural break in the scale (1 to 2 vs. 4 to 5) was used to create two categories (non-temperamental, NT vs. temperamental, T). This resulted in groups sizes of 352 and 42 for NT and T, respectively. For QBA attributes and four-platform standing scale measures, quartile placement was used to categorize scores into 1 of 4 groups, with 1 being the lower scores and 4 being the higher scores. Distribution per trait is presented in Table 2.6 and resulted in relatively even sample sizes per category.

Table 2.6. Distribution of calves and summary statistics per category for Qualitative Behavior Assessment (QBA) attributes and four-platform standing scale (FPSS) measures[1]

Temperament traits[2]		N per group	Minimum	Q1	Q2	Q3	Maximum
Positive QBA	Apathetic	96 to 100	2.50	23.84	46.95	75.14	133.83
	Calm	97 to 99	2.20	50.24	85.28	108.87	131.11
	Curious	96 to 99	2.53	11.52	21.50	36.22	75.04
	Happy	97 to 99	1.63	13.36	33.39	54.38	102.88
	Positively Occupied	96 to 100	2.08	13.77	26.18	40.13	73.11
	Relaxed	96 to 99	3.89	45.97	80.75	105.42	131.30
Negative QBA	Active	96 to 101	2.75	26.36	46.48	68.96	121.49
	Agitated	96 to 100	2.59	8.75	19.05	37.45	119.99
	Attentive	97 to 100	4.34	34.64	48.28	61.21	98.55
	Distressed	96 to 100	0.62	2.55	3.90	7.92	60.79
	Fearful	95 to 100	2.84	9.38	18.31	32.34	100.53
	Irritated	93 to 101	2.16	7.47	15.96	30.07	117.63
FPSS	SSD	95 to 103	3.73	24.00	35.03	46.18	123.26
	CVSSD	94 to 103	0.01	0.04	0.06	0.08	0.21

[1]Q1 to Q3 refer to quartile cut-offs for the 25th, 50th, and 75th percentiles. QBA are scored on a 136 mm visual analog line, therefore expected quartile breakdowns would be Q1 = 34, Q2 = 68, and Q3 = 102. The number per quartile group (N per group) is the range of calves that had records in those quartile groups across eye traits.

[2]Temperament traits include positive and negative oriented Qualitative Behavior Assessment (QBA) attributes, and weight data from the four-platform standing scale (FPSS) that included the standard deviation of weight over a set of 500 records (SSD) and its coefficient of variation (CVSSD).

When fitting these subjective and objective temperament trait categories as fixed effects independently, there were only 8 instances of significant modeled effects (Table 2.7). An additional 4 instances showed tendencies of association of modeled and response variables (Table 2.7).

Table 2.7. P-values when different categorical temperament traits were fitted independently of each other as fixed effects for eye traits.[1]

Temperament Trait[2]		EW	IRT_{MIN}	IRT_{AVG}	IRT_{MAX}
DS		**0.005**	0.217	0.322	0.254
TS		**0.004**	0.345	0.799	0.394
Positive QBA	Apathetic	0.139	**0.018**	0.914	0.764
	Calm	0.570	0.512	0.333	0.110
	Curious	0.826	0.181	0.076	**0.048**
	Happy	0.352	0.484	**0.019**	**0.008**
	Positively Occupied	0.173	0.374	**0.016**	0.105
	Relaxed	0.827	0.472	0.128	0.160
Negative QBA	Active	0.332	0.537	0.089	0.088
	Agitated	0.119	0.201	0.626	0.329
	Attentive	0.435	0.526	0.620	0.427
	Fearful	0.287	0.206	0.422	**0.038**
	Irritated	0.268	0.178	0.144	0.160
	Distressed	0.226	0.202	0.146	0.319
FPSS	SSD	0.164	0.752	0.763	0.311
	CVSSD	0.108	0.815	0.635	0.073

[1]Significant ($P < 0.05$) are bolded and underlined whereas tendencies ($P < 0.10$) are underlined for each eye trait, including proportion of white of the eye measured (EW) and the minimum, average, and maximum thermal eye temperature (IRT_{MIN}, IRT_{AVG}, IRT_{MAX}, respectively, □).

[2]Temperament traits include docility score (DS), temperament score (TS), positive and negative oriented Qualitative Behavior Assessment (QBA) attributes, and weight data from the four-platform standing scale (FPSS) that included the standard deviation of weight over a set of 500 records (SSD) and its coefficient of variation (CVSSD).

For EW, the only two traits that indicated significant association were DS and TS categories (Table 2.7). Even with lower sample sizes in more temperamental categories, differences in the proportion of the sclera that was visible increased in both instances, which was also supported by a linear contrast conducted on DS categories 1 and 2 compared to DS categories of 3 and 4 ($P = 0.021$).

Table 2.8. Least square means and standard errors based on docility (DS) and temperament (TS) score categories for the proportion of white of the eye measured on a calf[1]

	Category			
Trait	1	2	3	4
DS	0.338 ± 0.004[a]	0.352 ± 0.007[a,b]	0.385 ± 0.018[b]	0.440 ± 0.055[a,b]
TS	0.339 ± 0.004[b]	0.366 ± 0.009[a]	--	--

[a,b]Superscripts that differ within a row differ ($P < 0.05$).

[1]DS category is based on the original 1 to 6 scale, where this population only had scores fall into the first 4 categories. TS categories were divided based on non-temperamental scores (1 and 2, listed as category 1) and more temperamental scores (scores greater than 2, listed as category 2).

For thermal eye traits (IRT_{MIN}, IRT_{AVG}, and IRT_{MAX}), five QBA attributes were found to have significant associations (Table 2.7). Positively oriented QBA indicated a general increase in thermal traits as the expression of that attribute increased, whereas negatively oriented QBA indicated a general decrease in thermal traits as the expression of that attribute increased. For example, a linear contrast between averages of categories 1 and 2 compared to categories 3 and 4 for happy on IRT_{AVG} and IRT_{MAX} clearly showed that happier animals had higher thermal temperatures ($P = 0.006$ and 0.001, respectively). For IRT_{MIN}, more apathetic animals (categories 3 and 4) had lower thermal temperatures on average compared to less apathetic animals (categories 1 and 2; $P = 0.04$).

Table 2.9. Least square means and standard errors based on significant Qualitative Behavior Assessment attribute categories for thermal eye traits.[1]

		Category			
Thermal Eye Trait	Temperament trait	1	2	3	4
IRT_{MIN}	Apathetic	$28.70 + 0.25^{a}$	$27.90 + 0.23^{a,b}$	$27.99 + 0.24^{a,b}$	$27.61 + 0.27^{b}$
IRT_{AVG}	Positively occupied	$33.15 + 0.11^{b}$	$33.48 + 0.11^{a,b}$	$33.54 + 0.11^{a}$	$33.20 + 0.11^{a,b}$
	Happy	$33.14 + 0.11^{b}$	$33.26 + 0.11^{a,b}$	$33.59 + 0.11^{a}$	$33.40 + 0.11^{a,b}$
IRT_{MAX}	Fearful	$36.33 + 0.09^{a,b}$	$36.34 + 0.09^{a}$	$36.23 + 0.09^{a,b}$	$36.00 + 0.09^{b}$
	Curious	$36.02 + 0.09^{b}$	$36.28 + 0.09^{a,b}$	$36.34 + 0.09^{a}$	$36.27 + 0.09^{a,b}$
	Happy	$36.02 + 0.09^{b}$	$36.13 + 0.09^{a,b}$	$36.33 + 0.09^{a,b}$	$36.40 + 0.09^{a}$

[a,b]Superscripts that differ within a row differ ($P < 0.05$).

[1]Eye traits include: proportion of white of the eye measured (EW) and the minimum, average, and maximum thermal eye temperature (IRT_{MIN}, IRT_{AVG}, IRT_{MAX}, respectively, □).

Investigating significant effects provided some insight into the relationship of the eye traits with temperament (Table 2.9), but significant differences were often numerically small (i.e., a small effect size). This brings into question how effective it would be to use these eye traits in the field.

