SERUM CONCENTRATIONS OF CORTISOL INDUCED BY EXOGENOUS ADRENOCORTICOTROPIC HORMONE (ACTH) ARE NOT PREDICTIVE OF RESIDUAL FEED INTAKE (RFI) IN BRAHMAN CATTLE

A Senior Scholars Thesis

by

BRYAN JOSEPH AGADO

Submitted to the Office of Undergraduate Research
Texas A&M University
in partial fulfillment of the requirements for the designation as

UNDERGRADUATE RESEARCH SCHOLAR

April 2009

Major: Biomedical Science
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Associate Dean for Undergraduate Research: Robert C. Webb

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ABSTRACT

Serum Concentrations of Cortisol Induced by Exogenous Adrenocorticotropic Hormone (ACTH) Are Not Predictive of Residual Feed Intake (RFI) in Brahman Cattle. (April 2009)

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Identification of feed efficient cattle by determination of residual feed intake (RFI) of individual animals is both laborious and expensive (negative RFI value=efficient; positive RFI value=inefficient). A less costly method to predict RFI is needed. Knott et al. reported that rams with poor feed efficiency (positive RFI values) are more responsive to exogenous adrenocorticotropic hormone (ACTH); thus, we tested the hypothesis that response to an ACTH challenge in Brahman cattle is directly associated with RFI. Brahman bulls (n=12) (390±19 kg BW) and heifers (n=12) (334±12 kg BW), age 15±1 mon, with established RFI values were used. To establish RFI, after the calves were weaned, they were evaluated in separate 70 d test periods for each gender during which the animals were limit fed (2.65% BW/d) in a Calan gate feeding system. The 6 lowest and 6 highest ranking of each gender, males and females, respectively, were used to assess cortisol response to exogenous ACTH, total n = 24. Blood samples were taken

via indwelling jugular catheter every 15 min from 3 h prior to challenge through 4 h after challenge at time 0 h with ACTH (0.1 IU/kg BW). Serum concentrations of cortisol were determined by radioimmunoassay using Coat-A-Count kits (intra-assay variation of 7.7% and inter-assay variation of 7.6%). Data were analyzed using GLM specific for repeated measures. Cortisol concentrations were affected by time ($P<0.0001$) and gender ($P<0.005$) but were not affected by RFI grouping ($P>0.10$). Basal cortisol concentrations (M=7±1; F=14±2 ng/ml), peak cortisol concentrations (M=37±3; F=64±4 ng/ml), amplitude of responses (M=31±3; F=49±4 ng/ml), and area under the curves pre-challenge (M=189±30; F=414±60 ng/ml•h) differed ($P<0.01$) between genders. These data indicate that cortisol response to an ACTH challenge is not a useful predictor of RFI in Brahman cattle. However, a sexual dimorphism in the cortisol response to an ACTH challenge was detected in Brahman cattle.

DEDICATION

This thesis is in dedication to my Grandpa, Daniel Agado Sr., who told me about a city named Bryan and its neighboring city College Station, much like our San Benito and Harlingen.

ACKNOWLEDGEMENTS

First and foremost, I would like to acknowledge Dr. Ronald D. Randel, my supervising professor, for encouraging me to take on this one year journey. Dr. Randel has shown me through hard work and persistence that all is achievable. I would also like recognize Dr. Thomas H. Welsh, Dr. Thomas D. A. Forbes, and Dr. Jeff Carroll. These gentlemen supplied the funds, wisdom, and opportunities for me to complete this project as well as others. Mr. Don Neuendorff, Herd Manager at the Texas *Agri*Life Research Center at Overton, allowed me to practice many of the concepts and techniques that students read and learn in the classroom but are not presented with the opportunity to use in real time management. Thanks must be given to the reproductive physiology graduate students of Texas A&M University for helping me the on various crossroads along the path of research. I would like to thank the scientists and support staff of Texas *Agri*Life Research because without them, many of the comforts we enjoy in life today would otherwise be impossible. Finally, I would like to thank Texas A&M University for providing an education in agriculture that I personally believe is second to none.

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CHAPTER I

INTRODUCTION

Improvements in the beef industry have for a long time focused primarily on output traits such as body weight, carcass composition, and fertility. Input traits, which cost of feeding constitutes the highest percentage at any level of production, are now being more closely examined. After one year of divergent selection for residual feed intake, progeny of highly efficient (low RFI) parents were more efficient and consumed less feed over a 120 day test period (Herd et al., 1997). Females who underwent RFI testing post-weaning maintained their efficiency status later in life (Arthur et al., 1999). Steer progeny after a single generation of selection for RFI did not differ in their performance in the feedlot setting except for the low RFI steers eating less per unit of gain (Richardson et al., 1998).

Measurement of RFI is both laborious and expensive. A less expensive and timelier manner of determining efficiency in cattle is desirable in our high fuel and feedstuff cost production environment. Scientists are beginning to investigate if there are any biological factors associated with the differences observed in RFI. 37% of the variation in RFI can be attributed to protein turnover, tissue metabolism, and stress (Richardson and Herd, 2004). Rams, with no previous selection for RFI, had responses to an

This thesis follows the style and format of the Journal of Animal Science.

adrenocorticotropic hormone (ACTH) challenge which were predictive of RFI ranking (Knott et al., 2008).

The delayed appearance of RFI as a sought after technology and selection tool despite the conception of the idea in 1963 can be attributed to the intensive nature of collecting individual feed intake. In search of a biological parameter that is predictive of residual feed intake in Brahman cattle, this undergraduate thesis tests the hypothesis that there is a difference in the chemical hormesis (Calabrese et al., 2007) response from administration of exogenous adrenocorticotropic hormone challenge in Brahman cattle.

