EVALUATION OF ADRENAL FUNCTION, GROWTH, CARCASS CHARACTERISTICS, BLOOD METABOLITES, HEMATOLOGICAL AND IMMUNE PARAMETERS IN ANGUS, BRAHMAN, BONSMARA X ANGUS AND BONSMARA BEEF STEERS

A Thesis

by

REGINA JACOBS HOLLENBECK

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

August 2005

Major Subject: Physiology of Reproduction

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Chair of Committee, Thomas H. Welsh, Jr.
Committee Members, Ronald D. Randel
Gordon E. Carstens
T.D.A. Forbes
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ABSTRACT

Evaluation of Adrenal Function, Growth, Carcass Characteristics, Blood Metabolites, Hematological and Immune Parameters in Angus, Brahman, Bonsmara X Angus and Bonsmara Beef Steers. (August 2005)

Regina Jacobs Hollenbeck, B.S., University of Idaho

Chair of Advisory Committee: Dr. Thomas H. Welsh, Jr.

Adrenal function, blood metabolites, hematological parameters, growth, and carcass characteristics were compared in tropically-adapted (Brahman,) intermediate (Bonsmara and Bonsmara X Angus crossbred,) and temperate (Angus; n=10 each) beef steers. An adrenal gland challenge was conducted, entailing serial blood collection at 15-min intervals for a 12.5-h period, with administration of exogenous ACTH (0.1 IU/kg BW) 2.5-h into the experiment. Steers were maintained on Coastal bermudagrass pastures overseeded with ryegrass for five month; body weights and blood samples were obtained every 21 days.

An anterior pituitary/adrenal gland challenge was conducted, entailing serial blood collection at 120, 90, 60 and 30 min prior to, and 10, 20, 30, 60 and 120 min following administration of exogenous CRH (0.1 ug/kg BW).

Physical and physiological signs of heat stress were assessed, and blood samples were obtained for analysis. Exit velocity was measured. Carcass characteristics were determined post-slaughter.

Statistical analysis was conducted using ANOVA for repeated measures, using least square means and Pearson's and Spearman's correlation analyses. Bonsmara and Bonsmara X Angus had lower basal cortisol (CS) than Angus and Brahman steers. Angus steers had greater adrenal responsiveness to ACTH, and responded faster to CRH than the other breedtypes. Bonsmara steers were slower in responding to CRH, and returning to basal CS following ACTH or CRH administration.

Angus and Bonsmara X Angus grew faster during the finishing phase than Brahman or Bonsmara steers. Angus had higher quality grades than other breedtypes; rib-eye area and hot carcass weight were greater in Angus than Brahman steers, but similar among Angus, Bonsmara X Angus and Bonsmara steers. Angus and Brahman were less docile than Bonsmara and Bonsmara X Angus steers.

Angus steers had higher respiration rates and serum concentrations of sodium, lower aldosterone during moderate heat exposure, and lesser serum concentrations of glucose, urea and cholesterol than tropically-influenced breedtypes. Angus had rectal and surface temperatures similar to those of Brahman, but greater than those of Bonsmara X Angus or Bonsmara steers.

Intermediate breedtypes like the Bonsmara provide a compromise to producers, allowing them to address the demands of consumers while raising cattle better suited to survival in tropical climates.

This thesis is dedicated to my husband Russ, who has been my anchor,

my salvation and my inspiration.

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I would like to also thank the Texas Beef Initiative Project for providing funding for the project, and to Robert Bruner and George Chapman, who donated cattle for the project.

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Finally, thanks to my husband Russ, my brother Joe and my parents John and Debbie, who have been there for me every step of the way.

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CHAPTER I

INTRODUCTION

In animal agriculture, profitability is a function of how efficiently the animals utilize feed resources. Animals that efficiently convert feed to gain cost less to produce. In a value-based animal agriculture system, it is imperative to acquire a thorough understanding of the endocrine factors that contribute to development of a more efficient beef animal. Hormones of the adrenal axis (hypothalamus-pituitary-adrenal; HPA), and the somatotrophic axis (the hypothalamus, anterior pituitary gland, and liver) are crucial to growth and development of healthy cattle. It is important that an understanding of the interactions between HPA and somatotrophic axes be developed in order to minimize the adverse impact of stressors on production.

Beef cattle are exposed to numerous managerial, climatic, and social stressors during the normal course of production. Common stressors of beef animals include transport, handling, temperature extremes, humidity, solar radiation, water and/or feed deprivation, exposure to novel situations, and isolation (Silanikove, 2000). Exposure to stressors may diminish efficiency of beef production by suppressing the immune system and/or growth performance of calves.

Prior studies have noted that *Bos indicus* (tropically adapted) and *Bos taurus* (temperate) breedtypes have significantly different blood concentrations of

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adrenocorticotropin releasing hormone (ACTH; Carroll et al., 1996; Bruner et al., 1996) and cortisol (CS; Koch et al., 2000). *Bos indicus* and *Bos taurus* cattle also exhibit different adrenal gland weights, adrenocortical area (Koch et al., 2000). These differences suggest that there may be a differential stress response, which could translate to differential alteration of immune function and growth performance among breedtypes.

The manner in which an animal copes with handling stress is frequently referred to as temperament. Temperament can be objectively assessed by measuring escape velocity from the squeeze chute (Burrow et al., 1988), which is positively correlated to basal plasma concentration of cortisol. Evidence suggests there is a significant correlation of temperament with rate of gain and meat tenderness (Voisinet et al., 1997). Also, temperament is positively related to breedtype (Schaefer et al., 1997; Bindon, 2002). A high degree of heritability (r=0.54) is associated with temperament in cattle (Burrow et al. 2001, 1988; Bindon, 2002). Quiet, contented groups of pigs and cattle are more productive than restless, uneasy ones (Ewbank, 1969), suggesting that performance may improve in populations of docile pigs and cattle.

The objectives of this study were to identify whether temperate and tropically-adapted cattle differ with regard to stress response, thermoregulation, growth rate, carcass characteristics and temperament. Specifically, this study concentrated on the following areas:

1) assessment of breedtype differences in basal cortisol, response to an exogenous dose of corticotropin-releasing hormone (CRH) and adrenocorticotropic hormone (ACTH);

2) analysis of breedtype differences in expression of physical parameters indicative of heat stress, including respiration, rectal temperature, electrolytes, metabolites and body surface heat dissipation;

3) expression of physiological parameters involved in thermoregulation, metabolism and immune function, including plasma aldosterone, calcium, phosphorus, sodium, potassium, chloride, glucose, urea, cholesterol, B-HBA, hemoglobin, hematocrit and immunological parameters;

4) analysis of the relationship of plasma concentrations of cortisol to average daily gain and body condition score during the course of a five-month grazing period and after 112 d in a feedlot situation, several weeks prior to slaughter;

5) correlation of rib-eye area, adjusted fat thickness, yield grade, quality grade, percent kidney, pelvic and heart (KPH) fat, carcass value, days on feed and feedlot rate of gain with plasma concentrations of cortisol and temperament.

We postulated that breedtype-associated differences would exist among the parameters measured. Specifically, we expected temperate breedtypes to a have greater plasma concentrations of cortisol than tropically-adapted steers. We expected the tropically-adapted steers to display less severe symptoms indicative of heat stress upon exposure to environmental conditions at the upper end of the thermo-neutral zone. We expected to detect that cortisol and growth characteristics would be negatively related, and there would be a positive association between desirable growth and carcass characteristics and calmer temperaments; we expected temperate breedtypes and intermediate composites to be less excitable than tropically-adapted breedtypes.

CHAPTER II

LITERATURE REVIEW

The Stress Response and Its Effectors

Stressors affecting beef cattle production can stem from social, management or environmental sources, Some common stressors include social isolation, regrouping, crowding, transport, disease, wind, dust, heat and cold stress or nutritional deficiency, to name a few (DiVita, 2001). The stress response is comprised of a multi-faceted cascade initiated by the reaction of the hypothalamus to a stressor (Figure 1). The hypothalamus secretes the neuropeptides, corticotropin-releasing hormone (CRH), and vasopressin (Aguilera and Rabadan-Diehl, 2000); CRH coordinates the behavioral and physical changes that occur during stress (Grammatopoulos and Chrousos, 2002). In response to the binding of CRH, the anterior pituitary gland secretes the hormone, adrenocorticotropin (ACTH), which is a peptide hormone derived from proopiomelanocortin protein (Roselli-Rehfuss et al., 1993). ACTH stimulates secretion of the steroid hormone, cortisol, by binding to ACTH receptors (ACTH-R) in the cortex of the adrenal gland (Roselli-Rehfuss et al., 1993). In addition to the release of cortisol, ACTH induces up-regulation of steroidogenic cytochrome P450 dependant messenger ribonucleic acids (Bornstein and Chrousos, 1999); cytochrome P450 enzymes determine the fate of steroid precursors through the steroidogenic pathway, and the eventual conversion of the precursors into androgens, mineralocorticoids or glucocorticoids such as cortisol (Mesiano et al., 1993). Cortisol acts in a negative feedback manner on the hypothalamus and the anterior pituitary gland to inhibit the release of CRH and ACTH

respectively (Canny et al., 1989). Cortisol functions systemically in the immune response, metabolism and reproduction (Sapolsky, 2000). Plasma concentrations of cortisol are considered to be indicative of stress response in domestic animals (Silanikove, 2000; Sapolsky et al., 2000).

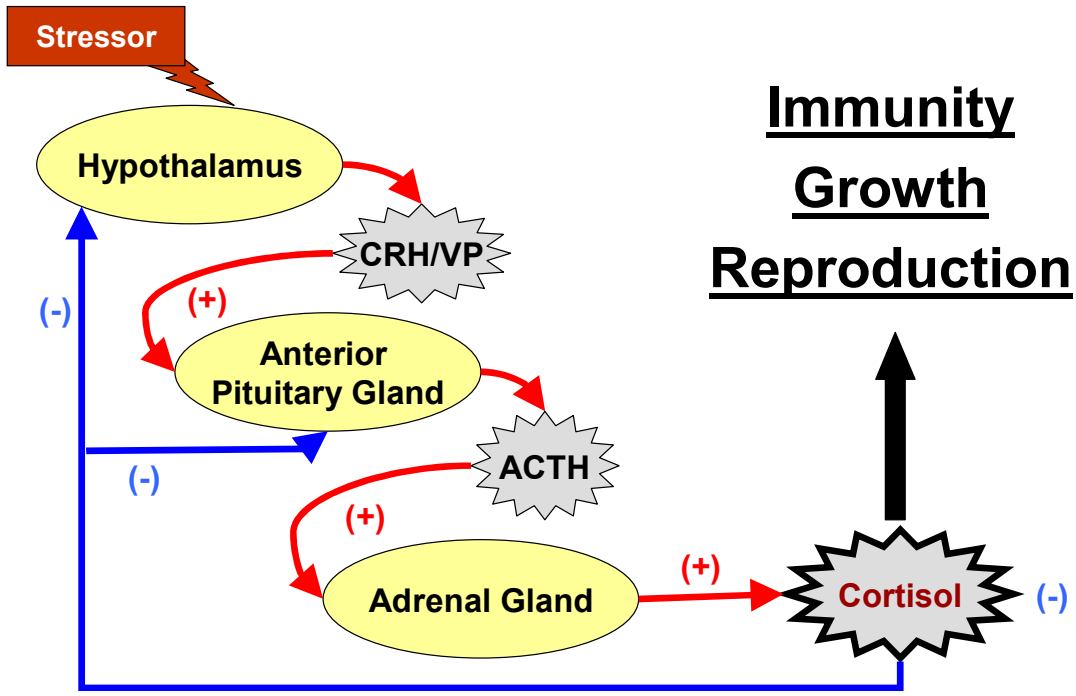

Figure 1. A stressor exerts its influence on immunity, growth and reproduction through its actions on the HPA axis, which consists of the hypothalamus, anterior pituitary gland and adrenal gland.

Systemic Effects of Cortisol

Cortisol serves the body in times of stress to elevate metabolic rate, increase blood glucose concentrations through insulin antagonism, trigger metabolic activities such as gluconeogenesis, lipolysis, and protein catabolism (Hillman, 1982). In addition to its catabolic activity in muscle, Cortisol can catabolize bone. An *in-vitro* study evaluating the effects of cortisol on expression of vascular endothelial growth factor concluded that cortisol can inhibit bone formation, partly through a 20% decrease in the expression of vascular endothelial growth factor in growth plate chondrocytes (Koedam et al., 2002).

Cortisol acts as a powerful anti-inflammatory agent, capable of altering the percentage and distribution of types of leukocytes, i.e., percent neutrophils increases, lymphocytes and immunoglobulins decrease, and eosinophils may decrease slightly if present prior to the stress (Hillman, 1982). The anti-inflammatory properties of cortisol make it a potent inhibitor of immune function. In ewes transported by truck, cortisol exerts changes at the hypothalamus to reduce the number of gonadotropin releasing hormone pulses and amplitude of the pulses, in turn reducing the pulsatile secretion of luteinizing hormone (Phogat et al., 1999), thus disrupting estrous cyclicity and reproductive efficacy. In a study examining the effects of weaning and separation stress on dairy calves and their dams, increases in plasma cortisol were noted to occur in conjunction with the increase in peripheral concentration of catecholamines, epinephrine and norepinephrine; this evidence may indicate a mediatory role of stress on catecholamine synthesis and secretion (Lefcourt and Elsasser, 1995).

Stress Exerts Negative Effects by Altering Feeding Behavior

Behavioral symptoms of stress include decreased feed and water intake, which has physiological ramifications (Nandi et al., 2002). McGuire et al. (1989) observed a 3 to 4 kg/d decrease in dry matter feed intake (DMI) in mid-lactation cows subjected to thermal stress, compared with a constant rate of intake by cows in a similar stage of production maintained in the thermo-neutral zone (TNZ). A study evaluating the effects of shade and misting on performance of feedlot cattle noted greater dry matter intake (9.46 kg/d) in cattle with access to shade, when compared to cattle without access to shade (8.80 kg/d; Mitlohner et al., 2001). A similar study using feedlot heifers indicated that availability of shade increased dry matter intake by seven percent, and improved feed conversion by three percent (Thomas et al., 2002). Guernsey heifers exposed to ambient temperatures of 33.5°C consumed less feed (6.2 kg/d vs. 9.4 kg/d; $P<0.05$) than heifers exposed to temperatures of 18.2°C (Abilay et al., 1975).

Fasting in feedlot cattle for a period of 72 consecutive hours resulted in significantly lower (1,000 mmol X 10^{-1}) plasma glucose concentrations compared to non-fasted animals, while free fatty acid concentrations were 900 umol X 10^{-1} greater (Van Der Walt et al., 1993). As glucose becomes depleted due to a reduction in feed intake, the body catabolizes fat, muscle and glycogen to obtain energy for bodily processes. Reduction in plasma glucose is accompanied by a rise in GH concentrations and decrease in insulin concentrations. Because IGF-I serves as a down-regulator of GH, a state of heightened GH secretion indicates that IGF-I concentrations are low, and thus, the physiological state is not conducive to growth (Clemmons et al., 1987); IGF-I is

a key hormone for growth, which mediates cellular proliferation, differentiation and metabolism.

In conjunction with decreased growth, muscle-weakening proteolysis also results from excessive plasma concentrations of cortisol. Proteolysis is evidenced by increased plasma total protein; in an experiment assessing plasma metabolite concentrations following handling, transport and slaughter, Brahman-Hereford-Afrikander heifers subjected to handling had a 10.7 g/L increase in total protein, over Friesland and Nguni control cows which were accustomed to being handled and having blood samples taken. Compared to the control cows, total plasma protein content in the heifers following transport and slaughter was elevated 4.7 and 1.7 g/l, respectively (Mitchell et al., 1988). Cortisol-induced hypokalemia, which hyper-polarizes and stabilizes the muscle cell membrane making stimulation more difficult, can compound the problem of muscle weakness by making muscle actions even more challenging (Silanikove, 2000).

Stress Negatively Impacts Growth and Decreases Carcass Quality

Stressors such as crowding, transport, handling, and heat can substantially decrease growth of cattle. For instance, Simmental heifers restricted to 1.5-square meter stanchions experienced a 0.13 kg/d reduction in average daily gain and a 20 kg final body weight deficit, when compared to heifers housed in less confined stanchions (Fisher et al., 1997). Crossbred steers fasted, then transported for 2 d in a truck lost 3.3 kg more body weight, than the 15.4 kg lost by steers in the control group, which was fasted in stalls in a barn (Phillips et al., 1991). Administration of ACTH to male Sprague-Dawley rats for an 11 d period, mimicking a recurrent stressor resulted in a 25 g

loss in body weight, compared to the 30 g gain in body weight experienced by rats given injections of saline (Armario et al., 1986). Charolais-crossbred feedlot heifers with adequate access to shade reached their target slaughter weight 20 d sooner than did heifers without access to shade; at d 131 of the study heifers with access to shade weighed an average of 547 kg, whereas heifers without access to shade weighed only 520 kg (Mitlohner et al., 2001). Handling of weanling calves in order to obtain blood samples via vena cava puncture reduced weight gains by about 36% compared to calves that were not handled; each subsequent handling session resulted in an additive 36% decrease in weight gain (Crookshank et al., 1979).

In a study conducted by Laugero and Moberg (2000), male C57B1/6 mice were exposed to stressors consisting of restraint, immunological challenge with lipopolysaccharide (LPS), or restraint + LPS for seven days; over the course of the seven days, body weights of control mice increased, restraint mice remained the same, LPS mice decreased by 3.5 g, and LPS + restraint mice decreased by 3.5 g. The plasma corticosterone and IGF-I concentrations had an inverse relationship, with treated mice displaying greater plasma corticosterone concentrations than control mice on d 1, d 3, d 6 and d 7, and control mice having greater plasma IGF-I concentrations than treated mice on d 1, d 3, d 6 and d 7.

Some measures of meat quality which are adversely impacted by transport and handling, include color, texture, pH and moisture; carcasses referred to as “dark cutters” are generally sub-par to other carcasses, with regard to these measures of meat quality (Price and Tennesson, 1981). Animals that respond negatively to the stress of high

environmental temperatures (Scanga et al., 1998), or the stress involved in transport and handling prior to slaughter are more prone to be dark cutters (Schaefer et al., 1997). Dark cutting carcasses grade lower, and are less tender and palatable than non-dark cutters (Schaefer et al., 1997). Yearling heifers fed for 130 to 150 d in a feedlot with access to shade had 21.1 percent fewer dark cutting carcasses and had an average hot carcass weight 15.9 kg greater than heifers without access to shade. In addition, the shaded heifers had greater back fat thickness, and fifty percent more choice carcasses than the un-shaded heifers (Thomas et al., 2002).

Metabolite Concentrations, Rectal Temperature and Respiration Reflect Stressfulness

Stress associated with either transport, handling, or high environmental temperature may be responsible for the disruption of normal secretion patterns of numerous metabolic hormones and metabolites. A study conducted by Mitchell et al. (1988) comparing plasma metabolite concentration of castrated oxen and heifers with Brahman, Hereford, and Afrikander influence during handling to handling-accustomed Friesland and Nguni cows noted increases in blood hematocrit, total protein, lipid, lactate, and glucose. Cattle unaccustomed to handling had 21% greater hematocrit, 10.7 g/L greater total plasma protein, 5.4 g/L greater plasma lipid content, 3.7 mmol/L greater lactate and 0.9 mmol/L greater plasma glucose than the cows accustomed to handling (Mitchell et al., 1988), thus illustrating the insulin antagonistic, proteolytic, lipolytic properties of the stress response.

Gluconeogenic and insulin-antagonistic properties of cortisol have been illustrated by measuring plasma glucose concentrations following induction of cortisol

release by administration of ACTH. One such study, performed on Friesian, Jersey and Illawarra calves, using saline administration as a control, demonstrated a reduction of plasma glucose following administration of the treatment. In the ACTH treated calves, the mean increase in plasma glucose 4 to 8 h following the injection was reflective of the gluconeogenic and insulin-antagonistic properties of cortisol; plasma glucose concentrations from the calves that received ACTH were greater ($P<.007$) than plasma glucose concentrations in calves receiving only saline (Ramin et al., 1995).

Hematological parameters which can be affected by stress include packed cell volume (PCV), erythrocyte number, hemoglobin content, mean corpuscular hemoglobin (MCH), mean corpuscular volume (MCV), and leukocyte number. Transport and handling stress have also been characterized by increases in serum chloride, hemoglobin, urine sodium, and urine osmolality, and decreases in blood pH, and interstitial water space (Schaefer et al., 1997).

The effects of prolonged exposure to either heat or cold stress was studied in eleven-month-old Brahman and Hereford cattle. Cattle were assigned in even breed and gender proportions to one of two rooms kept at either 21°C and 65% humidity or 32°C and 95% humidity for a period of one year. While Brahman cattle had higher ($P<0.05$) PCV, and erythrocyte number than Hereford cattle, neither these parameters nor hemoglobin or leukocyte number differed significantly ($P>0.05$) due to heat exposure. In contrast, the cattle exposed to high heat and humidity had a significantly decreased ($P<0.01$) MCH and MCV, compared to those maintained at a moderate temperature. Overall, Brahman cattle had lower MCV ($P>0.05$) and MCH ($P<0.05$) than Hereford

cattle (Gutierrez et al., 1971). Heat stress studies reported Holstein cows in Florida, exposed to high ambient temperatures averaging 87°F (30.5ºC), and full sunlight, to have increased plasma concentration of cortisol ($P<0.02$) and packed cell volume (Elvinger et al., 1992).

Holstein-Friesian calves infected with S Typhimurium strain IR715 and monitored over a 3 d period as part of an immune challenge had greater PCV, red blood cell count and increased hemoglobin concentrations ($P<0.01$) than contemporaries not infected with this strain of bacteria. Additionally, by 48 h post-inoculation, infected calves experienced an increase in plasma glucose and urea concentrations not experienced by non-infected calves. Inoculated calves had decreased ($P<0.05$) plasma sodium, total CO_2, calcium, total protein and albumin, and calcium, compared to control calves (Santos et al., 2002). These findings indicate that non-environmental stressors also elicit an increase in serum metabolites and electrolytes.

Respiration rate and rectal temperature were also assessed in the experiment described above, and both were elevated ($P<0.01$) in heat stressed cows, compared to cows kept in a thermo-regulated environment (Elvinger et al., 1992); this evidence concurs with results from research conducted on heat stressed Holstein cows in Louisiana (Lee et al., 1976), which demonstrated elevated rectal temperature and respiration among heat-stressed cows.

An evaluation of rectal temperature (RT) and respiration rate (RR) during heat stress among Angus, Brahman, Hereford, Romosinuano and Senepol beef heifers indicated that Senepol have lower RT and RR than either Angus or Brahman cattle

($P<0.001$). Romosinuano cattle have lower RR and RT than Angus ($P<0.001$), but are not different from Brahman. Angus have greater RT ($P<0.001$) than Brahman, Senepol or Romosinuano, but have greater RR ($P<0.01$) than only Brahman and Romosinuano cattle. Brahman have lower RR than the other breedtypes ($P<0.001$), lower RT ($P<0.001$) than Angus, and higher RT ($P<0.001$) than Senepol cattle (Hammond et al., 1996).

Prenatal and Postnatal Stress Impacts Neonatal Stress Response

Studies of fetal and neonatal animals exposed to stress in-utero or shortly after birth indicate that there are permanent consequences of stress. Fetal and neonatal body weights are reduced as the result of exposure to stress, and long-term alterations to the HPA axis occur. For instance, on average Brahman or Brahman X Tuli crossbred calves exposed to *in-utero* to ACTH administration were 3.2 kg heavier ($P<0.08$) at birth than calves not exposed to ACTH *in-utero* (Lay et al., 1997a). Progeny of Brahman cows exposed to transportation stress, or to administration of exogenous ACTH also have greater body weights at d 266 of gestation compared to calves not exposed to stressors *in-utero* (28.7 vs. 23.9 ± 1.8 kg; $P < 0.07$); pituitary glands of stress-exposed calves were larger (12.63 vs. 8.24 ± 1.10 g/kg BW; $P < 0.008$) than those of the non-stress exposed calves (Lay et al., 1997b).

Pregnant guinea pigs exposed to dexamethosone (1.0 mg/kg body weight), a synthetic glucocorticoid, on d 50 and d 51 of pregnancy produce offspring with roughly a 34.4 g increase in body weight ($P<0.05$), 2.0 g lighter brains ($P<0.05$), 0.7 g lighter hearts ($P<0.05$) and 0.3 g lighter adrenal glands ($P<0.05$) compared to offspring of

guinea pigs injected with 200 ug/kg saline (70%)/propylene glycol (30%) (Dean et al., 2001). Additionally, *in-utero* exposure to dexamethosone decreased the expression of glucocorticoid receptors (GR) in the pars distalis ($P>0.05$), paraventricular nucleus ($P>0.05$), ventromedial hypothalamus ($P>0.05$) and thalamus ($P>0.05$) and significantly decreased the expression of GR in the cingulated cortex ($P<0.05$; Dean et al., 2001). In Wistar rats, prenatal exposure to dexamethosone throughout gestation resulted in a 15% decreased birth weight ($P<0.005$) compared to rats not exposed to dexamethosone *in-utero*; when dexamethosone exposure was restricted to the third trimester, the reduction in birth weight was 6.4%, indicating the effects of exogenous glucocorticoids may vary depending on the stage of gestation at glucocorticoid administration (Welberg and Seckl, 2001). Wistar rats exposed to dexamethosone during the last trimester *in-utero* display a 19% reduction in the expression of hippocampal glucocorticoid receptor mRNA; accordingly, CRH mRNA in the paraventricular nucleus was increased by 17%, thus indicating that prenatal stress may have long-term effects on hormonal responses to stress (Welberg and Seckl, 2001).

Fetal sheep experiencing prolonged hypoxemia resulting from reduced maternal fraction of oxygen at d 134 and d 136 of gestation had significantly ($P<0.05$) increased mRNAs encoding P450 side chain cleavage enzyme and 3ßHSD, but not P450C17 in the adrenal gland, compared to non-hypoxemia exposed fetuses (Braems et al., 1998), indicating that the stress of hypoxemia is a stimulus for adrenal steroidogenesis. Steroidogenic acute regulatory (StAR) protein, which functions to increase adrenal growth and steroidogenesis through enhanced cholesterol metabolism (Artemenko et al.,

2001), is suppressed ($P<0.05$) in growth restricted neonatal sheep (6.9 ± 1.7 AU/ug adrenal protein) in the third trimester of gestation when compared to non-growth restricted neonates (17.1 AU/ug adrenal protein; Coulter et al., 2002). Permanent alteration of the fetal HPA axis by gestational stress is further evidenced by the decreased adrenal content of enkaphalin (ENK) containing peptides (ENK is an enzyme important for catecholamine synthesis) in growth restricted ovine fetuses as early as d 90 of gestation (Coulter et al., 1998). Ewes experiencing periconceptional undernutrition carry fetuses displaying an increase in ACTH secretion ($P<0.05$), but no change in ACTH receptor, or Star protein expression later in gestation, (Edwards et al., 2002).

Large White X Chester White and Landrace X Yorkshire crossbred neonatal boars restrained in small cages (restraint stress) at 27 d of age had body weights which were 18% greater than non-restrained controls (Klemcke et al., 1995). Restraint of neonatal boars also resulted in greater plasma concentration of cortisol ($P<0.04$), compared to non-restrained boars (Klemcke et al., 1995). Similarly, the stress experienced by piglets deprived of maternal contact resulted in an increase in neonatal cortisol (16.98 ± 2.5 vs. 68.3 ± 8.2 ng/mL; Klemcke and Pond, 1991). These results indicate that the HPA axis is functional even in the neonatal animal. Stress exposure in fetal and neonatal animals has the potential to induce long-term alterations to the HPA axis and immune function (Matthews, 2002; Welberg et al., 2001). Production strategies could use breedtypes that adapt easily to production stressors to minimize the effects of stress in-utero.

Stress Response Affects Immune Function

The stress incurred by cattle under normal production conditions has proven to have deleterious effects on immune function. In the normal inflammatory response, a nuclear factor (NF-κB) composed of a Rel A (p65) and NF-κB1 (p50) subunits (Zhao and Karalis, 2002) increased the expression of the genes for many cytokines, enzymes and adhesion molecules in chronic inflammatory diseases (Zhang and Ghosh, 2001; Figure 2). Glucocorticoids, such as cortisol, inhibit the inflammatory response by binding to the p65 subunit of NF-κB, thus inhibiting NF-κB from activating inflammatory genes. Another way glucocorticoids can suppress inflammation is by binding to the corticoid-glucocorticoid-receptor complexes, which in turn bind to a glucocorticoid response element in the promoter region of the IκBα gene to induce the synthesis of IκBα. In this instance, IκBα in turn binds the NF-κB molecule to prevent activation of inflammatory genes (Barnes and Karin, 1997). CRH exerts an anti-inflammatory effect indirectly via cortisol production (Agelaki et al., 2002).

Cortisol is elevated upon exposure to pathogens. When compared to pigs given sterile growth media intra-nasally, crossbred barrows given *A. pleuropneumoniae* intra-nasally had a more rapid and sustained response ($P<0.05$) of cortisol secretion and TNF-ά production, and serum TNF-α concentrations were greater for the duration of the study (Balaji et al., 2002). Adrenocortical cells of rats, cattle and humans have receptors for interleukin-6 and TNF-α; these two molecules function in the HPA axis, by traveling to the hypothalamus via vagal sensory afferent neurons (Graham et al., 1999) and modulating the release of CRH from the hypothalamus, in turn inducing the release of

ACTH from the anterior pituitary. In cattle IL-6 administration resulted in elevated cortisol, while administration of TNF-α resulted in decreased ACTH-stimulated cortisol secretion (Judd et al., 2000).

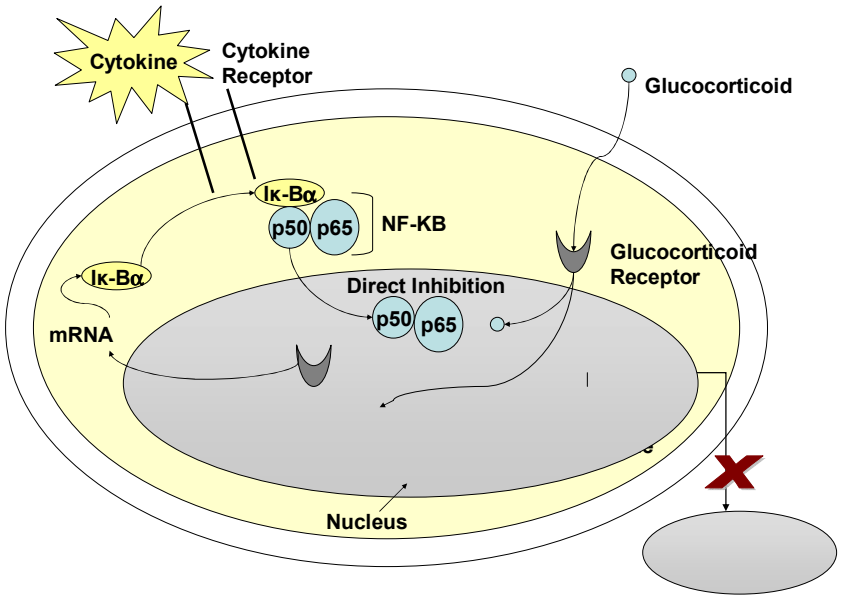

Figure 2. Glucocorticoids inhibit the immune response by promoting transcription of the inhibitory IK-Bά compound and blocking transcription of mRNA which codes for inflammatory proteins. (Modified from Barnes and Karin, 1997)

Cortisol suppresses immune function. Holstein dairy cows characterized as having either high (HC) or low plasma cortisol (LC) concentrations in response to a novel environment were utilized to study how stress impacts immune response to endotoxin-induced mastitis. Cows were socially isolated and inoculated with endotoxin in an intra-mammary manner. Plasma concentrations of cortisol in both HC and LC cows increased between 3 and 5.5 h post-inoculation; plasma concentrations of cortisol in HC cows were greater throughout the study. HC cows had significantly greater ($P<0.05$) reductions in the number of peripheral lymphocytes beginning at 10 h post-inoculation (Hopster et al., 1998); a reduction in peripheral lymphocyte numbers may be reflected in the animal's inability to initiate immune responses to pathogens.

The degree to which immune function is depressed differs between Angus and Simmental steers receiving an intranasal inoculation of bovine rhinotraecheitis (Arthington et al., 1997). Angus steers had higher rectal temperature response than Simmental steers ($P<0.05$) at d 2, d 3, d 4, d 5, d 6 and d 7 following inoculation; fever response to a pathogen is caused by cytokines such as interleukin-1, tumor necrosis factor-ά and interleukin-6 (Klasing, 1988; Arthington et al., 1997). Angus steers demonstrated greater ($P<0.05$) immunoglobulin titers than Simmental steers on d 7, d 14 and d 21 post-inoculation (Engle et al., 1999).

Angus steers had a greater ($P<0.05$) lymphocyte blastogenic response to pokeweed mitogen (162.78 vs. 151.52 CPM X 10^3) and phytohemagglutinin (160.19 vs. 120.33 CPM X 10^3) than Simmental steers (Engle et al., 1999). In Sprague Dawley rats, kainic-acid induced hippocampal damage was greater ($P<0.001$) at 24 and 72 h post-

administration in rats with adrenal glands or induced glucocorticoid elevation than in adrenalectomized rats. Interleukin-1ά and 1-ß as well as TNF-α mRNA expression was greater in rats with increased glucocorticoid concentrations (Dinkel et al., 2003).

Exposure to stress *in-utero* can affect the immune responses of neonatal animals. For instance, progeny of female Rhesus monkeys stressed through exposure to multiple cage changes and social instability during gestation demonstrated lower TNF-ά and IL-6 responses to 10 ng/mL LPS than monkeys not exposed to gestational stress (Coe et al., 2002). Additionally, immunoglobulin G concentrations were an average of 200 mg/dL ($P<0.05$) greater in undisturbed neonates compared to those exposed to stress *in utero*; gestational stress may result in a lasting alteration of the HPA axis and immune function (Coe and Crispen, 2000). Restraint stress in pregnant sows during the last 5 weeks of gestation resulted in decreased immunoglobulin titres in piglets 1-3 d old, decreased lymphocyte proliferation in response to T-cell mitogen ConA in piglets at d 1 and d 7 of age, suppressed immune response to an LPS challenge at d 1 and d 35, and an overall trend for greater piglet morbidity and mortality (Tuchscherer et al., 2002). Piglets removed from maternal presence and subjected to cold stress prior to the first nursing had a reduction ($P<0.10$) in serum gamma-globulin at 14.5 (31.5 vs. 24.4 mg/mL $^{-1}$), 26.5 (28.6 vs. 24.7 mg/mL $^{-1}$), 38.5 (30.0 vs. 25.7 mg/mL $^{-1}$) and 50.5 (26.9 vs. 23.8 mg/mL $^{-1}$) hours of age, compared to piglets removed from their dams and maintained in the thermo-neutral zone (Blecha and Kelley, 1981). Immunoglobulins are a component of maternal colostrum which is crucial to the development of passive immunity in neonates (Kruse, 1983); these data suggest that stress may inhibit the absorption of

gamma globulins from colostrum (Blecha and Kelley, 1981).

When immune function suffers, susceptibility of animals to disease increases; disease states have consequences which directly contradict the goals of animal production. Tissue wasting, which is observed in many diseases, occurs as the result of anorexia, reprioritization of nutrient utilization and changing endocrine and cytokine environment (Sartin et al., 1998). During trauma or sepsis, animals may lose as much as 20% of their body protein; much of the loss is in the form of skeletal muscle (Biolo et al., 1997) which is the building block of the lean mass of a beef carcass. Adverse reaction to exposure to pathogens results in a marked decline in IGF-I, (Elsasser et al., 2000), thus inhibiting muscle growth. In illness, the secretion patterns of metabolic hormones regulating growth are impaired; through the catabolism of lean tissue, depressed immune function ultimately negates growth, resulting in lower carcass weight and decreased carcass quality.

Stress Impacts Reproduction

Stress exerts effects on reproduction in a number of ways including altered reproductive endocrine function, interruption of estrous cycles and subsequently reduced fertility. Stress interrupts the estrous cycle by disruption of the release of reproductive hormones, gonadotropin-releasing hormone and luteinizing hormone, during the follicular phase of the estrous cycle (Moenter et al., 1990). Luteinizing hormone pulse frequency and amplitude during transport of ovariectomized ewes decreased significantly ($P<0.05$) compared to the pretreatment values (Dobson and Smith, 2000). Exogenous ACTH, and transport stress act on the pituitary to decrease the amount of

luteinizing hormone secreted in response to GnRH, which makes ovarian follicles mature more slowly (Phogat et al., 1999). Estrous cycle length in Guernsey heifers exposed to either 18.2°C (control) were shorter (19.5 d; $P<0.05$) than heifers exposed to 33.5°C (heat stressed; 21.4 d). Additionally, the duration of estrus was shorter in heat stressed heifers ($P<0.05$) compared to control heifers (12.5 h vs. 17.0 h; Abilay et al., 1975). Heat stress in estrous cycling dairy cattle can lead to the early emergence of the pre-ovulatory follicle, in turn lengthening the follicular dominance period and decreasing the viability of the oocyte (Wolfenson et al., 2000). In boars, treatment with ACTH induced a significant and sustained increase ($P<0.05$) in plasma testosterone concentrations which peaked at 5.58 ± 0.74 ng/mL, compared to no increase in testosterone in boars injected with saline. Adrenocorticotropin also induced significant increases in progesterone and corticosteroids ($P<0.05$) which peaked at 8.49 ± 1.0 ng/mL and 162.26 ng/mL ± 25.61 respectively; these increased concentrations persisted for 225 and 410 minutes, respectively. Administration of ACTH to boars had no significant effect on luteinizing hormone (Juniewicz and Johnson, 1984). Acquiring a better understanding of HPA and growth axis hormones in steers may aid in the development of management practices which could be applied to breeding stock as well.

Temperament and Its Relationship to Stress and Carcass Characteristics

Temperament of beef cattle is associated with the manner in which the animals deal with the stress of being handled. Previous experiences during handling such as excessive noise, a maladjusted chute, or use of electronic prods can also contribute to the level of stress experienced by an animal while being handled (Grandin, 1998). Genetic

factors such as breedtype and lineage can also dictate how much stress is experienced by cattle during handling (Voisinet et al., 1997).

Temperament can be characterized in several ways. A crush test can be performed by analyzing the behavior of a beef animal while they are held in a confined space, such as a squeeze chute, in close proximity to humans (Fordyce et al., 1988b). A flight speed test (referred to in this document as escape velocity) utilizes two light beams focused on infra-red reflectors with a trigger on/off mechanism as the light beams are broken, thus effectively measuring the amount of time it takes an animal to cover a given distance, such as two meters (Burrow et al., 1988). Both of the methods described above produced repeatable results, and accurately identify animals that typically exhibit troublesome behavior (Burrow et al., 1988).

In terms of approach-avoidance behavior, which is the tendency of animals to approach a human stationed at a set point in a field, or to flee when the human approaches them (Murphey et al., 1981), temperament measured using the crush test (Fordyce et al., 1982) and the flight speed test (Burrow et al., 1988) there is a recognizable difference among different breedtypes of cattle. At eighteen months of age, flight speeds of Brahman-cross and Bonsmara cattle (Afrikander X Hereford X Shorthorn cross) were significantly different ($P<0.01$) between breedtypes; Bonsmara cattle took 1.08 seconds to cover a 1.7-meter distance, whereas Brahman cross bred cattle took 1.13 seconds (Burrow wt al., 1988). Voisinet et al. (1997) observed a marked difference in temperament during the course of handling utilizing a method similar to the crush test described above, with a score of 1 indicating a calm temperament and 5

indicating a violent temperament; *Bos indicus* crossbred steers were less docile ($P<0.001$) than *Bos taurus* steers (temperament ranking of 3.46 ± 0.09 vs. 1.80 ± 0.1; respectively) and concluded that the tropically-adapted breedtypes were more restless, and troublesome during routine handling than were their temperate counterparts. Lanier et al. (2000) observed a greater sensitivity ($P<0.05$) to sounds and touching in Holstein cattle than in beef breeds; sensitivity was assessed by watching for flinching of the animal upon exposure to these stimuli.

A complex and definite relation between stress and temperament exists. Female mice experiencing restraint stress while pregnant resulted in a 15% greater tendency toward infanticidal behavior compared to mice experiencing no restraint during pregnancy; conversely, restrained mice exhibited a 38% lessened tendency toward aggression directed at other female mice (Vom Saal et al., 1991). In tufted capuchins, personality traits such as aggressive, confident, curious, effective and opportunistic behavior were negatively correlated (r = -0.39 or greater) with cortisol reactivity, while behavior characterized as apprehensiveness, fearfulness, insecurity, submissiveness and tenseness were positively correlated with cortisol reactivity (r = 0.39 or greater); additionally, animals with higher cortisol reactivity played less (r = -0.26), explored their home cages less (r = -0.47) and required higher levels of proximity and contact with their mothers (r = 0.33; Byrne and Suomi, 2002). Breedtype differences as they relate to stress and behavior exist between European Large White and Chinese Meishan pigs. Basal cortisol concentrations were higher in Chinese Meishan pigs (96.1 ± 1.1 vs. 44.9 ± 1.1 ng/mL; $P<0.0001$). When the two breedtypes were exposed to a novel environment,

defecation and locomotion scores (two indicators of comfortable pig behavior) were higher in the Large White pigs ($P<0.0001$; Desautes et al., 1999).

