

## **Inheritance of Some Sweat Gland and Hair Follicle Characteristics in Cattle**

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### *Abstract*

Using measurements made on cows in the herds of the Hannah Research Institute (Ayrshire), the West of Scotland Agricultural College (Ayrshire and Friesian) and in the twin herd of the Animal Breeding Research Organisation (Ayrshire), repeatability and heritability estimates were obtained for three hair follicle and four sweat gland traits. Average repeatability was high (50-70%) for all characters except angle of slope of the hair (18%). Heritability estimates were extremely variable among the different herds and methods of measurement but there was evidence of considerable genetic variation, particularly for sweat gland traits. The most consistent heritability estimate (30-45%) was given by the ratio of sweat gland length to diameter. The potential use of skin types for the selection of cattle for tropical regions is discussed.

### **Introduction**

In studies of the sweat glands and hair follicles of world cattle, Jenkinson and Nay (1972, 1973) showed that indigenous tropical cattle in general had a smaller hair follicle depth (*FD*) and more frequently a lower sweat gland length to diameter ratio (*L/D*) than European cattle. They concluded that within European breeds with a wide range of skin types, selection of animals with a thin hair follicle depth and a sac-like sweat gland (type I skin) could perhaps lead to improved heat tolerance and milk production of the breed in warm climates. Before such a skin index could be of value in the selection of cattle for tropical regions, a significant relationship between skin measurements and production in warm conditions would have to be established and the degree of heritability of such skin indices would have to be high. The current study was undertaken to determine the degree of heritability of sweat gland and hair follicle measurements in cattle.

### **Materials and Methods**

Duplicate skin samples were obtained by biopsy from the midside of a total of 637 Ayrshire and Friesian cows from four different herds (Table 1). The samples were taken with a high-speed punch (Findlay and Jenkinson 1960), 0.373 cm in diameter, and processed and measured as described by Jenkinson and Nay (1968). Measurements were made of hair follicle depth (*FD*) and length (*FL*) and of sweat gland length (*L*) and diameter (*D*) as defined by Jenkinson and Nay (1968). From these measurements sweat gland shape (*L/D*) and volume [ $V = \frac{1}{2}\pi L(D)^2$ ] and the angle,  $\theta$ , of slope of the hair ( $\sin \theta = FD/FL$ ) were calculated. Hair follicle depth and length could not, however, be measured in all instances; by definition these measurements are obtained from actively growing follicles, and in a small percentage of the skin samples most of the hairs were in the resting phase of the hair cycle.

Some of the animals were sampled on two occasions (Table 3). From these figures the repeatability of the measurements was calculated as the regression of the second reading on the first. This calcu-

lation was made within herds and within breeds. The effects of season and year were also determined and where necessary the data were corrected for these influences (by adding or subtracting the appropriate differences) before proceeding to the calculation of heritabilities. The Auchincruive data were corrected to the mean values obtained at the sampling in June 1968, the Hannah data to March 1968 and the Blythbank data to May 1968. The results from the Blythbank animals under 2 years of age were, however, first corrected for age; previous work (Jenkinson and Nay 1968) had shown that age effects were negligible on animals over 2 years. The data from the animals sampled in October 1967 and May 1968 were used for this correction since most of the animals which were sampled in 1969 and 1970 were adult. The animals were grouped into age classes (in months) as follows: 10–11, 12–13, 14–15, 16–17, 18–20, 21–23 and >24. The correction used was the difference between the mean of the group and the mean for the animals of 2 years of age and over. The calculations were made separately for the two seasons and for these experiments they were considered to be more reliable than predictions from regression equations.

