STRESS RESPONSE EFFECTS ON GROWTH, CARCASS CHARACTERISTICS, AND TENDERNESS IN BONSMARA-INFLUENCED STEERS

A Thesis

by

SHOLLIE MARIE FALKENBERG

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2006

Major Subject: Animal Science

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Approved by:

Co-Chairs of Committee,	J. W. Holloway Rhonda Miller
Committee Members,	F. M. Rouquette Ron Randel Gordon Carstens
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ABSTRACT

Stress Response Effects on Growth, Carcass Characteristics, and Tenderness in Bonsmara-Influenced Steers.

(May 2006)

Shollie Marie Falkenberg, B.S., Texas A&M University

Co-Chairs of Advisory Committee: Dr. J. W. Holloway
Dr. Rhonda K. Miller

Half-blood Bonsmara steers were evaluated for temperament during stressful situations to discover the relationships between behavioral stress responses, growth, carcass characteristics and tenderness. Two experiments were conducted to evaluate behavioral stress responses at different stages in the U.S. beef production system with growth, carcass characteristics and tenderness. The first experiment evaluated stress responses at both time of weaning and at the beginning of the feedlot period on half-blood Bonsmara X Beefmaster steers. Steers (n=156) were weaned and paired to destinations of either Uvalde or Overton for winter grazing. At weaning cattle were weighed, and temperament measurements were recorded. After grazing winter pastures, cattle entered the feedlot and were measured for temperament, weight, and condition and frame scores. Cattle were harvested in two groups; each group was selected for harvest when they reached a backfat of approximately 7 mm. Backfat endpoints were determined by visual assessment and ultrasound. Carcass data were recorded approximately 36 hrs post-mortem, and 2.5cm steaks were removed from the 13th rib for Warner-Bratzler shear force determination.

The second experiment involved Bonsmara X Angus (n=207) steers grazed on wheat pasture and fed at Cattletown feedlot near Hereford, TX. The steers were evaluated near the beginning and end of the finishing phase for performance and temperament. They were harvested in two groups; each group was selected for harvest when they reached approximately 7 mm of backfat as determined by visual assessment and ultrasound. In experiments 1 and 2, behavioral or temperament measures and hormonal responses were related to each other. It appeared as cattle become acclimated to the production system, temperament measures lose their predictive ability. In Experiment 1, weaning exit velocity appeared to be more related to economically important traits such as ADG ($r = -0.26$), ribeye area ($r = -0.37$), and Warner Bratzler shear force ($r = 0.27$), although beginning feedlot exit velocity was associated with feedlot weights ($r = -0.30$). In Experiment 2, end feedlot measurements tended to be more associated with feedlot weight ($r = -0.20$), but there did not seem to be any high relationships with carcass characteristics and tenderness.

DEDICATION

I dedicate this thesis to my family; my parents, Leland and Janice Falkenberg; my brother, Nyland Falkenberg; my grandparents, James G. and Dorothy Coleman and Eric William and Sophie Falkenberg. My family has been an invaluable part of my life, and has helped mold me into the person that I am today. Their unconditional love, support, and encouragement helped give me the strength to achieve my goals.

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CHAPTER I

INTRODUCTION

One of the goals of the beef industry has been to produce a palatable, uniform, tender and cost efficient product. Inherent genetic variation in the current beef cattle population induces variation in cattle performance, beef palatability, product uniformity and production costs.

Stress has been shown to elicit multiple physiological responses. Loerch and Fluharty (1999) found that metabolism was stimulated and products of energy and protein metabolism may be altered in response to stressful events. Stress also has been shown to suppress appetite, reduce down growth rate, alter digestive and rumen function, and compromise immune function (Loerch and Fluharty, 1999).

The effect of environmentally-induced stress on an animal's subsequent response and their ability to adapt to the stress has been related to live animal performance (Mitlohner et al., 2002). It has been hypothesized that repeated activation of the hypothalamic-pituitary-adrenal axis (HPA) during growth would have negative impacts on carcass characteristics, meat tenderness, and end-product yield. Stress has been shown to negatively impact live animal performance. Steers that have been heat stressed have lower ADG, lower dry matter intake, and decreased feed efficiency than those that received shading to mitigate heat stress (Mitlohner et al., 2001, 2002). Brown et al. (2004) found that flighty steers which had a greater response to handling (the

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stressor) had higher feed to gain ratios, and exit velocity was negatively correlated with ribeye area. Vann et al. (2004) reported flighty cattle had lower USDA Quality and Yield grades and higher Warner-Bratzler shear force values.

Grandin (1993) stated that animals will become habituated to non-aversive handling over time. Becker and Labato (1997) also found that calves that had been exposed to gentle handling exhibited more inquisitive behavior, handled more quickly, and attempted fewer escapes than those that had not been handled. Burrow et al. (1988) found exit velocity at weaning to be heritable, but when measured at 18 mo the heritability estimates were lower. Since cattle tend to adapt, measurements early in production may be more predictive of performance as early response to strees may be more indicative of an animals physiological response before the confounding effects of adaptive behavior.

The specific response of cattle to stress is variable. Some cattle adapt or cope with stress more effectively than others. Identification or measurement of an animal's response to stress may provide a tool for identification of cattle that are not negatively impacted by stress. Bonsmara cattle (*Bos taurus Africanus*) have been imported into the United States by Mr. George Chapman as an alternative to *Bos indicus*-influenced cattle for use in sub-tropical beef production systems. Bonsmara cattle have been selected for production and adaptation to subtropical environments and have been shown to produce tender beef (Strydom, 1994). It has been hypothesized that these cattle may not have as negative of a response to stress and (or) they may adapt to stress more effectively than other breeds of cattle due to their unique selection history.

The first hypothesis is that behavioral and hormonal measures, used as indicators of a steer's stress response, are associated with ADG, carcass characteristics and Warner-Bratzler shear force in Bonsmara-sired cattle. The second hypothesis based on measurements of stress responsiveness observed at weaning, upon entry to the feedlot, and at harvest (or at the end of the feedlot phase) have different associations with ADG, carcass characteristics and Warner-Bratzler shear force in Bonsmara-sired cattle. Differences in predictability at three times during production, may be due to the ability to adapt to stress.

The objectives of this study were to quantify behavioral or temperament traits and hormonal responses at weaning and multiple postweaning stages in Bonsmara sired steers using serum cortisol concentrations, exit velocity, facial hair patterns chute and pen scores and a modified temperament score as an indication of stress responsiveness. Stress responsiveness measurements over time were used as an indication of adaptability. These measurements were used to determine relationships between behavioral, hormonal, and adaptive responses with live animal pasture and feedlot growth, carcass characteristics and beef tenderness in Bonsmara sired steers

CHAPTER II

LITERATURE REVIEW

The activation of the hypothalamic-pituitary-adrenal (HPA) axis in response to stimuli is an important survival mechanism that gives a living organism the ability to regain a homeostatic state. The activation of the HPA axis alters the metabolism of carbohydrates, proteins, and lipids to make energy available for the animal to cope with the stimuli. This is the basis for the "fight of flight" response observed when animals encounter a stressor. Burrow and Dillon (1997) reported negative associated effects from this response and observed a decrease in feedlot and carcass performance and hypothesized that nervous cattle partition nutrients differently than calm cattle.

Definition of stress

An organism strives to maintain homeostasis at the cellular level. When cellular conditions are altered by an exterior factor, the organism attempts to restore its homeostatic state via a number of mechanisms. Walter Cannon was the first to introduce the term "homeostasis" to describe "the coordinated physiological processes which maintain most of the steady states in the organism" (Cannon, 1929). One factor eliciting such a response is a stressor. The term stressor is used to quantify any event that activated the HPA axis, regardless of magnitude of the response and which specific components are stimulated. The word "stress" usually revolves around mental strain, anguish, or anxiety, although a proper discussion of stress should include any and all factors responsible for the activation of the HPA axis and the physiological consequences thereof. Stress responses can be positive (eustress) or negative (distress) experiences.

Hans Selye deserves much of the credit for introducing the term “stress” and for popularizing the concept of stress in the scientific and medical literature of the 20th century. Selye mainly focused on the hypothalamic-pituitary-adrenal (HPA) axis as the key effector of the stress response. Selye (1936) identified the alarm reaction as a non-specific response that consisted of adrenal gland enlargement; shrinkage of the thymus, spleen, and lymph nodes; and ulceration to the gastric mucosa,. Although this response has since been shown to be primarily mediated by the hypothalamus, anterior pituitary, and adrenal glands acting in concert, it can be elicited by a number of other events.

The alarm reaction was later designated the “general adaptation syndrome” (GAS) and GAS was defined to have three successive phases: the alarm, resistance, and exhaustion stages (Selye, 1973). During the stages of GAS, the intensity of the stress response may vary; however, the neural and endocrine patterns characterizing the stage of alarm would be the same as those characterizing the other stages (Selye, 1973). Most of the stressful stimuli induced two types of responses, either a general stress response or an individual response (Pacak and Palkovits, 2001). A general stress response, common to all stressors, involves the release of adrenal corticotrophic hormone (ACTH) followed by adrenal secretion cortisol. An individual stress response is mediated by conditioning factors, such as genetic and predisposition factors.

Classification of a stressful stimuli. Weiner (1991) described stressors as selective pressures from the physiological or social environment that threaten or challenge an organism and elicit compensatory response patterns. Chrous and Gold (1992) defined stress as a state of disharmony or of threatened homeostasis, evoking physiologically or behaviorally adaptive responses. They usually occur stereotypically and produce a nonspecific stress syndrome when the threat to homeostasis exceeds a threshold. In general, stressors can be divided into four main categories: 1) physical (cold, heat or noise) or chemical (poisons) stressors that can have either a negative or, in some situations, a positive psychological component; 2) psychological stressors that reflect a learned response to previously experienced adverse conditions; 3) social stressors reflecting disturbed interactions among individuals; and 4) stressors that challenge cardiovascular and metabolic homeostasis (Pacak et al., 1998). Psychological stressors effect emotional processes and may result in behavioral changes such as anxiety, fear, or frustration. Social stressors include placing an animal into a territory of a dominant animal, or maternal separation.

In terms of duration, stressors may be divided into two main categories, acute and chronic stressors. Acute stressors are usually a single or a time-limited exposure. Chronic stressors can be classified as prolonged exposure or continuous exposure stressors. Acute and chronic stressors vary in their intensity and duration, and this is usually dependant on how the stressor is perceived. The extent to which individuals can cope with stressful situations varies, and these differences are a product of duration of the stress, genetics, developmental influences, experience, training, social aspects, and current mental and physical health (DeLongis and Preece, 2000).

Neuroendocrine responses to stress. Although the entire central nervous system (CNS) is involved in the maintenance of internal homeostasis and participates in the organization of stress responses, some areas of the nervous system may have specific roles in these regulatory mechanisms. Stressful stimuli may reach the CNS through somato-or visero-sensory pathways through spinal or brainstem neurons (Pacak and Palkovits, 2001). Somatosensory signals are detected by specific receptors and carried by spinal and cranial sensory nerves. Viserosensory signals arise from the body and may reach spinal and supraspinal receptors by neural or humeral pathways (Sapolsky et al., 2000). Stress responses can be divided into short and long circuit categories. Short circuit mechanisms are called spinal stress responses. Long circuit are called supraspinal stress responses and involve the hypothalamus and cerebral cortex.

The maintenance of homeostasis requires precise coordination of autonomic, neuroendocrine, and behavioral responses to contend with constant perturbations of the internal and external environments (McEwen et al., 1986). The recognition of a stress response involves two major routes. The first is the activation of the HPA axis. Stress induced activation of the HPA axis results in a series of events that allows the individual to cope with the stressful stimulus. The second major pathway mediating physiological stress responses in animals is activation of the sympatho-adrenal axis (Minton et al., 1994). This results in release of the adrenergic neurotransmitters, adrenaline and noradrenalin, from the sympathetic nerves and medullae of the adrenal glands. The sympatho-adrenal activation occurs within seconds of the perceived threats (Eriksen et al., 1999). The first wave, occurring almost immediately in response to a stressor involves: 1) enhanced secretion of catecholamine (epinephrine and norepinephrine) from the sympathetic nervous system; 2) hypothalamic release of cortitropin releasing hormone (CRH) into the portal circulation and seconds later, enhanced secretion of pituitary ACTH; 3) decreased hypothalamic release of gonadotrophic releasing hormone (GnRH) and shortly thereafter, decreased secretion of pituitary gonadotropins; and 4) pituitary secretion of (PRL) and growth hormone (GH), and pancreatic secretion of glucagons (Gerrard and Grant, 2003).

A second, slower wave involves the steroid hormones. Over the course of minutes, glucocorticoid (GC) secretion is stimulated and gonadal steroid secretion is suppressed. A lag time exists before a stress-induced endocrine response reaches the target tissue as an affect. The hormones secreted from the first wave exert most of their affects through second messenger cascades within seconds to a few minutes. In contrast, because the bulk of steroid actions are genomic, few GC actions are exerted until about an hour after the onset of the stressor.

The early wave of endocrine stress responses and physiological consequences of increased circulating levels of GCs, can be categorized into two GC actions, modulating and preparative actions. Modulating actions alter an organism's response to the stressor and include; permissive, suppressive, and stimulatory actions. Preparative actions prime the organism's response to a subsequent stressor or aid in adapting to a chronic stressor (Sapolsky et al., 2000). Permissive actions are typically associated with basal concentrations of GCs, and the other three types of actions with stress-induced concentrations (Sapolsky et al., 2000).

Hormone effects. Varied hormonal influences bring about the major physiological changes of the stress response. Within a few minutes, these changes include: 1) diversion of energy to muscle in the form of mobilization of stored energy, inhibition of subsequent energy storage, and decreased gluconeogenesis; 2) enhanced substrate delivery to muscle via enhanced cardiovascular tone; 3) stimulation of immune function; 4) inhibition of reproductive physiology and behavior (in the form of rapid declines in proceptive and receptive behavior); and 5) decreased eating and appetite (Gibson, 1981).

The early phases and endocrine mediators of the metabolic stress response include rapidly elevated blood glucose concentrations, in part by mobilization from existing stores, and by inhibition of further storage through a rapid insulin resistance. Energy is diverted from storage sites to muscle, and these changes are brought about by the catecholamines, glucagons, and GH (Black et al., 1982). The most noticeable effect of GCs upon metabolism is their ability to increase circulating glucose concentrations. Glucocorticoids are a class of hormones derived from cholesterol. Cortisol, the glucocorticoid of primary concern, functions to stimulate gluconeogenesis, proteolysis of muscle tissues, and lipolysis of adipose tissues (Sherwood, 1997). These metabolic shifts ensure that the body has adequate energy available to address the perceived stressor. Catecholamines are a class of hormones derived from tyrosine (Sherwood, 1997). Epinephrine plays a significant role during a stress response since it has stimulatory effects on α- and β-receptors. Under non-stressed conditions, catecholamines function to regulate certain body functions. When the animal is stressed catecholamines increase heart rate, raise blood pressure, and increase free fatty acid concentrations (Shaw and Tume, 1992). Fisher (1990) proposed that animals evading predators may have decreased heart rate and cardiac output, and increased vascular resistance in all target tissues. Epinephrine can also stimulate glycogenolysis, lipolysis and increase overall metabolic rate (Shaw and Tume, 1992). Epinephrine and glucagon act quickly, whereas GCs act slowly to enhance and prolong for several hours the increase in blood glucose due to epinephrine or glucagon (Dimitriadis et al., 1997). Selye (1936) reported that impaired capacity to mobilize substrates can become fatal during stress when the animal is already food deprived.

Habitation or adaptation

As discussed earlier, exposure to stressors (perceived or actual threats to the organism) leads to the activation of the HPA axis and the secretion of glucocorticoids in proportion to the magnitude of the threat. With repeated or continuous exposure to a given stressor there was a decrease in the output of HPA hormones (Hennessy et al., 1979). Conceptually, two mechanisms could explain the decrease in HPA hormone output with experience (Ruys et al., 2004). First, with repeated or continued stress, the animal’s perception of the stressor changes. As an animal learns that the stressor does not represent an actual threat, it loses its novelty and fear. Thus the animal becomes less responsive, and has reduced reaction to the stressor, and there would be moderation of the activation of the HPA axis. With sufficient experience, the situation no longer elicites an HPA response and the situation can no longer be considered a stressor. This change in behavior and physiology is referred to as habituation (Ruys et al., 2004).

A second mechanism that could result in a reduced HPA response with experience may occur at a physiological level. The response to the HPA system may be dampened due to excessive stimulation by GCs that may result in an increase in negative physiological or behavioral feedback sensitivity. Response to the stressor may be limited by the altered dynamics of the system rather than by the animal’s perception of potential risk from the stressor. This mechanism is referred to as adaptation (Ruys et al., 2004). Adaptation allows the HPA response to be attenuated, but not eliminated. Changes in the effectiveness of the stressor in eliciting HPA activation are expected, but only temporarily. Thus, adaptation and habituation predict a reduction of the HPA hormone output with repeated exposure to a stressor, but they represent very different psychological and physiological states of the animal. In the case of production animals, they are subjected to many different environments and stressors. The concept of adaptation is a key survival mechanism and trait.

Allostasis was originally defined by Sterling and Eyer (1981) and defined as the ability to maintain stability of the internal milieu through change. McEwen (1998) adapted the idea of allostasis into stress research as the active process of adaptation by production of various mediators such as adrenal steroids, catecholamines, cytokines, tissue mediators, and immediate early genes. Exposure to a chronic stressful situation initiates physiological responses, leading to allostatic (adaptive) responses. If allostatic responses are efficient, adaptation occurs and the organism is protected from damage. Crookshank et al. (1979) reported that in cattle agitation and cortisol concentrations decreased with subsequent experiences in the handling facility, because the cattle became habituated or adapted.

Adaptation is defined as the evolution of traits that enhance survival and reproductive fitness within a population's unique and prevailing environment (Swanson, 1995). Adaptation can also be described as the intrinsic ability of an animal to tolerate conditions outside of its comfort zone. Criteria for successful animal adaptation include: coping with changing environments; handling prevailing environmental stress; utilizing habitat efficiently; resisting disease and parasites; and reproducing regularly within the specific environment (Hohkenboken et al., 2005). Adaptation is achieved when an individual can utilize environmental resources efficiently and sustainably, in spite of the stresses and challenges of their prevailing environment. McBride (1984) observed "the fit between an animal and its environment is never a static one". McBride indicated that the mechanism involving this dynamism involves two possible outcomes to changes in an animal's environment: 1) the animal adjusts by gaining increased skills at exerting control over its environment, resulting in "adaptation"; or 2) it fails to exert control over its environment and lapses into a phenomenon called "learned helplessness." Animals essentially "give up" responding to environmental stimuli. Although milder forms of the condition may be perceived as being positive from the standpoint of confined farm animals not "fighting" long-term physical and behavioral restrictions. Learned helplessness is generally considered detrimental to psychological well-being and can have physiological consequences (Maier and Seligman, 1976). The question remains, what allows some cattle to be more tolerant of wider ranges of sensations than others, and in turn allows some cattle to adapt faster and more efficiently than others?

Resources for adaptation. Tools for adaptation include (Hohkenboken et al., 2005) anatomical (hooves, hide and hair), physiological (respiration or alimentation), immunological (antibodies or inflammation), and behavioral (flight or fight). Sources of adaptation can be innate or heritable and include acquired, learned, and producer supplied. Acquired might involve passive and active immunity or becoming acclimated. While learned could be maternal training or age and experience. Other sources may be producer supplied with the help of vaccinations and parasite control. Olson et al. (2003) observed that slick-haired calves tended to grow faster, and slick haired cows gave more milk when compared to normal haired dams. Other research has reported that cattle differing in adaptation to heat varied in site of fat accumulation and lipoprotein lipase activity (Sprinkle et al., 1998). Hearnshaw et al. (1979) proposed that age or experience could influence behavior. In many instances, management systems and environments are changing more rapidly than animal populations can adapt to such changes. Natural selection and intensified management may create or increase the stress already inherent in our production systems.

Beef cattle cannot be profitable unless they are productive, efficient and produce a desirable end product. Improved adaptation should describe cattle that are more elastic, and can fit and mold into a broad production system. In order to be adaptive selection for traits that push the animals to perform in a stressful environment are necessary. There will always be the dilemma of deciding to what extent the environment should be modified to meet the needs of the cattle and to what extent cattle should meet the demands of the environment.

Beef cattle production

Productivity of beef cattle enterprises depends not only on the inherent ability of animals to grow and reproduce, but also on the ability of the animals to withstand stressors of the environment that impact production traits and then to adapt or to conform. The phenotypic performance of an animal is the summation of the genetic (G) effect, the environmental (E) effect, and the genetic by the environmental interactions ($P=G+E+(GxE)$). It is evident that the relative growth performance of various breeds is heavily dependant on the environmental constraints. Breeds that can cope with different environmental factors can be identified. The growth rate of European or British breeds of cattle (Bos taurus) is lower under tropical conditions than in temperate areas (Frisch and Vercoe, 1978). Zebu breeds (Bos indicus) are well adapted to the tropics in terms of survival, but their growth rate is also low by temperate standards (Frisch and Vercoe, 1978). Combining the complementary strengths of two or more breeds through crossbreeding is usually done to produce the most productive animal for the environment. Additionally, desirable amounts of productive and adaptive attributes can be obtained. Crossbred cattle tend to be more productive than straightbred cattle under stressful conditions (Frisch and Vercoe, 1978). Composite breeds have been developed to take advantage of strengths within each breed, and have been developed or selected for greater adaptability in stressful environements.

The Bonsmara breed was developed in the late 1930's and early 1940's by Prof. Jan Bonsma at the Mara station in South Africa, and is a composite of 5/8 Afrikaner (tropically adapted breed) and 3/8 Hereford and Shorthorn. The name "Bonsmara" was derived from Jan "Bonsma" the professor who help develop the breed, and "Mara" the farm on which the animals were bred. The breed was developed with the goal of adaptability, tenderness, and productivity in the subtropical region. Due to their breeding selection, Bonsmara have the potential to produce high quality meat. Both the Hereford and Shorthorn have been shown to produce steaks comparable to that of Angus (Wheeler et al., 1996). The Afikaner is an indigenous breed of the Sanga type. Sanga cattle are not related to the Indian Bos indicus breeds (Brahman), as generally believed. Bonsmara influenced cattle have been shown to produce carcasses of comparable quality to British cattle that are considered tender under US production systems (Holloway et al., 2000; Miller et al., 2005). Research in South Africa has suggested that carcass characteristics and Warner-Bratzler shear force values of Bonsmara cattle are similar to those of British cattle breeds produced under the same production conditions (Strydom, 1994). George Chapman, starting in 1996, imported Bonsmara germplasm into the United States, and Bonsmara-influenced cattle are currently being produced in some areas of the southwest and in Colorado.

Stress and beef production

Stress response has been well understood to negatively affect growth and productive efficiency in livestock (Mitlohner et al., 2001, 2002), and increased stress response has been linked to reduced immune function (Rosenkranz et al., 2003).

Cortisol, a stress hormone, can have profound effects on protein, carbohydrate, and lipid metabolism. Increased cortisol concentrations have been shown to negatively impact weight gain in cattle (Obst, 1974). A common stressor to many animals is heat stress. Mitlohner et al. (2001, 2002) examined the effect of providing shade and misters to mitigate heat stress in fed (or feedlot) cattle. Providing shade reduced respiration rates during feeding. Additionally, when comparing cattle provided with shade and misters to cattle without shade or misters, the shaded cattle had higher ADG (1.60 vs 1.41 kg/d, respectively), greater DM intake and improved feed efficiency. At slaughter, the cattle from the shaded pens had heavier carcass weights, higher marbling scores, and a lower incidence of dark cutting beef.

A common meat quality defect attributed to antemortem stress is the incidence of "dark cutting" lean. Antemortem stressors have been linked to meat quality defects such as the dark, firm, and dry (Apple et al., 1995) and pale, soft, and exudative (Rosenvold and Anderson, 2003) lean conditions. These defects are attributed to abnormal muscle pH decline by stress-induced glycolytic metabolism. Apple et al. (1995) reported that stressed animals had higher plasma epinephrine and cortisol concentrations during stress treatments compared to the non-stressed controls. The increase in glucocorticoid and catecholamine concentrations coincided with increased serum glucose and lactate concentrations. These results would suggest that stressed lambs effectively mobilized glycogen stores for use in a "fight or flight" response to a stressor. The stressed animals in this study produced meat with very high pH, dark colored lean, and chops that had lower Warner-Bratzler shear force values. Beltran et al. (2004) also reported that high ultimate pH in beef carcasses associated with antemortem stress was associated with increased m-calpain activity and greater tenderness.

Other researchers have reported relationships between urinary catecholamine measured at slaughter, ultimate pH, and shear force in bulls and cows. Lowe et al. (2004) reported that non-mixed bulls had greater glycolytic potential, lower urinary epinephrine concentrations, and mean shear force for the commingled bulls was higher than the mean shear force observed for the non-mixed bulls.

In studies that apply a stressor treatment, it is difficult to differentiate the effects of antemortem stress on tenderness from those due strictly to muscle pH. However, it is likely that stress responses caused by common management practices may have a negative impact on productivity, carcass characteristics, and tenderness independent of muscle pH. Burrow et al. (1988) suggested that stressed cattle partition nutrients differently and this partitioning leads to lower weights and less efficient animals. Additionally, it is difficult to assess the effects of stressors applied as treatments, because many aspects of data and sample collection may also be stressful to control animals. Differences in the results between studies and between animals is likely due to how the animal perceives the aversiveness or the threat of the procedure. These perceptions or responses could be due to previous handling or novel experiences. The squeeze chute or handling may be perceived as a neutral and non-threatening experience to one animal; to another animal, it may trigger intense fear (Grandin, 1997). This may also explain why some cattle that perceive the chute or handling as a bad experience may remember it and become more stressed when handled in the future, while other animals have lower cortisol concentrations over time.

Stress status of an animal can be assessed via behavioral responses or measures of tissues and fluids (Shaw and Tume, 1992). In their review, the authors evaluated both catecholamine and cortisol concentrations as indicators of stress status, and concluded that cortisol concentration within a contemporary group was an acceptable gauge of stress response. Cortisol concentrations are hard to infer, since there are many factors that can have an impact on these concentrations. While cortisol concentrations of 2 to 4 ng/mL can differ statistically, the biological implications are difficult to infer. Curley et al. (2004) reported a strong relationship between animal temperament within a contemporary group and stress responsiveness in cattle. Curley et al. (2004) also found that cattle with more excitable temperaments also had more extensive responses to CRH and ACTH challenges. Those animals also had a higher basal concentration of circulating glucocorticoids, which may suggest a chronic state of activation of the HPA axis. However, Shaw and Tume (1992) noted that a given corticoid concentrations did not necessarily mean that the stress level was unacceptable. Temperament and behavior have become a concern for beef producers not only for handling concerns, but cattle with excitable temperaments have been reported to have higher serum cortisol levels (Stahringer et al., 1989, Lanier et al., 2000). Efforts to mitigate the amount of stress cattle are exposed to when they enter the feedlot have been evaluated as cattle do not rapidly adapt to the feedlot environment. A decrease in weight gain between cattle that do not adapt as compared to cattle that adapt to the feedlot setting, has been reported

(Petherick et al., 2003). Temperament and stress have been closely associated, and the behavior of cattle has become a method for indicating or selecting cattle that could be more stress responsive cattle or less adaptive (Curley et al., 2004).