Heritability of temperament is high at weaning (0.54) and moderate at 18 months of age (0.26; Bindon, 2002). A study assessing the effects of different environmental, management and social stimuli on the docility of Limousin cattle showed the most significantly influential sources of variation ($P<0.05$) in docility to be husbandry system and sire; the heredity estimate in Limousin cattle was 0.22 (Le Niendre et al., 1995).

Temperament scoring has practical applications in animal production in that more temperamental animals have lower live weights, and lower rates of gain than animals behaving in a calm manner during routine handling (Voisinet et al., 1997). For example, steers with a temperament ranking of 1 or 2 gained more (1.04 ± 0.03 and 1.05 ± 0.03 kg/d respectively) than steers with a temperament ranking of 3 or 4 (0.95 ± 0.03 and 0.94 ± 0.06 kg/d respectively; $P\leq0.05$). The flight time or escape velocity of a beef animal from the chute seems to be predictive of how tender the meat of their offspring will be; there is a -0.53 genetic correlation between flight time and LD peak force, which measures how tender the meat of the strip loin is (Bindon, 2002). There is a negative correlation (r = -0.22) between flight time and meat color (Bindon, 2002); meat color is genetically linked to meat tenderness (0.30 to 0.43); therefore, sires with light, bright meat and slower flight times tend to produce more tender progeny. Additionally, a positive correlation (0.41) exists between flight time and Meat Standards Australia tenderness score, and a positive correlation (0.11) exists between flight time and retail yield percentage (Bindon, 2002).

CHAPTER III

MATERIALS AND METHODS

Forty steers representing four different breed types (Angus, Brahman, Bonsmara X Angus, and Bonsmara; n=10 each) were transported by truck after weaning to the Texas A&M University Agricultural Research and Extension Center at Overton, TX (Latitude 32° 17' 39"N, Longitude 94° 58' 31"W), where they were housed communally in outdoor paddocks for an adaptation period of 1.5 mo (TAMU IAACUC Animal Use Protocol #2001-81). Animals were maintained on pastures of Coastal bermudagrass overseeded with ryegrass for a five mo period, during which time BW, body condition scores, and blood samples were obtained at 28 d intervals. The steers completed the finishing phase at Texas Tech University in Lubbock, where they were assigned to pens of five according to breed and BW. In Lubbock, steers consumed a finishing ration fed in concrete bunks. Figure 3 depicts a timeline of research projects and collection dates.

Comparison of Adrenal Responsiveness to ACTH

Between the dates of December 9th and December 18th, 2001, steers from each breedtype were randomly assigned to one of ten sample collection groups; each collection grouping included one animal from each breedtype. Animals had cannulas inserted into the jugular vein 12 h prior to the beginning of blood collection. The morning of the collection day the animals were haltered, and tied in stanchions. The 7.5-h sampling period was divided into a Pre-ACTH time frame, and a post-ACTH time frame, with Atime 0" indicating the time at which porcine ACTH (0.1 IU/kg; Peninsula

Laboratories; Belmont, California) was delivered via indwelling jugular cannula. Blood was collected into 10 mL vacutainers containing 0.117 mL of 15% (K3) EDTA solution (17.55 mg), at 15-min intervals during the 2.5-h pre-ACTH time period, and at 15-min intervals for the five h following the administration of porcine ACTH. Following collection of each sample, the cannulas were flushed with heparinized saline (15 IU/mL) to prevent clotting. All blood was immediately placed on ice, and plasma was harvested no more than 1.25 h post-collection. Plasma was aliquotted into 12X75 mm plastic tubes, and stored at -20 ° C until radioimmunoassay for plasma concentrations of cortisol (Chen et al., 1978) were performed.

Comparison of Plasma Cortisol and Average Daily Gain

For five months, between December and May, 40 steers (n=10 each Angus, Brahman, Bonsmara, Bonsmara X Angus) were maintained on pastures of rye-ryegrass overseeded on Coastal bermudagrass. A blood sample was obtained from each steer via coccygeal venipuncture (using uncoated 15 mL glass tubes) at the time of weight assessment. Blood was placed on ice until serum was harvested. Serum was aliquotted into 12X75 mm plastic tubes and stored at -20C until radioimmunoassays for serum cortisol and/or aldosterone (DSL 8600 Coated Tube RIA) concentrations were

performed. Maximum, minimum and average daily temperatures during the two-week period immediately preceeding each blood collection and weigh date (Table 1) were determined in order to assess whether serum cortisol differed with temperature among temperate and tropically-adapted breedtypes.

Comparison of Anterior Pituitary Responsiveness to CRH

Following the grazing period, 32 steers (n=8) were chosen at random to participate in an experiment comparing anterior pituitary responsiveness to administration of exogenous CRH (Peninsula Laboratories; Belmont, California). The 4.5-h sampling period was divided into a The CRH challenge, heat stress challenge, and physiological analysis conducted therewith occurred in May near the end of the grazing period. The finishing period began in May and concluded when the steers were harvested in September; in August, as the finishing phase neared completion escape velocity, serum metabolites and serum concentrations of adrenal steroids were measured.

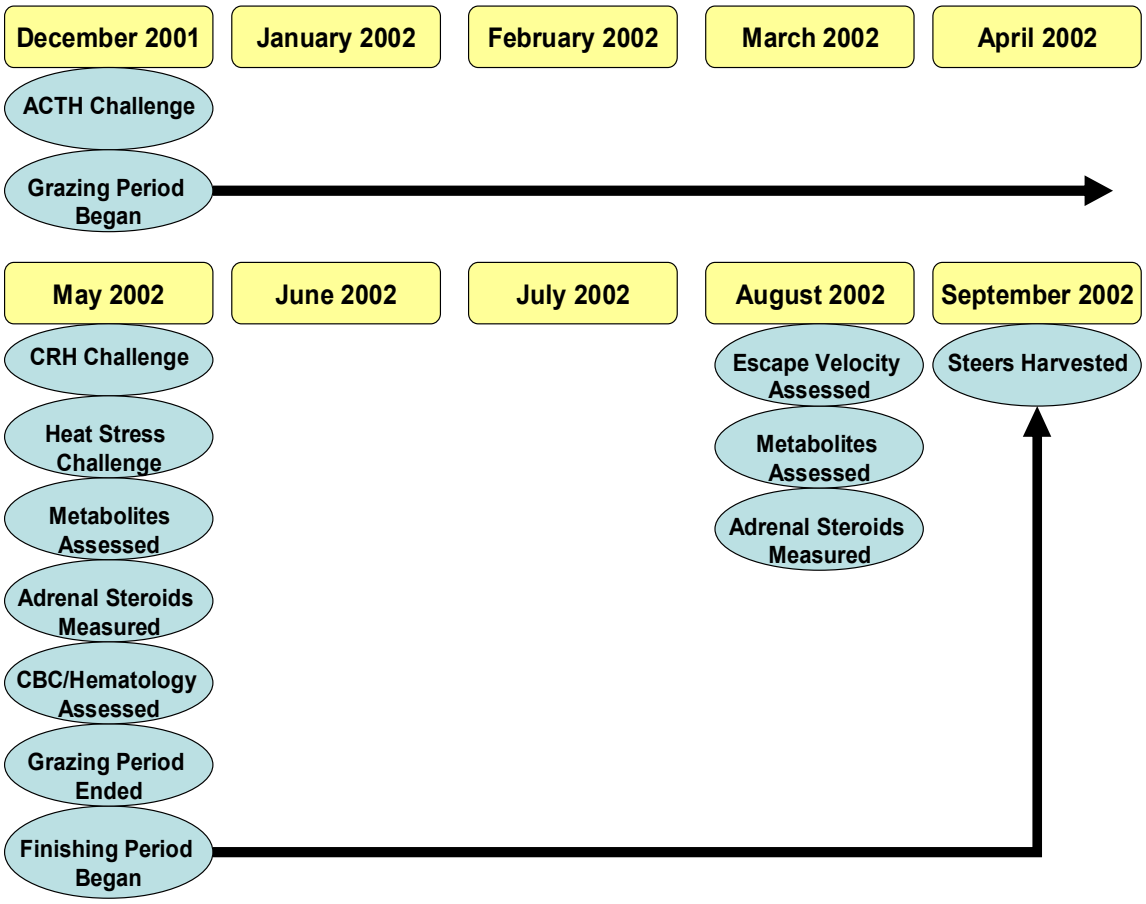

Figure 3. Project timeline. The ACTH challenge was conducted in December prior to the steers beginning the grazing period.

Table 1. Maximum, minimum and average daily temperatures during the two-week period immediately preceding each blood collection and weigh date.

Date Range	Maximum Temperature (ºC)	Minimum Temperature (ºC)	Average Temperature (ºC)
December 5, 2001 to December 19, 2001	**16.9**	**7.2**	**11.8**
December 21, 2001 to January 4, 2002	**9.9**	**-0.5**	**4.4**
January 25, 2002 to February 8, 2002	**15.5**	**4.2**	**9.5**
February 15, 2002 to March 1, 2002	**16.6**	**3.7**	**10.3**
March 8, 2002 to March 22, 2002	**18.9**	**8.6**	**13.5**
April 5, 2002 to April 19, 2002	**25.3**	**16.0**	**20.3**
April 19, 2002 to May 3, 2002	**27.7**	**18.8**	**23.1**

Pre-CRH time period, and a post-CRH time period, with Atime 0" indicating the time at which CRH was delivered via indwelling jugular cannula. Blood samples were collected into 10 mL vacutainers containing 0.117 mL of 15% (K3) EDTA solution (17.55 mg), via indwelling jugular catheter every 30 min for 2.5 h prior to administration of 0.1 ug/ kg BW CRH (Veissier et al., 1999) to identify basal plasma concentrations of the metabolic hormones. Blood samples were harvested at 10, 20, 30, 60, 90, and 120 min post-CRH administration to determine response of the anterior pituitary gland and adrenal gland to the stimulatory CRH dose. Following collection of each sample, the cannulas were flushed with heparinized saline (15 IU/mL) to prevent clotting. Plasma was aliquotted into 12X75 mm plastic tubes and stored at -20C until radioimmunoassays assessing plasma concentrations of cortisol were performed.

Comparison of Heat Stress Parameters

Following completion of the CRH challenge phase, thirty-seven steers (n=8 Angus, n=10 Brahman, n=10 Bonsmara and n=9 Bonsmara x Angus) were broken into groups of four (groups included n=1 of each breedtype). Respiration rate (breaths/minute) was visually assessed while steers stood undisturbed in groups in outdoor pens, prior to individually entering a squeeze chute inside a building. Environmental data was collected using HOBO data loggers (Onset Computer Corp.); ambient temperature was determined to be 24.06 $\pm$ 0.13 °C, relative humidity was 41.96 $\pm$ 0.57 % and the temperature-humidity index value was 69.68 $\pm$ 0.12.

Steers, individually, entered the building through a door leading directly into a working chute. The door was immediately closed behind each steer. The steers were

contained in a squeeze chute without their heads being caught. Body surface temperature on the dorsal and right side surfaces was assessed using digital infrared thermal imaging (Meditherm Vet2000). Digital infrared thermal imaging (DITI) can be used to assess the amount of heat on the surface of the hide, as represented by differing color variations in a digitized image (Figure 32). DITI measurements were categorized separately as the mean surface temperature along the right dorsal mid-line from rump to shoulder (dorsal) and right side over the ribs (right side) images. DITI measurements were categorized separately as the mean surface temperature along the right dorsal mid-line from rump to shoulder (dorsal) and right side over the ribs (right side) images. Rectal temperature was determined using a rectal thermometer prior to collection of two blood samples (10 mL each) via coccygeal venipuncture into an uncoated tube and a tube containing 0.117 mL of 15% (K3) EDTA solution (17.55 mg).

Blood samples from each steer were immediately placed on ice after a drop of blood from the EDTA tube lid was smeared on a glass slide. The blood samples were centrifuged at 3600 g for 30 minutes, then serum was harvested from the uncoated tube12 h later, and aliquotted into 12X75 mm plastic tubes; one tube was frozen at -20 ºC until a radioimmunoassay assessing plasma cortisol and aldosterone concentration was performed. The second serum aliquot, the un-centrifuged EDTA tube and the blood smear slide were sent to the Texas Veterinary Medical Diagnostic Laboratory where plasma was harvested and analyzed for hematological parameters, the blood smear slide underwent a complete blood count (CBC) procedure and serum metabolites were evaluated. Docility was assessed based on the temperament of each steer over the

duration of the five mo grazing period (1 = calm, 2 = moderately agitated / anxious, 3 = very agitated / aggressive).

Finishing Phase and Carcass Characteristic Comparison

Subsequent to the heat stress challenge, steers were shipped to Texas Tech University in Lubbock, Texas, (latitude 33° 39' N, longitude 101° 49' W) where they were housed in outdoor pens with concrete floors and fed a finishing ration for a period of 93 to 151 d to reach a back fat thickness of 1.0 cm. During the finishing phase steers were weighed every 28 d.

Two weeks prior to slaughter of the first group of steers, a blood sample was collected via coccygeal venipuncture. At the time of sample collection, the ambient temperature was 33ºC with 50% humidity and THI of 81. Serum was harvested 12 h later and aliquotted into 12X75 mm plastic tubes; one tube was frozen at -20C until radioimmunoassays assessing plasma cortisol and aldosterone concentration were performed. The other aliquot was sent to the Texas Veterinary Medical Diagnostic Laboratory for evaluation of serum metabolites and electrolytes. Escape velocity was quantified using a Farm Tek Electronic Timer, which measured how long it took each steer to clear two beams of light placed 1.82 m apart immediately after exiting the squeeze chute.

At the time of slaughter, carcass data were collected (hot carcass weight, rib-eye area, back fat thickness, kidney heart and pelvic fat, yield grade, and quality grade). In addition, carcass value, and days on feed were determined.

Sample Analysis

Plasma and serum cortisol (Chen et al., 1978; Mitchell et al., 1988) and aldosterone (DSL 8600 coated tube RIA kit for aldosterone; Diagnostic Systems Laboratories Inc., Webster, Texas) concentrations were assessed by radioimmunoassay; the protocol followed to assess plasma cortisol appears in Appendix B. Plasma metabolite and electrolyte concentrations as well as complete blood count were determined by the Texas Veterinary Medical Diagnostic Laboratory at Texas A&M University, College Station.

Statistical Analysis

Data were evaluated using SAS (SAS Institute Inc., Cary, NC). Breedtype was used as an independent variable within the PROC GLM function. Two breedtype comparison schemes were utilized: one scheme compared temperate Angus steers to tropically-adapted Brahman steers whereas the second compared temperate Angus steers, temperate-tropically-adapted composite Bonsmara steers, and Bonsmara X Angus crossbred steers. Breedtype comparisons were broken down in order to make more useable comparisons of performance and physiological traits between breedtypes with differing degrees of tropical-adaptation. The model statements used for statistical analysis were identical, except that one compared Angus and Brahman, whereas the other compared Angus, Bonsmara X Angus and Bonsmara. A sample model statement appears in Appendix A.

The model for statistical investigation of the ACTH challenge included ANOVA specific for repeated measurements. Parameters assessed by using the GLM procedure

of SAS included initial basal concentrations of cortisol (CS), CS concentrations just prior to stimulation with ACTH, peak height of CS response, amplitude of CS response, time required for CS concentrations to return to basal concentrations, and average basal concentration following the return of CS concentrations to a basal state as parameters for comparison; pair-wise comparisons of least squares means were used to determine statistically significant differences in these parameters between breedtypes. The Excel program (Microsoft ® 2002) was used to calculate means and area under the hormone profile curves using the trapezoidal rule.

Data from the CRH challenge were evaluated using ANOVA specific for repeated measurements. Parameters assessed by using the GLM procedure of SAS were as follows: initial basal concentrations of CS, CS concentrations just prior to stimulation with CRH, peak height of CS response, amplitude of CS response, time required for CS concentrations to return to basal concentration, and average basal concentration following the return of CS concentration to a basal state; pair-wise comparisons of least squares means were used to determine statistically significant differences in these parameters between breedtypes. The Excel program (Microsoft ® 2002) was used to calculate means and area under the hormone profile curves using the trapezoidal rule.

To detect correlations between the results of the CRH and ACTH challenges, individual challenge parameters described above were analyzed for correlation with the PROC CORR function of SAS. Additionally, measurements of temperament, growth, carcass traits, electrolytes, metabolites and immune parameters were correlated using this function. An overall correlation coefficient between each set of parameters was

derived among breeds by using the PROC CORR function, whereas the correlation coefficients within each breedtype were obtained by using the PROC CORR; BY BREED command.

We postulated that breedtype-associated differences would exist among the parameters measured. Specifically, we expected temperate breedtypes to have greater plasma concentrations of cortisol than tropically-adapted steers. We expected the tropically-adapted steers to display less severe symptoms indicative of heat stress upon exposure to environmental conditions on the upper end of the thermo-neutral zone. We expected to see a negative correlation between cortisol and growth characteristics, and a positive association between desirable growth and carcass characteristics and calmer temperaments; we expected temperate breedtypes and temperate-tropically-adapted composites to be less excitable than tropically-adapted breedtypes. Data that was statistically different between breeds is depicted in graphic form within the text; Appendix C contains graphical representations of key parameters which were not statistically different among breeds, while Appendix D contains a series of tables summarizing data values that did not differ among breeds.

CHAPTER IV

RESULTS: ASSESSMENT OF THE HPA AXIS

Effect of Exogenous ACTH on Plasma Concentration of Cortisol in Angus and Brahman Steers

Pre-ACTH Challenge Period. The mean plasma concentrations of cortisol in Angus and Brahman steers during the experimental period (2.5-h pre and 10 h post administration of exogenous ACTH at "time 0") are depicted in figure 4. The 2.5-h period prior to administration of ACTH is referred to as the pre-ACTH challenge period. Within 15 min of administration of ACTH plasma concentrations of cortisol were elevated to a peak level, from which the plasma concentrations of cortisol declined toward pre-ACTH and "time 0" values. Following administration of ACTH, the area under the curve did not differ between Angus and Brahman steers.

For the 2.5 h prior to administration of ACTH, mean plasma concentrations of cortisol were similar in Angus and Brahman steers (Appendix C, Figure 61). Similarly, plasma concentrations of cortisol immediately prior to administration of ACTH ("time 0") were not different between Angus and Brahman steers (Appendix C, Figure 62).

Post- ACTH Challenge Period. The peak of the plasma cortisol response to ACTH is the mean of the highest plasma concentration of cortisol attained by each steer within each breedtype, following the administration of ACTH. Peak plasma concentrations of cortisol were 13.71 ng/mL greater in Angus steers ($P<0.01$) than in Brahman steers (Figure 5). The amplitude of the cortisol response to ACTH is the difference between "time 0" plasma concentration of cortisol, and peak plasma

concentration of cortisol. The amplitude of cortisol response to ACTH was 15.68 ng/mL greater ($P<0.005$) in Angus steers than in Brahman steers (Figure 6). The area under the curve tended to be greater ($P<0.06$) in Angus (6619.27 + 624 ng/mL) than Brahman steers (4894.5 + 624 NG/ML) during the two h following ACTH, although the post-challenge basal concentrations of cortisol were not different ($P>0.05$).

The time required to attain the maximal cortisol response to ACTH was not different ($P>0.05$) between Angus and Brahman steers (Appendix C, Figure 63). The time required to return to basal plasma concentrations of cortisol was determined by assessing how many minutes it took, following the peak in plasma concentrations of cortisol, for plasma concentrations of cortisol to return to concentrations similar to those seen during the pre-ACTH period (Appendix C, Figure 64). The amount of time required for plasma concentrations of cortisol to return to basal did not differ ($P>0.05$) between Angus and Brahman steers. Mean plasma concentrations of cortisol, following reestablishment of basal plasma concentrations of cortisol through the end of the study, were not different ($P>0.10$) between Angus and Brahman steers (Appendix C, Figure 65). Non-significant values appear in table 2.

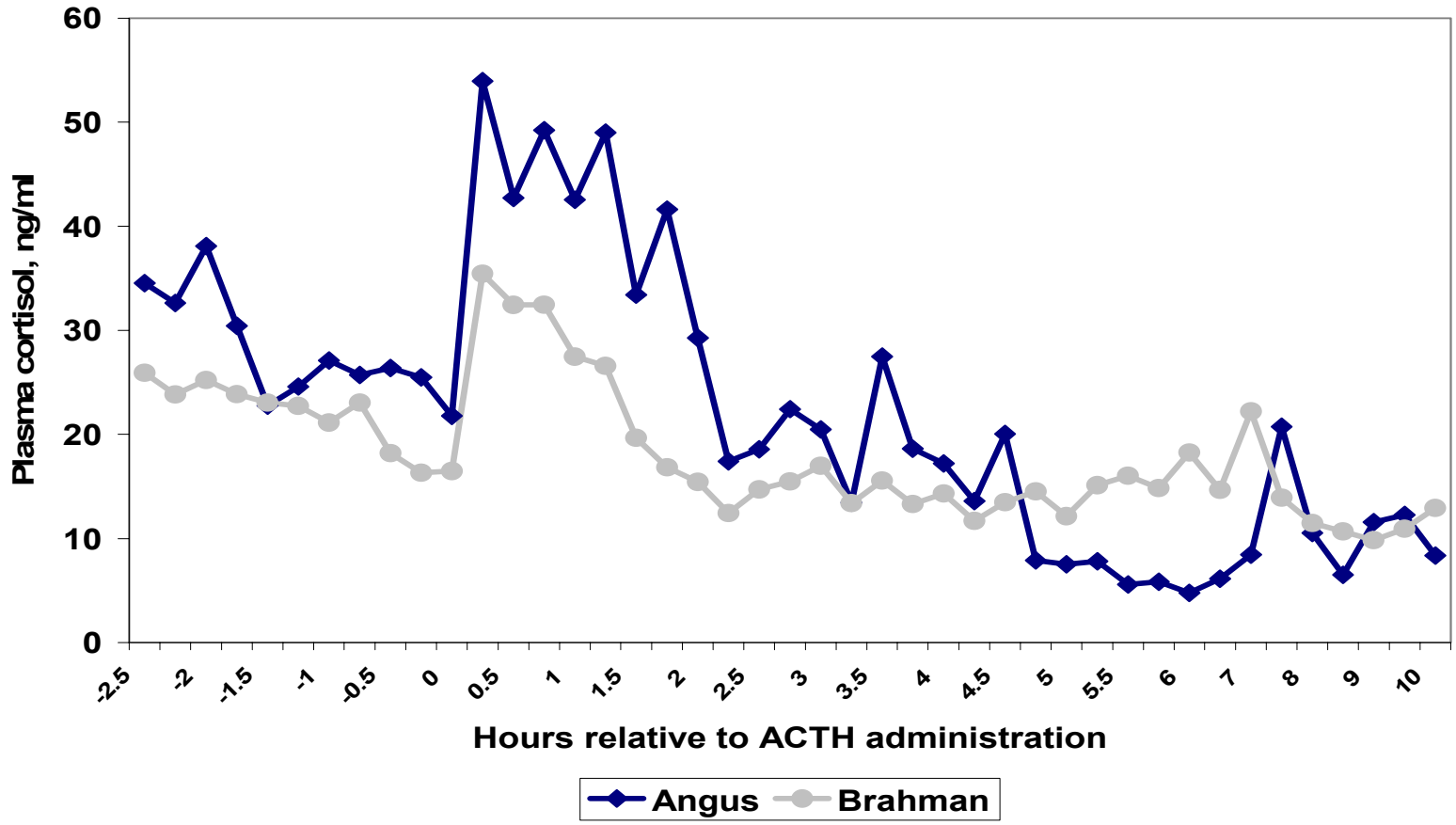

Figure 4. Plasma concentrations of cortisol in Angus and Brahman steers prior to and following ACTH administration. (n=8 of each breedtype)

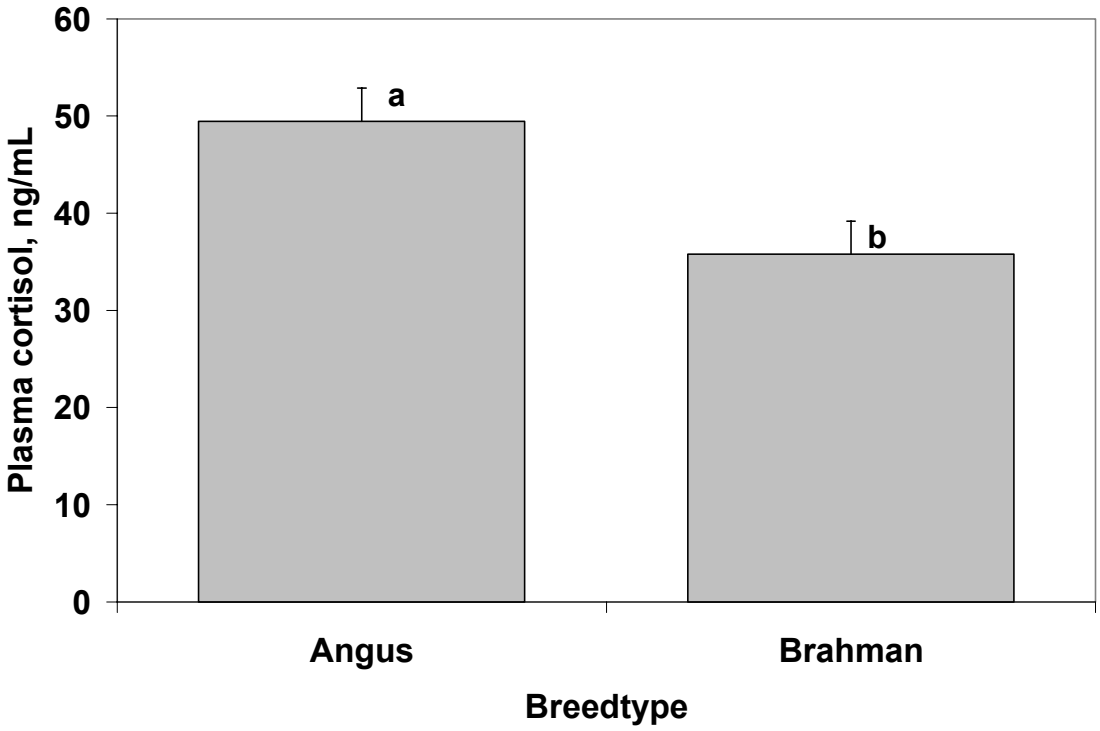

Figure 5. Peak plasma concentrations of cortisol attained as the result of ACTH administration in Angus and Brahman steers. a,b differ $P<0.05$.

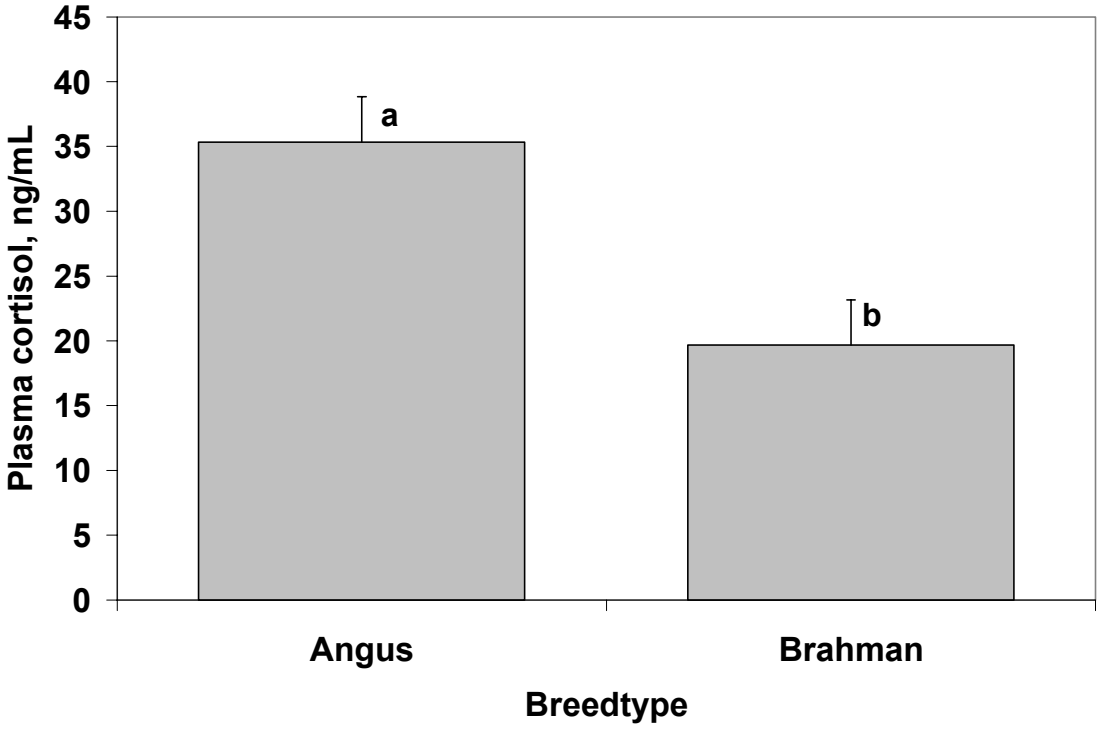

Figure 6. Amplitude of plasma cortisol response to ACTH administration in Angus and Brahman steers. a,b differ $P<0.05$.

Table 2. Mean values for parameters which did not differ between Angus and Brahman steers during the ACTH challenge.

	Breedtype		
Parameter	Angus	Brahman	SEM
Pre-ACTH basal plasma cortisol, ng/mL	25.91	21.67	3.93
Plasma cortisol at "time 0" pre-ACTH, ng/mL	14.12	16.10	3.27
Time to reach peak cortisol post-ACTH, min	33.0	36.0	4.18
Time to return to basal cortisol post-ACTH, min	60.0	66.0	8.68
Post-ACTH basal plasma cortisol, ng/mL	11.19	15.34	2.77

Effect of Exogenous ACTH on Plasma Concentration of Cortisol in Angus, Bonsmara X Angus Crossbred and Bonsmara Steers

Pre-ACTH Challenge Period. Mean plasma concentrations of cortisol in Angus, Bonsmara X Angus crossbred and Bonsmara steers during the experimental period (2.5-h pre and 10 h post administration of exogenous ACTH at "time 0") are depicted in Figure 7. The 2.5-h period prior to administration of ACTH is referred to as the pre-ACTH challenge period. Within 15-min of administration of ACTH, plasma concentrations of cortisol were elevated to a peak concentration, from which plasma concentrations of cortisol declined toward pre-ACTH and "time 0" values. During the pre-ACTH period, Bonsmara steers had a lesser ($P<0.02$) area (2033.41 ± 418.0 ng/mL) under the curve than either Angus (4749.6 ± 418.0) or Bonsmara X Angus steers (4706.0 ± 418.0).

For the 2.5 h prior to administration of an intravenous bolus of ACTH, mean plasma concentrations of cortisol were over two times greater ($P<0.02$) in Angus and Bonsmara X Angus than in Bonsmara steers (Figure 8). Similarly, plasma concentrations of cortisol just prior to administration of ACTH ("time 0") of Bonsmara X Angus steers were greater ($P<0.01$) than that of Bonsmara steers; plasma concentration of cortisol of Angus steers was intermediate to the Bonsmara and Bonsmara X Angus, and did not differ ($P>0.05$) from either breedtype (Figure 9).

Post-ACTH Period. Peak plasma concentration of cortisol did not differ ($P>0.05$) among Angus, Bonsmara X Angus crossbred and Bonsmara steers. The amplitude of the cortisol response did not differ ($P>0.05$) among Angus, Bonsmara X Angus and Bonsmara steers. Area under the curve did not differ ($P>0.05$) among Angus, Bonsmara X Angus and Bonsmara steers following administration of ACTH.

Time to attain cortisol response to ACTH was no different ($P>0.05$) among Angus, Bonsmara X Angus crossbred and Bonsmara steers. Plasma cortisol in Angus and Bonsmara X Angus crossbred steers returned to basal concentration more quickly ($P<0.01$) than Bonsmara steers (Figure 10). Angus had post-challenge basal plasma concentration of cortisol which was nearly two times greater ($P<0.05$) than that of Bonsmara steers; Bonsmara X Angus steers had post-challenge basal concentration of cortisol which was intermediate to, and not different ($P>0.05$), from those of Angus and Bonsmara steers (Figure 11). Non-significant values are displayed in Table 3.

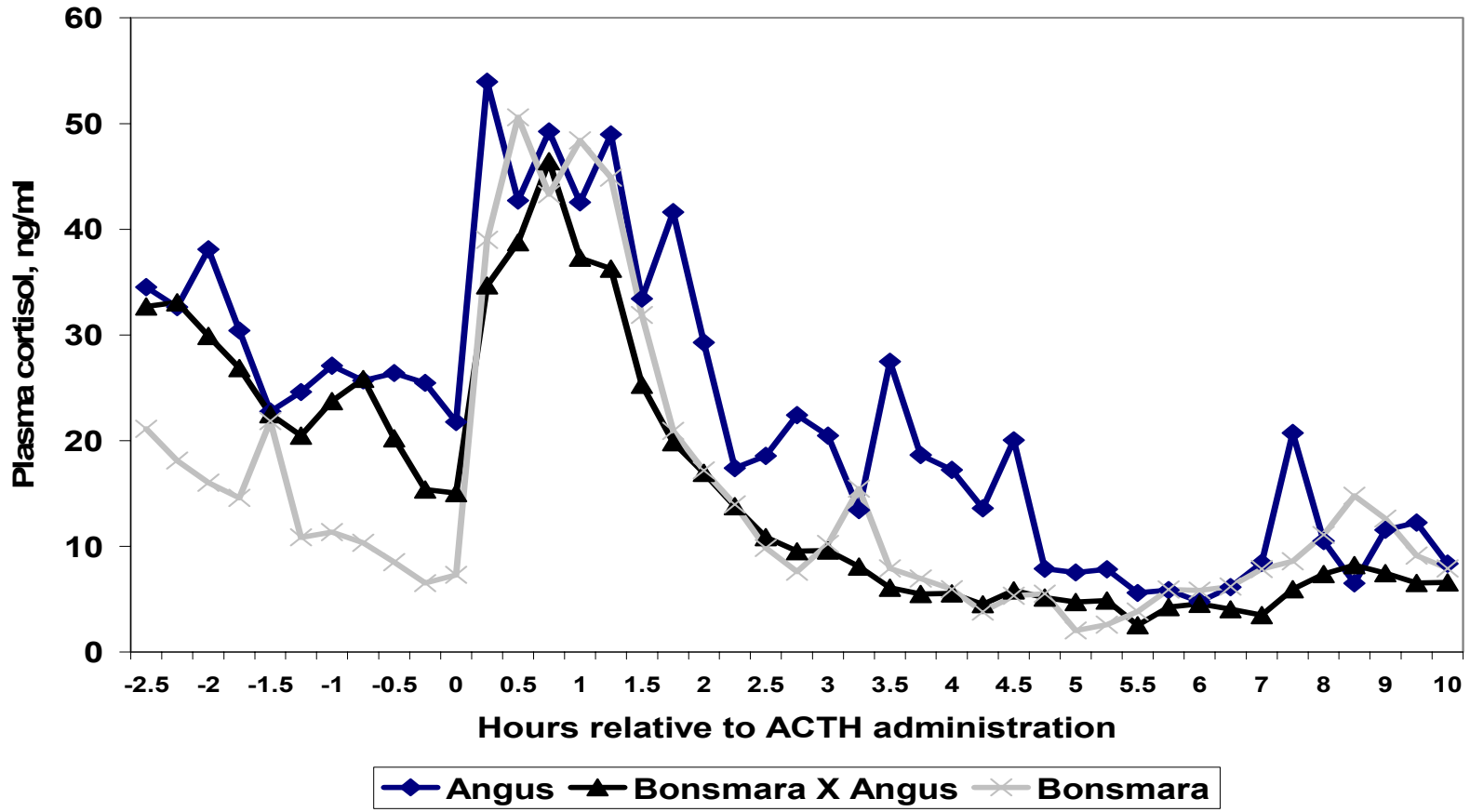

Figure 7. Plasma concentrations of cortisol for Angus , Bonsmara X Angus crossbred and Bonsmara steers prior to and following ACTH administration. (n=8 steers of each breedtype.)

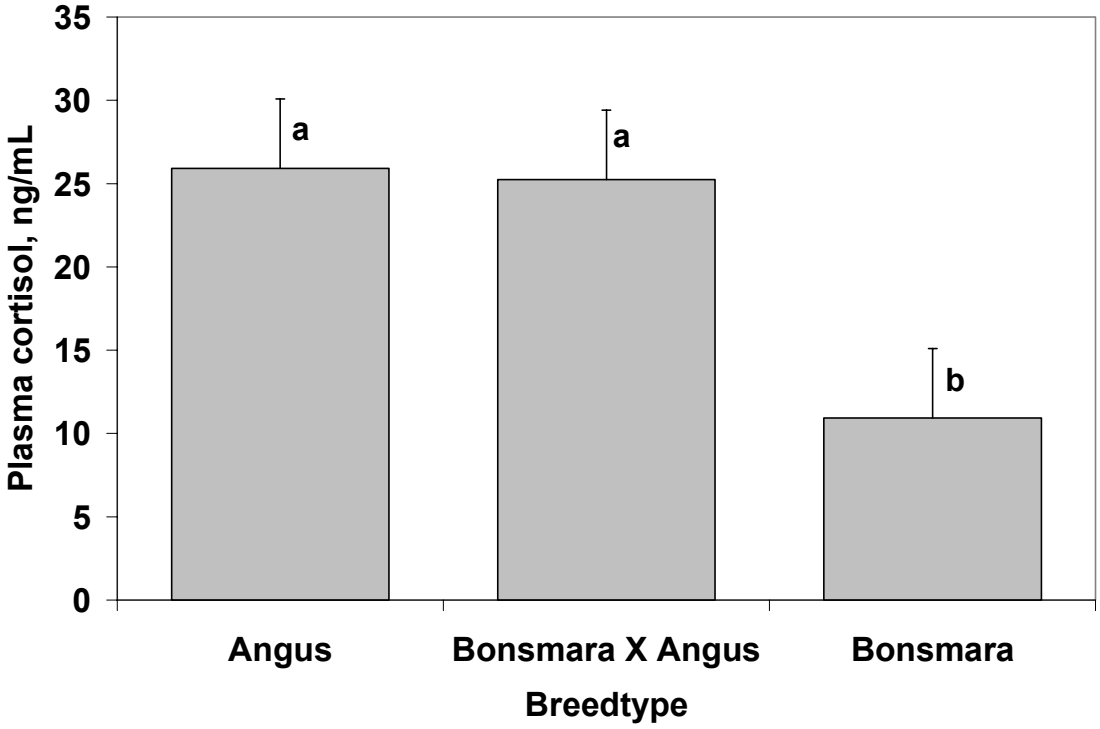

Figure 8. Plasma concentration of cortisol during the 2.5-hour pre-ACTH challenge time-frame in Angus, Bonsmara X Angus and Bonsmara steers. a,b differ $P<0.05$.

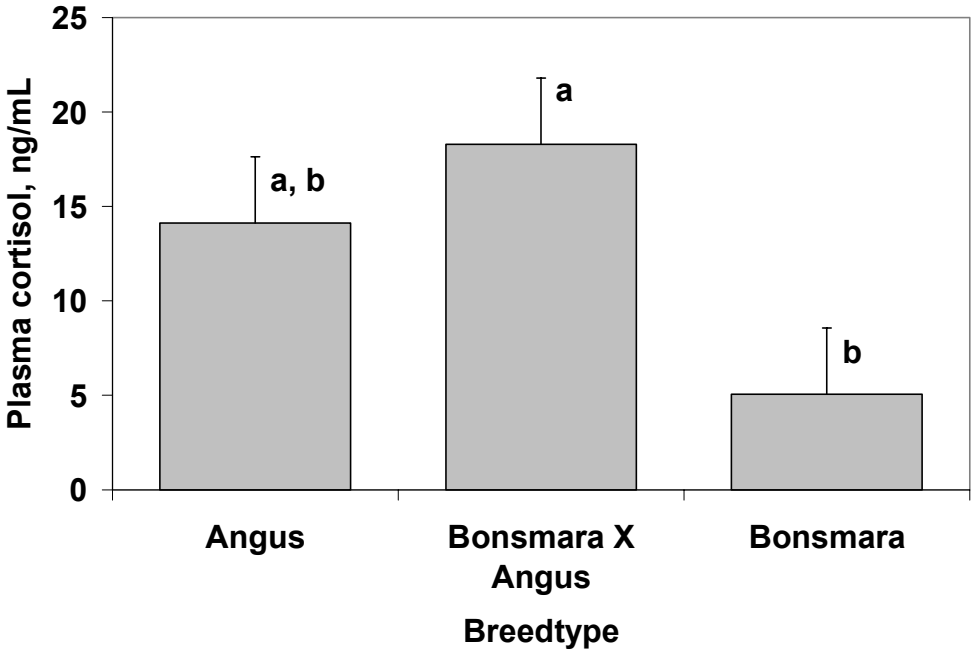

Figure 9. Plasma concentration of cortisol just prior to ACTH administration (i.e., "time 0) in Angus, Bonsmara X Angus and Bonsmara steers. a,b differ $P<0.05$.