2.5. Discussion

Computer vision technology has been used to evaluate animal behavior in the past. In 2008, Cangar et al. (2008) used an automatic real-time computer vision system to monitor the locomotion and posture behavior of pregnant cows prior to calving (Cangar et al, 2008). Compared to our study of trying to predict the behavior in different grade levels, Cangar only used the image analysis method to predict eating, walking, lying or drinking behavior. There is limited research that uses thermal imaging technology to evaluate beef cattle behavior. In 2019, researchers in Brazil used thermal technology to measure body temperature of beef cattle in a crop-livestock-forestry environment system (Giro et al., 2019). They monitored the body temperature change on cattle in different activity locations throughout the year, but did not use thermal temperature as a predictor for the behavior grading system. Other experiments have shown that EW was an appropriate indicator of temperament (Core et al., 2009; Khasawneh, 2016), therefore thermal eye temperature could be used as an indicator to evaluate beef cattle temperament because of the statistical association between temperature and EW. This may be because EW and thermal eye temperature traits are both stress level indicators of the animal. The mean of EW in this study was 34%; higher than the baseline values of 25% presented by (Sandem et al., 2002). This means cattle opened their eyes wider in the current experiment due to potential genotype difference among the experimental cattle. In physiological terms, an animal opening their eyes more widely is linked to the mechanism behind pupil dilatation (Cunningham and Klein, 2007). Sandem et al. (2002) suggested that showing the white of the eye, brought about by withdrawal of the eyelids, is a sign of frustration or other stress reaction. In such a situation, the reason is theorized that the animal wants to be able to see clearly to detect solutions to the problem. Adrenaline released by the sympathetic nervous system causes the eyes to open up more widely, which means more eye white exposed when stress level goes up (Hardee et al., 2008). The measure of thermal eye temperature as a stress indicator has been investigated in several studies (Foster and Ijichi, 2017; Gjendal et al., 2018; Schaefer et al., 2004; Stewart et al., 2007; Valera et al., 2012). In biological terms, the temperature of the extremities and skin are largely dependent on the amount of blood flowing through peripheral vessels. When the animal's sympathetic nervous system is activated due to stress, heart rate increases and blood flow is redistributed (Hsieh et al., 1990). The eye and its surrounding skin tissue provide an image that may reflect the sympathetic-vagal balance of the animal (Stewart et al., 2005), whereby blood flow in the eyes will increase when the animal is experiencing stress; hence the temperature of the eye increases. We hypothesized that thermal eye temperature and EW both reflected the different physiological responses of cattle associated with their different temperament profile while being exposed to a consistent stressful situation (capture). This study found that the sympathetic nervous system is stronger in aggressive animals (DS and TS), thus they showed more eye white. In this study, the anatomical location of IRT_{MAX} was always located in the medial posterior palpebral border of the lower eyelid and the lacrimal caruncle. This location is consistent with work completed by (Stewart et al., 2008). Contrary to IRT_{MAX}, the IRT_{MIN} may have an anatomical location outside of the eyelid; which may be the reason for the lower correlation coefficient with EW. The IRT_{AVG} is affected by both IRT_{MIN} and IRT_{MAX}, thus the correlation was intermediate. As IRT_{MAX} has the highest correlation coefficient and a fixed anatomical location in the eye itself, it could be the most consistently applicable indicator for accessing cattle temperament.

There were no statistically significant relationships of IRT_{MIN}, IRT_{AVG} IRT_{MAX} with TS or DS. The correlations between EW and DS and between EW and TS were low, 0.005 and 0.004 at the $P < 0.05$ level. Eye white percentage and thermal eye temperature traits (IRT_{MIN}, IRT_{AVG}, IRT_{MAX}) are objective evaluation methods, whereas TS and DS are subjective in nature. Low and insignificant correlations between subjective and objective temperament evaluation methods were also found in previous studies (Jones, 2013; Schwartzkopf-Genswein et al., 2012b; Stockman et al., 2012). This may be because the results of subjective methods can vary depending on the observers' experience and bias. Even detailed scoring instructions could not eliminate subjectivity in scoring (Lanier et al., 2000; Purcell et al., 1988). There was one study that found the FPSS had a moderate correlation level ($r = 0.42$) with the temperament score (Yu et al., 2020). The FPSS method, however, still requires cattle to be handled, and the ultimate goal of the current experiment was to identify an automated method of temperament evaluation that does not require cattle handling.

There were no statistically significant relationships of EW, IRT_{MIN}, IRT_{AVG} and IRT_{MAX} for SSD and CVSSD. That may be because of the differences of the test situations. Data of EW, IRT_{MIN}, IRT_{AVG} and IRT_{MAX} were collected when calves were restrained by chute, while FPSS were performed without any physical restraint. Diversities in animal handling may have influenced cattle temperament (Lanier et al., 2000), Sant'Anna and Paranhos da Costa (2013) and (Yu et al., 2020) reported the same association tendencies, in which traits/methods had the greatest/weakest associations when they were applied and collected under/without restrained conditions.

As previously mentioned, the associations of eye and QBA traits provide us some insight into the relationship of the eye traits with temperament. The QBA trait most closely associated with IRT_{MAX} was fearful, which was identified as a 'stressed' or 'irritated' score in previous studies (Sant'Anna and Paranhos da Costa, 2013; Stockman et al., 2012) that could increase stress level and be expressed as a nervous reaction. In our study, the IRT_{MAX} temperature decreased, in general, as the level of fearfulness increased (Table 2.9). Eye white percentage was not significantly correlated with any QBA attribute; this was also the case for FS and QBA attributes (Stockman et al., 2012). As Yu et al. (2020) identified, DS is a restrained method that did not align with non-restrained methods such as TS and QBA. Therefore, it is likely that EW and IRT traits also did not align with those measures for the same reason. Secondly, since calves were being evaluated in two different scenarios prior to evaluation of QBA, it is also likely that the stress of those handling situations are influencing QBA scores and making EW and IRT traits less related to them. This is a limitation of studies with several temperament evaluations placed on the calf. The reasons responsible for the low (or absence of) associations of eye measures with QBA traits could include many factors such as animal handling methods, environmental effects or breed types. One study showed the increased percentage of eye white can generally be seen as an indicator of activation of a motivational system, involving the need to monitor the environment carefully (Sandem et al., 2002). The EW values measured in our study were under the condition that cows were restrained in the chute, which could potential effect the correlation result because of the activation of a type of motivational system at a certain time period. Church et al. (2014) confirmed that modest wind speed and solar loading affected the variation in accuracy of the infrared thermography method on cattle. The study also discussed certain cattle breed’s coat color (black angus breed) appear to increase in temperature in summer compared to other lighter colored breeds. Another recent study on eye temperature relationship with cattle welfare showed inconsistencies across their different experiments and IRT statistical relationships due to different environmental conditions (Cuthbertson et al., 2020). The number of animals evaluated in the research population also could be a potential factor that influences the result. Core et al. (2009) used 48 heifers (group 1), 39 bulls (group 2), and 60 steers (group 3) and found the EW measurement was correlated with all three groups’ temperament scores ($r = 0.674$, 0.950 and 0.696, respectively). Another study showed only subjectively observed aggressive rear-end thrashing could be tested for correlation with the EW percentage when using 24 cows as experiment samples (Sandem et al., 2006). Future research must include breed, environment, and sample population as factors to validate the correlation relationship between EW values and beef cattle temperament.

2.6. Conclusion

This study evaluated the use of infrared thermography and computer vision technologies to predict beef cattle temperament. For infrared thermography method, maximum, average, and minimum eye temperature (IRT_{MIN}, IRT_{AVG}, IRT_{MAX}) were extracted from the thermal imagery data obtained by a hand-held thermal camera device. The percentage of the eye with the sclera visible in a digital image (eye white percentage, EW) was extracted by a modified near-infrared (NIR) camera. The result failed to show a strong relationship between thermal temperature imagery, EW and beef cattle temperament. Future studies should focus on two fronts, 1) acquiring larger numbers of cattle with greater variation in temperament to further explore the use of thermal imaging technology to predict beef cattle temperament and 2) rectal temperature should be added as an additional point of information relative to the physiological manifestation of the stress responses (such as cortisol, adrenaline, etc.) and indirect measurement for beef cattle temperament.