CHAPTER II

LITERATURE REVIEW

Stress

Stress as defined by Fraser et al. (1975) states that stress occurs if an animal is required to make abnormal or extreme adjustments in its physiology or behavior in order to cope with adverse aspects of its environment and management. Stressors are individual factors that contribute individually or in concert with other stressors to elicit a stress response from an animal (Fraser et al., 1975). An example of such would be a drop in temperature, and a combination of stressors would include the previous during transportation. Chousos and Gold (1992) simplifies the definition of stress, but no less in scope, as a state of disharmony or threatened homeostasis.

Hypothalamic-pituitary-adrenal axis

The perception of endangered homeostasis initiates a cascade of events that follow along the hypothalamic-pituitary-adrenal (HPA) axis. Corticotrophin releasing hormone (CRH) secretions increase during activation of the stress response (Stratakis et al., 1995). Corticotrophin releasing hormone in turn activates the pituitary-adrenal axis (Rock et al., 1984). Corticotrophin releasing hormone induces the release adrenocorticotropic hormone (ACTH) from the anterior pituitary gland (Carroll et al., 2007; Ono et al., 1984; Rock et al., 1984). Adrenocorticotropic hormone acts on the adrenal cortex to release the glucocorticoid (GC) hormone, cortisol (Minton, 1994).

Corticotrophin releasing hormone

Vale et al. (1981) purified a 41-residue peptide from ovine hypothalamic extract that stimulated the release of ACTH from cultured anterior pituitary cells. This extract was then shown to increase plasma ACTH concentrations *in vivo* in the male rat model (Rivier et al., 1982). This releasing peptide termed corticotrophin releasing factor (CRF) was later renamed to corticotrophin releasing hormone (CRH). Innumerable studies have recognized the stimulatory effects of CRH. Corticotrophin releasing hormone demonstrated a dose dependent behavior in adult steers when exogenous bovine CRH (bCRH) was administered via indwelling jugular catheter (Gupta et al., 2004). It has been proposed that the cerebrospinal fluid can act as a conduit for certain neural hormones (Post et al., 1982). Ovine CRH (oCRH) was administered into the fourth ventricle of rhesus monkeys which initiated activity of the pituitary-adrenal axis similar to an intravenous administration of oCRH (Rock et al., 1984). A dose related response was observed when third ventricle administrations of oCRH were administered to ovariectomized (OVX) female rats (Ono et al., 1984).

Hypothalamic-pituitary-adrenal axis and growth axis

Cortisol, the main stress hormone, inhibits growth hormone (GH) secretion and increases deposition of adipose tissue when chronically present. Dieguez et al. (1988) postulated that at the hypothalamic level, cortisol inhibits GH secretion despite a wealth of evidence that GC's have a stimulatory effect at the pituitary level. Male and female patients with Cushing's disease exhibited a decreased response to growth hormone

releasing hormone (GHRH) (Smals et al., 1986). CRH was shown in a rat model to decrease plasma GH concentrations starting 15 minutes through 60 minutes post injection when CRH was injected into the third ventricle at a concentration of 0.1 nmol (Ono et al., 1984)

Increased levels of stress have been associated with wasteful nutrient utilization. Increased cortisol concentrations have been associated with alternative metabolic activity which includes increased heart rate (Fisher et al., 1982), blood glucose concentrations and insulin clearance (Black et al., 1982), and adipose tissue deposition (Knott et al., 2008; Stratakis et al., 1995). The body makes nutrients available via gluconeogenesis and lipolysis and oxygen by increasing respiratory rate (Chrousos and Gold, 1992). These phenomena are all associated with inefficient nutrient utilization.

Feed efficiency

Montaño-Bermudez (1990) demonstrated a difference in estimated maintenance requirements per metabolic body weight (MBW) between fed cattle that had a low, a medium, or a high milking dam. Estimated requirements were 9-12% and 4-16% higher for medium and high milking calves, respectively, than the low milking calves (Montano-Bermudez et al., 1990). Replacement heifers that were selected for low and high growth rates at one year of age in Australia showed that later as cows, the high growth rate cows consumed less feed per kilogram of calf weaned than the low growth rate cows. Furthermore, some cows consumed 50% less feed per kilogram of weaned

calf of similar size and from the same selection line (Parnell et al., 1994). These reports indicate a difference in the efficient use of feed by cattle. With the price of corn increasing in the United States by 106% in the last ten years albeit a 12.4% increase in production of corn per acre in the same time period (United States Department of Agriculture, 2008), it is imperative that producers realize the importance of feed efficiency of their cattle.

Two measures of feed efficiency have been proposed in the past, feed:gain ratio and gain:feed ratio. The latter was used more often because a higher value was associated with better efficiency. This data can be very misleading because animals with similar gain:feed ratios can have very different rates of gain or feed intake values (Sainz and Paulino, 1994). Koch et al. (1963) first proposed the idea of measuring the residual of the actual feed intake minus the expected feed intake. The idea of using residual feed intake (RFI) as a measure of feed efficiency has seen increased interest recently because of rising fuel cost and feedstuff cost.