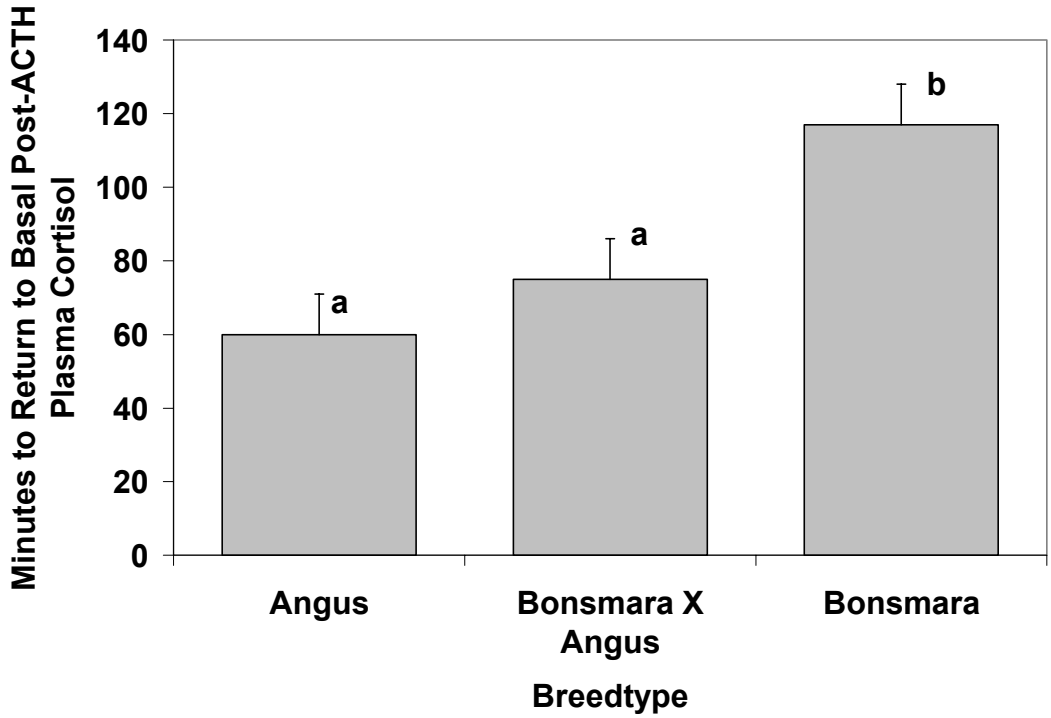

Figure 10. Amount of time required for plasma cortisol to return to pre-challenge basal concentration in Angus, Bonsmara X Angus and Bonsmara steers. a,b differ $P<0.05$.

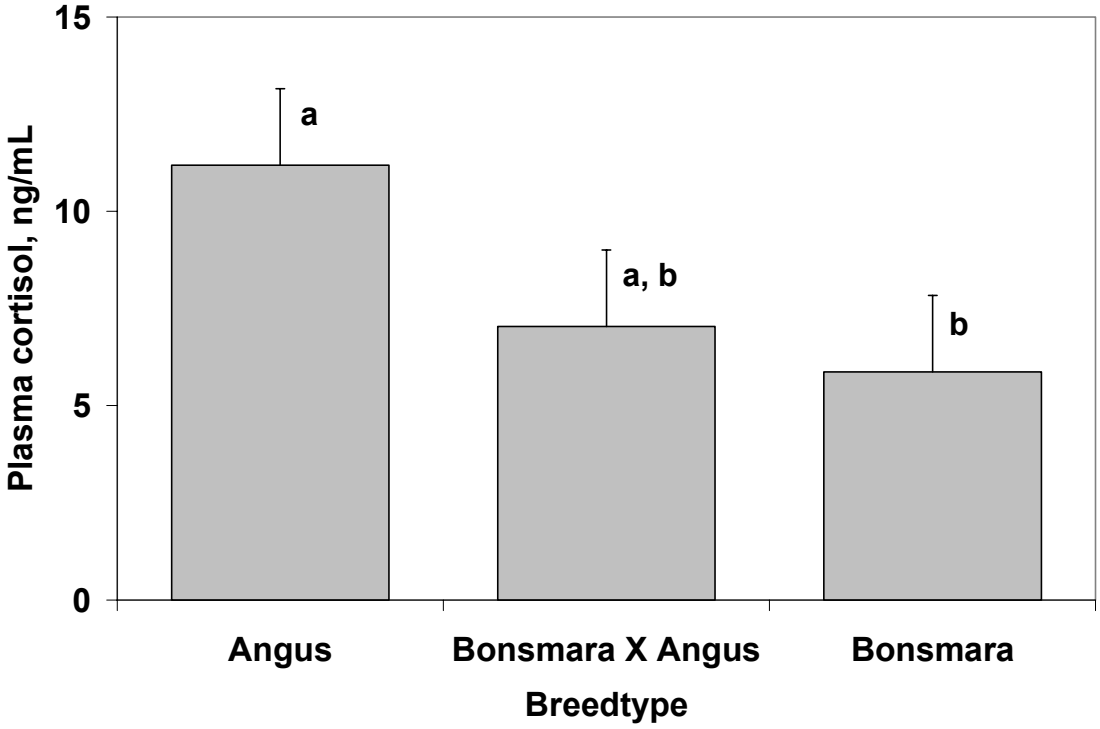

Figure 11. Post-ACTH challenge basal plasma concentration of cortisol in Angus, Bonsmara X Angus and Bonsmara steers. a,b differ $P<0.05$.

Table 3. Mean values for parameters which did not differ between Angus, Bonsmara X Angus and Bonsmara steers during the ACTH challenge.

Parameter	Breedtype			SEM
	Angus	Bonsmara X Angus	Bonsmara	
Amplitude of cortisol response to ACTH, ng/mL	35.34	34.3	36.5	5.2
Peak height of cortisol response to ACTH, ng/mL	49.48	50.6	41.5	4.9
Time to reach peak cortisol post-ACTH, min	33.0	36.0	27.0	4.6

Effect of Exogenous CRH on Plasma Concentration of Cortisol in Angus and Brahman Steers

Pre-CRH Challenge Period. Mean plasma concentrations of cortisol in Angus, and Brahman steers during the experimental period (2.0-h pre and 2.0 h post administration of exogenous CRH at "time 0") are depicted in Figure 12. The 2.0-h period prior to administration of CRH is referred to as the pre-CRH challenge period. Within 15-min of administration of CRH, plasma concentrations of cortisol were elevated to a peak level from which the plasma concentrations of cortisol declined toward pre-CRH and "time 0" values.

For the 2.0 h prior to administration of CRH, mean plasma concentration of cortisol were similar in Angus and Brahman steers. Similarly, plasma concentrations of cortisol just prior to administration of CRH ("time 0") were not different ($P>0.05$) between Angus and Brahman steers. The area under the curve during the pre-CRH time-frame was not different ($P>0.05$) between Angus and Brahman steers, and was negatively correlated (r = -0.19) with the pre-ACTH period negatively in Angus steers and positively (r = 0.38) in Brahman steers.

Post-CRH Challenge Period. The peak of the plasma cortisol response to CRH is the average within each breedtype of the highest plasma concentration of cortisol attained by each steer following the administration of CRH. Peak plasma concentration of cortisol was not different ($P>0.05$) between Angus steers and Brahman steers. Angus steers had similar amplitude of cortisol response to CRH to Brahman steers. Area under the curve was not different ($P>0.05$) between Angus and Brahman steers following

administration of CRH, and was correlated with the post-ACTH mean concentrations of plasma cortisol positively (r = 0.78) in Brahman and negatively (r = -0.40) in Angus steers.

The time required to attain the maximal cortisol response to CRH was 8.5-minutes less in Angus (11.25 ± 3.54 min; $P<0.001$) than Brahman steers (20.0 ± 3.5 min; Figure 13). The time required to return to basal plasma concentrations of cortisol was determined by assessing how many minutes it took, following the peak in plasma concentration of cortisol, for plasma concentration of cortisol to return to concentrations similar to those seen during the pre-CRH period. The amount of time required for plasma concentration of cortisol to return to basal did not differ ($P>0.05$) between Angus and Brahman steers. Mean plasma concentration of cortisol following reestablishment of basal plasma concentrations of cortisol after the CRH challenge, through the end of the study, was not different ($P>0.05$) between Angus and Brahman steers. Values for parameters which did not differ are displayed in Table 4.

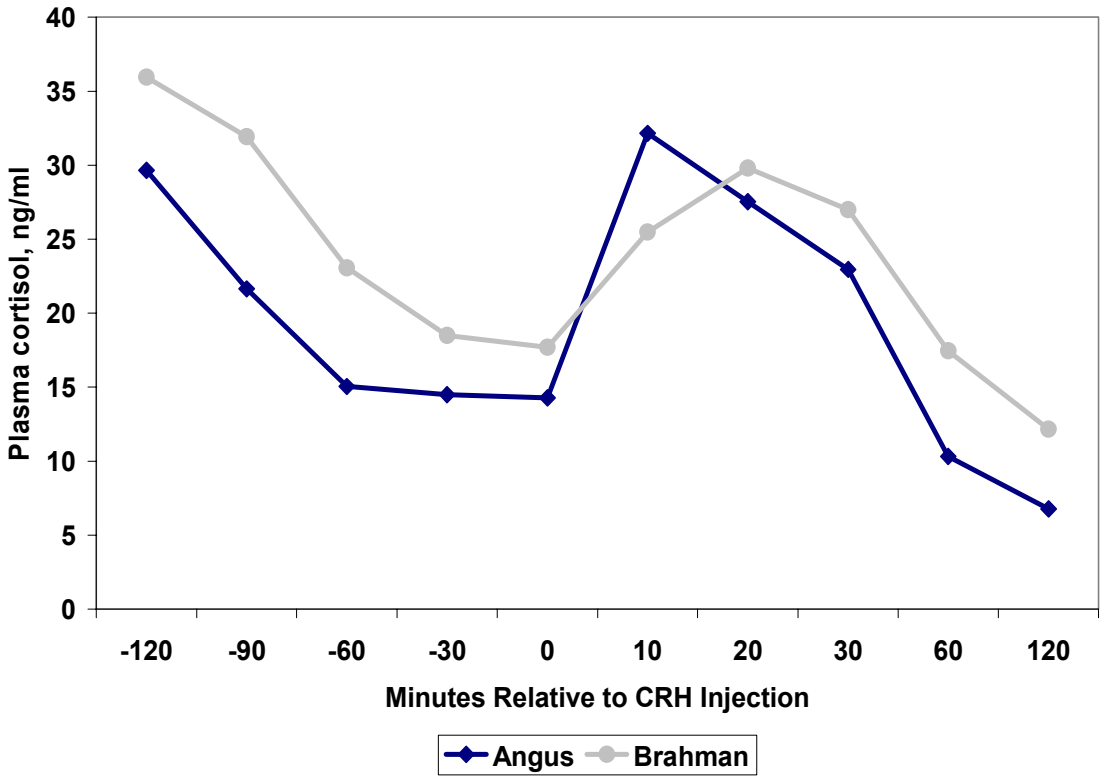

Figure 12. Plasma concentrations of cortisol in Angus and Brahman steers prior to and following CRH administration. (n=8 of each breedtype.)

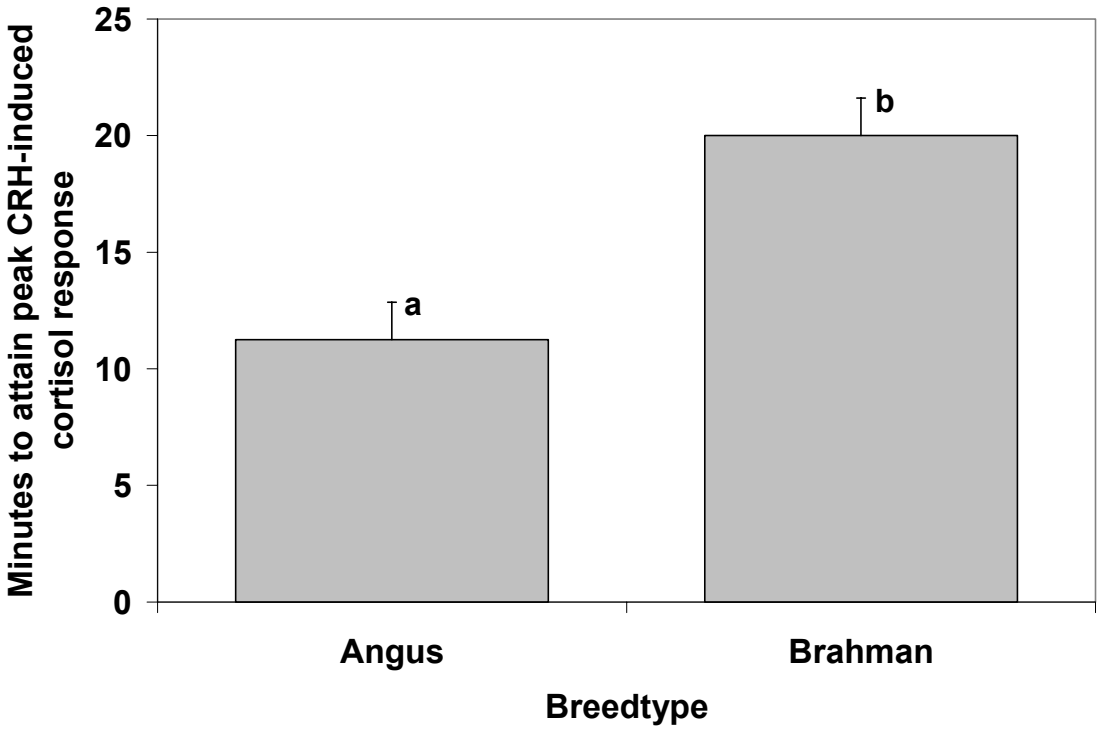

Figure 13. Time required to attain maximal plasma cortisol response to CRH in Angus and Brahman steers. a,b differ $P<0.05$.

Table 4. Mean values for parameters which did not differ between Angus and Brahman steers during the CRH challenge.

	Breedtype		
Parameter	Angus	Brahman	SEM
Basal plasma cortisol prior to CRH administration, ng/mL	19.02	25.42	4.74
Plasma cortisol at "time-0" prior to CRH administration, ng/mL	14.28	17.69	5.56
Amplitude of cortisol response to CRH, ng/mL	19.81	14.8	3.99
Peak plasma cortisol response to CRH, ng/mL	34.09	32.49	3.64
Time to return to basal cortisol post-CRH, min	40.0	32.5	12.65
Post-CRH basal plasma cortisol, ng/mL	11.41	16.92	2.59

Effect of Exogenous CRH on Plasma Concentration of Cortisol in Angus, Bonsmara X Angus Crossbred and Bonsmara Steers

Pre-CRH Period. Mean plasma concentration of cortisol in Angus, Bonsmara X Angus crossbred and Bonsmara steers during the experimental period (2.0-h pre and 2.0 h post administration of exogenous CRH at "time 0") are depicted in Figure 14. The 2.0-h period prior to administration of CRH is referred to as the pre-CRH challenge period. Within 15-min of administration of CRH plasma concentrations of cortisol were elevated to peak values from which the plasma concentrations of cortisol declined toward pre-CRH and "time 0" values.

For the 2.0 h prior to administration of CRH, mean plasma concentrations of cortisol were 245% greater ($P<0.02$) in Angus than in Bonsmara steers; Bonsmara X Angus crossbred steers had plasma concentrations of cortisol which were intermediate to, and not different ($P>0.05$) from plasma concentrations of cortisol in either the Angus or Bonsmara steers (Figure 15). Just prior to administration of CRH, at "time 0", Bonsmara X Angus steers had a 9 ng/mL lower ($P<0.05$) mean plasma concentration of cortisol than Angus steers; plasma concentration of cortisol among Bonsmara steers was intermediate to the Bonsmara X Angus and Angus, and did not differ ($P>0.05$) from either breedtype (Figure 16). The area under the curve was smaller ($P<0.01$) for Bonsmara steers (1206.4 ± 462 ng/mL) than Bonsmara X Angus (2340.3 ± 462 ng/mL) or Angus steers (2959.5 ± 462 ng/mL) during the time-frame prior to administration of CRH; area under the curve between the pre-CRH and pre-ACTH periods was correlated

negatively (r = -0.19) in Angus steers, but not in Bonsmara X Angus (r = 0.00) or Bonsmara steers (r = -0.07).

Post-CRH Period. Peak plasma concentrations of cortisol were over 10 ng/mL greater in Angus ($P<0.01$) than in Bonsmara X Angus crossbred or Bonsmara steers (Figure 17). The amplitude of the cortisol response to CRH is the difference between "time 0" plasma concentration of cortisol and peak plasma concentration of cortisol. The amplitude of the cortisol response did not differ ($P>0.05$) among Angus, Bonsmara X Angus and Bonsmara steers. Following administration of CRH, the area under the curve was greater ($P<0.01$) in Angus steers (3351.35 ± 329 ng) than in Bonsmara X Angus steers (2070.6 ± 329 ng). Areas under the curve following ACTH and CRH were negatively correlated (r = -0.40) in Angus steers, and positively correlated in Bonsmara (r = 0.21) and Bonsmara X Angus steers (r = 0.33).

Angus steers attained maximal concentrations of cortisol in response to CRH twice as quickly as Bonsmara steers ($P<0.004$); Bonsmara X Angus crossbred steers did not differ from either parent breed of steer in the amount of time required to attain maximal cortisol response to CRH (Figure 18). Plasma cortisol in Angus and Bonsmara X Angus crossbred steers returned to basal concentrations more quickly ($P<0.10$) than Bonsmara steers (Figure 19). Angus had post-challenge basal plasma concentrations of cortisol which were nearly two-times greater than those of Bonsmara X Angus steers ($P<0.05$); Bonsmara steers had post-challenge basal concentrations of cortisol which were intermediate to, and not different from those in Angus and Bonsmara X Angus steers (Figure 20).

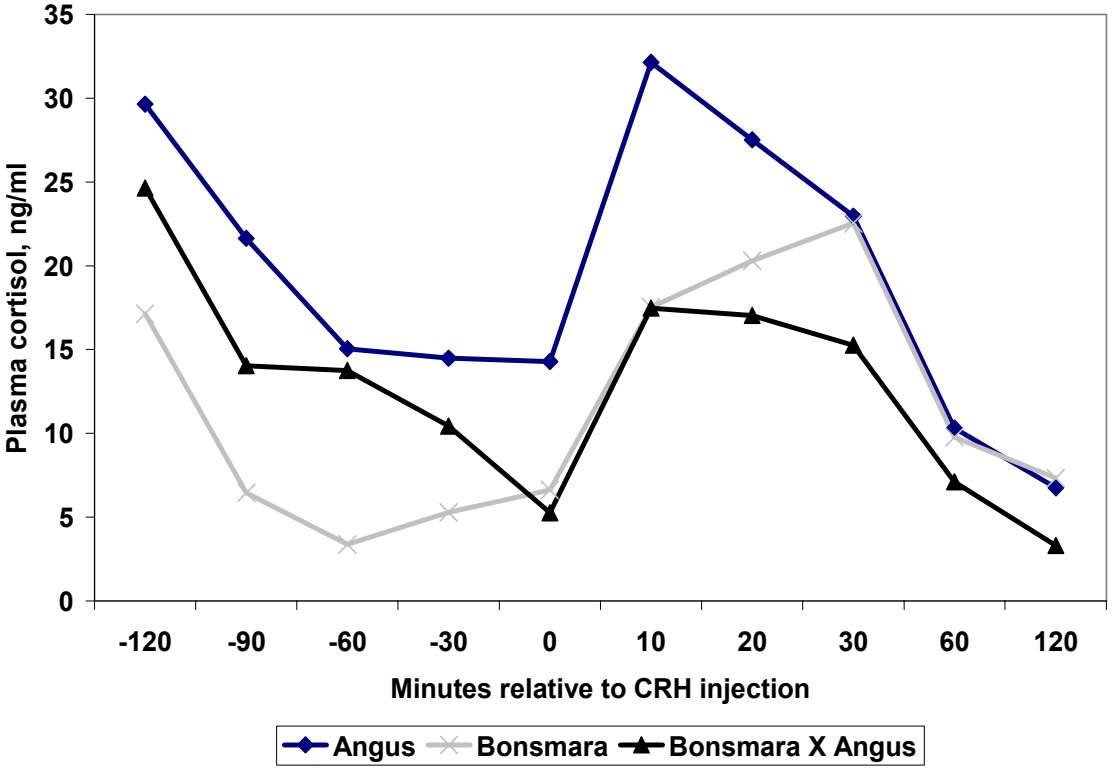

Figure 14. Plasma concentrations of cortisol in Angus, Bonsmara X Angus and Bonsmara steers prior to and following CRH administration. (n=8 of each breedtype).

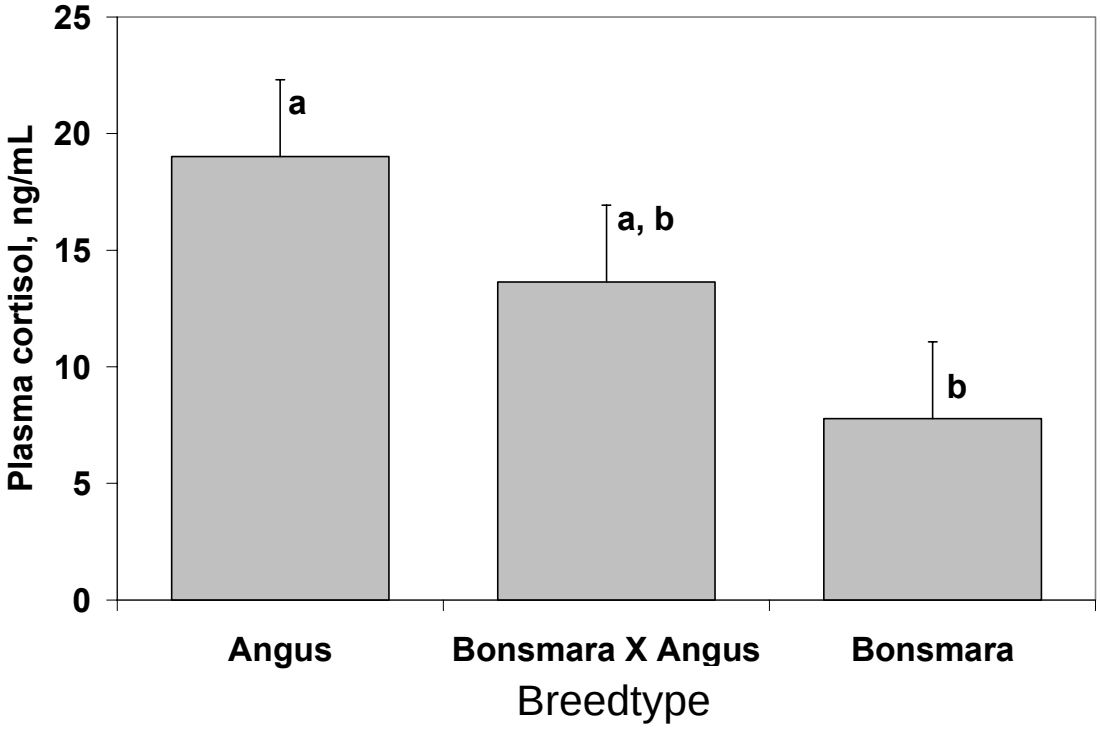

Figure 15. Pre-CRH challenge plasma concentrations of cortisol in Angus, Bonsmara X Angus and Bonsmara steers. a,b differ $P<0.05$.

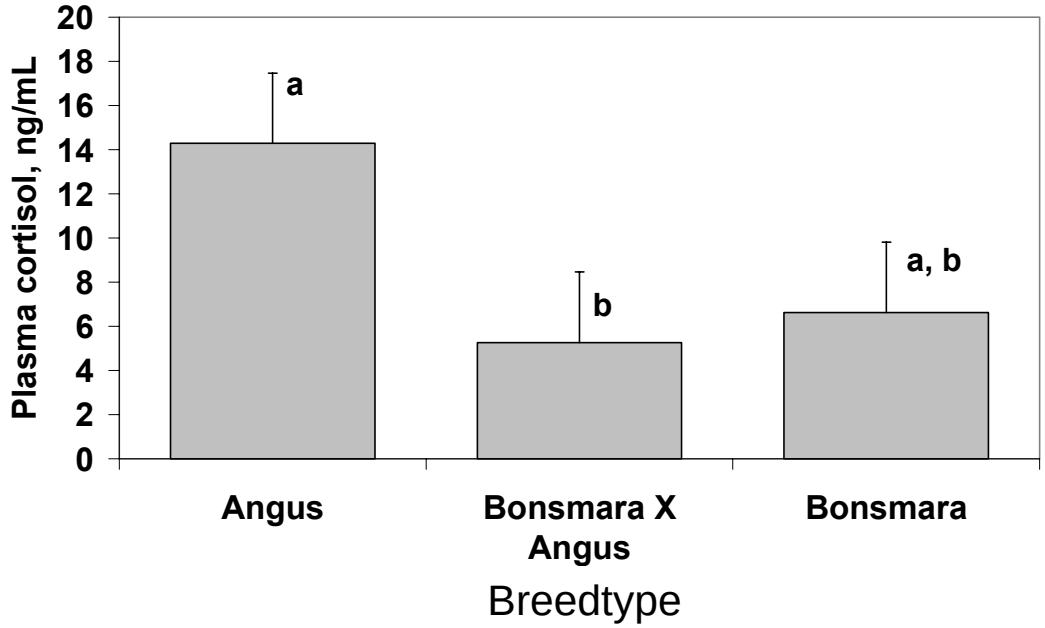

Figure 16. Plasma concentration of cortisol just prior to administration of CRH ("time 0") in Angus, Bonsmara X Angus and Bonsmara steers. a,b differ $P<0.05$.

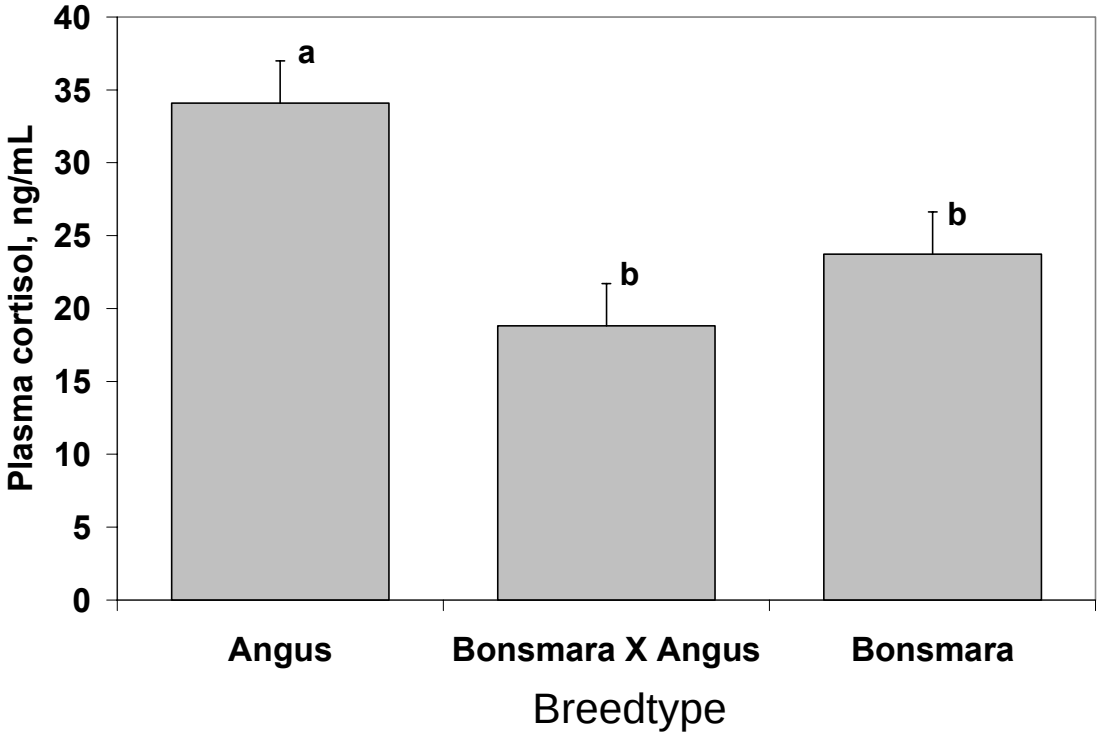

Figure 17. Peak plasma cortisol response to CRH administration in Angus, Bonsmara X Angus and Bonsmara steers. a,b differ $P<0.05$.

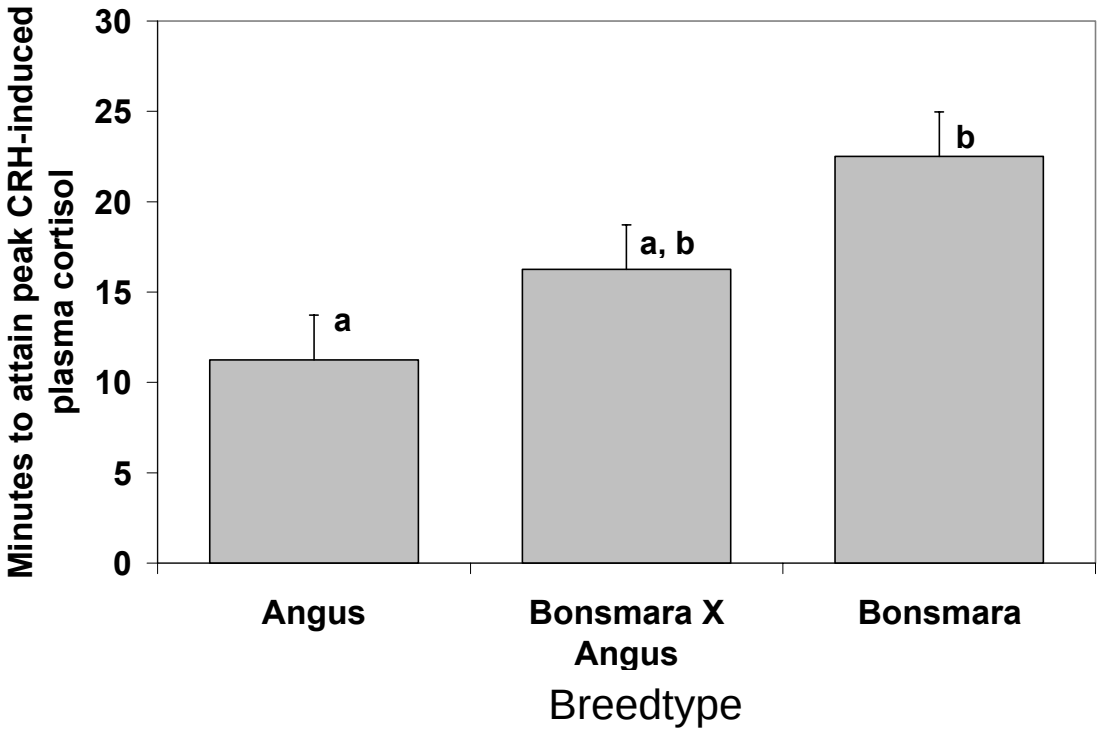

Figure 18. Time required to attain maximal plasma cortisol response to CRH in Angus, Bonsmara X Angus and Bonsmara steers. a,b differ $P<0.05$.

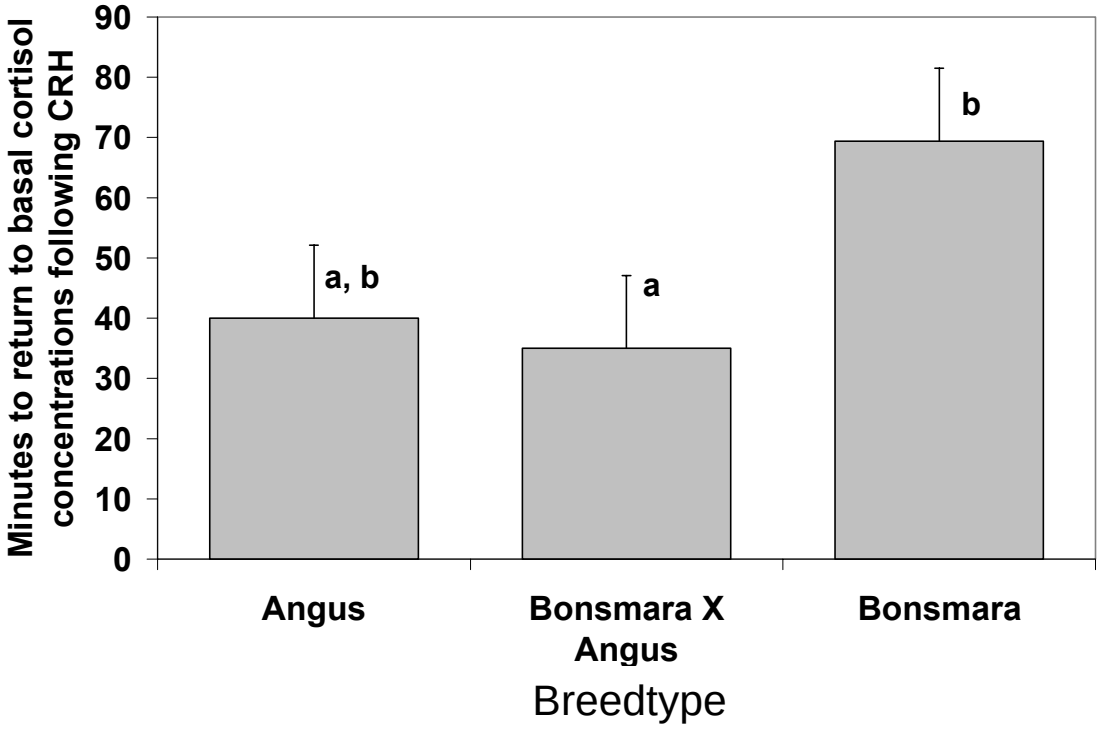

Figure 19. Time required for plasma concentrations of cortisol to return to basal following CRH in Angus, Bonsmara X Angus and Bonsmara steers. a,b differ $P<0.10$.

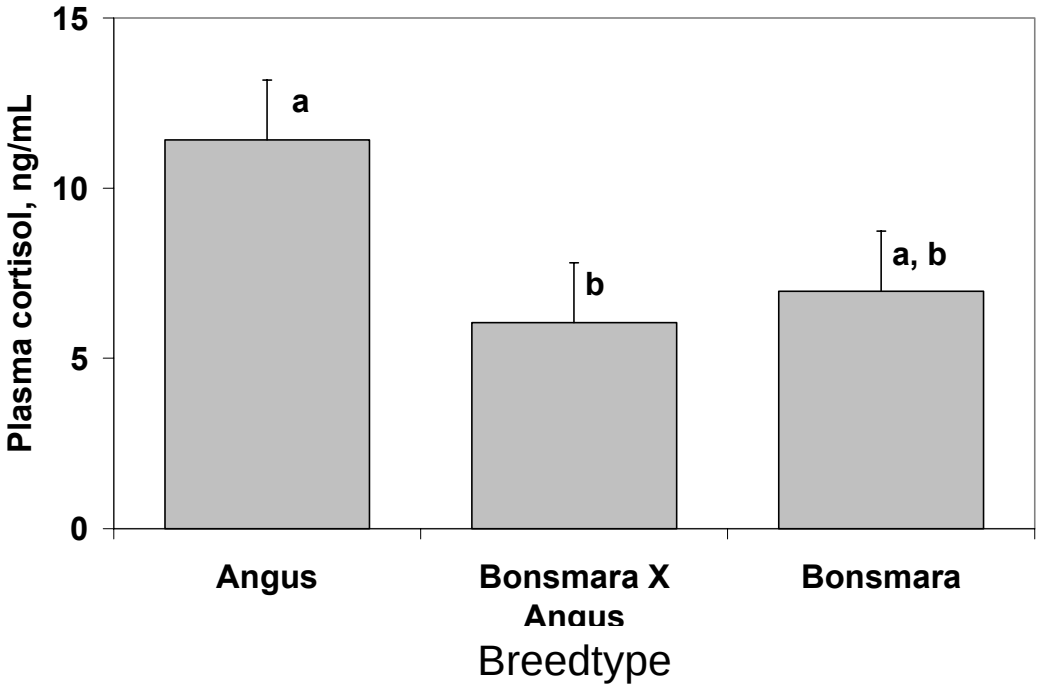

Figure 20. Post-CRH challenge basal plasma concentrations of cortisol in Angus, Bonsmara X Angus and Bonsmara steers. a,b differ $P<0.05$.

CHAPTER V

RESULTS: ASSESSMENT OF GROWTH AND CARCASS CHARACTERISTICS

Comparison of Growth and Carcass Characteristics in Angus and Brahman Steers

Average Daily Gain and Mean Plasma Concentrations of Cortisol While Grazing. During the five-month grazing period, average daily gain (ADG) tended to be greater ($P<0.08$) in Angus compared with Brahman steers. Values for carcass parameters which did not differ between Angus and Brahman steers are depicted in Table 5.

Mean plasma cortisol during the five-month grazing period was not different between Angus and Brahman steers. In Angus steers, ADG was moderately negatively correlated (r = -0.37) with mean monthly plasma cortisol. For Brahman steers, there was a weak positive (r = 0.27) correlation between mean monthly plasma cortisol and ADG.

Average Daily Gain While in the Feedlot. While steers were in the feedlot at Texas Tech University consuming a finishing diet, average daily gain was 0.59 kg/d greater among Angus steers ($P<0.0001$; Figure 21) than Brahman steers. Average daily gain while in the feedlot was moderately correlated to carcass traits, (Table 6) such as adjusted fat thickness (AFT), hot carcass weight (HCW), rib-eye area (REA), yield grade (YG), carcass value (CV) and percent kidney, heart and pelvic fat (%KPH).

Prior to slaughter, each animal had to attain a minimal kill weight of 1000 pounds (454.54 kg) and a back fat thickness of 0.5 inches (1.27 cm; as determined by ultrasound). Steers were sent to slaughter with their breedtype contemporaries, to ensure

uniformity within a breedtype with regard to days on feed. It took Brahman steers 68 more days on feed to reach an acceptable slaughter weight and fatness (159 ± 0 d; $P<0.05$) than the Angus steers (91 ± 0 d; Figure 22).

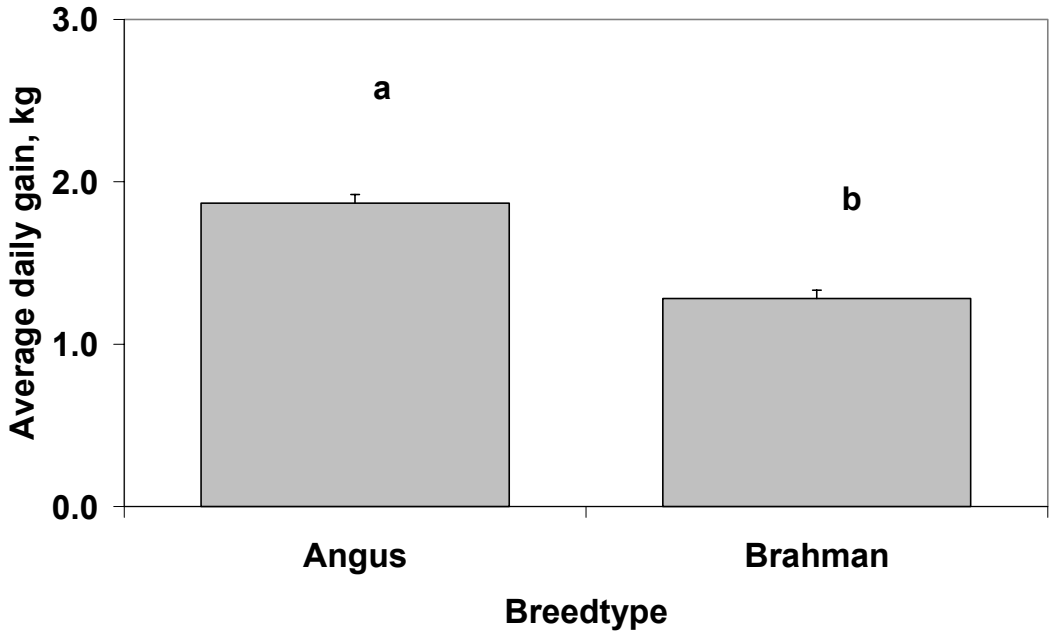

Figure 21. Average daily gain during the feedlot (finishing) phase for Angus and Brahman steers. a,b differ $P<0.05$.

Table 5: Mean values for growth, carcass and temperament characteristics which did not differ between Angus and Brahman steers.