CHAPTER 3. EVALUATION OF BEEF CATTLE TEMPERAMENT USING VIDEO TECHNOLOGY[1]

3.1. Abstract

Cattle temperament has potential impacts on growth, carcass characteristics, and meat quality. Both objective and subjective measures have been used to assess temperament such as, temperament scores (TS), docility scores (DS), flight speed (FS), and exposed eye white percentage (EW). The subjective methods of determining TS are potentially stressful for the animals and labor-intensive. Video technology (VT) has the advantage of being noninvasive, automated, and remotely operable, compatible with cloud based complex algorithms, and facilitates immediate field deployment of results. The applied incorporation of VT has not been reported as a beef cattle temperament evaluation method, therefore, the objectives of this research were to (1) verify the feasibility of VT as a measure of beef cattle temperament and (2) assess the accuracy and reliability of the VT measurements in comparison to TS and DS. One hundred and seventy calves were video recorded in a squeeze chute. Simultaneously, DS and TS measurements for the same calves were determined. Maximum movement distance (MMD), average movement distance (AMD), and moving frequency (MF) were calculated and outputted according to the distances measured from the videos using an algorithm developed in this research. The Pearson correlation coefficient among MMD, AMD, MF, TS, and DS were calculated. Pearson correlation coefficients of MF versus TS was 0.264 ($P < 0.001$), MF versus DS was 0.438 ($P < 0.001$); AMD versus DS was 0.017 ($P = 0.838$), AMD versus TS was 0.107 ($P = 0.192$); MMD versus DS was 0.058 ($P = 0.481$); and MMD versus TS was 0.077 ($P = 0.350$).

[1] The adopted material in this chapter was co-authored by William Ogdahl and Xin Sun. William Ogdahl designed the prototype of the experiment setting and had primary responsibility for collecting beef cattle video data. William Ogdahl was the primary developer of the project idea that is advanced here.

This study showed MF could be a good indicator for accessing cattle temperament coupled with VT used as a quantitative tool with minimal equipment to assess temperament of beef cattle as a means to provide an objective method for selecting cattle exhibiting desirable temperament.

3.2. Introduction

Cattle temperament has been defined previously as an animal's response to a handler's actions or the given environment that the animal finds itself in at any given time during different life stages (Burrow, 1997; Grandin, 1993). Studies have shown that compared to cattle with aggressive temperament, cattle with docile temperament are easier to manage and handle (Boivin et al,. 1998; Grandin, 1993), and often have greater productivity (Turner et al., 2011), better meat quality (Cafe et al., 2011; Hall et al., 2011) and superior immune response to pathogens and parasites (Fell, Colditz, Walker, & Watson, 1999; Prayaga & Henshall, 2005). Thus, temperament is an economically important trait. Various temperament measurement techniques have been introduced over the decades, such as Temperament Scores（TS）(Sant'Anna, A.C., Paranhos da Costa, 2013), Docility Scores (DS) (BIF, 2020) or Flight Speed (FS) (H Burrow, Seifert, & Corbet, 1988), and Eye White Percentage (EW) (Core, Widowski, Mason, & Miller, 2009). Temperament score and DS are subjective methods evaluated and assigned to cattle by human evaluators subjectively. Comparing to objective evaluation methods, the benefits of subjective evaluation methods are that no additional equipment is needed, and evaluation can be conducted, and results obtained quickly. However, the reliability of assessment via subjective methods may be reduced because of observer's bias and (or) inexperience (Core et al., 2009; Curley Jr, Paschal, Welsh Jr, & Randel, 2006).

Objective temperament evaluation methods, such as FS and EW are not susceptible to human subjectivity and typically assumed to have acceptable reliability, but they do require the purchase, set-up, and maintenance of equipment (Parham, Tanner, Wahlberg, Grandin, & Lewis, 2019). In contrast, subjective measurements can be labor intensive and possess the potential of being stressful for the animals and possibly the evaluator.

Video technology, also known as VT, involves the recording and playing back of moving pictures and sound. In the case of the present research, VT refers to the use of video recordings obtained under specific conditions to assess beef cattle temperament. Video technology is a type of machine vision technology that has the advantages of integrating noninvasive automated remote sensing systems and cloud-based complex algorithms that can provide immediate field deployment of results (Cominotte et al., 2020). Also, compared to other objective temperament evaluating methods, VT requires fewer or simpler equipment and/or devices (such as a simple video recorder) to conduct temperament analysis. The use of VT has been employed to extract animal biometric measurements (Shakeri et al., 2018; Stewart, Wilson, Schaefer, Huddart, & Sutherland, 2017) and behaviors (Haley, Rushen, & Passillé, 2000). However, to date, no research has been conducted using video technology to evaluate cattle temperament. Thus, we hypothesize that VT will be able to measure beef cattle temperament and will replace or enhance other methods of cattle temperament score measurement.

The objectives of this study were to (1) verify the feasibility of VT as a measure of beef cattle temperament, and (2) assess proof of concept and potential reliability of the VT measurements by comparing those with TS and DS.

3.3. Materials and Methods

3.3.1. Animals

All cattle used in this research were managed according to the Federation of Animal Science Guide for the Care and Use of Agricultural Animals in Agriculture Research and Teaching (FASS, 2010). All procedures were reviewed and approved by the Institutional Animal Care and Use Committee of North Dakota State University (protocol A18005). Cattle management, experimental protocol, and husbandry are described in Chapter 2 and briefly below.

The experiments were conducted at the Central Grasslands Research Extension Center of North Dakota State University. Beef cattle image data and temperament measurement were conducted over two consecutive days in October of 2017. The handling facility and collection procedure were previously described in Hulsman Hanna et al. (2019) and Yu et al. (2020). One-hundred and fifty Calves approximately 5 to 6 months of age were separate from their dams and moved from their home pens to a handling facility. Groups of calves were moved through the raceway into the working facility to a silencer chute (Moly Manufacturing Inc., 101 Lorraine, KS). Each calf's head was restrained by a head gate for approximately one minute. At this time, DS, videos, eye images and temperature (Chapter 2) were recorded. Once the animals head was released, they were then moved directly onto the four-platform standing scale (FPSS; Pacific Industrial Scale, British Columbia, Canada) and weight was collected on each quadrant of the scale. Following FPSS, cattle were released to an open working pen for TS and Qualitative Behavioral Assessment (QBA) evaluation, this experiment did not use QBA however future implications should consider the objective properties as described in chapter 2.

3.3.2. Subjective Temperament Assessment

Subjective temperament scoring of docility score, temperament score and qualitative behavior assessment have been previously described (Chapter 2) and below in Table 3.1. For each subjective scoring method (DS, TS, QBA attributes), 4 evaluators scored each animal. The average across those evaluators per method were used in this study to reduce the influence of evaluator's experience, stress of evaluating individually, and personal bias.

Table 3.1. Criteria of evaluation scales used for temperament evaluations

Evaluation Method	Scales	Criteria
Docility Scores[1]	1	Docile. Mild disposition. Gentle and easily handled. Stands and moves slowly during processing. Undisturbed, settled, somewhat dull. Does not pull on head gate when in chute. Exits chute calmly.
	2	Restless. Quieter than average but may be stubborn during processing. May try to back out of chute or pull back on head gate. Some flicking of tail. Exits chute promptly
	3	Nervous. Typical temperament is manageable, but nervous and impatient. A moderate amount of struggling movement and tail flicking. Repeated pushing and pulling on head gate. Exits chute briskly
	4	Flighty (Wild). Jumpy and out of control, quivers and struggles violently. May bellow and froth at the mouth. Continuous tail flicking. Defecates and urinates during processing. Frantically runs fence line and may jump when penned individually. Exhibits long flight distance and exits chute wildly.
	5	Aggressive. May be similar to Score 4, but with added aggressive behavior, fearfulness, extreme agitation, and continuous movement which may include jumping and bellowing while in chute. Exits chute frantically and may exhibit attack behavior when handled alone.
	6	Very Aggressive. Extremely aggressive temperament. Thrashes about or attacks wildly when confined in small, tight places. Pronounced attack behavior.
Temperament Scores[2]	1	The animal walks slowly, allowing close proximity to the observer.
	2	Trots or runs for a few seconds while allowing moderate approximation with the observer.
	4	Runs the entire time of the observation, looks for an escape with constant tail movement, and does not allow close approximation with the observer.
	5	Runs the entire time of the observation, jumps against the fence, and tries to attack the observer.

