ABSTRACT

PSAROS, KAYLA MELISSA. Heritability of Hair Coat Shedding Scores in Angus dams and the Relationship with Pre-weaning Growth in their Calves. (Under the direction of Dr. Joseph Cassady and Dr. Gary Hansen).

Heat stress is a major concern for some beef cattle producers. Methods to select cattle that are resistant to the negative effects of heat stress are economically important for these producers. Decreases in feed intake, conception rates, and milk production lead to reduced gains for cows and calves. A visual scoring method of how winter hair coat is shed may help to identify cattle more resistant to heat stress. The objectives of the study were to collect hair coat shedding scores (HCS) on registered Angus dams throughout the Southeast, Missouri, and Texas and to explore the relationship between HCS of the dam and kilograms of calf weaned per day of age of dam. Hair coat shedding scores were collected from 20 farms in 2011-2012 in North Carolina, South Carolina, Virginia, Tennessee, Kentucky, Missouri, Alabama, and Texas. Hair coat shedding scores were on a 1-5 scale with 5 being a cow with a full winter hair coat and a 1 being a slick summer coat. Two technicians independently scored each cow. Using the average of the two scores, cows were assigned to two categories. If the average score was above 3, she was considered as not shed and denoted as 1. If the average score was less than 3, she was considered as shed and denoted as 0. Data were analyzed in SAS. Hair coat score was affected by owner, year and age of dam. The odds of being shed increased as age increased from 0.38 for 3 year olds, 0.44 for 4 year olds and 0.47 for 5 years and older cows ($p < 0.01$). Herd life was calculated as the age (d) of the date of the most recent calf weaned minus the birth date of the cow. The analysis of herd life also

demonstrated that, on average, cows that were older (56.73 days, $p < 0.01$) were more likely to be shed. Cows that were considered shed, on average, weaned calves 2.54 kg ($p < 0.01$) heavier than cows that were not considered as shed. Shed cows also weaned 30.62 kg ($p < 0.05$) more in total kg of weaning weight over their lifetime compared to cows that were not shed. Phenotypic correlations between HCS and herd life, weaning weight and total weaning weight are 0.014 ($p > 0.05$), -0.096 ($p < 0.01$), and -0.023 ($p > 0.05$), respectively. The correlations are low, which suggests that other environmental parameters are affecting the statistically significant relationships in the model. Variance components were estimated for HCS using THRGIBBS1F90. Heritability was moderate at 0.42 (95% CI, 0.367 0.478) and in agreement with previous studies (Williams et al 2006; Gray et al, 2011). In conclusion, genetic variability in hair coat has been determined, but due to the low phenotypic correlations indirect selection for total weaning weight may not be as valuable of a selection tool for producers when compared to other selection tools.

Heritability of Hair Coat Shedding Scores in Angus dams and the Relationship with Pre-Weaning Growth in their Calves

by
Kayla Melissa Psaros

A thesis submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the degree of
Master of Science

Animal Science

Raleigh, North Carolina

2013

APPROVED BY:

_____   _____
Dr. David A. Dickey   Dr. C. Scott Whisnant

_____   _____
Dr. O. Wayne Robison   Dr. Gary R. Hansen, Committee Co-Chair

_____
Dr Joseph P. Cassady, Committee Co-Chair

DEDICATION

To my supportive and loving husband, Jeff

BIOGRAPHY

Kayla M Psaros was born Kayla Fleetwood on July 31st, 1989 in Florida. She moved to North Carolina in the 3rd grade. In high school, she was exposed to agriculture classes and FFA which inspired her to pursue a career in animal agriculture. She attended North Carolina State University. She obtained her Bachelors of Science in Animal Science with a minor in Genetics. She continued her education at North Carolina State University to obtain her Masters Degree.

ACKNOWLEDGMENTS

I would like to thank all my committee members Dr. Dave Dickey, Dr. Scott Whisnant and Dr. O.W. Robison, and especially my co-advisors Dr Joe Cassady and Dr Gary Hansen, for their advice and guidance that they have provided throughout my career as a graduate student.

I would like to acknowledge and thank everyone who helped me to collect my data for my research project. This includes Peggy Overton, Kent Gray, Brittany Richardson, Keena Mullen, Kumud Dhakal, Shihui Jiao, Dr Trent Smith and others at Mississippi State University, and of course all of the producers who allowed us to come to their farms to collect the data.

I would like to thank Dr Tara McDaneld for accepting me as a summer intern in her lab at the United States Meat Animal Research Center in Clay Center, Nebraska. I would also like to thank Dr. John Keele and Dr. Larry Kuehn for their help and guidance while analyzing genomic data at US MARC.

I would also like to thank my friends and office mates, Emily Cook and Miranda Bryan, for encouraging me and keeping me sane while finishing up my program.

Last, but certainly not least, I would like to thank my husband for his continued support throughout my career as a graduate student. Your encouragement and remarkable ability to make me laugh when I needed it most will not be forgotten.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1

LITERATURE REVIEW

Introduction

In the beef cattle industry, optimal cattle performance is essential for producing a healthy, affordable product for consumers. Genetic components and environmental stressors affect a cow's optimal performance, which includes maintenance, growth, lactation, and reproduction. Cattle can be selected to tolerate different environmental stressors such as drought, low quality nutrition, severe cold, and high heat. Cattle are dynamic and able to adapt to different environmental stressors as long as the stressor does not exceed the individual animal's tolerance threshold for a continuous period of time (Hahn, 1999).

One of the stressors that some cattle producers must consider in the southern United States is elevated ambient temperature in the summer months. As the temperature rises, cattle must be able to efficiently dissipate heat in order to remain healthy, productive animals. If cattle cannot dissipate heat efficiently, heat stress can occur. Heat stress has been associated with reduced growth, abortion, and mortality (Blackshaw and Blackshaw, 1994; Amundson et al, 2005). Determining which genetic components that lead to heat tolerance in cattle are essential for selection.

The objective of this literature review is to summarize the existing literature regarding thermoregulation in cattle and the importance of maintaining a normal body temperature. Heat stress and the detrimental effects it can cause in the beef cattle industry by reducing overall performance will be discussed. Special emphasis will be given to the use of a visual scoring method of hair coat shedding and how it has been associated with heat stress and

tolerance in beef cattle.

Thermoregulation in Cattle

Cattle have developed adequate heat exchange mechanisms that allow them to endure the changing environment. During summer months, high ambient temperatures can cause cattle to suffer from heat stress if it cannot adequately dissipate excess heat. Methods of dissipating excess heat include evaporative cooling, convection, conduction, and radiation (Blackshaw and Blackshaw, 1994).

Ferguson and Dowling (1955) investigated cattle sweat glands and determined that the main source of heat loss at high ambient temperatures is due to the evaporation of sweat. Evaporative cooling occurs when the air temperature is reduced by the transfer of heat from air to evaporative water (Morrison, 1983). A cow must be able to efficiently regulate its body temperature by dissipating heat, so when air temperatures approach those of skin temperature, the evaporation of water through the respiratory tract and sweating of the skin occurs (Lee, 1967). Evaporative cooling has been confirmed as the main mechanism for heat dissipation in other studies (Kibler and Brody, 1952; Dowling, 1956; Allen, 1962; Allen et al, 1969). The vapor pressure of water, or absolute humidity, affects the rate of evaporation so it is expected to affect the rate of respiratory heat loss (Morrison, 1983). Allen (1962) reported that Jersey heifers had a higher respiratory rate than Zebu heifers indicating that Jersey cattle rely more on respiratory evaporation. Worstell and Brody (1953) also reported that Zebu

cattle had lower respiratory rates.