	Breedtype		
Parameter	Angus	Brahman	SEM
ADG while grazing, kg	0.85	0.7	0.05
Adjusted fat thickness, cm	1.2	1.0	0.1
Yield grade	2.84	2.69	0.19
Carcass value, dollars	718.25	679.39	16.78
% KPH	2.44	2.25	0.14
Exit velocity, m/sec	1.67	2.20	0.18
Temperament score	2.3	2.3	0.19

Table 6: Pearson's correlation coefficients of selected carcass characteristics in Angus and Brahman steers.

	Breedtype		
Parameter	Angus	Brahman	Overall
Adjusted fat thickness	0.22[b]	0.23	0.47[a]
Hot carcass weight	0.80[a]	0.65[a]	0.68[a]
Rib-eye area	-0.03	0.57	0.53[a]
Yield grade	0.63[b]	0.08	0.28
Carcass value	0.83[a]	0.52	0.57[a]
% KPH	0.52	-0.40	0.22

[a] $P<0.05$
[b] $P<0.10$

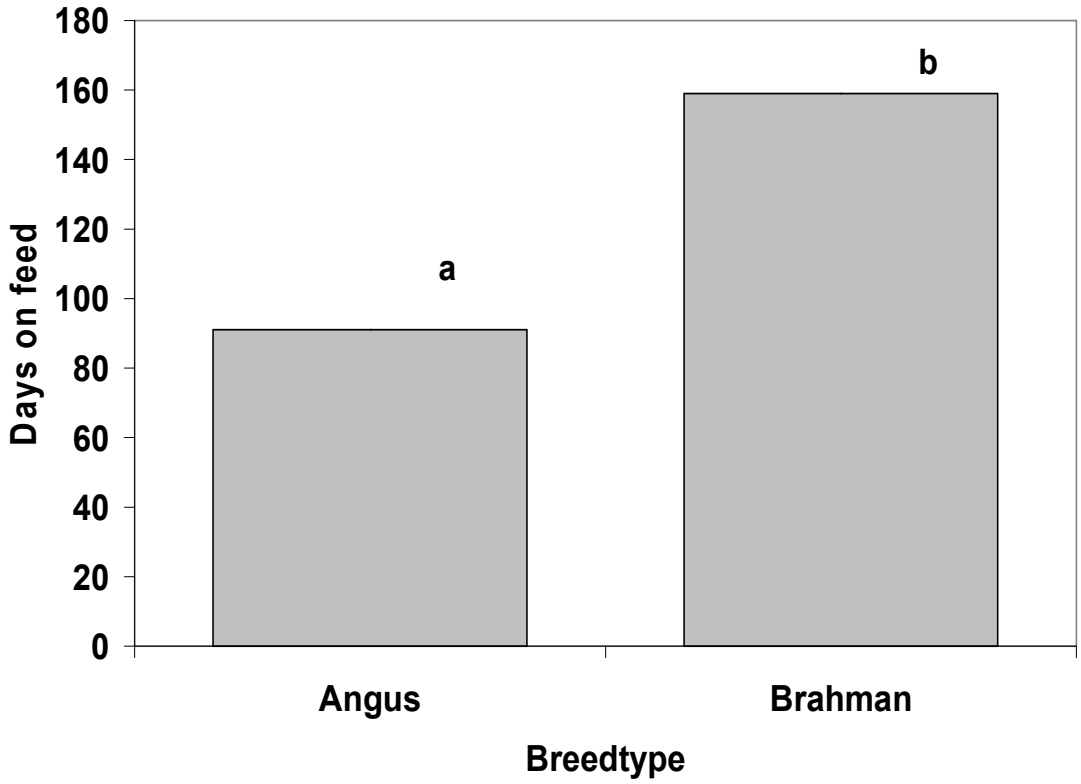

Figure 22. Days on feed required for steers of Angus and Brahman steers to reach slaughter weight and fat thickness. a,b differ $P<0.05$.

Carcass Characteristics. Adjusted fat thickness is a measurement which takes into consideration the subcutaneous fat thickness between the twelfth and thirteenth ribs, as well as the degree of fat cover on the rest of the carcass. Carcasses of Angus steers had a similar adjusted fat thickness (1.2 ± 0.1 cm) to those of Brahman steers (1.0 ± 0.1 cm), because they were fed to reach the same degree of fat cover.

Angus steers averaged higher quality grades ($P<0.01$) than did Brahman steers. Seventy-five percent of the Angus steers graded low choice and twenty-five percent graded high select, whereas only ten percent of the Brahman steers graded low choice and fifty percent graded high select; thirty percent graded low select, and the remaining ten percent graded standard (Figure 23).

Angus steers had a greater hot carcass weight ($P<0.05$), on average, than did Brahman steers (Figure 24). Mean carcass value was similar ($P>0.05$) between Angus (718.25 ± 18.76 dollars) and Brahman steers (679.38 ± 16.78 dollars).

Surface area of the rib-eye between the twelfth and thirteenth ribs is measured in square inches. Rib-eye area was 2.4 square cm greater in Angus steers ($P<0.03$) than in Brahman steers (Figure 25). The percentage of kidney, heart and pelvic fat (%KPH) did not differ ($P>0.05$) between Angus and Brahman steers.

Yield grades did not differ ($P>0.05$) between Angus and Brahman steers.

Temperament. The behavior score is indicative of how docile or agitated a steer acted when in close proximity to humans; the more docile a steer was, the lower his behavior score. There was no difference ($P>0.05$) in the mean behavior scores for Angus and Brahman steers. The measurement of meters per second covered by a steer

leaving the squeeze chute is known as escape velocity. Brahman steers had a greater escape velocity (2.20 ± 0.70 meters/second; $P<0.07$) than the Angus steers (1.67 ± 0.37 meters/second). Escape velocity and behavior score were positively correlated (r = 0.32); steers with rapid escape velocities were easily agitated or upset when in close proximity to humans. Escape velocities and behavior scores were also positively correlated (r = 0.35 and r = 0.33) with basal concentrations of cortisol. Escape velocity was associated negatively with adjusted fat thickness, hot carcass weight, rib-eye area, yield grade, average daily gain and carcass value. Specific correlation values are outlined by breedtype in Table 7.

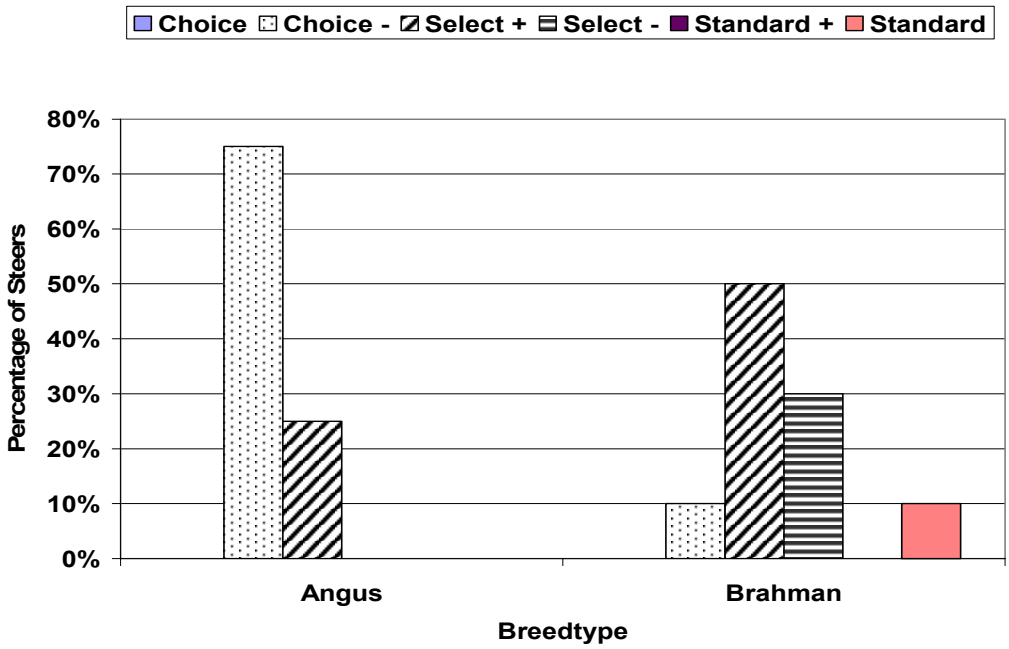

Figure 23. Percentage of carcasses from Angus and Brahman steers receiving each quality grade. a,b $P<0.05$.

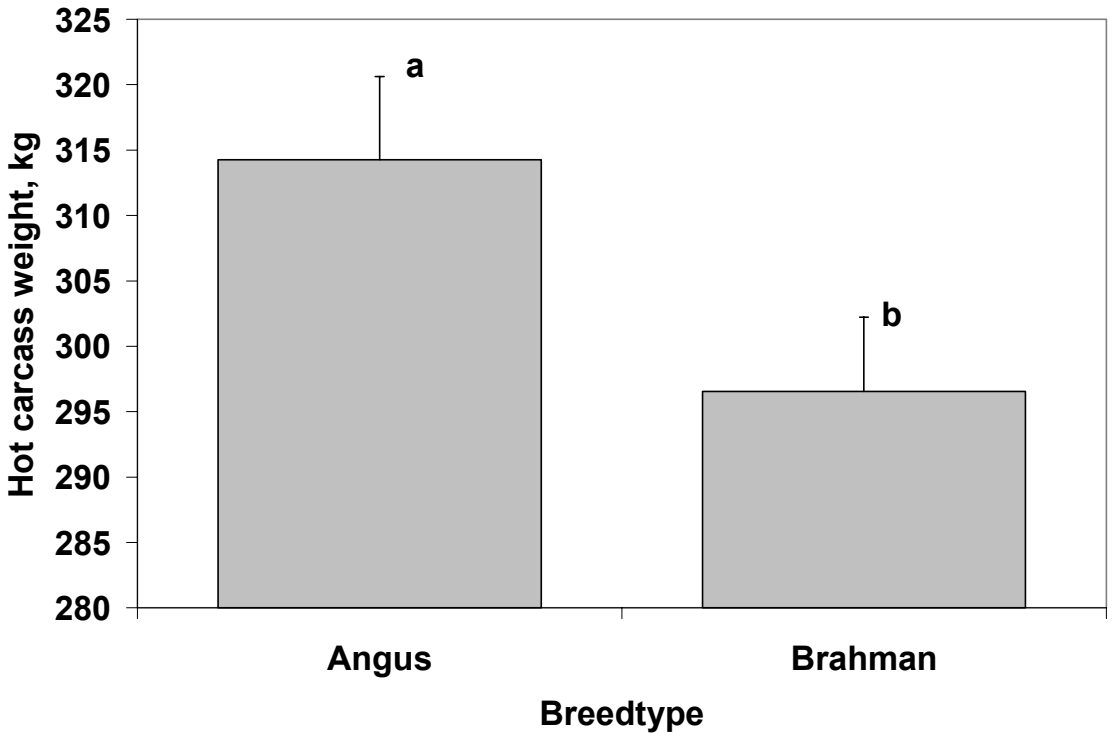

Figure 24. Hot carcass weights of carcasses from Angus and Brahman steers. a,b $P<0.05$.

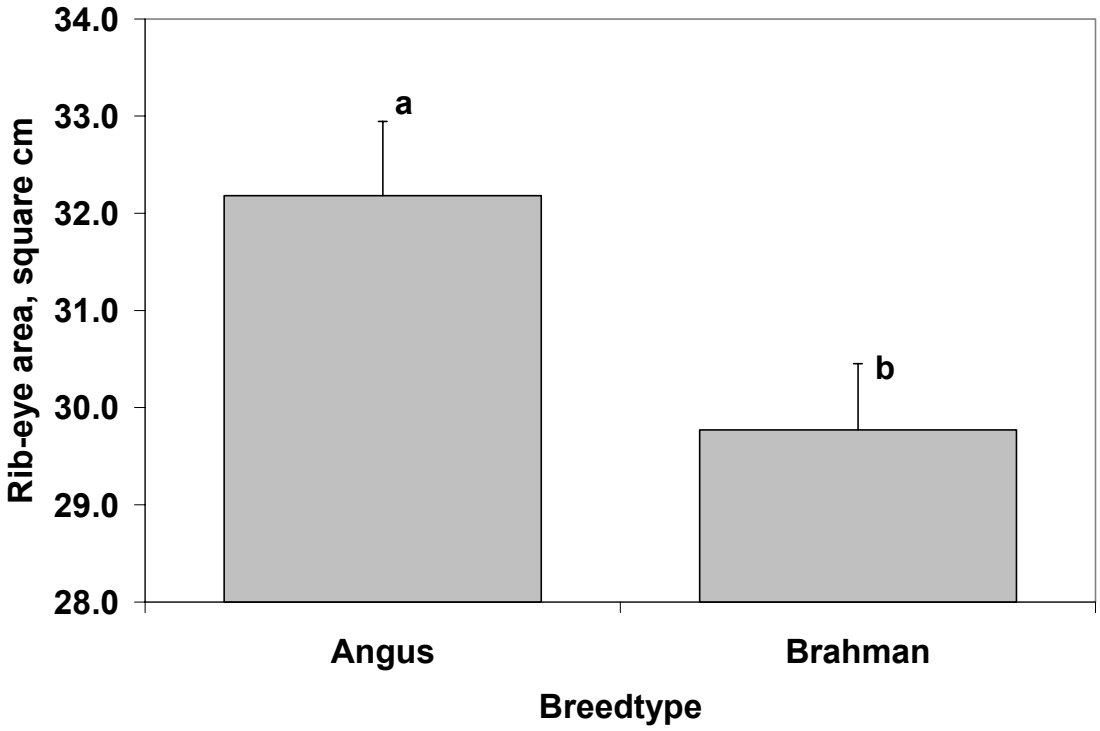

Figure 25. Rib-eye areas from carcasses of Angus and Brahman steers. a,b $P<0.05$.

Table 7: Pearson's correlation coefficients of selected carcass and stress characteristics with exit velocity in Angus and Brahman steers.

	Breedtype		
Parameter	Angus	Brahman	Overall
Adjusted fat thickness	-0.61	-0.47	-0.56[a]
Hot carcass weight	-0.75	-0.32	-0.50[a]
Rib-eye area	-0.12	0.44	-0.04
Yield grade	-0.40	-0.55	-0.50[a]
Carcass value	-0.42	0.06	-0.18
Average daily gain	-0.30	-0.07	-0.44[a]
Pre-ACTH basal plasma cortisol	0.14	0.72	0.32
Post-ACTH basal plasma cortisol	-0.23	0.58	0.43[a]
Pre-CRH basal plasma cortisol	-0.58	-0.01	-0.06
Post-CRH basal plasma cortisol	-0.48	0.34	0.20

[a] $P<0.06$.

Comparison of Growth and Carcass Characteristics in Angus, Bonsmara X Angus, and Bonsmara Steers

Average Daily Gain and Mean Plasma Concentrations of Cortisol While Grazing. Following the ACTH challenge, steers were maintained on rye-ryegrass overseeded on Coastal bermudagrass pastures for a five-month period; blood samples and body weights were obtained at four-week intervals. Plasma cortisol was determined as described in the materials and methods section above. ADG while grazing did not differ ($P>0.05$) among Angus (1.86 ± .12 lb/d), Bonsmara X Angus (1.74 ± .12 lb/d) and Bonsmara steers (1.85 ± .12 lb/d).

Angus steers had over 30% higher mean monthly plasma concentrations of cortisol (Figure 26) than either Bonsmara X Angus ($P<0.05$), or Bonsmara steers ($P<0.03$). In Angus steers, average daily gain was moderately negatively correlated (r = -0.37) with mean monthly plasma cortisol. In Bonsmara X Angus and Bonsmara steers, there was a positive correlation (r = 0.15 and r = 0.34, respectively) between mean monthly plasma cortisol and average daily gain.

Average Daily Gain While in the Feedlot. Average daily gain while steers were in the feedlot at Texas Tech University consuming a finishing diet tended to be greater (0.10 kg/d) among Angus steers ($P>0.10$) than the Bonsmara X Angus steers and was higher (0.25 kg/d; $P<0.02$) than the Bonsmara (Figure 27). Average daily gain while in the feedlot was moderately correlated to carcass traits (Table 8) including adjusted fat thickness (AFT), hot carcass weight (HCW), rib-eye area (REA), yield grade (YG), carcass value (CV), and percent kidney, heart and pelvic fat (%KPH). Values for

carcass parameters which did not differ among Angus, Bonsmara and Bonsmara X Angus steers are shown in Table 9.

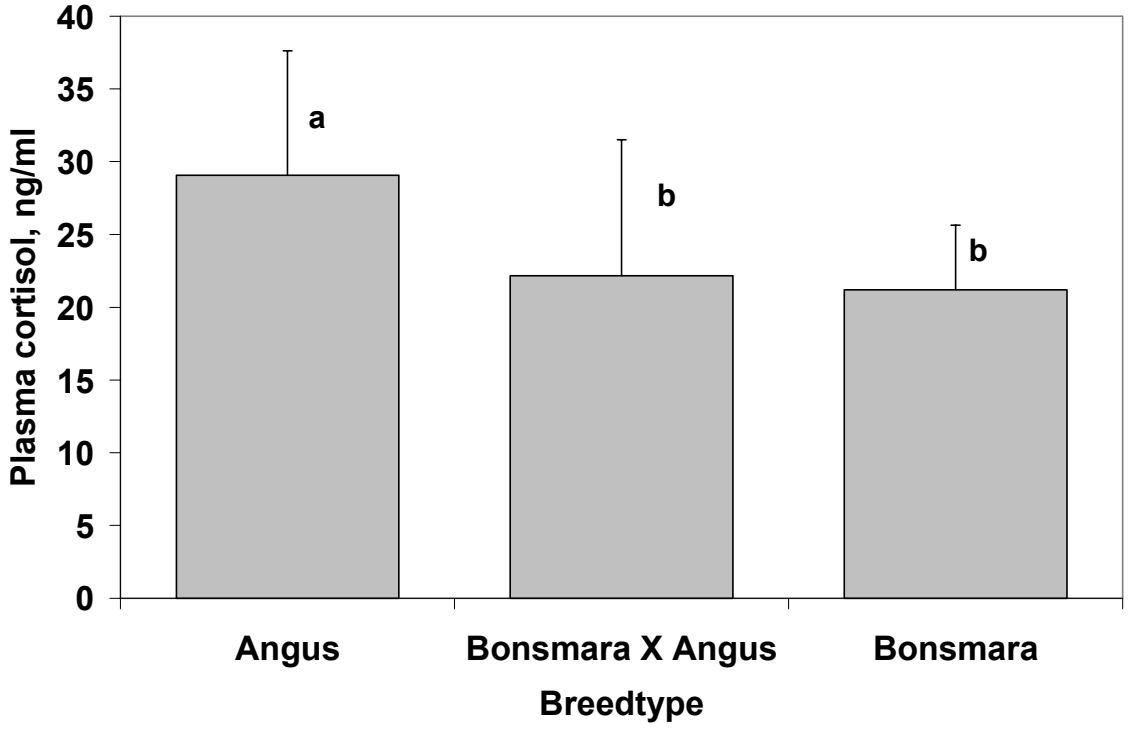

Figure 26. Average plasma cortisol during the five-month grazing period in Angus, Bonsmara X Angus and Bonsmara steers. a,b differ $P<0.05$.

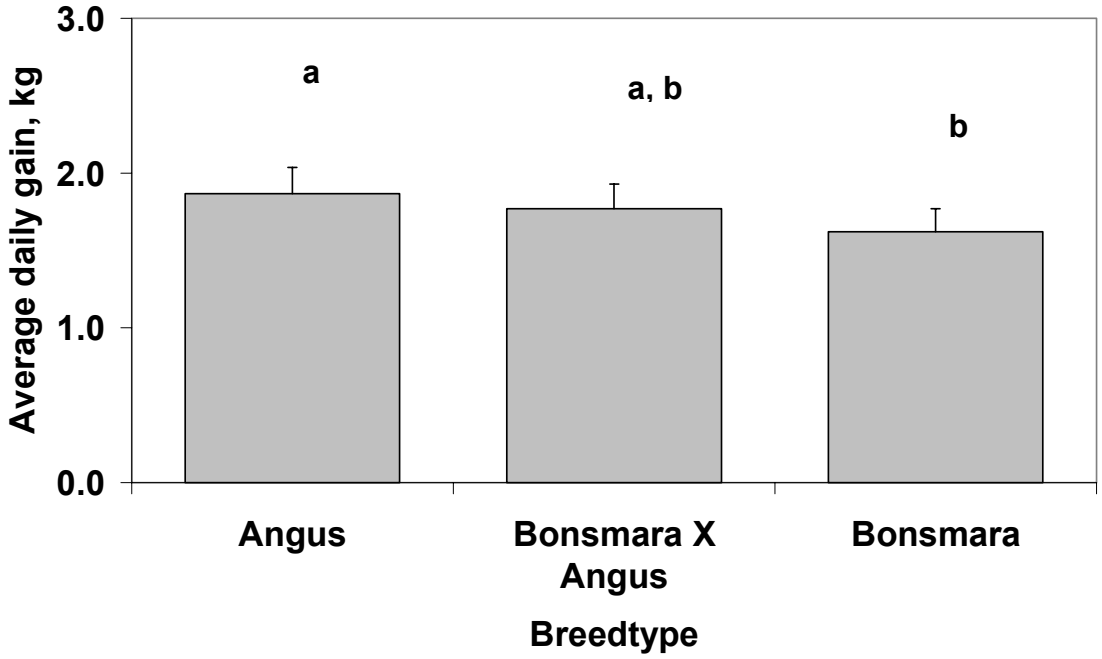

Figure 27. Average daily gain during the feedlot (finishing) phase for Angus, Bonsmara X Angus and Bonsmara steers. a,b differ $P<0.05$.

Table 8: Pearson's correlation coefficients of selected carcass characteristics with average daily gain in Angus, Bonsmara X Angus and Bonsmara steers.

Parameter	Breedtype			Overall
	Angus	Bonsmara X Angus	Bonsmara	
Adjusted fat thickness	0.22[b]	0.31	0.61[b]	0.49[a]
Hot carcass weight	0.80[a]	0.47	0.58[b]	0.65[a]
Rib-eye area	-0.03	0.57	-0.18	0.09
Yield grade	0.63[b]	-0.17	0.81[a]	0.54[a]
Carcass value	0.83[a]	0.57	0.79[a]	0.72[a]
% KPH	0.52	-0.31	0.27	0.26

[a] $P<0.05$

[b] $P<0.10$

Table 9: Mean values for growth and carcass characteristics which did not differ among Angus, Bonsmara and Bonsmara X Angus steers.

Parameter	Breedtype			SEM
	Angus	Bonsmara X Angus	Bonsmara	
Grazing ADG, kg	0.85	0.79	0.84	0.05
Adjusted fat thickness, cm	1.2	1.1	1.15	0.1
Hot carcass weight, kg	314.3	304.9	299.0	5.77
Rib-eye area, square cm	32.18	30.81	31.36	0.79
Yield grade	2.84	2.78	2.73	0.14
Days on feed	91.0	91.0	131.0	0
Carcass value, dollars	718.3	676.3	687.7	16.7
% KPH	2.44	2.39	2.25	0.10

Angus and Bonsmara X Angus steers reached an acceptable slaughter weight and fatness in 91± 0 d, which was 40 d more quickly (P>0.05) than the Bonsmara steers (131 ± 0 d).

Carcass Characteristics. Adjusted fat thickness measured on Angus carcasses was similar to the adjusted fat thicknesses of both Bonsmara X Angus crossbred steers and Bonsmara steers, as steers were fed to reach the same degree of fatness.

Angus steers averaged higher quality grades (Figure 28) than either the Bonsmara X Angus steers (P<0.01) or the Bonsmara steers (P<0.04). Seventy-five percent of the Angus steers graded low choice and twenty-five percent graded high select. Bonsmara X Angus crossbred steers graded as follows: 11.1% low choice, 44.4%high select, 33.3% low select and 11.1 % high standard. Bonsmara steers graded as follows: 40% low choice, 20% high select, 20% low select and 20% high standard.

Hot carcass weights of Angus steers (314.26 ± 6.45 kg), Bonsmara X Angus steers (304.9 ± 6.09 kg) or Bonsmara steers (299.0 ± 5.77 kg) did not differ (P>0.05) from one another. Mean carcass value did not differ (P>0.05) among Angus (718.25 ± 18.70 dollars), Bonsmara X Angus steers (676.26 ± 17.60 dollars) and Bonsmara steers (687.69 ± 16.70 dollars).

Rib-eye areas did not differ ($P>0.05$) among Angus, Bonsmara X Angus steers and Bonsmara steers. The percentage of kidney, heart and pelvic fat (%KPH) did not differ ($P>0.05$) among Angus, Bonsmara X Angus and Bonsmara steers. Yield grades of Angus steers, Bonsmara X Angus and Bonsmara steers did not differ ($P>0.05$) from one another.

Temperament. Based on temperament scores, Angus steers were not as docile (Figure 29) as either Bonsmara X Angus steers ($P<0.02$) or Bonsmara steers ($P<0.0002$). Temperament scores of Bonsmara and Bonsmara X Angus steers did not differ ($P>0.05$). Escape velocities of Bonsmara X Angus steers and Bonsmara steers were slower ($P<0.04$ and $P<0.01$, respectively) than the Angus steers (Figure 30). Escape velocity and behavior score were positively correlated (r = 0.32); steers with rapid escape velocities were easily agitated or upset when in close proximity to humans. Escape velocities and behavior scores were also positively correlated (r = 0.35 and r = 0.33) with basal concentrations of cortisol. Specific correlations between escape velocity and carcass characteristics are outlined by breedtype in Table 10.

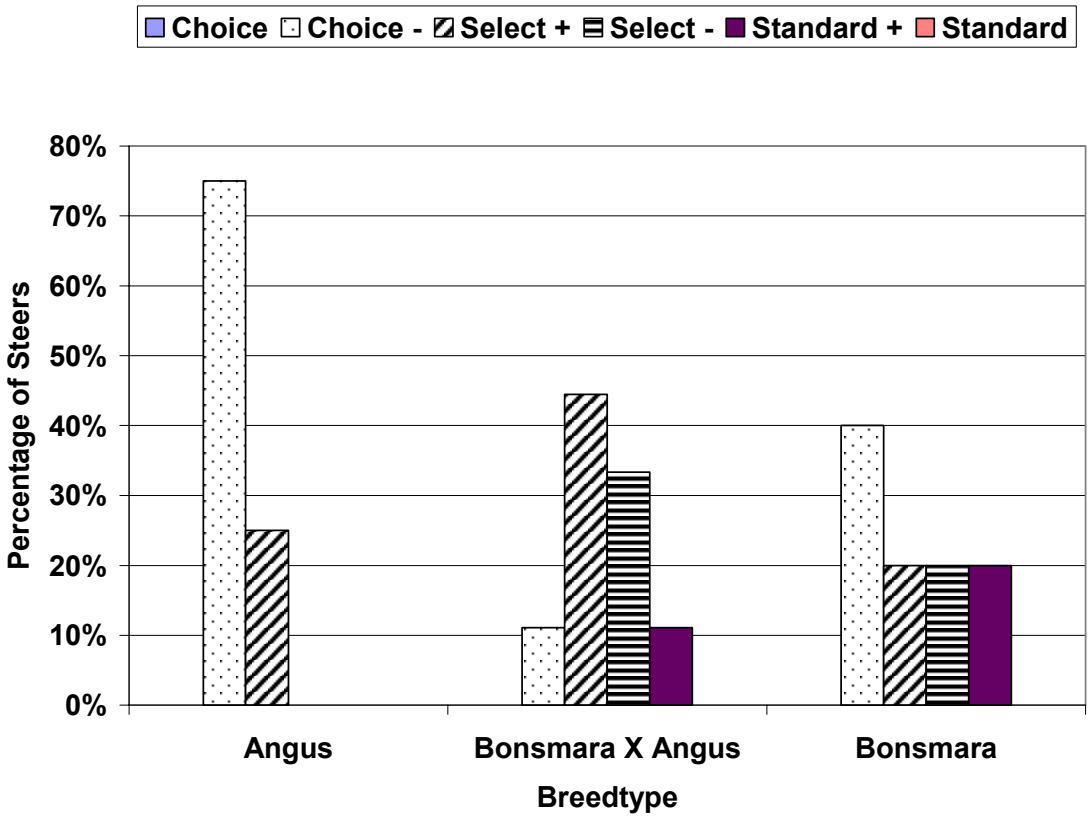

Figure 28. Percentage of carcasses from Angus, Bonsmara X Angus and Bonsmara steers receiving each quality grade. a,b $P<0.05$.

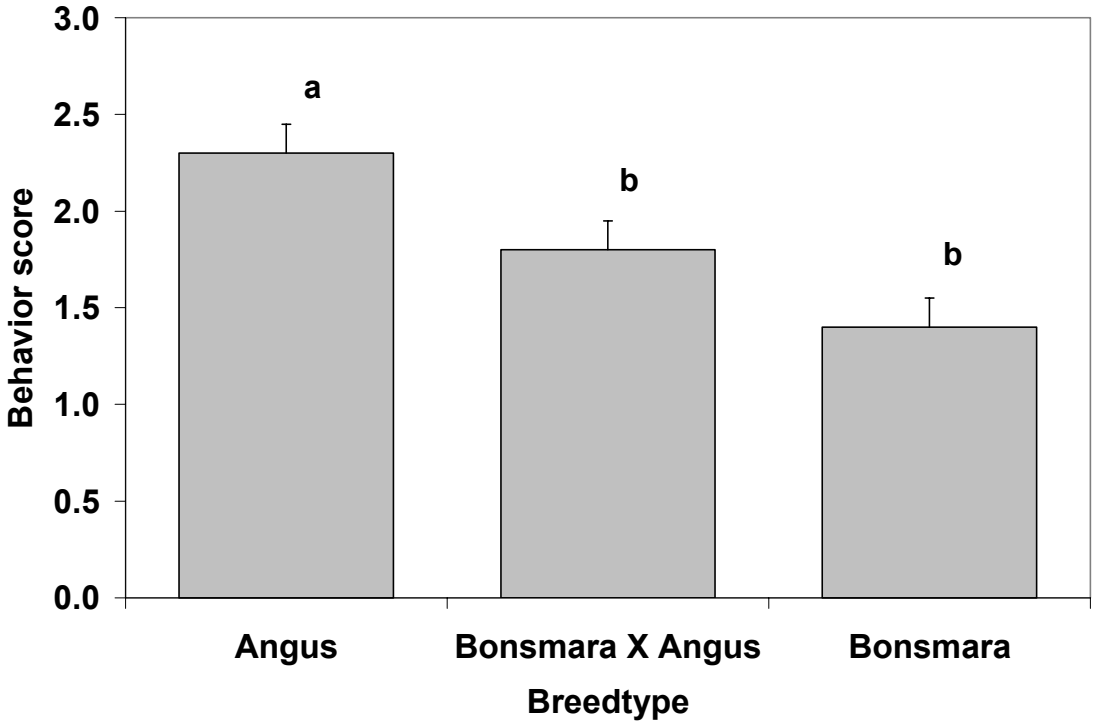

Figure 29. Behavior scores of Angus, Bonsmara X Angus and Bonsmara steers. a,b $P<0.05$.

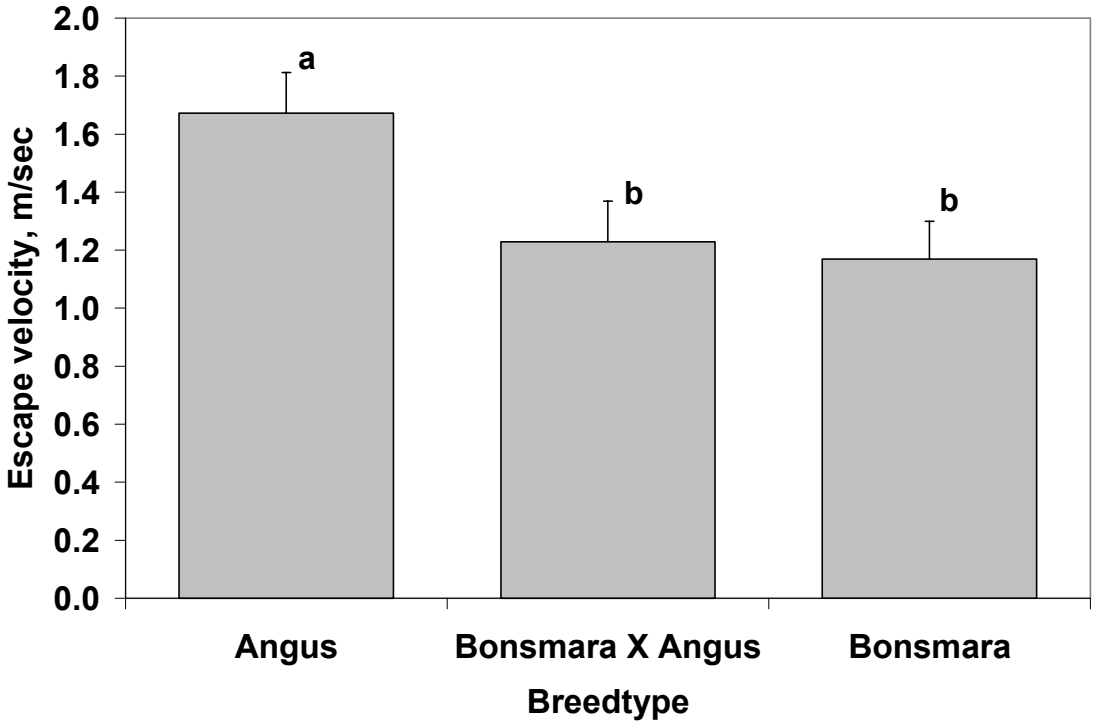

Figure 30. Escape velocity from the chute of Angus, Bonsmara X Angus and Bonsmara steers. a,b $P<0.05$.

Table 10: Pearson's correlation coefficients of selected carcass and stress characteristics with exit velocity in Angus, Bonsmara x Angus and Bonsmara steers.

Parameter	Breedtype			Overall
	Angus	Bonsmara X Angus	Bonsmara	
Adjusted fat thickness	-0.61	-0.35	-0.25	-0.27
Hot carcass weight	-0.58	-0.34	0.06	0.03
Rib-eye area	-0.12	-0.67[b]	-0.47	-0.29
Yield grade	-0.40	0.34	0.13	0.07
Carcass Value	-0.42	-0.12	-0.16	-0.01
Average daily gain	-0.30	-0.75[b]	-0.17	-0.06
Pre-ACTH basal plasma cortisol	0.14	0.14	0.14	0.28
Post-ACTH basal plasma cortisol	-0.23	0.19	-0.06	0.23
Pre-CRH basal plasma cortisol	-0.58	-0.24	-0.52	-0.12
Post-CRH basal plasma cortisol	-0.48	0.22	0.23	0.11

[a] $P<0.05$

[b] $P<0.10$

CHAPTER VI

RESULTS: PHYSICAL AND PHYSIOLOGICAL MEASUREMENT OF HEAT STRESS

Physical and Physiological Assessment of Heat Stress in Angus and Brahman Steers

Respiration. Angus steers had 175% greater mean respiration rate ($P<0.0006$) than did Brahman steers (Figure 31).

Temperature. Rectal temperature did not differ ($P>0.05$) between Angus (39.72 ± 0.27 ºC) and Brahman steers (39.62 ± 0.24 ºC). Angus steers had mean dorsal and right side DITI temperatures which were not different ($P>0.05$) from those found in Brahman steers (an example thermogram is shown in Figure 32). Respiration rate was positively correlated with dorsal DITI Value (r = 0.48), and right side DITI value (r = 0.44).

Serum Concentrations of Electrolytes. Serum concentrations of electrolytes including sodium, potassium, chloride, magnesium, phosphorus and calcium were determined from blood samples obtained once at the end of the grazing stage of production (May), and then once again in as the steers were nearing completion of the finishing stage of production (August).

Serum concentrations of sodium were higher in Angus steers (141.6 ± 3.93 meq/L) following the grazing stage, ($P<0.05$) than in Brahman steers (138.7 ± 2.0 meq/l; Figure 33). Similarly, when serum metabolites were assessed near the end of the finishing stage, Angus steers had serum sodium concentrations which were greater

($P<0.02$) than the mean serum sodium concentration of Brahman steers (Figure 34). Sodium was positively correlated to chloride (r = 0.89) and potassium (r = 0.18). Serum potassium concentrations were not different ($P>0.10$) between Angus and Brahman steers when serum electrolytes were assessed following the completion of the five-month grazing stage, or when serum electrolytes were assessed near the completion of the finishing phase. Following the completion of the grazing stage, serum chloride concentrations between Angus and Brahman steers tended to be similar ($P<0.07$). However, near the conclusion of the finishing stage, serum chloride concentrations were 3.0 meq/L greater ($P<0.04$) in Angus than in Brahman steers (Figure 35).

Serum calcium was not different ($P>0.10$) between Angus and Brahman steers when serum electrolytes were assessed following the completion of the grazing stage, but near the conclusion of the finishing stage (Figure 36) Angus steers had 2.0 mg/dL greater serum calcium concentrations ($P<0.0003$) than the Brahman steers. Following the completion of the grazing stage and near the conclusion of the finishing stage, serum phosphorus concentrations between Angus and Brahman steers were similar ($P>0.10$). Serum magnesium concentrations were not different ($P>0.10$) between Angus and Brahman steers when following the grazing stage, or near the end of the finishing stage.

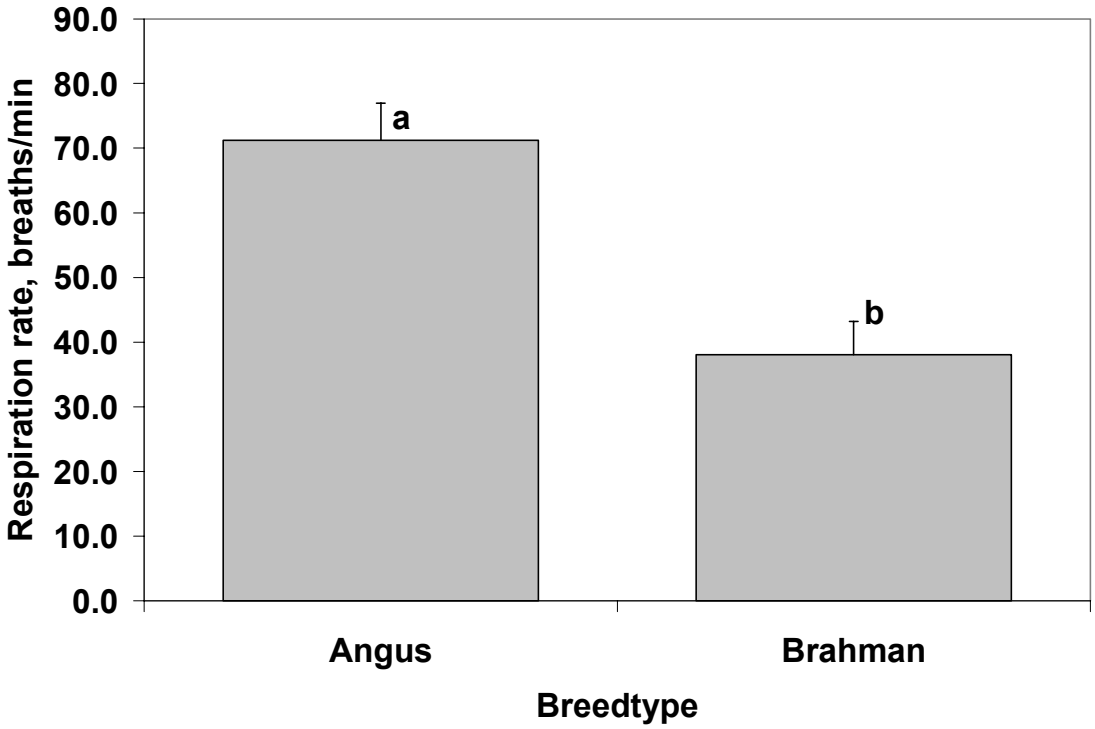

Figure 31. Respiration rate of Angus and Brahman steers. a, b $P<0.05$.