Table 1. Source of material

Herd	Breed	Dates of sampling	No.	Age
Hannah Research Institute, Ayr, Scotland	Ayrshire	July 1960	14	Over 2 years
		March 1968	141	Over 2 years
		September 1969		
		March 1970		
West of Scotland Agricultural College, Auchincruive, Ayr, Scotland	Ayrshire	June 1968 June 1970	89	Over 2 years
West of Scotland Agricultural College, Auchincruive, Ayr, Scotland	Friesian	March 1961	17	Over 2 years
		June 1968	110	Over 2 years
		June 1970		
Animal Breeding Research Organisation, Blythbank, Edinburgh, Scotland	Ayrshire	October 1967	266	10 months to over 5 years
		May 1968		
		November 1969		
		May 1970		

For the Auchincruive and Hannah animals the heritability of each of the skin measurements was estimated (i) by half-sib correlation, i.e. by intraclass correlation within sires calculated from the variance components within and between sires and (ii) by the regression of daughter on dam within sires. These calculations were made within herds and breeds.

The Blythbank animals were from the Animal Breeding Research Organisation (ABRO) Twin Uniformity Trial (Donald 1953). They included (a) 16 pairs of monozygotic twins (MZ), (b) 24 pairs of two-egg twins (DZ), (c) 12 pairs of full sibs (FS), the contemporary offspring of identical twin dams by the same sire, (d) 40 pairs of contemporary half-sibs (HS) and (e) 26 pairs of contemporary unrelated animals (U). The loss of one member from any one of these pairs resulted in a further group of 30 unpaired, unrelated, non-contemporary animals. The husbandry regime was controlled and kept as similar as possible from year to year.

Examination of this array of genetic relationships ranging from identical twins to unrelated animals enabled estimation of the amount of variation arising from various environmental and genetic sources. Various models were examined. Each related some or all of the eleven observed mean squares obtained from the different genetic categories (MZ, DZ, etc.) to their expected values in terms of some or all of the following five components:

- (1) environmental variation between contemporary animals (members of a pair) reared together ( $e^2$ ),
- (2) additional environmental variation found between animals that were non-contemporary and consequently not reared together side by side ( $c^2$ ),
- (3) variation originating from differences in the prenatal maternal environment of single-born animals as opposed to the common prenatal environment of twins ( $m^2$ ),
- (4) additive genetic variation ( $h^2$ ),
- (5) non-additive genetic variation ( $d^2$ ).

For every trait, estimates of environmental components ( $e^2$  and  $c^2$ ) were very similar for most models. Estimates of maternal components ( $m^2$ ) for prenatal environment, on the other hand, were always very variable, never large, often negative, and never significant. They were therefore not included in subsequent models with the result that the standard errors for the other components were greatly reduced.

Components of additive and non-additive genetic variation, if both included in the same model, gave highly erratic estimates with large standard errors and it was clear that the data were incapable of separating these genetic components. When only one genetic component was included in the model, fairly good estimates were obtained. In general, additive and non-additive genetic models gave an equally good fit to the data. However, since the additive component was of much greater interest in relation to selection, the final model nominally included only the additive genetic component. Nevertheless, estimates of additive heritability given in Table 6(b) may include some non-additive genetic variation.

Out of the 103 pairs included in the analysis of follicle traits, two pairs (both DZ) were excluded as extreme deviants. Likewise, out of the 118 pairs included in the analysis of sweat gland traits, one pair (FS) was excluded for the same reason. The goodness of fit of various models improved noticeably as a result of these exclusions, but the estimates of the components were not greatly affected.

**Table 2. Effect of age on skin measurements**

Blythbank herd, mean values

Season and year: Age (months):	Autumn 1967		Spring 1968	
	10-23	> 24	10-23	> 24
Number of animals	22	40	30	83
Follicle depth, $FD$ (mm)	1.46	1.68	1.45	1.46
Follicle length, $FL$ (mm)	1.85	2.13	1.85	1.95
Angle of slope, $\theta$ (degrees)	52	52	52	49
Number of animals	22	40	31	111
Sweat gland length, $L$ ( $\mu\text{m}$ )	793	975	777	822
Sweat gland diameter, $D$ ( $\mu\text{m}$ )	96	124	104	116
Length/diameter, $L/D$	8.34	7.90	7.51	6.93
$10^{-6} \times$ Sweat gland volume, $V$ ( $\mu\text{m}^3$ )	5.74	11.77	6.58	8.69

## Results and Discussion

### *Effect of Age*

The animals sampled in the Hannah and Auchincruive herds were all over 2 years of age and since previous experience had shown that skin measurements do not change significantly after this age no corrections were applied to the data from these herds. However, in the Blythbank herd some animals were under 2 years of age. Table 2 shows that these animals had shorter and shallower hair follicles and smaller sweat glands than older animals. These figures are in agreement with the observations of Schotterer (1932) and Hafez *et al.* (1955). Furthermore, the observed differences were greater in autumn than in spring. The values for all animals under 2 years were therefore corrected for age additively and separately for the two seasons as previously described.