However, different cattle breeds exhibited differing levels of evaporative cooling. Evaporative cooling rates have also been reported to differ among *Bos taurus* and *Bos indicus* breeds. Kibler and Brody (1952) and Allen et al (1962) noted that *Bos indicus* breeds have a larger sweat gland than *Bos taurus* breeds; however, the maximum sweating rates of cattle were similar for *Bos taurus* and *Bos indicus* breeds (Kibler and Brody, 1952; Ferguson and Dowling, 1955).

Schleger and Turner (1965) reported that sweating rates differed in *Bos indicus* and *Bos taurus* breeds. The authors used a 7-point hair coat scoring system they developed to compare the differences of sweating rates in the different breeds. They reported that in the *Bos taurus* cattle, the lower coat score (sleeker, short coat) is associated with high sweating rates when the cattle were exposed to moderate to high heat stress. This association was not seen in the *Bos indicus* cattle under the same conditions. Seif et al (1979) also reported that *Bos indicus* cattle had lower sweating rates than *Bos taurus* even though they have lower rectal temperatures. They concluded that other mechanisms must be in place for these cattle to more efficiently dissipate heat than *Bos taurus* cattle.

Other mechanisms that cattle use to dissipate heat include heat exchange through convection, conduction, and radiation (Blackshaw and Blackshaw, 1994). Increased blood flow to the skin allows for the increase in heat loss due to convection and conduction (Choshniak et al, 1982). Finch (1985) investigated the effect of high heat on non-evaporative

4

heat transfer, more specifically on tissue conductance (ease of transfer of metabolic heat internally to the skin) and non-evaporative heat loss from the skin to the environment to determine the thermoregulatory differences in the cattle breeds. Purebred *Bos taurus* steers benefitted the least from the non-evaporative heat loss when exposed to high heat. Tissue conductance dropped along with a fall in metabolic rate and a rise in respiratory heat loss resulted in reduced heat flow from the core to the skin. The crossbred *Bos taurus* x *Bos indicus* steers experienced similar results to the purebred, but were able to maintain tissue conductance. The *Bos indicus* purebreds were able to maintain tissue conductance and had the lowest rate of heat storage at the highest temperatures. *Bos indicus* cattle are more able to efficiently increase heat loss through non-evaporative heat loss (Finch, 1985).

Heat Stress

Due to higher humidity and higher ambient temperatures, the risk of cattle experiencing heat stress increases significantly (Morrison, 1983; Blackshaw and Blackshaw, 1994; Mader, 2003; Berman, 2005). It has also been documented that different breeds of cattle (*Bos taurus* versus *Bos indicus*) react differently to heat stress, in terms of production and reproductive efficiency. *Bos indicus* cattle are more able to maintain adequate production and reproductive efficiency under heat stress than *Bos taurus* cattle.

Reduced Production and Efficiency

As the ambient temperature increases, cattle show changes in behavior and physiology which lead to reduced efficiency (Bonsma 1949; Ittner et al, 1958; Warwick, 1958). Heat stress can cause reduced overall growth rate of cattle and can decrease milk production (Morrison, 1983). An animal that cannot adequately dissipate excess heat from its body will reduce its feed intake in order to reduce the amount of internal heat production. Heat stress can also affect the maintenance energy of the animal because higher temperatures cause an animal to use energy to dissipate heat as well as maintain adequate metabolic action (McDowell et al, 1969).

Young cattle experiencing heat stress often exhibit reduced feed intake which results in reduced growth rate and an extended time to reach market weight. When time to market weight is extended, feed for maintenance increases and fixed costs associated with days on feed increase. The result is increased costs and reduced profit for producers. Hahn et al (1974) studied the effects of moderate heat stress and severe heat stress. Hereford cattle were exposed to the heat stress for about 5 weeks and then returned to thermoneutral conditions. The cattle under the moderate heat stress exhibited compensatory growth and within a couple of weeks, they were at the same weight as the control group. The cattle under severe heat stress were also returned back to normal thermoneutral conditions, but these animals did not exhibit the same amount of growth as compared to the control group. Morrison and Lofgreen (1979) also reported a decrease in feed intake and rate of gain for heat stressed cattle.

Ragsdale et al (1957) investigated the growth rate of three breeds of cattle (Brahman, Santa Gertrudis, and Shorthorn) at 10º C and 27º C. They found that only Shorthorn calves were affected adversely by the higher temperature. There have also been reported differences in production for dairy cattle exposed to high heat. Colditz and Kellaway (1972) reported that Holstein-Friesian cattle had reduced gains at higher heat than when compared to normal temperatures. They also reported differences between breeds with the Brahman x Holstein-Friesian having the highest average daily gain when compared to Holstein-Friesian and Brahman purebreds.

Reduced Reproductive Performance

It has been reported that reproductive performance decreases when cattle are exposed to heat stress. Bond and McDowell (1972) investigated the long-term effects of high heat and humidity (32º C and 60% relative humidity) on female beef cattle by comparing animals acclimated to cold weather (average temperature of 1.2º C) to animals acclimated to warm summer weather (24.4 º C). Physiological responses that were measured included ovarian activity, length of estrous cycle, pregnancy rate, body temperature, respiration rate, body growth rate, water intake and hair coat growth (Bond and McDowell, 1972).

The winter acclimated heifers experienced dramatic changes in the physiological responses measured when exposed to the high heat. The rectal temperatures increased for about 7 weeks and either remained constant or returned to normal values by 11 weeks with a

similar effect on respiration rates. The summer acclimated heifers also experienced increased

rectal temperatures and respiration rate; however, these animals showed a rapid decline in

these measures followed by fluctuations throughout the trials (Bond and McDowell, 1972).

Kamal et al (1962) also reported that cattle acclimated to warm weather showed lower signs

of heat stress than cattle acclimated to cold temperatures. Johnson *et al* (1961) and Gangwar

(1964) reported that cattle exposed to high heat, eventually acclimated to the environment

after a period of time. Both groups experienced anestrus when exposed to prolonged high

heat, but eventually began to cycle normally as the heifers acclimated to the heat. A

reduction in ovary function was also noted for the winter acclimated heifers. One of the

important physical changes observed was the difference in hair coat between the two groups.

The winter acclimated groups shed their hair coat and there was a noticeable decrease in coat

depth while being in the high heat chamber. The summer acclimated cattle did not exhibit the

same shedding of the coat with only some observed thinning. The authors concluded that

high heat leads to reproductive problems and causes immediate changes in the physiological

processes in cattle, independent of previous acclimation to warm weather or not (Bond and

McDowell, 1972).

As mentioned above, heat stress causes reproductive problems such as reduced

developmental rates of embryos, which decreases the probability of the cow successfully

producing another calf. Other reproductive problems can include an alteration in

folliculogenesis (Wolfensen et al, 2000), reduced uterine blood flow (Roman-Ponce et al,

1978) and a reduction of progesterone circulation (Rosenberg et al 1982; Wise et al 1988;Younas et al 1993). It has also been documented that breeds respond differently to heat stress, especially with respect to embryo development (Block et al, 2002; Eberhardt et al, 2009; Satrapa et al, 2011). Recently, Silva et al (2013) investigated the effects of heat stress on embryo development, quality and survival in both *Bos indicus* and *Bos taurus* cattle produced in vitro. Embryos were from both *Bos indicus* and *Bos taurus* and randomly separated into a control group (38.5º C for continued period) and a heat stress (41º C for 6 hours and then back to38.5º C) group. Embryos subjected to heat stress had lowered rates of development and lower overall quality. In all cases, the *Bos indicus* embryos were less affected by the heat stress than the *Bos taurus.* The authors concluded that heat stress reduces the developmental rates of bovine embryos and reported significant differences between cattle breeds.

