EFFECT OF HAIR CHARACTERISTICS ON THE ADAPTATION OF CATTLE TO WARM CLIMATES

T.A. Olson[1], C.C. Chase, Jr.[2], C. Lucena[1], E. Godoy[1], A. Zuniga[1] and R. J. Collier[3]

[1]Dept of Animal Sciences, University of Florida, Gainesville, USA
[2]STARS, USDA-ARS, Brooksville, Florida, USA
[3]Dept of Animal Sciences, University of Arizona, Tucson, USA

INTRODUCTION

In spite of the fact that Bonsma (1949) started the discussion of the importance of hair coat type and color over 50 years ago and extensive studies were done, primarily in Australia, in the late 1950's and early 1960's (Schleger and Turner, 1960; Turner and Schleger, 1960), those of us involved in the cattle industry in warm climates today still have to deal with problems associated with excess quantities and undesirable types of hair. Also, while a great number of traits are now being included in the genetic evaluations of the Angus and other *Bos taurus* breeds, no evaluation of possible variation in summer hair coats is available to aid in the selection of more heat tolerant cattle.

In Latin America and throughout the tropical world, the F_1 crosses of temperate breeds of *Bos taurus* sires on zebu cows generally are quite short-haired and quite adapted to the temperatures and, to some extent, to the ectoparasites of the tropics. The problems, regarding hair coats, arise when a second generation of such *Bos taurus* sires are used or if *inter se* mating of the F_1 crosses is practiced. As crossbreeding has become practiced to a greater degree in the last few decades in Latin America, almost exclusively through artificial insemination, problems associated with excess hair have become of greater concern.

Walsberg (1988) described solar heat gain as a function of the properties of the coat, including structure, insulative properties, short-wave reflectivity, and the optical properties of the hair as well as skin color. Hair depth, length and diameter are also important characteristics of hair that can influence heat gain from the environment. In this discussion we shall review the effects of hair characteristics that have been previously reported as well as discuss the impact of a major gene influencing hair type, the *Slick hair* gene, on adaptation to warm climates.

RELATIONSHIP OF HAIR COAT TYPE TO HEAT TOLERANCE AND PRODUCTIVITY

Bonsma (1949) discussed the properties of the hair that are associated with greatest adaptation to warm climates. Cattle with smooth coats composed of straight hairs of greater diameter were said to have more developed sweat and sebaceous glands, and Bonsma expected that cattle with such coats would more effectively utilize evaporative cooling.

A system of subjective evaluation of hair coats was developed and reported by Turner and Schleger (1960) that used a scale of 1 to 7 to describe differences in hair length and other, largely related to hair diameter, characteristics. Scores of 6 and higher would have a furry or woolly appearance and feel. As each hair coat score was further subdivided into +, average, and -, a 21 point score was actually utilized. The factors affecting such hair coat scores were also studied by Turner and Schleger (1960) and they found that the scores were influenced by season, age, sex, health and degree of fatness/emaciation as well as, of course, the breed type of the animal. They also observed that not only were the hair coat scores of Brahman and Africander-sired crossbreds lower than those of British cattle but that the hair coat scores of Hereford cattle bred in a subtropical area (Queensland) were significantly lower than those of Hereford originating in a temperate (New South Wales) area of Australia.

Turner and Schleger (1960) indicated that the correlations of hair coat score with skin temperature, rectal temperature and respiration rate in British cattle were 0.580, .0.434, and 0.300, respectively (all $P < 0.01$) but that comparable correlations in zebu crossbreds were lower and nonsignificant. They also showed that hair coat score was highly correlated with growth rate ($r = -0.577$) in British cattle but not within the zebu crossbreds. Differences in coat score, however, did effectively explain the difference in growth rate between zebu crossbred and British cattle. Schleger (1967) found that the regression of milk yield on hair coat score in Australian Illawarra Shorthorns was negative and highly significant.

The evaluation of hair coat types has primarily been done through subjective means, and is thus, difficult to standardize. Schleger and Turner (1960), therefore, examined a number of attributes of cattle coats, some of them which could be measured objectively, including depth, diameter, density, texture, curliness, weight per unit area and others to determine their relationships with skin temperature, growth rate, and the subjective overall hair score. No combination of these characteristics, however, was as highly correlated to growth as the overall hair score, although depth of coat and hair diameter were the most useful. Dowling (1956) separated a group of 2-year old beef Shorthorn bulls into two groups based on hair coat type and the group with greater summer haircoats (four times the hair weight and three times the hair length) were 104 kg lighter and showed much greater increases in rectal temperatures while standing in the sun than did the group with less hair. The “hairier” group also showed a very low degree of hair medullation which, in a subsequent study, Dowling (1959) demonstrated was highly correlated with rectal temperature. Dowling further suggested that shorter, thicker, medullated hairs, which also were stiffer, would enhance air movement to the skin surface and thus allow greater opportunity of evaporative cooling. Turner and Schleger (1960) have indicated that visual hair scores are highly heritable and associated with growth in warm climates, but they have never been included in any animal improvement schemes of which we are aware. The heritability of hair score within cattle of British breeding, however, was found to be much higher (63%) than that found for zebu crossbred cattle (24%).