1 Beef Improvement Federation. 2010
2 Conexão Delta, G. 2011

3.3.3. Objective Temperament Measurement with Video Technology

Description, operation, and data calculations for the four-platform scale assessment of beef cattle temperament were previously described in chapter 2.

3.3.3.1. Video Image Acquisition System.

A digital video recorder (Kodak PlaySport ZX5 Black, Eastman Kodak Company, Rochester, NY, US) was positioned vertically above of the silencer chute and perpendicular to the back of the calves to acquire and save video footage of the beef cattle within the working system (Figure 3.1). The total duration of videos was 417 minutes, frame rate was 30/s, resolution was 1920×1088 pixels. After one calf was recorded, the next calf took the position and was caught by the chute. All calves were identified individually by ear tag. The camera continued recording beginning when the first calf entered the raceway until the last calf left the chute, in order for a constant video to be cut into individual video segments at a later time. When the calf's head was secured, the rear body of the calf from neck to hip could move freely in directions perpendicular to the sideways. One strip of blaze orange tape was initially placed on the stationary parallel support bar of the working chute raceway, while another blaze orange strip was placed on each calf’s tailhead prior to chute entry (Figure 3.2). The orange tape was selected because of its high visibility in videos and images. The orange tape stuck on the tailhead of each calf (positioned as Marker 1 in Figure 3.2) was used to define length units and considered the starting point of distance measurements in the subsequent image analysis. The other orange tape stuck on a stationary support bar (positioned as Marker 2 in Figure 3.2) was used to define the end point of distance measured in the subsequent image analysis. The marker was removed from the calf once all data was collected as to not disrupt the animal’s natural reaction to the capture, and nor removal.

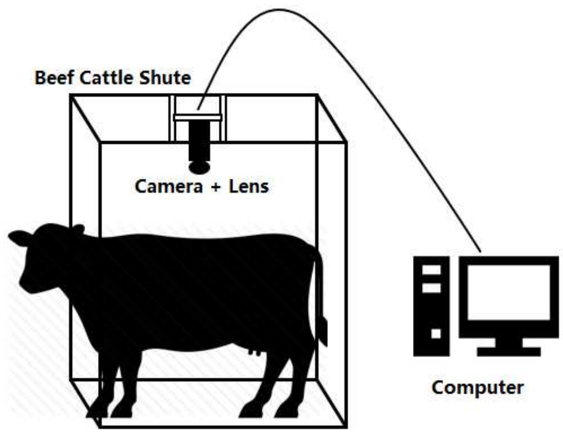

Figure 3.1. Beef Cattle Temperament Video Image Acquisition System

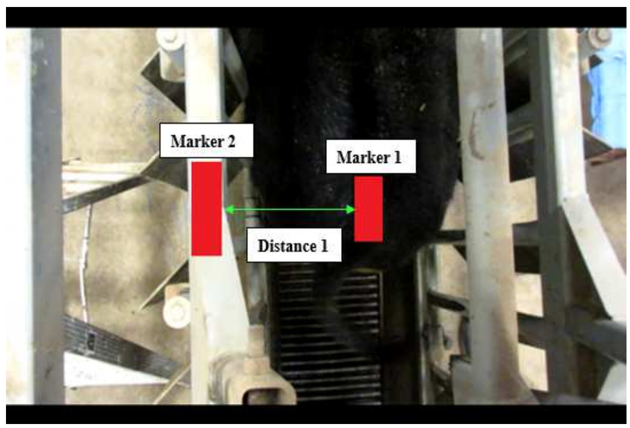

Figure 3.2. Beef Cattle Temperament Video Image Collection Method

3.3.3.2 Video Clip Extraction

A 5-second video clip for each calf was extracted from the original video. Each video clip began by capturing the moment the calf's head was secured by the chute. The length of the video clip was based on the efficiency of the subsequent processing program. According to our observations, most cattle tended to behave similarly after the head was caught for 5 seconds. Therefore, video recorded after 5s did not reveal any additional means for the delineation of beef cattle temperament.

3.3.3.3. Image Capture

Images were captured using the software of Snip & Sketch (Microsoft Corporation, Redmond, WA, US). Images were captured from video at 0.5s intervals starting at 0 seconds for each calf when the head was captured, as observed in the video. Thus, 11 frames were obtained for each animal from the 5s video clip. An example of 11 image frames saved in the observation process is shown in Figure 3.3. Although the head of calf was caught, its rear body（from neck to hip）could move freely. Therefore, the tape appeared at different positions in the 11 frames.

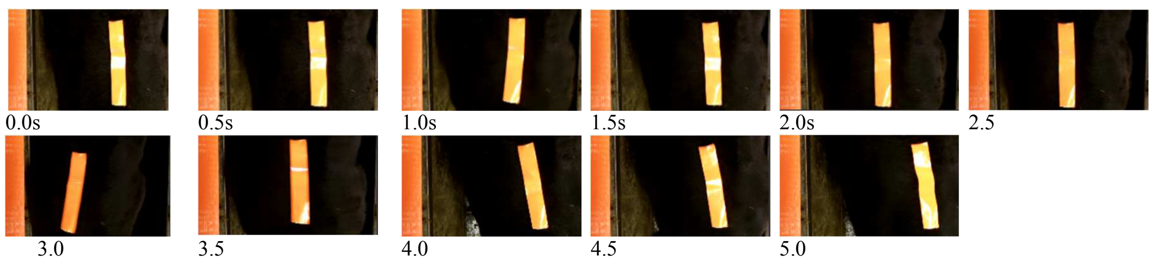

Figure 3.3. Example of captured images

Movement measurements for each calf were observed as the distances from marker 1 (back of the calf, Figure 3.2) to marker 2 (distance reference board, Figure 3.2) in each image. Differences were measured using Digimizer 4.2.6 software (MedCalc Software Ltd, Ostend, Belgium).

Before measuring, the length unit of each image was defined by the width (48mm) of the orange tape with the vertical distance most often starting from the top left corner of the cattle tailhead tape (marker 1) to the side edge of the orange tape on the stationary bar (marker 2) (it was observed that because of the differing lengths of body and placement of the marker, that the measuring could not always be form the top left corner of the tape.) Eleven distances were obtained from the 11 frames obtained for each calf. We defined D_i = as the distance measured in the *i*-th s image between marker 1 and marker 2 (Figure 3.2). After measuring, the distances were integrated into an algorithm for the automatic output/calculation of the different analytical parameters, described in the following section.

3.3.3.4. Video Technology Temperament Calculation

Three parameters were calculated to evaluate temperament. The first, Maximum Movement Distance (MMD) is the maximum distance change over all 0.5s intervals of each calf. Since the time interval between two adjacent images is 0.5s, the absolute value of the difference in distance measured from the two pictures will reflect the length of the calf moving in the horizontal direction within the 0.5s of captured video. The MMD was calculated using the following equation:

$$MMD = \max(|D_{(i+0.5)} - D_{\mathrm{i}}|)$$

Where: D_i = distance measured from the image at the i-th s, i = 0, 0.5, 1, 1.5, …, 5.

The second parameter, Average Movement Distance (AMD), is the average value of all distances within 0.5s intervals of each calf. Average Movement Distance was calculated using the following equation:

$$AMD = \frac{\sum_{i=0}^{10}(|D_{(i+0.5)} - D_i|)}{10}$$

Where: D_i = distance measured from the image at the i-th second, i=0, 0.5, 1, 1.5-5.

The third parameter, Movement Frequency (MF) was the number of times a calf would swing horizontally over a certain period of time. In this study, the period of time was 5s. It can be reflected by the changing trend of D_i whereby D_i increased or decreased relative to the cattle completing a swing in the corresponding time interval. Figure 3.4 is the graph of D_i over time of one calf. As show in Figure 3.4, D_i decreases first and then increases ($D_{0.0}$ to $D_{1.0}$), illustrating the calf's movement from 0.0s to 1.0s is to approach marker 1 first and then move away from it. In this case, we can conclude that the calf completed a swing. In another case of $D_{1.5}$ to $D_{2.5}$, D_i

increases but does not decrease. Therefore, we can conclude that the movement of the calf from 1.5s to 2.5s is to maintain a distance away from marker 1, but without changing the direction of movement. This cannot be regarded as a swing. To sum up, MF can be calculated by the following equation:

$$MF = \begin{cases} 0, \ i = 0 \\ \sum_{0.5}^{5} SW, \ i = 0.5 \sim 5 \end{cases}$$

Where: SW = the number of swings per calf in 5s, the initial value is 0, and:

$$SW = \begin{cases} 1, \ (D_i < D_{i+1} \ and \ D_i < D_{i+1}) or \ (D_i > D_{i+1} \ and \ D_i > D_{i+1}) \\ 0, \ else \end{cases}$$

Where: D_i = distance measured from the image at the i-th second, i = 0, 0.5, 1, 1.5, …, 5.