Temperament

What is temperament? Scott and Fredericson (1951) identified "tameness" as the absence of conflict behavior, and the term "wildness" as the tendency to escape. These terms both encompass an animals reaction towards man. From *The Lasater Philosophy of Cattle Raising* (Lasater, 1972), "No one likes wild cattle, so why raise them?" Some beef producers do consider temperament to be an important trait (Elder et al., 1980) due to concerns for animal handler safety. Gonyou (1994) commented that abnormal behaviors are often taken as indicators of response to stressful events, and that research emphasis is shifting to the causative factors of these behaviors. Animals that have undesirable temperament are classified as excitable and tend to have increased venous cortisol concentrations (Lanier et al., 2000). Temperament has been defined as an animal's behavioral responses to handling by humans (Burrow, 1997). These behavioral responses can range from demonstrations of docility to fear or nervousness, to non-responsiveness exhibited by freezing behavior (immobility), to escape or flighty behavior and aggressive or attack behavior. However, within the scientific community much misunderstanding has accompanied this term, as researchers have used temperament when referring to the nervousness, skittishness, quietness, excitability, individuality, libido, constitution, and emotionality of animals (Stricklin and

Kautzscanavy, 1984). For the purpose of this discussion, the term "temperament" will be defined as the reaction elicited by an individual animal to handling by humans.

Temperament classifications. Visual assessments have been used in order to understand animal behavior or temperament. Numerical scoring methods have been used to quantify the differences in temperament between animals (Voisinet et al., 1997). These tests make a subjective assessment of the animal's behavior in different testing situations. Stress responsiveness is dependant on the constraints in a particular environment. Since each animal may view a particular situation as more or less threatening than another, various measures need to be observed during stressful exposures. Pen scores (Hammond et al., 1996) allow the animal to move freely in a test area, usually in the presence of an observer; exit velocity or flight speed (Burrow, et. al., 1988) measures the escape response; chute scores (Grandin, 1993) measure the response while being confined; and facial whorl patterns are associated with early development.

Multiple tests to assess animal behavioral responses after or during restraint have been developed. Tests such as pen scores and exit velocity tests are common types of escape from restraint test. Hammond et al. (1996) described a pen scoring method based on the behaviors exhibited when an animal exited a squeeze chute that it was confined in and entered a pen area. The ratings used were: 1) walks slowly, can be approached slowly, not excited by humans; 2) runs along fences, stands in corner if humans stay away; 3) runs along fences, head up and will run if humans come closer, stops before hitting gates and fences, avoids humans; 4) runs, stays in back of the group, head high and very aware of humans, may run into fences and gates; and 5) excited, runs into fences, runs over anything in its path. Hammond et al. (1996) also measured cortisol concentrations and found a relationship between pen scores and cortisol concentration. These researchers also noted that order or the time required to handle the animal in the restraint chute had significant effects on temperament scores.

Burrow et al. (1988) described a more objective method for evaluating temperament and defined it as the flight speed test. This test consisted of measuring electronically the time elapse between two sets of timers placed 1.83 meters apart and .9 meter in front of a squeeze chute. Flight speed was calculated as the time it took a steer to travel though a 1.83 meter run. Exit velocity is the rate (m/sec) at which an animal exits the squeeze chute (Curley et al., 2004). Burrow et al. (1988) reported that heritability estimates were high ($h=0.54$) for flight speed when measured earlier in production. These researchers also found more docile animals, as determined by slow flight speeds, demonstrated estrus in the presence of an observer more often than did their more temperamental contemporaries ($P<0.05$). These results would suggest that decreased reproductive efficiency in temperamental animals can lead to a decrease in production. Burrow et al. (1988) concluded that these types of tests are helpful in measuring the fear response of the animal. Fear is a very strong stressor, and the highly variable results of handling are likely to be due to different levels of psychological stress (Grandin, 1997). To more adequately measure a stress or fear response different types of scoring methods are used to evaluate animals during handling.

Tests that involve restraint and physically inhibit an animals natural movement are measurements of an animals response to restraint. Behaviors measured while restricted in the squeeze chute; include the amount of movement, vocalizations, eliminations, tail swishing, kicking, audible respiration, baulking and attempts to escape. The chute scoring method or test is one type of restraint test. Grandin (1993) described the ratings for chute scoring as: 1) calm, no movement; 2) slightly restless; 3) squirming, occasionally shaking the squeeze chute; 4) continuous, very vigorous movement and shaking of the squeeze chute; and 5) rearing, twisting of the body and struggling violently. These measurements were made after the head and tail gates were both shut, and the evaluator stood at the head end of the chute. Grandin (1993) indicated that culling decisions should not be based on a single evaluation of temperament, because there were a high percentage of cattle with highly variable ratings. Although, in some animals the tendency to become behaviorally agitated was stable over time, some animals become more agitated over time. Therefore, animals responded differently when measured multiple times.

Grandin et al. (1995) described a method by which horse trainers have casually observed that the position of round whorls (trichoglphs) on a horse's forehead is related to temperament (Tellington-Jones and Bruns, 1985; Barker, 1990; Friedly, 1990). Hair whorl position has been used to predict the behavior of a horse during training. An adapted procedure described by Grandin et al. (1995) allowed the animal to enter the chute and once their head was captured and restrained, a recorder measured from the middle of the eye to the whorl. Whorls located below the bottom of the eyes were reported as negative numbers, whorls even with the eye line were zero, and whorls above the eyes were positive numbers. Animals that had more than one whorl were classified as doubles and no hair whorls were considered as none. Grandin et al. (1995) reported that cattle with a hair whorl position above the eyes were more behavioral agitated both in the squeeze chute and while exiting the squeeze chute. The authors reported a positive linear relationship ($p<0.001$) between cattle temperament while restrained in the squeeze chute and location of the facial hair whorl.

Results from these studies would suggest that responses vary for different stressors. The combination of multiple temperament measures may be helpful in determining the reactions or responses associated with stressors inherent in the production system. Identifying animals that adapt to handling, become more behaviorally agitated, or remain behaviorally stable over time could be assessed by measuring temperament at multiple stressful periods (weaning, entry to the feedlot and exiting the feedlot). Evaluating the amount of change between successive measures during the production system could be a valuable tool to predict production adaptability.

Temperament and beef production

Animals are discriminative between different kinds of human interaction (Gonyou et al., 1986) and also between different types of restraints where adverse events occur (Rushen, 1986). The levels of aversion expressed by individual animals; however, are relatively persistent across multiple handling experiences (Grandin, 1993). Therefore, handling experiences early in life, particularly at weaning, appear to have a critical effect on the temperaments in cattle (Fordyce et al., 1988). Grandin (2003) reported that animals have a learned behavior and thus develop preferences.

Age tends to be confounded with the effects of previous handling experiences. Temperament of animals that have not been exposed to adverse handling routines seems to improve with increasing age or experience. Flight speed, as an objective measurement of temperament, has been found to be moderately heritable (h^2=0.54) at weaning, but lower heritability (h^2=0.26) has been reported at 18 mo of age (Burrow et al., 1988). This indicates that the variation among animals in temperament reduces over time. Sato (1981) found that cattle become milder with age, although the ranking of temperament scores for individual animals did not change though life. Burrow et al. (1988) did not find differences in flight speed between bulls and heifers at weaning, but heifers had faster slight speed than the bulls at 18 months of age. The bulls in that study had been handled more intensively than the heifers. This would suggest that increasing experience with aging may affect temperament measures. Curley et al. (2004) found that exit velocity measures in Brahman bulls, classified as temperamental, decreased in subsequent evaluations taken 60 d apart. However, bulls classified as intermediate or calm demonstrated little change with subsequent evaluation. Grandin (1993) stated that animals will become habituated to non-aversive handling over time. Similarily, Becker and Lobato (1997) found that calves that had been exposed to gentle handling showed more inquisitive behavior, could be moved through the working facility faster, and attempted fewer escapes than those that had not been handled. Hearnshaw et al. (1979) reported that temperament scores at the first time of testing were higher than at subsequent testing, which indicated that animals were becoming accustomed to the handling routine. Hearnshaw and Morris (1984) reported that cows had lower mean temperament scores than their calves and they attributed this effect to greater adaptation to management by the cows. Grandin (1993) found that displays of agitation were consistent among rankings in animals during repeated restraint sessions at 30 d intervals (5 total sessions). The collective results from these studies indicates, for various temperament indicators, that animals tend to adapt to repeated handling over time, but the relative rankings within contemporary groups would be consistent. Habituation to a handling procedure may arise when the animal learns that there is always an eventual escape (Fox, 1984). Thus, habituation may depend on the predictability, controllability, or previous experience to the stressor, and thereby, its aversiveness (Hargreves and Hutson, 1990). The most beneficial time to measure temperament may be at weaning, since this is often the first handling the animal experiences, and animals have not conformed to the environment. Examination of the relationships of measures of temperament, as a measure of response to stress, with production traits at different time periods during the production system using animals that appear to adapt over time versus animals that do not adapt may provide a better understanding of the effect of adaptability.

Performance. Data regarding temperament effects on animal performance are limited, but appear to indicate relationships worthy of further investigation. Phillips (2004) investigated the effects of isolation stress on calf performance. It was hypothesized that feeding calves in groups would be less stressful. Calves were classified as group or individually reared, and evaluated for intake and weight gain. The group reared calves had greater intakes, spent more time eating, and ruminating time was increased compared to individual calves. Other research has reported that pre-exposing animals to stressful aspects of a feedlot environment have increased performance. Petherick et al. (2003) found that exposing animals to a part of the feedlot setting a little at a time resulted in greater feed intakes and higher weight gains during the beginning of the feedlot period. Researchers have also used multiple behavioral responses at weaning to sort cattle into feedlot groups (Fell et al., 1999). These researchers used weaning chute score and flight speed as a method to classify cattle into nervous (poor temperament) and calm groups (good temperament). They reported that within the poor temperament group, as classified by flight speed and chute scores, this group was found to be correlated with increased adrenalcortical activity and undesirable production outcomes. They also found that of the behavioral measures used in their experiment, the chute scoring method was the least discriminative method for identifying temperament. Most of the cattle scored less than 2 for chute scores and there were very few extreme scores. Fell et al. (1999) concluded that flight speed may be a better indicator, since flight speed was not a subjective measure.

Petherick et al. (2002) used flight speed as a measure of temperament at the beginning of the feeding period and found that more flighty cattle had lighter final weights. They also observed the trend that flighty cattle had lower ADG and decreased feed conversion efficiency. Burrow and Dillon (1997) recorded flight speed for the first 12 wk; each week, and the mean of the first five week flight speed measurements were used as the temperament rating. Their EV rating affected live weight gain and final liveweight in the feedlot. Cattle with milder temperaments in their study tended to have lower ADG and higher feed-to-gain ratios. Other researchers have found similar results. Brown et al. (2004) observed a decrease in dry matter intake and ADG in the feedlot for bulls that exhibited a fast exit velocity upon entry into the feedlot compared to slow exit velocity cattle.

While Fell et al. (1999) suggested that EV was a more discriminative measure of behavioral responsiveness, some research has reported relationships between chute scores and cattle performance. Voisinet et al. (1997a) evaluated chute scores as a measure of temperament two weeks after entering the finishing phase of production in two experiments. The first experiment evaluated *Bos taurus* and *Bos indicus* cross calves, and found significant increases in ADG for the calm *Bos taurus* cattle. No significant differences were observed in the *Bos indicus* cross calves, but the calm calves had numerically higher ADG than the excitable cattle. The second experiment utilized just *Bos indicus* cross calves and temperament score explained a significant amount of the variation in ADG. Animals with temperament scores of 1 or 2 had higher (P<0.05) ADG than the animals with scores of three.

Gauly et al. (2001) used a pen scoring method and applied human pressure and observed the animals reaction for a period of time. At that time a pen score was assigned. They also used a chute score along with the pen method and found that the more docile animals tended to be the more productive animals.

Results from these experiments suggest that individual responses to stress can be evaluated and can be predictive of feedlot performance, but multiple measures of behavioral responses may be more discriminating and allow producers to sort cattle into more representative groups. It would appear that most of the literature indicates pwn score and exit velocity or flight speed are more associated with production performance as compared to chute scores. While these measures may be the most predictive, the literature indicates that multiple temperament measures would provide a better understanding of behavioral stress responses.

Carcass characteristics. Only a limited amount of research has reported relationships with carcass characteristics and behavioral responses. Voisinet et al. (1997b) found a greater percentage of the excitable animals as indicated by chute scores assigned 2 weeks prior to entering the feedlot, produced border line dark cutters than the calmer animals. Wulf et al. (1997) also reported that chute scores were moderately correlated with carcass characteristics. Chute scores were negatively correlated with carcass weight, and CIE L* and b* values (r= -0.24, -0.34, and -0.23, respectively). Other relationships between chute scores and fat thickness, ribeye area, KPH, marbling, and yield grades have not been reported and the impacts associated with these responses are important.

Other behavioral observations have been associated with carcass characteristics. Brown et al. (2004) reported that exit velocity, measured upon entry to the feedlot, was negatively correlated with ribeye area but not backfat or intramuscular fat in Bonsmara bulls. Petherick et al. (2002) reported similar results and found flight speed was negatively correlated with dressing percentage. These researchers also found that there was a tendency (*P*>0.05) for the calm cattle to produce carcasses 10 kgs heavier than flighty cattle. Petherick et al. (2002) did not report relationships between flight speed and fat thickness, KPH, marbling or quality grades, and yield grades.

Pen scores have been used as a behavioral indicator of stress response and are related to hormonal stress responses (Hammond et al., 1996).

Tenderness. Vann et al. (2004) found a low-to-moderate relationship between measures of temperament and Warner-Bratzler shear force (r=0.24 to 0.35). Voisinet et al. (1997b) also found more excitable cattle as determined by chute scores measured two wk prior to entering the feedlot produced steaks that were tougher when compared to calm animals. Wulf et al. (1997) found chute scores were positively correlated with 24-h calpastatin activity and Warner-Bratzler shear force values (r=0.35 and 0.49, respectively).

Overview. While temperament measurements early in production tend to be more heritable and animals conform as they progress in the production system. Results from past research have found relationships with performance, carcass characteristics and tenderness measured during the feeding period. Differences in results are likely due to differing levels of fear, how the animal perceives a threat during a procedure, past experiences, and when the animal is evaluated for temperament. Since animals tend to adapt or become acclimated as they advance through the system, measurements earlier in production may be more beneficial in predicting production performance. While temperament measured later in the feeding period has been shown to be effective in predicting less productive animals, earlier measurements may prove to be more predictive.

Since cattle need to conform to an environment quickly and with minimal inputs, efforts to identify more docile animals could lead to a more efficient and productive system. Growth, weight gain, carcass merit and tenderness are of economic interest to the producer and the industry, having the tools to help achieve the most benefit could become key factors in maximizing production by cattle. Within the production system there is a link between most production traits (behavior, growth, weight, and carcass characteristics) and altering or manipulating one aspect can cause a cascade of events that affects a multitude of traits. The importance of knowing the impact or problem associated with altering these traits can help produce a more desirable animal or product.

Identification of factors that influence end product quality or yield may be beneficial to help sort cattle based on observations earlier in production. Temperament may be a helpful tool to help predict more acceptable carcasses. Since temperament tends to be related to weight gain and heavier, higher yielding carcasses, these traits may be of importance to include as predictive factors affecting red meat yield.

Red meat yield. Studies have examined carcass composition between breed or cattle types and between sex classes (Koch et al., 1976, 1979, and 1982). These studies have indicated that continental European cattle tend to have a higher percentage of lean meat yield than do English cattle. Reiling et al. (1992) studied the effect of impacting the yield grade equation with the addition of HCW, longissimus muscle area, fat cover, and sex class. These researchers found the addition of HCW in the Yield grade equation increased the accuracy of the prediction equation very little. Other researchers have studied the effect of live animal ultrasound measures to predict beef carcass retail yield.

In a study using 180 steers representing 11 sire-breeds groups, Hamlin et al. (1995), reported that ultrasonic measurements of fat thickness and longissimus muscle area, when combined with live weight, accounted for 61 to 64% of the variation in percentage of retail product. Greiner et al. (2003) developed live animal ultrasound prediction equations for weight and percentage of retail product. Steers were measured for 12th rib fat thickness, rump fat thickness, longissimus muscle area, and body wall thickness within 5 days prior to harvest. Carcass measurements included in USDA quality and yield grade calculations were obtained. Regression equations to predict weight and percentage retail product were developed using either live animal weight or carcass traits as independent variables were constructed. These researchers reported that most of the variation in weight of retail product was accounted for by live weight and carcass weight with R^2 values of 0.66 and 0.69, respectively. They also found that fat measurements accounted for the largest portion of the variation in percentage of retail product when used as a single predictors. These results indicate that live animal equations using ultrasound measurements are similar in accuracy to carcass measurements for predicting beef carcass composition, and alternatively enhance the predictive capability of live animal-based equations for retail yield. Other studies have reported similar results. Herring et al. (1994) reported final step-wise regression models using live animal or carcass equations ranked the animals equally for kg of retail product yield.

Weight seems to account for a lot of the variation in red meat yield. It would appear that factors affecting weight would be a useful tool to help account for other variation when predicting yield. Research would indicate that live animal traits rank cattle similarly to that of carcass traits in prediction equations. The addition of multiple live animal and carcass traits could increase the accuracy of factors predicting red meat yield. The more knowledge available, the better we can be at predicting performance and how cattle need to be sorted based on selection criteria.

Despite significant advancements in the current knowledge of factors affecting beef quality and tenderness, the incidence of unacceptable beef continues to be a problem for the beef industry (Brooks et al., 2000). The identification of factors that predispose animals to inefficiencies in production, undesirable carcasses and tough meat would aid in designing breeding and management programs to mitigate these factors.

CHAPTER III

MATERIALS AND METHODS

Two experiments were conducted to evaluate the relationship between chute scores (CHUTE), pen scores (PEN), exit velocity (EV), and facial whorl distance (FACE) as indicators of temperament or behavior, and serum cortisol concentrations on average daily gain (ADG), carcass characteristics, and tenderness in half-blood Bonsmara cattle. The objective of this study was to characterize cattle based on measurements or observations of temperament and evaluate temperament as a measure of stress responsiveness and to determine relationships with growth, carcass characteristics and longissimus muscle tenderness. A third experiment was conducted on a subset of animals to determine the variation in feedlot performance, carcass measurements and red meat yield.

Experiment 1

The experimental units consisted of 139 spring-born Bonsmara X Beefmaster (BONB) steers weaned on Dos Amigos Ranch near Roswell, New Mexico and weaned on November 11, 2002, and 21 spring-born Bonsmara X (Tropically Adapted Breed X Angus) (BONX) bull calves that were weaned at the Harris Ranch at Cline, TX on October 17, 2002. The tropically adapted breeds were either; Tuli, Senepol, or Brahman.

For calves at the Dos Amigos Ranch, body condition score (BCS), frame score (FRAME), CHUTE, PEN, EV, weight and order through the chute (OTC) was determined at weaning. Exit velocity, adapted from Burrow et al. (1988), was determined as the rate at which the animals exited the working chute and traversed a 0.9 m distance in front of the chute where the measurement began. Exit velocity was calculated as the rate (m/sec) it took a steer to travel through a 1.83 m run. Infrared sensors were used to remotely trigger a timing apparatus at the beginning and ending of the run. Chute scores were based on visual appraisal of each steer while it was confined unrestrained in a working chute (W-W Livestock Systems, Inc., Thomas, OK)[1], (Grandin, 1993). The scores were based on a 1 to 5 scale (Table 1). Pen scores were based on visual assessments of each steer after release from the working chute and while the steer was confined to a pen (Hammond et al., 1996). The scores were based on a 1 to 5 scale (Table 2). Body condition scores and FRAME were assigned by an evaluator as the animal exited the chute. The BCS method was defined by Lowman (1976) as modified by Herd and Sprott (1998) (Table 3). The frame score method was an adapted version from the Beef Improvement Federation Guidelines (2002). Scores were based on a 1 to 9 scale with 1 being the shortest and 9 being the tallest (Table 4).

Bull calves produced at the Harris Ranch were castrated and weighted at weaning. Steers were put in a dry lot and allowed *ad libitum* access to hay and 0.9 kg/hd/d of a 20% crude protein range cube, prior to being put on ryegrass pasture.

Bonsmara X Beefmaster steers weaned at the Dos Amigos Ranch were paired by weight and pairs were randomly allocated to a destination of either TAES-Uvalde or TAES-Overton for post-weaning growth on pasture. A graphical representation Table 1.

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[1] Beefmaster XL-2VG, length=289.6 cm, width=104.1 cm, and height=198.1 cm

Table 1. Observations associated with the individual categories of chute scores to evaluate animal temperament (Grandin, 1993).

Chute score	Description
1	Calm-no movement
2	Restless shifting
3	Squirming, occasional shaking of weigh box
4	Continuous vigorous movement and shaking of weigh box
5	Four, plus rearing, twisting, or violently struggling

Table 2. Observations associated with the individual categories of pen scores to evaluate animal temperament (Hammond et al., 1996).

Pen score	Description
1	Walks slowly, can be approached slowly, not excited by humans
2	Runs along fences, stands in corner if humans stay away
3	Runs along fences, head up and will run if humans come closer, stops before hitting gates and fences, avoids humans
4	Runs, stays in back of group, head high and very aware of humans, may run into fences and gates
5	Excited, runs into fences, runs over anything in its path

Table 3. Observations associated with the individual categories of condition to evaluate animal backfat (Herd and Sprott, 1998).

Condition score	Description
1	Bone structure of shoulders, ribs, back, and hips sharp to touch and easily visible. Little evidence of fat deposits or muscling.
2	Little evidence of fat deposition but some muscling in hindquarters. The spinous processes feel sharp to touch and are easily seen with some space between them.
3	Beginning of fat cover over the loin, back, and foreribs. Backbone still highly visible. Processes of the spine can be identified individually by touch and may still be visible. Spaces between the processes are less pronounced.
4	Foreribs not as noticeable; 12th and 13th ribs still noticeable to the eye. The transverse spinous processes can be identified only by palpation (with slight pressure) to feel rounded rather than sharp. Full but straightness of muscling in the hindquarters.
5	12th and 13th ribs not visible to the eye unless the animal has been shrunk. The transverse spinous processes can only be felt with firm pressure to feel rounded-not noticeable to the eye. Spaces between the processes not visible and only distinguishable with firm pressure. Areas on each side of the tail head are fairly well filled but not mounted.
6	Ribs fully coved, not noticeable to the eye. Hindquarters plump and full. Noticeable sponginess to covering of foreribs and on each side of the tail head. Firm pressure now required to feel transverse processes.
7	Ends of the spinous processes can only be felt with very firm pressure. Spaces between processes can barely be distinguished at all. Abundant fat cover on either side of tail head with some patchiness evident.
8	Animal taking on a smooth, blocky appearance; bone structure disappearing from sight. Fat cover thick and spongy with patchiness.
9	Bone structure not easily seen or easily felt. Tail head buried in fat. Animal's mobility may actually be impaired by exces amount of fat.

Table 4. Observations associated with the individual categories of frame to evaluate animal size (Beef Improvement Federation guidelines, 2002).

	Frame Score								
	1	2	3	4	5	6	7	8	9
Age (months)	Height in meters								
9	0.97	1.02	1.07	1.13	1.18	1.23	1.28	1.33	1.38
14	1.08	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48
15	1.09	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50
16	1.11	1.16	1.21	1.26	1.31	1.36	1.41	1.46	1.51
17	1.12	1.17	1.22	1.27	1.32	1.37	1.42	1.47	1.52
18	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.48	1.53
19	1.14	1.19	1.24	1.29	1.34	1.39	1.44	1.49	1.54

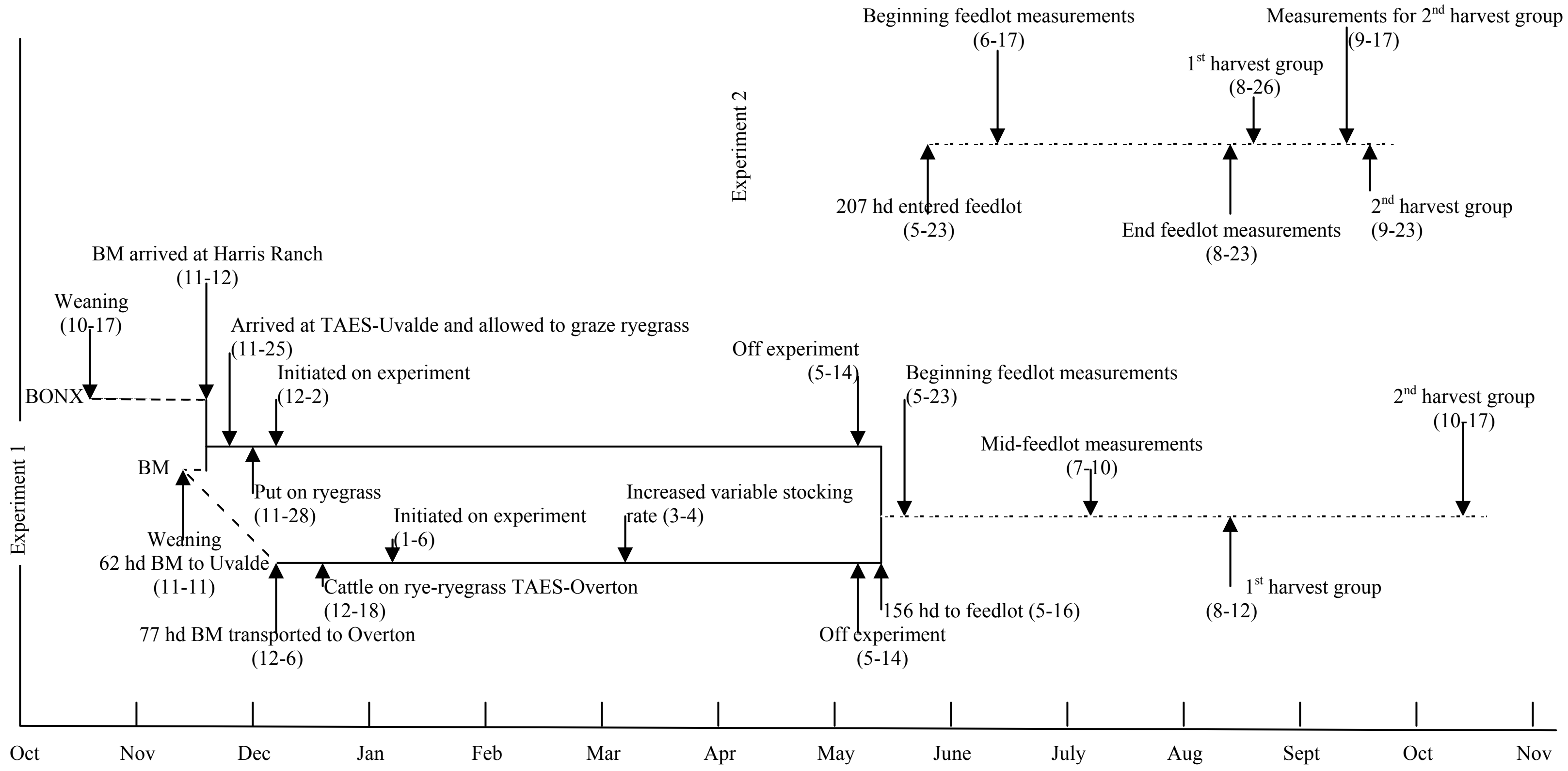

Figure 1. Timeline of events for experiments 1 and 2.

illustrating the path or treatments each group of cattle was subjected is presented in Figure 1.