RELATIONSHIP OF HAIR COLOR TO HEAT TOLERANCE AND PRODUCTIVITY

Bonsma (1949) discussed the appropriate coloration of cattle to be resistant to high temperatures and high solar radiation as having a white, yellow or reddish brown hair coat with yellow, reddish brown or black skin. Schleger (1962) observed that within cattle all of which were red, that intensity of coloration (darker red) was positively associated with growth, contrary to what might have been expected. Darker red animals also were not found to have higher rectal temperatures. On the other hand, lighter colored cows tended to wean heavier calves than darker red cows. Schleger (1967) found that the regression of milk yield on intensity of red coloration in Australian Illawarra Shorthorns was highly significant, indicating that darker red cows produced less milk.

Finch et al. (1984) investigated the impact of coat coloration along with hair coat type in Brahman, Brahman X Shorthorn, and Shorthorn yearling steers. Coloration of the steers ranged from white to dark red. Dark red and red steers of the Brahman and Shorthorn breeds had a higher absorption of solar radiation than white steers. This led to higher skin temperatures in red steers of these breeds but the differences between the colorations for rectal temperature were significant only for Shorthorn steers. Color also affected growth with the lighter colored steers gaining faster on pasture but the advantage for white steers was only great in Shorthorn steers. Higher coat scores (hairier) were associated with lower gains but the effect was greater in lighter-colored than darker colored steers. They also noted that the lighter colored steers spent more time in the sun than did darker steers but that again, the effect was greater in Shorthorn than in Brahman steers. Also, the regression of coat score on time spent in the sun was greater in darker colored steers. Apparently, the greater effects of coloration in Shorthorn cattle were due its reduced ability to reduce the heat load associated with greater absorption of solar radiation via sweating which was further impeded by their thicker, woollier coats.

Mader et al. (2002) examined the effect of hair color in feedlot steers during the summer months in Nebraska and found that tympanic temperatures of dark steers (including pre-dominantly black but some red) were over 0.5º C higher ($P < 0.05$) during the afternoon and early evening than those of white (presumably Charolais crossbred) steers. The dark steers also were observed to pant more ($P < 0.01$) and tended ($P < 0.07$) to "bunch" more than white steers under warm conditions. In a subsequent study, Davis et al. (2003) compared the tympanic temperatures of black vs. white Charolais X Angus crossbred steers while under severe heat stress and being full-fed. The temperatures of the black steers were higher ($P < 0.05$) throughout the day than those of the white steers and averaged 0.5º C higher at 1900.

Several authors have reported that Holstein cows with a greater percentage of white are more productive in warm climates than predominantly black Holsteins (Hansen,1990; Becerril et al., 1993). The regression of milk yield on percentage white was 1.91 kg ($P < 0.01$) and the regression of days open on percentage white tended to be favorable for cows being rebred during the warm season (Becerril et al., 1993). Gaughan et al. (1998) observed that Holstein cows with higher percentages of white were less likely to seek shade as temperatures increased than cows with higher percentages of black. Hillman et al. (2001) observed that predominantly black Holstein cows absorbed 89% of solar radiation as opposed to 66% for predominantly white cows and that their skin surface temperature rose about 4.8º C as opposed to only about 0.7º C for the white cows. They also reported that the rectal temperatures of black Holsteins exposed to direct sunlight will rise 0.7º C/hr even when sprayed with water as opposed to only 0.3º C/hr for the predominantly white cows. Maia et al. (2005) examined differences between the black and white hair coats of Holstein cows maintained under tropical conditions and observed significant differences between black and white hair coats for all the traits that they evaluated. White coats were thicker and their hairs were longer, narrower and more dense than black-coated areas on the same animals. The effective transmissivity and absorptivity of the black coats were higher ($P <0.05$) than those of white coats.