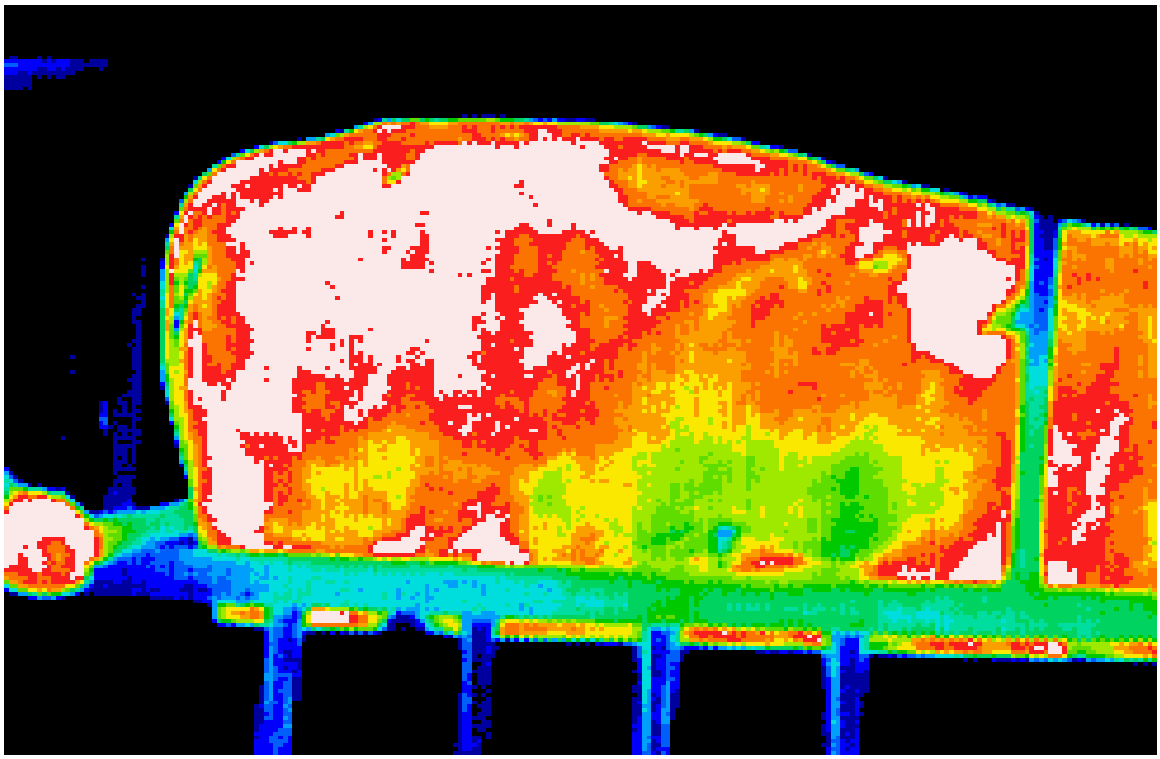

Figure 32. Example digital infrared thermal image. Surface temperature radiation appears as pixels of color ranging from deep shades indicating cool temperatures to white, indicating hotter temperatures.

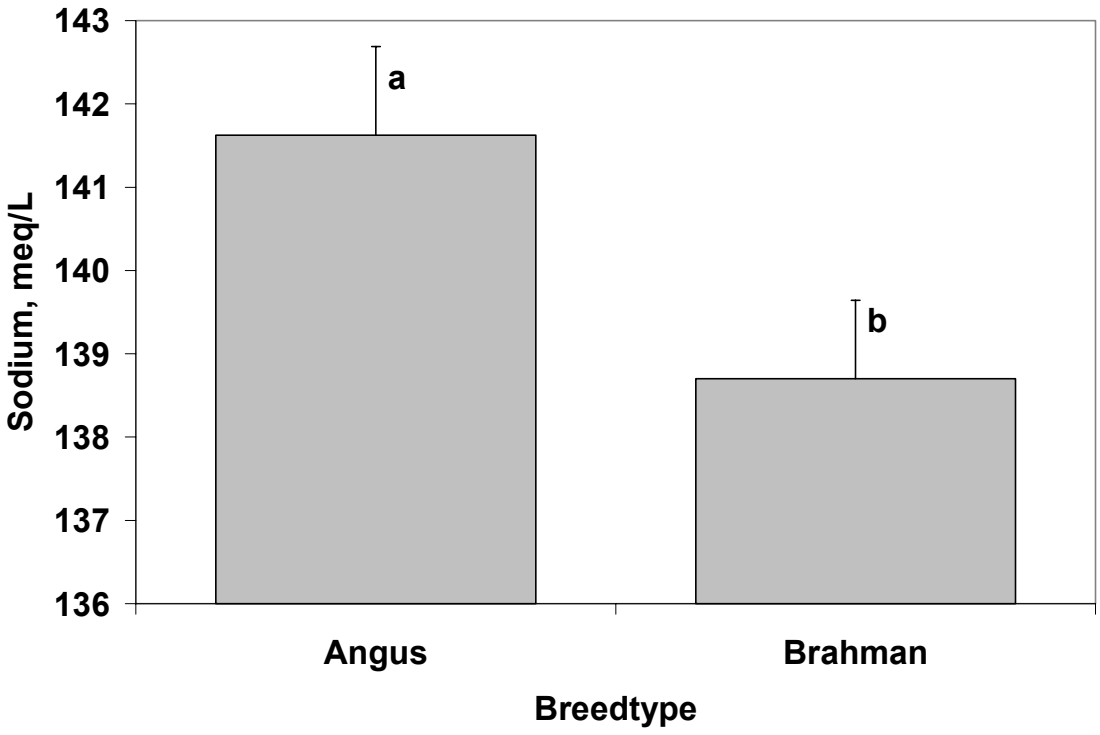

Figure 33. Serum sodium concentrations in Angus and Brahman steers as measured near the end of the grazing period. a, b differ $P<0.05$.

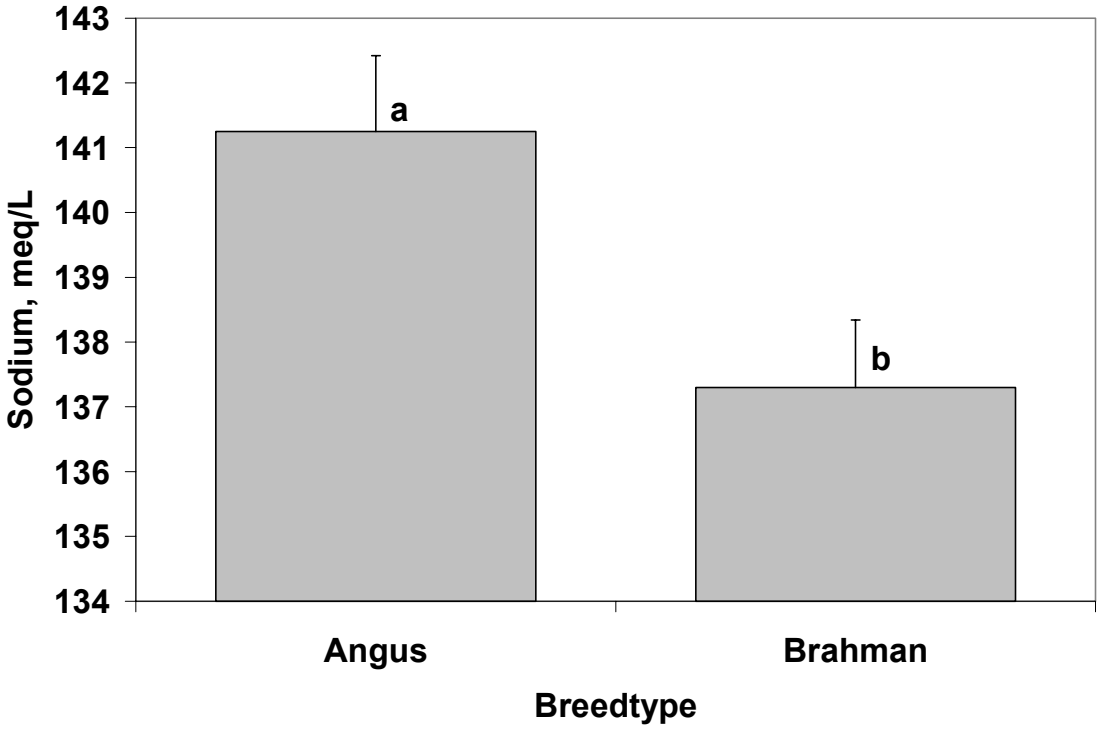

Figure 34. Serum sodium concentrations in Angus and Brahman steers as measured near the end of the finishing period. a, b differ $P<0.05$

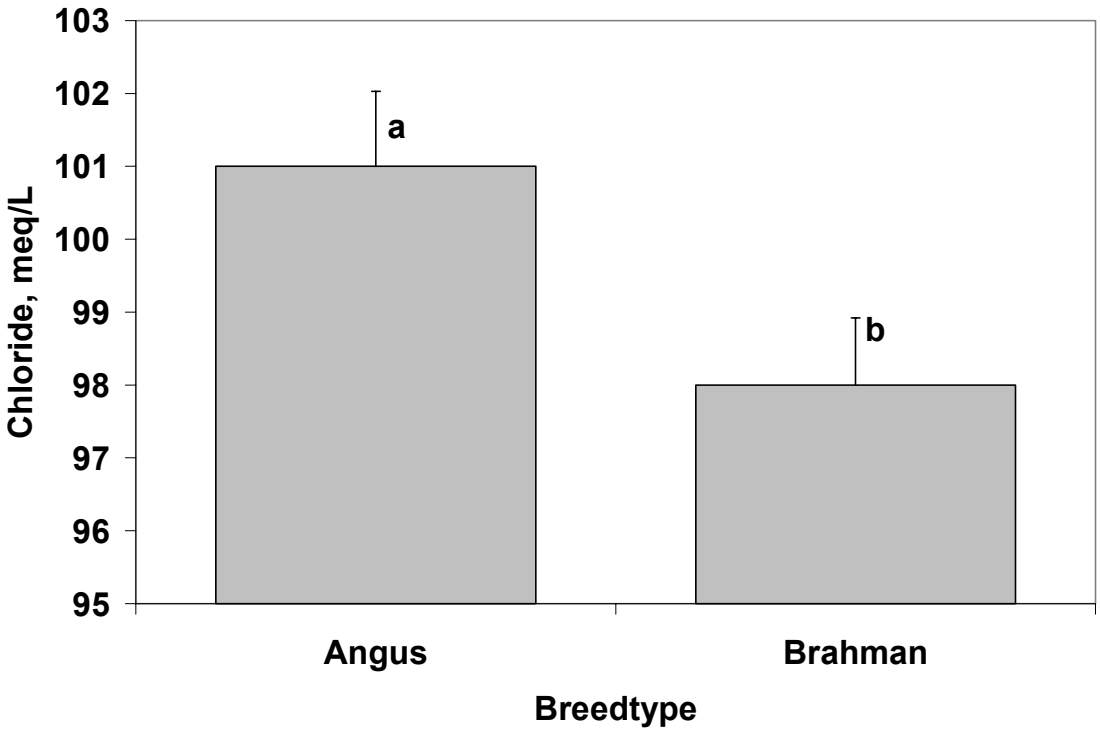

Figure 35. Serum concentrations of chloride measured near the end of the finishing period in Angus and Brahman steers. a, b differ $P<0.05$.

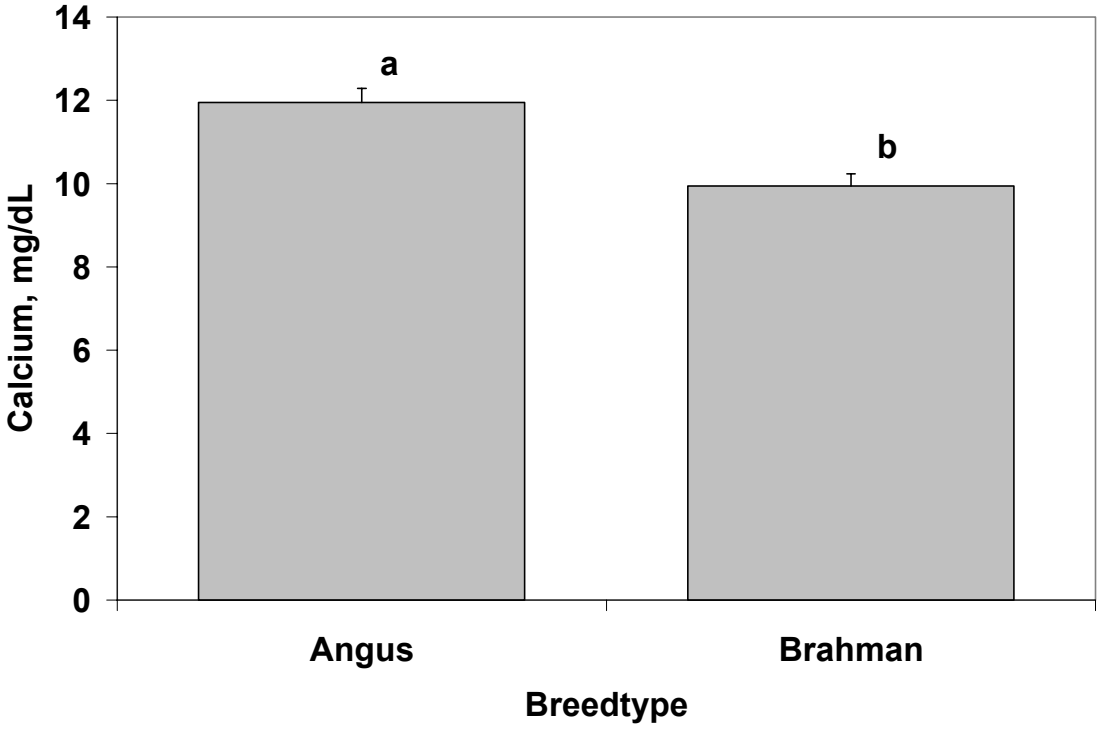

Figure 36. Serum concentrations of calcium in Angus and Brahman steers as measured near the end of the finishing period. a, b differ $P<0.05$.

Serum Metabolites. Serum albumin concentrations, when measured following the completion of the grazing stage, and near the conclusion of the finishing stage tended to be similar ($P<0.08$) between Angus and Brahman steers. Serum urea concentrations, as assessed following the completion of the grazing stage (Figure 37) were 35% greater ($P<0.01$) in Brahman steers than in Angus steers; near the conclusion of the finishing stage serum urea concentrations were not different ($P<0.29$) between Angus and Brahman steers. Serum concentrations of glucose assessed following the completion of the grazing stage were 28.90 mg/dL greater ($P<0.02$) in Brahman steers than in Angus steers (Figure 38); near the conclusion of the finishing stage, serum concentrations of glucose concentrations were not different ($P>0.10$) between Angus and Brahman steers. Following the completion of the grazing phase and near the end of the finishing period (Figures 39 and 40, respectively), serum concentrations of cholesterol were nearly 40% greater ($P<0.005$) in Brahman than in Angus steers. Serum concentrations of ß-Hba assessed following the completion of the grazing stage ($P>0.10$) as well as near the conclusion of the finishing stage ($P<0.09$) tended to be similar between Angus and Brahman steers. Tables 11 and 12 contain values of physical and physiological parameters which did not differ between breeds.

Table 11: Mean values of physical parameters which did not differ between Angus and Brahman steers.

	Breedtype		
Parameter	Angus	Brahman	SEM
Rectal temperature, ºC	39.7	39.6	0.24
Dorsal DITI value, ºC	37.7	37.2	0.27
Right side DITI value, ºC	36.5	35.9	0.29

Table 12: Mean values of physiological parameters which did not differ between Angus and Brahman steers.

	Breedtype		
Parameter	Angus	Brahman	SEM
Serum calcium, mg/dl	9.64	9.78	0.13
Serum phosphorus, mg/dl	5.89	6.15	0.28
Serum magnesium, meq/l	1.86	1.74	0.08
Serum albumin, g/dl	3.56	3.37	0.07
Serum B-HBA, umol/l	280.25	282.0	14.0
Serum Potassium, meq/l	5.35	5.23	0.14
Serum Chloride, meq/l	100.88	98.2	0.94

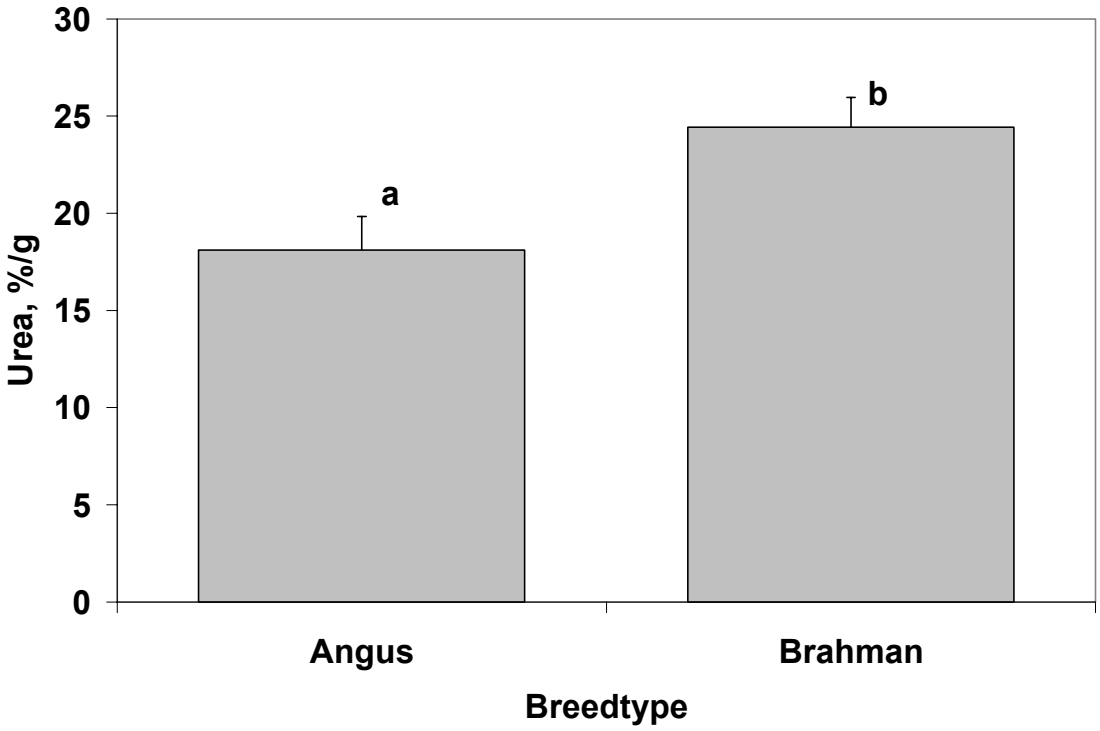

Figure 37. Serum urea concentrations in Angus and Brahman steers as measured at the end of the grazing period. a, b differ $P<0.05$.

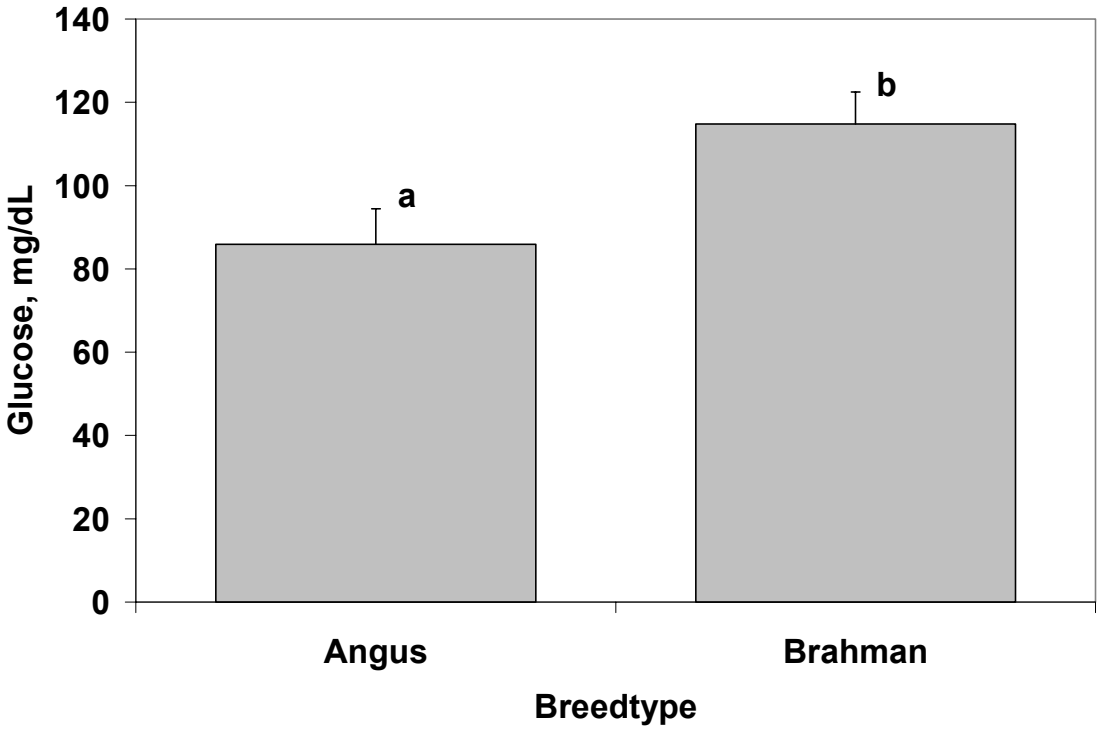

Figure 38. Serum glucose concentrations in Angus and Brahman steers as measured at the end of the grazing period. a, b differ $P<0.05$.

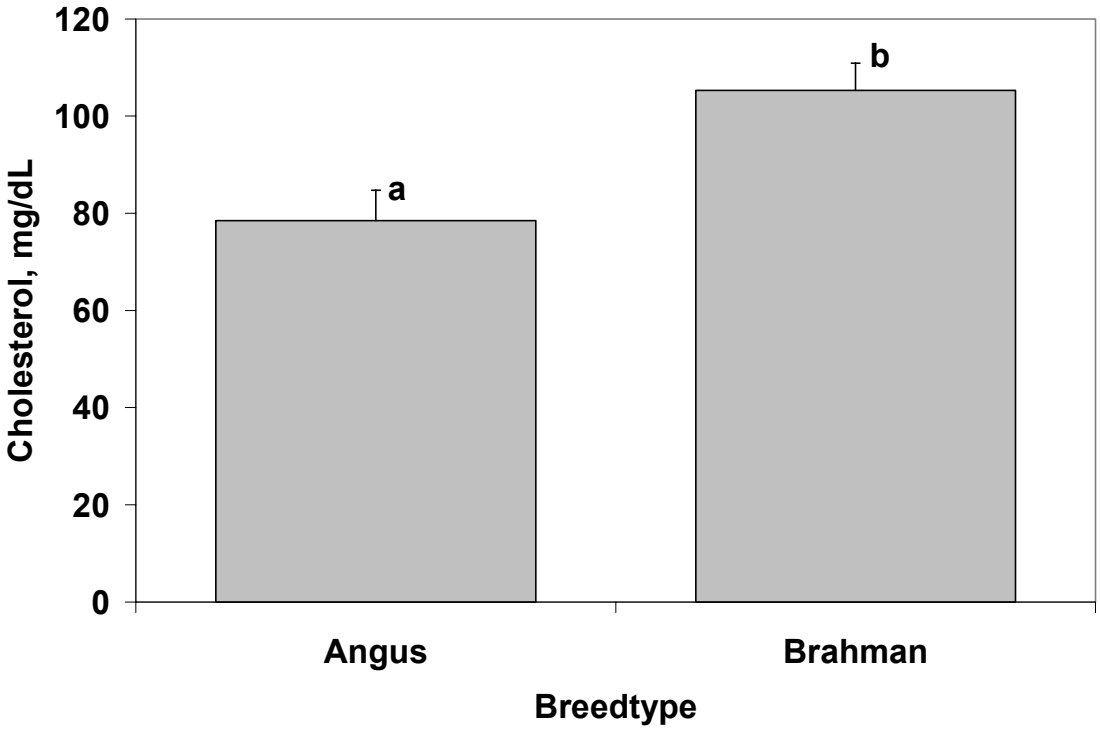

Figure 39. Serum cholesterol concentrations in Angus and Brahman steers as measured at the end of the grazing period. a, b differ $P<0.05$.

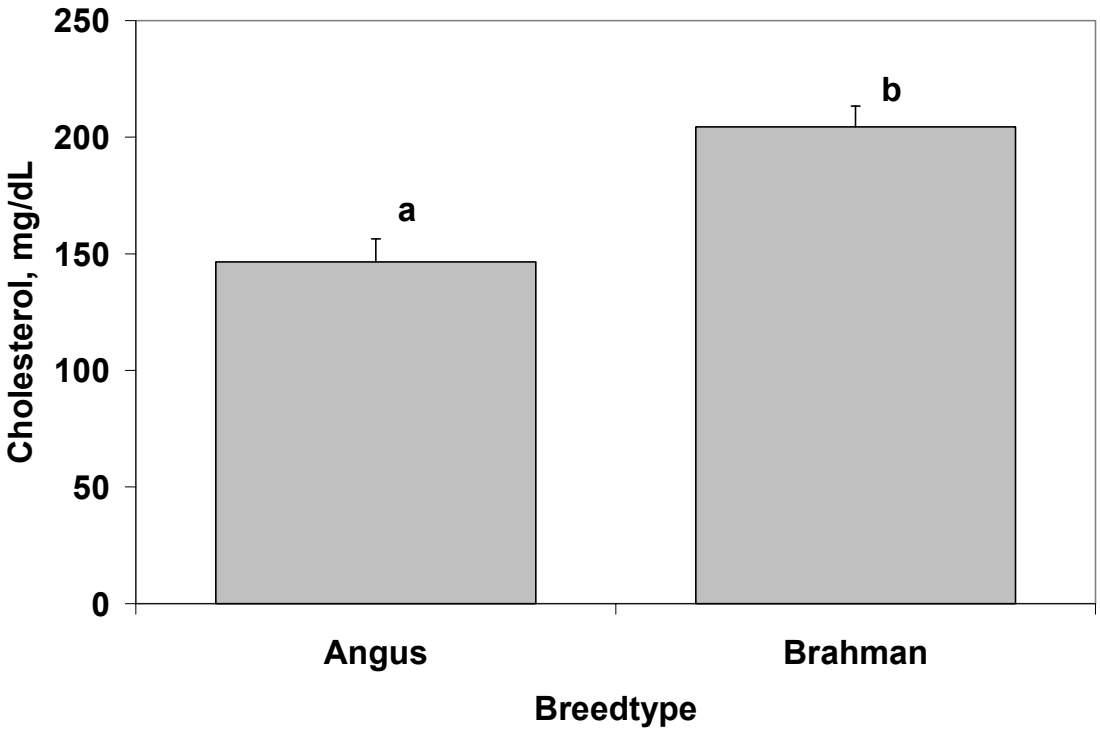

Figure 40. Serum cholesterol concentrations in Angus and Brahman steers as measured near the end of the finishing period. a, b differ $P<0.05$.

Adrenal Hormones. Serum concentrations of cortisol measured at the end of the five-month grazing period were not different ($P>0.10$) between Angus (14.46 ± 3.75 ng/mL) and Brahman steers (20.61 ± 3.35 ng/mL;); serum concentrations of cortisol near the conclusion of the finishing period, in August were also similar ($P>0.10$) between Angus (20.60 ± 2.39 ng/mL) and Brahman steers (22.28 ± 2.14 ng/mL).

Serum concentrations of aldosterone were similar ($P>0.10$) between Angus and Brahman steers when blood samples were obtained on March 1, 2002. When assessed following the completion of the grazing stage, serum concentrations of aldosterone were not different ($P>0.10$) between Angus steers and Brahman steers. In August, near the completion of the finishing phase, Brahman steers had 50% greater serum concentrations of aldosterone than Angus steers ($P<0.01$, Figure 41).

Hematological Parameters. There was no difference ($P>0.10$) in mean red blood cell count or plasma hemoglobin between Angus and Brahman steers. Hematocrit percentage (packed cell volume) was not different ($P>0.10$) between Angus and Brahman steers, and mean plasma protein concentrations were similar ($P>0.10$) between the two breedtypes. Plasma concentration of fibrinogen did not differ ($P>0.10$) between Angus and Brahman steers. Mean corpuscular volume, mean corpuscular hemoglobin and mean corpuscular hemoglobin content were all similar ($P>0.10$) between Angus and Brahman steers.

Immunological Parameters. White blood cell counts were similar ($P>0.10$) between Angus (9375.00 ± 1338.9 cells/μL) and Brahman steers (9390.00 ± 1197.5 cells/uL). Absolute neutrophil count and differential neutrophile percentage did not

differ between Angus and Brahman steers ($P>0.10$). Absolute lymphocyte counts and differential lymphocyte percentages were not different ($P>0.10$) between Angus and Brahman steers. Absolute monocyte count and differential monocyte percentage were similar ($P>0.10$) between Angus and Brahman steers. Absolute eosinophil count and differential eosinophil percentage were also tended to be similar ($P>0.07$) between Angus and Brahman steers.

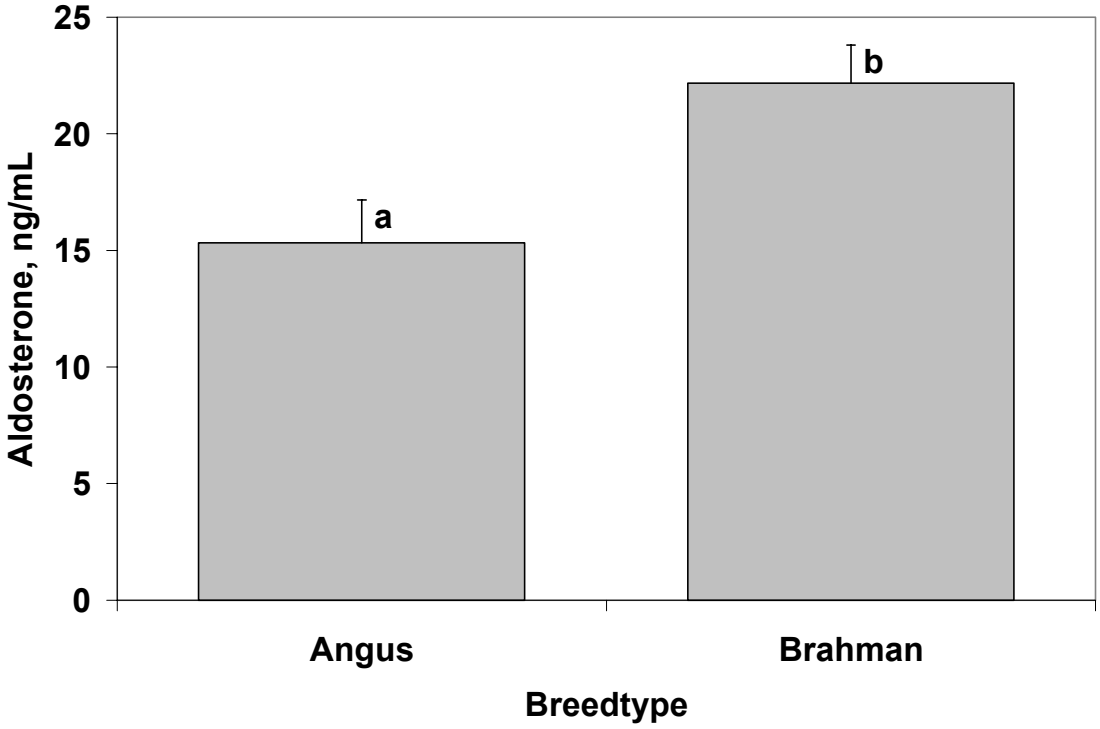

Figure 41. Serum concentrations of aldosterone in Angus and Brahman steers as measured in August, near the end of the finishing stage. a, b differ $P<0.05$.

Physical and Physiological Assessment of Heat Stress in Angus, Bonsmara X Angus Crossbred and Bonsmara Steers

Physical Measurements. Bonsmara and Bonsmara X Angus steers had similar respiration rates and respired 25% less rapidly ($P<0.05$ and $P<0.003$, respectively) than the Angus steers (Figure 42). Rectal temperature for Angus steers was 0.62ºC higher ($P<0.01$) than rectal temperatures of either Bonsmara X Angus or Bonsmara steers. Mean rectal temperature did not differ ($P>0.10$) between Bonsmara and Bonsmara X Angus steers (Figure 43). DITI measurements were categorized separately as the mean surface temperature along the right dorsal mid-line from rump to shoulder (dorsal) and right side over the ribs (right side) images. Mean dorsal surface temperature of Angus steers was not different ($P>0.05$) from the dorsal surface temperature of either Bonsmara X or Bonsmara steers. Bonsmara X Angus and Bonsmara steers had a mean right side surface temperature which was over 1ºC lower ($P<0.05$) than the right side surface temperature of Angus steers (Figure 44). Respiration rate was positively correlated with dorsal DITI Value ($r = 0.48$), and right side DITI value ($r = 0.44$).

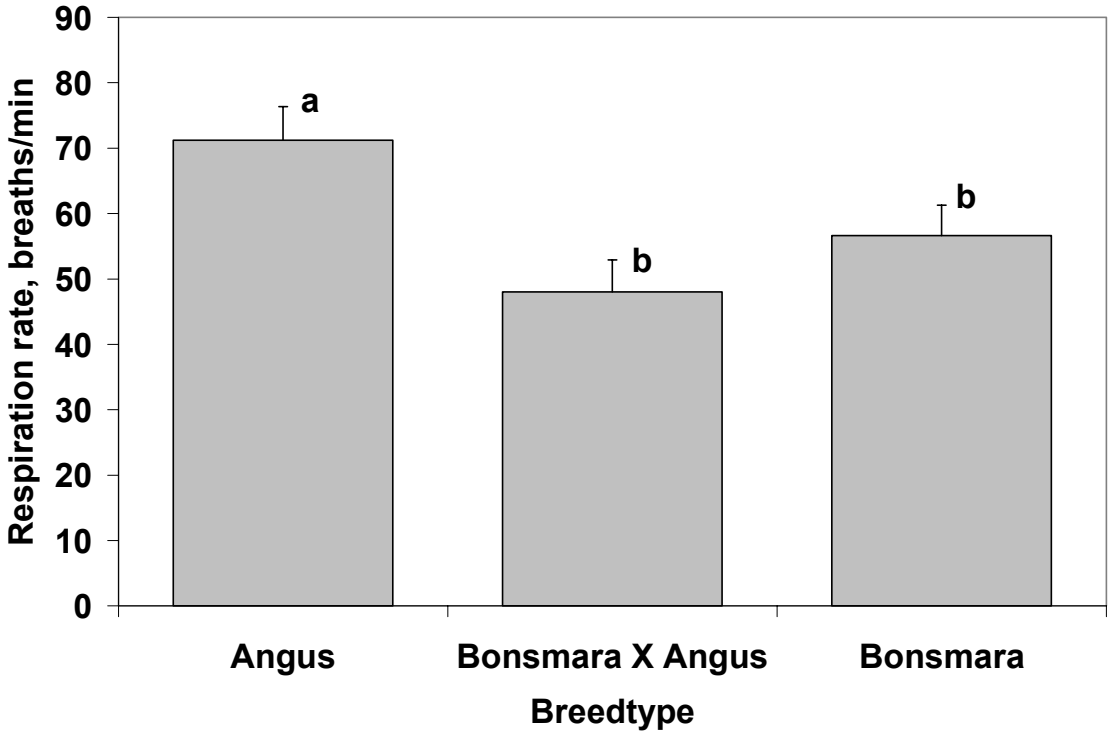

Figure 42. Respiration rate for Angus, Bonsmara X Angus and Bonsmara steers. a, b differ $P<0.05$.

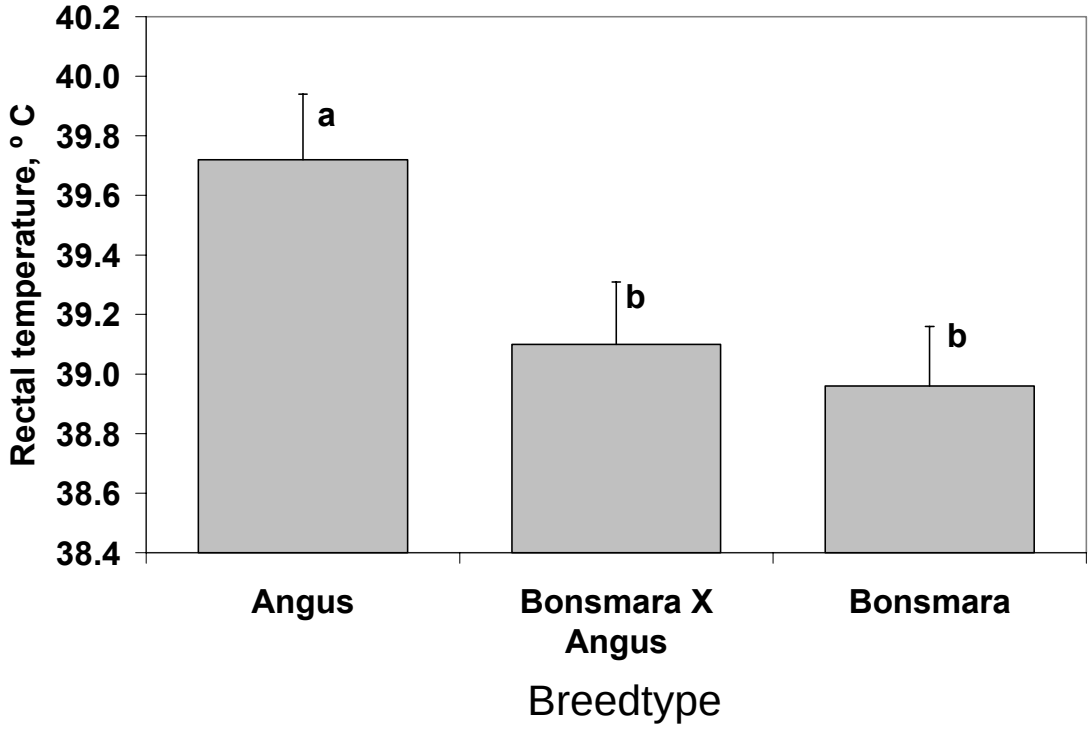

Figure 43. Rectal temperature of Angus, Bonsmara X Angus crossbred and Bonsmara steers. a, b differ $P<0.05$.

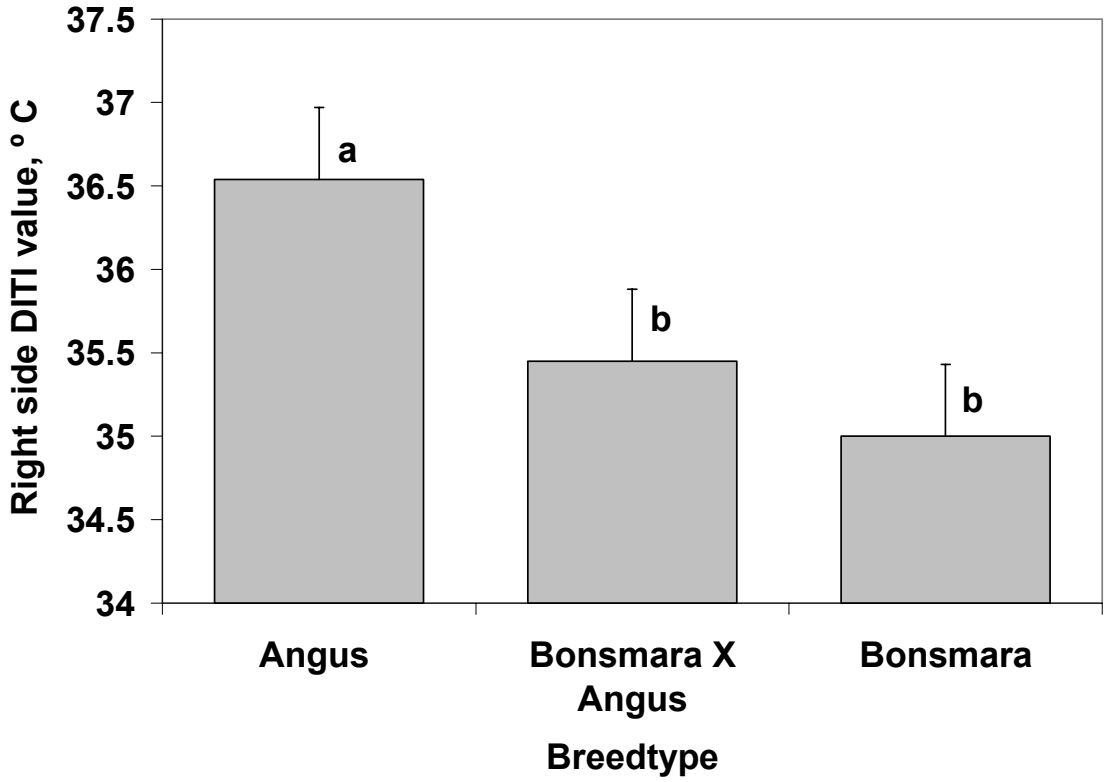

Figure 44. Right side Digital Infrared Thermal Imaging (DITI) temperature values of Angus, Bonsmara X Angus crossbred and Bonsmara steers. a, b differ $P<0.05$.

Serum Electrolytes. Serum concentrations of electrolytes including sodium, potassium, chloride, magnesium, phosphorus and calcium were determined from blood samples obtained once at the end of the grazing stage of production (May), and then once again in as the steers were nearing completion of the finishing stage of production (August).

Serum sodium concentrations following the completion of the grazing stage and near the conclusion of the finishing stage were not different ($P>0.10$) among Angus, Bonsmara X Angus and Bonsmara steers. Serum concentrations of sodium were positively correlated to chloride (r = 0.89) and potassium (r = 0.18). Serum concentrations of potassium and chloride were not different ($P>0.10$) at the end of the grazing period or near the completion of the finishing phase among Angus, Bonsmara X Angus crossbred and Bonsmara steers.