One day after weaning, the 62 BONB steers assigned to Uvalde were transported to the Harris Ranch in Cline, TX. Two days after arriving at the Harris Ranch, the BONB steers were weighed and commingled with the BONX steers at the Harris Ranch. All animals at Uvalde were allowed *ad libitum* access to hay and 0.9 kg/hd/d of a 20% crude protein range cube. Eleven days after commingling the cattle at the Harris ranch, the BM and BONX cattle were transported (15 miles) to the Texas A&M Agricultural Research and Extension Center in Uvalde, TX where they were dry-loted and fed the same ration as before. Following a three-d dry-lot period at the TAES-Uvalde the BONB and BONX steers were allowed to graze winter ryegrass pasture (‘TAM 90’ annual ryegrass, *Lolium multiflorum L.*). After a five-d adjustment period these steers were weighed on experiment while being allowed continuous access to water and feed. At this time ultrasound (Pie Medical Equipment, The Netherlands)[2] measurements for initial backfat prior to grazing were recorded. The imaging of the backfat was performed approximately 5 cm lateral from the spinous processes of the spine and centered over the 12th rib. Vegetable oil was used as a couplant and the probe was placed transversely directly on the hide of the cattle. Total fat depth was determined by measuring the distance from the outer layer of the skin to the interface of the bottom layer of fat and the dorsal surface of the longissimus muscle. The cattle remained on

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[2] Pie Medical Scanner 200 SCL with ASP-18 Probe 3.5 MHz, 18 cm long, 128 crystal elements

ryegrass pasture at TAES-Uvalde for 162 d, until termination of grazing when they were weighed off experiment, and BF measurements were obtained.

The 77 BM steers assigned to TAES-Overton remained in drylot in Roswell, NM for 25 days post-weaning and then transported to the Texas A&M Agricultural Research and Extension Center in Overton, TX. Cattle were allowed *ad libitum* Costal bermudagrass hay and 0.9 kg/hd/d of a 4:1 (corn:SBM) ration for a 12 d dry lot adjustment period before initiation of a winter pasture (Maton 'rye', *Secale cereale* + 'TAM 90' annual ryegrass, *Lolium multiflorum L.*) grazing experiment.

In order to accurately quantify animal performance on winter pasture, Overton steers were randomly assigned and allotted to their treatment groups. The cattle were allowed to graze 19 d on rye-ryegrass pasture as an adjustment period to allow for rumen-digestive adaptation and adjust to new animal groups. The grazing treatments were designed to evaluate two stocking methods x two stocking rates x two stocking strategies. Each of the eight treatment combinations (2x2x2 factorial arrangement of treatments) had two pasture replicates, for a total of 16 pastures. The first factor was stocking method where cattle were randomly assigned to either continuous stocking or an eight-paddock rotation with an approximate two-day residence and a 14-d rest for each pasture. The second factor was stocking rate whereby pastures were stocked at approximately 0.9 steer/ha at initiation of grazing (low), or at approximately 1.7 steers/ha at initiation of grazing (medium). The third factor was stocking strategy. The two stocking strategies were either fixed stocking rate and not changed during the entire grazing period of January to May, 2003 and variable stocking rate where stocking rate at initiation (both at 0.9 and 1.7/ha) were fixed for 57 d, and then both stocking rates were increased to approximately 3 hd/ac for the remainder of the grazing period 75 d. Steers at TAES-Overton were measured for BF by ultrasound upon initiation of the grazing experiment and after termination of the grazing experiment as previously described.

Upon completion of the winter grazing, the steers from Uvalde and Overton were transported approximately 50 and 475 km, respectively, and entered Liveoak feedlot in Batesville, TX 211 d postweaning for BONX and 186 d for BM steers .

Seven days after entering the feedlot, steers were evaluated for temperament via facial whorl patterns (FWP), CHUTE, PEN, EV, and OTC. Other measurements included WT and BCS and FS. Cattle were herded through a chute system as quickly as possible, without the use of electrical prods, and they were restrained in a hydraulic squeeze chute. Vertical distance (cm) of facial whorls from eye level was measured. Steers exited from a scale-mounted (Beefmaster XL-2VG, length = 114 cm/width = 41 cm/height = 78 cm) chute where WT and CHUTE were determined. The recorder stood directly in front of the chute to gain a clear view of the whorl location. The center of the hair whorl was used as the reference point to determine the position. The hair whorl was characterized as: 1) high, if the center was above a horizontal line connecting the top of the eyes; 2) middle, if the center was located between the top and bottom of the eyes; and 3) low, if the center was located below a horizontal line connecting the bottom of the eyes. Animals that had more than one hair whorl were classified as “doubles” and no hair whorls on the forehead were classified as “none” (Grandin et al., 1995). The whorl also was measured with a tape measure (cm) as the distance above or below a horizontal line connecting the bottom of the eyes. Steers exited the chute into an alley area where EV was measured and PEN were assigned.

While the cattle were restrained in a hydraulic squeeze chute, blood samples (15 ml) were obtained via coccygeal venipuncture. Blood samples were stored on ice to allow for coagulation, and then centrifuged for 15 min at approximately 2200 RPM within 4 h to harvest serum. Serum was frozen and stored at -20°C until cortisol (CS) concentrations were determined via radioimmunoassay. The radioimmunoassay was conducted in the Reproductive Physiology lab at Texas A&M University, College Station under the supervision and assistance of Dr. Tom Welsh. Serum concentration of CS, as determined on duplicate aliquots of sera samples, used a single antibody RIA procedure adapted from Willard et al. (1995). Rabbit anti-cortisol antiserum (Pantex, Div. of Bio-Analysis Inc., Santa Monica, CA Cat. #P44) was diluted 1:2500 and standards were made by serial dilution (8000 pg/100 μL to 3.9 pg/100 μL) of 4-pregnen-11β, 17, 21-triol-3,20-dione (Steroids Inc., Newport RI, Cat. #Q3880-000) and radio-labeled cortisol (^{3}H-Hydrocortisone 1,2-^{3}H, NEN, Boston MA, Cat. #NET-185). Cortisol concentrations were calculated using Assay Zap software (Biosoft, Cambridge, UK) and counts per minute (cpm) were obtained from a liquid scintillation spectrometer (Beckman Coulter LS 6500, Fullerton, CA). Cortisol antiserum cross-reactions were corticosterone (60%), deoxycorticosterone (48%), progesterone (0.01%), and estradiol (0.01%) as determined by Pantex. Interassay and intraassay CV were 9.44% and 0.39%, respectively.

After 55 d on feed (DOF), animals were measured for subcutaneous fat thickness at the 12th -13th rib using ultrasound as previously described. Rate of fattening was projected from the sequence of ultrasound BF measurements and harvest endpoints were determined. Cattle were harvested in two groups based on projected BF over the 12th and 13th rib. Therefore, steers were harvested after 88 or 147 DOF (August 12, 2003 and October 17, 2003, respectively) to an approximate 7 mm subcutaneous fat thickness harvest endpoint. Prior to leaving the feedlot for harvest, a final weight was recorded. All weights in the feedlot included allowing the cattle continued access to feed and water prior to handling or weighing. On harvest day, animals were transported approximately 320 km to Sam Kane Beef Processing Facility in Corpus Christi, TX.

Steers were harvested using commercial procedures at Sam Kane Beef Processors. Carcasses were electrically stimulated prior to eviceration using 328, 328, and 204 V, sequentially for approximately 5 sec each time. Pre-visceration carcasses were chilled at 0 ± 2°C for approximately 48 h post-harvest. A spray chill was applied at approximately six h post-mortem and then intermittently for the next eight h during chilling. At approximately 48 hrs post-harvest, carcasses were ribbed at the 12th and 13th rib interphase and hot carcass weight (HCW, kg), 12th rib backfat thickness (BFT, mm), estimated percentage of kidney, pelvic and heart fat (KPH, %), ribeye area (REA, cm^2), and marbling score (MS) were determined as defined by USDA (1997). Carcass measurements were obtained by trained Texas A&M University personel following the United States Department of Agriculture (USDA, 1997) guidelines, and Yield and Quality grades were calculated according to USDA (1997) using the carcass measurements. A 2.5 cm steak was removed from the 13th rib for Warner-Bratzler shear force determination at 14 d post-harvest.

Steaks for Warner-Bratzler shear force determination were vacuum-packaged in B620 bags (Cryovac Inc., Indianapolis, IN), boxed and then placed in a cooler for 14 d at 4°C. After aging, the samples were stored at -80° C. Forty-eight h prior to cooking, steaks were placed in a 2°C cooler and allowed to thaw. Steaks were weighed and iron constant thermocouples were placed in the geometric center of each 2.54 cm steak. The steaks were cooked on a Farberware Open-Hearth grill (Faberware Co., Bronx, NY) to a temperature of 35°C, and then steaks were turned. Steaks were removed from the grill when the internal temperature was 70°C. Temperature was monitored using a continuous recording potentiameter. Steaks were weighed after cooking, and cooking loss percentage was calculated by subtracting the raw weight from the cooked weight and dividing the difference by the raw steak weight. Cook time was calculated by measuring the time the steak was placed on the grill until taken off the grill. Steaks were cooled for a minimum of four h at room temperature (20°C) before testing. Six, 1.27 cm cores were removed parallel to the longitudinal orientation of the muscle fiber from each steak. Each core was sheared once using a Universal Testing Instrument (Model SSTM-500, United Calibration Corp., Hunnington Beah, CA) equipped with a V-notch Warner-Bratzler blade, and a 50 kg compression load cell with a cross-head speed of 200 mm/min as defined by American Meat Science Association (AMSA, 1995). The average force (kg) required to segment the six cores was reported for each steak and used for data analysis.

Experiment 2

Two hundred and seven spring-born (2002) Bonsmara X Angus (BA) were weaned from the Bird Ranch near Dalhart, TX in the fall. Cattle were grazed on wheat pasture in Dalhart, TX prior to being placed on experiment.

The experiment was initiated when steers were placed on a high concentrate diet at Cattletown feedlot (Hereford, TX) on May 23, 2003. Cattle were weighed using a hydraulic squeeze chute (Moly Manufacturing, Inc., Lorraine, KS) and ear-tagged at the initiation of the study, in feedlot traits of beginning WT (kg) and OTC were determined. At 25 DOF, the cattle again were restrained using a hydraulic chute and weight, ultrasound measurement of BF, FACE, and OTC were recorded. Facial whorl distance was measured as in Experiment 1. Cattle were worked quickly and as quietly as possible without the use of electrical prods.

Upon exiting the chute, EV were recorded as defined in Experiment 1. Cattle were confined to a pen area where they were assigned PEN and evaluated for BCS and FRAME as in Experiment 1. The measurements taken at this time were defined as beginning feedlot measurements. After 92 DOF, cattle were again processed through the working facility at the feedlot and OTC, EV and weight were determined. As the cattle exited the hydraulic chute, a modified temperament score was recorded as well as PEN, BCS, and FS. The modified temperament score was a subjective aggression rating determined by a technician standing at the head of the squeeze chute. A 20 liter bucket was placed approximately 4.5 meters directly in front of the squeeze chute in the path of the steer leaving the chute. The scores recorded were: 1) Wide avoidance; 2) Less avoidance; 3) Ignores; 4) Curious, smells bucket; and 5) Aggressive, charges bucket. This method was developed in an attempt to partition temperament into fright, curiosity, and aggression components. Traits measured during this working period were defined as end feedlot measurements.

Body condition scores and ultrasound measurements were used to estimate a harvesting endpoint of 7 mm of subcutaneous fat over the 12th and 13th rib interface. Cattle were harvested in two groups after 95 (n=161) and 123 (n = 46) DOF at Cargill Meat Solutions (Plainview, TX). For cattle harvested on 123 DOF weight, BCS, and FRAME were recorded prior to harvest at 117 DOF and defined as final feedlot traits.

Steers were harvested using commercial procedures at Cargill Meat Solutions. Carcasses were electrically stimulated 8 times with 50 V as they passed through a 40 ft section post-visceration. A spray chill (0 ± 4°C) was applied prior to evisceration and then again intermittently for 48 h post-mortem during chilling. Carcasses were ribbed at the 12th and 13th rib interphase and HCW (kg), BFT (mm), KPH, REA, and MS were determined by a trained Excel employee according to USDA (1997). The USDA Yield and Quality grades (1=Prime; 2=Choice; 3=Select; 9=Standard) were calculated according to USDA (1997) using carcass measurements. A vision yield grade was calculated from video images using a standard 2.5% KPH. Percent marbling also was determined using the Cargill Meat Solutions video image system. A rib section was removed by Cargill personnel, vacuum-packaged then aged at 2^{O}C for 21 d, and placed in a -80^{O}C freezer until used for WBS evaluation as described in Experiment 1.

Experiment 3

Beef USDA Choice and Select top sirloin (n=51; IMPS #184) and strip loins (n=146; IMPS #180) from Experiment 2 were obtained from one carcass side. Carcasses were fabricated approximately 48 hours post-mortem and subprimals were vacuum packaged and stored at approximately 0°C for 27 days and transported (0°C) to Freedman Foods (Freedman Food Service of Dallas, Inc., Dallas, TX) for further processing. Subprimals were stored at 0°C for 24 h before conducting the retail product yield cutting test. Four professional meat cutters from Freedman Foods were used.

Retail yields were determined for strip loins. Purge was calculated by taking the weight of the strip loin in the package and subtracting the difference in weight of the strip loin after it was removed from the package. The difference was multiplied by 100 and expressed as percent purge loss.

Top loin steaks (340 g) were cut from the strip loin and top loins from one strip were weighed together. Vein steaks (steaks that had M. *gluteus medius* on both sides of the cut) also were cut from each strip loin and weighed together. All steaks were trimmed to a 6 mm fat thickness, the back strap was removed, and the tails were trimmed to 2.54 cm. The amount of trimmable fat was weighed and excess trim (30% fat) also was weighed and reported.

The top sirloin butt subprimals were removed from the package and weighed (kg). Percent purge loss was calculated as described earlier. Top butt subprimals were trimmed to 6 mm of external fat and the trimmable fat was weighed. The sciatic nerve and the *m. gluteobicepts* were removed from the top butts. The *m. gluteobicepts* was weighed, and 225 g steaks were individually cut from the *m. gluteus medium*. Steaks from a subprimal were recombined and weighed. The remaining lean was cut into beef for stew and lean trimmings that contained approximately 30% fat. Beef for stew and lean trimmings were weighed.

Statistical analysis

Descriptive statistics were calculated for Experiment 1, 2, and 3 using PROC MEANS. Simple correlation coefficients were determined between temperament measures from Experiments 1 and 2 and live animal performance, carcass characteristics, and tenderness using PROC CORR. To determine the effect of pre-finishing pasture background treatments on live animal performance, carcass characteristics, and tenderness data were analyzed by Analysis of Variance using the general linear model (GLM) procedure of SAS (Version 6.12, Cary, NC, 1998) with a predetermined significance level of $P \leq 0.05$. Pre-finishing background treatment was defined as a main effect. For variables that were affected by pre-finishing background treatment, least squares means were calculated and differences between means were determined using the standard error PDIFF function.

Exit velocity data were converted to discrete data that was defined as slow less than the mean EV, and fast greater than the mean EV categories. The four categories for Experiment 1 were: 1) Slow/Slow (SS) where mean weaning and beginning feedlot were less than 3.53 m/s for weaning EV and 2.91 m/s for beginning feedlot EV ; 2) Fast/Slow (FS) where mean weaning EV was greater than 3.53 m/s and beginning feedlot EV was less than 2.91 m/s; 3) Slow/Fast (SF) where weaning EV was less than

3.53 and beginning feedlot EV was greater than 2.91; and 4) Fast/Fast (FF) where mean weaning and beginning feedlot EV were greater than 3.53 m/s for weaning EV and 2.91 m/s for beginning feedlot EV. The four categories for Experiment 2 were: 1) Slow/Slow (SS) where mean beginning and end feedlot were less than 2.85 m/s for beginning EV and 2.38 m/s for end feedlot EV; 2) Fast/Slow (FS) where mean beginning EV was greater than 2.85 m/s and end feedlot EV was less than 2.38 m/s; 3) Slow/Fast (SF) where beginning EV was less than 2.85 and end feedlot EV was greater than 2.38; and 4) Fast/Fast (FF) where mean beginning and end feedlot EV were greater than 2.85 m/s for beginning EV and 2.38 m/s for end feedlot EV. To determine the effect of EV categories on live animal performance, carcass characteristics, and tenderness data were analyzed by Analysis of Variance using the general linear model (GLM) procedure of SAS with a predetermined significance level of $P \leq 0.05$. Exit velocity category was defined as a main effect. For variables that were affected by EV categories, least squares means were calculated and differences between means were determined using the standard error pdiff function.

Exit velocity data were converted to discrete data that was defined as exit velocity groups of slow, medium and fast based on <0.5 SD, ± 0.5 SD, and >0.5 SD, respectively, from the mean. Weaning EV categories from Experiment 1 and beginning feedlot EV groups from Experiment 2 were analyzed by Analysis of Variance using PROC GLM procedure of SAS with EV group described as a main effect. Linear, cubic, and quadratic effects were tested using orthogonal contrasts and there were no significant cubic or quadratic effects. Least squares means were calculated and if differences in EV groups were reported ($P<0.05$) then least squares means were separated using the standard error PDIFF function.

Temperament variables in Experiment 2 were analyzed by principal component analysis using PROC FACTOR as a rotated factor pattern. Factor loadings were assigned a common name that reflected the importance of the factor in predicting each of the observed variables, that is, the coefficients in the pattern matrix corresponding to the factor. The rotated pattern matrix measured how close the elements are to 0 or 1, with the elements closer to 1 being the factor loading reflective of the elements. Factor elements the closest to 1 were considered the loading reflective of that pattern and then the factors were used to test association with production variables.

CHAPTER IV

RESULTS

Experiment 1

Descriptive statistics. Exit velocity was numerically faster at weaning (Table 5) than at the beginning of the feeding period (Table 6; 3.5 vs 2.9 m/s). The standard deviation; however, was higher for EV measured at the beginning of the feedlot period as compared to that measured at weaning. This would suggest that, in general, animals adapted or conformed to the production system, but some did not. Chute scores and pen scores measured at weaning (Table 5) were slightly lower, but similar ($P>0.1$), than beginning of the feedlot period chute and pen scores (Table 6). Serum cortisol concentrations measured at the beginning of the feedlot period (Table 6) were generally low, although cortisol concentrations ranged from 1.01 to 28.15 ng/mL. Cattle performance on pasture and in the feedlot was 1.0 kg/d (Table 5) and 1.39 kg/d (Table 6), respectively. The gains reported from this study were comparable to cattle fed similarily (Coffey et al., 2002). Marbling scores ranged from average Choice to Standard, but the mean marbling score was high Select. Carcass backfat measurements ranged from 2.5 to 12.7 mm, but averaged 7 mm, as defined by design. Mean Warner-Bratzler shear force (Table 7) was 2.67 kg and ranged from 1.51 to 4.63 kg. Four percent of steaks had Warner-Bratzler shear force values above 3.9 kg, considered tough by Shackelford et al. (1991). Lung scores averaged 2.1. McKenna et al. (2002) reported that about 75% of lungs were condemned. Therefore, steers in Experiment 1 had less

Table 5. Descriptive statistics for pre-feedlot temperament and performance characteristics (Experiment 1)

Variable	N	Mean	Std Dev	Minimum	Maximum
Weaning exit velocity (m/s)	138	3.53	0.798	1.19	5.85
Weaning chute score	137	1.9	0.800	1.0	4.0
Weaning pen score	138	1.4	0.60	1.0	3.0
Weaning wt. (kg)	160	221.1	48.28	114.9	346.4
On pasture backfat (mm)	147	4.5	2.09	1.3	9.0
On pasture wt. (kg)	159	226.9	46.39	121.2	325.5
Off pasture backfat (mm)	156	7.1	1.71	3.6	13.5
Off pasture wt. (kg)	156	362.0	54.95	254.2	517.6
Pasture ADG (kg/d)	156	1.00	0.219	0.32	1.60

Table 6. Descriptive statistics for performance and temperament measures in the feedlot (Experiment 1)

Variable	N	Mean	Std Dev	Minimum	Maximum
In feedlot exit velocity (m/s)	156	2.91	0.944	1.01	5.24
In feedlot chute score	156	2.1	1.04	1.0	5.0
In feedlot pen score	155	1.7	0.82	1.0	4.0
In feedlot cortisol (ng/mL)	156	10.98	5.72	1.01	28.15
Facial whorl distance (cm)[a]	135	6.5	4.63	-2.0	18.0
Change in exit velocity (m/s)[b]	135	-0.57	1.052	-3.42	2.49
Average exit velocity (m/s)[c]	135	3.24	0.696	1.51	5.55
Speedclass	135	2.3	1.16	1.0	4.0
In feedlot wt. (kg)	156	344.8	50.26	249.7	488.1
Mid-feedlot backfat (mm)	152	9.2	1.70	5.6	14.7
Mid-feedlot wt. (kg)	151	430.5	50.54	295.6	580.2
End feedlot wt (kg)	152	494.5	37.54	381.4	626.5
Feedlot ADG (kg/d)	152	1.39	0.310	0.50	2.55

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[a] Distance above or below a horizontal line connecting the bottom of the eyes
[b] In feedlot exit velocity-Weaning exit velocity
[c] (In feedlot exit velocity + Weaning exit velocity)/2

Table 7. Carcass characteristics and Warner-Bratzler shear force descriptive statistics (Experiment 1)

Variable	N	Mean	Std Dev	Minimum	Maximum
Hot carcass weight (kg)	88	290.4	24.91	251.5	364.6
Dressing %	88	61.3	2.31	55.9	65.5
Carcass backfat (mm)	88	7.0	2.47	2.5	12.7
Adjusted preliminary yield grade	88	2.69	0.309	2.0	3.9
Ribeye area (cm^2)	88	78.65	7.805	61.92	99.33
Kidney, pelvic and heart fat (%)	88	2.2	0.32	1.5	3.0
Marbling score	88	409.8	53.20	280.0	540.0
Quality grade[a]	88	692.6	31.14	590.0	747.0
Yield grade	88	2.2	0.398	1.1	3.3
Hump height (cm)	80	4.3	0.663	3.0	6.0
Lung score	88	2.1	0.72	1.0	3.0
Warner-Bratzler shear force (kg)	133	2.67	0.591	1.51	4.63

[a] USDA Beef Quality Grade: 700=Choice; 600=Select; 500=Standard

respiratory disease than normally expected.