Heat Tolerance

In order for beef cattle to be productive, they must be able to tolerate and acclimate to the environment they are raised in. There has been research conducted throughout the years to determine how cattle dissipate excess heat efficiently.

Due to reported differences in a cow's ability to dissipate heat efficiently, differences in heat tolerance can be assumed. According to Hahn (1999), the temperature zone for optimal beef cattle performance is between 5-15ºC but will vary depending on individual

cattle health, ability to adapt to the climate, availability of adequate feed and water, and the presence of parasites or other pests. The temperature range also varies depending on other environmental factors, such as a wet coat. Increased air velocities leads to an increase in the temperature range. Exposure to solar radiation and elevated humidity leads to a decrease in the temperature range (Hahn, 1999).

The ability of cattle to acclimate to elevated ambient temperature is essential for heat tolerance. As discussed above, Bond and McDowell (1972) investigated the effects of high heat on summer acclimated cattle versus high heat on winter acclimated cattle. The ability of cattle to acclimate to high heat at a faster rate reduces the adverse effects of decreased feed intake and reduced reproductive performance. Bianca (1959a) reported that calves exposed to a daily temperature of 45º C and 28% relative humidity over a 3 week period resulted in an increase in sweating rates and a lower metabolic rate. Kibler et al (1965) reported increases in respiratory and evaporation rates after one week of high heat exposure. The cattle then showed a 25% decrease in these rates by week 2, showing acclimatization was starting to occur.

As has been discussed, cattle breeds differ in their ability to thermoregulate and ability to adapt to high heat. Hansen (2004) investigated the physiological and cellular adaptations of *Bos indicus* cattle to heat stress. *Bos indicus* cattle have the ability to thermoregulate under high heat stress more efficiently than *Bos taurus* cattle which in part is due to genetic adaptations that have occurred over time between the two breeds. *Bos indicus*

cattle have acquired genes which allow them to more efficiently dissipate heat and be more heat tolerant than *Bos taurus* cattle.

Another aspect of heat tolerance is the role of hair coat. Dowling (1956) used a heat tolerance equation to determine a cow's ability to dissipate heat immediately after being stressed. However, the cattle were separated by length of hair coat so the differences in the groups could have been attributed to differences in length of coat or a combination of sweating and length of hair coat. Yeates (1955) investigated the effects of photoperiodicity on hair coat growth in cattle. Calves exposed to short day periods and constant ambient temperature (similar to daylight in winter months) experienced a reduction in hair coat shedding and length of the hair increased. Calves exposed to longer day periods and also constant temperature (common with warm summer months) experienced a shedding of the coat. The two groups were then exposed to high heat stress and the calves that had the thicker, longer coats experienced a rapid increase in rectal temperature while the calves with the short coats did not experience the rapid increase in rectal temperatures. Yeates concluded that cattle with the thicker hair coats would most likely be at a disadvantage in the warm subtropical regions due to the inability to adequately dissipate internal heat. Dowling (1959) investigated the differences in medullation patterns of winter hair coat versus summer hair coat. The winter hair coat has longer, less medullated fibers that allow for heat insulation while the summer coat has thicker, short medullated fibers that are stiffer and result in an enhancement of air movement at the skin surface.

Thick, dense hair coats have been shown to reduce the ability of heat loss through conduction and convection and leads to typical adverse affects of heat stress. These thicker hair coats are more typically observed on *Bos taurus* cattle (Finch et al, 1984). *Bos taurus* cattle that have sleeker, shorter hair coats also appear to have lower internal body temperatures as well as increased gains and reproductive performance. Turner and Schleger (1960) created a visual hair coat scoring system for cattle on a scale of 1-7 with a 1 having an "extremely short" coat to a 7 with a "very wooly" coat. Calves were scored from about 3 months of age to 23 months. An important aspect of the research indicated that for each unit decrease in coat score, there was an 11.3 kg increase in growth of *Bos taurus* calves. Skin and rectal temperatures were also recorded. In the *Bos taurus* breeds, the lower hair coat scores were associated with lower skin temperature.

Although a biological mechanism relating hair coat and growth was not determined, the authors pointed out that the correlation between growth and hair coat are important as they relate to the efficiency of heat dissipation. Schleger and Turner (1960) wanted to determine which hair characteristics are responsible for the correlation between hair coat and performance. They investigated depth of coat, hair diameter, percentage of medullated hairs, maximum length of fine hairs, hair curvature and follicle angle. However, they determined that the hair coat score is a better assessment of performance when compared to individual hair characteristics.

Gray et al (2011) also investigated the effects of hair coat shedding, but used the

scores of the dam and the relationship to weaning weight of the calf. Hair coat shedding scores (HCS) were on a 5-point scale with 1 being a slick summer coat and 5 being a thick, winter coat. The scores were collected on Angus dams every 30 days for five months. Cows were separated into two categories consisting of cows that had shed and cows that had not shed by a specific date. Cows which had reached a shedding score of 3 or less by June 1st, on average, weaned calves that were 11.1 kg heavier when compared to the cows that had hair coat scores of 4 or 5 on June 1st. Classification of cows based on the 5 point hair coat scoring system may provide an objective measure for identifying cows differing in heat tolerance.

Selection for Heat Tolerance

As has been discussed, variation exists within and among breeds for the ability to tolerate high heat stress and efficiently dissipate excess heat. Among breed selection for heat tolerance has been practiced for many years. This is one of the reasons that Bos indicus cattle are used in crossbreeding programs in regions which commonly experience elevated ambient temperatures. Developing a method of objectively measuring and selection within Bos Taurus breeds for heat tolerance would be beneficial for cattle producers, as well as, for overall cattle well-being. Heat tolerance is a combination of the cow's ability to dissipate excess heat by evaporative cooling, radiation, convection and conduction. Certain cattle breeds have been shown to be more heat tolerant when compared to others by their ability to dissipate excess heat more efficiently. One aspect of this difference is the hair coat (Hansen,

2004).

It has been well documented that *Bos indicus* and *Bos indicus*-influenced cattle are better able to tolerate the high levels of heat, so these cattle do not experience reduced gains and reproductive performance due to high environmental heat (Ragsdale et al, 1957; Finch, 1986; Carvalho et al, 1995; Silva et al, 2013). Hansen (2004) reported that due to *Bos indicus* cattle being able to experience less severe adverse affects of heat stress, producers would benefit from crossbreeding *Bos indicus* cattle with *Bos taurus* cattle to obtain heat tolerant cattle. *Bos indicus* cattle normally do not experience the same reduced feed intake, growth rate, milk yield and reproductive performance compared to *Bos taurus* cattle under hot climates.

However, there are some genetic characteristics of *Bos indicus* cattle that reduce their desirability to be crossbred in the United States. These characteristics include the perception of poor meat tenderness, short estrus duration, increased time to puberty in heifers, and poor temperament. Selecting for the beneficial traits of heat tolerance while avoiding the undesirable traits can help overall cattle performance. One aspect of heat tolerance that has shown genetic and phenotypic variation is the hair coat. *Bos indicus* cattle are known to have sleeker, shorter coats that appear to increase the ability to dissipate heat. *Bos indicus* cattle are believed to have evolved and accumulated genes associated with increased heat tolerance, with a component being a sleeker, shorter hair coat (Hansen, 2004).

Prayaga et al (2009) reported on the importance of heat tolerance in beef cattle. They

investigated different aspects of heat tolerance, such as rectal temperature during ambient temperature of greater than 30º C, coat color and coat score. Rectal temperatures have a low to moderate heritability with coat score having a moderate to high heritability. Selecting animals that have lower hair coat scores and normal rectal temperatures under heat stress could lead to cattle with heat tolerance.