### *Effect of Year and Season*

Table 3 lists the mean values obtained for the same animals sampled on two occasions. In general the hair follicle measurements were the same on both occasions. However, the Hannah animals exhibited a significant increase in follicle length and

Table 3. Effect of year and season on skin measurements  
Brackets link mean figures for same animals sampled on two occasions

Herd	Date of sampling	Hair follicle measurements:				Sweat gland measurements:				
		No.	FD (mm)	FL (mm)	$\theta$ (degrees)	No.	L ( $\mu$ m)	D ( $\mu$ m)	L/D	$10^{-6} \times V$ ( $\mu$ m <sup>3</sup> )
Hannah (Ayrshire)	July 1960	14	1.50	1.83	55	14	749	130	5.80	10.0
	March 1968	22	{ 1.52	{ 1.93	{ 54	43	{ 862	{ 126	{ 6.92	{ 10.8
	March 1970		{ 1.65*	{ 2.06*	{ 54		{ 905	{ 126	{ 7.18	{ 11.8
	September 1969	17	{ 1.82	{ 2.29	{ 54	19	{ 829	{ 116	{ 7.17	{ 8.8
	March 1970		{ 1.63*	{ 2.11*	{ 51		{ 918*	{ 121	{ 7.64	{ 11.1*
Auchincruive (Friesian)	March 1961	17	1.54	1.89	54	17	1041	135	7.71	14.9
	June 1968	21	{ 1.45	{ 1.70	{ 59	24	{ 822	{ 88	{ 9.45	{ 5.0
	June 1970		{ 1.50	{ 1.73	{ 61		{ 914*	{ 109*	{ 8.59	{ 8.9*
Auchincruive (Ayrshire)	June 1968	15	{ 1.36	{ 1.81	{ 49	19	{ 752	{ 112	{ 6.86	{ 7.5
	June 1970		{ 1.45	{ 1.86	{ 52		{ 836*	{ 125*	{ 6.82	{ 10.5*
Blythbank (Ayrshire)	October 1967	13	{ 1.71	{ 2.15	{ 53	14	{ 1036	{ 74	{ 8.34	{ 12.5
	November 1969		{ 1.68	{ 2.17	{ 51		{ 1044	{ 81*	{ 7.83	{ 15.0
	May 1968	31	{ 1.44	{ 1.93	{ 49	51	{ 828	{ 127	{ 7.15	{ 9.1
	May 1970		{ 1.46	{ 1.95	{ 49		{ 915*	{ 137*	{ 6.76	{ 14.0*

\*  $P > 0.05$ .

depth between March 1968 and March 1970. This may have been due to different weather conditions in the two years or more likely to changes in husbandry; the Blythbank animals which were kept under the same husbandry conditions throughout the experimental period did not exhibit a similar increase between May 1968 and May 1970. The decrease in hair follicle measurements in the Hannah herd between September 1969 and March 1970 is an effect of season corresponding to the similar difference between the Blythbank autumn and spring samples. Hair follicle depth and length are greater in winter than in summer (Hayman and Nay 1961; Nay and Hayman 1963).

In general, sweat glands were larger at the second sampling. Here age and yearly changes may be confounded especially since 3 of the 14 (autumn) and 2 of the 51 (spring) Blythbank animals were under 2 years of age at the first sampling. The effect of season is not clear; it appears to be different in the Hannah and Blythbank herds. The present results are not, however, inconsistent with those of Hayman and Nay (1958) who concluded that sweat gland volume was minimal in summer and maximal in spring and autumn. The results confirm the findings of Nay and Hayman (1963) that sweat gland shape does not alter with season.