Backgrounding effects. Since cattle were backgrounded at different locations and exposed to different treatments, least squares means were calculated and compared between the 9 different stocker treatments for pre-feedlot, feedlot and carcass characteristics (Table 8, 9 and 10). Cattle varied in fat thickness prior to the start of the grazing experiment from 3.6 to 13.5 mm, and there were differences ($p<0.05$) in fatness between the treatments and locations. Stocker treatment at Overton affected ($p<0.05$) backfat, off-rye-ryegrass and hot carcass weight, and ADG on-rye-ryegrass (Table 8). Additionally, pasture perfomrance affected ADG in the feedlot (Table 9), and HCW and dressing percent (Table 10). As steers were fed for 88 and 147 days on feed (DOF) to a projected fat constant endpoint of 7 mm during finishing, nutritional and management practices for steers prior to entering the finishing phase expectedly impacted production performance. While stocker treatments impacted ADG, and cattle that gained slower on ryegrass tended to gain faster in the feedlot, final live weight, carcass characteristics and tenderness were not impacted by stocker treatments. Understanding the effect of stocker treatments on live animal growth and carcass characteristics is important. The pre-feedlot treatment created variation in the feeder calves similar to cattle in the industry that would traditionally enter a feedlot from a variety of nutritional backgrounds. Therefore, variation in stocker management of steers provided a backdrop not dissimilar to industry situations to understand the relationship between temperament and stress on feedlot performance, carcass characteristics, and tenderness. Since we wanted to incorporate the variation induced by stocker treatment, these effects were considered

Table 8. Effects of grazing treatment on pre-feedlot measurements (Experiment 1)[a]

Location	Overton	Overton	Overton	Overton	Overton	Overton	Overton	Overton	Uvalde
Method	Continuous	Continuous	Rotational	Rotational	Continuous	Continuous	Rotational	Rotational	Continuous
Strategy[b]	Fixed	Variable	Fixed	Variable	Fixed	Variable	Fixed	Variable	Fixed
Level[c]	Low	Low	Low	Low	Medium	Medium	Medium	Medium	Medium
Weaning exit velocity (m/s)	4.21 ± 0.262	3.36 ± 0.237	3.78 ± 0.278	3.68 ± 0.237	3.45 ± 0.218	3.73 ± 0.278	3.12 ± 0.297	3.27 ± 0.278	3.48± 0.099
Weaning pen score	1.7 ± 0.20	1.3 ± 0.18	1.4 ± 0.21	1.5 ± 0.18	1.5 ± 0.17	1.3 ± 0.21	1.3 ± 0.23	1.1 ± 0.21	1.5 ± 0.08
Weaning chute score	2.2 ± 0.27	1.8 ± 0.24	1.9 ± 0.29	1.7 ± 0.24	1.9 ± 0.22	2.3 ± 0.29	1.7 ± 0.31	1.8 ± 0.29	1.9 ± 0.10
Weaning wt (kg)	232.9 ± 15.86	220.6 ± 14.35	239.3 ± 16.82	209.2 ± 14.34	193.5 ± 13.20	243.6 ± 16.82	243.5 ± 19.99	245.5 ± 16.82	217.7 ± 5.16
On ryegrass backfat (cm)	0.70^{f}± 0.025	0.64^{ef}± 0.023	0.64^{ef}± 0.027	0.64^{ef}± 0.023	0.60^{e}± 0.021	0.66^{ef}± 0.027	0.65^{ef}± 0.029	0.62^{e}± 0.027	0.25^{d}± 0.009
On ryegrass wt (kg)	237.2 ± 15.42	220.9 ± 13.95	246.8 ± 16.36	218.0 ± 13.95	208.2 ± 12.83	247.5 ± 16.36	243.8 ± 17.49	245.0 ± 16.36	223.7 ± 5.05
Off ryegrass backfat (cm)	0.87^{f}± 0.042	0.87^{f}± 0.038	0.89^{f}± 0.044	0.81^{ef}± 0.038	0.78^{ef}± 0.035	0.85^{f}± 0.044	0.81^{ef}± 0.047	0.70^{e}± 0.044	0.60^{d}± 0.014
Off ryegrass wt (kg)	398.1^{e}± 17.61	375.5^{de}± 15.93	406.4^{e}± 18.68	367.2^{de}± 15.9	359.7^{de}± 14.65	391.3^{e}± 18.68	375.5^{de}± 20.0	370.3^{de}± 18.68	346.6^{d}±5.87
Ryegrass ADG (kg/d)	1.14^{e}± 0.071	1.08^{de}± 0.064	1.12^{e}± 0.075	1.06^{de}± 0.064	1.05^{de} ± 0.059	1.03^{de}± 0.075	0.94^{de}± 0.081	0.91^{d}± 0.075	0.95^{de}± 0.024

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[a] Least square means from the model: Y=weaning exit velocity, weaning chute score, weaning weight, weaning pen score, weaning order through the chute, on ryegrass weight, on ryegrass backfat, off ryegrass weight, off ryegrass backfat, beginning feedlot pen score, beginning feedlot exit velocity, beginning feedlot cortisol, beginning feedlot chute score, facial whorl distance, change in exit velocity, average exit velocity, beginning feedlot weight, beginning feedlot order through the chute, mid-feedlot order through the chute, mid-feedlot backfat, mid-feedlot weight, end feedlot weight, end feedlot order through the chute, average daily gain on ryegrass, average daily gain in the feedlot, hot carcass weight, dressing percent, carcass backfat, adjusted preliminary yield grade, ribeye area, kidney pelvic and heart fat, marbling score, quality grade, yield grade, hump height, lung score, and mean shear force

[b] Strategy consisted of Fixed (the stocking rate was not changed the entire grazing period) or Variable (stocking rate at initiation were fixed until March 4, 2003, and then both stocking rates were increased to approximately 3 hd/ac for the duration of the grazing period)

[c] Level was either Low (approximately 0.9 steer/ac at initiation of grazing) or Medium (approximately 1.7 steers/ac at initiation of grazing)

[def] Least squares means with different superscripts within a row differ, P<0.05

Table 9. Effects of grazing treatment on feedlot measurements (Experiment 1)[a]

Location Method Strategy[b] Level[c]	Overton Continuous Fixed Low	Overton Continuous Variable Low	Overton Rotational Fixed Low	Overton Rotational Variable Low	Overton Continuous Fixed Medium	Overton Continuous Variable Medium	Overton Rotational Fixed Medium	Overton Rotational Variable Medium	Uvalde Continuous Fixed Medium
In feedlot exit velocity (m/s)	2.87 ± 0.313	2.73 ± 0.283	3.01 ± 0.332	3.41 ± 0.283	3.08 ± 0.260	3.09 ± 0.331	3.40 ± 0.355	3.20 ± 0.332	2.74 ± 0.104
In feedlot pen score	2.1 ± 0.28	1.7 ± 0.25	1.8 ± 0.29	1.5 ± 0.25	1.8 ± 0.24	1.6 ± 0.29	1.1 ± 0.31	2.0 ± 0.29	1.7 ± 0.09
In feedlot chute score	2.2 ± 0.35	1.9 ± 0.32	2.6 ± 0.37	2.0 ± 0.32	2.3 ± 0.29	2.2 ± 0.37	1.7 ± 0.40	2.1 ± 0.37	2.0 ± 0.12
In feedlot cortisol (ng/mL)	16.23 ± 1.870	12.21 ± 1.691	10.66 ± 1.983	10.67 ± 1.691	9.49 ± 1.556	14.01 ± 1.983	12.67 ± 2.120	9.77 ± 1.983	10.22 ± 0.623
In feedlot FWD (cm)[d]	7.0 ± 1.66	7.0 ± 1.48	5.5 ± 1.91	8.4 ± 1.56	4.8 ± 1.41	5.0 ± 1.77	6.5 ± 1.91	7.5 ± 1.66	6.5 ± 0.56
Change in exit velocity[e]	-1.35 ± 0.343	-0.63 ± 0.310	-0.77 ± 0.364	-0.27 ± 0.310	-0.37 ± 0.285	-0.65 ± 0.364	0.28 ± 0.389	-0.07 ± 0.364	-0.66 ± 0.133
Avg exit velocity (m/s)[f]	3.54 ± 0.343	3.04 ± 0.211	3.39 ± 0.247	3.54 ± 0.211	3.27 ± 0.194	3.41 ± 0.247	3.26 ± 0.265	3.24 ± 0..247	3.14 ± 0.090
In feedlot WT (kg's)	371.5 ± 16.48	359.1 ± 14.91	378.0 ± 17.48	349.2 ± 14.91	340.3 ± 13.71	365.5 ± 17.48	352.5 ± 18.69	349.9 ± 17.48	333.5 ± 5.49
Mid-feedlot backfat (cm)	0.99 ± 0.057	0.89 ± 0.054	0.97 ± 0.060	0.95 ± 0.054	0.88 ± 0.047	1.01 ± 0.060	0.92 ± 0.064	0.83 ± 0.060	0.92 ± 0.091
Mid-feedlot WT (kg's)	450.9 ± 16.65	429.4 ± 15.79	454.8 ± 17.66	412.8 ± 15.79	425.2 ± 14.42	465.5 ± 17.66	452.6 ± 18.88	428.5 ± 17.66	423.6 ± 5.62
End feedlot WT (kg's)	497.4 ± 12.38	509.4 ± 11.74	498.8 ± 13.13	477.6 ± 11.74	497.3 ± 10.30	509.6 ± 13.13	509.8 ± 14.04	516.1 ± 13.13	488.4 ± 4.18
ADG (kg/d)	1.13^{g}± 0.101	1.32^{ghi} ± 0.095	1.26^{ghi} ±0.107	1.25^{gh} ± 0.095	1.35^{ghi} ± 0.084	1.46^{hi} ± 0.107	1.47^{hi} ± 0.114	1.55^{hi} ± 0.107	1.44^{hi} ± 0.034

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[a] Least square means from the model: Y=weaning exit velocity, weaning chute score, weaning weight, weaning pen score, weaning order through the chute, on ryegrass weight, on ryegrass backfat, off ryegrass weight, off ryegrass backfat, beginning feedlot pen score, beginning feedlot exit velocity, beginning feedlot cortisol, beginning feedlot chute score, facial whorl distance, change in exit velocity, average exit velocity, beginning feedlot weight, beginning feedlot order through the chute, mid-feedlot order through the chute, mid-feedlot backfat, mid-feedlot weight, end feedlot weight, end feedlot order through the chute, average daily gain on ryegrass, average daily gain in the feedlot, hot carcass weight, dressing percent, carcass backfat, adjusted preliminary yield grade, ribeye area, kidney pelvic and heart fat, marbling score, quality grade, yield grade, hump height, lung score, and mean shear force

[b] Strategy consisted of Fixed (the stocking rate was not changed the entire grazing period) or Variable (stocking rate at initiation were fixed until March 4, 2003, and then both stocking rates were increased to approximately 3 hd/ac for the duration of the grazing period)

[c] Level was either Low (approximately 0.9 steer/ac at initiation of grazing) or Medium (approximately 1.7 steers/ac at initiation of grazing)

[d] Facial whorl distance=Distance above or below a horizontal line connecting the bottom of the eyes

[e] (In feedlot exit velocity + Weaning exit velocity)/2

[f] In feedlot exit velocity – Weaning exit velocity

[ghi] Least squares means with different superscripts within a row differ, $P<0.05$

Table 10. Effects of grazing treatment on carcass characteristics and Warner-Bratzler shear force measurements (Experiment 1)[a]

Location	Overton	Overton	Overton	Overton	Overton	Overton	Overton	Overton	Uvalde
Method	Continuous	Continuous	Rotational	Rotational	Continuous	Continuous	Rotational	Rotational	Continuous
Strategy[b]	Fixed	Variable	Fixed	Variable	Fixed	Variable	Fixed	Variable	Fixed
Level[c]	Low	Low	Low	Low	Medium	Medium	Medium	Medium	Medium
HCW (kg)	302.4^{ef}± 9.58	303.0^{ef}±13.55	292.1^{ef}±8.87	281.8^{e}±10.50	301.3^{ef}±8.87	306.1^{ef}±10.50	316.2^{f}±11.73	301.9^{ef}±10.50	281.9^{e}±3.64
Dressing %	63.0^{f}± 0.88	62.7^{ef}± 1.24	61.0^{ef}± 0.81	60.2^{e}± 0.96	62.3^{ef}± 0.81	63.2^{f}± 0.96	63.5^{f}± 1.07	60.6^{e}± 0.96	60.6^{e}± 0.32
Backfat (mm)	7.7 ± 1.00	9.3 ± 1.41	7.1 ± 0.92	5.8 ± 1.09	7.3 ± 0.92	8.6 ± 1.09	8.3 ± 1.22	5.8 ± 1.09	6.7 ± 0.36
Adjusted preliminary yield grade	2.9 ± 0.12	2.8 ± 0.18	2.8 ± 0.11	2.5 ± 0.14	2.7 ± 0.11	2.8 ± 0.14	2.8 ± 0.15	2.6 ± 0.14	2.6 ± 0.0
Ribeye area (cm^2)	75.92 ± 3.102	85.79 ± 4.392	75.40 ± 2.878	80.50 ± 3.419	79.72 ± 2.878	82.82 ± 3.400	86.30 ± 3.806	80.63 ± 3.400	77.27 ± 1.122
Kidney, pelvic and heart fat (%)	2.3 ± 0.13	2.2 ± 0.18	2.3 ± 0.12	2.1 ± 0.14	2.3 ± 0.12	2.1 ± 0.14	2.5 ± 0.16	2.0 ± 0.14	2.2 ± 0.05
Marbling score	433.3 ± 21.02	386.7 ± 29.72	425.7 ± 19.46	412.0 ± 23.02	424.3 ± 19.46	370.0 ± 23.02	360.0 ± 25.74	368.0 ± 23.02	416.5 ± 7.59
Quality grade[d]	703.5 ± 12.18	682.3 ± 17.22	703.0 ± 11.27	693.4 ± 13.34	703.1 ± 11.27	670.0 ± 13.34	656.8 ± 14.91	668.0 ± 13.34	696.7 ± 4.40
Yield grade	2.5 ± 0.159	2.1 ± 0.225	2.4 ± 0.147	1.9 ± 0.174	2.2 ± 0.147	2.2 ± 0.174	2.2 ± 0.195	2.0 ± 0.174	2.1 ± 0.058
Lung scores	2.3 ± 0.29	2.7 ± 0.41	2.1 ± 0.27	2.4 ± 0.32	2.4 ± 0.27	1.6 ± 0.32	2.0 ± 0.36	1.8 ± 0.32	2.0 ± 0.11
Hump height (cm)	4.3 ± 0.27	4.8 ± 0.38	4.8 ± 0.25	5.25 ± 0.47	4.1 ± 0.29	4.2 ± 0.29	4.0 ± 0.38	4.3 ± 0.29	4.3 ± 0.10
Warner-Bratzler shear force (kg's)	2.74 ± 0.199	2.48 ± 0.199	2.96 ± 0.211	2.75 ± 0.199	2.77 ± 0.180	2.96 0.243	2.50 ± 0.298	2.66 ± 0.225	2.62 ± 0.071

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[a] Least square means from the model: Y=weaning exit velocity, weaning chute score, weaning weight, weaning pen score, weaning order through the chute, on ryegrass weight, on ryegrass backfat, off ryegrass weight, off ryegrass backfat, beginning feedlot pen score, beginning feedlot exit velocity, beginning feedlot cortisol, beginning feedlot chute score, facial whorl distance, change in exit velocity, average exit velocity, beginning feedlot weight, beginning feedlot order through the chute, mid-feedlot order through the chute, mid-feedlot backfat, mid-feedlot weight, end feedlot weight, end feedlot order through the chute, average daily gain on ryegrass, average daily gain in the feedlot, hot carcass weight, dressing percent, carcass backfat, adjusted preliminary yield grade, ribeye area, kidney pelvic and heart fat, marbling score, quality grade, yield grade, hump height, lung score, and mean shear force

[b] Strategy consisted of Fixed (the stocking rate was not changed the entire grazing period) or Variable (stocking rate at initiation were fixed until March 4, 2003, and then both stocking rates were increased to approximately 3 hd/ac for the duration of the grazing period)

[c] Level was either Low (approximately 0.9 steer/ac at initiation of grazing) or Medium (approximately 1.7 steers/ac at initiation of grazing)

[d] USDA Beef Quality grade: 700=Choice; 600=Select; 500=Standard

[ef] Least square means with different superscripts within a row differ, P<0.05

part of the residual error in computations.

Simple correlations coefficients. Most temperament measurements were correlated with each other (Table 11). Beginning feedlot EV and weaning EV were plotted against each other and a regression line was calculated where EV=1.82 + .32 x weaning EV (r^2=0.03; Figure 2). Although EV tended to decrease from weaning to the beginning of the feeding period, it would appear that cattle that were flighty at weaning, continue to be flighty upon entry into the feedlot. Weaning CHUTE tended to have the lowest correlation with other temperament variables. Whorl distance was not correlated with any of the other temperament variables (Table 11). Observations of temperament upon entry to the feedlot tended to be more highly related than the same variable for both pre-feedlot (Table 12) and feedlot (Table 13) performance. In addition, change in EV was correlated with both pre-feedlot (r=-.30, Table 12) and feedlot (r=.20, Table 13) ADG. Serum cortisol concentration obtained at the beginning of the feedlot period tended to be more related to measurements of condition or fat prior to entering the feedlot, than to other measurements of performance such as weight or ADG (Table 12). Beginning feedlot exit velocity tended to have higher correlation values with animal weight prior to entering the feedlot (r=-0.28, Table 12) and in the feedlot (r=-0.30, Table 13) than did beginning feedlot pen scores and beginning feedlot chute scores. Smaller animals on pasture and in the feedlot had greater ($P<0.05$) beginning feedlot exit velocities, but beginning feedlot EV was not related to pre-feedlot and feedlot ADG. Although weaning EV did not have as high of correlation as other measures of temperament with weight or fatness. Weaning EV was correlated with on and off rye-

Table 11. Simple correlation coefficients for temperament measurements (Experiment 1)

	Weaning pen score	Weaning chute score	Beginning feedlot exit velocity (m/s)	Beginning feedlot pen score	Beginning feedlot chute score	Beginning feedlot cortisol (ng/mL)	Change in exit velocity (m/s)[a]	Average exit velocity (m/s)[b]	Facial whorl distance (cm)[c]
Weaning exit velocity (m/s)	0.44[d] 0.0001[e] 138[f]	0.14 0.11 137	0.28 0.001 135	0.32 0.0002 134	0.21 0.01 135	0.16 0.06 135	-0.51 0.0001 135	0.76 0.0001 135	0.10 0.31 115
Weaning pen score		0.24 0.004 137	0.20 0.02 135	0.54 0.0001 134	0.29 0.0006 135	0.18 0.04 135	-0.16 0.07 135	0.39 0.0001 135	-0.02 0.80 115
Weaning chute score			0.11 0.20 134	0.28 0.001 133	0.17 0.05 134	0.02 0.78 134	-0.007 0.95 134	0.16 0.07 134	0.06 0.15 135
Beginning feedlot exit velocity (m/s)				0.49 0.0001 155	0.47 0.0001 156	0.29 0.0002 156	0.68 0.0001 135	0.83 0.0001 135	0.03 0.69 135
Beginning pen score					0.49 0.0001 155	0.20 0.01 155	0.19 0.02 134	0.52 0.0001 134	0.08 0.35 134
Beginning feedlot chute score						0.28 0.0004 156	0.24 0.006 135	0.42 0.0001 135	-0.02 0.82 135
Beginning feedlot cortisol (ng/mL)							0.14 0.10 135	0.29 0.0006 135	-0.05 0.53 135
Change in exit velocity (m/s)[a]								0.16 0.06 135	-0.01 0.9084 115
Average exit velocity (m/s)[b]									0.10 0.29 115

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[a] In feedlot exit velocity – Weaning exit velocity

[b] (In feedlot exit velocity + Weaning exit velocity)

[c] Distance above or below a horizontal line connecting the bottom of the eyes

[d] Correlation coefficient

[e] P-value

[f] Number

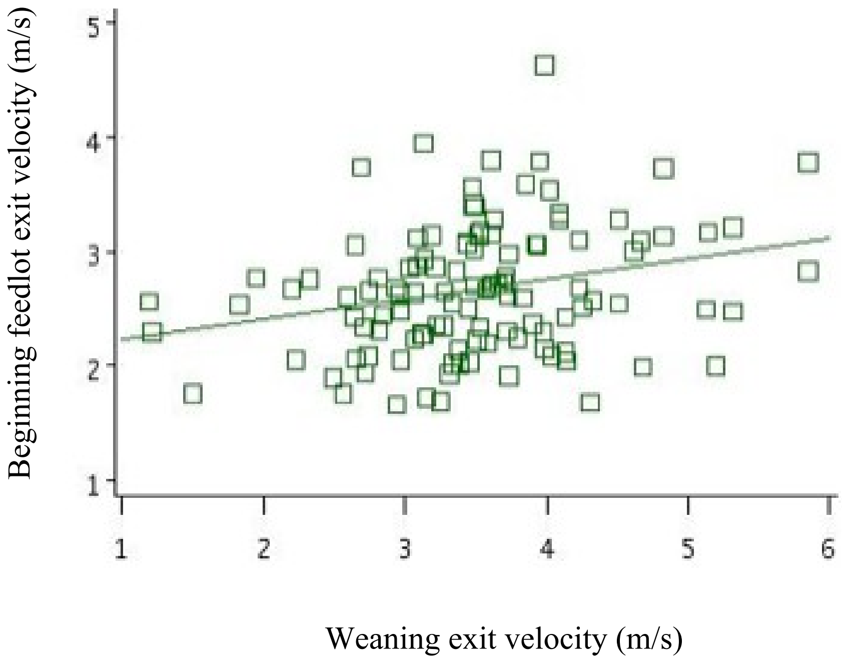

Figure 2. Linear regression line for beginning feedlot exit velocity and weaning exit velocity, experiment 1 (Y=1.82 + .32*weaning EV, R^2=0.08, RMSE=6.573).

Table 12. Simple correlation coefficients for temperament and pre-feedlot measurements (Experiment 1)

	Weaning exit velocity (m/s)	Weaning pen score	Weaning chute score	Beginning feedlot exit velocity (m/s)	Beginning feedlot pen score	Beginning feedlot chute score	Beginning feedlot cortisol (ng/mL)	Change in exit velocity (m/s)[a]	Average exit velocity (m/s)[b]	Facial whorl distance (cm)[c]
Weaning wt. (kg)	0.06[d]	0.08	0.08	-0.16	-0.04	-0.05	0.07	-.21	-0.10	0.12
	0.46[e]	0.33	0.36	0.04	0.63	0.53	0.41	0.01	0.22	0.15
	138[f]	138	137	156	155	156	156	135	135	135
On pasture backfat (cm)	0.10	-0.07	-0.01	0.09	-0.05	-0.02	0.22	-0.01	0.10	-0.01
	0.25	0.39	0.90	0.28	0.58	0.77	0.007	0.88	0.27	0.90
	137	137	136	144	143	144	144	135	135	124
On pasture wt. (kg)	0.01	0.04	0.03	-0.28	-0.18	-0.17	0.08	-0.25	-0.19	0.07
	0.91	0.63	0.77	0.0004	0.03	0.04	0.35	0.003	0.03	0.45
	137	137	136	156	155	156	156	135	135	135
Off pasture backfat (cm)	0.17	-0.01	-0.02	-0.02	-0.06	0.02	0.16	-0.17	0.07	0.09
	0.04	0.90	0.84	0.80	0.48	0.77	0.05	0.04	0.43	0.31
	135	135	134	156	155	156	156	135	135	135
Off pasture wt. (kg)	0.02	-0.03	0.01	-0.28	-0.20	-0.17	-0.04	-0.33	-0.22	0.11
	0.80	0.72	0.88	0.0004	0.01	0.03	0.66	0.0001	0.01	0.21
	135	135	134	156	155	156	156	135	135	135
Pasture ADG (kg/d)	0.02	-0.15	0.01	-0.13	-0.09	-0.08	-0.23	-0.30	-0.20	0.11
	0.80	0.08	0.91	0.11	0.26	0.35	0.003	0.0005	0.02	0.21
	135	135	134	156	155	156	156	135	135	135

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[a] In feedlot exit velocity – Weaning exit velocity

[b] (In feedlot exit velocity + Weaning exit velocity)

[c] Distance above or below a horizontal line connecting the bottom of the eyes

[d] Correlation coefficients

[e] P-value

[f] Number

Table 13. Simple correlation coefficients for feedlot and temperament measurements (Experiement 1)

	Weaning exit velocity (m/s)	Weaning pen score	Weaning chute score	Beginning feedlot exit velocity (m/s)	Beginning feedlot pen score	Beginning feedlot chute score	Beginning feedlot cortisol (ng/mL)	Change in exit velocity (m/s)[a]	Average exit velocity (m/s)[b]	Facial whorl distance (cm)[c]
In feedlot wt. (kg)	0.03[d]	-0.03	0.004	-0.32	-0.22	-0.21	-0.08	-0.35	-0.23	0.10
	0.73[e]	0.74	0.97	0.0001	0.006	0.008	0.34	0.0001	0.007	0.25
	135[f]	135	134	156	155	156	156	135	135	135
Mid-feedlot backfat (mm)	0.03	0.003	0.06	-0.10	-0.12	-0.11	0.03	-0.10	-0.04	-0.08
	0.75	0.98	0.49	0.22	0.14	0.16	0.75	0.25	0.63	0.34
	131	131	130	152	151	152	152	131	131	131
Mid-feedlot wt. (kg)	0.02	-0.07	0.03	-0.26	-0.21	-0.23	-0.06	-0.30	-0.20	-0.04
	0.79	0.44	0.75	0.002	0.010	0.004	0.44	0.0005	0.02	0.67
	130	130	129	151	150	151	151	130	130	130
End feedlot wt. (kg)	-0.15	-0.15	0.0007	-0.17	-0.21	-0.12	-0.04	-0.08	-0.24	0.04
	0.08	0.09	0.99	0.03	0.01	0.13	0.60	0.34	0.006	0.66
	131	131	130	152	151	152	152	131	131	131
Feedlot ADG (kg/d)	-0.26	-0.16	0.05	0.05	-0.07	0.03	-0.09	0.22	-0.13	-0.05
	0.003	0.07	0.55	0.52	0.39	0.69	0.27	0.01	0.13	0.58
	131	131	130	152	151	152	152	131	131	131

[a] In feedlot exit velocity – Weaning exit velocity

[b] (In feedlot exit velocity + Weaning exit velocity)

[c] Distance above or below a horizontal line connecting the bottom of the eyes

[d] Correlation coefficients

[e] P-value

[f] Number

ryegrass backfat (r=-0.17, Table 12), feedlot ADG (r=-0.26, Table 13), ribeye area (r=0.37, Table 14), yield grade (r=0.29, Table 15), and WBS force (r=.27, Table 15).

Regression analyses indicated that ADG decreased with each 0.09 kg/m/s (Figure 3) and WBS force increased at the rate of 0.18 kg/m/s (Figure 4) with each m/s change in weaning EV. Beginning feedlot EV was not correlated with carcass characteristics or tenderness (Table 14 and 15). Other notable correlations (P<0.05) included change in EV with REA (r=0.27, Table 14), yield grade and WBS force (r=-0.25 and r=-0.21, respectively, Table 15). Serum cortisol concentration was correlated with adjusted preliminary yield grade (r=0.21, Table 14), mean EV with REA (r=-0.21. Table 14). Whorl location was negatively correlated with carcass backfat (r=-0.43, Table 14), marbling score (r=-0.28, Table 15), and quality grade (r=-0.32, Table 15). Although simple correlation coefficients were low and there were no strong relationships, there were trends in the data and relationships that warrant further investigation. From this study we hypothesized that multiple temperament measures at different time periods may be more predictive of live animal performance, carcass characteristics and beef tenderness.