RFI tests are conducted over a 70 day period with biweekly weigh dates to allow appropriate measurement for growth, feed conversion, and RFI (Archer et al., 1997). Texas *Agri*Life Research at Overton conducts RFI testing over a 70 d period, but includes a 7 d adaption, learning period to the Calan gate feeder system and a 7 d post test feeding period for data collection supporting other research. Weekly weights are also taken as opposed to biweekly weights (Dittmar, 2007)

In a two part experiment, with a feedlot phase and an animal house phase, steers divergently selected for RFI were tested for differences in metabolites. High RFI (inefficient) steers did not differ ($P>0.10$) in cortisol concentration with low RFI (efficient) steers after the feedlot phase; following the animal house phase inefficient steers had numerically higher cortisol concentrations ($P<0.10$) than efficient steers. The conclusion was made that whole experiment (feedlot + animal house phases) RFI was negatively correlated with cortisol concentration ($P<0.05$) (Richardson et al., 2004). Rams, with no previous selection for RFI, had responses to an adrenocorticotropic hormone (ACTH) challenge which were predictive of RFI ranking. In contrast with the cattle data reported above pre ACTH challenge, post ACTH challenge, and the incremental change in serum cortisol concentrations were positively correlated with RFI ($P>0.05$, $P<0.001$, and $P<0.001$, respectively) (Knott et al., 2008).

284 four-year-old cows were retested for RFI after weaning their second calf, and the females that were more efficient (low RFI) as weanlings required less feed as cows (Arthur et al., 1999). This demonstrates that the use of RFI not only selects for increased feed efficiency at the younger stages of life, but that the increased efficiency will be maintained throughout a cow's entire production life.

CHAPTER III

MATERIALS AND METHODS

Two separate RFI test periods were conducted to establish RFI values and ranking. The cattle in the test were from the 2007 calf crop at the Texas *Agri*Life Research Center at Overton. The research animals consisted of purebred Brahman bulls and heifers. The RFI test on the heifers (n=49) was conducted post weaning, and the RFI test on the bulls (n=40) was conducted at approximately one year of age.

The tests were conducted using a Calan gate feeder system. A 7 day acclimation, teaching period, was used before day zero of the test. The heifers/bulls were sorted into pens of five or less depending on their weight at that time with similar weights in a pen. The Calan gates were tied open to allow the cattle to learn where the feed was dispersed. The gates were then allowed to be shut, but the locking mechanism was incapacitated. The cattle were able to push open the gates. Preferred eating stalls were then noted amongst the pens. An electronic key was placed on the neck of the animal that was specific to that animal's preferred stall, and the locking mechanism was restored to its original state. This accomplished the task of making sure an individual consumed their feed exclusively.

The tests were conducted over a 70 day period. Feedings were twice a day at 0800 and 1700 with half of the daily ration being distributed in the morning and the remaining

ration in the evening. The cattle were fed a sole ration at 2.65% of their body and water was offered *ad libitum*. The cattle were weighed on day 0 and every seven days there after. On weigh days, blood samples were collected from each individual via tail vessel puncture for research on other projects associated with these trials. The cattle were further examined for an additional 7 days post test for fecal sample collection also for other research. Daily inspection of health was conducted as well as periodic scraping the testing facility to remove feces.

Selection for the intensive bleed candidates consisted of the lowest RFI ranking (efficient) (n=6) and the highest RFI (inefficient) (n=6) of each gender (male, n=12; female, n=12). The intensive bleeding dates were 7 months and 2 weeks post RFI test on the heifers and bulls, respectively. The intensive bleeds were conducted on a gender basis with the bulls being challenged first and the heifers second. Each gender challenge was conducted over a 3 day period (4 head/day) due to facility constraints. The intensive bleed candidates were housed in 15 x 61 meter pens and were feed *ad libitum* coastal hay and water during the three day challenge periods.

On challenge day, indwelling jugular catheters were in place by 0700. The temporary indwelling jugular cannulas consisted of approximately 15 cm of polytetrafluroethylene tubing (o.d. 1.66 mm). They were inserted into the external jugular vein through a 14 gauge thin walled stainless steel biomedical needle (o.d. 2.11 mm). 10 cm of the cannula were inserted into the external jugular vein, and 5 cm remained outside. The

viability of the cannula was checked followed by securing it with branding cement and portions of porous surgical tape (12.7 x 5.08 cm). Fixed to the end of the cannula was 2 m of plastic tubing (i.d. 1.59 mm, o.d. 3.18 mm). The plastic tubing was adhered to metal frame work of the chute system and routed to the caudal end of the animal. This was to reduce the perceived stress of personnel approaching to collect the blood sample. The animals were restricted into individual segments of the chute system, and they were allowed to stand or lie down during the 7 hour intensive sampling period.

The animals were chosen at random for their day of challenge within the three day challenge period assigned to each gender. Post-cannulation, the cattle were allowed 30 minutes to rest. The first blood sample was taken at 0730 and the subsequent blood samples were placed on ice until they were centrifuged to collect plasma. The plasma was then stored at -20° C. After collecting 10 cc of whole blood, the plastic tubing and cannula were purged with 10 cc of physiological saline followed by 10 cc of heparinized physiological saline. The cattle were allowed 180 minutes to reach basal cortisol concentrations (Curley Jr. et al., 2008) At time 0, after collection of whole blood but prior to purging of the lines, 0.1 IU/kg BW of ACTH was administered to each individual. 240 minutes were allotted for the chemical hormesis response to occur and allow the cattle to return to basal cortisol concentrations. The cattle were observed for 24 hours post challenge to monitor any adverse effects on the animals' health.

Cortisol concentrations were determined by radioimmunoassay using Coat-A-Count® Cortisol kits purchased from Siemens, Medical Solutions Diagnostics. Alterations to the kit's directions encompassed the calibration of the assay. To more accurately determine the anticipated lower concentrations of cortisol, additional cortisol calibrators were added, 0.5 and 2.5 μg/ml. The Coat-A-Count Cortisol antiserum cross reactions were: corticosterone, 0.94%; deoxycorticosterone, 0.26%; and progesterone, 0.02% (Coat-A-Count Cortisol, Siemens). The intra-assay and inter-assay variations were 7.7% and 7.6%, respectively.