**Table 4.** Skin measurements of twin and single animals in Blythbank herd after correction for age and season

Values are mean  $\pm$  s.e.

Twins (MZ+DZ)			Singles (FS+HS+U)		
Hair follicle measurements			Sweat gland measurements		
No. of animals	72	134	No. of animals	80	156
Depth, <i>FD</i> (mm)	1.51±0.02	1.49±0.02	Length, <i>L</i> (μm)	822±14	842±16
Length, <i>FL</i> (mm)	1.94±0.02	1.95±0.02	Diameter, <i>D</i> (μm)	116±1	117±2
Angle of slope, <i>θ</i>	49°12'±24'	49°42'±24'	Length/diameter, <i>L/D</i>	7.08±0.12	7.35±0.12
			10 <sup>-6</sup> × Volume, <i>V</i> (μm <sup>3</sup> )	8.85±0.26	9.19±0.38

#### *Effect of Twinning*

It is clear from the averages in Table 4 that there was no significant difference in the hair follicle or sweat gland characteristics between twins [monozygous (MZ) and dizygous (DZ)] and singles [full sibs (FS), half-sibs (HS) and unrelated (U)].

#### *Repeatability*

The estimates of repeatability based on the material shown in Table 3 are given in Table 5. The values represent the regression of the second measurement on the first measurement taken on the same cow. The estimates from the various groups were averaged by weighting each figure according to the reciprocal of its error variance. The angle of slope of the hair is clearly a character of low and inconsistent repeatability. Overall the repeatabilities of the other characters were high and were most consistent for the ratio of sweat gland length to diameter (i.e. shape) and to a lesser extent for follicle depth and sweat gland length.

#### *Heritability*

Table 6(a) shows the estimates of heritability obtained from the measurements made on the Hannah and Auchincruive cattle. The estimates for the various herds and breeds

were combined by weighting them according to the reciprocal of their error variances. Except for the values of 30–38 for sweat gland shape, the heritabilities estimated by the two methods tended to be inconsistent and not significantly different from zero. The apparently significant negative values are difficult to explain. These herds were kept under normal commercial conditions: there may, however, have been changes in management from year to year and some animals may have been used in feeding trials.

Table 5. Repeatability of skin measurements

Values are regression  $\pm$  S.E.

Source of material	Hair follicle measurements:			Sweat gland measurements:			
	FD	FL	$\theta$	L	D	L/D	V
Hannah							
Spring-Spring	0.54 $\pm$ 0.25	0.09 $\pm$ 0.21	-0.05 $\pm$ 0.08	0.63 $\pm$ 0.22	-0.03 $\pm$ 0.21	0.44 $\pm$ 0.12	0.37 $\pm$ 0.26
Autumn-Spring	0.18 $\pm$ 0.50	0.89 $\pm$ 0.27	0.41 $\pm$ 0.30	0.26 $\pm$ 0.34	0.48 $\pm$ 0.51	0.43 $\pm$ 0.23	0.55 $\pm$ 0.57
Auchincruive							
Friesian	0.34 $\pm$ 0.19	0.55 $\pm$ 0.30	0.43 $\pm$ 0.14	0.49 $\pm$ 0.22	1.57 $\pm$ 0.31	0.66 $\pm$ 0.22	1.40 $\pm$ 0.40
Ayrshire	0.57 $\pm$ 0.16	0.48 $\pm$ 0.31	0.37 $\pm$ 0.16	0.39 $\pm$ 0.23	0.59 $\pm$ 0.30	0.44 $\pm$ 0.21	0.45 $\pm$ 0.40
Blythbank							
Autumn	0.61 $\pm$ 0.27	0.90 $\pm$ 0.19	0.03 $\pm$ 0.42	0.58 $\pm$ 0.48	0.24 $\pm$ 0.32	0.30 $\pm$ 0.57	0.78 $\pm$ 0.46
Spring	0.63 $\pm$ 0.17	0.32 $\pm$ 0.13	0.20 $\pm$ 0.18	0.64 $\pm$ 0.27	0.55 $\pm$ 0.19	0.64 $\pm$ 0.16	0.81 $\pm$ 0.27

Table 6. Heritability of skin measurements based on (a) Hannah and Auchincruive herds and (b) Blythbank herd

Values for (a) are  $h^2 \pm$  S.E. expressed in percentages. Values for (b) are percentages of total variance  $\pm$  S.E.