Least squares means. Since weaning EV and change in EV seemed to have similar patterns of correlations across all the traits, and beginning feedlot EV was more highly correlated with pre-feedlot and feedlot traits, weaning and beginning feedlot EV were used to categorize cattle into 4 groups (Figure 5); Slow/Slow, Slow/Fast, Fast/ Fast, and Fast/Slow. Slow/Slow EV categories were used to describe cattle that did not show an undesirable response to handling during the entire production system. Fast/Fast EV

Table 14. Simple correlation coefficients for carcass characteristics and temperament (Experiment 1)

	Weaning exit velocity (m/s)	Weaning pen score	Weaning chute score	Beginning feedlot exit velocity (m/s)	Beginning feedlot pen score	Beginning feedlot chute score	Beginning feedlot cortisol (ng/mL)	Change in exit velocity (m/s)[a]	Average exit velocity (m/s)[b]	Facial whorl distance (cm)[c]
Hot carcass wt (kg)	-0.17[d]	-0.16	0.07	-0.08	-0.11	-0.14	-0.04	0.04	-0.18	0.16
	0.13[e]	0.16	0.53	0.46	0.32	0.21	0.74	0.70	0.12	0.18
	78[f]	78	78	88	87	88	88	78	78	76
Dressing percent	0.12	0.07	-0.05	0.07	0.11	-0.03	0.17	-0.04	0.12	-0.15
	0.29	0.57	0.69	0.50	0.29	0.78	0.12	0.73	0.30	0.21
	78	78	78	88	87	88	88	78	78	76
Carcass backfat (mm)	0.02	0.06	0.005	-0.03	-0.17	-0.04	0.19	-0.01	0.01	-0.30
	0.89	0.60	0.97	0.80	0.11	0.71	0.08	0.90	0.94	0.008
	78	78	78	88	87	88	88	78	78	76
Adjusted preliminary yield grade	0.19	0.21	0.02	-0.03	-0.06	-0.04	0.21	-0.15	0.12	-0.19
	0.09	0.06	0.90	0.75	0.59	0.70	0.05	0.19	0.31	0.10
	78	78	78	88	87	88	88	78	78	76
Ribeye area (cm^2)	-0.37	-0.20	0.11	-0.03	-0.15	-0.10	-0.01	0.27	-0.25	0.0004
	0.0008	0.08	0.32	0.80	0.16	0.34	0.90	0.02	0.03	0.99
	78	78	78	88	87	88	88	78	78	76
Kidney, pelvic and heart fat (%)	-0.16	-0.09	-0.05	0.07	-0.09	-0.08	-0.10	0.18	-0.05	-0.14
	0.18	0.44	0.69	0.50	0.43	0.45	0.34	0.11	0.68	0.23
	78	78	78	88	87	88	88	78	78	76

[a] In feedlot exit velocity – Weaning exit velocity

[b] (In feedlot exit velocity + Weaning exit velocity)

[c] Distance above or below a horizontal line connecting the bottom of the eyes

[d] Correlation coefficients

[e] P-value

[f] Number

Table 15. Simple correlation coefficients for carcass characteristics, tenderness and temperament (Experiment 1)

	Weaning exit velocity (m/s)	Weaning pen score	Weaning chute score	Beginning feedlot exit velocity (m/s)	Beginning feedlot pen score	Beginning feedlot chute score	Beginning feedlot cortisol (ng/mL)	Change in exit velocity (m/s)[a]	Average exit velocity (m/s)[b]	Facial whorl distance (cm)[c]
Marbling score	0.02[d]	-0.08	-0.06	-0.04	-0.08	-0.01	-0.01	0.02	-0.009	-0.28
	0.84[e]	0.51	0.58	0.70	0.44	0.92	0.91	0.83	0.94	0.01
	78[f]	78	78	88	87	88	88	78	78	76
Quality grade	0.03	-0.01	-0.06	-0.02	-0.02	0.03	-0.01	-0.009	0.02	-0.32
	0.82	0.93	0.62	0.83	0.83	0.76	0.90	0.94	0.83	0.005
	78	78	78	88	87	88	88	78	78	76
Yield grade	0.29	0.15	-0.09	-0.03	-0.01	-0.01	0.09	-0.25	0.16	-0.13
	0.01	0.18	0.42	0.81	0.91	0.92	0.39	0.03	0.16	0.26
	78	78	78	88	87	88	88	78	78	76
Hump height (cm)	0.13	-0.09	-0.17	0.15	-0.07	0.17	-0.11	-0.002	0.16	0.03
	0.29	0.48	0.17	0.17	0.55	0.13	0.33	0.99	0.19	0.78
	71	71	71	80	79	80	80	71	71	69
Lung score	0.005	0.10	-0.15	0.05	-0.10	0.02	0.10	-0.07	-0.05	-0.03
	0.97	0.39	0.18	0.67	0.36	0.85	0.36	0.54	0.67	0.79
	78	78	78	88	87	88	88	78	78	76
WBS force (kg)	0.27	0.10	0.05	0.01	0.03	0.03	0.03	-0.21	0.17	-0.01
	0.005	0.30	0.63	0.89	0.72	0.72	0.76	0.02	0.10	0.88
	113	113	112	133	132	133	133	113	113	114

[a] In feedlot exit velocity – Weaning exit velocity
[b] (In feedlot exit velocity + Weaning exit velocity)
[c] Distance above or below a horizontal line connecting the bottom of the eyes
[d] Correlation coefficients
[e] P-value
[f] Number

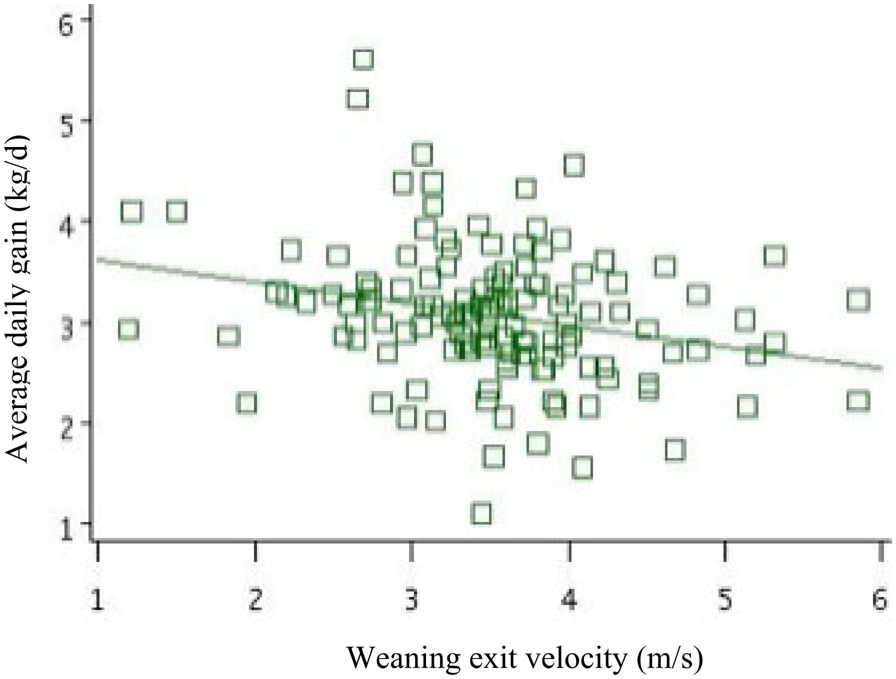

Figure 3. Linear regression line for average daily gain and weaning exit velocity, experiment 1 [Y=1.74 + (-0.09*weaning EV), R^2=0.07, RMSE=0.667].

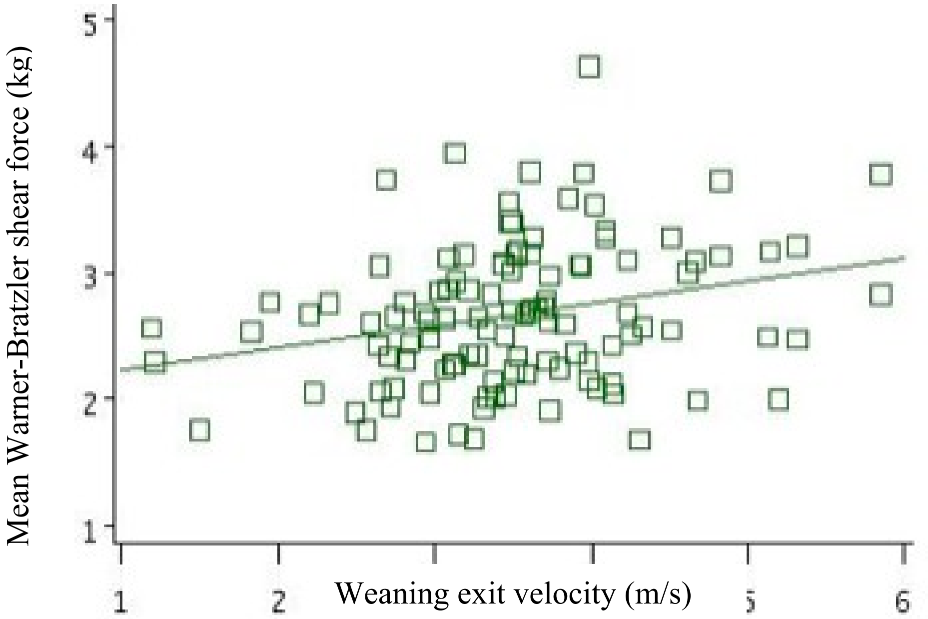

Figure 4. Linear regression line for mean Warner-Bratzler shear force and weaning exit velocity, experiment 1 (Y=2.04 + 0.18*weaning EV, R^2=0.05, RMSE=0.615).

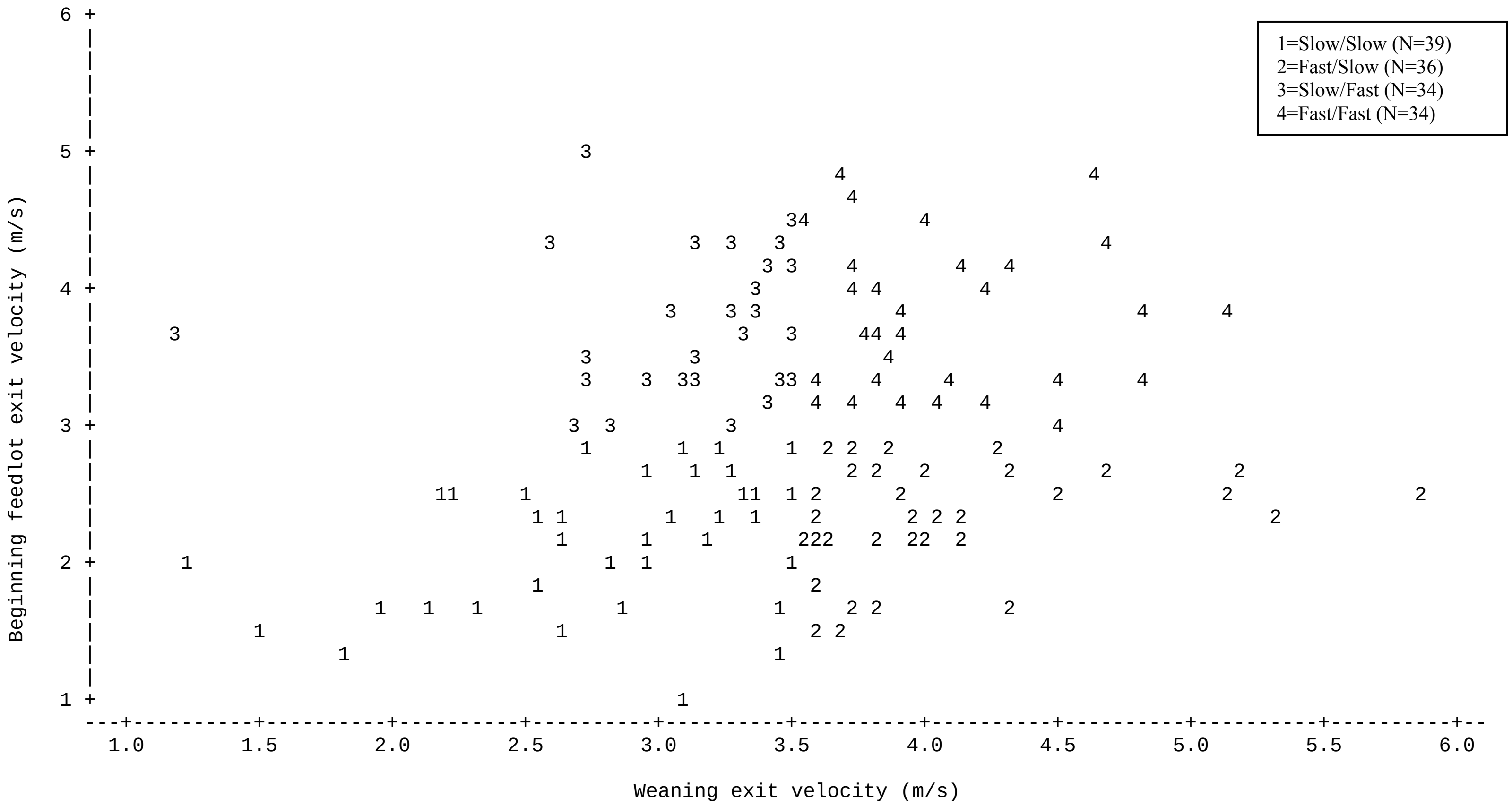

Figure 5. Beginning feedlot exit velocity and weaning exit velocity denoted by exit velocity category (experiment 1).

were categorized as cattle that responded adversely to both stressful situations. Fast/Slow EV cattle were described as animals that adapted and had a more desirable response each time they were handled. Slow/Fast EV cattle were defined as the group that did not adapt and became more behaviorally agitated over time. Comparisons between behavioral response groups enabled examination of animals that were behaviorally resistant to management compared to those that adapted over time. Some cattle apparently did not conform or acclimate to the production system.

Temperament measures and live animal weight and backfat prior to entering the feedlot were affected by EV categories (Table 16). Weaning PEN were higher for the fast EV cattle at weaning. Although cattle in the Slow/Fast category were numerically lower than the fast EV cattle at weaning they were not statistically different. The Fast/Slow cattle had higher weaning weights and the cattle that had faster EV at weaning had more backfat and higher ADG on ryegrass (Table 16). Cattle that had slow EV at the beginning of the feedlot period had numerically higher weights going onto pasture. Cattle in the SF group had less 12th and 13th rib backfat off pasture (Table 16).

Differences in temperament measures and live animal weight and backfat during the feedlot phase were also affected by EV categories. Beginning feedlot chute scores and pen scores seemed to follow the same trend, cattle in the Slow/Slow groups had lower chute and pen scores than the other three groups, and cattle in the Slow/Fast and Fast/Fast numerically had faster EV than the slow beginning feedlot EV groups (Table 17). Serum cortisol concentration tended to increase gradually from the SS to the FF group (Table 17). However, increases in feedlot EV had greater impact on in feedlot

Table 16. Least squares means and standard error for pre-feedlot measurements as effected by exit velocity categories at weaning and beginning of the feedlot period (Experiment 1)

Weaning exit velocity (m/s)		Slow	Fast	Slow	Fast
Beginning feedlot EV (m/s)	Number	Slow	Slow	Fast	Fast
Weaning exit velocity (m/s)	137	2.84^{a} ± 0.085	4.08^{c} ± 0.092	3.11^{b} ± 0.101	4.15^{c} ± 0.093
Weaning pen score	137	1.1^{a} ± 0.090	1.7^{b} ± 0.10	1.4^{ab} ± 0.11	1.5^{b} ± 0.10
Weaning chute score	136	1.8 ± 0.13	2.0 ± 0.13	1.8 ± 0.15	2.1 ± 0.14
Weaning wt. (kg)	159	218.4^{a} ± 6.35	240.7^{b} ± 8.04	212.2^{a} ± 8.04	214.6^{a} ± 8.15
On pasture backft (mm)	146	3.9 ± 0.30	4.7 ± 0.35	4.5 ± 0.37	5.1 ± 0.35
On pasture wt. (kg)	158	233.7^{b} ± 6.10	238.6^{b} ± 7.82	219.7^{ab} ± 7.71	211.4^{a} ± 7.83
Off pasture backfat (mm)	155	6.6^{a} ± 0.23	7.7^{b} ± 0.28	3.7^{a} ± 0.28	7.5^{b} ± 0.28
Off pasture wt. (kg)	155	362.1^{a} ± 7.28	389.6^{b} ± 9.09	342.3^{a} ± 8.96	354.5^{a} ± 9.09
Pasture ADG (kg/d)	155	0.95^{a} ± 0.028	1.12^{b} ± 0.035	0.91^{a} ± 0.035	1.04^{b} ± 0.03

[abc] Least squares means with different superscripts within a row and exit velocity category differ, P<0.05, from the model: Y=weaning exit velocity, weaning chute score, weaning weight, weaning pen score, weaning order through the chute, on ryegrass weight, on ryegrass backfat, off ryegrass weight, off ryegrass backfat, beginning feedlot pen score, beginning feedlot exit velocity, beginning feedlot cortisol, beginning feedlot chute score, facial whorl distance, change in exit velocity, average exit velocity, beginning feedlot weight, beginning feedlot order through the chute, mid-feedlot order through the chute, mid-feedlot backfat, mid-feedlot weight, end feedlot weight, end feedlot order through the chute, average daily gain on ryegrass, average daily gain in the feedlot, hot carcass weight, dressing percent, carcass backfat, adjusted preliminary yield grade, ribeye area, kidney pelvic and heart fat, marbling score, quality grade, yield grade, hump height, lung score, and mean shear force

Table 17. Least squares means and standard error for feedlot measurements as effected by exit velocity categories at weaning and beginning of the feedlot period (Experiment 1)

Weaning exit velocity (m/s)		Slow	Fast	Slow	Fast
Beginning feedlot exit velocity (m/s)	Number	Slow	Slow	Fast	Fast
Beginning feedlot exit velocity (m/s)	156	2.13^{a} ± 0.070	2.31^{a} ± 0.087	3.77^{b} ± 0.086	3.82^{b} ± 0.087
Beginning feedlot pen score	155	1.3^{a} ± 0.11	1.7^{b} ± 0.13	1.8^{b} ± 0.13	2.2^{c} ± 0.13
Beginning feedlot chute score	156	1.5^{a} ± 0.13	2.1^{b} ± 0.16	2.6^{c} ± 0.16	2.5^{bc} ± 0.16
Beginning feedlot cortisol (ng/mL)	156	9.34^{a} ± 0.761	9.91^{ab} ± 0.950	12.36^{bc} ± 0.936	13.20^{bc} ± 0.950
Beginning feedlot facial whorl distance (cm)[d]	135	6.1 ± 0.68	6.8 ± 0.84	5.6 ± 0.86	7.8 ± 0.84
Change in exit velocity (m/s)[e]	135	-0.67^{b} ± 0.104	-1.75^{a} ± 0.110	0.67^{d} ± 0.119	-0.32^{c} ± 0.110
Average exit velocity (m/s)[f]	135	2.49^{a} ± 0.068	3.19^{b} ± 0.072	3.44^{c} ± 0.078	3.99^{d} ± 0.072
In feedlot wt. (kg)	156	348.3^{b} ± 6.57	371.1^{c} ± 8.20	323.0^{a} ± 8.09	335.5^{ab} ± 8.20
Mid-feedlot backfat (mm)	152	9.3 ± 0.24	9.5 ± 0.31	9.2 ± 0.29	9.0 ± 0.30
Mid-feedlot wt. (kg)	151	433.3 ± 6.84	449.0 ± 8.94	418.0 ± 8.41	421.4 ± 8.80
End feedlot wt. (kg)	152	497.6 ±5.13	502.2 ± 6.71	483.8 ± 6.31	493.6 ± 6.50
Feedlot ADG (kg/d)	152	1.39 ± 0.042	1.34 ± 0.055	1.49 ± 0.052	1.34 ± 0.053

[abcd] Least squares means with different superscripts within a row and exit velocity category differ, P<0.05, from the model: Y=weaning exit velocity, weaning chute score, weaning weight, weaning pen score, weaning order through the chute, on ryegrass weight, on ryegrass backfat, off ryegrass weight, off ryegrass backfat, beginning feedlot pen score, beginning feedlot exit velocity, beginning feedlot cortisol, beginning feedlot chute score, facial whorl distance, change in exit velocity, average exit velocity, beginning feedlot weight, beginning feedlot order through the chute, mid-feedlot order through the chute, mid-feedlot backfat, mid-feedlot weight, end feedlot weight, end feedlot order through the chute, average daily gain on ryegrass, average daily gain in the feedlot, hot carcass weight, dressing percent, carcass backfat, adjusted preliminary yield grade, ribeye area, kidney pelvic and heart fat, marbling score, quality grade, yield grade, hump height, lung score, and mean shear force

[d] Distance above or below a horizontal line connecting the bottom of the eyes

[e] In feedlot exit velocity – Weaning exit velocity

[f] (In feedlot exit velocity + Weaning exit velocity)/2

cortisol than weaning EV, and had slight increased effects as EV increased after weaning. Increases from weaning EV had less effect on in feedlot CS but this tendency was consistent regardless of in feedlot EV. In addition, cattle demonstrating fast EV at the beginning of the feedlot period had numerically lower weights than their corresponding slow EV counterparts (Table 17). Even though the fast EV cattle tended to be lighter throughout the experiment, there were no apparent differences in weight at the end of the finishing phase (Table 17). Average daily gain during the feedlot phase was the same ($P>0.10$) for all EV classifications (Table 17). The Slow/Fast group continued to exhibit the lowest weights recorded in the feedlot.

Carcass characteristics and tenderness measures did not differ across EV categories (Table 18). Carcass backfat, marbling score and USDA quality grade were numerically lower for the Fast/Fast EV group when compared to the other groups (Table 18). While no statistical differences were found, cattle with slow EV at weaning still had the lowest WBS force measurements (Table 18). There may have been no statistical differences between the EV categories since there were weak correlation relationships. This did not allow for much variation when EV was categorized.

The cattle were also categorized into slow, medium, and fast EV groups based on half a standard deviation from the overall mean weaning EV value (Table 19). These categories were used to identify the extreme exit velocities, or the slow and fast groups. Significant linear effects ($p<0.05$) were observed for weaning EV in off ryegrass backfat, feedlot ADG, carcass backfat, ribeye area, yield grade, and WBS force (Table 19).

Table 18. Least squares means and standard error for carcass and tenderness measurements as effected by exit velocity categories at weaning and beginning of the feedlot period (Experiment 1)

Weaning exit velocity (m/s) Beginning feedlot exit velocity (m/s)	Number	Slow Slow	Fast Slow	Slow Fast	Fast Fast
Hot carcass weight (kg)	88	291.2 ± 4.37	294.2 ± 5.48	285.1 ± 5.48	290.8 ± 6.97
Dressing %	88	60.9 ± 0.40	61.8 ± 0.50	61.8 ± 0.50	60.4 ± 0.63
Backfat (mm)	88	7.1 ± 0.043	7.1 ± 0.055	7.0 ± 0.055	6.6 ± 0.070
Adjusted preliminary yield grade	88	2.7 ± 0.05	2.7 ± 0.07	2.6 ± 0.07	2.7 ± 0.09
Ribeye area (cm^2)	88	79.92 ± 4.005	76.63 ± 1.709	79.14 ± 1.709	77.53 ± 2.167
Kidney, pelvic and heart fat (%)	88	2.2 ± 0.06	2.1 ± 0.07	2.2 ± 0.07	2.1 ± 0.09
Marbling score	88	414.8 ± 9.33	402.4 ± 11.70	416.7 ± 11.70	397.7 ± 14.87
Quality grade[a]	88	695.1 ± 5.48	688.7 ± 6.87	695.8 ± 6.87	687.2 ± 8.73
Yield grade	88	2.1 ± 0.07	2.3 ± 0.09	2.1 ± 0.09	2.2 ± 0.11
Lung score	88	1.9 ± 0.13	2.2 ± 0.16	2.1 ± 0.16	2.1 ± 0.20
Hump height (cm)	80	4.2 ± 0.12	4.2 ± 0.15	4.5 ± 0.15	4.3 ± 0.20
Warner-Bratzler shear force (kg)	133	2.61 ± 0.083	2.82 ± 0.109	2.55 ± 0.105	2.80 ± 0.122

Least squares means from the model: Y=weaning exit velocity, weaning chute score, weaning weight, weaning pen score, weaning order through the chute, on ryegrass weight, on ryegrass backfat, off ryegrass weight, off ryegrass backfat, beginning feedlot pen score, beginning feedlot exit velocity, beginning feedlot cortisol, beginning feedlot chute score, facial whorl distance, change in exit velocity, average exit velocity, beginning feedlot weight, beginning feedlot order through the chute, mid-feedlot order through the chute, mid-feedlot backfat, mid-feedlot weight, end feedlot weight, end feedlot order through the chute, average daily gain on ryegrass, average daily gain in the feedlot, hot carcass weight, dressing percent, carcass backfat, adjusted preliminary yield grade, ribeye area, kidney pelvic and heart fat, marbling score, quality grade, yield grade, hump height, lung score, and mean shear force

[a] USDA Beef Quality Grade: 700=Choice; 600=Select; 500=Standard

Table 19. Least squares means, standard errors and p-values for backfat, weight, average daily gain and carcass characteristics and Warner-Bratzler shear force as effected by exit velocity groups at weaning (Experiment 1)

	Experiment 1 Weaning exit velocity group[a]					
Variable	Number	Slow	Medium	Fast	P-value	RMSE
Backfat off pasture, cm	135	0.66^{c}	0.73^{cd}	0.76^{d}	0.05	0.171
WT off pasture, kg	135	361.3	371.1	367.9	0.71	55.63
In feedlot weight, kg	135	341.6	351.5	349.7	0.65	51.33
End feedlot weight, kg	131	507.0	492.7	494.4	0.20	38.13
Average daily gain, kg/d	131	1.52^{c}	1.38^{d}	1.29^{c}	0.009	0.303
Hot carcass weight, kg	78	300.1	290.4	290.0	0.31	24.61
Backfat, cm	78	0.76^{c}	0.59^{d}	0.74^{c}	0.009	0.230
Ribeye area, cm^2	78	81.85^{c}	78.95^{cd}	74.88^{d}	0.02	7.746
Yield grade	78	2.2^{c}	2.0^{c}	2.4^{d}	0.0008	0.35
WBS force, kg	113	2.46^{c}	2.70^{cd}	2.83^{d}	0.03	0.556

[a] Slow=< mean – 0.5 SD, Medium=mean – 0.5 SD to mean + 0.5 SD, Fast= > mean + 0.5 SD

[b] RMSE: Root Mean Square Error from Analysis of Variance table.

[cd] Least squares means with different superscripts within a row and velocity group differ, $P<0.05$, from the model Y=backfat off pasture, weight off pasture, in feedlot weight, end feedlot weight, feedlot ADG, hot carcass weight, carcass backfat, ribeye area, yield grade, shear force

Experiment 2

Descriptive statistics. Initial EV was 0.48 m/s greater than final (2.85 vs. 2.38 m/s, p>0.10, Table 20). The standard deviation for end feedlot EV was larger than beginning feedlot EV, and the maximum change in EV was positive indicating that some cattle did not appear to conform or adapt to the feedlot environment (Table 20). Pen scores were similar at the beginning of the feedlot period and at the end of the feedlot period (Table 20).

Mean carcass backfat was 9.8 mm (Table 21). The target fatness for the study was 10 mm. Quality grade ranged from Prime to Standard and the average quality grade was Choice with a mean marbling percent of 2.4 (Table 21). Mean WBS force was 2.84 and ranged from 1.76 to 5.22 (Table 21), but only 4% of the cattle harvested produced steaks < 3.9 kg.

Factor analysis. In order to better understand the relationship among temperament variables, the data were analyzed using factor analysis (Table 22). Factor 1 was characterized by EV and PEN (Table 22). Factor 2 was characterized by a high single loading for change in EV that would be considered an indication of adaptability (Table 22). Factor 3 had a high loading only for order through the chute upon entry or exiting the feedlot (Table 22). Multiple behavioral responses could be useful indicators of stress responsiveness. Behavioral responses were grouped into factor loadings and each factor was used as a response category. These categories were used to test the effects of multiple behavioral measures on various live animal performance traits, carcass characteristics and tenderness.