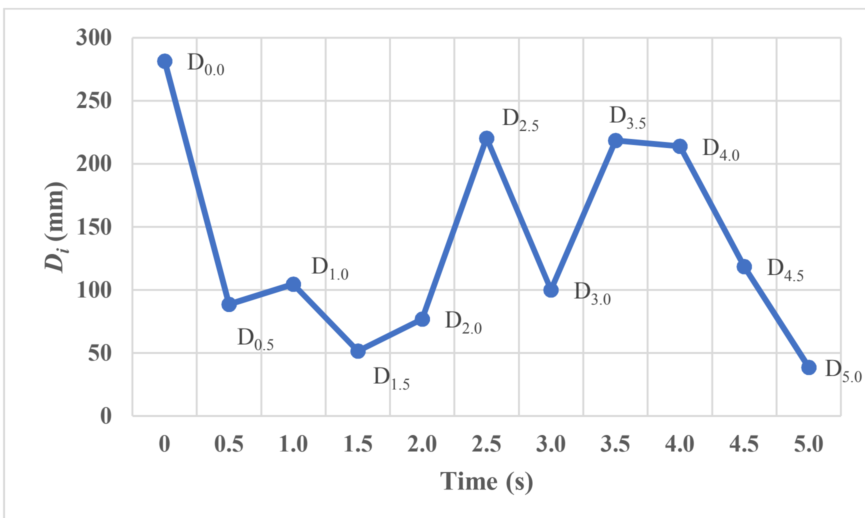

Figure 3.4. The distance (*D_i*) over time reflecting the calf's movement frequency

3.3.4. Statistical Analysis

A total of 1500 images were collected to calculate MMD, AMD and MF. The mean, SD, minimum and maximum for MMD, AMD, MF, TS and DS were calculated across calves. Pearson and Spearman Rank correlation coefficients were calculated among MMD, AMD, MF, TS, and DS. All data were analyzed using SPSS v19.0 (SPSS, Inc, Chicago, IL, USA) statistical package and results were considered statistically significant at $P < 0.01$.

3.4. Results

The mean, SD, minimum and maximum for MMD, AMD, MF, TS and DS are presented in Table 3.2. There was a large number of docile and few highly reactive animals observed in the present study.

Pearson correlation coefficients of MMD, AMD, MF, TS, and DS can be found in Table 3.3. There was a significant correlation coefficient between TS and DS (0.264, $P < 0.001$), but the correlation value (r) was low. Correlation coefficients of MF were statistically significant for TS (0.299, $P < 0.001$) and DS (0.438, $P < 0.001$). The correlation between DS and MF was moderately high ($r > 0.4$), indicating this parameter may be a good indicator for accessing beef cattle temperament in the same situation of DS

Table 3.2 Descriptive statistics of Maximum Movement Distance (MMD), Average Movement Distance (AMD), Moving Frequency (MF), Temperament Score (TS) and Docility Scores (DS) for all cattle in the study.

Variable	n	Mean	SD	Minimum	Maximum
DS	150	1.55	0.33	1.00	3.25
TS	150	2.16	0.90	1.00	4.75
AMD	150	39.77	17.60	5.09	111.39
MMD	150	110.52	48.37	15.00	274.90
MF	150	4.15	1.28	0.00	7.00

Table 3.3. Pearson correlation coefficients for Maximum Movement Distance (MMD), Average Movement Distance (AMD), Moving Frequency (MF), Temperament Score (TS) and Docility Scores (DS), N=150.

ITEM	TS	AMD	MMD	MF
DS	0.264** P<0.001	0.017 P=0.838	0.058 P=0.481	0.299** P<0.001
TS		0.107 P=0.192	0.077 P=0.350	0.438** P<0.001
AMD			0.788** P<0.001	0.363** P<0.001
MMD				0.228** P=0.005

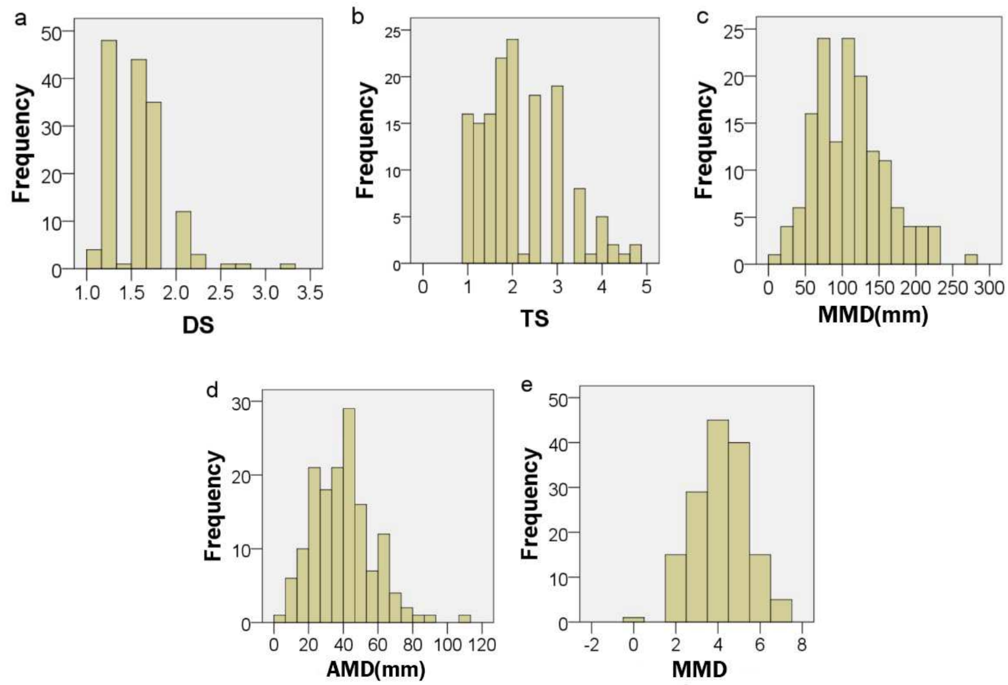

Figure 3.5. Frequency distribution of (a) Docility Scores, (b) Temperament Score, (c) Maximum Movement Distance; as well as (d) Average Movement Distance and (e) Moving Frequency, N=150.

3.5. Discussion

The distributions of DS, TS, MMD as well as AMD and MF for the herd evaluated are presented in Figure 3.5. Only MMD and AMD had a normal distribution according to the Kolmogorov-Smirnov test ($P > 0.05$); nevertheless, based on the graphical analysis, we assumed that the MF distribution was approximated to normal (Figure 3.5e). The relationship between DS/TS and AMD/MMD/MF are shown in Figure 3.6.