Hutchinson and Brown (1969) reported that black hair coats absorb more solar radiation than do white ones but that the radiation penetrated further into the white than black hair coats. This might lead to the question of why the zebu breeds of the tropics tend to be white. This is answered in part by the fact that the hair of zebu cattle is short and dense which would retard penetration but offer little insulative value. The lack of insulative value is likely advantageous in the dissipation of heat from the animal during those times of the day when the animal is not exposed to solar radiation. da Silva et al. (2003) examined the reflectance, transmittance and absorptance of the haircoat and skin of black, red, white and gray hide samples from *Bos taurus* and *Bos indicus* cattle. Red coats reflected more of the solar radiation than did black while white and gray coats tended to reflect even more. The samples from light gray colored Nelores showed particularly high reflectance values at low wavelengths, higher than those of the white areas of Holsteins and this was attributed to the fact that the Nelore haircoat is composed of thick, short hairs with a high density that fit closely to the skin which results in a bright surface that increases reflectance.

SHEDDING/SUMMER-WINTER DIFFERENCES

In the southeastern part of the U.S., evaluation of the adaptation of individual *Bos taurus* cattle is often based on how rapidly they shed their winter coats in the spring. Hayman and Nay (1960) evaluated the winter and summer coats as well as the relative shedding rates of *Bos taurus*, *Bos indicus* and crossbred cattle. They observed that all types of cattle had short, light summer coats and long, heavy winter coats but that the coats of *Bos indicus* were always shorter and lighter. While no differences were found in hair diameters of coats of *Bos taurus* cattle during the winter and summer months, the hair diameters of *Bos indicus* cattle were greater in summer than in winter. It appeared that *Bos indicus* cattle and shorter-haired *Bos taurus* cattle responded to winter by growing a double coat with a percentage of long hairs but that *Bos taurus* cattle with longer coats in summer simply grew a uniform, even longer, coat in winter. In addition, they reported that *Bos taurus* X *Bos indicus* crossbred cattle grew coats very similar to *Bos indicus* cattle in the summer and very similar to *Bos taurus* cattle in the winter! This fact may explain, in part, the very high levels of heterosis observed for such crosses in subtropical climates where neither purebred *Bos taurus* nor purebred *Bos indicus* cattle are fully adapted to the prevailing conditions for the entire year.

THE *SLICK HAIR* GENE: A SINGLE GENE APPROACH TO HEAT TOLERANCE

Study of the *Slick hair* gene began with determination that Senepol cattle were more heat tolerant than Angus and Hereford cattle at the Subtropical Agricultural Research Station near Brooksville, FL. The Senepol is a *Bos taurus* composite breed developed on St. Croix, U.S. Virgin Islands and is noted for being very short-haired. Rectal temperatures of Senepol cattle under heat stress were often 0.5º C lower than Angus and Hereford cattle (Hammond et al., 1996). Crosses of Senepol with Angus and Hereford were subsequently found to be similar in heat tolerance to Senepol (Hammond et al., 1996;1998). Observation that calves of Senepol X Angus crossbred cows generally possessed either the short, sleek hair of the Senepol or normal, longer hair and other evidence led to the conclusion that a major gene for hair type that was dominant in mode of inheritance was responsible (Olson et al., 2003). The slick-haired phenotype is visually dramatic and usually easy to differentiate from normal-haired individuals of temperate *Bos taurus* ancestry, however, as the evaluations of the hair type were subjective, clipped hair weights (175-cm^2) were collected in September from the right side of animals approximately 10 cm below the spine. The hair weights of calves with slick hair (0.74 g) were much less ($P < 0.001$) than those of calves scored as normal-haired (2.41 g). Comparisons of the heat tolerance of these Charolais-sired, slick- and normal-haired 25% Senepol cattle of the same breed composition showed that slick-haired animals were able to maintain rectal temperatures approximately 0.5º C lower than those of normal-haired animals when under heat stress. Also, respiration rates of normal-haired animals were higher ($P < 0.01$) than those of slick-haired animals.

In Florida, we have been using upgrading to incorporate the *Slick hair* gene into Holstein cattle. Olson et al. (2002) reported the impact of the *Slick hair* gene on rectal temperatures, skin temperatures and respiration rates of 75% Holstein:25% Senepol yearling bulls and heifers. Clipped hair weights in July were 11.5 mg/cm^2 for slick-haired animals as opposed to 17.8 mg/cm^2 for normal-haired animals ($P < 0.05$). Rectal and skin temperatures were 0.34 and 0.49º C lower for the slick-haired individuals and their respiration rates were 12.4 breaths per minute (all $P < 0.05$) lower than those of their normal-haired siblings.