Table 20. Descriptive statistics for performance in the feedlot (Experiment 2)

Variable	N	Mean	Std Dev	Minimum	Maximum
In feedlot wt. (kg)	207	385.6	39.57	255.1	499.4
Beginning feedlot exit velocity (m/s)	205	2.85	0.897	0.79	5.74
Beginning feedlot pen score	206	2.1	1.01	1.0	7.0
Beginning feedlot backfat (cm)	207	0.39	0.106	0.14	0.69
Beginning feedlot wt. (kg)	207	428.5	46.04	288.3	563.0
End feedlot exit velocity (m/s)	207	2.38	0.925	0.64	5.42
End feedlot pen score	207	2.4	1.18	1.0	5.0
End feedlot bucket score	207	2.1	1.09	1.0	5.0
End feedlot wt. (kg)	207	525.1	55.35	313.3	660.6
Change in exit velocity (m/s)[a]	205	-0.48	1.030	-3.40	2.87
Average exit velocity (m/s)[b]	205	2.61	0.750	0.71	5.15
Harvest feedlot wt. (kg)	207	532.4	46.05	390.4	660.6
Days on feed	207	104.7	10.75	99.0	125.0
Beginning feedlot ADG(kg/d)[c]	207	1.59	0.89	-1.77	5.98
Feedlot ADG (kg/d)[d]	207	1.42	0.31	0.78	2.55

[a] End feedlot exit velocity – Beginning feedlot exit velocity
[b] (End feedlot exit velocity + Beginning feedlot exit velocity)/2
[c] (Harvest weight-In feedlot weight)/23 DOF
[d] (Harvest weight-In feedlot weight)/harvest DOF

Table 21. Descriptive statistics for carcass characteristics and tenderness (Experiment 2)

Variable	N	Mean	Std Dev	Minimum	Maximum
Hot carcass wt. (kg)	207	328.6	28.66	240.9	409.1
Carcass backfat (mm)	207	9.8	3.47	1.0	24.9
Ribeye area (cm^2)	207	85.08	9.172	42.57	110.94
Hump height (cm)	205	7.5	0.96	5.1	10.4
Quality grade[a]	207	2.9	1.53	1.0	9.0
Yield grade	196	2.1	0.37	1.0	3.0
Percent marbling	207	2.4	0.80	0.9	5.7
Vision yield grade	207	2.5	0.64	1.0	5.4
Warner-Bratzler shear force (kg)	204	2.84	0.563	1.76	5.22

[a] USDA Beef Quality Grade: 1=Prime; 2=Choice; 3=Select; 9=Standard

Table 22. Rotated factor patter for temperament measurements at the beginning and end of the feedlot period (Experiment 2)

Variable Description of factor loadings	Factor 1 Exit velocity and pen score	Factor 2 Change in exit velocity	Factor 3 Order through chute
Beginning feedlot exit velocity (m/s)	0.63	-0.75	-0.05
Beginning feedlot pen score	0.75	0.01	0.10
Beginning feedlot order through chute	-0.13	-0.20	0.71
End feedlot exit velocity (m/s)	0.87	0.32	-0.08
End feedlot pen score	0.83	0.01	-0.05
End feedlot bucket score	-0.56	-0.19	0.14
End feedlot order through chute	0.02	0.19	0.80
Change in exit velocity[a]	0.22	0.94	-0.03
Average exit velocity[b]	0.91	-0.25	-0.08
Speedclass[c]	0.85	-0.13	-0.11
Variance explained by each factor	4.34	1.74	1.20
Proportion of variance explained	0.44	0.17	0.12
Cumulative variance explained	0.44	0.61	0.7

[a] End feedlot exit velocity – Beginning feedlot exit velocity

[b] (End feedlot exit velocity + Beginning feedlot exit velocity)/2

[c] 1=(Beginning and End feedlot exit velocity < mean);
2=(Beginning feedlot exit velocity > mean and End feedlot exit velocity < mean);
3=(Beginning feedlot exit velocity < mean and End feedlot exit velocity > mean);
4=(Beginning and End feedlot exit velocity > mean)

Simple linear correlations. All temperament variables were correlated with each other (Table 23). The relationship between beginning and end EV was plotted and a regression line was constructed to best fit the data (Figure 6). A regression for end feedlot exit velocity and beginning feedlot EV indicated that end feedlot EV increased by 0.37 m/s for every m/s increase in beginning feedlot EV. Although there may have been a decrease in EV over time, cattle that tended to be more flighty at the beginning of the feeding period tended to remain flighty cattle upon exiting the feedlot. Temperament measurements obtained either upon entering or exiting the feedlot were more related to each other than measurements taken at different times (Table 23). Also, like-temperament (i.e., beginning and end EV) measurements tended to be more related to one another even at different time periods (Table 23).

Simple linear correlations then were used to evaluate the relationship between temperament variables, feedlot and carcass performance traits, and WBS force tenderness. Although all the correlations were relatively low (r<0.20), all feedlot performance measurements, excluding feedlot ADG, were generally more highly related to end feedlot EV and pen scores than the other temperament-related variables (Table 24). Beginning feedlot EV was not correlated with any feedlot performance measurements, but beginning feedlot pen score was correlated with in feedlot weight (r=-0.15, P=0.03, Table 24). Factor 1 (EV and PEN) was related to beginning feedlot measurements (r=-0.15, P=0.02), factor 2 (change in EV) was correlated with beginning feedlot backfat (r=-0.14, P=0.04), and factor 3 (OTC) was found to be related to rate of maturation being positively related to beginning feedlot backfat (r=0.44, P<0.01),

Table 23. Simple correlation coefficients for temperament measurements (Experiment 2)

	Beginning feedlot pen score	End feedlot exit velocity (m/s)	End feedlot pen score	Change in exit velocity[a]	Average exit velocity[b]
Beginning feedlot exit velocity (m/s)	0.39[c]	-0.17	0.46	-0.55	0.82
	0.0001[d]	0.0001	0.0001	0.0001	0.0001
	204[e]	205	205	205	205
Beginning feedlot pen score		0.36	0.71	0.11	0.55
		0.0001	0.0001	0.13	0.0001
		205	206	204	204
End feedlot exit velocity (m/s)			0.62	0.58	0.83
			0.0001	0.0001	0.0001
			207	205	205
End feedlot pen score				0.16	0.65
				0.03	0.0001
				205	205
Change in exit velocity (m/s)[a]					0.03
					0.67
					205

[a] End feedlot exit velocity – Beginning feedlot exit velocity

[b] (End feedlot exit velocity + Beginning feedlot exit velocity)/2

[c] Correlation coefficients

[d] P-value

[e] Number

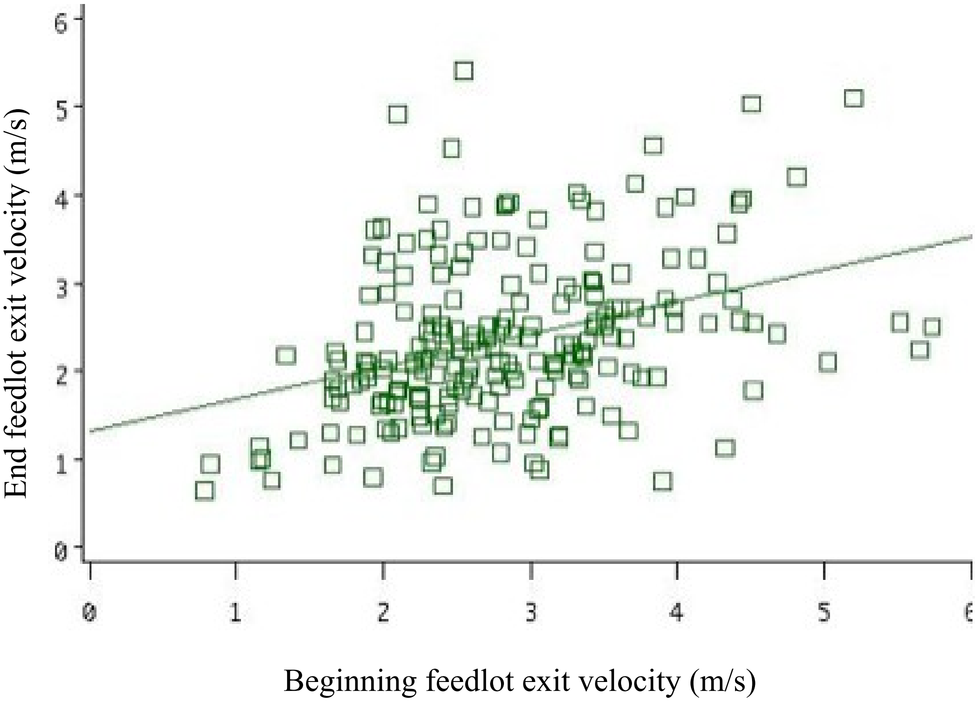

Figure 6. Linear regression line for end feedlot exit velocity and beginning feedlot exit velocity, experiment 2 (Y=1.31 + 0.37*beginning feedlot EV, R^2=0.13, RMSE=0.836).

Table 24. Simple correlation coefficients for feedlot performance and temperament measurements (Experiment 2)

	Beginning feedlot exit velocity (m/s)	Beginning feedlot pen score	End feedlot exit velocity (m/s)	End feedlot pen score	Change in exit velocity[a] (m/s)	Average exit velocity[b] (m/s)	Factor1[c]	Factor2[d]	Factor3[e]
In feedlot WT (kg)	-0.09[f]	-0.15	-0.18	-0.19	-0.07	-0.15	-0.16	-0.01	-0.06
	0.21[g]	0.03	0.01	0.007	0.32	0.03	0.02	0.88	0.43
	205[h]	206	207	207	205	205	204	204	204
Beginning feedlot backfat (cm)	-0.04	-0.04	-0.16	-0.16	-0.09	-0.12	-0.15	-0.14	0.44
	0.53	0.53	0.02	0.02	0.20	0.10	0.03	0.04	0.0001
	205	205	207	207	205	205	204	204	204
Beginning feedlot WT (kg)	-0.06	-0.06	-0.19	-0.21	-0.10	-0.14	-0.16	-0.04	-0.07
	0.37	0.37	0.007	0.003	0.15	0.04	0.02	0.58	0.31
	205	205	207	207	205	205	204	204	204
End feedlot WT (kg)	0.01	-0.08	-0.15	-0.16	-0.12	-0.09	-0.11	-0.09	-0.14
	0.85	0.28	0.04	0.02	0.07	0.18	0.12	0.20	0.05
	205	206	207	207	205	205	204	204	204
Final feedlot WT(kg)	-0.007	-0.08	-0.16	-0.16	-0.12	-0.09	-0.12	-0.08	-0.14
	0.92	0.25	0.02	0.02	0.08	0.18	0.08	0.27	0.04
	205	206	207	207	205	205	204	204	204
DOF[i]	0.03	0.10	0.13	0.14	0.07	0.08	0.12	0.07	-0.01
	0.70	0.17	0.07	0.05	0.30	0.24	0.10	0.31	0.91
	205	206	207	207	205	205	204	204	204
Beginning average daily gain (kg/d)	0.02	0.04	-0.07	-0.09	-0.07	-0.02	-0.05	-0.06	-0.04
	0.73	0.53	0.31	0.20	0.27	0.73	0.52	0.42	0.42
	205	206	207	207	205	205	204	204	204
Feedlot averge daily gain (kg/d)	0.09	0.04	-0.07	-0.05	-0.13	0.02	-0.02	-0.13	-0.14
	0.21	0.61	0.31	0.43	0.07	0.77	0.75	0.06	0.05
	205	206	207	207	205	205	204	204	204

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[a] End feedlot exit velocity – Beginning feedlot exit velocity
[b] (End feedlot exit velocity + Beginning feedlot exit velocity)/2
[c] Exit velocity and pen score
[d] Change in exit velocity
[e] Order through the chute
[f] Correlation coefficients
[g] P-value
[h] Number
[i] Days on feed

negatively related to both final feedlot weight (r=-0.14, P=0.05), and overall ADG (r=-0.14, P=0.05, Table 24). The relationship between ADG and factor 3 was plotted, and a best-fit line was constructed. Average daily gain declined at the rate of -0.04 kg/d per unit increase in Factor 3 (OTC, Figure 7).

The relationships between temperament measurements or factors and carcass characteristics or tenderness were small and generally not significant (P>0.05, Table 25). Carcass backfat was found to be correlated with beginning feedlot EV (r=0.15, P=0.04), change in EV (-0.17, P=0.02), and factor 2 (r=-0.19, P=0.01, Table 25). Quality grade was related to beginning feedlot EV (r=0.18, P=0.01) and factor 2 (r=-0.14, P=0.04), while percent marbling was related to beginning feedlot pen score (r=-0.16, P=0.02), end feedlot EV (r=-0.17 P=0.01), and factor 1 (r=0.17, P=0.02, Table 25). Other significant correlations included: yield grade with end feedlot EV (r=-0.15, P=0.04), average EV (r=-0.14, P=0.05), and factor1 (r=-0.16, P=0.03); and vision yield grade with change in EV (r=-0.16, P=0.03) and factor 2 (r=-0.15, P=0.04, Table 25).

Least square means. Since exit velocity tended to be the most objective measure of temperament and tended to be related to feedlot performance, carcass characteristics, and tenderness and as relationships were different for beginning EV than for end EV. Therefore, exit velocity was categorized into four groups based on slow and fast beginning and end EV. This was done in order to characterize animals that always were slow or fast (did not adapt to feedlot conditions), as compared to those that decreased (became more gentle) or increased (became more flighty) in EV over the feeding period. The four categories were: 1) Slow/Slow (SS) where mean beginning and end feedlot

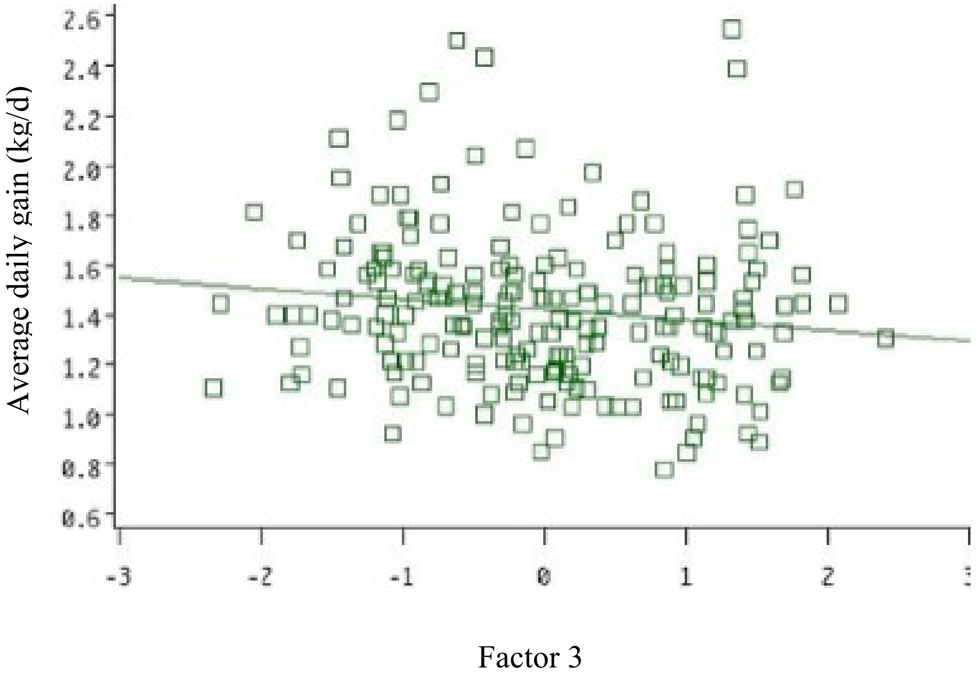

Figure 7. Linear regression line for average daily gain and factor 3, experiment 2 [Y=1.42 + (-0.04*factor 3) R^2=0.02, RMSE=0.308].

Table 25. Simple correlation coefficients for carcass characteristics, tenderness, and temperament measurements (Experiment 2)

	Beginning feedlot exit velocity (m/s)	Beginning feedlot pen score	End feedlot exit velocity (m/s)	End feedlot pen score	Change in exit velocity (m/s)[a]	Average exit velocity (m/s)[b]	Factor1[c]	Factor2[d]	Factor3[e]
HCW	-0.05[f]	-0.10	-0.13	-0.11	-0.06	-0.10	-0.10	-0.02	-0.13
	0.49[g]	0.17	0.06	0.12	0.39	0.16	0.16	0.81	0.06
	205[h]	206	207	207	205	205	204	204	204
Carcass backfat (cm)	0.15	0.01	-0.05	-0.01	-0.17	0.06	0.01	-0.19	0.04
	0.04	0.83	0.49	0.85	0.02	0.41	0.91	0.01	0.55
	205	206	207	207	205	205	204	204	204
Ribeye area	0.009	-0.02	0.05	0.01	0.05	0.04	0.04	0.05	-0.09
	0.90	0.77	0.46	0.83	0.50	0.53	0.53	0.45	0.19
	205	206	207	207	205	205	204	204	204
Quality grade[i]	0.18	0.02	0.03	0.05	-0.12	0.13	0.09	-0.14	0.01
	0.01	0.77	0.66	0.45	0.07	0.07	0.20	0.04	0.86
	205	206	207	207	205	205	204	204	204
Yield grade	-0.09	-0.11	-0.15	-0.12	-0.06	-0.14	-0.16	-0.03	-0.05
	0.24	0.11	0.04	0.09	0.42	0.05	0.03	0.66	0.46
	194	195	196	196	194	194	193	193	193
% marbling	-0.07	-0.16	-0.09	-0.17	-0.03	-0.10	-0.17	-0.02	-0.07
	0.32	0.02	0.18	0.01	0.68	0.14	0.02	0.79	0.35
	205	206	207	207	205	205	204	204	204
Vision yield grade	0.05	-0.01	-0.11	-0.06	-0.15	-0.04	-0.06	-0.15	0.04
	0.45	0.85	0.11	0.40	0.04	0.60	0.36	0.04	0.58
	205	206	207	207	205	205	204	204	204
Hump height (cm)	0.05	0.08	0.04	0.04	0.009	0.06	0.08	0.01	-0.04
	0.51	0.23	0.60	0.55	0.90	0.39	0.25	0.90	0.53
	203	204	205	205	203	203	202	202	202
WBS force (kg)	0.10	0.05	0.02	0.11	-0.06	0.08	0.09	-0.08	-0.03
	0.16	0.48	0.73	0.12	0.40	0.26	0.22	0.27	0.69
	202	203	204	204	202	202	201	201	201

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[a] End feedlot exit velocity – Beginning feedlot exit velocity

[b] (End feedlot exit velocity + Beginning feedlot exit velocity)/2

[c] Exit velocity and pen score

[d] Change in exit velocity

[e] Order through the chute

[f] Correlation coefficient

[g] P-value

[h] Number

[i] USDA Beef Quality Grade: 1=Prime; 2=Choice; 3=Select; 9=Standard

were less than 2.85 m/s for beginning EV and 2.38 m/s for end feedlot EV (Table 20); 2) Fast/Slow (FS) where mean beginning EV was greater than 2.85 m/s and end feedlot EV was less than 2.38 m/s; 3) Slow/Fast (SF) where beginning EV was less than 2.85 and end feedlot EV was greater than 2.38; and 4) Fast/Fast (FF) where mean beginning and end feedlot EV were greater than 2.85 m/s for beginning EV and 2.38 m/s for end feedlot EV (Figure 8). These categories were used to classify cattle as described in Experiment 1.

Beginning feedlot pen scores increased 1.1 units from the SS to the FF EV categories measured at the beginning of the feedlot, and end feedlot pen scores increased 1.7 units from the SS to the FF EV category measured at the end of the feedlot phase (Table 26). For both beginning and end feedlot pen scores, the Slow/Slow category was significantly different from the other three categories. Beginning feedlot weights tended to be higher for the slow EV groups recorded at the end of the feeding period and for the fast EV groups recorded at the beginning (Table 26). Significant differences were observed for end feedlot “bucket” or modified temperament score. The slow EV category at the end of the feedlot had higher “bucket” scores than the fast EV category. The EV groups did not differ in carcass characteristics of tenderness (Table 27). When simple correlations coefficients were calculated few relationships were detected between temperament or behavioral traits and carcass characteristics. It is most likely there were no statistical differences between the EV categories as the simple correlation coefficients were low (Table 25). Therefore, EV categories explained very little of the variation in carcass characteristics. Simple linear correlations for temperament response

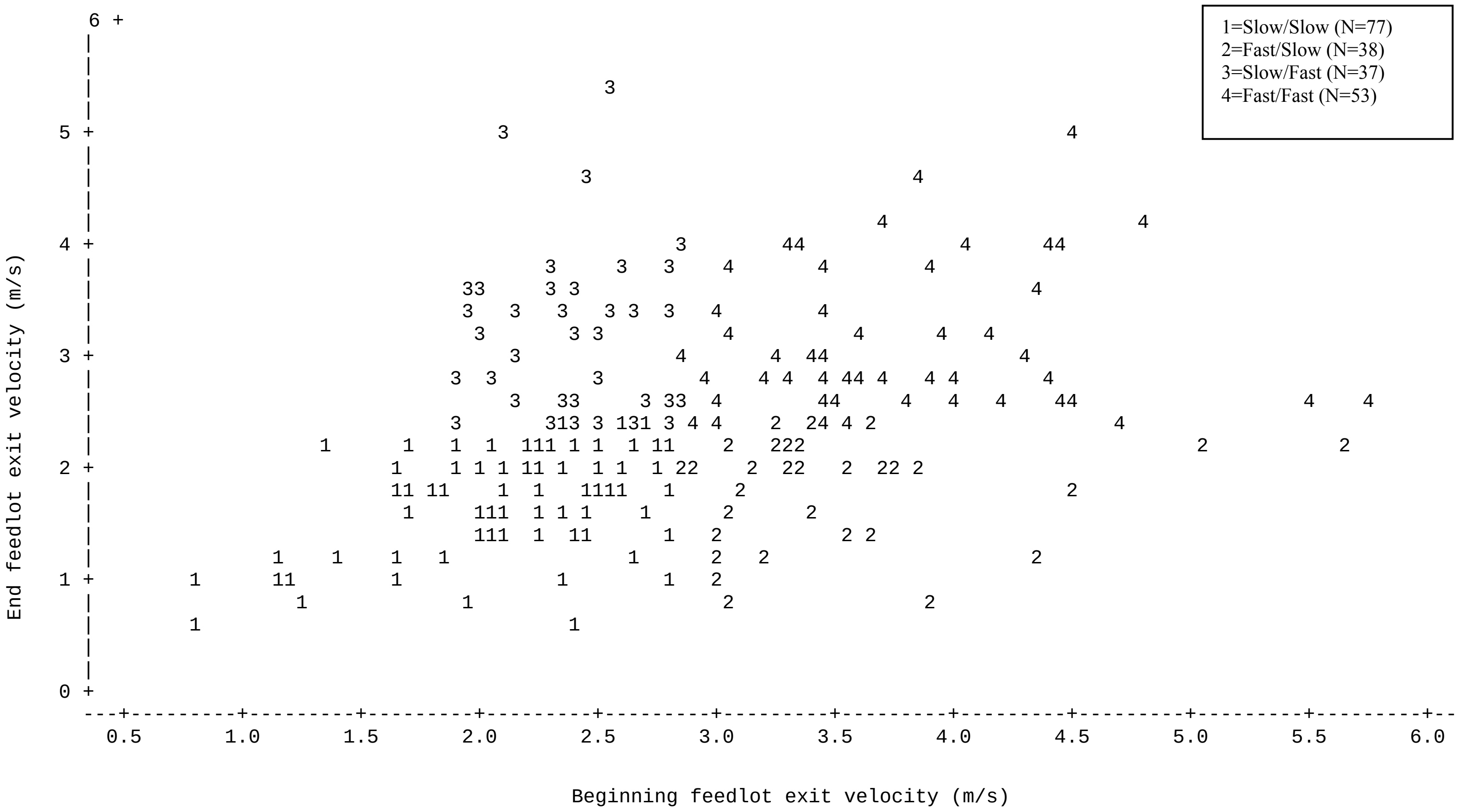

Figure 8. End feedlot exit velocity and beginning feedlot exit velocity denoted by exit velocity category (experiment 2).

Table 26. Least squares means and standard error for feedlot measurements as effected by exit velocity categories at the beginning and end of the feedlot period (Experiment 2)

Beginning feedlot exit velocity (m/s) End feedlot exit velocity (m/s)	Number	Slow Slow	Fast Slow	Slow Fast	Fast Fast
In feedlot wt. (kg)	207	387.7 ± 4.49	394.8 ± 6.40	377.7 ± 6.32	381.8 ± 5.42
Beginning feedlot exit velocity (m/s)	205	2.13^{a}± 0.060	3.45^{c} ± 0.086	2.39^{b} ± 0.087	3.78^{d} ± 0.072
Beginning feedlot pen score	206	1.6^{a} ± 0.10	1.8^{a} ± 0.14	2.4^{b} ± 0.14	2.7^{b} ± 0.12
Beginning feedlot backfat (cm)	207	10.1 ± 0.31	10.2 ± 0.44	9.4 ± 0.43	9.6 ± 0.37
Beginning feedlot wt. (kg)	207	431.5^{ab} ± 5.18	442.9^{b} ± 7.38	415.0^{a} ± 7.28	423.7^{ab} ± 6.25
End feedlot exit velocity (m/s)	207	1.69^{a} ± 0.065	1.81^{a} ± 0.093	3.23^{b} ± 0.092	3.16^{b} ± 0.079
End feedlot pen score	207	1.5^{a} ± 0.10	2.1^{b} ± 0.15	3.2^{c} ± 0.15	3.2^{c} ± 0.12
End feedlot bucket score	207	2.5^{b} ± 0.12	2.4^{b} ± 0.16	1.6^{a} ± 0.16	1.6^{a} ± 0.14
End feedlot wt. (kg)	207	526.0 ± 6.24	542.5 ± 8.89	509.1 ± 8.77	523.0 ± 7.53
Final feedlot wt. (kg)	207	534.3 ± 5.19	545.9 ± 7.39	518.4 ± 7.30	530.2 ± 6.26
Days on feed	207	104.7 ± 1.22	101.7 ± 1.74	106.3 ± 1.72	105.4 ± 1.47
Beginning feedlot ADG (kg/d)	207	1.63 ± 0.101	1.79 ± 0.144	1.38 ± 0.142	1.55 ± 0.122
Feedlot ADG (kg/d)	207	1.42 ± 0.035	1.49 ± 0.050	1.34 ± 0.050	1.42 ± 0.043
Change in exit velocity (m/s)[c]	205	-0.44^{b} ± 0.080	-1.65^{a} ± 0.144	0.83^{c}± 0.116	-0.63^{b} ± 0.097
Average exit velocity (m/s)[d]	205	1.91^{a} ± 0.048	2.63^{b} ± 0.069	2.80^{b} ± 0.070	3.47^{c}± 0.058

[abc]Least squares means with different superscripts within a row and exit velocity category differ, $P<0.05$, from the model Y=in feedlot weight, beginning exit velocity, beginning pen score, beginning backfat, beginning feedlot weight, end exit velocity, end bucket score, end pen score, end feedlot weight, final feedlot weight, days on feed, beginning feedlot ADG, feedlot ADG, change in exit velocity, average exit velocity, hot carcass weight, carcass backfat, ribeye area, hump height, quality grade, yield grade, percent marbling, vision yield grade, average shear force

[d]End feedlot exit velocity – Beginning feedlot exit velocity

[e](End feedlot exit velocity + Beginning feedlot exit velocity)/2

Table 27. Least squares means and standard error for carcass characteristics and tenderness as effected by exit velocity categories at the beginning and end of the feedlot (Experiment 2)

Beginning feedlot exit velocity (m/s) End feedlot exit velocity (m/s)	Number	Slow Slow	Fast Slow	Slow Fast	Fast Fast
Hot carcass weight (kg)	207	327.0 ± 3.25	338.2 ± 4.62	326.7 ± 4.56	325.6 ± 3.91
Carcass backfat (mm)	207	9.5 ± 0.39	10.7 ± 0.56	9.1 ± 0.55	10.1 ± 0.47
Ribeye area (cm^2)	207	84.17 ± 1.045	86.24 ± 1.490	86.17 ± 1.471	84.88 ± 1.264
Quality grade[a]	207	2.7 ± 0.17	3.2 ± 0.25	2.6 ± 0.24	3.2 ± 0.21
Yield grade	196	2.1 ± 0.04	2.0 ± 0.06	2.0 ± 0.06	2.0 ± 0.05
% marbling	207	2.6 ± 0.09	2.4 ± 0.13	2.4 ± 0.13	2.3 ± 0.11
Vision yield grade	207	2.50 ± 0.072	2.61 ± 0.103	2.36 ± 0.102	2.51 ± 0.087
Hump height (cm)	205	7.41 ± 0.110	7.50 ± 0.158	7.26 ± 0.156	7.65 ± 0.132
Warner-Bratzler shear force (kg)	204	2.13 ± 0.042	2.03 ± 0.063	2.03 ± 0.058	2.02 ± 0.053

Least squares means from the model Y=in feedlot weight, beginning exit velocity, beginning pen score, beginning backfat, beginning feedlot weight, end exit velocity, end bucket score, end pen score, end feedlot weight, final feedlot weight, days on feed, beginning feedlot ADG, feedlot ADG, change in exit velocity, average exit velocity, hot carcass weight, carcass backfat, ribeye area, hump height, quality grade, yield grade, percent marbling, vision yield grade, average shear force

[a] USDA Beef Quality Grade: 1=Prime; 2=Choice; 3=Select; 9=Standard

measurements were not correlated with tenderness, and no relationships were detected between EV categories for Warner-Bratzler shear force.