Olson et al (2003) investigated the genetics of hair coat in *Bos taurus* cattle by crossbreeding Holstein cattle with thick, wooly coats to Carora cattle with slick coats. The slick-hair gene is found in Senepol cattle and Spanish-derived breeds in Central and South America. A backcross of normal-haired sires to Senepol-crossed dams, assumed heterozygous resulted in both slick-haired and normal-haired progeny. The gene associated with slick hair cattle is believed to be dominant. The calves with slick hair were shown to have lower rectal temperatures compared to the cattle with thicker hair. The weaning weights did not differ between the normal-hair calves and the slick-haired, but that could have been due the fact that calves were nursed by slick-haired dams. There was an indication that the slick-haired calves had higher gains post-weaning compared to the normal-haired calves.

Dikmen et al (2008) also compared the production of slick-haired cows versus normal-haired cows. They reported similar findings of Olson et al (2003) in that the slick-haired cows were better able to regulate body temperature than normal-haired cows. In the slick-haired cows, reduced rectal temperatures and post-weaning gain appear to be signs of heat tolerance that would be beneficial for dairy cattle production.

Increased milk production in high heat environments is important for the dairy industry, but the slick-haired gene needs to be incorporated into the beef cattle industry to help alleviate heat stress in the United States. Senepol crosses with common beef cattle breeds, Angus and Charolais, have been shown to be as heat tolerant as *Bos indicus* breeds but with better meat quality, docility, and insect resistance (Mariasegaram et al, 2007). Mariasegaram et al (2007) conducted a genome-wide study utilizing DNA pooling to locate the slick hair gene. They reported that the slick hair gene is most likely on chromosome 20. Determining the location of the gene can assist in selecting cattle for heat tolerance as it relates to sleeker hair.

The incorporation of the slick gene could benefit the cattle industry in the United States. Commercial cattle producers could use this to help incorporate the gene so their cattle are less likely to suffer from the adverse effects of heat stress. However, for cattle producers who use only registered breeds, crossbreeding is most likely not going to be used in those herds. For those producers, the hair coat scoring system could be an option to select cattle. As has been reported by Turner and Schleger (1960) and Gray et al (2011), the hair coat is moderately heritable and has been associated with growth and production on different breeds. The hair coat scoring system could be incorporated into a selection program to help select cattle that are more heat tolerant.

Summary

An important aspect of cattle production is the proper management of daily environmental stressors that can cause adverse affects on overall cattle performance. A reduction in efficiency, production, and reproduction are common results of high heat environmental stressor. Cattle must be able to efficiently thermoregulate in order to avoid the adverse effects of heat stress.

The thermoregulatory mechanisms of cattle vary between breeds and can explain how some breeds are able to reduce the adverse affects of high heat loads. Evaporative cooling is the main mechanism for the reduction of internal heat in *Bos taurus* cattle along with conduction, convection, and radiation loss. In *Bos indicus* cattle, non-evaporative heat loss is a primary mechanism that can help explain the differences in efficiency between the two breeds. The sweating rates are normally lower in *Bos indicus* breeds, but the rectal temperatures normally remain constant despite the high heat stress.

Heat stress is a common environmental stressor that cattle producers need to manage. Studies have shown that high heat stress over extended periods of time result in reduced average daily gain of cattle and reduced overall weight of beef cattle. *Bos taurus* cattle have a reduced rate of embryo development, quality, and survival when exposed to even acute high heat stress as compared to *Bos indicus* cattle. Anestrus and reduced ovarian activity have also been reported as an adverse affect of high heat stress. However, cattle are dynamic animals that can adapt to their surrounding environment as long as the intensity and duration is not so

severe that the individual cannot acclimate. Cattle that are acclimated to the higher temperatures are more likely to be able to dissipate heat when exposed to a high heat environment as compared to cattle acclimated to cold temperatures.

Heat tolerance can be defined as an animal's ability to adequately dissipate high heat without experiencing the adverse effects. The genetics of the animal influence this ability. Certain beef cattle breeds have been reported as being more heat tolerant than others, mainly *Bos indicus* and *Bos indicus*-influenced cattle. These cattle have the ability to dissipate excess heat, by either higher sweating rates or other biological mechanisms that have not been found. These cattle also have shorter, sleeker hair coats that aid in the ability to dissipate excess heat. *Bos taurus* cattle that shed their winter coats at a faster rate have been shown to have increased gain.

Selection for heat tolerant cattle is important for cattle producers in hot, humid climates. Heat tolerance is essential for cattle to remain highly productive animals. *Bos indicus* cattle are known to be more heat tolerant than *Bos taurus* cattle due to their ability to more efficiently dissipate heat. However, these cattle also have undesirable genetic characteristics such as poor meat quality and shorter estrus duration. Research has shown that cattle that are able to shed their winter hair coat in the warm summer months, are more likely to tolerate heat stress and produce a heavier calf. A selection method for heat tolerance based on hair coat can help alleviate environmental stresses associated with high heat. The ability of cattle to produce heavier calves is a benefit for not only the cow-calf producer, but also the

feedlot owners and the consumer as well due to the decreased input of feed needed to obtain the optimal weight for slaughter.

LITERATURE CITED

Allen, T.E. 1962. Responses of Zebu, Jersey, and Zebu x Jersey crossbred heifers to rising temperature, with particular reference to sweating. Aust. J. Agric Res. 13: 165-179.

Allen, T.E., J.W. Bennett, and S.M. Donegan, J.C.D. Hutchinson. 1969. Moisture, its accumulation and site of evaporation in the coats of sweating cattle. J. Agri. Sci. 74: 247-258.

Berman, A. 2005. Estimates of heat stress relief needs for Holstein dairy cows. J. Anim. Sci. 83: 1377-1384.

Bianca W. 1959a. Acclimatisation of calves to a hot, dry environment. J. Agri. Sci. 52: 296-304

Blackshaw, J.K. and A.W. Blackshaw. 1994. Heat stress in cattle and the effect of shade on production and behavior: a review. Aust. J. Exp. Agric. 34: 285-295.

Block, J., C.C. Chase Jr., and P.J. Hansen. 2002. Inheritance of resistance of bovine preimplantation embryos to heat shock: relative importance of the maternal vs paternal contribution. Mol. Repro. Dev. 63: 32-37.

Bond, J. and R.E. McDowell. 1972. Reproductive performance and physiological responses of beef females as affected by a prolonged high environmental temperature. J. Anim. Sci. 35(4): 820-829.

Bonsma, J.C. 1949. Breeding cattle for increased adaptability to tropical and subtropical environment. J. Agr. Sci. 39: 204

Carvalho, F.A., M.A. Lammoglia, M.J. Simoes, and R.D. Randel. 1995. Breed affects thermoregulation and epithelial morphology in imported and native cattle subjected to heat stress. J. Anim. Sci. 73: 3570-3573.

Choshniak, I., D. McEwan-Jenkinson, D.R. Blatchford, and M. Peaker. 1982.Blood flow and catecholamine concentration in bovine and caprine skin during thermal sweating. Com. Biochem. Physiol. 71C: 37-42.

Colditz, P.J. and R.C. Kellaway. 1972. The effect of diet and heat stress on feed intake, growth, and nitrogen metabolism in Friesian, F_1 Brahman × Friesian, and Brahman heifers. Aust. J. Agri. Res. 23(4): 717-725.