Area-under-the-curve (AUC) was determined by $AUC=\Sigma \{[(CS_n + CS_{n+1}) / 2] * h\}$ where CS represents cortisol concentration and h is the time span between the collection of samples in hours. The equation: $AUC\ Resp= \Sigma \{[(CS_n + CS_{n+1}) / 2] * h\} – [BCS * (h_b – h_0)]$ represents the response of cortisol after the administration of exogenous ACTH where BCS is the basal cortisol concentration, h_b is the time that cortisol concentration returned to baseline, and h_0 is time 0 with ACTH administration.

The effects of time, RFI grouping, and time*RFI group interaction on cortisol concentrations over the duration of sampling were determined by ANOVA specific for repeated measures using the MIXED model procedure in SAS. The covariant structure for this MIXED model procedure was heterogeneous 1st order autoregressive. Males and females were analyzed separately with the designation of being either high RFI or low RFI as the treatment groups.

A second analysis was conducted in which RFI groups were pooled together to determine the effect of sex on cortisol curve parameters such as basal cortisol concentration, peak cortisol concentration, amplitude of cortisol response to exogenous ACTH, AUC post challenge, and AUC of the response. For this ANOVA, the general linear model was used in SAS where our model was simply SEX = CURVE PARAMETERS.

CHAPTER IV

RESULTS AND DISCUSSION

Bulls

Efficient and inefficient bulls demonstrated increased initial cortisol concentrations as shown in Figure 1. Cortisol concentration decreased to basal level 45 min preceding the ACTH challenge and basal concentrations were maintained through time 0. Basal cortisol concentrations were 6.22 ng/ml and 6.80 ng/ml for efficient bulls and inefficient bulls, respectively. No significant difference was observed between basal cortisol concentrations between efficient and inefficient bulls ($P>0.1$).

At time 0, 0.1 IU/kg BW of exogenous ACTH was administered via the indwelling jugular catheter. Immediately following the administration of the challenge agent, a 6 fold increase was observed from the efficient bulls and a 7 fold increase from the inefficient bulls ($P = 0.98$). Peak cortisol concentrations were observed by 60 min at a concentration of 37.95 ng/ml and at 45min at a concentration of 33.46 ng/ml for efficient and inefficient bulls, respectively. No significant differences between efficient and inefficient bulls were observed for peak cortisol concentrations ($P = 0.73$) or time to peak cortisol concentrations ($P = 0.53$). The amplitudes, the differences between peak and basal cortisol concentrations, were 33.37 ng/ml for the efficient bulls and 28.02 ng /ml for the inefficient bulls ($P = 0.61$). An observed gradual decrease in cortisol concentration followed the peak plasma cortisol concentrations in both groups of cattle.