The cattle were also categorized into slow, medium, and fast EV groups based on half a standard deviation from weaning and from beginning feedlot EV mean levels (Table 28). These categorizes were used to identify cattle with extreme slow and fast exit velocities. Significant linear effects ($p<0.05$) were observed for beginning EV in weight off-ryegrass and in-feedlot weight (Table 28). End feedlot weight was numerically lower for flighty or fast EV cattle and approaching significance ($p=0.08$, Table 28).

Regression analysis. Multiple regression procedures were used to describe the influence of temperament factors on feedlot performance (Table 29). Even though R^2 values were low, differences were reported (Table 29). More flighty cattle (large values for factor 1) were lighter at the beginning of the feedlot period, had less backfat and tended to be smaller throughout the feeding period (Table 29). Cattle that did not adapt temperamentally during the feeding period (large values of factor 2, Table 23) had lower backfat and tended have lower weights during the feeding period (Table 29). Steers that went through the chute last (large values for factor 3, Table 23), were smaller and fatter.

The R^2 values also were low for regression equations predicting carcass characteristics from the temperament factors (Table 30). For factor 1 (EV and PEN) flighty cattle had lower yield grades and less marbling. Factor 2 (change in EV) indicated that less adaptive cattle have less ($p<0.05$) backfat and lower ($p<0.05$) quality and yield grades (Table 30).

Table 28. Least squares means, standard errors and p-values for backfat, weight, average daily gain and carcass characteristics and Warner-Bratzler shear force as effected by exit velocity groups at the beginning of the feedlot period (Experiment 2)

		Experiment 2 Beginning feedlot exit velocity group[a]				
Variable	Number	Slow	Medium	Fast	P-value	RMSE[b]
In feedlot wt., kg	207	356.6[c]	353.0[c]	317.3[d]	0.0001	47.68
End feedlot wt., kg	205	498.4	499.0	483.5	0.08	37.16
Feedlot ADG, kg/d	205	1.39	1.37	1.43	0.64	0.311
Hot carcass wt., kg	205	290.0	295.4	280.9	0.16	24.66
Backfat, mm	205	6.8	4	0.66	0.16	24.66
Ribeye area, cm^2	205	78.24	79.53	77.46	0.65	1.218
Yield grade	194	2.1	2.2	2.1	0.59	0.40
Warner-Bratzler shear force, kg	202	2.70	2.64	2.69	0.87	0.595

[a] Slow=< mean – 0.5 SD, Medium=mean – 0.5 SD to mean + 0.5 SD, Fast= > mean + 0.5 SD

[b] RMSE: Root Mean Square Error from Analysis of Variance table.

[cd] Least squares means with different superscripts within a row and velocity group differ, $P<0.05$, from the model Y=in feedlot weight, end feedlot weight, feedlot ADG, hot carcass weight, carcass backfat, ribeye area, yield grade, mean shear force

Table 29. Regression coefficients for factor analysis using temperament measures (Experiment 2)

Variable Factor description	Intercept	Factor1 exit velocity and pen score	Factor2 Change in exit velocity	Factor3 Order through chute	R^2	RMSE[b]
In feedlot wt. (kg)	385.8 ± 2.73	-6.37[a] ± 2.740	-0.40 ± 2.740	-2.16 ± 2.740	0.03	39.05
Beginning feedlot backfat (cm)	9.9 ± 0.16	-0.4[a] ± 0.17	-0.4[a] ± 0.17	1.2[a] ± 0.17	0.24	0.235
Beginning feedlot wt. (kg)	428.6 ± 3.14	-7.5[a] ± 3.14	-1.8 ± 3.14	-3.2 ± 3.14	0.03	44.799
End feedlot wt. (kg)	525.8 ± 3.78	-6.0 ± 3.79	-4.9 ± 3.79	-7.6[a] ± 3.79	0.04	54.02
Final feedlot wt. (kg)	533.0 ± 3.15	-5.6 ± 3.16	-3.5 ± 3.16	-6.6[a] ± 3.16	0.04	45.03

[a] $P<0.05$

[b] Root Mean Square Error from Analysis of Variance Table

Table 30. Regression coefficients for factor analysis using temperament measures (Experiment 2)

Variable	Intercept	Factor1	Factor2	Factor3	R^2	RMSE[b]
Carcass backfat (mm)	9.8 ± 0.24	0.03 ± 0.24	-0.7[a] ± 0.24	0.1 ± 0.24	0.04	0.346
Quality grade	2.9 ± 0.11	0.14 ± 0.11	-0.22[a] ± 0.11	0.02 ± 0.11	0.03	1.53
Yield grade	2.1 ± 0.03	-0.06[a] ± 0.027	-0.01 ± 0.027	-0.02 ± 0.026	0.03	0.366
% marbling	2.4 ± 0.06	-0.1[a] ± 0.06	-0.02 ± 0.056	0.05 ± 0.056	0.03	0.798
Vision yield grade	2.5 ± 0.04	-0.04 ± 0.045	-0.09[a] ± 0.045	0.02 ± 0.045	0.03	0.637
Warner-Bratzler shear force (kg)	2.84 ± 0.040	0.05 ± 0.040	-0.04 ± 0.040	-0.02 ± 0.040	0.01	0.565

[a] $P<0.05$

[b] Root Mean Square Error from Analysis of Variance Table

Experiment 3

Descriptive statistics. A subgroup of cattle was used from Experiment 2 in a retail cutting test for strip loins. Only cattle that graded Choice or Select were used in the experiment. As a point of reference, descriptive statistics were reported for feedlot measurements (Table 31), carcass and tenderness measurements (Table 32), cut-out percentages as part of the strip loin (Table 33), and cut-out percentages as part of the final live weight and hot carcass weight (Table 34). The values from the sub-group of animals were comparative to all the animals used in Experiment 2. Cattle in the sub-group tended to have heavier weights, faster EV going into the feedlot (Table 20 and 31), lower hump heights, and smaller REA (Table 21 and 32). Also, within the subgroup of animals from Experiment 2, a retail cutting test was conducted on top butt sub-primals from cattle that graded Choice. As a point of reference, descriptive statistics were reported for feedlot performance (Table 35), carcass and tenderness measurements (Table 36), cut-out percentages as part of the sub-primal (Table 37), and cut-out percentages as part of the live and hot carcass weight (Table 38). Cattle used in the top butt cutting test also had comparative values to the entire group of cattle used in Experiment 2, although the cattle graded Choice. The subgroup tended to have heavier weights, faster EV (Table 20 and 35), lower hump heights, larger REA and increased percent marbling (Table 21 and 36).

Regression analyses. Regression equations were constructed to predict the relationship of percentage of red meat yield within the sub-primal, final live weight, and hot carcass weight from carcass characteristics (Table 39). Carcass variables that were

Table 31. Descriptive statistics for feedlot measurements of cattle used in strip loin (IMPS #180) cutting test (Experiment 3)

Variable	N	Mean	Std Dev	Minimum	Maximum
In feedlot wt. (kg)	146	398.6	33.67	322.7	500.0
Beginning feedlot wt. (kg)	146	445.4	35.97	363.6	563.6
Beginning feedlot backfat (mm)	146	4.0	1.08	1.4	6.9
Beginning feedlot body condition score	145	6.5	0.81	4.0	9..0
Beginning feedlot frame score	145	5.4	0.86	3.0	7.0
Beginning feedlot exit velocity (m/s)	146	2.78	0.819	0.82	5.65
Beginning feedlot pen score	145	2.0	0.94	1.0	4.0
End feedlot wt. (kg)	146	546.3	40.49	472.7	661.4
End feedlot body condition score	145	8.9	1.12	4.0	9.0
End feedlot exit velocity (m/s)	146	2.31	0.871	0.70	5.04
End feedlot pen score	146	2.3	1.11	1.0	5.0
End feedlot bucket score	146	2.2	1.11	1.0	5.0

Table 32. Descriptive statistics for carcass characteristics and tenderness of cattle used in strip loin (IMPS #180) cutting test (Experiment 3)

Variable	N	Mean	Std Dev	Minimum	Maximum
Hot carcass weight (kg)	146	334.2	27.62	240.9	409.1
Carcass backfat (cm)	146	9.8	3.49	4.3	24.9
Hump height (cm)	146	3.0	0.38	2.0	4.1
Quality grade[a]	146	2.4	0.50	2.0	3.0
Yield grade	145	2.1	0.39	1.0	3.0
Ribeye area(cm^2)	146	85.72	9.224	42.57	110.94
% marbling	146	2.5	0.75	1.2	5.7
Warner-Bratzler shear force (kg)	146	2.87	0.49	1.84	4.69

[a] USDA Quality Grade: 3=Choice; 2=Select

Table 33. Descriptive statistics for strip loin (IMPS #180) weight and component cut-out values as percent of strip loin weight (Experiment 3)

Variable	N	Mean	Std Dev	Minimum	Maximum
Strip loin wt (kg)	146	5.62	0.628	4.25	7.66
340 g steak wt., % strip loin	146	54.0	5.51	36.0	78.0
Vein steaks wt., % strip loin	146	13.0	4.45	5.0	33.0
Trim wt., % strip loin	144	16.0	4.02	8.0	40.0
Stew meat wt., % strip loin	146	2.0	2.33	0.0	8.0
Fat and bone wt., % strip loin	146	16.0	4.89	4.0	34.0

Table 34. Descriptive statistics for strip loin (IMPS #180) weight and component cut-out values as percent of carcass and final live weight (Experiment 3)

Variable	N	Mean	Std Dev	Minimum	Maximum
Strip loin, % final feedlot wt.	146	1.0	0.10	0.8	1.0
340 g steak wt., % harvest wt.	146	0.6	0.06	0.4	0.8
Vein steak wt.,% harvest wt.	146	0.1	0.04	0.06	0.3
Strip loin, % carcass wt.	146	2.0	0.24	1.0	3.0
340 g steak wt., % carcass wt.	146	0.9	0.16	0.6	1.0
Vein steak wt., % carcass wt.	146	0.2	0.07	0.08	0.5

Table 35. Descriptive statistics for feedlot measurements of cattle used in top butt (IMPS #184) cutting test (Experiment 3)

Variable	N	Mean	Std Dev	Minimum	Maximum
In feedlot wt. (kg)	50	404.5	30.28	343.2	486.4
Beginning feedlot wt. (kg)	50	443.6	32.60	363.6	534.1
Beginning feedlot backfat (mm)	50	4.1	1.12	1.9	6.9
Beginning feedlot body condition score	50	6.5	0.68	5.0	9.0
Beginning feedlot frame score	50	5.4	0.88	3.0	7.0
Beginning feedlot exit velocity (m/s)	50	2.86	0.809	1.15	5.65
Beginning feedlot pen score	50	1.9	0.87	1.0	4.0
End feedlot wt. (kg)	50	543.4	36.5	486.4	650.0
End feedlot body condition score	50	9.1	0.99	7.0	11.0
End feedlot exit velocity (m/s)	50	2.32	0.871	0.70	5.04
End feedlot pen score	50	2.3	1.17	1.0	5.0
End feedlot bucket score	50	2.2	1.17	1.0	5.0

Table 36. Descriptive statistics for carcass characteristics and tenderness of cattle used in top butt (IMPS #184) cutting test (Experiment 3)

Variable	N	Mean	Std Dev	Minimum	Maximum
Hot carcass wt. (kg)	50	333.9	22.35	293.2	397.7
Carcass backfat (mm)	50	9.7	3.33	4.6	18.0
Hump height (cm)	50	3.0	0.33	2.2	3.7
Quality grade[a]	50	3.0	0.50	3.0	3.0
Yield grade	50	2.0	0.32	1.0	3.0
Ribeye area (cm^2)	50	86.24	8.101	66.44	103.2
% marbling	50	2.9	0.77	1.6	4.5
Warner-Bratzler shear force (kg)	50	2.85	0.421	2.14	3.68

[a] USDA Quality Grade: 3=Choice

Table 37. Descriptive statistics for top butt (IMPS #184) weight and component cut-out values as percent of top butt weight (Experiment 3)

Variable	N	Mean	Std Dev	Minimum	Maximum
Top butt wt. (kg)	50	6.02	0.524	5.18	7.57
Cap wt., % top butt	50	27.0	4.52	21.0	52.0
225 g steaks wt., % top butt	50	41.0	3.73	31.0	49.0
Trim wt., % top butt	50	18.0	2.67	13.0	23.0
Stew meat wt., % top butt	50	6.0	2.52	2.0	13.0
Fat and bone wt., % top butt	50	9.0	3.71	3.0	21.0

Table 38. Descriptive statistics for top butt (IMPS #184) weight and component cut-out values as percent of carcass and final live weight (Experiment 3)

Variable	N	Mean	Std Dev	Minimum	Maximum
Top but wt., % final feedlot wt.	50	2.0	0.18	1.0	2.0
Cap wt., % final feedlot wt.	50	0.5	0.09	0.4	1.0
225 g steak wt., % final feedlot wt.	50	0.7	0.07	0.6	1.0
Top butt wt., % carcass wt.	50	1.0	0.07	0.9	1.0
Cap wt., % carcass wt.	50	0.3	0.06	0.2	0.6
225 g steak wt., % carcass wt.	50	0.5	0.04	0.3	0.6

Table 39. Regression coefficients for cutability of strip loins (IMPS #180) and top butts (IMPS #184) as predicted by carcass characteristics (Experiment 3)

Variable	b_o	b_1	b_1 variable	b_2	b_2 variable	b_3	b_3 variable	b_4	b_4 variable	R^2	RMSE
340 g strip steaks, % strip loin	0.638	-0.0005	Hot carcass wt	0.0004	Yield grade	0.009	Ribeye area	-0.05	Backfat	0.21	0.0494
Strip loin wt., % carcass wt.	0.028	-0.00004	Hot carcass wt	0.00003	Yield grade	-0.00001	Ribeye area	0.002	Backfat	0.38	0.0018
340 g strip steaks, % carcass wt.	0.016	-0.00003	Hot carcass wt	0.00002	Ribeye area					0.33	0.0091
Strip loin wt., % harvest wt.	0.012	-0.00001	Hot carcass wt	0.001	Backfat					0.15	0.0009
340 g strip steaks, % harvest wt.	0.007	-0.00001	Hot carcass wt	0.0001	Ribeye area					0.17	0.0006
225 g center-cut steaks, % top butt wt.	0.523	-0.0008	Hot carcass wt	0.008	Ribeye area					0.23	0.0343
225 g center-cut steaks, % carcass wt.	0.012	-0.00002	Hot carcass wt							0.34	0.0074
225 g center-cut steaks, % harvest wt.	0.006	-0.00001	Hot carcass wt	0.00009	Ribeye area					0.22	0.0004

predictive of final red meat yield included carcass weight, fatness, and REA (Table 39).

It was hypothesized that the addition of multiple pre-and post-harvest measures would improve the predictability of the regression equations. The variables recorded throughout the feeding period and at harvest were compiled and analyzed using a factor analysis (Table 40). Factor 1 was comprised of feedlot weight measurements. Factor 2 was made up of the temperament measurements, which included beginning and feedlot EV and pen scores. Factor 3 loadings were characterized by loadings for carcass measurements of ribeye area, and carcass backfat which are indicative of yield grade. Factor 4 was characterized by marbling with loadings for quality grade and percent marbling, Factor 5 had loadings for condition and frame scores recorded during the feedlot period. It does not appear that the factor loadings are dependant when the measurement was recorded. Like measurements tend to be indicative of the factor loadings and the loadings can easily be grouped or described.

In order to better predict the relationships of red meat yield within the sub-primal, factors were used to determine what other variables had predictive value. The most predictive variable was factor 1 (weight, Table 41). Factor 2 (temperament) was important only as a percentage of live weight (Table 41), factor 3 (YG) was predictive half the time for the cut-out values (Table 41), and factor 5 (BCS and FRAME) was important in steak yield cut-outs (Table 41). Factor 4 (marbling) was not related or a good indicator of cut-out percentages (Table 41).

The addition of feedlot performance and carcass characteristics in the regression equations increased the R^2 for strip WT as a percentage of the HCW (+0.16, Table 39

Table 40. Rotated factor pattern for feedlot data, carcass characteristics and tenderness (Experiment 3)

Variable Description of factor loadings	Factor 1 Weight	Factor 2 Temperament	Factor 3 Fatness	Factor4 Marbling	Factor 5 Body conditon and frame score
In feedlot wt (kg)	0.87	-0.12	0.07	0.10	0.12
Beginning feedlot wt. (kg)	0.93	-0.09	0.13	0.05	-0.001
Beginning feedlot backfat (mm)	0.22	-0.08	0.44	-0.03	-0.28
Beginning feedlot body condition score	0.25	-0.22	0.24	0.14	-0.58
Beginning feedlot frame score	0.18	0.03	-0.02	-0.002	0.81
Beginning feedlot exit velocity (m/s)	-0.03	0.68	0.16	0.09	-0.02
Beginning feedlot pen score	-0.07	0.80	-0.001	-0.13	0.10
End feedlot wt. (kg)	0.91	-0.004	0.10	0.05	0.02
End feedlot body condition score	0.47	-0.14	0.08	0.18	-0.58
End feedlot exit velocity (m/s)	-0.08	0.76	-0.16	-0.03	0.08
End feedlot bucket score	-0.03	-0.55	0.13	0.09	-0.22
End feedlot pen score	-0.09	0.85	-0.04	-0.14	0.14
Hot carcass wt. (kg)	0.82	-0.01	-0.05	-0.21	-0.12
Quality grade	-0.04	0.10	0.05	-0.89	0.09
Yield grade	0.20	-0.14	0.65	-0.06	0.11
Ribeye area (cm^2)	0.42	0.06	-0.64	-0.19	-0.05
Carcass backfat (mm)	0.04	0.11	0.81	0.06	-0.09
Percent marbling	-0.04	-0.11	0.12	0.91	0.07
Warner-Bratzler shear force (kg)	0.07	0.11	0.08	0.10	0.27
Proportion of variance explained	0.22	0.15	0.10	0.08	0.07
Cumulative variance explained	0.22	0.38	0.48	0.56	0.63

Table 41. Regression coefficients for cutability of strip loins (IMPS #180) and top butts (IMPS #184) as predicted by feedlot measurements, carcass characteristics, and tenderness (Experiment 3)

Variable	b_o	b_1	b_1 variable	b_2	b_2 variable	b_3	b_3 variable	R^2	RMSE
340 g strip steaks, % strip loin	0.541	-0.013	Factor 1[a]	-0.023	Factor 3[b]	0.009	Factor 5[c]	0.24	0.0492
Strip wt., % carcass wt.	0.017	-0.0006	Factor 1	0.0008	Factor 3			0.22	0.0020
340 g strip steaks, % carcass wt.	0.009	-0.0005	Factor 1	0.0002	Factor 5			0.19	0.009
Strip loin wt., % harvest wt.	0.010	-0.0003	Factor 1	0.0002	Factor 2[d]	0.0003	Factor 3	0.16	0.0009
340 g strip steaks, % harvest wt.	0.006	-0.0003	Factor 1	0.00007	Factor 2	-0.00009	Factor 3	0.18	0.0006
225 g center-cut steaks,% top-butt wt.	0.419	-0.017	Factor 1	0.012	Factor 5			0.24	0.0343
225 g center-cut steaks, % carcass wt.	0.008	-0.0005	Factor 1					0.25	0.0007
225 g center-cut steaks, % carcass wt.	0.005	-0.0003	Factor 1	0.00009	Factor 2	0.0001	Factor 5	0.32	0.0004

[a] Weight
[b] Fatness
[c] Body condition and frame score
[d] Temperament

and 41), 340 g strip steaks as a percentage of HCW (+0.14, Table 39 and 41), 225 g center-cut steaks as a percent of HCW (+0.09, Table 39 and 41), and 225 g center-cut steaks as percent of final feedlot weight (+0.10, Table 39 and 41).

CHAPTER V

DISCUSSION

Relationships among measures of temperament

Results from experiments 1 and 2 indicated that temperament measures were usually correlated with each other (Table 11 and 22). Serum cortisol concentrations measured in Experiment 1 were correlated to some measures of temperament. When cattle were categorized, cortisol concentration gradually increased from the Slow/Slow to Fast/Fast group and between the Slow/Slow and Fast/Fast groups there was approximately a 4 ng/mL increase. Even though these concentration of cortisol differed statistically, the biological implications of a 4 ng/mL difference are most likely not biologically significant. Cortisol concentrations in the blood have been used as indicators of stress level (Lefcourt, 1986). Other studies have reported cortisol concentrations from *Bos indicus* genotypes exposed to transport stress of 24 km, ranging from 25 to 35 ng/mL when taken 1 h after transport (Lay et al., 1996). Other authors have reported physiological cortisol concentrations in cattle to range from a baseline of 0.5 to 9.0 ng/mL (Grandin, 1997) to extreme stress of 120 ng/mL (Locatelli et al., 1989). Crookshank et al. (1979) reported that in cattle, agitation and cortisol concentrations decreased with subsequent experiences in the handling facility, because the cattle became habituated. Cortisol concentrations in this study do not appear to be indicative of stress levels, and appear to be closer to the baseline range. Although the concentrations in this study are not high, there was an increase in cortisol with increased agitation as shown by behavioral measures.

Exit velocities in Experiment 1 decreased from weaning to in-feedlot measurements and a reduction in exit velocity was also observed in experiment 2 for in-feedlot to end-feedlot measurements (Table 6 and 20). This indicates that cattle may gentle or adapt as they progress through a production system. Although there may be a decrease in EV over time, cattle that tended to be more flighty early in production tended to remain more flighty throughout production (Figure 1 and 5). While EV tended to decrease in subsequent evaluations, CHUTE and PEN in experiment 1 and 2 increased with time. In Experiment 2, temperament measures obtained within a time period, in the feedlot, were more related to each other than when measures were from other times (Table 22). Also, like-temperament measures (EV, PEN and CHUTE) tended to be more related to one another, even at different time periods (Table 22). The relationships reported in Experiment 2, were not as strong as in Experiment 1. This could be attributed to environmental factors, since cattle in Experiment 1 were handled and scored at different locations and different types of facilities, and cattle in Experiment 2 were handled on the same location and in the same working facility and no measurements were taken at weaning or during the stocker grazing period.

Behavioral indicators of discomfort include attempting to escape, vocalization, kicking, or struggling (Grandin, 1997). Hargreaves and Hutson (1990) likewise showed that getting sheep accustomed to people and reducing their flight zone was somewhat successful at reducing aversion to repeated handling procedures, although not enough to overcome the effects of highly aversive procedures. Habituation to a handling procedure may arise when the animal learns that there is always an eventual escape (Fox, 1984).

Thus, habituation may depend on the predictability, controllability, or previous experience of the stressor and thereby its aversiveness (Hargreves and Hutson, 1990). Lyons (1989) reported that the degree of behavioral agitation expressed by animals during routine handling procedures was consistent over multiple handling experiences. Grandin (1993) also found similar results, and concluded that certain individuals have the tendency to become behaviorally agitated and were stable over time. Differences in the results between studies and between animals were likely due to how the animal perceived the aversiveness of a procedure due to previous handling or if it was a novel experience. While some measures of behavior indicate that the animal is adapting, other measures seem to show the opposite and animals get more agitated or do not adapt over time. These responses could be attributed to animal perception and environmental factors. The squeeze chute or handling may be perceived as neutral and non-threatening to one animal; to another animal, it may trigger intense fear (Grandin, 1997). This may also explain why some cattle that perceive the chute or handling as a bad experience, may remember it and become more stressed when handled in the future, while other animals gentle over time.

Since cattle tend to adapt over time it would appear that behavioral observations evaluated earlier in production would measure the intial response of the animal. As cattle progress in the system the responses are masked either due to handling, weight, or adaptation. While multiple behavioral measures may be the best method to evaluate responses to different inherent stressors in an environment, EV appears to be the best single evaluation for behavioral stress response since it is more discriminative measure.

Relation of measures of temperament and performance

Temperament variables measured at the beginning of the finishing phase tended to be more related to pre-feedlot and feedlot performance in Experiment 1, although, beginning feedlot EV had a higher relationship with weight measurements prior to entering the feedlot and during the feeding period than other temperament variables measured at the same time. Change in EV in Experiment 1 was correlated with ADG on ryegrass and in the feedlot, while cortisol tended to be related to fat measurements. Weaning EV did not have the highest correlation values as compared to other measures of temperament, but weaning EV was related to other important production traits, such as backfat and ADG. In Experiment 2, all of the correlations were relatively low for all feedlot measurements and performance measures were generally more related to end feedlot EV and pen scores than other temperament variables. Beginning feedlot EV was not correlated with any feedlot performance measures. Factors from the factor analysis were also related to feedlot performance.

In an attempt to evaluate adaptability as cattle progressed in the production system, cattle were categorized into EV groups. When the cattle were categorized into EV groups in Experiment 1, the fast EV group at the beginning of the feedlot tended to have the lowest weights throughout the experiment and the least amount of backfat coming off of ryegrass, but no noticeable differences in weight were detected at the end of the feeding period. Although the fast EV cattle at the beginning of the feeding period were not the heaviest cattle, they did tend to have higher ADG in the feedlot and the fast EV cattle at weaning tended to have higher ADG on ryegrass. The results in Experiment

2 tended to show feedlot weights were higher for the slow EV group at the end of the feeding period, but higher for the fast EV groups measured at the beginning of the feeding period. Average daily gain also tended to be higher for the FS EV group at the beginning of the feeding period.