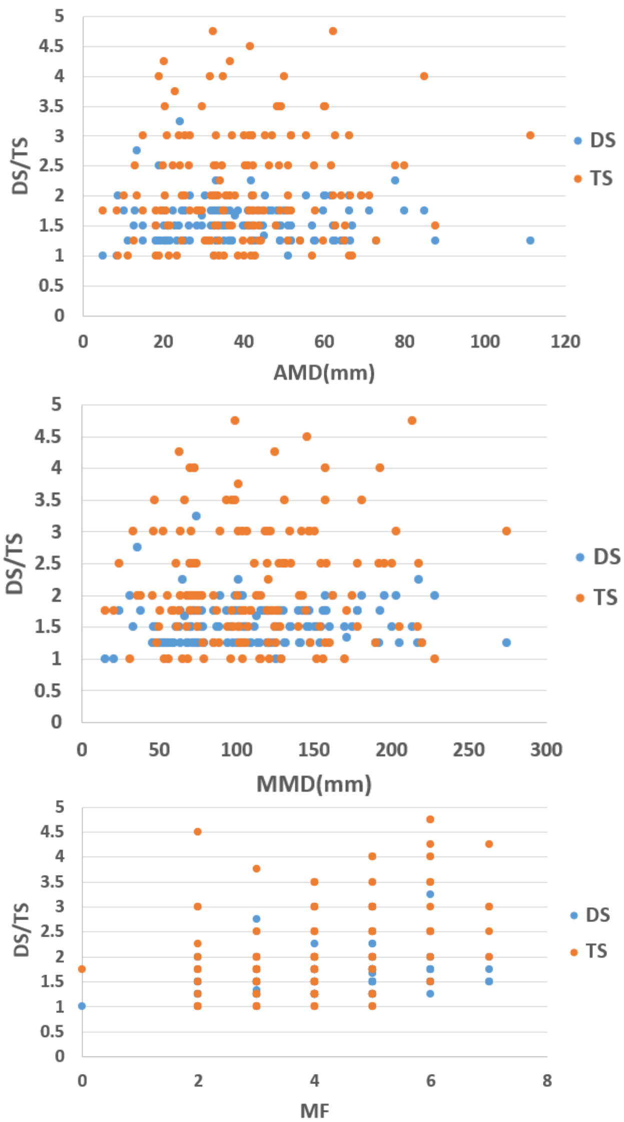

Figure 3.6. Relationships between Docility Score (DS)/Temperament Score (TS) and Maximum Movement Distance (MMD)/ Average Movement Distance (AMD)/ Moving Frequency (MF), N=150.

Computer vision technology has been used to evaluate animal behavior in the past. In 2008, Cangar et al. used automatic real-time computer vision systems to monitor the locomotion and posture behavior of pregnant cows prior to calving (Cangar et al, 2008). Compared to our study evaluating video technology to predict the behavior in different grade levels, Cangar used the image analysis method to predict eating, walking, lying, or drinking behavior.

The large number of docile (have a score 1 or 2) and the small number of highly reactive animals observed in the present study are consistent with the previous reported research (Gibbons, Lawrence, & Haskell, 2011; Halloway & Johnston, 2003; Kadel, Johnston, Burrow, Graser, & Ferguson, 2006; Kilgour, Melville, & Greenwood, 2006; Tőzsér et al., 2003). The authors were unable to identify any research to conclude that heifers were calmer than mature cows, steers, or bulls in the working chute. However, Grandin (1993) found that steers were generally calmer in a chute test than bulls.

The correlation between TS and DS (0.264, $P < 0.001$) (Table 3.3) was low but significant, which indicated that approximately 26% of observations were similar in correlation. This may result from the different experimental conditions. The differences in animal handling may have had an effect on cattle temperament (Lanier, Grandin, Green, Avery, & McGee, 2000). Docility score is designed and evaluated when animals are processed through the squeeze chute while TS is evaluated when animals leave the chute on their way to home pens. Another possible reason is both TS and DS are subjective measures. Other research such as Heiber (2016) have shown that subjective analysis animal temperament can vary depending on the observers, whereby the reliability of assessment dramatically decreased if the observers were not familiar with cattle behavior or not practiced in scoring (Lanier et al., 2000).

Correlations between MF and TS (0.438, $P < 0.001$), and between MF and DS (0.299, $P < 0.001$) were statistically significant. However, these correlations (between MF either with TS and DS) were higher than those between MMD and TS, and AMD and DS indicating that this parameter (MF) may be a better indicator for accessing temperament. From the results, we can see a positive correlation of MF with TS and DS, which means larger TS or DS scores corresponds to greater MF. This finding is consistent with the criteria of subjective temperament assessment methods (Curley Jr et al., 2006; Federation, 2010; Grandin, 1993), which defined aggressive and violent actions (continually shaking and thrashing) with higher numeric scores and calm and slight actions (no movement or quiet) with lower numeric scores.

In this study, there was no significant correlation between AMD and DS (0.017, P = 0.838), as well as AMD and TS (0.107, P = 0.192). Similarly, very low, insignificant correlations were found between MMD and DS (0.058, P = 0.481), as well as MMD and TS (0.077, P = 0.350). This was mainly because the MMD and AMD are related to the physical characteristics of cattle. After the calf's head is caught, its rear body makes a roughly circular movement around the neck, the radius of the circle is the body length of calf. This made MMD and AMD proportional to the body length of the calf and weakened their representation of the intensity of movements of test cattle. Also, the leg length of the calf may play the same role in this aspect. Another effect is the position of the tape. The closer the tape stuck to the cow's hip, the larger the MMD value will be acquired. Finally, the MMD and AMD may be averaged because of circular movement of the rear body. For the interval of capturing images from video is 0.5s, some distances may miss in images when the cattle moved fast. Unlike MMD and AMD, MF accumulates the trend of distance changes instead of size, therefore it is not sensitive to the size of distance and is not affected by the physical characteristics of cattle and the position of the tape. So, it is significantly related to TS and DS). The strong association may be due to the fact that both parameters are relatively similar and are derived from the same source data. It is conceivable that MMD and AMD will be effective predictors under similar physical conditions and minor image capturing intervals.

There were no statistically significant relationships found between AMD for DS (0.017, P = 0.838) and TS (0.107, P = 0.192), neither between MMD for DS (0.058, P = 0.481) and TS

(0.077, P = 0.350), meaning that MMD and AMD should not be used to evaluate temperament according to this study. However, MMD was strongly associated with AMD and the values were highly significant (0.788, P < 0.001 Correlations between MF and MMD (0.228, P = 0.005) and AMD (0.363, P < 0.001) were moderate and significant.

Although MMD and AMD were not significantly correlated with TS and DS, MMD, AMD, and MF were significantly correlated with each other. Meanwhile, MMD showed a strong correlation with AMD (0.788, P < 0.001) and a relatively low correlations with MF (0.228, P = 0.005). However, AMD showed a moderate correlation with MF (0.363, P < 0.001) and showed a strong correlation with MMD (0.788, P < 0.001). This is reasonable since both MMD and AMD are similar and derived from the same data population. The change in MF indicates the change in moving distance, which will be accumulated into the calculation of AMD. As the MF increases, the number/frequency of distance changes increases within 5s, resulting in increasing MF. It proves that the cattle must move faster in each changing interval; faster moving speeds usually result in greater MMD.

3.6. Conclusion

Research utilizing video technology for the assessment of beef cattle temperament is in its infancy and merits further analysis. Because docility and temperament scoring are both subjective measures, research exploring the relationships between video technology-based measurements and other objective measurements (such as the relationship with flight speed and exposed eye white percentage) is warranted. Also, video technology score calculating is automatic, however distance measurements rely on manual software, which is time-consuming. An algorithm must be developed to improve the processing efficiency and eliminate the need for manual intervention to meet commercial needs. Further, the impact of screenshot interval (we evaluated 0.05 second intervals) on evaluation accuracy must be determined to better understand the degree of accuracy needed for further research.

In order to make the final conclusion as to the relevance of video technology for use in the commercial beef production chain, we must test the technology's ability to assess economically important temperament traits that can be selected genetically. Research assessing the relationship between VT and cattle temperament and such economically important traits as meat tenderness, marbling, and back fat qualities should be conducted. In order for these relationships to be determined, many more animals would need to be included in this type of study. This study showed that VT has potential as a objective means to evaluate cattle temperament. The high significant correlation of Moving Frequency (MF) with Docility Scores (DS) indicates that MF could be a valuable indicator under the experimental conditions of this article. Video technology has the advantages of being noninvasive, automated, remote, and the complex algorithms can be "cloud based" (which will achieve immediate field deployment of results). Thus, video technology could be a more practical way of assessing cattle temperament where other measures cannot be measured. As a proof-of-concept experiment, the authors believe there is a future for VT in the production animal agricultural space.

3.7. Literature Cited

Bartolomé E, Sánchez MJ, Molina A, Schaefer AL, Cervantes I, Valera M. Using eye temperature and heart rate for stress assessment in young horses competing in jumping competitions and its possible influence on sport performance. Animal. 2013;7(12):2044-2053.

BIF, 2010. Guidelines for uniform beef improvement programs. Beef Improvement Federation, Verona, USA.