Following the completion of the grazing stage, Angus and Bonsmara had serum calcium concentrations which were not different from one another ($P>0.10$), but were greater ($P<0.03$ and 0.0006, respectively) than the serum calcium concentrations of Bonsmara X Angus crossbred steers (Figure 45). Near the conclusion of the finishing stage (Figure 46), serum concentrations of calcium in Angus steers were over 1.4 mg/dL higher than those of either Bonsmara X Angus ($P<0.0001$) or Bonsmara steers ($P<0.001$); serum calcium did not differ ($P<0.10$) between Bonsmara and Bonsmara X Angus steers when measured near the conclusion of the finishing stage. Following the completion of the grazing stage serum concentrations of phosphorus and magnesium were not different ($P>0.10$) between Angus, Bonsmara X Angus and Bonsmara steers,

although near the completion of the finishing phase serum concentrations of magnesium were greater ($P<0.0006$ and 0.003, respectively; Figure 47) in Angus and Bonsmara X Angus steers. Physiological parameters which did not differ among Angus, Bonsmara and Bonsmara X Angus steers are shown in Table 13.

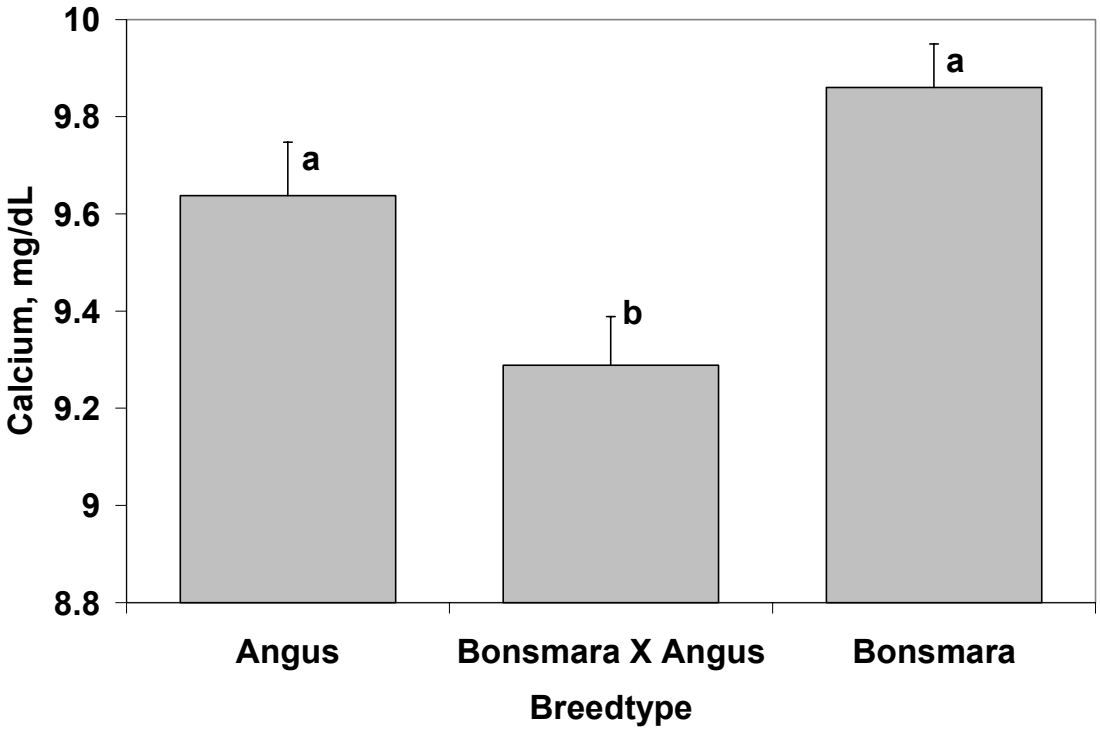

Figure 45. Serum calcium concentrations in Angus, Bonsmara X Angus crossbred and Bonsmara steers as measured following the completion of the grazing phase. a, b differ $P<0.05$.

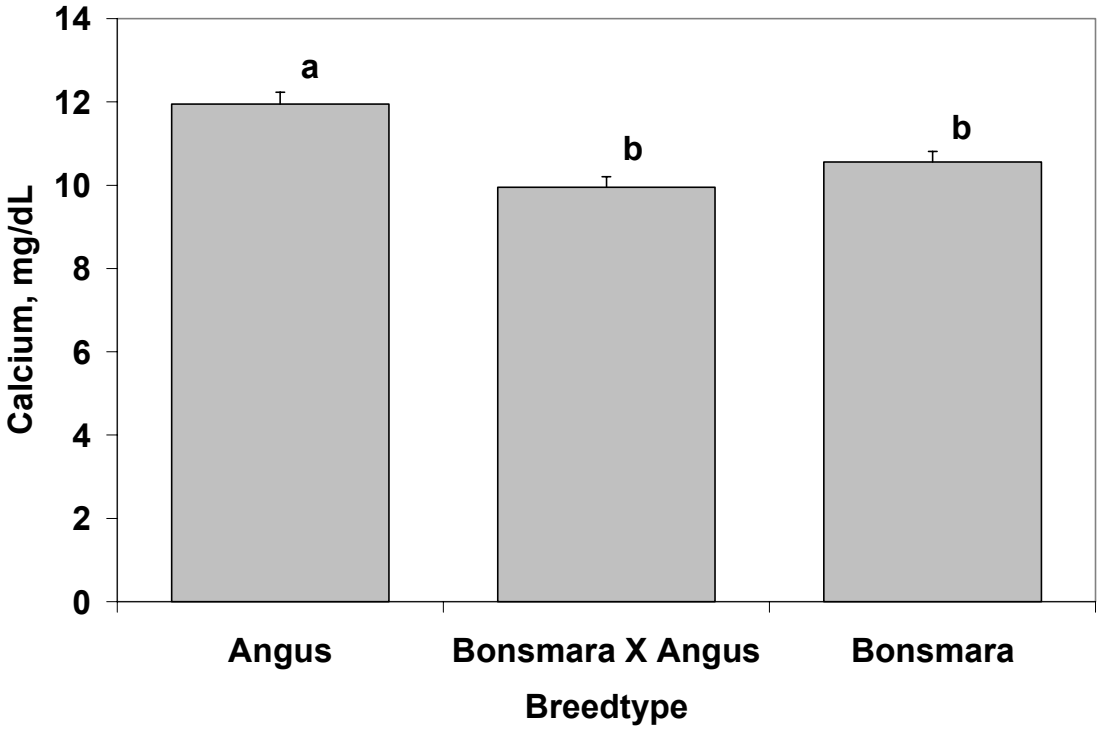

Figure 46. Serum calcium concentrations in Angus, Bonsmara X Angus crossbred and Bonsmara steers as measured near the completion of the finishing phase. a, b, c differ $P<0.05$.

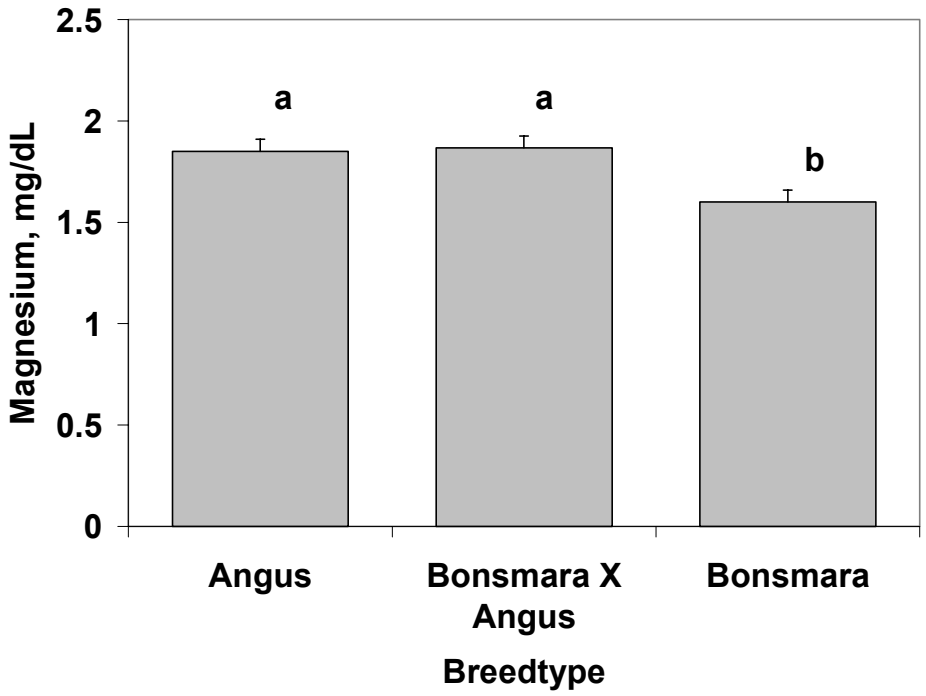

Figure 47. Serum magnesium concentrations in Angus, Bonsmara X Angus crossbred and Bonsmara steers as measured near the completion of the finishing phase. a, b differ $P<0.05$.

Serum Metabolites. Serum albumin concentrations following the completion of the grazing stage and near the conclusion of the finishing stage tended to be similar ($P>0.08$) among Angus, Bonsmara X Angus and Bonsmara steers. Serum urea concentrations following the completion of the grazing stage were 2.49 %/g less in Angus than in Bonsmara X Angus ($P<0.06$), and 3.21 %/g less in Angus than Bonsmara steers ($P<0.02$) but were not different ($P>0.10$) between Bonsmara X Angus and Bonsmara steers (Figure 48). Near the conclusion of the finishing stage Angus steers had serum urea concentrations which were similar ($P>0.10$) to those of Bonsmara X Angus and Bonsmara steers; serum urea concentrations near the conclusion of the finishing stage were 3.87 %/g greater ($P<0.05$) in Bonsmara X Angus than Bonsmara steers (Figure 49).

Serum concentrations of glucose assessed following the completion of the grazing stage did not differ ($P>0.10$) among Angus, Bonsmara X Angus and Bonsmara steers. Near the completion of the finishing phase, serum concentrations of glucose were 28.8 mg/dL less in Angus steers than in Bonsmara X Angus ($P<0.08$), and 38.6 mg/dL less ($P<0.02$) than in Bonsmara steers (Figure 50). Serum concentrations of cholesterol following the grazing stage were over 20 mg/dL greater in Bonsmara steers than in either Angus ($P<0.0003$) or Bonsmara X Angus steers ($P<0.004$) and did not differ ($P>0.10$) between Angus and Bonsmara X Angus steers (Figure 51). Near the conclusion of the finishing stage, serum concentrations of cholesterol were over 55 mg/dL less in Angus steers than either Bonsmara X Angus ($P<0.0001$) or Bonsmara steers ($P<0.001$); Bonsmara X Angus steers had 33 mg/dL higher serum cholesterol

concentrations ($P<0.03$) than Bonsmara steers (Figure 52). Serum concentrations of ß-Hba assessed following the completion of the grazing stage and near the conclusion of the finishing phase tended to be similar ($P>0.08$) among Angus, Bonsmara X Angus and Bonsmara steers.

Table 13: Mean values for serum concentrations of electrolytes and metabolites which did not differ among Angus, Bonsmara and Bonsmara X Angus steers.

Parameter	Breedtype			SEM
	Angus	Bonsmara X Angus	Bonsmara	
Serum calcium, mg/dl	9.64	9.29	9.86	0.09
Serum phosphorus, mg/dl	5.89	6.69	6.69	0.34
Serum magnesium, meq/l	1.86	1.69	1.72	6.5
Serum albumin, g/dl	3.56	3.36	3.5	0.08
Serum glucose, mg/dl	85.88	87.11	76.10	5.64
Serum B-HBA, umol/l	280.25	249.33	252.4	29.71
Serum sodium, meq/l	141.63	142.33	141.7	1.12
Serum Potassium, meq/l	5.35	5.07	5.23	0.12
Serum Chloride, meq/l	100.88	100.56	100.30	1.01

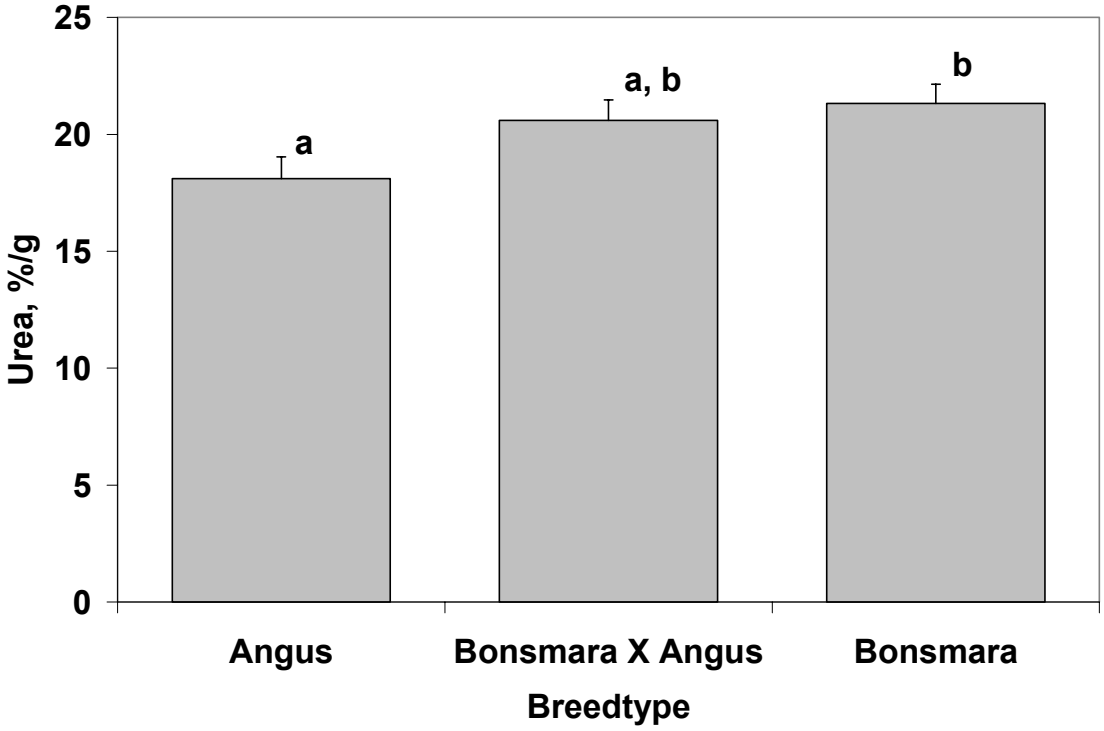

Figure 48. Serum urea concentrations in Angus, Bonsmara X Angus and Bonsmara steers as measured following the conclusion of the grazing stage. a, b differ $P<0.05$.

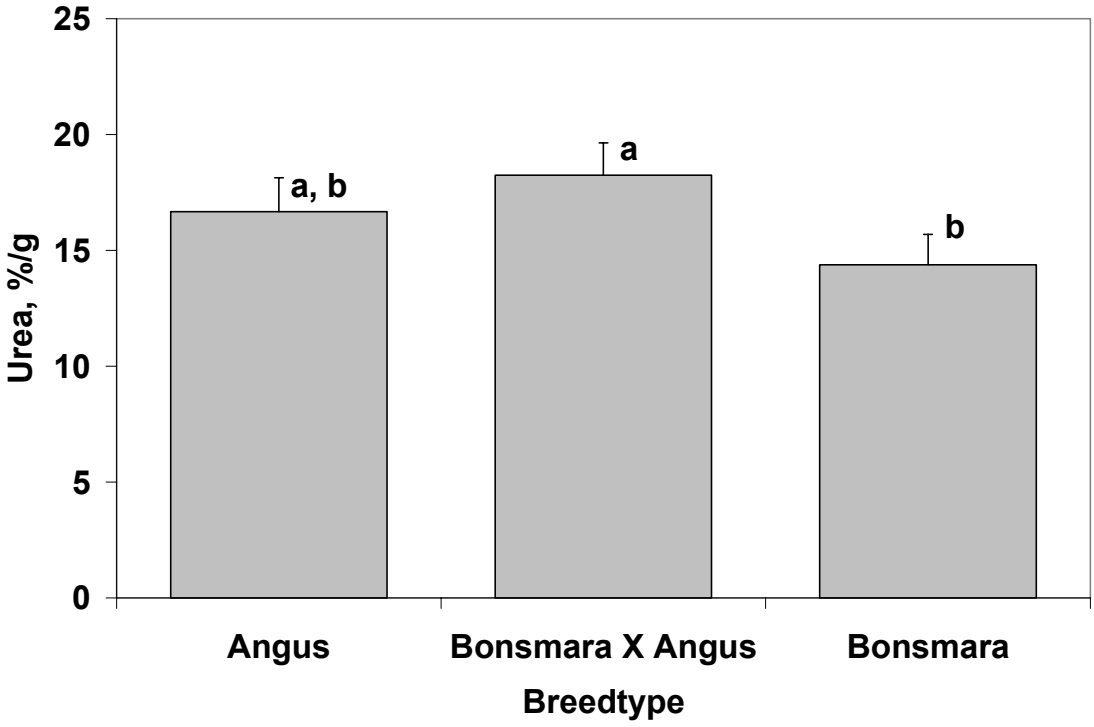

Figure 49. Serum urea concentrations in Angus, Bonsmara X Angus and Bonsmara steers as measured near the end of the finishing phase. a, b differ $P<0.05$.

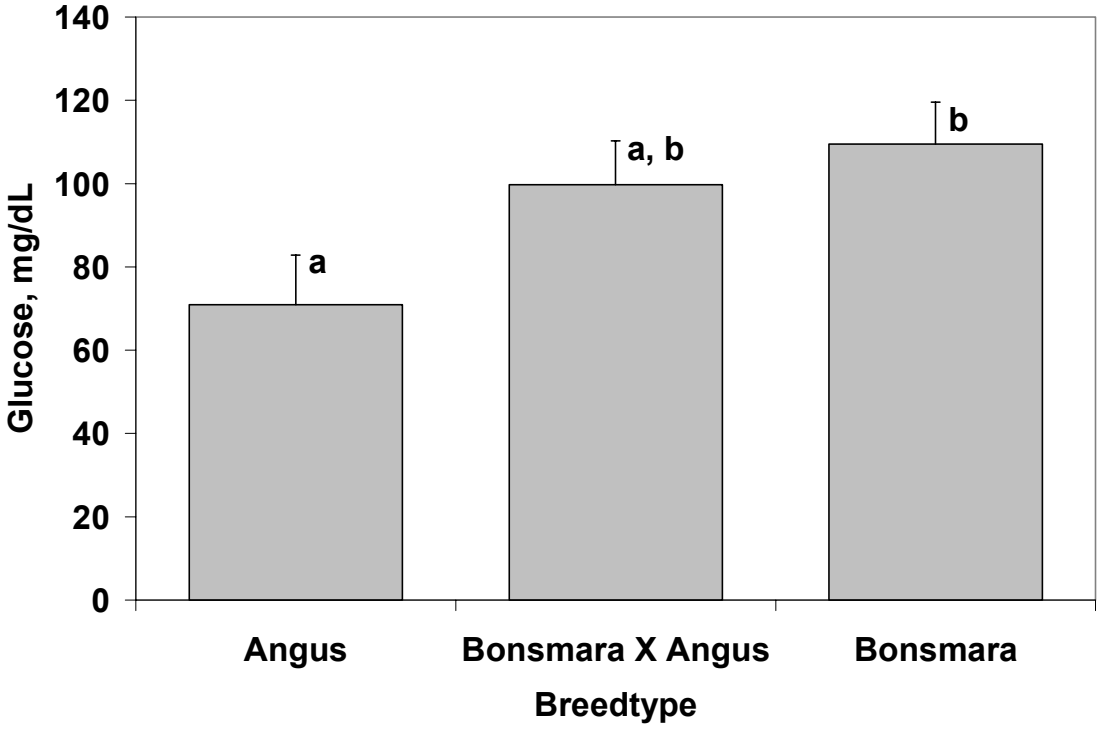

Figure 50. Serum glucose concentrations in Angus, Bonsmara X Angus and Bonsmara steers as measured near the conclusion of the finishing phase. a, b differ $P<0.05$.

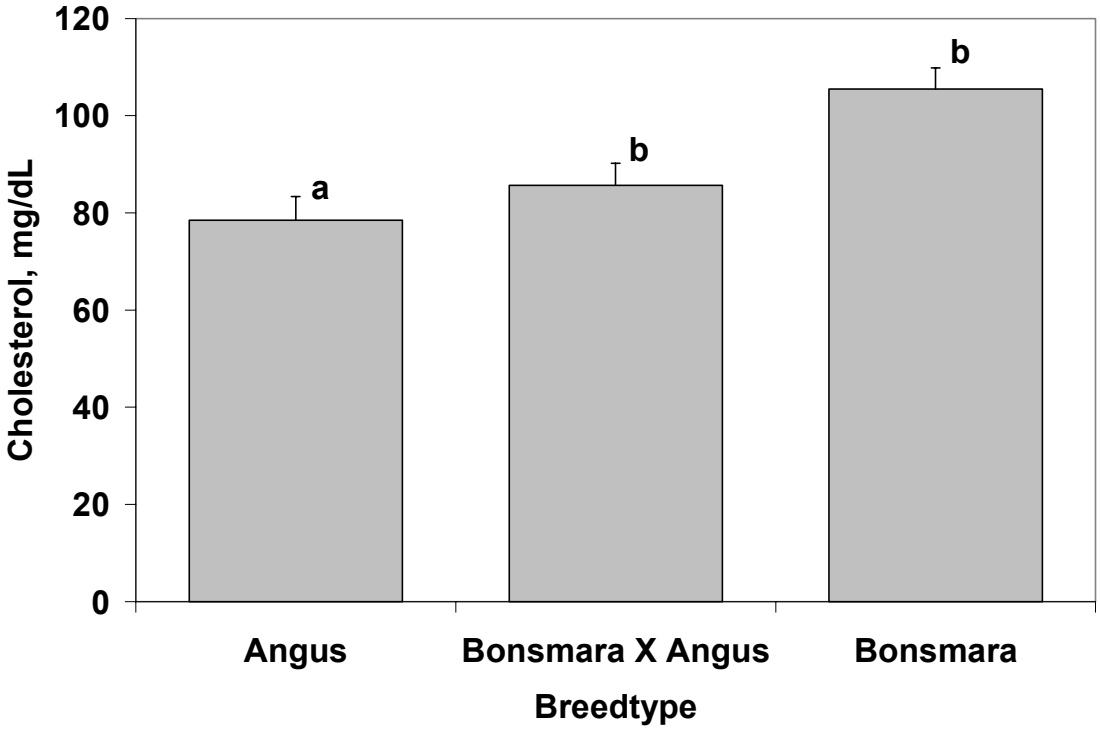

Figure 51. Serum cholesterol concentrations in Angus, Bonsmara X Angus and Bonsmara steers as measured following the grazing phase. a, b differ $P<0.05$.

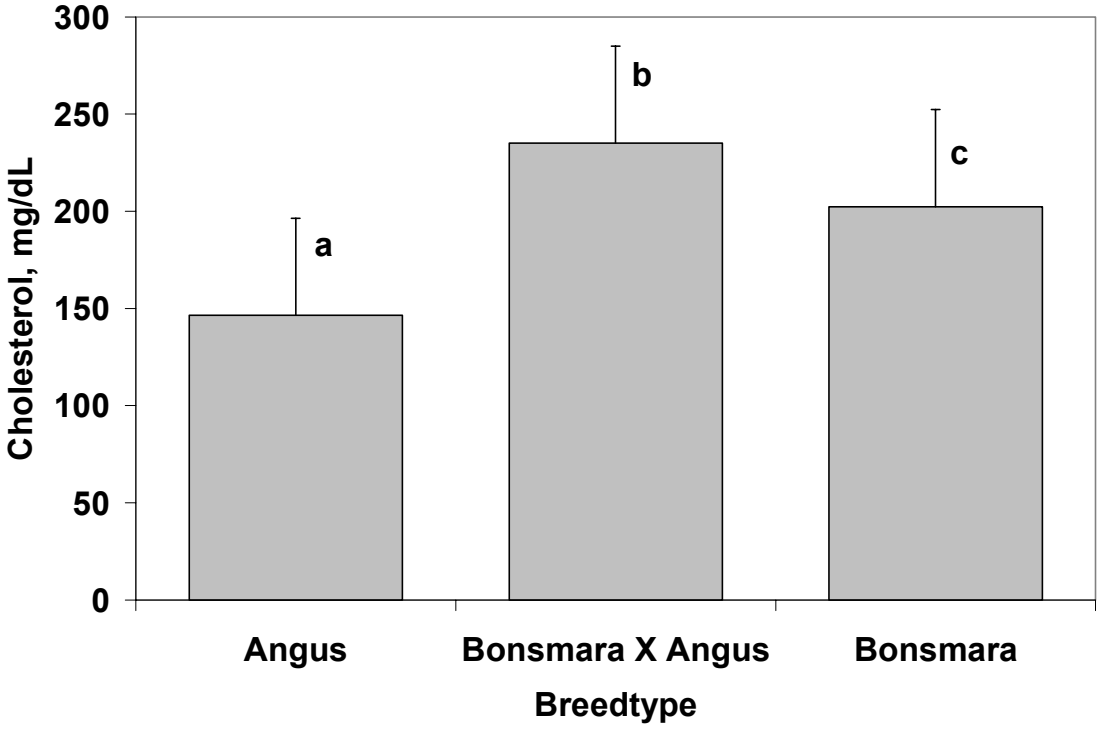

Figure 52. Serum cholesterol concentrations in Angus, Bonsmara X Angus and Bonsmara steers as measured near the completion of the finishing phase. a, b, c differ $P<0.05$.

Adrenal Hormones. Serum cortisol measured following the completion of the grazing stage was not different ($P>0.10$) among Angus, Bonsmara X Angus and Bonsmara steers. Serum cortisol concentrations near the conclusion of the finishing stage were 9.62 ng/mL greater ($P<0.02$) in Angus than Bonsmara X Angus steers (Figure 53). Serum cortisol concentrations near the conclusion of the finishing stage did not differ ($P>0.10$) between Bonsmara and either Bonsmara X Angus or Angus steers.

When serum aldosterone was measured in March, during the course of the grazing period, Angus steers had over 38 ng/mL greater serum aldosterone than either Bonsmara X Angus ($P<0.04$) or Bonsmara steers ($P<0.03$; Figure 54). Near the conclusion of the grazing period, serum concentrations of aldosterone were not different ($P>0.10$) among Angus, Bonsmara X Angus and Bonsmara steers. When serum aldosterone was assessed near the completion of the finishing phase, Bonsmara steers had over 15 ng/mL greater serum concentrations of aldosterone than either Bonsmara X Angus steers ($P<0.008$) or Angus steers ($P<0.001$; Figure 55). Serum aldosterone was positively correlated (r = 0.53) with escape velocity, and rectal temperature (r = 0.37).

Hematological Parameters. Red blood cell count was similar ($P>0.10$) among Angus, Bonsmara X Angus and Bonsmara steers. Mean plasma hemoglobin and total plasma protein were similar ($P>0.10$) among Angus, Bonsmara X Angus and Bonsmara steers. Hematocrit percentage of Angus steers (34.16 ± 0.99%) tended to be greater ($P<0.10$) than hematocrit percentage of Bonsmara X Angus steers (33.47 ± 0.93 %), and significantly greater ($P<0.03$) than that of Bonsmara steers (32.77 ± 0.89 %; Figure 56); hematocrit percentage of Bonsmara did not differ ($P>0.10$) from Bonsmara X Angus

steers. Plasma fibrinogen concentrations were 111.11 mg/dL greater ($P<0.05$) in Bonsmara steers than in Bonsmara X Angus crossbred steers (Figure 57); Angus steers had plasma concentrations of fibrinogen which were intermediate to those of Bonsmara and Bonsmara X Angus steers. Mean corpuscular volume and mean corpuscular hemoglobin content were similar ($P>0.10$) among Angus, Bonsmara X Angus crossbred and Bonsmara steers. Mean corpuscular hemoglobin was not different ($P>0.10$) between Angus (15.78 ± 1.46 pg) and Bonsmara X Angus steers (14.91 ± 1.38 pg) or Bonsmara X Angus steers and Bonsmara steers (14.03 ± 1.31 pg), but was greater ($P<0.03$) in Angus than in Bonsmara steers (Figure 58).

Immunological Parameters. White blood cell counts were not different ($P>0.10$) between Angus and Bonsmara X Angus steers, but were more numerous ($P<0.02$) in Bonsmara than in Bonsmara X Angus steers (Figure 59). Absolute neutrophil counts and differential neutrophile percentages were not different ($P>0.10$) among Angus, Bonsmara X Angus and Bonsmara steers. Absolute lymphocyte count was not different ($P>0.10$) when comparing Angus with Bonsmara X Angus or Bonsmara steers (Figure 60); but was significantly greater ($P<0.03$) in Bonsmara than Bonsmara x Angus steers. Differential lymphocyte percentage was not different ($P>0.10$) among Angus, Bonsmara X Angus and Bonsmara steers. Absolute monocyte count and differential monocyte percentage were not different ($P>0.10$) among Angus, Bonsmara X Angus and Bonsmara steers. There was no difference ($P>0.10$) among Angus, Bonsmara X Angus and Bonsmara steers with regard to absolute eosinophil count or differential eosinophil percentage.

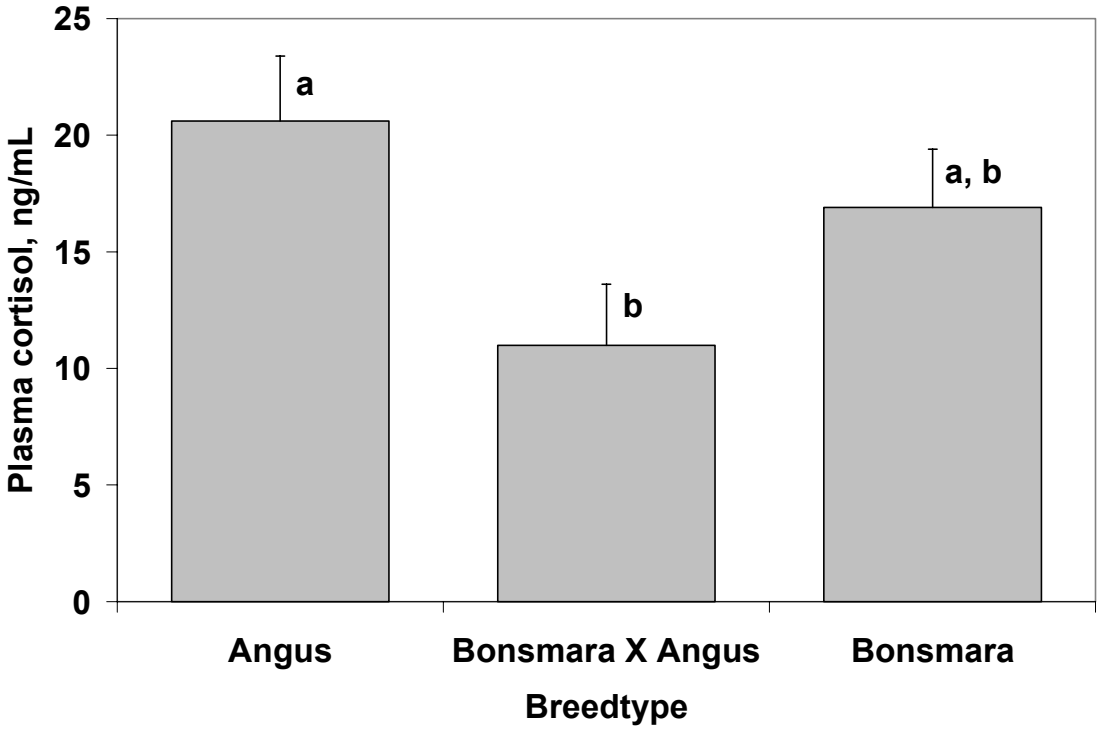

Figure 53. Peripheral blood concentrations of cortisol in Angus, Bonsmara X Angus crossbred and Bonsmara steers as measured near the completion of the finishing phase. a, b differ $P<0.05$.

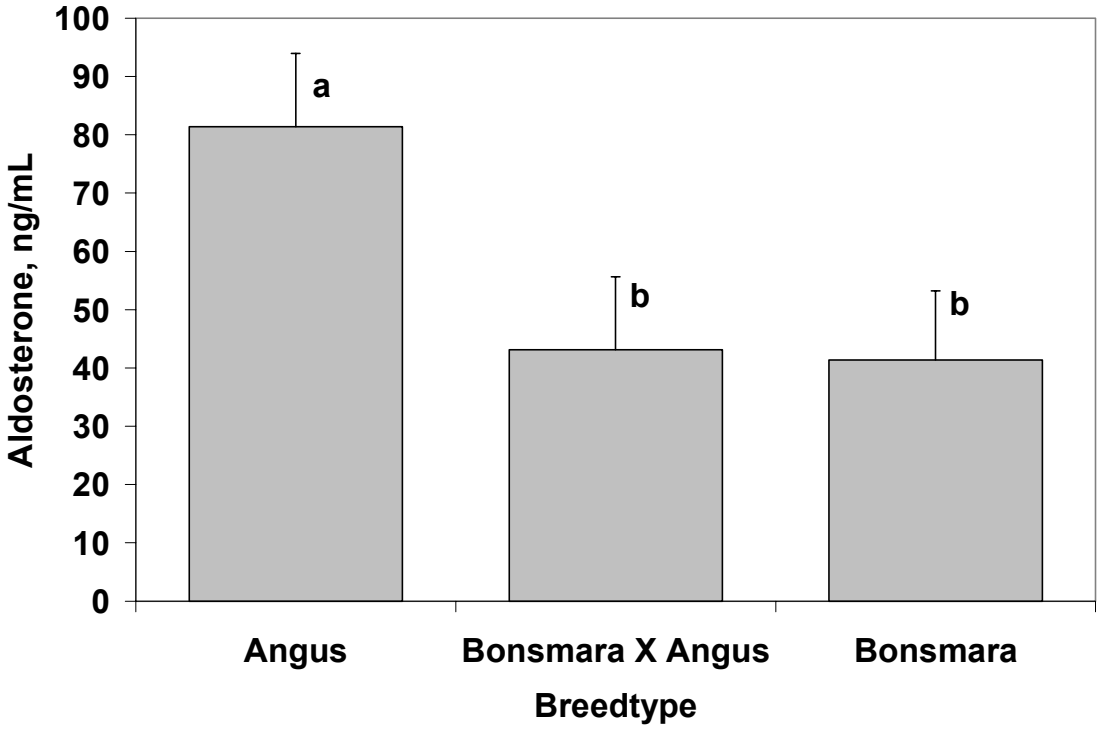

Figure 54. Peripheral blood concentrations of aldosterone in Angus, Bonsmara X Angus crossbred and Bonsmara steers as measured during the grazing phase. a, b differ $P<0.05$.

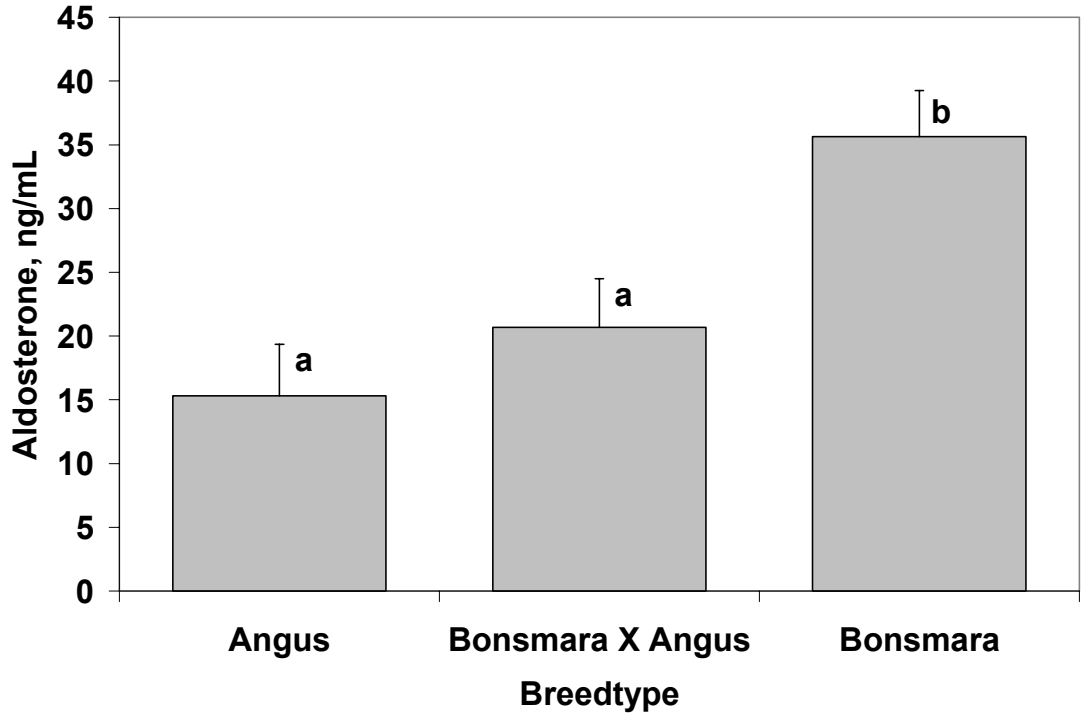

Figure 55. Peripheral blood concentrations of aldosterone in Angus, Bonsmara X Angus crossbred and Bonsmara steers as measured near the completion of the finishing phase. a, b differ $P<0.05$.

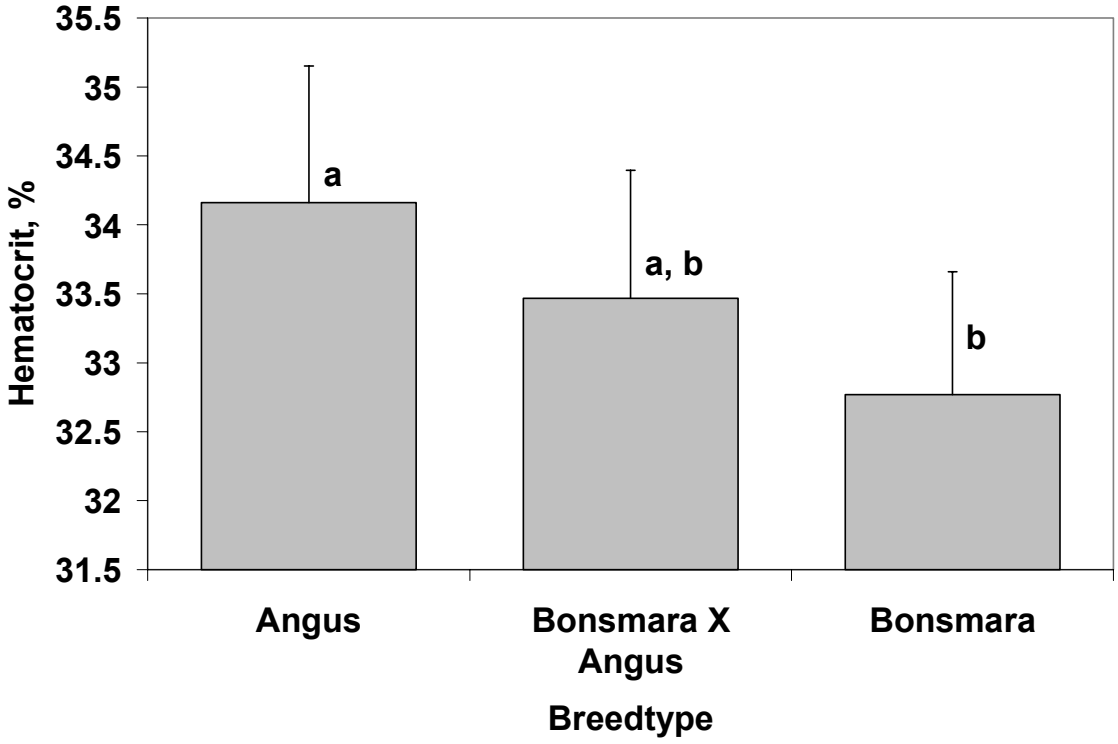

Figure 56. Packed cell volume in Angus, Bonsmara X Angus and Bonsmara steers. a, b differ $P<0.05$.