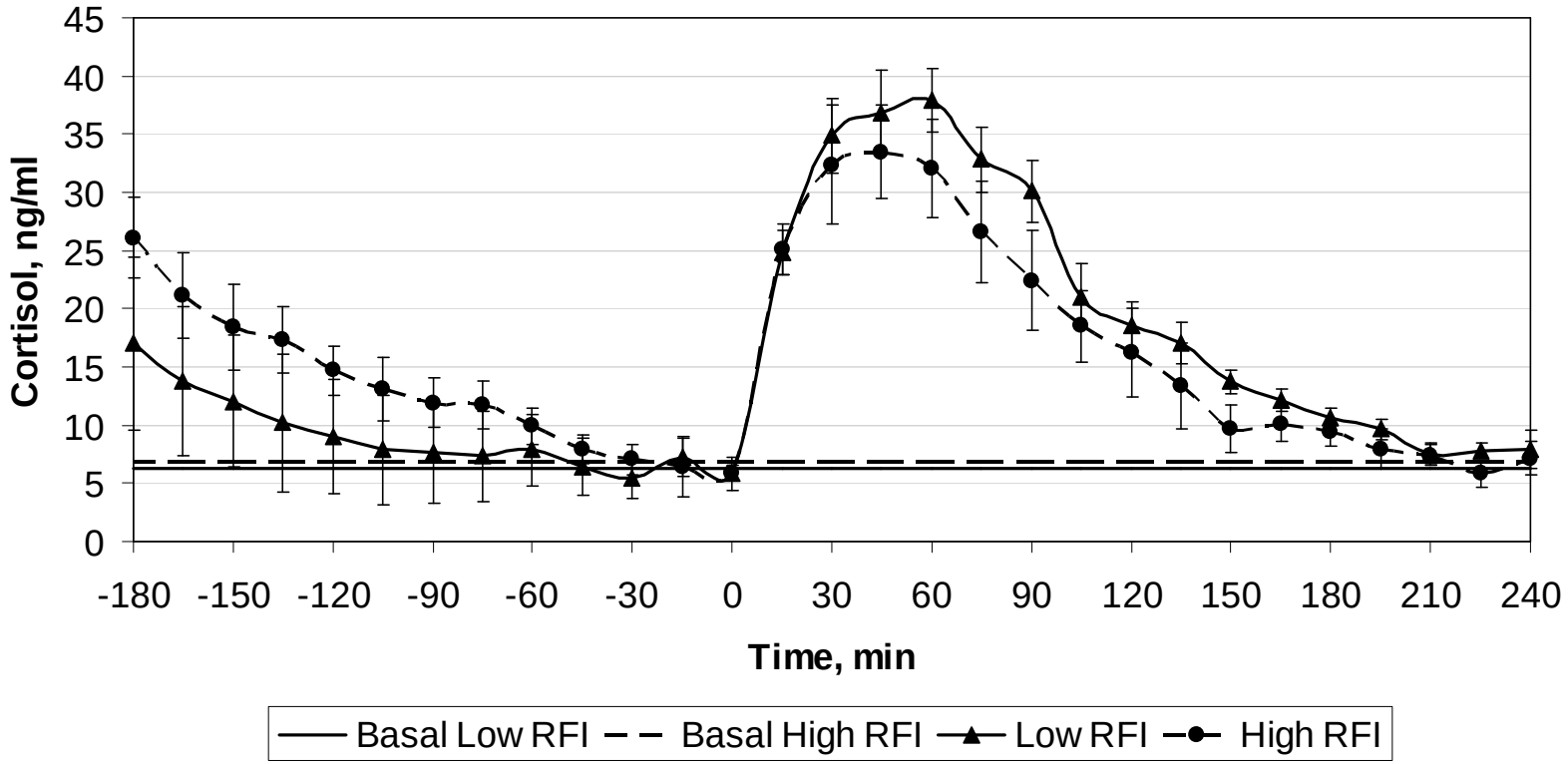

Figure 1. Low RFI (efficient) and high RFI (inefficient) bulls' responses to exogenous ACTH. 0.1 IU/kg BW ACTH administered at Time 0.

By 210 min post challenge, the bulls had basal cortisol concentrations approximately 1 ng/ml above their initial basal cortisol concentrations. The effect of RFI grouping and RFI grouping*time interaction were deemed insignificant ($P > 0.1$) while the effect of time was significant ($P < 0.0001$) throughout the duration of serial sampling.

Heifers

Data from the three challenge days were pooled for statistical analysis and presented in Figure 2. The heifers exhibited initially increased concentrations of cortisol due to the stress of handling followed with a subsequent gradual decrease and stabilization at approximately 90 min pre-challenge. Basal cortisol concentrations were determined to be 15.01 ng/ml and 13.53 ng/ml for efficient and inefficient groupings, respectively ($P > 0.1$).

At time 0 min, 0.1 IU/kg BW was administered to each heifer via their indwelling jugular catheter. The efficient heifers demonstrated a 460% increase, and a 520% increase was observed from the inefficient heifers ($P = 0.55$). The efficient heifers' cortisol concentrations peaked at 55.62 ng/ml at 45 min post challenge, and the inefficient heifers peaked at 62.53 ng/ post-challenge. The peak cortisol concentrations and times to peak concentrations were not significant ($P = 0.47$ and $P = 0.36$, respectively. The amplitudes were also not significantly different ($P = 0.31$) with values of 46.00 ng/ml for the efficient and 52.61 ng/ml for the inefficient heifers.

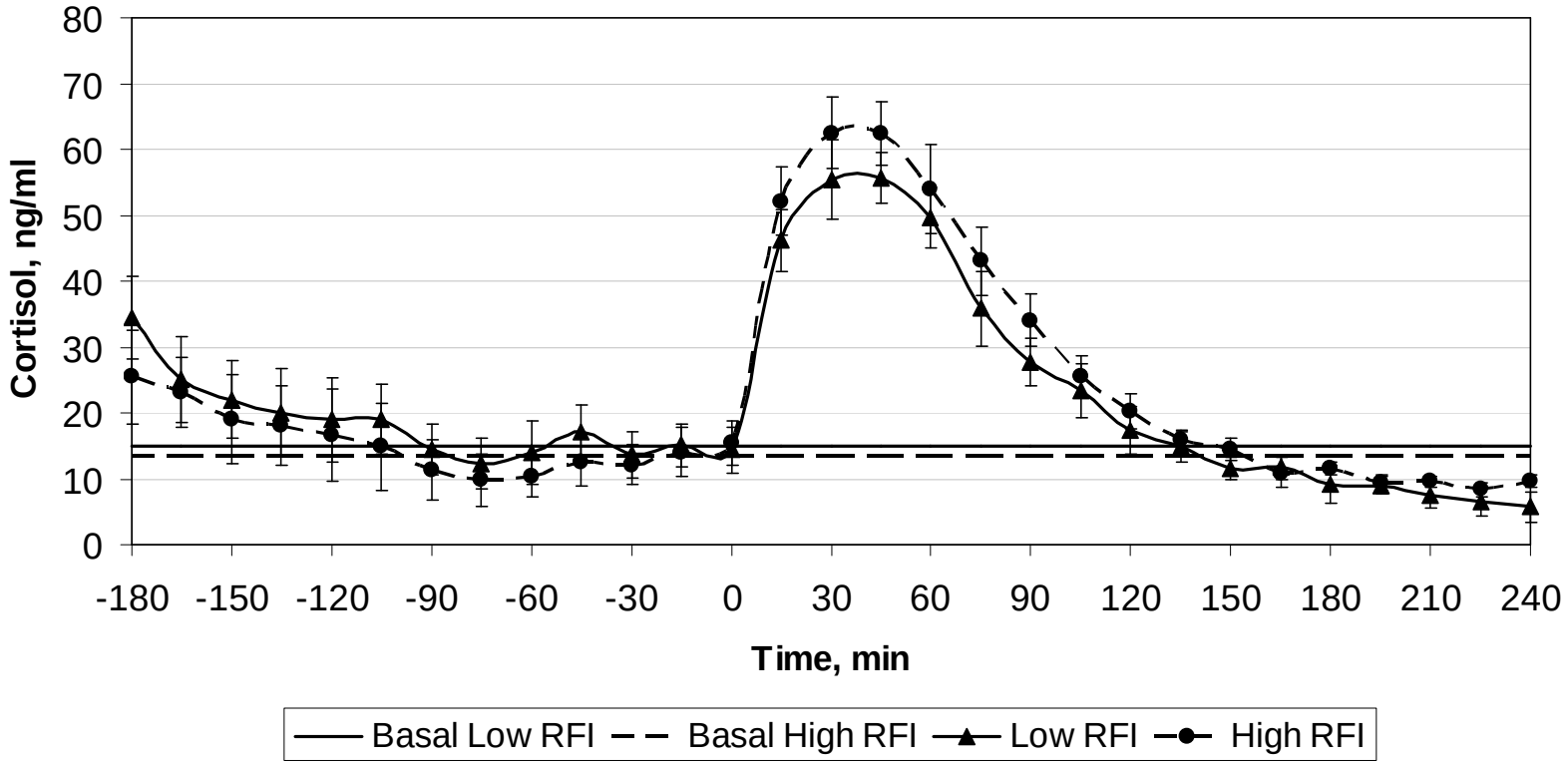

Figure 2. Low RFI (efficient) and high RFI (inefficient) heifers' responses to exogenous ACTH. 0.1 IU/ kg BW were administered at Time 0.