Heat tolerance and grazing activities of upgraded Holstein calves with and without the *Slick hair* gene. Given that cattle with the *Slick hair* gene are able to maintain lower temperatures and respiration rates under heat stress conditions, it is logical to assume that they might continue grazing during hotter periods of the day than would animals of the same breed composition but with the *Slick hair* gene. Hammond and Olson (1994) have previously shown that Senepol cows did show more grazing activity during the daylight hours than did Hereford cows. To investigate whether or not slick-haired animals would show more grazing activity during the hotter parts of the day than contemporary animals with normal hair, we evaluated the growth rate, grazing activity, rectal temperatures and respiration rates of weaned 87.5% Holstein bull calves with slick and normal hair at the Subtropical Agricultural Research Station. We purchased 35 weaned bull calves sired by ¾ Holstein:¼ Senepol bulls with slick hair and from Holstein cows from a private dairy in Florida and transported them to the Subtropical Agricultural Research Station (Brooksville, Florida) during March of 2003. The rectal temperatures, respiration rates, growth, grazing activities, and clipped hair weights of these young bulls were evaluated under grazing conditions without access to supplemental feeding during the summer months of 2003. Clipped hair weights obtained during July indicated that those Holstein bulls identified as possessing the slick phenotype (0.026 g) had much less hair ($P < 0.01$) than their normal-haired half-brothers (0.210 g). The respiration rates of these young Holstein bulls showed that the slick-haired bulls had fewer breaths per minute, 60.8 and 61.8 ($P < 0.001$), than did their normal-haired siblings, 70.1 and 71.9, during AM and PM evaluations, respectively. The slick-haired bulls also maintained slightly lower rectal temperatures ($P < 0.10$) even though they were breathing much more slowly. The rectal temperatures of both slick and normal-haired bulls were both under 38º C even during the afternoon hours, indicating that neither group was under heat stress.

A higher percentage ($P < 0.01$) of the slick-haired, upgraded bulls than their normal-haired sibs continued to graze later in the morning (900 and 1000) and also returned to grazing earlier ($P < 0.05$) earlier in the afternoon (1500). Over the total grazing period of about 2 months, the slick-haired bulls gained significantly more weight than their normal-haired siblings (40.1 vs 35.5 kg) in spite of having heavier initial weights. Turner and Schleger (1960) mentioned that coat score at weaning was weakly correlated with pre-weaning gain but well correlated with post-weaning gain. In Florida, Olson et al. (2003) found that there was no growth advantage for slick-haired Charolais-sired calves up to weaning but such calves did gain faster than their normal-haired contemporaries postweaning as long as high temperatures persisted.

Effects of the *Slick hair* gene on productivity of dairy cows in Venezuela. The Carora breed of Venezuela is a composite dairy breed with slick hair. It was developed from crosses of Brown Swiss with a local, dairy criollo breed (Criollo Amarillo). Calves with normal hair continue to be born from slick-haired parents of this breed. The gene frequency of the *Slick hair* gene in this population is probably around 0.70. For a number of years, a large dairy in the central region of Venezuela near Barquisimeto has been using the Carora in a crossbreeding program with Holstein, initially in an attempt to improve the reproductive efficiency of foundation Holstein cows. Cows in this herd are maintained under drylot conditions in a hot, but desert-like environment. Olson et al. (2003) reported that F_1 crossbreds in milk in this herd included 288 cows with slick hair and 75 cows with normal Holstein-type hair. The rectal temperatures of the slick-haired F_1 crossbreds were 0.5º C lower than their normal-haired contemporaries and 305-d milk yield was 411 kg higher (both $P < 0.05$). The mating procedure at this dairy was to backcross the F_1 crossbreds to Holsteins and to thus produce 75% Holstein:25% Carora crossbreds which also segregated for hair type. A group of 109 ¾ Holstein:¼ Carora cows were compared to a group of 110 of their normal-haired paternal half-sisters. The slick-haired cows produced 984 kg more milk ($P < 0.01$) in their first lactations and had calving intervals 43 days shorter ($P < 0.01$) than their normal-haired sisters.

Effects of the slick hair gene on skin and rectal temperatures, respiration rate and sweating rate in Holstein cows. Schleger and Turner (1965) reported that *Bos taurus* (British) steers with lower hair scores (sleeker coater) had higher sweating rates and that this resulted in their lower body temperatures. Sweating rate, along with skin and rectal temperatures, were investigated in first lactation 7/8 Holstein cows with and without the *Slick hair* gene at a commercial dairy located near Okeechobee in southern Florida. They were daughters of three 75% Holstein:25% Senepol bulls and calved for the first time from one to six months prior to the collection of data from June through August of 2005.