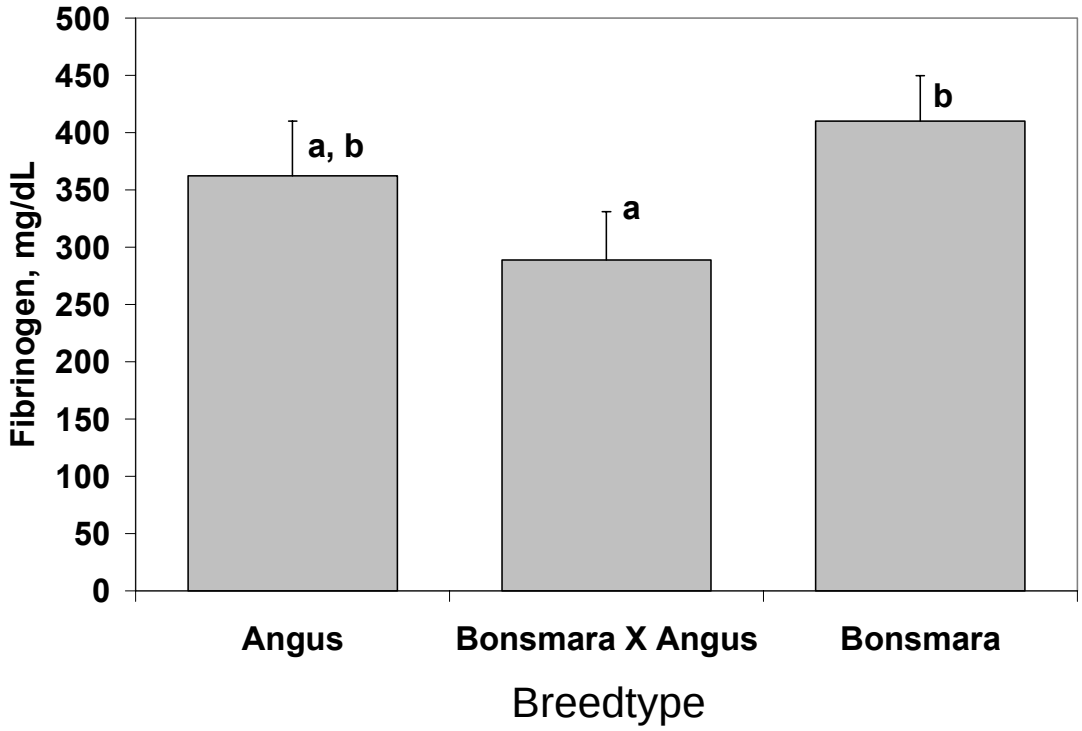

Figure 57. Fibrinogen concentrations in Angus, Bonsmara X Angus and Bonsmara steers. a, b differ $P<0.05$.

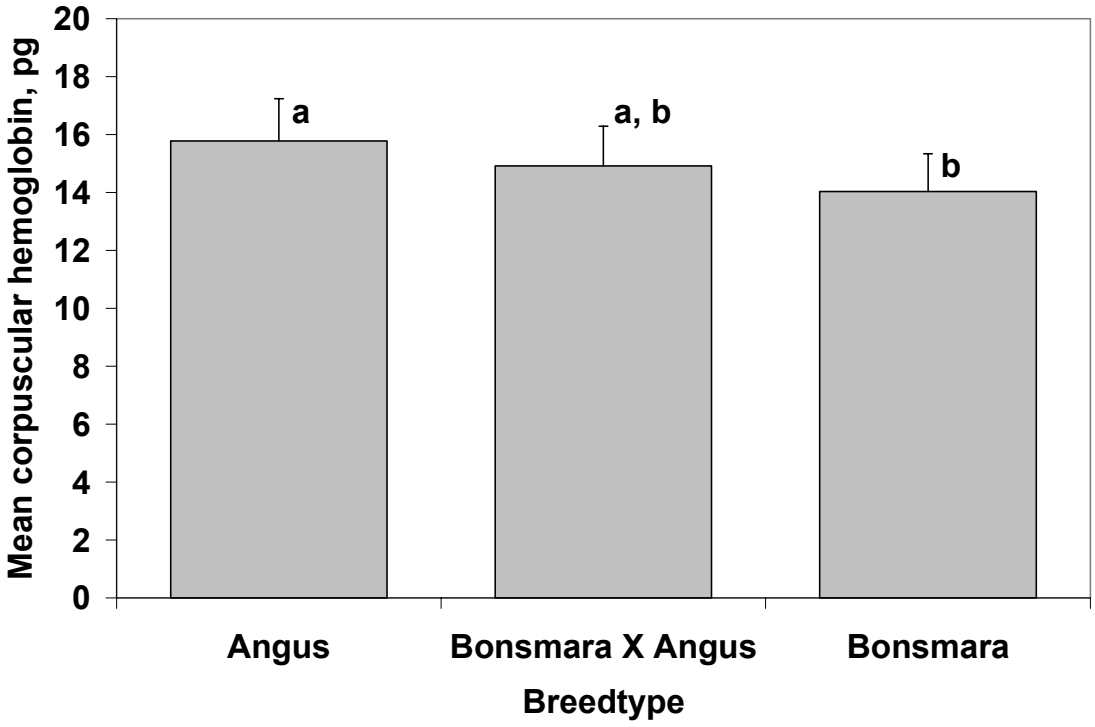

Figure 58. Mean corpuscular hemoglobin in Angus, Bonsmara X Angus and Bonsmara steers. a, b differ $P<0.05$.

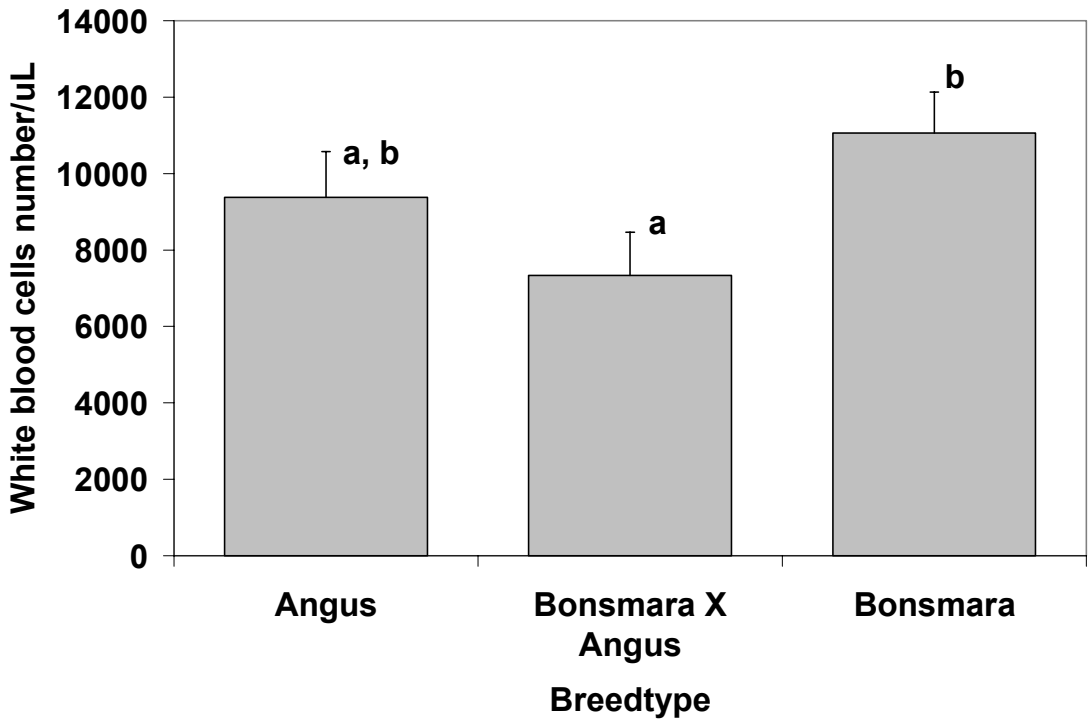

Figure 59. White blood cell count in Angus, Bonsmara X Angus and Bonsmara steers. a, b differ $P<0.05$.

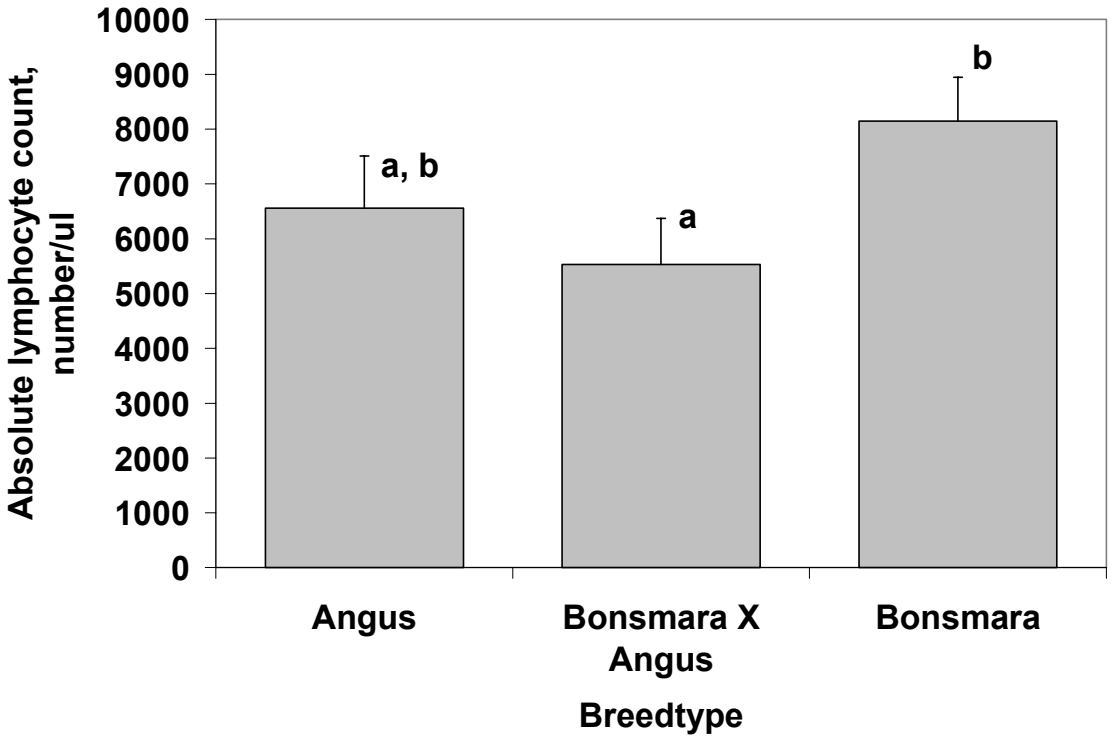

Figure 60. Absolute lymphocyte count in Angus, Bonsmara X Angus and Bonsmara steers. a, b differ $P<0.05$.

CHAPTER VII

DISCUSSION

A series of experiments were conducted over the course of a year on forty steers representing four different breed types of temperate (Angus, n=10), tropically-adapted (Brahman, n=10), and temperate-tropically-adapted composite (Bonsmara X Angus, and Bonsmara; n=10 each) beef steers. These experiments targeted differences in adrenal responsiveness, growth and carcass characteristics, response to elevated environmental temperatures, serum metabolite and electrolyte concentrations, hematological and immune parameters. The experiments were conducted to test three main hypotheses:

1) Adrenal responsiveness to exogenous ACTH and CRH varies by breedtype among beef steers of temperate, tropically-adapted or temperate-tropically-adapted composite lineage.

2) Growth and carcass characteristics vary by breedtype among beef steers of temperate, tropically-adapted or temperate-tropically-adapted composite lineage.

3) Reflective of different methods of combating elevated environmental temperatures, physical and physiological parameters of heat stress vary by breedtype among beef steers of temperate, tropically-adapted or temperate-tropically-adapted composite lineage.

In general, we observed greater plasma concentrations of cortisol in Brahman and Angus steers than in Bonsmara or Bonsmara X Angus steers throughout the ACTH and CRH challenges, with greater amplitude of response to ACTH, but not CRH in

temperate-influenced steers. Plasma concentrations of cortisol following either challenge returned to basal concentrations more slowly in Bonsmara steers than in other breedtypes. Carcass characteristics were similar among Angus, Bonsmara X Angus and Bonsmara steers. Physical indices of heat stress such as rectal and surface temperature was similar between Angus and Brahman, whereas the tropically-influenced Brahman, Bonsmara X Angus and Bonsmara steers displayed respiration rates and physiological indices of heat stress which were different from those displayed by temperate Angus steers.

Effect of Exogenous ACTH and CRH on Plasma Concentration of Cortisol in Beef Steers

The pattern of plasma concentrations of cortisol in these studies, with samples obtained from a serial blood collection centered around administration of ACTH or CRH, mirrored the pattern illustrated by previous researchers (Paape et al., 1977; Gwazdauskas et al., 1980; Juniewicz and Johnson, 1984; Minton, 1994; Veissier et al., 1995; Verkerk and Mcmillan, 1997), with the establishment of basal concentrations of cortisol prior to the administration of exogenous ACTH or CRH, and a rapid peak plasma cortisol response within approximately 30-minutes of treatment, which gradually diminished for several h until basal plasma concentrations of cortisol were reestablished.

Contrasted with data from Koch et al. (2000), who observed greater basal plasma concentrations of cortisol in temperate Angus bulls than in tropically-adapted Brahman bulls, Angus steers maintained plasma concentrations of cortisol which were similar to those of Brahman steers prior to administration of ACTH and following the return to basal. Other studies of temperate (Hereford) and tropically-adapted (Brahman) bulls

reported no difference in basal plasma concentrations of cortisol collected during the course of a serial blood collection period in the fall and spring (Berardinelli et al., 1992). Blood samples collected from Brown Swiss, Holstein-Friesian, and White Fulani heifers over two consecutive estrous cycles during each of the four quarters of the hot humid seasonal tropical climate of Ibadan, Southern Nigeria showed no breedtype or adaptation-associated difference in basal plasma concentrations of cortisol (Adeyemo et al., 1981). Temperament scores of Brahman and Angus steers (to be discussed later in this section) were similar, indicating a similar perception of threat from human contact; the similar basal plasma cortisol concentrations in Angus and Brahman steers could be attributed to a similarly intense fear of human contact.

Like Zavy et al. (1988), who noted a greater adrenal response to ACTH in steers of *Bos taurus* (Angus X Hereford) breeding than those containing some *Bos indicus* (Brahman X Angus), we noted greater peak plasma concentrations of cortisol and greater amplitude of the peak response in temperate Angus than tropically-adapted Brahman steers, and the area under the curve for the 2 h following administration of ACTH was greater in Angus than Brahman steers. This phenomenon could be reflective of the larger adrenal gland size and greater StAR protein expression in Angus compared to Brahman bulls which were noted by Koch et al. 2000; the adrenal gland of Angus cattle may be able to produce cortisol more efficiently than the adrenal gland of Brahman cattle. The ACTH dose we utilized was a pharmacological dose and a larger adrenal gland with more StAR protein could make more use of the bolus injection of ACTH than the smaller adrenal with less StAR protein. The strong negative correlation in Angus

steers, and the strong positive correlation in Brahman steers between post-ACTH and post-CRH area under the curve indicates that the adrenal gland of Angus steers may have the capability to respond to larger doses of ACTH, or may be more sensitive to ACTH than Brahman steers, thus explaining the greater cortisol response to ACTH seen in Angus steers.

In contrast to the ACTH challenge, peak plasma concentrations of cortisol and amplitude of cortisol response to CRH were no greater in Angus than Brahman steers. The release of cortisol from the adrenal gland elicited by the administration of CRH is first modulated by release of ACTH from the anterior pituitary gland. The similarity in area under the curve, peak response and amplitude to CRH may be attributed to similar modulation of CRH by the anterior pituitary glands of Angus and Brahman steers. Some reports (Veissier et al., 1999; McFarlane et al., 1995) have shown an additive effect of vasopressin and CRH on adrenal secretion of cortisol. Veissier et al. 1999 also noted a more appreciably decreased sensitivity to CRH upon repeated exposure among calves than among other mammals. The observation that Angus steers reached peak plasma cortisol response more rapidly than did Brahman steers, may be related to increased sensitivity of the anterior pituitary to CRH in Angus steers.

Previous studies examining basal adrenal activity in heifers of Shorthorn *(Bos taurus*), Afrikaner (*Sanga*) and Bonsmara (intermediate) lineage that were individually confined to a 4.6 square meter pen observed that Bonsmara heifers had lower plasma concentrations of cortisol than either their temperate or tropically-adapted contemporaries (Erasmus and Krause, 1982). Consistent with the aforementioned

literature (Adeyemo et al., 1981; Zavy et al., 1982; Berardinelli et al., 1992), the Bonsmara steers in this study had significantly lower plasma concentrations of cortisol, and a smaller area under the curve prior to ACTH than either the Angus or Bonsmara X Angus steers. Interestingly, five-months after the ACTH challenge, when the CRH challenge was conducted, the Bonsmara, as well as the Bonsmara X Angus steers had lower basal plasma concentrations of cortisol and a smaller pre-challenge area under the curve. As they matured, Bonsmara X Angus steers may have adapted more easily than the Angus steers to the stresses of handling, which would in turn decrease their basal concentrations of cortisol through decreased activation of the HPA axis. The lower plasma concentrations of cortisol noted in Bonsmara cattle corresponds with the calm temperament scores noted later in this section, which reaffirms the assertion that basal concentrations of cortisol are reflective of how stressful handling is to the animal.

Differences in adrenal gland function would have likely been manifested as differential amplitudes of cortisol response and areas under the curve in response to the bolus of ACTH; Bonsmara X Angus steers may have larger, or more ACTH-sensitive adrenal glands than the Bonsmara, as they had greater areas under the curve in response to ACTH. The similarity in area under the curve between Angus and Bonsmara X Angus suggests that adrenal size and (or) StAR protein expression may be similar between the two breeds.

The breedtype-associated differences in adrenal responsiveness to CRH may be due to sensitivity of the anterior pituitary to CRH, or the ACTH secretion patterns of the anterior pituitary (Veissier et al., 1999; McFarlane et al., 1995). Steers that were more

sensitive to CRH at the level of the anterior pituitary, or released greater quantities of ACTH, would likely have displayed greater adrenal responsiveness to CRH than steers with lessened sensitivity to CRH or lower capacity for ACTH secretion. Supporting the theory of differential modulation of the stress response by the anterior pituitary gland, the area under the curve in response to CRH was larger in Angus than in Bonsmara X Angus steers; anterior pituitary secretion patterns of ACTH which are more similar to those in the Bonsmara than those in the Angus steers could explain the lesser response to CRH seen in the Bonsmara X Angus steers.

The length of time required for Bonsmara steers to reach the maximal cortisol response to CRH indicates that the anterior pituitary gland of Bonsmara-influenced cattle is slower to release ACTH in response to CRH from the hypothalamus, or that ACTH is released in smaller amounts from the anterior pituitary gland of Bonsmara-influenced cattle than Angus cattle. Such a scenario could also result from decreased sensitivity of the anterior pituitary to CRH (Veissier et al., 1999). More research is merited into the differences in the HPA axes of beef cattle, with special reference to stabile composites such as the Bonsmara.

Comparison of Growth and Carcass Characteristics

The average rate of gain during the grazing period was similar among Angus, Bonsmara X Angus and Bonsmara steers, despite greater average plasma concentrations of cortisol in Angus steers. While excessive plasma concentrations of cortisol can depress gain through catabolic mechanisms, some studies have reported a greater rate of gain in cattle with elevated plasma cortisol; specifically, beef heifers confined to a 1.5-

m^2 pen had plasma concentrations of cortisol which were less than heifers confined to a 2.0 m^2 pen (Fisher et al., 1997); ADG was greater in heifers with elevated plasma concentrations of cortisol. The plasma concentrations of cortisol observed during the grazing period had neither beneficial nor deleterious effects on the growth of the Angus steers, indicating that they were not chronically elevated enough to have catabolic effects.

Subsequent to initiation of the feedlot phase, Angus steers gained weight more rapidly than Brahman steers. DeRouen et al. (1973), as well as Freetly and Cundiff (1997) noted a trend toward greater post-weaning ADG in Angus than Brahman cattle, thus offering direct support for our findings, and justifying why it generally takes Brahman steers longer to reach an acceptable slaughter weight than the Angus steers. Browning et al. (1995) characterized the superior pre-weaning growth of Angus X Brahman F-1 over purebred Brahman calves, inferring that incorporation of germ plasm from temperate breedtypes of cattle may help to increase the growth rate of tropically-adapted breedtypes. Demonstrative of this principle was the rate of gain observed in Bonsmara X Angus steers, which was similar to the rate of gain of Angus steers.

When maintained on the same plane of nutrition for a similar amount of time, purebred Angus steers have been reported to have greater adjusted back fat thickness than Brahman steers or steers with Afrikander influence (De Rouen et al., 1973; Wheeler et al., 2001). On the contrary, when a standard for adjusted back fat prior to slaughter is set, it is physiologically plausible for tropically-adapted breedtypes to acquire an amount of back fat equitable to that of temperate breedtypes (Strydom et al., 2000).

Accordingly, adjusted back fat thickness was similar among steers in this study, regardless of breedtype or degree of tropical adaptation

Temperament

It has been reported (Fordyce et al., 1982) that Brahman crossbred cattle react more violently to being placed in the squeeze chute than do Afrikander crossbred cattle, which in turn react more violently to handling than do British breeds such as the Shorthorn. It has also been noted that cattle with tropical influence (i.e. Brahman, Brahford, Afrikander) react more adversely to handling, and exit the chute in a more rapid manner than do temperate breedtypes (i.e. Hereford, Simmental, Fresian) of cattle (Hearnshaw and Morris, 1984; Fordyce et al., 1988a). Conversely, we found that temperate Angus and tropically-adapted Brahman had similar temperaments, while both the Bonsmara and Bonsmara X Angus crossbred steers (representative of Afrikander cross cattle) were more docile than the Angus and Brahman steers. Because of the diverse background of the steers we used for this trial, it is possible that pre-weaning management practices may have altered the temperament of the steers in different ways; Brahman steers were part of a university herd of research cattle that are periodically handled in a calm manner, whereas the Angus came from a ranch situation using handling techniques of which we are unaware. It is possible that the Angus used in this study would have been more calm had they been handled in a different manner as calves.

The fear of human contact conveyed by exit velocity helps to explain why cattle with calm temperament gain weight more rapidly than purportedly excitable breedtypes such as the Brahman (Voisinet et al., 1997). An animal that is fearful of human contact

(as in a feedlot situation, where they have daily contact with humans) will likely expend more energy in avoiding humans than will an animal that is not afraid of humans; additionally, less docile animals may consume less feed due to their anxiety about contact with humans. Taking into account the more docile behavior exhibited by the Bonsmara steers in this study, previous studies corroborate this assertion by reporting greater ADG in Bonsmara than in Brahman bulls (Kreiner et al., 1991).

Physical and Physiological Assessment of Heat Stress

Physical Measurements. Heat, humidity and solar radiation are several environmental factors which contribute to heat stress (Gebremedhin, 1985). Because of the potentially damaging effects of heat stress on production traits of beef steers, and the resistance to heat stress typically exhibited by breedtypes of cattle with some degree of tropical adaptation, comparison of the physical and physiological manifestations of heat stress in different breedtypes of beef steers may be useful. We measured and compared respiration rate, rectal temperature, surface temperature, serum concentrations of cortisol and aldosterone, serum concentrations of metabolites and electrolytes, hematological values and immune parameters of steers exposed to moderate ambient temperatures and humidity.

Evaporative cooling by the respiratory tract occurs as fresh air is inspired and heat and CO_2 are expelled. Increased heat load will frequently be accompanied by increased respiration rate as the animal's body attempts to maintain thermo-neutrality in relation to the ambient temperature by dissipating heat load. Evaporative cooling from the respiratory tract accounts for about 32% of the total heat loss from steers exposed to

ambient temperatures of 35ºC (Thompson, 1985), while the remainder of evaporative cooling occurs from the skin. At high environmental temperatures, panting begins, thus increasing respiratory rate (Thompson, 1985); concurrently, blood flow to the skin and sinus passages increases, allowing for greater blood cooling potential. Respiration rates of temperate beef cattle exposed to heat and humidity are greater than those of tropically-adapted beef cattle (Carvalho et al., 1995; Hammond et al., 1998). As respiration is one method animals use to dissipate heat, it can be inferred that the steers which respire more slowly are more tolerant to heat, or more efficient at dissipating heat in other manners, such as through increased surface heat emissions via superior surface area or subcutaneous blood flow. Tropically-adapted Brahman steers have decreased respiration rates when compared to their temperate contemporaries; the tropical-influence in the breeding of the Afrikander-influenced steers may explain their slower respiration rates during mild heat.

Rectal temperatures of temperate beef cattle exposed to 37ºC heat and 60 to 65% relative humidity have been shown to be greater than those of tropically-adapted beef cattle exposed to the same ambient environmental conditions (Carvalho et al., 1995; Hammond et al., 1996). In our study, rectal temperatures were similar between temperate Angus and tropically-adapted Brahman steers, while only the rectal temperature of temperate-tropically-adapted composite Bonsmara and Bonsmara X Angus crossbred steers were lower than those of Angus steers. Rectal temperature was positively associated with temperament and exit velocity, indicating that the elevated rectal temperature observed in the less docile breedtypes may be attributed to the stress

associated with human contact, rather than heat stress; this theory agrees with one proposed by Hammond et al., (1996), which also postulated that there is a relationship between response to stress and rectal temperature.

Animals transmit thermal energy across the surface of their skin, according to the laws governing convection, which is the exchange of heat between the animal and their surrounding environment (Gebremedhim, 1985). The arterial system governing arterial heat exchange through the surface of the skin in cattle is at a more shallow location in the skin of heat-adapted breedtypes of cattle than in non-heat adapted temperate breedtypes (Rubsamen and Hales, 1985), which helps to facilitate efficient heat exchange in tropically-adapted breedtypes. Digital infrared thermal imaging (DITI) measures the amount of heat on the surface of the animals hide. The heightened heat dissipation seen in the less docile Angus and Brahman breeds may be attributed to contact stress in much the same manner as rectal temperature, although little information on either digital infrared thermography or temperament in cattle exists at the present time.

Adrenal Hormones. The thermo-neutral zone for beef cattle, as expressed in terms of ambient temperature is 13ºC to 25ºC (Yousef, 1985). The Missouri Extension Service indicates that high temperatures compounded by high humidity begin to have deleterious effects on cattle when the temperature-humidity index rises above 75; as acute heat stress is perceived, circulating concentrations of cortisol increase (Silanikove, 2000). Upon exposure to ambient temperature above the thermo-neutral zone, a rise in circulating concentrations of cortisol is typically seen (Yousef and Johnson, 1985b);

conversely, prolonged exposure to high ambient temperature has actually been shown to depress cortisol turnover rate and plasma concentrations of cortisol. It has been suggested that such a decrease in adrenal cortisol output may be mediated by a rise in core body temperature, which results in decreased blood flow to the large intestine, tongue and adrenal gland (Rubsamen and Hales, 1985).

Previous studies have reported that when exposed to temperature-humidity index (THI) conditions above 75, Brahman cattle have higher plasma cortisol and temperament scores than do Angus steers (Hammond et al., 1996), indicating that Angus are stressed by high environmental temperatures and humidity more easily than the tropically-adapted Brahman cattle. Contrary to this report, serum concentrations of cortisol did not differ between Angus and Brahman steers when they were assessed at the end of the grazing period when THI conditions were below 75, or near the completion of the finishing stage, when THI conditions were above 75, although Angus steers had higher serum concentrations of cortisol near the completion of the finishing stage than the Bonsmara X Angus steers, indicating that the Angus may have been approaching heat stress, while the Brahman, Bonsmara and Bonsmara X Angus steers were not significantly affected by the environment. The relative lack of difference in circulating concentrations of cortisol between temperate and tropically-adapted steers could be attributed to the reasonably low average temperature-humidity index of 69.4 ± 0.2 at the end of the grazing period. The relative lack of serum cortisol differences near the completion of the finishing stage could be caused by the relative lack of solar radiation and heat as the steers were processed in a covered chute system prior to blood being

harvested.

Aldosterone is a steroid hormone produced in the adrenal gland which acts to maintain blood volume by facilitating fluid retention by triggering the reabsorption of electrolytes, and consequently water, from the kidney into the bloodstream (Rubsamen and Hales, 1985). Serum concentrations of aldosterone during the course of, and at the conclusion of the grazing stage, when temperatures were below 20ºC were similar between temperate Angus steers and tropically-adapted Brahman steers, suggesting that at lower temperatures Brahman and Angus cattle have similar ease in maintaining blood volume. Serum aldosterone was not different at the conclusion of the grazing phase among Angus, Bonsmara X Angus and Bonsmara steers, although when serum concentrations of aldosterone were measured two months prior to the end of the grazing phase, Angus steers had higher serum concentrations of aldosterone than either Bonsmara X Angus or Bonsmara steers.

Cattle exposed to 35ºC heat for 24 h experience a reduction in plasma aldosterone, which is associated with a decrease in serum concentrations of both sodium and potassium (Yousef and Johnson, 1985a). *In-vitro*, adrenocortical cells incubated at 37ºC secreted about twice as much aldosterone as adrenocortical cells incubated at 40ºC (Davis et al., 1988) indicating that there may be temperature-sensitive enzymes responsible for the conversion of either corticosterone to 18-hydroxycorticosterone or 18-hydroxycorticosterone to aldosterone. In accordance with the aforementioned literature, following the conclusion of the feedlot stage, in August, serum concentrations of aldosterone were depressed in all four breedtypes studied.

At that time, serum concentrations of aldosterone were greater in Brahman than in temperate Angus steers. In addition, tropically-influenced Bonsmara steers had greater serum concentrations of aldosterone than either Bonsmara X Angus or Angus steers. The relative depletion of aldosterone among all breedtypes suggests that the 33ºC weather conditions, compounded by 50% humidity (which equates to a THI value of 82) may have been sufficient enough to deplete serum concentrations of aldosterone among all breedtypes. The more temperate breedtypes (Angus and Bonsmara X Angus) had the lower plasma concentrations of aldosterone; because of the increased susceptibility to heat stress of temperate breedtypes, serum concentrations of aldosterone in these steers may have been depleted sooner or to a greater extent by exposure to the heat.

Intravenous infusion of aldosterone in cattle has been associated with depressed serum sodium concentrations and elevated potassium concentrations (Riad et al., 1986). Conversely, data resulting from analysis of serial blood collection samples from dairy cattle during the course of a 22-h period showed a negative association between potassium and aldosterone (Aranas et al., 1987). When the body attempts to maintain blood volume, serum concentration of aldosterone rises, thereby increasing the amount of sodium (and consequently fluid volume) in the circulation. As the body becomes dehydrated, a negative correlation exists between aldosterone and sodium, and, potassium is usually negatively correlated to aldosterone. The more efficient the body is at combating dehydration, the more closely the correlations among aldosterone, potassium and sodium conform to these standards. Near the end of the finishing period, when environmental temperature was greatest, steers with a greater degree of tropical

adaptation (i.e. Brahman) had higher serum aldosterone which was positively correlated to sodium, indicating that their bodies were working to avoid dehydration. Angus and Bonsmara X Angus steers did not appear to be activating the secretion of aldosterone in order to maintain blood volume, which may be help to explain why they displayed more physical symptoms of heat stress following the completion of the grazing stage. Bonsmara steers had high serum concentrations of aldosterone and lower serum concentrations of sodium, signifying that they were not depleted of serum aldosterone as the Angus-influenced steers were, but the aldosterone had not affected sodium reabsorption to the same degree as it had in the Brahman steers.

Serum Electrolytes. Sodium, potassium and chloride are three electrolytes which are key in maintaining the osmotic balance as they are transferred between the kidney and the blood, subsequently helping to control systemic water retention. Dehydration, a state common during extended exposure to heat and/or water deprivation, such as in transport, is characterized by an increased serum concentrations of sodium (Rumsey and Bond, 1976). Serum sodium concentrations were greater in Angus steers than in Brahman steers in both May and August, while Bonsmara and Bonsmara X Angus steers had serum sodium concentrations similar to those found in the Angus steers. Because thermoregulation is in part controlled through the manipulation of blood volume, it makes sense that temperate Angus steers would have elevated concentrations of serum sodium, indicating the need to conserve body fluids. The difference in serum concentrations of electrolytes among breeds with differing degrees of tropical adaptation is related to the differing needs for efficient thermoregulation.

Previous studies have shown mean serum concentrations of sodium to be greater, and potassium to be less in cows administered ACTH than in cows given only saline, indicating that the stress response may play a role in regulating serum concentrations of sodium and potassium (Varner and Johnson, 1983). Further studies suggest that an increase in serum sodium may be consistent with handling stress, and thus may not be similar to heat stress alone (Schaefer et al., 1997). Together, with the increased serum concentration of sodium, handling stress can elicit an increase in serum chloride. Despite the differing responses to handling exhibited by different breedtypes, serum chloride did not differ by breedtype or degree of tropical-adaptation. It has been previously reported that potassium does not differ between temperate and tropically-adapted cattle (Ramirez et al., 1992), and does not change in concentration based on the degree of dehydration (Rumsey and Bond, 1976). In this study, potassium did not differ by breed or degree of adaptation following the conclusion of the grazing phase, or near the end of the finishing phase.

Serum Metabolites. Godfrey et al. (1991) observed greater serum urea concentrations among Brahman calves than Brahman X Angus crossbred calves maintained at thermo-neutral temperatures. Ramirez et al. (1992) reported greater serum concentrations of urea in tropically-adapted cattle than in temperate ones. Elevation of serum urea or glucose in all three tropically-influenced breedtypes over the temperate Angus steers was somewhat unexpected, as elevated serum concentrations of urea and glucose are typically associated with elevated plasma concentrations of cortisol, which mobilizes glycogen stores and the antagonizes insulin (Varner et al., 1983), and the

Bonsmara and Bonsmara X Angus had lower plasma concentrations of cortisol. Some adaptation-associated difference in serum glucose was expected, as calves of purebred tropically-adapted lineage have been shown to have greater serum concentrations of glucose than temperate-tropically-adapted crossbred calves when maintained at temperatures in the thermo-neutral zone (Ramirez et al., 1992; Godfrey et al., 1991).

It is unclear whether the greater serum concentrations of these metabolites in tropically-influenced cattle is due to the catabolic effects of stress (and stress related hormones) or differences in endocrine factors which impact metabolism. Further research regarding metabolic differences in temperate and tropically-adapted breedtypes, including differential expression of genes and hormones governing growth, is warranted.

Serum cholesterol concentrations were greater in steers with tropical influence than in temperate breedtype Angus steers. These results concur with findings of Wheeler et al. (1987) and Ramirez et al. (1992), in that they found serum cholesterol concentrations of purebred temperate breedtype steers tend to be less than those of Brahman crossbred steers. It is possible that the increased serum concentrations of cortisol are related to a lesser steroidogenic capacity of the tropically-adapted breedtypes resulting from less expression of StAR protein; the depressed rate of cholesterol transport compared to Angus steers leaves more free cholesterol in the blood.

Immunological Parameters. Wilson et al. (2002) concluded that normal handling of beef steers in either a feedlot or pasture arrangement did not disrupt immune function in a substantial enough manner to produce significant depression of most immune parameters. It is likely that the mild heat stress experienced by the steers when

blood samples were obtained for evaluation of immune parameters was not enough to exert much effect. The discrepancy in total white blood cell count observed between Bonsmara and Bonsmara X Angus steers can likely be explained by the greater relative abundance of lymphocytes in Bonsmara steers (Figure 60). Hopster et al. (1998) suggests that stress-responsiveness, specifically, the prevalence of Cortisol, modulates the number of peripheral lymphocytes. Because Bonsmara steers have generally lower plasma concentrations of cortisol, it is possible that lymphocyte numbers are better able to proliferate in Bonsmara steers than in the other breedtypes studied here.

The hypothesis that adrenal responsiveness to ACTH and CRH varies by breedtype among beef steers of temperate, tropically-adapted or temperate-tropically-adapted composite lineage is correct. The hypothesis that growth and carcass characteristics also varied by breedtype among beef steers of temperate, tropically-adapted or temperate-tropically-adapted composite lineage was also correct. The hypothesis that physical and physiological parameters of heat stress vary by breedtype among beef steers of temperate, tropically-adapted or temperate-tropically-adapted composite lineage was also correct, although a more distinct physical and physiological difference would be observed, had the hypothesis been that physical and physiological parameters of severe heat stress vary by breedtype among beef steers of temperate, tropically-adapted or temperate-tropically-adapted composite lineage.

CHAPTER VIII

GENERAL CONCLUSIONS

The data from this study indicate that Angus and Brahman steers have greater basal plasma concentrations of cortisol than Bonsmara or Bonsmara X Angus steers when exposed to normal handling practices involving interaction with humans. Angus have a greater adrenal cortisol release than Brahman steers in response to stimulation with exogenous ACTH; this could be facilitated by a larger adrenal gland and increased quantities of StAR protein in Angus compared to Brahman steers. Bonsmara take longer to respond to CRH administration than Angus steers, indicating there may be breedtype associated differences in sensitivity to CRH at the level of the anterior pituitary, and different degrees of vasopressin mediation in the stress response between breedtypes. As further evidence of differential modulation of the stress response, it took longer for plasma cortisol concentrations to return to basal in Bonsmara than in Angus steers. Further studies are merited to assess differences in modulation of the stress response, as well as the implications of the lower basal concentrations of cortisol and slower adrenal response time on growth and reproduction.

In terms of temperament, Bonsmara and Bonsmara X Angus steers behaved in a docile manner, whereas Angus and Brahman steers were more anxious and aggressive, which may in part explain the higher basal plasma concentrations of cortisol seen in those breedtypes during the pre and post-challenge periods of the ACTH and CRH challenges. Implications of ill temperament go beyond diminished ease and safety of handling. Ill-temperament may help to explain the compromised growth characteristics

and carcass quality seen in some breedtypes. While on pasture, all breedtypes gained equally well; however, Bonsmara steers more closely resembled the tropically-adapted Brahman steers in their demonstrated growth rate during the finishing stage, which was lower than that seen in Angus or Bonsmara X Angus steers. In evaluating these data, one must consider the relative scarcity of Bonsmara-type cattle in the United States, only the least valuable bull calves were castrated for this study, and thus may not be representative of the population in its entirety. Trials conducted in areas with greater relative abundance of this breed have reported greater rate of gain than that witnessed herein, indicating that their actual rate of gain as a breedtype may be more similar to that of Angus steers. This theory is supported by the similarities in carcass characteristics seen among Angus, Bonsmara X Angus and Bonsmara steers; while Angus steers had greater hot carcass weight and rib-eye area than Brahman steers, the same characteristics did not differ among Angus, Bonsmara X Angus and Bonsmara steers. While Angus steers graded higher than Brahman, Bonsmara X Angus and Bonsmara steers, the aforementioned similarities between carcasses from Angus, Bonsmara X Angus and Bonsmara steers suggest that intermediate breedtypes such as the Bonsmara may provide a compromise to producers, allowing them to address the demands of consumers while marketing animals which are better suited to survival in tropical climates than are many temperate breedtypes.

The Gulf Coast region of Texas is a semi-tropical climate, which is active in animal agriculture, and has a large number of cow/calf and stocker operations. In a region such as this, which is rich in forage and water, environmental conditions are a

major constraint to the success of beef cattle operations. For a majority of the year cattle are exposed to high environmental temperatures which are only intensified by the high humidity, and solar radiation. The influence of a tropically-adapted lineage was apparent in Bonsmara, Bonsmara X Angus and Brahman steers when parameters of heat stress were assessed under the aforementioned environmental conditions. At environmental temperatures of 25ºC and a THI of 65.85 the temperate Angus steers had a greater respiration rate than the heat-adapted Bonsmara or Bonsmara X Angus steers, or the tropically-adapted Brahman steers, indicating that they were working harder to dissipate heat through evaporative cooling in the lungs. Rectal temperature and right side surface temperature, is lower in Bonsmara and Bonsmara X Angus steers than Angus steers, which have temperature values similar to those of Brahman steers; because the greater rectal temperatures in Angus and Brahman steers correspond to their more excitable temperaments, it may be reasonable to conclude that heightened rectal temperatures were resultant of human interaction, and not thermal stress. At high environmental temperatures, Angus steers also had lower aldosterone than the tropically-influenced breedtypes, suggesting that prolonged exposure to heat more quickly depletes their serum concentrations of aldosterone, thus compromising blood volume maintenance and increasing the potential for dehydration.

The results of this study support the use of stable composites, such as the Bonsmara as a part of crossbreeding programs in beef cattle herds. Such composite breedtypes incorporate heat resiliency similar to that found in tropically-adapted breedtypes, while preserving the desirable growth and carcass characteristics

characteristic of temperate breedtypes. Breedtypes of beef animals that react more evenly to handling, and also display calmer temperaments are cattle that facilitate safe handling and better preservation of working facilities, while yielding a more desirable carcass compared to breedtypes that are ill tempered. By utilizing progressive management techniques, which incorporate the use of effective crossbreeding programs, producers in warmer climates can incorporate heat adaptation traits into their herds without compromising growth or carcass characteristics; such management techniques could minimize the deleterious effects of heat stress and, in turn, help to maximize profit.