After the cortisol peak, both groups of heifers exhibited an ensuing decrease in cortisol concentrations. Unlike the bulls, the heifers' cortisol concentrations dipped beneath their respective basal concentrations. The efficient heifers returned to basal concentration by 135 min post challenge while the inefficient heifers returned to basal by 165 min post-challenge ($P = 0.42$). The effects of RFI grouping and RFI grouping*time interaction were not significant ($P > 0.1$) while the effect of time was ($P > 0.0001$).

Males and females

While this was not one of the primary objectives of this experiment, some very important points and questions have arisen from the comparison of males and females. The data used for this analysis are the consolidation of the efficient and inefficient groups of each sex.

Both bulls and heifers exhibited the typical increased initial cortisol concentrations immediately following handling (Figure 3). Their cortisol concentrations continued to decrease through 45 min pre-challenge. A significant difference between the sexes was observed for basal cortisol concentrations ($P = 0.003$). Females demonstrated a higher basal concentration of 14.27 ng/ml compared to the bulls at 6.51 ng/ml. Immediately following the administration of the exogenous ACTH, the males had 6.6 fold increase in cortisol concentration while the females had 5 fold increase ($P = 0.32$). Significant differences were observed for peak cortisol concentrations and the amplitude of increase, but not for time to peak intervals. Males peaked at 45 min with a concentration of 35.15

ng/ml, and the females peaked at 30 min with a concentration of 59.03 ng/ml (peak: $P < 0.0001$ and time to peak: $P =. 0.24$). The magnitude of change from basal concentrations to peak concentrations were 30.87 ng/ml for the males and 49.31 ng/ml for the females ($P = 0.0015$).

The males' cortisol response does not drop below the pre-challenge basal concentration but does come within 1 ng/ml at 210 min through the remainder of the sample collection period. The females dropped below their pre-challenge basal cortisol concentration by 150 min post-challenge. Interestingly, the females' gradual decrease in cortisol concentration almost superimposes itself on the bulls' curve from 120 min post-challenge through the end of the sample collection period.