Dikmen, S., E. Alava, E. Pontes, J.M. Fear, B.Y. Dikmen, T.A. Olson, and P.J. Hansen. 2008. Differences in thermoregulatory ability between slick-haired and wild-type lactating Holstein cows in response to acute heat stress. J. Dairy Sci. 91(9): 3395-3402.

Dowling, D.F. 1956. An experimental study of heat tolerance of cattle. Aust. J Agri. Res. 7(5): 469-481

Dowling, D.F. 1959. The medullation characteristic of the hair coat as a factor in heat tolerance of cattle. Aust. J. Agri. Res. 10(5): 736-743.

Eberhardt, B.G., R.A. Satrapa, C.R.L. Capinzaiki, LA. Trinca, and C.M. Barros. 2009. Influence of the breed of bull (*Bos taurus* indicus vs. *Bos taurus* taurus) and the breed of cow (*Bos taurus* indicus, *Bos taurus* taurus and crossbred) on the resistance of bovine embryos to heat. Anim. Repro. Sci. 114: 54-61.

Ferguson,K.A. and D.F. Dowling. 1955. The function of cattle sweat glands. Aust. J. Agric. Res. 6(4): 640-644.

Finch V.A., I.L Bennett, and C.R. Holmes. 1984. Coat colour in cattle: effect on thermal balance, behavior and growth, and relationship with coat type. J. Agric. Sci. (Cam). 102: 141-147.

Finch, V.A. 1985. Comparison of non-evaporative heat transfer in different cattle breeds. Aust. J. Agric. Res. 36: 497-508.

Finch, V.A. 1986. Body temperature in beef cattle: Its control and relevance to production in the tropics. J. Anim. Sci. 62:531-542.

Gangwar, P.C. 1964. The effect of climatic stress on ovarian activity of dairy heifers. Ph.D. Thesis. La State University, Baton Rouge, La.

Gray, K.A, T. Smith, C. Maltecca, P. Overton, J.A. Parish, and J.P. Cassady. 2011. Differences in hair coat shedding, and effects on calf weaning weight and BCS among Angus dams. Livest. Sci. 140: 68-71.

Hahn, G.L. 1999. Dynamic responses of cattle to thermal heat loads. J. Anim. Sci. 77(2): 10-20.

Hahn, G.L. N.F. Meador, G.B. Thompson, and M.D. Shanklin. 1974. Compensatory growth of beef cattle in hot weather and its role in management decisions. Proc. Int. Livest. Environ. Symp., Amer. Soc. Agric. Eng., St Joseph, MI. 288.

Hansen, P.J. 2004. Physiological and cellular adaptations of zebu cattle to thermal stress. Anim Repro Sci. 82-83:349-360.

Ittner, N.R. T.E. Bond and C.F. Kelly. 1958. Methods of increasing beef production in hot climates. Calif. Agr. Exp. Sta. Bull. 761.

Johnson, J.E., G.A. Hindery, D.H. Hill, and A.J. Guidry. 1961. Factors concerned in hot weather effects on growth and feed efficiency of dairy heifers. J. Dairy Sci. 44: 1191

Kamal, T.H., H.D. Johnson, and A.C. Ragsdale. 1962. Metabolic reactions during thermal stress (35º to 95º F) in dairy animals acclimated at 50º and 80º F. Missouri Agr. Exp. Stat. Bull.

Kibler, H. and S. Brody. 1952. Influence of radiation intensity on evaporative cooling, heat production, and cardiorespiratory activities in Jersey, Holstein, and Brahman cows. Missouri Agric. Exp. Stat. Bull No. 574.

Kibler, H., H. Johnson, H.D. M.D. Shanklin, and L. Hain. 1965. Acclimation of Holstein cattle to 84º F (29º C) temperature: changes in heat producing and heat dissipating functions. Missouri Agri. Exp. Stat. Bull. No. 893.

Lee, D.H.K. 1965. Climatic stress indices for domestic animals. Int. J. Biometeorol. 9: 29-35.

Mader, T. L. 2003. Environmental stress in confined beef cattle. J Anim Sci. 81(E. Suppl.2): E110-E119.

Mariasegaram, M., C.C. Chase Jr., J.X. Chaparro, T.A. Olson, R.A. Brenneman and R.P. Niedz. 2007. The slick hair coat locus maps to chromosome 20 in Senepol-derived cattle. Anim. Gene. 38: 54-59.

McDowell, R.E., E. G. Moody, P.J. Van Soest, R.P. Lehman, and G.L. Ford. 1969. Effect of heat stress on energy and water utilization. J. Dairy Sci. 52: 188.

Morrison, S.R. and G.P. Lofgreen. 1979. Beef cattle response to air temperature. Trans. Amer. Soc. Agr. Eng. 22: 861.

Morrison, S.R. 1983. Ruminant heat stress: effect on production and means of alleviation. J. Anim. Sci. 57(6): 1594-1600.

Olson, T.A., C. Lucena, C.C. Chase Jr, and A.C. Hammond. Evidence of a major gene influencing hair length and heat tolerance in *Bos taurus* cattle. J Anim. Sci. 81: 80-90.

Prayaga, K.C., N.J. Corbert, D.J. Johnston, M.L. Wolcott, G. Fordyce and H.M. Burrow. 2009. Genetics of adaptive traits in heifers and their relationship to growth, pubertal and carcass traits in two tropical beef cattle genotypes. Anim. Prod. Sci. 49: 413-425.

Ragsdale, A.C., C.S. Cheng, and H.D. Johnson. 1957. Effects of constant and environmental temperatures of 50º F and 80º F on the growth responses of Brahman, Santa Gertrudis, and Shorthorn calves. Missouri Agri. Exp. Sta. Bull. No. 642.

Roman-Ponce, H., W.W. Thatcher, D. Caton, D.H. Barron, and C.J. Wilcox. 1978. Thermal stress effects on uterine blood flow in dairy cows. J. Anim. Sci. 46: 175-180.

Rosenberg, M., Y. Folman, Z. Herz, I. Flamenbaum, A. Berman, and M. Kaim. 1982. Effect of climatic conditions on peripheral concentrations of LH, progesterone and oestradiol-17β in high milk-yielding cows. J. Repro Fertil. 66: 139-146.

Satrapa, RA. T. Nabhan, C.F. Silva, R.A.L. Simões, E.M. Razza, R.Z. Puelker, L.A. Trinca, and C.M. Barros. 2011. Influence of sire breed (*Bos indicus* vs. *Bos taurus*) and interval from slaughter to oocyte aspiration on heat stress tolerance of *in vitro*-produced bovine embryos. Therio. 76(6): 1162-1167.

Schleger, A.V. and H.G. Turner. 1960. Analysis of coat characters of cattle. Aust. J. Agric. Res. 11: 875-885.

Schleger, A.V. and H.G. Turner. 1965. Sweating rates of cattle in the field and their reaction to diurnal and seasonal changes. Aust. J. Agric. Res. 16:92-106.

Seif, S.M, H. D. Johnson, and A.C. Lippincott. 1979. The effects of heat exposure (31º C) on Zebu and Scottish Highland cattle. Int. J. Biometeorol. 23: 9-14.

Silva, C.F., E.S. Sartorelli, A.C.S. Castilho, R.A. Satrapa, R.Z. Puelker, E.M. Razza, J.S. Ticianelli, H.P. Eduardo, B. Loureiro, and C.M. Barros. 2013. Effects of heat stress on development, quality, and survival of *Bos indicus* and *Bos taurus* embryos produced *in vitro.* Theriog. 79: 351-357.

Turner, H.G. and A.V. Schleger. 1960. The significance of coat type in cattle. Aust. J. Agri. Res. 11:645-663.

Warwick, E.J. 1958. Effects of high temperatures on growth and fattening in beef cattle, hogs, and sheep. J. Hered. 49: 69-74.