Boivin, X., Garel, J., Mante, A., & Le Neindre, P. 1998. Beef calves react differently to different handlers according to the test situation and their previous interactions with their caretaker. Applied Animal Behaviour Science, 55(3-4), 245-257.

Burrow, H., 1997. Measurements of temperament and their relationships with performance traits of beef cattle, Animal Breeding Abstract, pp. 477-495.

Burrow, H., Corbet, N., 2000. Genetic and environmental factors affecting temperament of zebu and zebu-derived beef cattle grazed at pasture in the tropics. Australian Journal of Agricultural Research. 51, 155-162.

Burrow, H., Seifert, G., Corbet, N., 1988. A new technique for measuring temperament in cattle. Proceedings of the Australian Society of Animal Production. Vol 17, 155.

Cafe, L., Robinson, D., Ferguson, D., Geesink, G., Greenwood, P., 2011a. Temperament and hypothalamic-pituitary-adrenal axis function are related and combine to affect growth, efficiency, carcass, and meat quality traits in Brahman steers. Domestic Animal Endocrinology. 40, 230-240.

Cafe, L., Robinson, D.L., Ferguson, D., McIntyre, B.L., Geesink, G., Greenwood, P., 2011b. Cattle temperament: persistence of assessments and associations with productivity, efficiency, carcass and meat quality traits. Journal of Animal Science 89, 1452-1465.

Church, J.S., Hegadoren, P., Paetkau, M., Miller, C., Regev-Shoshani, G., Schaefer, A., Schwartzkopf-Genswein, K., 2014. Influence of environmental factors on infrared eye temperature measurements in cattle. Research in veterinary science 96, 220-226.

Cominotte, A., Fernandes, A., Dorea, J., Rosa, G., Ladeira, M., van Cleef, E., . . . Neto, O. M. 2020. Automated computer vision system to predict body weight and average daily gain in beef cattle during growing and finishing phases. Livestock Science, 232, 103904.

Conexao Delta, G., 2011. Sumário de Touros: Hereford, Braford e Nelore 2011. GenSys: Brazil. http://www.gensys.com.br.

Core, S., Widowski, T., Mason, G., Miller, S., 2009. Eye white percentage as a predictor of temperament in beef cattle. Journal of Animal Science 87, 2168-2174.

Cunningham, J.G., Klein, B.G., 2007. Veterinary physiology. Saunders Elsevier Philadelphia.

Curley Jr, K., Paschal, J., Welsh Jr, T., & Randel, R. 2006. Exit velocity as a measure of cattle temperament is repeatable and associated with serum concentration of cortisol in Brahman bulls. Journal of Animal Science, *84*(11), 3100-3103.

Cuthbertson, H., Tarr, G., Loudon, K., Lomax, S., White, P., McGreevy, P., Polkinghorne, R., González, L.A., 2020. Using infrared thermography on farm of origin to predict meat quality and physiological response in cattle (Bos Taurus) exposed to transport and marketing. Meat Science 169, 108173.

Doube, M., Kłosowski, M.M., Arganda-Carreras, I., Cordelières, F.P., Dougherty, R.P., Jackson, J.S., Schmid, B., Hutchinson, J.R., Shefelbine, S.J., 2010. BoneJ: free and extensible bone image analysis in ImageJ. Bone 47, 1076-1079.

FASS, 2010. Guide for the care and use of agricultural animals in research and teaching. Federation of Animal Science Societies Champaign, IL, USA.

Fell, L., Colditz, I., Walker, K., Watson, D., 1999. Associations between temperament, performance and immune function in cattle entering a commercial feedlot. Australian Journal of Experimental Agriculture 39, 795-802.

Foster, S., Ijichi, C., 2017. The association between infrared thermal imagery of core eye temperature, personality, age and housing in cats. Applied Animal Behaviour Science 189, 79-84.

Gibbons, J. M., Lawrence, A. B., & Haskell, M. J. 2011. Consistency of flight speed and response to restraint in a crush in dairy cattle. Applied Animal Behaviour Science, *131*(1-2), 15-20.

Gjendal, K., Franco, N.H., Ottesen, J.L., Sørensen, D.B., Olsson, I.A.S., 2018. Eye, body or tail? Thermography as a measure of stress in mice. Physiology & behavior 196, 135-143.

Grandin, T., 1993. Behavioral agitation during handling of cattle is persistent over time. Applied Animal Behaviour Science 36, 1-9.

Haley, D., Rushen, J., & Passillé, A. d. 2000. Behavioural indicators of cow comfort: activity and resting behaviour of dairy cows in two types of housing. Canadian Journal of Animal Science, 80(2), 257-263.

Hall, N. L., Buchanan, D. S., Anderson, V. L., Ilse, B. R., Carlin, K. R., & Berg, E. P. 2011. Working chute behavior of feedlot cattle can be an indication of cattle temperament and beef carcass composition and quality. Meat science, 89(1)*,* 52-57.

Halloway, D., & Johnston, D. 2003. Evaluation of flight time and crush score as measures of temperament in Angus cattle. Paper presented at the Proceedings of the Association for Advancement of Animal Breeding Genetics.

Hardee, J.E., Thompson, J.C., Puce, A., 2008. The left amygdala knows fear: laterality in the amygdala response to fearful eyes. Social cognitive and affective neuroscience 3, 47-54.

Hieber, J. K., Temperament evaluation in Beef Cattle: Understanding evaluator bias within subjective measurements of docility score, temperament score, and qualitative behavioral assesment. M.S. diss. North Dakota State University, 2016

Hulsman Hanna, L. L., Hieber, J. K., Yu, H., Celestino, E. F. Jr., Dahlen, C. R., Wagner, S. A., et al. 2019. Blood collection has negligible impact on scoring temperament in angus-based weaned calves. Livestock Sci. 230:103835.

Hsieh, J.-C., Chan, K.-H., Lui, P.-W., Lee, T.-Y., 1990. Clinical application of infrared thermography in diagnosis and therapeutic assessment of vascular ischemic pain. Ma zui xue za zhi= Anaesthesiologica Sinica 28, 493-501.

Jones, T., 2013. Measurement of Temperament in Beef Cattle and its Relationships to Animal Production Characteristics.

Kadel, M. J., Johnston, D. J., Burrow, H. M., Graser, H.-U., & Ferguson, D. M. 2006. Genetics of flight time and other measures of temperament and their value as selection criteria for improving meat quality traits in tropically adapted breeds of beef cattle. Australian Journal of Agricultural Research, 57(9), 1029-1035.

Khasawneh, M., 2016. Evaluation and Assessment of Using E-Learning in Jordanian Universities, Managerial Perspective, In: Chova, L.G., Martinez, A.L., Torres, I.C. (Eds.), Iceri2016: 9th International Conference of Education, Research and Innovation, pp. 4716-4724.

Kilgour, R.J., Melville, G.J., Greenwood, P.L., 2006. Individual differences in the reaction of beef cattle to situations involving social isolation, close proximity of humans, restraint and novelty. Applied Animal Behaviour Science 99, 21-40.

King, D., Pfeiffer, C.S., Randel, R., Welsh Jr, T., Oliphint, R., Baird, B., Curley Jr, K., Vann, R., Hale, D., Savell, J., 2006. Influence of animal temperament and stress responsiveness on the carcass quality and beef tenderness of feedlot cattle. Meat science 74, 546-556.

Lanier, J., Grandin, T., Green, R., Avery, D., McGee, K., 2000. The relationship between reaction to sudden, intermittent movements and sounds and temperament. Journal of animal science 78, 1467-1474.

Macmillan, K., Colazo, M., Cook, N., 2019. Evaluation of infrared thermography compared to rectal temperature to identify illness in early postpartum dairy cows. Research in veterinary science 125, 315-322.

McGreevy, P., Warren-Smith, A., Guisard, Y., 2012. The effect of double bridles and jaw-clamping crank nosebands on temperature of eyes and facial skin of horses. Journal of veterinary behavior 7, 142-148.

Parham, J. T., Tanner, A. E., Wahlberg, M. L., Grandin, T., & Lewis, R. M. 2019. Subjective methods to quantify temperament in beef cattle are insensitive to the number and biases of observers. Applied Animal Behaviour Science, 212, 30-35.