Rectal temperatures and respiration rates were obtained on 28 days over the course of the summer on 16 slick-haired cows, 25 normal-haired paternal half-sisters to the slick cows and 18 Holstein cows of similar age and stage of lactation to the 7/8 Holstein cows. Data were analyzed using a model that included type of cow, milking group and date. Data to be reported here were from measurements obtained after milking during the daylight hours. The rectal temperatures of the slick-haired cows were lower ($P < 0.01$) than those of their normal-haired siblings and the contemporary Holsteins whose temperatures did not differ. While the slick-haired cows only averaged 0.2º C lower than the normal-haired groups in this study, the mean temperature of these groups, 38.7º C, did not indicate that they were heat-stressed. However, just as in the case of the evaluation of the male siblings of these cows, the slick-haired cows were able to maintain these somewhat lower rectal temperatures with a lower ($P < 0.01$) respiration rate, 63 breaths per minute as opposed to 72 and 73 breaths per minute for their normal-haired siblings and contemporary Holsteins, respectively. There was also an indication that the slick-haired cows were spending a greater percentage of the day grazing as the slick-haired cows were found to be in the cooling ponds 4 days (out of 28) less than were their normal-haired siblings and the contemporary Holsteins.

On August 19, sweating rate and skin temperatures were measured on slick (n=25) and normal-haired sibling (n=26) cows as well as a group of contemporary Holstein cows (n=17) along with measurement of respiration rate and rectal temperatures. These measurements were taken from 730 to 1500 h during the day as the cows exited the parlor and the effect of increasing air temperature as the day progressed was accounted for in the analysis of the data. Sweating rate was measured using a VapoMeter (Delfin Technologies) and skin temperature with an infrared thermometer. The hair was shaved in an approximately 9 to 10 cm^2 area in the loin region on the right side of each cow to allow accurate measurement of skin temperature and sweating rate. Skin temperature was not affected by group (slick, non-slick sibs, or contemporary Holsteins) but increased greatly ($P < 0.0001$) as air temperature increased as the day progressed. Respiration rates taken the same day did not differ among the groups but were numerically greater for the two normal-haired groups. Mean sweating rates of the three groups of cows, while markedly lower than those observed in regions of the country with lower relative humidity, were lower ($P < 0.01$) for the two groups of normal-haired cows than for the slick-haired cows (15.0, 10.1 and 7.9 gm/m^2 for the slick-haired, normal-haired sibs and contemporary Holsteins, respectively). This is much lower than maximal reported sweating rate in Holsteins (220 gm/m^2, Berman, 2005) and reflects the high vapor pressure in sub-tropical Florida compared to the semi-arid conditions of Israel. Furthermore, the differences between animals in rectal temperature (stored heat) are largely accounted for by differences in sweating rate, Table 1. Sweating rate increased in all groups as the day progressed and the air temperature increased but in slick-haired cows it reached higher levels at the highest temperatures.

Table 1. Effect of the slick hair gene on heat content and sweating rate in Holstein cows[A]

Parameter	Slick	Normal Sibs	Controls
Rectal Temp ºC	38.7	39.1	39
Respiration Rate /min	64	74.6	80
Sweating Rate g/m^2	15	10.1	7.9
Stored Heat[B] Kcal/6h	0	120	94
Sweating loss[C] Kcal/6h	182.7	110.7	86.6

[A]Surface area 3.5 M, Surface Area for Evaporation, 3.15 M, Kcal/gm of sweat = 0.580
[B]Difference in stored heat over 6 hour interval measurements were taken
[C]Represents total heat loss by sweating over 6 hour interval

CONCLUSION

Differences in coat type can have important effects on the adaptation of cattle to warm climates. Cattle with shorter hairs of greater diameter are generally more heat tolerant than cattle with other types of hair coats. Generally, cattle with lighter coat colors are more heat tolerant than those with darker colors and Holstein cows with greater percentages of white have been frequently been found to be more heat tolerant and more productive than Holstein cows with higher percentages of black. The *Slick hair* gene has been identified as a major, dominant gene that is responsible for the heat tolerance of the Senepol breed. Cattle with the *Slick hair* gene have significantly lower rectal temperatures and respiration rates than do cattle of the same breed composition with normal hair. Slick-haired cattle have also been observed to graze longer during the morning hours and return to grazing earlier in the afternoon during hot weather than normal-haired cattle. A possible reason for the improved heat tolerance of slick-haired cattle is that their sweating rate appears to be greater than that of normal-haired cattle. In Venezuela, crossbred cows with the slick phenotype had a first calving interval that was significantly shorter than that of their normal-haired siblings while producing more milk. Thus, it appears that the *Slick hair* gene has the opportunity to increase the heat tolerance as well as the productivity of *Bos taurus* cattle raised in warm climates.

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