Wise, M.E., R.E. Rodriguez, D.V. Armstrong, J.T. Huber, F. Wiersma, and R. Hunter. 1988. Fertility and hormonal responses to temporary relief of heat stress in lactating dairy cows. Therioge. 29: 1027-1035.

Wolfenson, D., Z. Roth, and R. Meidan. 2000. Impaired reproduction in heat-stressed cattle: basic and applied aspects. Anim. Repro. Sci. 60-61: 535-547.

Worstell, D.M. and S. Brody. 1953. Comparative physiological reactions of European and Indian cattle to changing temperature. Miss. Agri. Exp. Stat. Bull. No 515.

Yeates, N. T. M. 1955. Photoperiodicity in cattle: I. Season changes in coat character and their importance in heat regulation.

Younas M., J.W. Fuquay, A.E. Smith, and A.B. Moore. 1993. Estrous and endocrine responses of lactating Holsteins to forced ventilation during summer. J Dairy Sci. 76: 430-436.

CHAPTER 2

HERITABILITY OF HAIR COAT SHEDDING SCORES IN ANGUS DAMS AND THE RELATIONSHIP WITH PRE-WEANING GROWTH IN THEIR CALVES

Heritability of Hair Coat Shedding Scores in Angus dams and the Relationship with Pre-weaning Growth in their Calves

K.M. Psaros[1], C.S. Whisnant[1], O.W. Robison[1], D.A. Dickey[2], G.R. Hansen[1], J.P. Cassady[1]

[1]Department of Animal Science, North Carolina State University, Box 7261, NCSU Campus, Raleigh, NC 27695; [2]Department of Statistics, Box 8203, NCSU Campus, Raleigh, NC 27695

ABSTRACT:

Heat stress is a major concern for some beef cattle producers. Methods to select cattle with greater tolerance to the negative effects of heat stress are economically important for producers. Decreases in feed intake, conception rates, and milk production lead to reduced gains for cows and calves. A visual scoring method of how winter hair coat is shed may help to identify cattle more tolerant to heat stress. The objectives of the study were to collect hair coat shedding scores (HCS) on registered Angus dams throughout the Southeast, Missouri, and Texas and to explore the relationship between HCS of the dam and kilograms of calf weaned per day of age of dam. Hair coat shedding scores were collected from 20 farms in 2011-2012 in North Carolina, South Carolina, Virginia, Tennessee, Kentucky, Missouri, Alabama, and Texas. Hair coat shedding scores were on a 1-5 scale with 5 being a cow with a full winter hair coat and a 1 being a slick summer coat. Two technicians independently scored each cow. Using the average of the two scores, cows were assigned to two categories. If the average score was above 3, she was considered as not shed and denoted as 1. If the average score was less than 3, she was considered as shed and denoted as 0. Hair coat score

was affected by owner, year and age of dam. The odds of being shed increased as age

increased from 0.38 for 3 year olds, 0.44 for 4 year olds and 0.47 for 5 years and older cows

(P < 0.01). Herd life was calculated as the age (d) of the date of the most recent calf weaned

minus the birth date of the cow. The analysis of herd life also demonstrated that, on average,

cows that were older (56.7 days, P < 0.01) were more likely to be shed. Cows that were

considered shed, on average, weaned calves 2.54 kg (P < 0.01) heavier than cows that were

not considered as shed. Shed cows also weaned 30.62 kg (P < 0.05) more in total kg of

weaning weight over their lifetime compared to cows that were not shed. Phenotypic

correlations between HCS and herd life, weaning weight and total weaning weight are 0.014

(P > 0.05), -0.096 (P < 0.01), and -0.023 (P > 0.05), respectively. The correlations are low,

which suggests that other environmental parameters are affecting the statistically significant

relationships in the model. Variance components were estimated for HCS using

THRGIBBS1F90. Heritability was moderate at 0.42 (95% CI, 0.367 0.478) and in agreement

with previous studies (Williams et al 2006; Gray et al, 2011). In conclusion, genetic

variability in hair coat has been determined, but due to the low phenotypic correlations

indirect selection for total weaning weight may not as valuable of a selection tool for

producers when compared to other selection tools.

Introduction

In the beef cattle industry, optimal animal performance is affected by genetics and environmental stressors. A cow's ability to acclimate to environmental stressors is, in part, due to genetics. Identifying animals capable of maintaining optimal performance during times of environmental stress is a critical step when developing a selection program which includes heat tolerance as one of the breeding objectives. Cattle producers have limited control over the environment in which their animal must perform. Many cattle are raised in semi-arid and tropical regions where adaption to heat stress is critical to performance.

Cattle that are heat tolerant are better able to sustain performance during times of high heat stress as compared to cattle that are susceptible to heat stress (Morrison, 1983). Identifying measureable phenotypes which are correlated to heat tolerance and estimating the extent to which those phenotypes are genetically determined is critical to developing strategies for selecting for better heat tolerance. Hair coat shedding has been shown to vary among and within breeds (Turner and Schleger, 1960; Williams et al, 2006; Gray et al, 2011). Cattle with thicker, longer coats have greater difficulty regulating body temperature via conduction and convection during times of heat stress (Finch et al, 1984). Hair coat thickness and length varies in Angus cattle. Black Angus cattle also have dark hair color which increases the amount of solar radiation absorbed and further increases internal body heat (Hansen, 2004).

Angus dams are at a disadvantage in high heat environments, in part, due to the hair

coat. The ability of these dams to shed their winter coat at a rate that is adequate for optimal acclimation to seasonal increases in ambient temperature is important for maintaining optimal performance. The objective of this study was to estimate the heritability of hair coat shedding scores in registered Angus dams and the performance of their calves in multiple locations throughout the southeastern and south central regions of the United States.

Materials and Methods

Description of Animals

Hair coat shedding scores were collected on 5233 registered Angus dams from 2011-2012. There were cows with 2 hair coat scores which resulted in 6995 total records. There were 20 locations distributed across nine states (North Carolina, South Carolina, Virginia, Tennessee, Kentucky, Missouri, Texas, Alabama and Mississippi) as outlined in Table 1. Two locations were only visited the first year. Cows calved in both spring and fall.

Description of Data

During mid-May to June, two trained technicians scored each dam once for hair coat shedding as described by Gray et al (2011). The scale was from 1 to 5 with a 5 considered the full winter coat and 1 as a slick summer coat. A score of 3 was considered a cow with about half of her winter coat shed. A score of 4 was represented as a cow that had begun to shed

but had not reached the halfway point and a score of 2 was over halfway shed but was not completely shed (Table 2). Data were edited to remove duplicate records and any inaccurate cow identification numbers. Only cows which weaned a calf in 400 days prior to the date the HCS was recorded were included in the analysis.

Adjusted 205-day weaning weights and all associated data were provided by the American Angus Association and were adjusted for age of dam and sex of calf. Due to environmental differences across geographic regions, locations were separated into three regions. The regions were Southeast, Missouri and Texas as outlined in Table 1. Age of dam was calculated as the number of days from birth to the day she was visually scored. The number of days was then converted to years. All dams 5 years and older were grouped together. Herd life was calculated as the date of the cow's most recent weaned calf minus her birth date. For each cow, the total kilograms weaned per day of age was calculated as the sum of the weaning weight for all calves weaned divided by the cow's herd life in days.

After determining there were no significant differences between certain months on weaning weight, the months were grouped together as follows: January-March (JAN), April-June (APR), July-September (JUL), and October-December (OCT).