Petherick, J.C., Holroyd, R., Doogan, V., Venus, B., 2002. Productivity, carcass and meat quality of lot-fed Bos indicus cross steers grouped according to temperament. Australian Journal of Experimental Agriculture 42, 389-398.

Petherick, J., Holroyd, R., Swain, A., 2003. Performance of lot-fed Bos indicus steers exposed to aspects of a feedlot environment before lot-feeding. Australian journal of experimental agriculture 43, 1181-1191.

Prayaga, K., & Henshall, J. 2005. Adaptability in tropical beef cattle: genetic parameters of growth, adaptive and temperament traits in a crossbred population. Australian Journal of Experimental Agriculture, 45(8), 971-983.

Purcell, D., Arave, C., Walters, J., 1988. Relationship of three measures of behavior to milk production. Applied Animal Behaviour Science 21, 307-313.

Sandem, A., Braastad, B., Bøe, K., 2002. Eye white may indicate emotional state on a frustration–contentedness axis in dairy cows. Applied Animal Behaviour Science 79, 1-10.

Sandem, A., Janczak, A., Salte, R., Braastad, B., 2006. The use of diazepam as a pharmacological validation of eye white as an indicator of emotional state in dairy cows. Applied animal behaviour science 96, 177-183.

Sant'Anna, A.C., Paranhos da Costa, M., 2013. Validity and feasibility of qualitative behavior assessment for the evaluation of Nellore cattle temperament. Livestock Science 157, 254-262.

Schaefer, A., Cook, N., Tessaro, S., Deregt, D., Desroches, G., Dubeski, P., Tong, A., Godson, D., 2004. Early detection and prediction of infection using infrared thermography. Canadian journal of animal science 84, 73-80.

Schneider, C.A., Rasband, W.S., Eliceiri, K.W., 2012. NIH Image to ImageJ: 25 years of image analysis. Nature methods 9, 671-675.

Schwartzkopf-Genswein, K., Faucitano, L., Dadgar, S., Shand, P., González, L., Crowe, T., 2012a. Road transport of cattle, swine and poultry in North America and its impact on animal welfare, carcass and meat quality: A review. Meat science 92, 227-243.

Schwartzkopf-Genswein, K., Shah, M., Church, J., Haley, D., Janzen, K., Truong, G., Atkins, R., Crowe, T., 2012b. A comparison of commonly used and novel electronic techniques for evaluating cattle temperament. Canadian Journal of Animal Science 92, 21-31.

Shakeri, M., Cottrell, J. J., Wilkinson, S., Ringuet, M., Furness, J. B., & Dunshea, F. R. 2018. Betaine and antioxidants improve growth performance, breast muscle development and ameliorate thermoregulatory responses to cyclic heat exposure in broiler chickens. *Animals, 8*(10), 162.

Stewart, M., Stafford, K., Dowling, S., Schaefer, A., Webster, J., 2008. Eye temperature and heart rate variability of calves disbudded with or without local anaesthetic. Physiology & Behavior 93, 789-797.

Stewart, M., Webster, J., Schaefer, A., Cook, N., Scott, S., 2005. Infrared thermography as a non-invasive tool to study animal welfare. Animal Welfare 14, 319-325.

Stewart, M., Webster, J., Verkerk, G., Schaefer, A., Colyn, J., Stafford, K., 2007. Non-invasive measurement of stress in dairy cows using infrared thermography. Physiology & behavior 92, 520-525.

Stewart, M., Wilson, M., Schaefer, A., Huddart, F., & Sutherland, M. 2017. The use of infrared thermography and accelerometers for remote monitoring of dairy cow health and welfare. Journal of dairy science, 100(5), 3893-3901.

Stockman, C., Collins, T., Barnes, A., Miller, D., Wickham, S., Beatty, D., Blache, D., Wemelsfelder, F., Fleming, P., 2011. Qualitative behavioural assessment and quantitative physiological measurement of cattle naïve and habituated to road transport. Animal Production Science 51, 240-249.

Stockman, C.A., McGilchrist, P., Collins, T., Barnes, A.L., Miller, D., Wickham, S.L., Greenwood, P.L., Cafe, L.M., Blache, D., Wemelsfelder, F., 2012. Qualitative Behavioural Assessment of Angus steers during pre-slaughter handling and relationship with temperament and physiological responses. Applied Animal Behaviour Science 142, 125-133.

Tőzsér, J., Maros, K., Szentlèleki, A., Zàndoki, R., Nikodèmusz, E., Balàzs, F., . . . Alföldi, L. 2003. Evaluation of temperament in cows of different age and bulls of different colour variety. Czech journal of animal science, 8, 344-348.

Turner, S., Navajas, E., Hyslop, J., Ross, D., Richardson, R., Prieto, N., . . . Roehe, R. 2011. Associations between response to handling and growth and meat quality in frequently handled Bos taurus beef cattle. Journal of animal science*, 89*(12), 4239-4248.

Valente, T., Sant'Anna, A., Baldi, F., Albuquerque, L., da Costa, M.J.P., 2015. Genetic association between temperament and sexual precocity indicator traits in Nellore cattle. Journal of applied genetics 56, 349-354.

Valera, M., Bartolomé, E., Sánchez, M.J., Molina, A., Cook, N., Schaefer, A., 2012. Changes in eye temperature and stress assessment in horses during show jumping competitions. Journal of Equine Veterinary Science 32, 827-830.

Waynert, D. F., J. M. Stookey, K. S. Schwartzkoph-Fenswein, J. M. Watts, and C. S. Waltz. 1999. The response of beef cattle to noise during handling. Appl. Anim. Behav. Sci. 62:27-42.

Wemelsfelder, F., Hunter, E.A., Mendl, M.T., Lawrence, A.B., 2000. The spontaneous qualitative assessment of behavioural expressions in pigs: first explorations of a novel methodology for integrative animal welfare measurement. Applied Animal Behaviour Science 67, 193-215.

Yu, H., 2016. The exploration of a four-platform standing scale in the application of measuring temperament in beef cattle. North Dakota State University.

Yu, H., Morota, G., Celestino, E.F., Dahlen, C.R., Wagner, S.A., Riley, D.G., Hanna, L.L.H., 2020. Deciphering cattle temperament measures derived from a four-platform standing scale using genetic factor analytic modeling. bioRxiv.

CHAPTER 4. SUMMARY AND CONCLUSIONS

The key hypothesis and objectives for these experiments were to find a more accurate and objective measurement of behavioral responses to autonomic, physiologically induced stress conditions. For this to be pertinent information, it is also important that the measured stress conditions correspond to a greater expression of economic important traits. The research presented in chapter two was to attempt to accurately identify a more efficient method to objectively measure animal temperament using computer vision technologies. The author's aim was to discover an automated and cost-effective method to measure beef cattle temperament. However, the result failed to show a strong relationship between thermal temperature imagery, eye white area, and temperament. Future studies should be tested on a larger test group of cattle that possess a greater variation of observable temperament and include additional physiologically measurable variables such as rectal temperature, cortisol, epinephrine, and other stress-related blood metabolites.

The research presented in chapter 3 included novel video technology for the assessment of beef cattle temperament. Unlike most other temperament measurement systems, video technology is a means of automatic scoring, however mathematical quantification of distance measurement for assessment of beef cattle agitation relies on manual development of software applications. For commercial applications, an algorithm must be developed to improve processing efficiency and eliminate manual intervention of a trained researcher. With the large number of resources needed for objective measurements, research exploring the relationships between video technology-based measurements and other objective measurements is warranted. The rapid development of video surveillance systems used by private industry for home and (or) national security will drive the potential of video technology as an objective means to evaluate cattle temperament. Future research is needed to establish video thermography or computer vision technologies as an accurate means to replace, or at the very least, compliment traditional temperament measuring systems. In certain production systems, there are many possibilities for the technologies to improve cattle operating systems and enhance management decisions. For instance, upon arrival to the feedlot, receiving cattle could potentially be sorted into feeding and penning strategies based on behavior observations identified from this technology. Purebred producers could more accurately predict the temperament of bulls or cows that could add to their profitability and Expected Progeny Differences for docility. These objective technologies could assist in lightening the personnel burden on many ranches, feedlots, and cow-calf operations given labor remains one of the most limited resources in livestock production.