	Hair follicle measurements:			Sweat gland measurements:			
	<i>FD</i>	<i>FL</i>	$\theta$	<i>L</i>	<i>D</i>	<i>L/D</i>	<i>V</i>
(a) Hannah and Auchincruive herds							
Daughter–dam regression	–13±10	15±11	41±10	11±10	–7±9	38±10	–23±9
Half-sib correlation	17±13	11±17	–24±12	18±11	28±14	30±15	–8±11
	130 daughter–dam pairs			152 daughter–dam pairs			
	21 sires with 220 daughters			21 sires with 243 daughters			
(b) Blythbank herd							
Environmental							
<i>e</i> <sup>2</sup>	25±9	18±7	52±17	20±7	37±12	42±13	21±10
<i>c</i> <sup>2</sup>	45±13	45±13	33±15	18±13	11±13	12±13	20±17
Genetic <sup>A</sup>							
<i>h</i> <sup>2</sup>	30±15	38±13	15±25	62±16	52±21	45±22	59±21
<i>h</i> <sup>2</sup> contemporary	55±27	69±24	22±38	76±20	58±23	51±25	74±26

<sup>A</sup> Assumed additive.

The estimates based on the Blythbank herd [Table 6(b)] are probably more reliable since all the animals there were kept under rigidly controlled experimental conditions. The nature of the experimental design made possible estimates of two types of environmental variation in addition to heritability. Comments have been made in the Methods section on the interpretation and validity of these results.

Contemporary animals showed a significant amount of environmental variation ( $e^2$ ) in all skin traits, varying from about 20% of the total variation in follicle length and in sweat gland length and volume to up to about 50% in the angle of slope of the hair.

For the hair follicle traits there was a significant additional amount of variation due to non-contemporaneity of about 35–45%. For sweat gland traits, non-contemporaneity on average introduced less than half of this amount of additional variation and none of the estimates differed significantly from zero.

There was a significant genetic component of variation in all sweat gland traits. Estimates of heritability varied from 0.45 to 0.60, but they increased to fairly high values (0.50–0.70) for uniformly reared contemporary animals. Follicle traits showed less genetic variation than the sweat gland traits. Both depth and length had a heritability estimate of 0.30–0.40 but that for their ratio was insignificant and of the order of 0.15. For contemporary uniformly reared animals follicle length heritability increased from 0.40 to 0.70. Follicle depth heritability likewise increased from about 0.30 to 0.55 but the genetic component was not highly significant. The genetic component for the angle of slope of the hairs remained small and insignificant.

The total amount of genetic variation is reasonably well estimated from the twin data. Much more information would be required, however, before the total genetic variation could be effectively separated into its additive and non-additive components. There seems little doubt that there is a fair amount of genetic variation in sweat gland and hair follicle traits with the exception of angle of slope. The most consistent estimates were obtained for the ratio of sweat gland length to diameter. This was also the parameter least affected by annual and seasonal variation. It should, therefore, be possible by genetic selection to change sweat gland morphology, particularly the shape of the gland.

The short hair follicles and smaller and more numerous sweat glands of tropical cattle (Jenkinson and Nay 1973) could be, in part at least, a result of natural selection for adaptation to warm environments. Animals with this type of skin tend to have short thick coats (Jenkinson and Nay 1973) which in turn are characteristic of the more heat-tolerant animals (Dowling 1959). It would therefore appear that in selecting European cattle for tropical regions, especially from breeds with a wide range of skin types (Jenkinson and Nay 1973), it would be advantageous to choose those with a type I skin. It is not known, however, how resistant such animals are to disease, and it would have to be established that the repeatabilities and heritabilities calculated in a temperate climate also apply under tropical conditions. Consequently, a comparison of the skin types of cattle prior to importation to tropical regions with their subsequent productive performances in the tropics would be necessary before skin types could be widely used in practice for the selection of animals for warm climates.

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