Phenotypic Analysis

Data were analyzed using the SAS system (Version 9.2, SAS Inst. Inc. Cary, NC). Relationship between weaning weight of the calf and hair coat shedding score of its dam has

been shown to be related in previous research (Gray et al, 2011). If the average HCS was less than or equal to 3, then the cow was considered as shed. If the average HCS was greater than 3, the cow was considered as not shed.

Four models were used in the phenotypic analysis. The first model used HCS as the response variable and data were analyzed using PROC GLIMMIX. A binomial distribution with the link function as a logit was used. Fixed effects included owner nested within region, region, year, and age of dam. A random residual effect was used. The second model used adjusted weaning weight as the response variable and data were analyzed using PROC MIXED. The fixed effects included owner nested within region, region, sex of calf, year of HCS, region by year interaction, HCS, region by HCS interaction, and wean month. Dam of the calf was included as a random effect to account for the repeated records. Differences in each of the fixed effects were determined by using the Least Squares Means option in the MIXED procedure of SAS.

The third model was also analyzed by using PROC GLM in SAS. The response variable used was total kilograms weaned per dam. Fixed effects included in the model were owner nested within region, region, wean month, and HCS. Differences in each of the fixed effects were determined by using the Least Squares Means option in the GLM procedure of SAS.

The final model used herd life as the response variable and the data were analyzed using PROC GLM. The fixed effects included in the model were owner nested within region,

region, wean month, and HCS. Differences in each of the fixed effects were determined by using the Least Squares Means option in the GLM procedure of SAS. In all data analyses, the degrees of freedom were adjusted with the Tukey-Kramer adjustment.

Variance Component Estimation

Variance components were estimated for hair coat score as a threshold model using THRGIBBS1F90 (Misztal et al, 2002). The data were formatted by using the RENUMF90 program. A three generation pedigree of known parentage was used in the model. An animal model was fit which included fixed effects for owner of cow, region, year of score, and age of dam. A random cow effect was fit in the model. A single-chain of 150,000 iterations with a burn-in period of 50,000 samples was used. A visual confirmation of convergence was used by the trace plots in the POSTGIBBSF90 analysis. Heritability of HCS was estimated based on the variance components of the posterior means.

Results

Phenotypic Analysis

Least square means for each of the traits are shown in Table 3. Initially, the HCS were assigned to one of three categories for analysis. If a cow had an average HCS of less than 3, she was assigned to HCS1. If a cow had an average HCS between 3 or 4, she was assigned to HCS3. If a cow had an average HCS of 4 or greater, she was assigned to HCS5.

However, because calf WW did not differ (P > 0.10) for categories HCS1 and HCS3 but calf

WW did differ between HCS1 and HCS5 (P < 0.01) and between HCS3 and HCS5 (P <

0.05), it was determined that cows should be considered as either SHED or NOT SHED.HCS

was affected by all effects in the model (P < 0.001). There was variation of HCS between the

different herds; however, not all herds had significant differences in HCS within them.

Region was statistically significant in the model with the probability of being SHED in MO

as 0.45, SE as 0.38, and Texas as 0.45 (P < 0.05). Year was also statistically significant with

the first year having a probability of being SHED of 0.34 compared to 0.52 for the second

year (P < 0.01). Effect of age of dam was significant for HCS with the probability of being

SHED increasing as age increased. The probability of being SHED was 0.38, 0.44, and 0.47

for 3, 4, and 5 year old and older dams, respectively (P < 0.05).

Cows that were SHED weaned calves that weighed 2.5 ± 0.89 kg more than cows

NOT SHED (P < 0.01). All other fixed effects in the model were significant (P < 0.01).

There were some herds that did not have any statistically significant differences in weaning

weight (P > 0.10). The difference in weaning weights for the regions were statistically

significant with MO being different from both SE and TX with calves in MO weighing on

average 10.0 ± 1.09 kg and 11.6 ± 1.28 kg more, respectively (P < 0.01). Bull calves

weighed on average 25.9 ± 0.76 kg more than heifer calves (P < 0.01). Calves weighed on

average 10.8 ± 0.81 kg more in the second year than the first year. There were also

significant year by region interactions with calves weighing 26.8 ± 1.70 kg heavier in TX for

the second year when compared to the first (P < 0.01). In MO, the differences between the second year and first was 8.3 ± 1.20 kg (P < 0.01) and in the SE, the differences between the second and first year was 2.9 ± 1.23 kg (P < 0.01). There were significant differences in the wean month groups with the most significant difference between JAN and OCT with OCT calves weighing 26.1 ± 2.54 kg more than the calves in JAN (P < 0.01). Calves weaned in the APR group weighed on average 20.0 ± 1.96 kg more than in the JAN group (P < 0.01), 8.6 ± 1.10 kg more in the JUL group (P < 0.01), and 5.2 ± 1.96 kg less than the OCT group (P < 0.01). Calves weaned in the JAN group weighed on average 6.4 ± 2.94 kg less than JUL (P < 0.01). Calves weaned in the JUL group weighed on average 13.7 ± 2.04 kg less than the OCT group (P < 0.01).

Total kilograms weaned per dam was significantly affected by HCS with cows that were SHED as having weaned 30.6 ± 14.48 (P < 0.05) more kilograms over their lifetime than cows in the NOT SHED group. Wean group also affected the total kilograms weaned with JAN and OCT accounting for the most weight at 909.5 ± 44.70 kg (P < 0.01). The SE region averaged 861.52 ± 15.06 kg of total calf weaned per dam and was statistically different from MO at 726.2 ± 14.44 kg and TX at 671.5 ± 23.91 kg (P < 0.01); however, MO and TX were not statistically different from each other (P > 0.05).

Herd life was also affected by HCS. Cows that are SHED are on average 56.7 ± 21.62 days older than NOT SHED cows (P < 0.01). Significant differences were seen between some herds and all regions. The cows in the SE had the oldest herd life at 1880.5 days (5.2

years) with cows in TX averaged 1554.10 days old (4.3 years) and cows in MO averaged

1667.6 days old (4.3 years) and all regions were statistically different from each other (P <

0.01). Herd life was also affected by wean month group (P < 0.001). Cows that weaned

calves in JUL and OCT did not differ from each other (P > 0.10), but did differ from

the other wean groups. Cows that weaned calves in JAN and were older than cows that

weaned calves in APR, JUL and OCT (P < 0.01).

Variance Component Estimation

  The variance components of HCS were estimated using THRGIBBS1F90. Hair coat

shedding score was moderately heritable (h^2= 0.42, 95% CI 0.367 0.477).

Discussion

  A visual method of scoring hair coat shedding has been shown in previous studies to

be an indication of performance in animals (Turner and Schleger, 1960) and their progeny

(Gray et al, 2011). This study found associations between the HCS of the dam and growth of

the calves, which was previously reported in Gray et al (2011) on the same 5-point scale. The

estimate of the effect of cows, denoted as adapted, on weaning weight at 11.1 ± 2.8 kg was

greater than the estimate reported here. The phenotypic correlation was not reported, but the

genetic correlation was reported as moderately strong and negative suggesting that the dams

that shed earlier were more likely to wean heavier calves. This study used the same 5-point

scale and some of the same animals as Gray et al (2011), but this study was expanded to multiple locations and increased sample size to help validate the previous work.

Another aspect that was different between the two studies is the number of trained technicians who collected the scores. Gray et al (2011) used the same technicians for the entire study, but this study used multiple technicians. Because this is a subjective scoring system, consistency between scores is important for overall accuracy. The use of the average of the two HCS was used to try to counter-act the use of multiple technicians, but it may not have accounted for all the potential variation. Williams et al (2006) also investigated the relationship between hair slickness and growth in calves and reported that no phenotypic or genotypic correlations were found between growth traits and hair slickness in the US. The authors cautioned the implications of the results of the study due to the unknown number of technicians who scored cows and low sample size. Turner and Schleger (1960) discussed the importance of the same technicians scoring cattle to reduce variation due to subjectivity of the scores.