Fell et al. (1998) found that a significant percentage of individuals are unable to adapt successfully and have an unacceptably low weight gain. Other research has reported that pre-exposing animals to stressful aspects of a feedlot environment have increased performance. Petherick et al. (2003) found that exposing animals to a part of the feedlot setting a little at a time resulted in greater intakes and higher weight gains during the beginning of the feedlot period. Phillips (2004) investigated the effects of isolation stress on calf performance. Calves were classified as group or individually reared, and evaluated for intake and weight gain. The group reared calves had greater intakes, spent more time eating, and ruminating time was increased compared to individual calves. Other research found similar results and reported relationships with temperament and feedlot production. Researchers have also used multiple behavioral responses at weaning to sort cattle into feedlot groups (Fell et al., 1999). These researchers used weaning chute score and flight speed as methods to classify cattle into nervous (poor temperament) and calm groups (good temperament). They reported that the poor temperament group had increased cortisol concentrations or increased adrenalcortical activity and decreased weight gain as compared to the good temperament group. They also found that of the behavioral measures used in their experiment, the chute scoring method was the least discriminative since most of the cattle scored less than 2. They concluded that flight speed may be a better indicator of behavioral stress responses. While Fell et al. (1999) suggested that flight speed is a more discriminative measure of behavioral responsiveness, some research has reported relationships with chute scores and cattle performance. Voisinet et al. (1997a) evaluated chute scores as a measure of temperament 2 weeks after entering the finishing phase of production in 2 experiments. The first experiment evaluated *Bos taurus* and *Bos indicus* cross calves, and found significant increases in ADG for the calm *Bos taurus* cattle. No significant differences were observed in ADG for the *Bos indicus* cross calves, but the calm *Bos indicus* calves had numerically higher ADG than the excitable cattle. The second experiment utilized *Bos indicus*-cross calves. Temperament score explained a large amount of variation in ADG. Animals with temperament scores of one or two had higher ($p<0.05$) ADG than the animals with scores of three. Petherick et al. (2002) used flight speed as a measure of temperament at the beginning of the feedlot feeding period and found that more flighty cattle had lighter weights at the end of the feedlot period. They also observed the trend that flighty cattle had lower ADG and decreased feed conversion efficiency during the feedlot feeding period. Burrow and Dillon (1997) recorded EV for the first 12 weeks, and the mean of the first five EV measurements were used as the temperament rating. Their rating affected live weight gain and final live weight in the feedlot. Other researchers have found similar results. Brown et al. (2004) observed a decrease in dry matter intake and ADG in the feedlot for bulls that had a fast EV upon entry to the feedlot. Gauly et al. (2001) used a pen method and applied human pressure and observed the animals reaction for a period of time and assigned a score.

They also used a chute score along with the pen method and found that the more docile animals tended to be the more productive animals.

The effects of poor temperament on ADG were mainly a function of reductions in feed intake and inefficient use of feed. Factors regulating growth are inversely related to the animals stress response or their inability to tolerate stress. These observations agree with Philips (2004) who concluded that more flighty cattle spent less time ruminating and more time vocalizing. If cattle cannot adapt to a particular environment then these responses can be sustained over a period of time and cause substantial decreases in production.

Relation of measures of temperament and carcass characteristics

In Experiment 1, beginning feedlot EV was not correlated ($p<0.05$) with any carcass traits, but linear effects were observed for weaning EV for REA and Yield grade. Other temperament measures that were related to carcass traits include: change in EV with REA and yield grade; cortisol with adjusted preliminary yield grade; average EV with REA; and FWD with carcass backfat, marbling score and quality grade. Fat measurements tended to be lower for the FF EV group when compared to the other groups. In Experiment 2, the relationship between temperament measures or factors and carcass characteristics were generally small and not significant. Exit velocity and factors from the factor analysis tended to be more related to carcass characteristics than other measures of temperament. Although, there were no significant differences observed between carcass data and EV groups.

In addition to more docile cattle having better feedlot performance, other authors have reported moderate relationships with improved carcass characteristics. Voisinet et al. (1997b) also found a greater percentage of the excitable animals produced border line dark cutters than the calmer animals. These animals were also assigned chute scores as they were handled at the feeding facility two weeks prior to entering the feedlot. Wulf et al. (1997) also reported that chute scores were moderately correlated with carcass characteristics. Chute scores were negatively correlated with carcass weight, and CIE L* and b* values (r= -0.24, -0.34, and -0.23, respectively). Brown et al. (2004) reported that exit velocity measured upon entry to the feedlot was negatively correlated with ribeye area in Bonsmara bulls. Petherick et al. (2002) reported similar results and found EV was negatively correlated with dressing percentage. These researchers also found that calm cattle produced heavier carcasses than flighty cattle, but this difference was not statistically different in their study.

Temperament may be a helpful tool to help predict more acceptable carcasses. Since temperament tends to be related to weight gain and heavier, higher yielding carcasses, these traits may be of importance to include in prediction equations. Carcass measurements used in the prediction equations for Experiment 3 had the potential to help predict sub-primal weights and retail product yield. Since production traits tended to be related to carcass traits, it had been hypothesized that the addition of feedlot performance and temperament measures included in the prediction equation could more reliably predict red meat yield.

Weight appeared to be the most important variable in the prediction equation and temperament and fat were also important traits in the prediction equation. While the addition of temperament to the prediction equation did help explain more of the variation in some traits, the R^2 values were still too small and did not help improve the overall predictability of the equations.

Studies have examined carcass composition between breed or cattle types and between sex classes (Koch et al., 1976, 1979, and 1982). These studies have indicated that continental European cattle tend to have a higher percentage of cut-out than do English cattle. Reiling et al. (1992) studied the effect of impacting the yield grade equation with the addition of HCW, longissimus muscle area, fat cover, and sex class. These researchers found the addition of HCW in the Yield grade equation increased the accuracy of the prediction equation very little. Other researchers have studied the effect of live animal ultrasound measures to predict beef carcass retail yield. In a study using 180 steers representing 11 sire-breeds groups, Hamlin et al. (1995) reported that live animal ultrasonic measurements of fat thickness and longissimus muscle area, when combined with live weight, accounted for 61 to 64% of the variation in percentage of retail product. Greiner et al. (2003) developed live animal ultrasound prediction equations for weight and percentage of retail product. Steers were measured for 12th rib fat thickness, rump fat thickness, longissimus muscle area, and body wall thickness within 5 days of harvest. Carcass measurements included in USDA quality and yield grade calculations were obtained. Regression equations to predict weight and percentage retail product were developed using either live animal weight or carcass traits as independent variables. These researchers reported that most of the variation in weight of retail product was accounted for by live weight and carcass weight with R^2 values of 0.66 and 0.69, respectively. They also found fat measurements accounted for the largest portion of the variation in percentage of retail product when used as a single predictors. These results indicate that live animal equations using ultrasound measurements are similar in accuracy to carcass measurements for predicting beef carcass composition, and alternatively enhance the predictive capability of live animal-based equations for retail yield. Other studies have reported similar results. Herring et al. (1994) reported final step-wise regression models using live animal or carcass equations ranked the animals equally for kilograms of retail product yield.

This study would indicate that behavioral observations can help predict cattle that will produce more desirable carcasses. No single measurement of temperament or behavioral response was the most predictive and multiple measures were associated with carcass performance. While these behavioral measures were helpful to predict carcass characteristics, the addition of feedlot traits and carcass traits did not provide the necessary information to improve prediction of red meat yield. Hot carcass weight alone explained the largest amount of variation.

Relation of measures of temperament and WBS

In Experiment 1, significant linear effects were observed for weaning EV and WBS force, and change in EV was correlated with WBS force. Although, weaning EV was correlated with WBS force, the categories did not differ in WBS force. In

Experiment 2, there were no significant correlations with WBS, and as expected in Experiment 3 WBS force did not impact red meat yield.

Other investigators have found a low-to-moderate relationship between measures of temperament and Warner-Bratzler shear force (r=0.24 to 0.35; Vann et al. 2004). Voisinet et al. (1997b) also found more excitable cattle as determined by chute scores measured two weeks prior to entering the feedlot produced steaks that were tougher than steak from calm animals. Other research has found that chute scores were positively correlated with 24-h calpastatin activity and Warner-Bratzler shear force values (r=0.35 and 0.49, respectively) (Wulf et al., 1997).

Bonsmara have the potential to produce high quality meat. Both the Hereford and Shorthorn have been shown to produce tender meat (Wheeler et al., 1996). The Afikaner is an indigenous breed of the Sanga type. Sanga cattle are not believed to be related to the Indian *Bos indicus* breeds (Brahman), as generally believed. Bonsmara influenced cattle have been shown to produce comparable carcasses to British cattle that are considered tender under US production systems (Holloway et al., 2000, Miller et al., 2005). Research in South Africa has suggested that carcass characteristics and Warner-Bratzler shear force values are similar to those of British cattle breeds produced under the same production conditions (Strydom, 1994). Due to the unique selection history for productivity, adaptation and tenderness of the Bonsmara cattle, this breed of cattle may not be as prone to negative responses to stress and (or) they may adapt to stress more effectively than other breeds of cattle. Therefore, using the relationships between live animal measurements of stress and animal adaptability to stress to test subsequent feedlot ADG, carcass characteristics and meat tenderness in Bonsmara steers, the associations may have been weak or not significant due to the selection history for adaptabilty in this breed.

CHAPTER VI

CONCLUSIONS

While evidence for behavioral and hormonal responses to stress associated with average daily gain, carcass characteristics and tenderness were small, relationships were detected between these traits. The original hypothesis was accepted and it is theorized that the low associations were attributed to the lack of variation in stress responsiveness and productivity within this group of Bonsmara-influenced cattle. However, it did appear that stress responsiveness observed at weaning, upon entry to the feedlot, and at the end of the feedlot phase had different associations with economically important traits.

Weaning measurements tended to have a higher relationship with important production traits, and this indicated a higher relationship for EV early in production between growth, carcass characteristics and tenderness. Weaning can be viewed as a novel experience and these responses measure an initial reaction. Novelty is a very strong stressor (Moberg, 1982) and weaning can be a novel experience for many animals. Weaning may be the first time animals are handled. In the wild, novelty and strange sights or sounds are often a sign of danger (Grandin, 1993). After repeated exposure or handling the response may be masked, and this may be a reason why as cattle progress in the production system, behavioral responses lose their predictive ability.

It is hypothesized that the relationships associated with weaning EV and WBS force are a reflection of ADG in the feedlot and other unknown factors. As calm cattle had increased weights and higher ADG, this allowed for increased growth rates. Miller et al. (1987) reported that steers that produced the lightest and leanest carcasses produced tougher meat. Aberle et al. (1981) observed relationships among pre-harvest feeding regime, growth rate and collagen stability and tenderness in meat. Although, other results have indicated that stress-induced high post-mortem pH increased protease activity and leads to more tender meat (Beltran et al., 2004). The low and weak relationships indicated that stress may impact ADG and subsequently impact meat tenderness through production of lighter carcasses with less fat that are more susceptible to cold shortening. As all of the cattle in this study were electrically stimulated, electrical stimulation could help mask effects or reduce the relationships that were evaluated.

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APPENDIX A

Pooled data set

The data from the 2 experiments was compared prior to pooling the data. Although the 2 groups were managed differently, at different locations, and different breed types, beginning feedlot EV was very similar and ADG was relatively the same (Table A1). All traits constant across the 2 experiments were compared, and all the traits were significantly different (Table A1). To help represent the differences observed in these cattle, carcass hump height from each location was plotted again beginning feedlot EV (Figure A1). The cattle from Experiment 2 had significantly lower hump heights than the cattle from Experiment 1 (Figure A1). After comparing the two Experiments we decided to pool the data since there did not seem to be a handling response or a difference in EV due to different locations associated with EV. By combing or pooling the data, we believed this may provide the necessary animal variation to test EV as a measure of temperament for cattle entering the feedlot. Descriptive statistics are reported in Table A2 of the pooled data set.

Beginning feedlot measurements were correlated with in feedlot weight, DOF (Table A3), quality grade, and carcass backfat (Table A4). Although pooling the data from Experiment 1 and 2 provided more variation, this did not seem to help explain any more relationships with performance. Simple correlation coefficients between carcass characteristics and feedlot measurements are reported in Table A4, and carcass characteristics between themselves are reported in Table A5. Since there was quite a

Table A1. Comparison least squares means and standard error for measurements in Experiment 1 and 2

Variable	Experiment 1	Experiment 2	p-value
In feedlot weight (kg)	345.4 ± 3.65	385.6 ± 3.01	0.0001
Beginning feedlot exit velocity (m/s)	2.88 ± 0.077	2.85 ± 0.064	0.74
Final feedlot weight (kg)	496.4 ± 3.63	532.4 ± 2.95	0.0001
Days on feed	111.9 ± 1.72	104.7 ± 1.40	0.001
Average daily gain (kg/d)	1.38 ± 0.027	1.42 ± 0.022	0.31
Hot carcass weight (kg)	291.0 ± 2.94	328.2 ± 1.92	0.0001
Quality grade[a]	2.6 ± 0.151	2.9 ± 0.098	0.07
Yield grade	2.2 ± 0.040	2.1 ± 0.027	0.06
Carcass backfat (cm)	0.70 ± 0.034	0.98 ± 0.022	0.0001
Ribeye area (cm^2)	78.65 ± 0.146	85.13 ± 0.095	0.0001
Hump height (cm)	4.3 ± 0.054	2.9 ± 0.033	0.0001
Average Warner-Bratzler shear force (kg)	2.67 ± 0.500	2.84 ± 0.040	0.008

[a] USDA Beef Quality Grade: 1=Prime; 2=Choice; 3=Select; 4=Standard

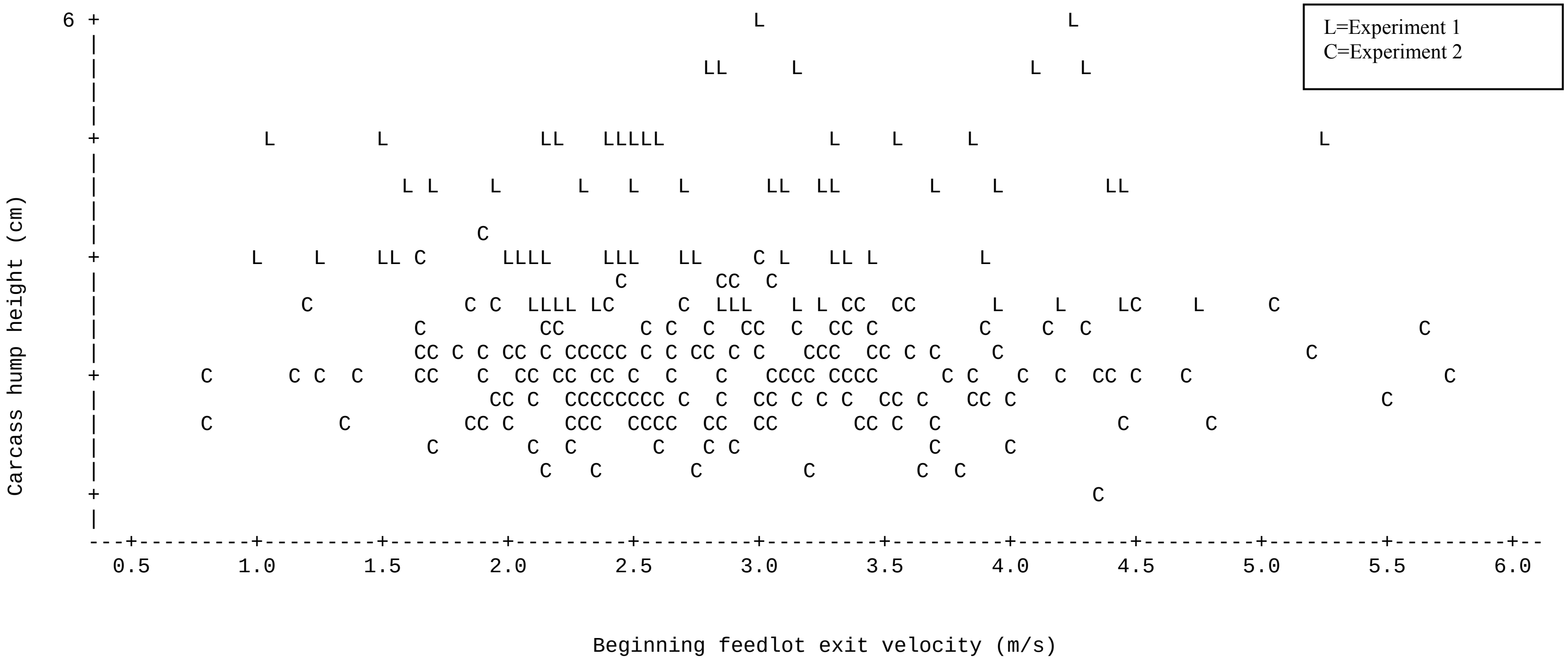

Figure A1. Hump height and exit velocity by experiment (Pooled data)

Table A2. Descriptive statistics for pooled data (Experiment 1 and 2)

Variable	N	Mean	Std Dev	Minimum	Maximum
Beginning feedlot exit velocity (m/s)	346	2.86	0.912	0.79	5.74
In feedlot weight (kg)	348	369.3	47.60	249.7	499.4
Final feedlot weight (kg)	344	518.0	45.92	390.4	660.6
Days on feed	344	107.5	20.38	90.0	150.0
Average daily gain (kg/d)	344	1.40	0.312	0.50	2.55
Hot carcass weight (kg)	295	317.1	32.40	240.6	408.6
Quality grade[a]	295	2.8	1.42	1.0	9.0
Yield grade	283	2.1	0.38	1.0	3.3
Ribeye area (in)	294	12.90	1.437	6.60	17.2
Carcass backfat (cm)	295	0.90	0.345	0.10	2.49
Hump height (cm)	284	3.3	0.78	2.0	6.0
Average Warner-Bratzler shear force (kg)	337	2.77	0.580	1.51	5.22

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[a] USDA Beef Quality Grade: 1=Prime; 2=Choice; 3=Select; 9=Standard

Table A3. Simple correlation coefficients for feedlot measurements (Pooled data)

	In feedlot weight (kg)	Beginning feedlot exit velocity (m/s)	Final feedlot weight (kg)	Days on feed	Average daily gain (kg/d)
In feedlot weight (kg)		-0.16	0.70	-0.59	0.02
		0.003	0.0001	0.0001	0.70
		346	344	344	344
Beginning feedlot exit velocity (m/s)			-0.05	0.12	0.06
			0.37	0.03	0.24
			342	342	342
Final feedlot weight (kg)				-0.21	0.59
				0.0001	0.0001
				344	344
Days on feed					-0.27
					0.0001
					344

Table A4. Simple correlation coefficients for carcass characteristics and feedlot measurements (Pooled data)

	Hot carcass weight (kg)	Quality grade	Yield grade	Ribeye area (in)	Carcass backfat (cm)	Hump height (cm)	Average Warner-Bratzler shear force (kg)
In feedlot weight (kg)	0.61 0.0001 295	0.04 0.49 295	0.11 0.07 283	0.28 0.0001 294	0.16 0.006 295	-0.11 0.07 284	0.12 0.03 337
Beginning feedlot exit velocity (m/s)	-0.02 0.70 293	0.13 0.02 293	-0.07 0.27 281	0.01 0.80 292	0.11 0.05 293	0.02 0.74 282	0.06 0.28 335
Final feedlot weight (kg)	0.79 0.0001 294	0.03 0.59 294	0.12 0.04 283	0.40 0.0001 294	0.26 0.0001 294	-0.15 0.01 284	0.07 0.19 336
Days on feed	0.11 0.05 294	0.08 0.14 294	-0.11 0.07 283	0.12 0.05 294	0.24 0.0001 294	-0.53 0.0001 284	-0.14 0.01 336
Average daily gain (kg/d)	0.33 0.0001 294	0.002 0.97 294	0.08 0.16 283	0.17 0.003 294	0.07 0.21 294	0.16 0.008 284	0.02 0.70 336

Table A5. Simple correlation coefficients for carcass measurements (Pooled data)

	Hot carcass weight (kg)	Quality grade	Yield grade	Ribeye area (in)	Carcass backfat (cm)	Hump height (cm)	Average Warner-Bratzler shear force (kg)
Hot carcass weight (kg)		0.08 0.17 295	0.10 0.08 283	0.58 0.0001 294	0.30 0.0001 295	-0.28 0.0001 284	0.04 0.51 290
Quality grade			-0.05 0.36 283	0.09 0.11 294	-0.10 0.08 295	-0.05 0.39 284	0.11 0.05 290
Yield grade				-0.27 0.0001 283	0.37 0.0001 283	0.07 0.22 273	0.05 0.35 278
Ribeye area (in)					-0.10 0.09 294	-0.15 0.01 284	0.05 0.38 289
Carcass backfat (cm)						-0.28 0.0001 284	-0.01 0.82 290
Hump height (cm)							-0.04 0.46 280

difference in hump height between the 2 experiments, we looked for a breedtype X EV interaction. Hump height did not appear to impact the speed at which the animals left the chute (Figure A2). Warner-Bratzler shear force measurement was plotted against beginning feedlot EV, although not significant, flightier cattle did tend to have higher WBS force measurements (Figure A3).

Correlation coefficients indicated that many of the variables are related to each other, so regression equations were constructed to help quantify the amount of change that may be expected when a variable is known or can be accounted for. When in feeldot weight, carcass backfat, hump height, location, and beginning feedlot exit velocity are included in the model statement the R^2 values were much higher (Table A6).

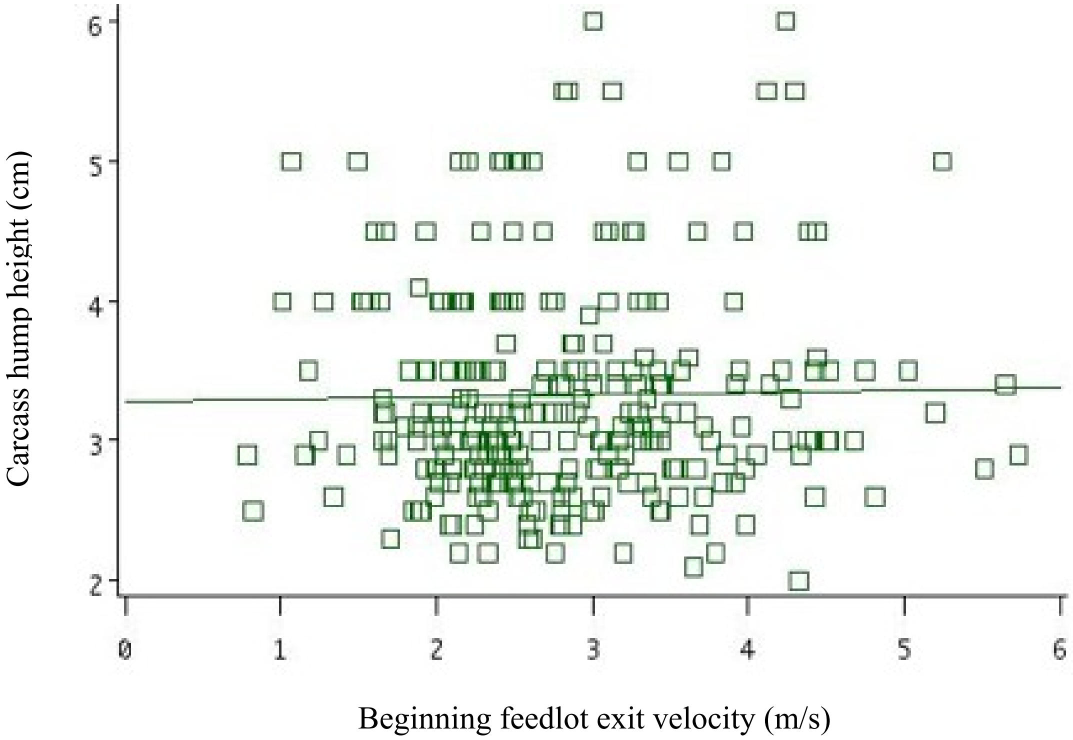

Figure A2. Linear regression line for carcass hump height and beginning feedlot exit velocity (Pooled data)

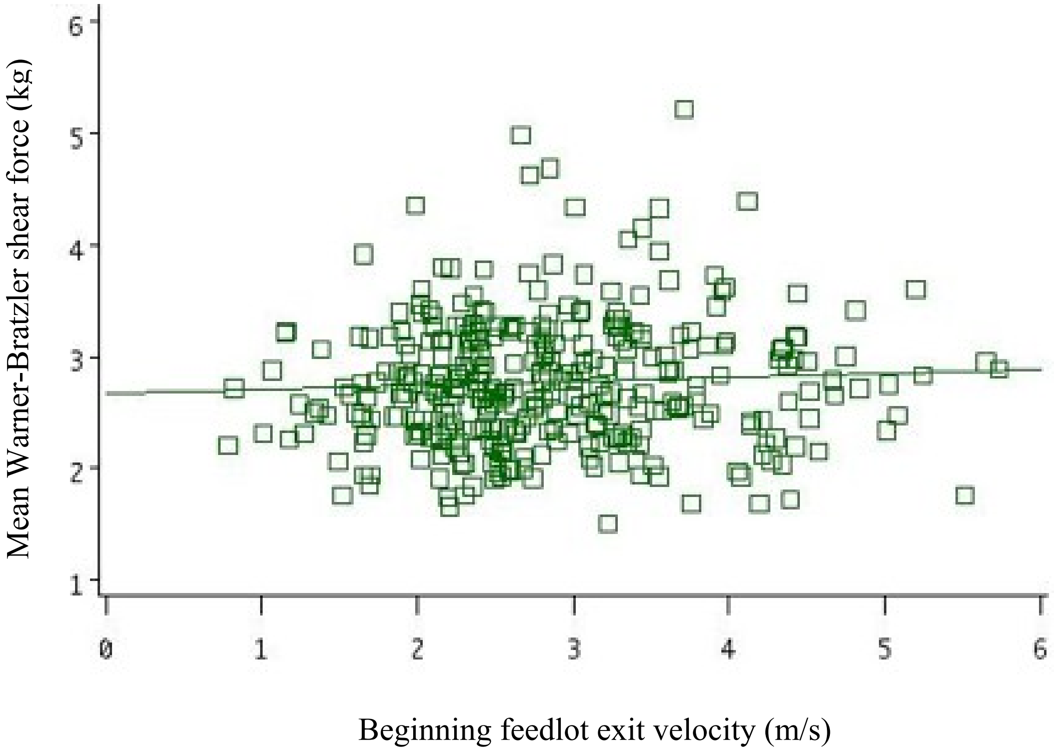

Figure A3. Linear regression line for mean Warner-Bratzler shear force and beginning feedlot exit velocity (Pooled data)

Table A6. Regression equations[a] for effects of exit velocity measure at the beginning of the feedlot period average daily gain, carcass characteristics, and tenderness (Pooled data)

Predicted variable (Y)	b_o	p>T	b_1	p>T	R^2	RMSE[b]
Average daily gain (kg/d)	1.26	0.0003	0.90	0.29	0.05	0.316
Final feedlot weight (kg)	483.3	0.0001	126.6	0.38	0.66	27.929
Hot carcass weight (kg)	285.6	0.0001	99.3	0.78	0.56	21.633
Ribeye area (cm^2)	73.51	0.0001	53.70	0.45	0.22	1.290
Average Warner-Bratzler shear force (kg)	4.59	0.0001	1.93	0.01	0.04	0.574

[a] Y=(In feedlot weight + Carcass backfat + Hump height + Location + Beginning feedlot exit velocity)

[b] Root Mean Square Error from Analysis of Variance Table

VITA

Shollie Falkenberg graduated from Uvalde High School in May of 2000. In the fall of that same year, Ms. Falkenberg started her undergraduate career at Southwest Texas Junior College and in the fall of 2001 she started attending Texas A&M University majoring in Animal Science. She was a member of the 2002 Junior Meat Judging Team, 2003 Junior Livestock Judging Team, as well as being a member of Aggie Cattle Womens Club and Saddle and Sirloin Club. After graduation, she began graduate school under the direction of Dr. J. W. Holloway and Dr. Rhonda Miller. Upon completion of her Master's Degree, she worked at the Texas A&M Research and Extension Center in Uvalde. Ms. Falkenberg can be contacted at P.O. Box 206/Knippa, TX 78870.