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APPENDIX A

Example SAS Model Used For Statistical Analysis

```
options ls=75 ps=50 nocenter;
title 'Thesis SAS for Angus and Brahman';
data opn;
input Breed $ ID PreACTH PreCRH Tm0ACTH Tm0CRH
      AmpACTH AmpCRH PkACTH PkCRH TmPkACT
      TmPkCRH TmRtACT TmRtCRH PBACTH PBCRH
      PB5ACTH ADGGraz ADGFdlt UBFTin FT AFT QG
      HCWTREA YG DOF CarcVal KPH DecCS JanCS FebCS
      MarACS MarBCS AprCS MayCS AvMtCS M-Ca A-Ca
      M-Phos A-Phos M-Mg A-Mg M-Alb A-Alb M-Urea A-
Urea  M-Glu A-Glu M-Chol A-Chol M-B-HBA A-B-HBA M-Na
      A-Na M-K A-K M-Cl A-Cl M-Hgb A-Hgb May CS Aug CS
      MarAld MayAld AugAld EscVel Behav Breaths/Min. Rect.
Temp. WBC DNP DLC DMC DEP ANP ALC AMC AEP RBC HGB
      PCV MCV MCH MCHCPP FBG;
cards;
A  27   Values for each parameter in model statement…
A  28   Values for each parameter in model statement…
A  37   Values for each parameter in model statement…
A  38   Values for each parameter in model statement…
A  48   Values for each parameter in model statement…
A  49   Values for each parameter in model statement…
A  50   Values for each parameter in model statement…
A  73   Values for each parameter in model statement…
A  75   Values for each parameter in model statement…
A  948  Values for each parameter in model statement…
B  1001 Values for each parameter in model statement…
B  1006 Values for each parameter in model statement…
B  1008 Values for each parameter in model statement…
B  1017 Values for each parameter in model statement…
B  1020 Values for each parameter in model statement…
B  1021 Values for each parameter in model statement…
B  1023 Values for each parameter in model statement…
B  1036 Values for each parameter in model statement…
B  1039 Values for each parameter in model statement…
B  1040 Values for each parameter in model statement…
;
proc sort; by breed id;
proc print;
proc glm;
```

```
classes breed ID;
model PreACTH      PreCRH      Tm0ACTH     Tm0CRH      AmpACTH
      AmpCRH       PkACTH      PkCRH       TmPkACT     TmPkCRH
      TmRtACT      TmRtCRH     PBACTH      PBCRH       PB5ACTH
      ADGGraz      ADGFdlt     UBFTin      FT     AFT  QG     HCWTREA
      YG     DOF   CarcVal     KPH    DecCS JanCS  FebCS MarACS
      MarBCS       AprCS MayCS         AvMtCS      M-Ca  A-Ca  M-Phos
      A-Phos       M-Mg  A-Mg  M-Alb  A-Alb  M-Urea       A-UreaM-Glu A-Glu
      M-Chol       A-Chol      M-B-HBA     A-B-HBA     M-Na  A-Na  M-K
      A-K    M-Cl  A-Cl  M-Hgb A-Hgb May CS         Aug CS        MarAld
      MayAld       AugAld      EscVel Behav  Breaths/Min.  Rect. Temp.   WBC
      DNP    DLC   DMC   DEP   ANP    ALC   AMC   AEP   RBC   HGB   PCV
      MCV    MCH   MCHCPP      FBG
=breed/ss1 ss3;
lsmeans breed/stderr pdiff;
proc corr;
proc corr; by breed;
proc corr spearmans;
proc corr spearmans; by breed;
run;
```

APPENDIX B

Cortisol Radioimmunoassay Technique

Preparation of reagents

PBSG (0.01 M Phosphate Buffered Saline w/0.1% gel)

1) Dissolve the following in 900 mL de-ionized water in a 1000 mL beaker at room temperature while stirring:

8.17 g NaCl

0.856 g NaH_2PO_4 H_20 (monobasic)

0.54 g NaH_2PO_4 (dibasic)

3.2 g EDTA

0.1 g Thimerosal powder (Merthiolate)

2) Adjust pH to 7.0 with NaOH and transfer the EDTA-PBS solution to a liter volumetric flask. Qs with de-ionized water.

3) Put 1.0 g gelatin to a 1.0 liter bottle and add the EDTA-PBS solution from step #2.

4) Dissolve gelatin by stirring over low heat for approximately 2 h.

5) Store at 4ºC.

Charcoal-Dextran Suspension

1) Combine 500 mL de-ionized water, 3.125 g Charcoal Norit SPXX and 0.3125 g Dextran Pharmacia T-70 in a 1.0 liter beaker.

2) Stir with a magnetic stir bar at medium speed until thoroughly mixed.

3) Store at 4ºC.

Preparation of Standards

*Standards are prepared by making an 8000 pg/500 µL stock solution **(Standard A)** of cortisol by adding 320 µL of 1 ug/mL cortisol to 19.68 mL PBSG, and performing 1:2 dilutions with PBSG in the manner described below.

Standard Tube	**Concentration of Cortisol in Standard Tube**		**Comprised of:**
B	4000 pg/500 µL	=	10 mL Standard A + 10 mL PBSG
C	2000 pg/500 µL	=	10 mL Standard B + 10 mL PBSG
D	1000 pg/500 µL	=	10 mL Standard C + 10 mL PBSG
E	500 pg/500 µL	=	10 mL Standard D + 10 mL PBSG
F	250 pg/500 µL	=	10 mL Standard E + 10 mL PBSG
G	125 pg/500 µL	=	10 mL Standard F + 10 mL PBSG
H	62.5 pg/500 µL	=	10 mL Standard G + 10 mL PBSG
I	31.25 pg/500 µL	=	10 mL Standard H + 10 mL PBSG
J	15.6 pg/500 µL	=	10 mL Standard I + 10 mL PBSG
K	7.8 pg/500 µL	=	10 mL Standard J + 10 mL PBSG
L	3.9 pg/500 µL	=	10 mL Standard K + 10 mL PBSG

Preparation of Trace

1) Reconstitute tritiated hydrocortisone with an known volume of EtOH.

2) Count 10 µL of the mixture on the beta counter and record the dilution factor.

3) Stock can be stored at -20ºC for 2 years.

4) To make working concentration of trace, dilute the stock solution with PBSG (for these assays, 30 mL PBSG: 300 µL stock trace.

5) Count for the working trace solution should be approximately 13,000 CPM.

Preparation of Pools

Low Pool

1 mL pooled steer serum

500 µL of 4000 pg/ 500 µL standard

500 µL of 1000 pg/ 500 µL standard

48 mL PBSG

Medium Pool

1mL pooled steer serum

500 µL of 8000 pg/ 500 µL standard

500 µL of 2000 pg/ 500 µL standard

48 mL PBSG

High Pool

1 mL pooled steer serum

3.0 mL of 8000 pg/ 500 µL standard

0.5 mL of 2000 pg/ 500 µL standard

45.5 mL PBSG

Preparation of the standard curve

* The standard curve(s) are prepared according to the table pictured below. "T" tubes

are total tubes, which contain only trace and are indicative of the total CPM of the trace being used. "N" tubes contain only trace, but have charcoal added prior to spinning the tubes; "N" tubes measure the amount of trace which is not removed by the charcoal. "O" tubes contain antibody and trace, and measure the total binding of the trace to the antibody.

Standard Name	**PBSG**	**Sample**	**Antibody**	**Tracer**	**Charcoal**
T	800	0	0	100	0
N	600	0	0	100	200
O	500	0	100	100	200
3.9	0	500	100	100	200
7.8	0	500	100	100	200
15.6	0	500	100	100	200
31.25	0	500	100	100	200
62.5	0	500	100	100	200
125	0	500	100	100	200
250	0	500	100	100	200
500	0	500	100	100	200
1000	0	500	100	100	200
2000	0	500	100	100	200
4000	0	500	100	100	200
8000	0	500	100	100	200

Performing the Assay

1) Pipette 40 µL plasma sample (in duplicate) into plain polystyrene 12 X 75 mm tubes.

2) Bring tubes volume to 500 µL by adding PBSG.

3) At this point tubes may be placed at 4C overnight, or –20C for several weeks.

4) If frozen, remove samples from –20C and thaw them.

5) Pipette low, medium, and high cortisol pools (500 µL/ tube).

6) Incubate pools and samples at 70ºC in a water bath for 1 h.

7) Pipette 500 µL of each standard into its respective 12 X 75 mm polystyrene tube(s).

8) Pipette 800 µL PBSG into T tubes, 600 µL into N tubes, and 500 µL into O tubes.

9) Make cortisol trace (13,000 CPM) by adding ~150 µL stock trace to 30 mL PBSG.

10) Remove sample tubes and pools from incubation at 70ºC, and allow them to stand at room temperature for 30 minutes, or until cool.

11) Integrate standard tubes into sample racks.

12) Add 100 µL cortisol antibody to all tubes except for T, and N tubes.

13) Add 100 µL trace (@ 13,000 CPM) to all tubes.

14) Shake tubes thoroughly and incubate at 4C overnight.

15) Turn carbon + dextran Charcoal onto spin at medium speed for ½ h.

16) Add 200 µL charcoal to all tubes but T tubes and vortex thoroughly.

17) Allow tubes to sit with charcoal for ~10 minutes.

18) Spin tubes in the centrifuge at 2,800 RPM and 4C for 20 minutes.

19) Fill scintillation vials with scintillation cocktail.

20) Pour off sample tube supernatant into scintillation vials, and shake them.

21) Cap vials with caps and place them on the beta counter machine.

APPENDIX C

Graphical Representation of Parameters Displaying No Breedtype Associated Difference

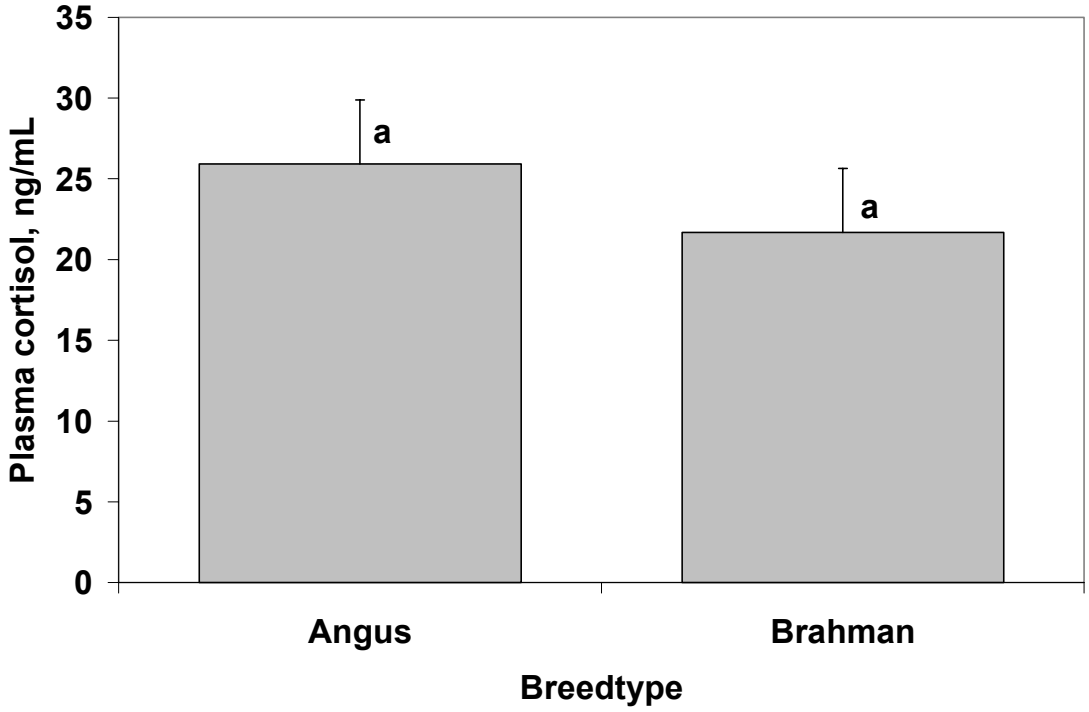

Figure 61. Plasma concentrations of cortisol during the 2.5-hour pre-ACTH challenge time-frame in Brahman and Angus steers.

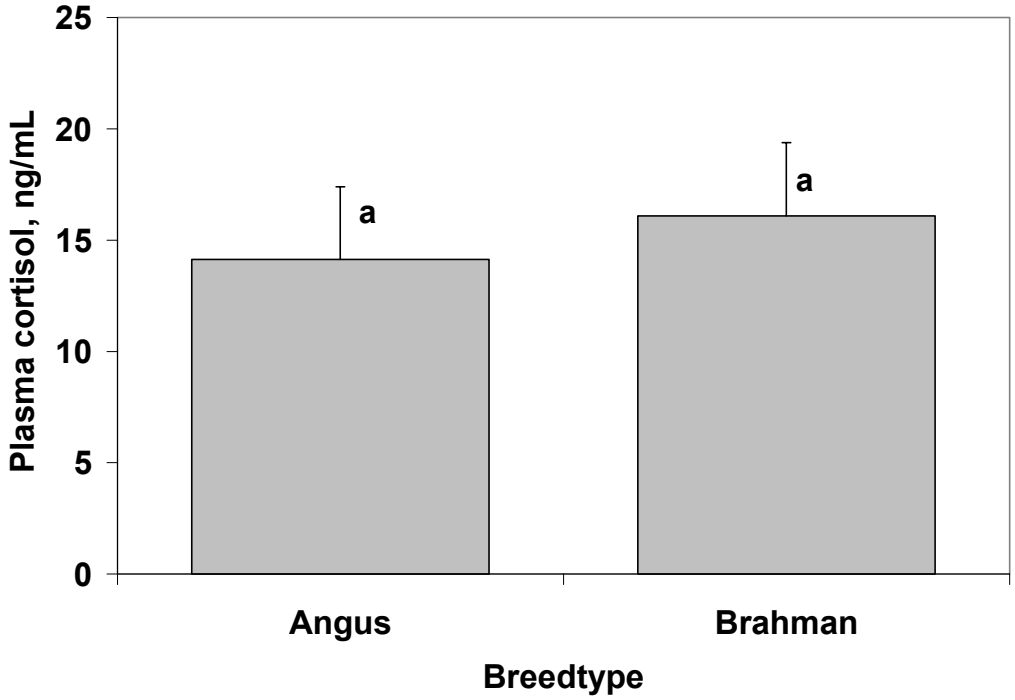

Figure 62. Plasma concentrations of cortisol just prior to ACTH administration (i.e., "time 0") in Angus and Brahman steers.

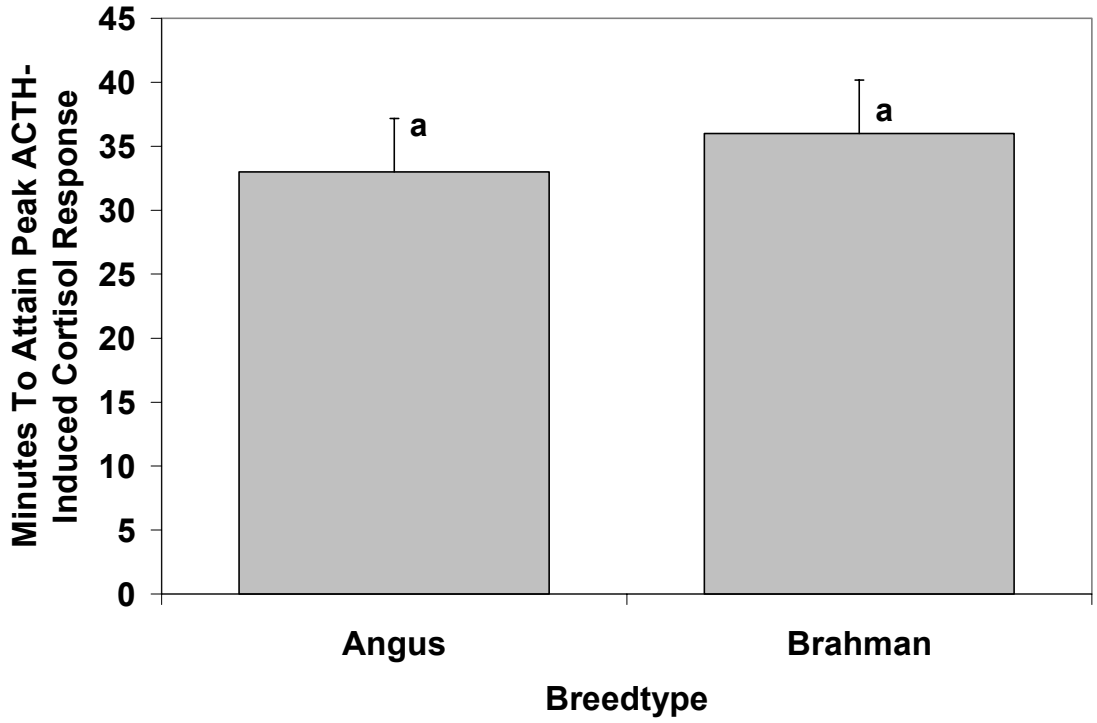

Figure 63. Amount of time required to attain the maximal cortisol response to ACTH in Brahman and Angus steers.

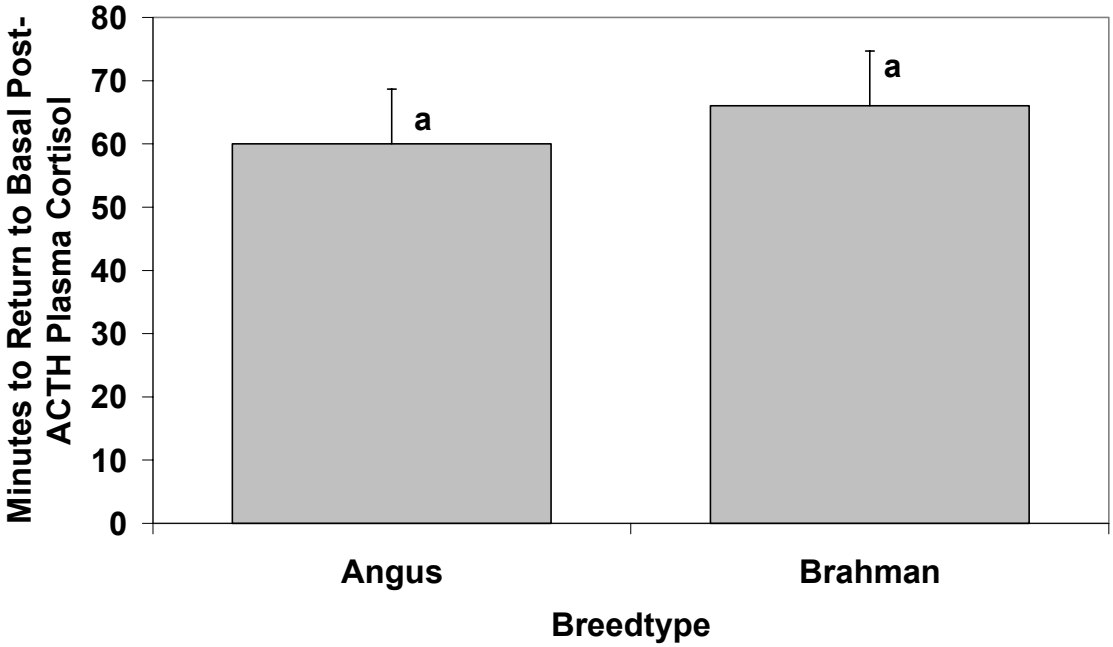

Figure 64. Amount of time required for plasma cortisol to return to pre-challenge basal concentrations in Brahman and Angus steers.

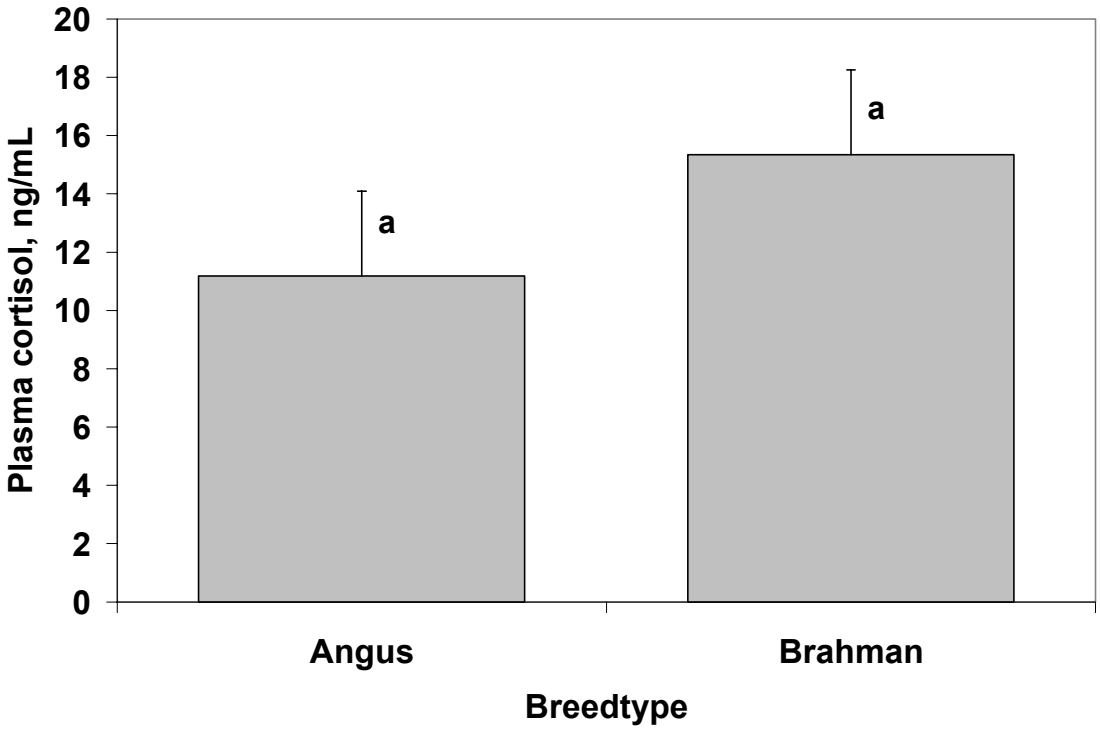

Figure 65. Post-ACTH challenge basal plasma concentration of cortisol in Brahman and Angus steers.

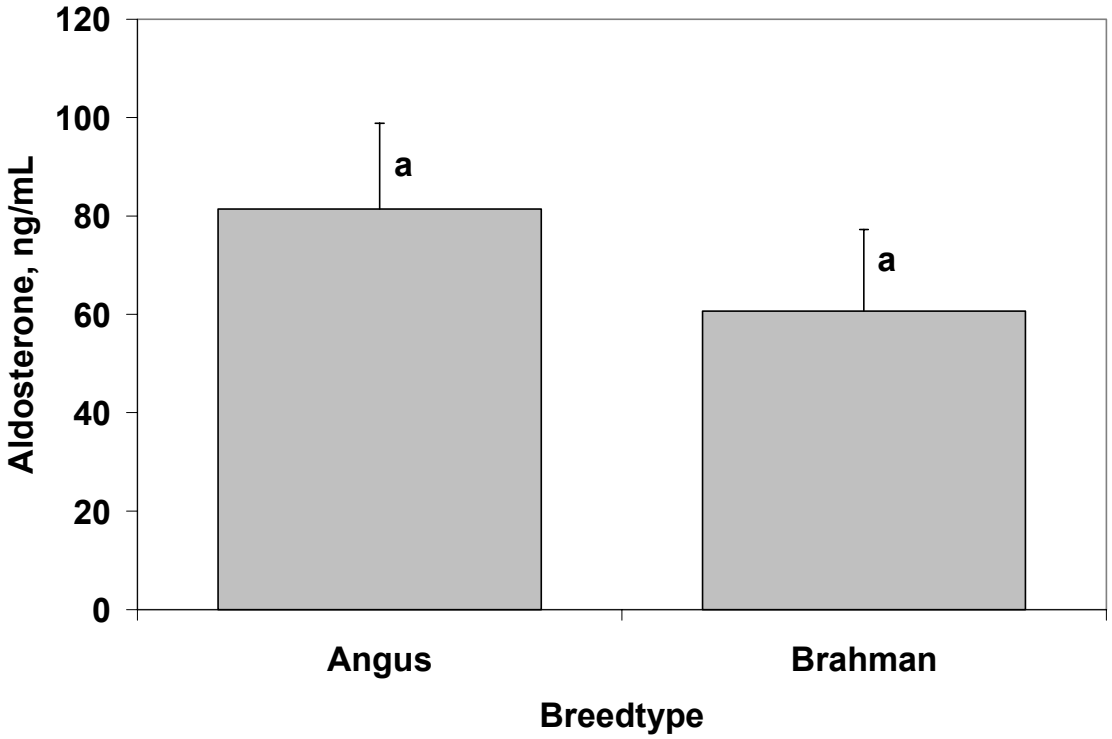

Figure 66. Serum concentrations of aldosterone in Angus and Brahman steers as measured in March, during the grazing stage. a, b differ $P<0.05$.

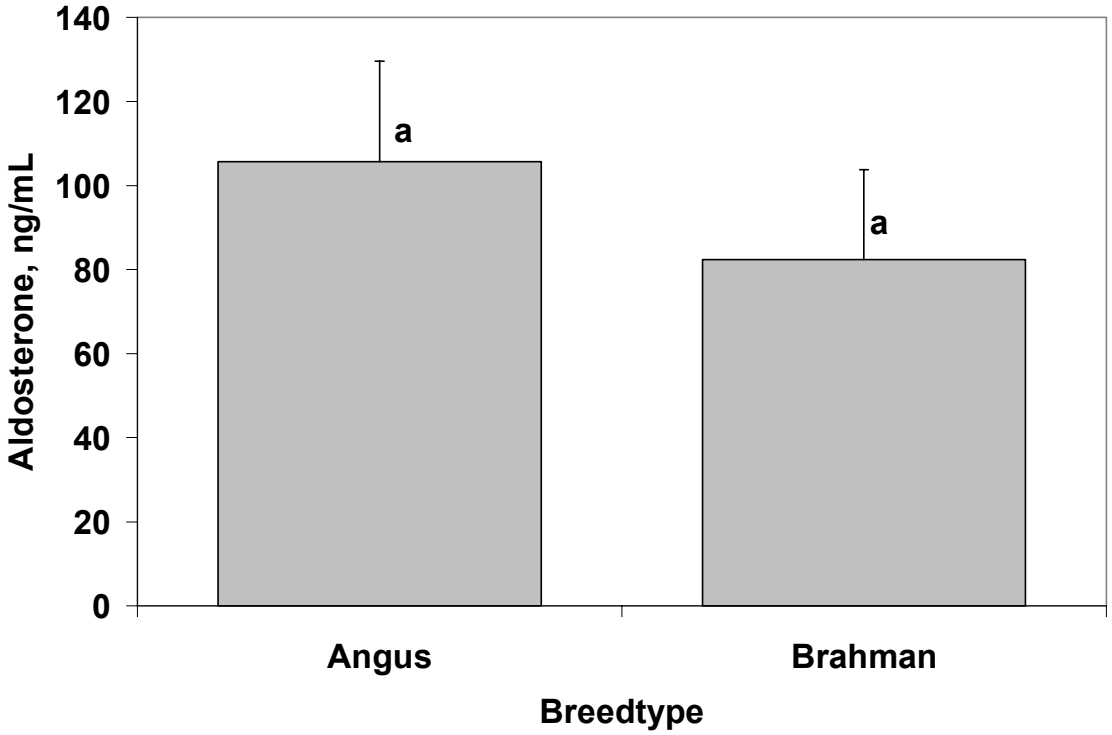

Figure 67. Serum concentrations of aldosterone in Angus and Brahman steers as measured in May, at the end of the grazing stage. a, b differ $P<0.05$.

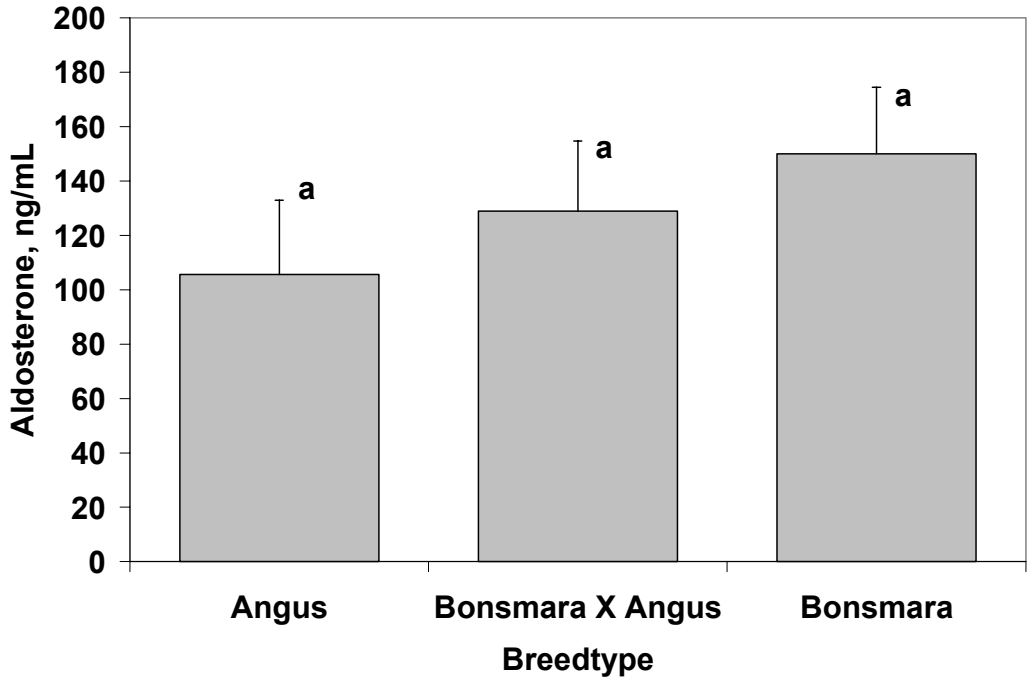

Figure 68. Peripheral blood concentrations of aldosterone in Angus, Bonsmara X Angus crossbred and Bonsmara steers as measured after the completion of the grazing phase. a, b differ $P<0.05$.

APPENDIX D

Table Detailing Values Which Were Not Statistically Different Between Angus and Brahman Steers

Growth and Carcass Characteristics						
	Angus			Brahman		
Grazing ADG (kg)	4.1	±	0.26	3.45	±	0.24
Adjusted Fat Thickness (cm)	1.22	±	0.1	0.97	±	0.1
Yield Grade	2.84	±	0.20	2.69	±	0.18
Carcass Value (Dollars)	718.25	±	18.76	679.39	±	16.78
%KPH	2.44	±	0.14	2.25	±	12.00
Monthly Assessment of Cortisol						
	Angus			Brahman		
Monthly Cortisol-December (ng/mL)	34.17	±	4.00	22.17	±	4.00
Monthly Cortisol-January (ng/mL)	41.51	±	6.45	29.82	±	6.45
Monthly Cortisol-February (ng/mL)	41.36	±	5.59	41.98	±	5.59
Monthly Cortisol-March 1 (ng/mL)	20.73	±	3.49	28.92	±	3.49
Monthly Cortisol-March 22 (ng/mL)	24.26	±	4.15	23.14	±	4.15
Monthly Cortisol-April (ng/mL)	27.87	±	3.81	29.56	±	3.81
Monthly Cortisol-May (ng/mL)	23.09	±	2.64	21.74	±	2.64
Average Monthly Cortisol (ng/mL)	31.52	±	3.09	28.19	±	3.09
Serum Metabolites Following the Grazing Phase						
	Angus			Brahman		
Serum Calcium (mg/dL)	9.64	±	0.14	9.78	±	0.13
Serum Phosphorus (mg/dL)	5.89	±	0.32	6.15	±	0.28
Serum Magnesium (meq/L)	1.86	±	0.08	1.74	±	0.08
Serum Albumin (g/dL)	3.56	±	0.08	3.37	±	0.07
B-Hba (umol/L)	280.25	±	15.74	282.00	±	14.08
Serum Potassium (meq/L)	5.35	±	0.16	5.23	±	0.14
Serum Chloride (meq/L)	100.88	±	1.05	98.20	±	0.94
Serum Metabolites Near the End of the Finishing Phase						
	Angus			Brahman		
Serum Phosphorus (mg/dL)	8.95	±	0.52	8.43	±	0.47
Serum Magnesium (meq/L)	1.85	±	0.08	1.90	±	0.07
Serum Albumin (g/dL)	3.58	±	0.08	3.55	±	0.07
Serum Urea (mg/dL)	16.66	±	1.90	19.49	±	1.70
Serum Glucose (mg/dL)	62.00	±	16.32	85.70	±	14.60
B-Hba (umol/L)	250.63	±	15.74	213.50	±	14.08

Serum Potassium (meq/L)	6.66	±	0.26	6.32	±	0.23
Adrenal Function Throughout Production						
	Angus			**Brahman**		
Heat Stress Cortisol Following Grazing (ng/mL)	14.46	±	3.75	20.61	±	3.35
Heat Stress Cortisol While Finishing (ng/mL)	20.60	±	2.39	22.28	±	2.14
Aldosterone While Grazing (ng/mL)	81.38	±	17.46	60.67	±	16.56
Aldosterone Following Grazing (ng/mL)	105.68	±	23.96	82.37	±	21.43
Temperament						
	Angus			**Brahman**		
Behavior Score	2.30	±	0.19	2.30	±	0.19
Physical Measurements of Heat Stress						
	Angus			**Brahman**		
Rectal Temperature (°C)	39.72	±	0.27	39.62	±	0.24
Dorsal DITI Value (°C)	37.65	±	0.41	37.19	±	0.27
Right Side DITI Value (°C)	36.54	±	0.35	35.87	±	0.29
Immunological Parameters						
	Angus			**Brahman**		
White Blood Cell Count/µL	9375.00	±	1338.90	9390.00	±	1197.50
Differential Neutrophil Percentage	23.38	±	3.65	22.20	±	3.26
Differential Lymphocyte Percentage	71.50	±	3.78	69.10	±	3.38
Differential Monocyte Percentage	2.71	±	0.62	2.50	±	0.58
Differential Eosinophil Percentage	3.00	±	1.32	6.30	±	1.02
Absolute Neutrophil Count/µL	2364.13	±	534.50	2053.11	±	503.90
Absolute Lymphocyte Count/µL	6560.13	±	852.60	7284.33	±	803.83
Absolute Monocyte Count/µL	203.29	±	62.06	213.71	±	66.34
Absolute Eosinophil Count/µL	315.50	±	193.23	665.89	±	157.77
Hematological Parameters						
	Angus			**Brahman**		
Red Blood Cell Count (X 10^6 cells/µL)	7.83	±	0.37	9.05	±	0.34
Hemoglobin (g/dL)	12.31	±	1.56	12.36	±	1.48
Packed Cell Volume (%)	34.16	±	1.24	35.56	±	1.17
Mean Corpuscular Volume (fl)	43.79	±	2.76	39.48	±	2.60
Mean Corpuscular Hemoglobin (pg)	15.78	±	1.81	13.76	±	1.70
Mean Corpuscular Hemoglobin Content (g/dL)	36.08	±	2.42	34.79	±	2.28
Plasma Protein (g/dL)	7.64	±	16.43	7.60	±	15.49
Fibrinogen (mg/dL)	362.50	±	46.37	344.44	±	40.90

APPENDIX E

Table Detailing Values Which Were Not Statistically Different Between Angus, Bonsmara X Angus and Bonsmara Steers

Growth and Carcass Characteristics									
	Angus			Bonsmara X Angus			Bonsmara		
Grazing ADG (Pounds)	1.86	±	0.12	1.74	±	0.12	1.85	±	0.12
Adjusted Fat Thickness (Inches)	0.48	±	0.04	0.42	±	0.04	0.46	±	0.04
Hot Carcass Weight (Pounds)	691.38	±	14.20	670.78	±	13.40	657.80	±	12.70
Rib-eye Area (Square Inches)	12.67	±	0.34	12.13	±	0.33	12.35	±	0.31
Yield Grade	2.84	±	0.16	2.78	±	0.15	2.73	±	0.14
Days on Feed	91.00	±	0.00	91.00	±	0.00	131.00	±	0.00
Carcass Value (Dollars)	718.25	±	18.70	676.26	±	17.60	687.69	±	16.70
%KPH	2.44	±	0.11	2.39	±	0.10	2.25	±	0.10
Monthly Assessment of Cortisol									
	Angus			Bonsmara X Angus			Bonsmara		
Monthly CS-December (ng/mL)	34.17	±	4.53	24.88	±	4.53	15.49	±	4.53
Monthly CS-January (ng/mL)	41.51	±	4.34	25.34	±	4.34	29.65	±	4.34
Monthly CS-February (ng/mL)	41.36	±	5.60	34.26	±	5.60	29.81	±	5.60
Monthly CS-March 1 (ng/mL)	18.66	±	3.52	20.30	±	3.52	20.07	±	3.52
Monthly CS-March 22 (ng/mL)	21.84	±	3.70	14.07	±	3.70	11.48	±	3.70
Monthly CS-April (ng/mL)	25.09	±	3.93	19.83	±	4.14	20.60	±	3.93
Monthly CSl-May (ng/mL)	20.78	±	2.87	17.45	±	3.00	21.26	±	2.87
Temperament									
	Angus			Bonsmara X Angus			Bonsmara		
Physical Measurements of Heat Stress									
	Angus			Bonsmara X Angus			Bonsmara		
Dorsal DITI Value (°C)	37.65	±	0.41	36.66	±	0.44	36.44	±	0.40
Serum Metabolites Following the Grazing Phase									
	Angus			Bonsmara X Angus			Bonsmara		
Serum Calcium (mg/dL)	9.64	±	0.11	9.29	±	0.10	9.86	±	0.09
Serum Phosphorus (mg/dL)	5.89	±	0.40	6.69	±	0.32	6.69	±	0.30
Serum Magnesium (meq/L)	1.86	±	7.16	1.69	±	6.75	1.72	±	6.40
Serum Albumin (g/dL)	3.56	±	0.08	3.36	±	0.08	3.50	±	0.07
Serum Glucose (mg/dL)	85.88	±	5.99	87.11	±	5.64	76.10	±	5.35
B-Hba (umol/L)	280.25	±	3.22	249.33	±	31.32	252.40	±	29.71
Serum Sodium (meq/L)	141.63	±	1.19	142.33	±	1.12	141.70	±	1.06
Serum Potassium (meq/L)	5.35	±	0.12	5.07	±	0.12	5.23	±	0.11

Serum Chloride (meq/L)	100.88 ± 1.07	100.56 ± 1.01	100.30 ± 0.96
Serum Metabolites Near the End of the Finishing Phase			
	Angus	Bonsmara X Angus	Bonsmara
Serum Calcium (mg/dL)	11.95 ± 0.28	9.94 ± 0.26	10.56 ± 0.25
Serum Phosphorus (mg/dL)	8.95 ± 0.42	8.00 ± 0.39	8.14 ± 0.37
Serum Albumin (g/dL)	3.58 ± 0.06	3.71 ± 0.06	3.63 ± 0.05
B-Hba (umol/L)	250.63 ± 21.38	215.00 ± 20.15	197.40 ± 19.12
Serum Sodium (meq/L)	141.25 ± 1.18	138.00 ± 1.11	139.50 ± 1.06
Serum Potassium (meq/L)	6.66 ± 0.20	6.43 ± 0.19	6.26 ± 0.18
Serum Chloride (meq/L)	101.00 ± 0.88	100.22 ± 0.83	101.00 ± 0.78
Adrenal Function in Throughout Production			
	Angus	Bonsmara X Angus	Bonsmara
Heat Stress CS Following Grazing (ng/mL)	14.46 ± 3.04	15.83 ± 2.88	14.47 ± 2.73
Heat Stress CS While Finishing (ng/mL)	20.60 ± 2.79	10.98 ± 2.63	16.90 ± 2.50
Aldosterone Following Grazing (ng/mL)	105.68 ± 27.30	128.93 ± 25.70	149.98 ± 24.40
Immunological Parameters			
	Angus	Bonsmara X Angus	Bonsmara
Differential Neutrophil Percentage	23.38 ± 3.48	19.89 ± 0.28	22.60 ± 3.11
Differential Lymphocyte Percentage	71.50 ± 3.67	75.56 ± 3.46	72.80 ± 3.29
Differential Monocyte Percentage	2.71 ± 0.58	2.00 ± 0.62	2.90 ± 0.52
Differential Eosinophil Percentage	3.00 ± 597.68	2.78 ± 488.00	2.00 ± 517.00
Absolute Neutrophil Count/µL	2364.13 ± 615.00	1484.44 ± 597.82	2340.70 ± 550.06
Absolute Monocyte Count/µL	203.29 ± 85.96	149.86 ± 91.90	370.60 ± 76.89
Absolute Eosinophil Count/µL	315.50 ± 58.47	183.78 ± 47.74	238.88 ± 50.63
Hematological Parameters			
	Angus	Bonsmara X Angus	Bonsmara
Red Blood Cell Count (X 10^6 cells/µL)	7.83 ± 0.30	8.15 ± 0.28	8.36 ± 0.27
Hemoglobin (g/dL)	12.31 ± 1.24	12.10 ± 1.17	11.65 ± 1.11
Mean Corpuscular Volume (fl)	43.79 ± 2.35	41.22 ± 2.21	39.44 ± 2.10
Mean Corpuscular Hemoglobin Content (g/dL)	36.08 ± 1.90	36.14 ± 1.79	35.54 ± 1.70
Plasma Protein (g/dL)	7.64 ± 12.99	7.38 ± 12.24	7.75 ± 11.61

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Publications

Five Abstracts (Presented Four)