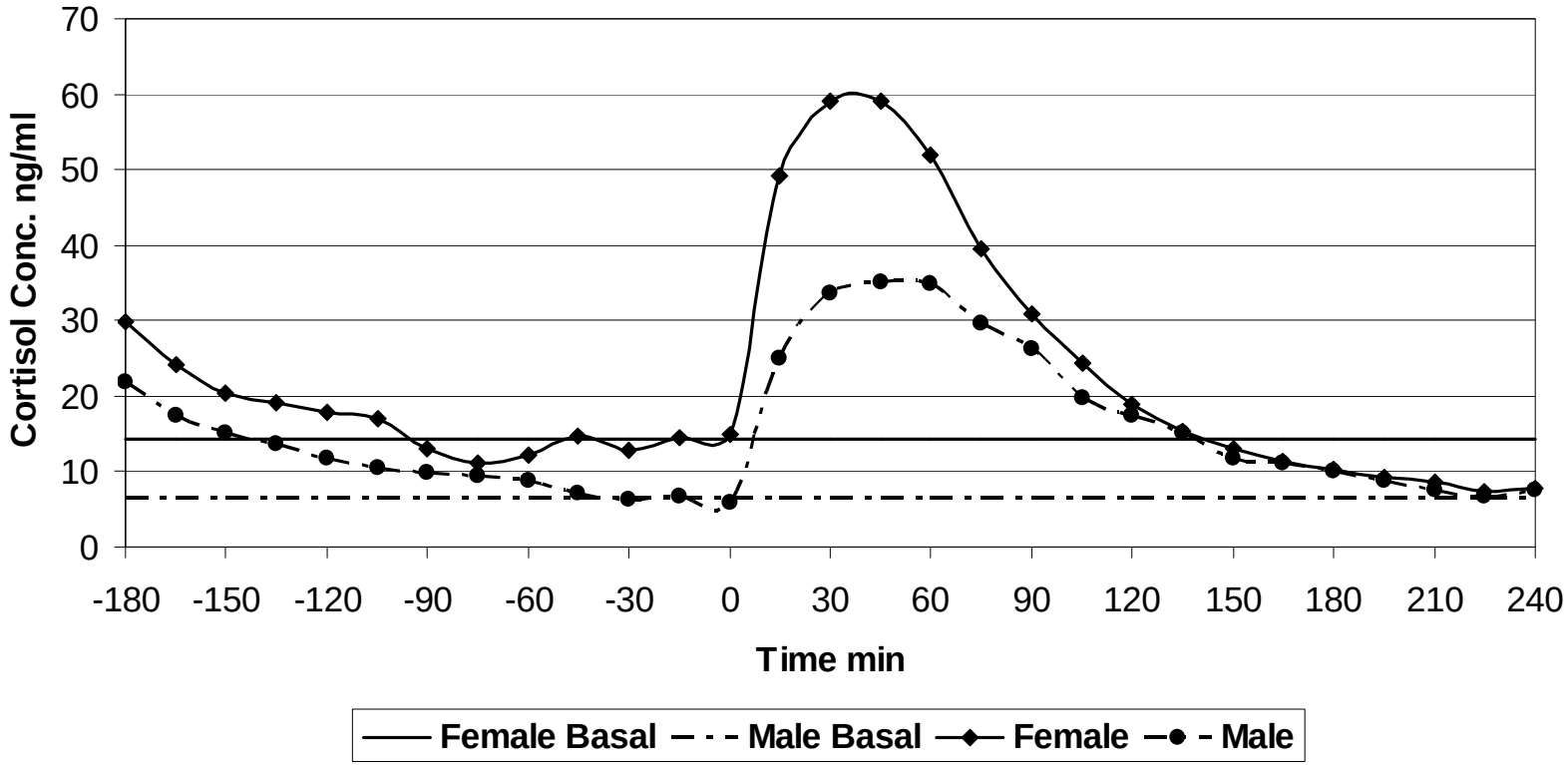

Figure 3. Comparison of males' and females' responses to administration of exogenous ACTH. Data for this analysis are the combination of both RFI groups into each gender.

CHAPTER V

CONCLUSIONS AND IMPLICATIONS

In the search for a biological parameter that is predictive of residual feed intake, the hypothesis that a stress challenge using intra venous administration of exogenous adrenocorticotropic hormone must be rejected in cattle. No significant differences were observed in the parameters of the cortisol response curves between efficient and inefficient animals of either sex. We did observe significant differences between males and females. Males and females differed in basal cortisol concentrations, peak cortisol concentrations, and amplitude change with the females being higher than the males. This suggests that females are more responsive to exogenous ACTH than bulls.

In a nine-month study conducted Verkerk and Macmillan (1997), bulls were not as responsive to exogenous ACTH as steers from 8 through 15 months of age. Verkerk and Macmillan (1997) postulated that a hormone of testicular origin may alter the HPA axis. Results from our study and Verkerk and Macmillan's study (1997) suggest that males and females differentiate in their HPA axes, and that this could be a result of androgen metabolism and/or negative feedback from the androgens on the HPA axis. Another postulation would be that exposure to androgens or estrogens in utero are responsible, at least in part, to sexually dimorphic development of the HPA axis. In a study of the influence temperament on the HPA amongst Brahman heifers, temperamental heifers exhibited a muted adrenal response to pharmaceutical bCRH and

ACTH administered intravenously (Curley Jr. et al., 2008). The temperamental heifers maintained higher basal cortisol concentrations but had similar peaks which equated to decreased amplitudes and response. This is in contrast to our experiment in that whereas the females maintained higher basal cortisol concentrations, they also maintained significantly higher peak concentrations and consequently exhibited a greater response.

Future directions that should be pursued are: 1) reevaluation of the original objective in *Bos taurus* cattle and 2) determination of which androgen(s) is/are responsible for these observed differences and at which level(s) of the HPA axis.

It is well documented throughout the research literature that differences exist between *Bos taurus* and *Bos indicus* cattle. Many of these differences are the result of adaptations from their origins, European descent versus extreme south Asia descent.

The study of the HPA axis, glucocorticoids, and their impact on immunity is of interest to scientists, veterinarians, and members of industry. Modifying treatments and managerial practices based on the sex of the animal and stage of sexual maturation has the potential to reduce costs by reducing physiological stress on the animal. Reduced stress equals better performance of the animal and better dividends for producers, and consequently for the consumers.

REFERENCES

Archer, J. A., P. F. Arthur, R. M. Herd, P. F. Parnell, and W. S. Pitchford. 1997. Optimum postweaning test for measurement of growth rate, feed intake, and feed efficiency in british breed cattle. J. Anim Sci. 75: 2024-2032.

Arthur, P. F., J. A. Archer, R. M. Herd, E. C. Richardson, S. C. Exton, C. Oswin, K. C. P. Dibley, and D. A. Burton. 1999. Relationship between postweaning growth, net feed intake and cow performance. Proceedings of the Thirteenth Conference Association for the Advancement of Animal Breeding and Genetics. p 484-487, Mandurah, Western Australia.

Black, P. R., D. C. Brooks, P. Q. Bessey, R. R. Wolfe, and D. W. Wilmore. 1982. Mechanisms of insulin resistance following injury. Annals Of Surgery 196: 420-435.

Calabrese, E. J., K. A. Bachmann, A. J. Bailer, P. M. Bolger, and J. Borak. 2007. Biological stress response terminology: Integrating the concepts of adaptive response and preconditioning stress within a hormetic dose-response framework. Toxicology and Applied Pharmacology 222: 122-128.

Carroll, J. A., N. H. McArthur, and T. H. Welsh, Jr. 2007. In vitro and in vivo temporal aspects of acth secretion: Stimulatory actions of corticotropin-releasing hormone and vasopressin in cattle [electronic resource]. Zentralblatt fur Veterinarmedizin. Journal of Veterinary Medicine. Series A, Physiology, Pathology, Clinical Medicine. Reihe A 54: 7-14.

Chrousos, G. P., and P. W. Gold. 1992. The concepts of stress and stress system disorders. JAMA: Journal of the American Medical Association 267: 1244.

Curley Jr., K. O., D. A. Neuendorff, A. W. Lewis, J. J. Cleere, T. H. Welsh, and R. D. Randel. 2008. Functional characteristics of the bovine hypothalamic-pituitary-adrenal axis vary with temperament. Hormones and Behavior 53: 20-27.

Dieguez, C., M. D. Page, and M. F. Scanlon. 1988. Growth hormone neuroregulation and its alterations in disease states. Clinical Endocrinology 28: 109-143

Dittmar, R. O. I. 2007. Determining biological sources of variation in residual feed itake in brahman heifers during confinement feeding and on pasture., Texas A&M University, College Station.