The significance of HCS on herd life demonstrates that, on average, the older cows were more likely to be shed than not shed. According to the analysis of HCS, as the cows aged up to 5 years, the probability of shedding increased. The results of these two models could be demonstrating how HCS is only important for cows up to a specific age, and then afterwards, HCS is not important on the life of the cow. It is also possible that as cattle age, they develop the ability to acclimate to heat stress, so shedding of the hair coat isn't as

essential. Also, cattle with optimal performance are more likely to be retained in the herd, regardless of the cow's ability to shed her winter coat, demonstrating the complex factors which affect beef production.

For both weaning weight and total kilograms weaned per dam, variation was seen within and among herds with some herds having no statistically significant within herd differences in weaning weight among HCS categories. Region was also a significant component for the differences in weights. Regions were separated due to known differences in nutrition, management and weather. In the SE and MO, many of the pastures contained tall fescue which is known to harbor the endophyte fungus. Endophyte-infected fescue can result in a condition known as "fescue toxicosis" which causes a reduction in feed intake, milk production, conception rate, an inability to efficiently dissipate excess body heat as well as the loss of hooves and ears (Bacon et al, 1977; Paterson et al, 1995). Another symptom of fescue toxicosis is winter hair coat retention (Porter and Thompson, 1992). Differences in HCS in the regions where tall fescue is consumed could possibly be linked to the cow's ability to tolerate the adverse effects of the endophyte. However, this study did not investigate the presence of the endophyte.

The phenotypic correlations between the traits were low (Table 4). This was an unexpected result and differs from the findings previously reported. Based on the estimated heritability of HCS it was concluded that there is substantial genetic variation for the trait. Weaning weight is typically considered a moderately heritable trait. However, it is important

to remember that HCS is being measured on the dam and weaning weight measured on the calf is being treated as a trait of the dam.

Another explanation for differences in HCS is the presence of a genotype by environment interaction. Most producers select cows that have performed the best to be bred in the next season. However, there are many other factors that a producer considers when selecting cows to be bred such as structure, udder confirmation, temperament, age, etc. It is possible that producers in certain areas have been indirectly selecting for HCS by selecting for improved performance. It has been reported that cattle with sleeker, shorter coats are less likely to exhibit heat stress due to the ability to efficiently dissipate heat. Even if the relationship between weaning weight and HCS is low, the older cows are most likely more reproductively efficient since they have not been culled due to the inability to become pregnant. Lifetime production of cows is important for cattle producers so determining which animals are performing optimally can help producers select the "best" animals for their production system.

Even though there was a low correlation between the traits of the dam and the calves, hair coat score is moderately heritable indicating that genetic as well as environmental conditions influence the coat. Turner and Schleger (1960) found that the hair coat influenced heifer, young bull, and steer growth from weaning to yearling. However, there was poor association between the hair coat of the dam and growth of the calf, even though the growth was measured after weaning. In which case the immediate maternal environment has been

removed so the genetics of the calf is in full effect, even though the maternal environment continues to influence the future production of her calf. The hair coat of the calf could indicate future growth and production. If a heifer has a low hair coat score, then she may be more heat tolerant and able to withstand future environmental stresses.

Conclusions

Beef cattle have to acclimate during times of heat stress to avoid the adverse affects associated with elevated body temperature. Weaning weight of calves can be negatively affected by cows that cannot adequately dissipate excess heat and suffer from heat stress. Genetic and phenotypic variation is evident in the hair coat of Angus dams, but it cannot be determined if a faster shedding cow is always going to be more productive. Due to the low phenotypic correlation of hair coat in dams and subsequent growth in calves, indirect selection for hair coat in dams as the result of selection for increased production in calves is not recommended. However, previous research has shown an association between post-weaning growth and hair coat in heifer calves. Future research in the subsequent reproductive performance of heifer calves and bulls that have shown to have increased growth with low HCS is suggested.

LITERATURE CITED

Bacon, C.W., J.K. Porter, J.D Robbins, E.S. Luttrell. 1977. Epichloë typhina from toxic tall fescue grasses. Appl and Envir Micro. 34(5): 576-581.

Finch V.A., I.L Bennett, C.R. Holmes. 1984. Coat colour in cattle: effect on thermal balance, behavior and growth, and relationship with coat type. J. Agric. Sci. (Cam). 102: 141-147.

Gray, K.A, T. Smith, C. Maltecca, P. Overton, J.A. Parish, J.P. Cassady. 2011. Differences in hair coat shedding, and effects on calf weaning weight and BCS among Angus dams. Livest. Sci. 140: 68-71.

Hansen, P.J. 2004. Physiological and cellular adaptations of zebu cattle to thermal stress. Anim Repro Sci. 82-83:349-360.

Misztal I., S. Tsuruta, T. Strabel, B. Auvray, T. Druet, D.H. Lee. 2002. Blupf90 and related programs (bgf90). Proc 7th World Genet Appl. Livest. Prod. Montpellier, France.

Morrison, S.R. 1983. Ruminant heat stress: effect on production and means of alleviation. J. Anim. Sci. 57(6): 1594-1600.

Paterson, J., C Forcherio, B. Larson, M. Samford, M. Kerley. 1995. The effects of fescue toxicosis on beef cattle productivity. J. Anim. Sci. 73: 889-898.

Porter J.K. and F.N. Thompson. 1992. Effects of fescue toxicosis on reproduction in livestock. J. Anim. Sci. 70: 1594-1603.

Turner, H.G. and A.V. Schleger. 1960. The significance of coat type in cattle. Aust. J. Agri. Res. 11:645-663.

Williams, J.L., D.J. Garrick, R.M. Enns, K.L. Shirley. 2006. Inheritances of hair slickness score and its correlation with growth. In: Proc, West Sect, Amer Soc of Anim Sci. 57: 29-31.

Table 1. Number of records in data by region, state and location

Region	State	Number of Locations	Total Records Per State
Southeast	North Carolina	2	409
	South Carolina	1	656
	Virginia	4	937
	Tennessee	2	357
	Kentucky	1	124
	Alabama	1	138
	Mississippi	1	170
Missouri	Missouri	4*	2776
Texas	Texas	4	1428
Total		20	6995

*There were three producers, but one producer owned two herds that were geographically separate. Those two locations were treated as separate herds.

Table 2. Description of hair coat shedding scores*

Hair coat shedding score	Definition
5	Full winter coat
4	Coat is beginning to shed
3	Coat is halfway shed
2	Coat is mostly shed
1	Sleek, short summer coat

*Modified from Gray et al, 2011

Table 3. Means and standard errors of traits by year

Variable	Estimate 2011	2012
Weaning Weight, kg	269.4 ± 0.63	275.2 ± 0.69
Total WW per Cow, kg	804.0 ± 10.78	678.6 ± 9.32
Herd life	1683.3 ± 12.44	1685.2 ± 12.97
HCS, 1-5 scale	3.4 ± 0.02	2.9 ± 0.02
HCS, shed or not shed	0.39 ± 0.01	0.55 ± 0.01
Total # Animals	3790	3205

Table 4. Pearson Correlation Coefficients for each trait

	Total WW per dam	HCS	Herd life	Weaning Weight
Total WW per dam	1.00	-0.023	0.878**	0.041**
HCS		1.00	0.014	-0.096**
Herd life			1.00	-0.068**
Weaning Weight				1.00

*$p < 0.05$
**$p < 0.01$