Fisher, L. A., J. Rivier, C. Rivier, J. Spiess, W. Vale, and M. R. Brown. 1982. Corticotropin-releasing factor (CRF): Central effects on mean arterial pressure and heart rate in rats. Endocrinology 110: 2222-2224.

Fraser, D., J. S. D. Ritchie, and A. F. Fraser. 1975. The term "stress" in a veterinary context. British Veterinary Journal 131: 653-662.

Gupta, S., B. Earley, S. T. L. Ting, N. Leonard, and M. A. Crowe. 2004. Technical note: Effect of corticotropin-releasing hormone on adrenocorticotropic hormone and cortisol in steers. J. Anim Sci. 82: 1952-1956.

Herd, R. M., J. A. Archer, P. F. Arthur, E. C. Richardson, J. H. Wright, K. C. P. Dibley, and D. A. Burton. 1997. Performance of progeny of high vs. low net feed conversion efficiency cattle. Proceedings of Association for the Advancement of Animal Breeding and Genetics. p 742-745, Dubbo, NSW, Australia.

Knott, S. A., B. J. Leury, F. R. Dunshea, and L. J. Cummins. 2008. Rams with poor feed efficiency are highly responsive to an exogenous adrenocorticotropin hormone (ACTH) challenge [electronic resource]. Domestic Animal Endocrinology 34: 261-268.

Koch, R. M., L. A. Swiger, D. Chambers, and K. E. Gregory. 1963. Efficiency of feed use in beef cattle. J. Anim. Sci. 22: 486-494.

Minton, J. E. 1994. Function of the hypothalamic-pituitary-adrenal axis and the sympathetic nervous system in models of acute stress in domestic farm animals. J. Anim. Sci. 72: 1891-1898.

Montano-Bermudez, M., M. K. Nielsen, and G. H. Deutscher. 1990. Energy requirements for maintenance of crossbred beef cattle with different genetic potential for milk. Journal of Animal Science 68: 2279-2288.

Ono, N., M. D. Lumpkin, W. K. Samson, J. K. McDonald, and S. M. McCann. 1984. Intrahypothalamic action of corticotrophin-releasing factor (crf) to inhibit growth hormone and lh release in the rat. Life Sciences 35: 1117-1123.

Parnell, P. F., R. M. Herd, D. Perry, and B. Bootle. 1994. The trangie experiment-respnses in growth rate, size, maternal ability, reporductive performance, carcase composition, feed requirements and herd profitiability. Proceedings-Australian Society of Animal Production No. 20. p 17-26.

Post, R. M., P. Gold, D. R. Rubinow, J. C. Ballenger, W. E. Bunney, and F. X. Goodwin. 1982. Peptides in the cerebrospinal fluid of neuropsychiatric patients: An approach to central nervous system peptide function. Life Sciences 31: 1-15.

Richardson, E. C., and R. M. Herd. 2004. Biological basis for variation in residual feed intake in beef cattle. 2. Synthesis of results following divergent selection. Australian Journal of Experimental Agriculture 44: 431-440.

Richardson, E. C., R. M. Herd, J. A. Archer, and P. F. Arthur. 2004. Metabolic differences in angus steers divergently selected for residual feed intake. Australian Journal of Experimental Agriculture 44: 441-452.

Richardson, E. C., R. M. Herd, J. A. Archer, R. T. Woodgate, and P. F. Arthur. 1998. Steers bred for improved net feed efficiency eat less for the same feedlot performance. Proceedings of the Australian Society of Animal Production No. 22. p 213-216.

Rivier, C., M. Brownstein, J. Spiess, J. Rivier, and W. Vale. 1982. In vivo corticotropin-releasing factor-induced secretion of adrenocorticotropin, beta-endorphin, and corticosterone. Endocrinology 110: 272-278.

Rock, J. P., E. H. Oldfield, H. M. Schulte, P. W. Gold, P. L. Kornblith, L. Loriaux, and G. P. Chrousos. 1984. Corticotropin releasing factor administered into the ventricular csf stimulates the pituitary-adrenal axis. Brain Research 323: 365-368.

Sainz, R. D., and P. V. Paulino. 1994. Residual feed intake. *Sierra Foothill Research & Extension Center*. Paper 2004_residual_feed_intake. http://repositories.cdlib.org/anrrec/sfrec/2004_residual_feed_intake

Smals, A. E., G. F. Pieters, A. G. Smals, T. J. Benraad, and P. W. Kloppenborg. 1986. Human pancreatic growth hormone releasing hormone fails to stimulate human growth hormone both in cushing's disease and in cushing's syndrome due to adrenocortical adenoma. Clinical Endocrinology 24: 401-407.

Stratakis, C. A., P. W. Gold, and G. P. Chousos. 1995. Neuroendocrinology of stress: Implications for growth and development. Hormone Research 43: 162-167.

United States Department of Agriculture, National Agriculture Statisics Service. 2008. 2008 Agricultural Statistics, Grain and Feed. In: NASS (ed.) No. 2008. USDO. ISBN 978-0-16-079497-1. http://www.nass.usda.gov/Publications/Ag_Statistics/2008/TOC2008.pdf

Vale, W., J. Spiess, C. Rivier, and J. Rivier. 1981. Characterization of a 41-residue ovine hypothalamic peptide that stimulates secretion of cortitropin and beta-endorphin. Science (New York, NY) 213: 1394-1397

Verkerk, G. A. and K. L. Macmillan. 1997. Adrenocortical responses to an adrenocorticotropic hormone in bulls and steers. J. Anim. Sci. 75: 2520-2525

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