# SWEAT GLAND AND HAIR FOLLICLE MEASUREMENTS AS INDICATORS OF SKIN TYPE IN CATTLE

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*Summary*

An attempt has been made to find a suitable indicator of skin type which could be used for comparing the skin of cattle throughout the world. The effects of age, sex, and habitat on a number of skin measurements were studied. The influence of nutrition and of season and exercise on these measurements is discussed and within-animal regional differences are considered. It was concluded that sweat gland shape, which was defined as the ratio of sweat gland length to sweat gland diameter, is a reliable indicator of cattle skin type when measured on skin samples from the neck or midside of adult cattle. Other skin measurements, such as hair follicle depth, may also prove useful under more restricted conditions and in the subclassification of the skin type based on sweat gland shape.

## I. Introduction

The sweat glands and hair coat of cattle play an important part in their thermoregulation (Dowling 1959; McLean 1963). The components of the hair follicle unit have been described in a number of different breeds (Yamane and Ono 1936; Findlay and Yang 1950; Carter and Dowling 1954), and the dimensions of some of them have been measured (Hafez, Badreldin, and Shafei 1955; Nay and Hayman 1956; Nay and Dowling 1957; Walker 1960; Pan 1963, 1964). There is, however, little information concerning the anatomy of the skin of cattle in different countries. Such information could be of value in the selection of cattle for tolerance to different environments and of practical value to the leather industries in a number of countries. Information on the skin characteristics of different breeds might also shed light on the history and evolution of domestic cattle. To enable comparisons between different breeds of cattle in different habitats to be made, it is necessary to develop a suitable technique to ensure uniform sampling and processing, and to find a skin feature which only reflects differences between breeds and is largely unaffected by other factors.

The present work describes measurements made of different structures in cattle skin, and the effect of age, sex, and habitat on them, in order to find a standard which could be used for comparing the skin of different cattle breeds. The technique of collection and processing of the skin samples for uniformity is also described, and the work forms the first part of an investigation comparing bovine skin types throughout the world.

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## II. Materials and Methods

### (a) *Animals Used*

Various measurements were made on skin samples which were obtained from a total of 598 male, female, and castrated male cattle of different ages and from different habitats. All were in a good nutritional state. The effect of age on these measurements was studied mainly in a herd of 85 Ayrshire cows of various ages ranging from 2–12 years. For sex comparisons, data from a group of 181 adult Friesian cattle comprised of 90 bulls, 52 cows, and 39 steers were used. Differences due to habitat were studied using six breeds (Ayrshire, Friesian, Galloway, Shorthorn, Guernsey, and Jersey) of cattle in Britian and comparing them with their counterparts in New South Wales. The relationships between the different skin measurements were assessed using data from 332 adult cows of nine breeds (Ayrshire, Beef Shorthorn, Dairy Shorthorn, Friesian, Galloway, Guernsey, Hereford, Highland, and Jersey).

### (b) *Technique*

Duplicate skin samples were taken from each animal. For practical reasons the specimens were taken from the neck immediately after death using a trephine 1 cm in diameter (Carter and Dowling 1954), or from the midside of live animals by biopsy using a high-speed punch 0·373 cm in diameter (Findlay and Jenkinson 1960). The processing technique used was essentially that of Nay and Hayman (1956) as modified by Nay (1959). All the samples, irrespective of their source, were processed in the same laboratory, and each skin character was always measured by the same person. The duplicate skin samples were fixed in 12% formol saline and from one of them sections (400–500 $\mu$ thick) were cut by hand perpendicular to the skin surface, using a safety razor blade. Care was taken to prevent drying of the tissue to avoid distortion and collapse of the sweat glands. The sections were stained in a 0·1% aqueous solution of polychrome methylene blue for 5 min, washed in water, and finally treated for 3–5 min in a freshly prepared aqueous solution containing equal parts of 1% potassium ferrocyanide and 5% ammonium molybdate. The sections were rinsed in water, dehydrated in alcohol, cleared in cedar wood oil for 10 min, and mounted in Canada balsam. From the second skin specimen, horizontal frozen sections 25–35 $\mu$ thick were cut on a microtome, stained in an aqueous 0·5% solution of Nile blue sulphate, and mounted in Kaiser's glycerol gelatin.

### (c) *Measurements*

Measurements of the quantities listed below were made on perpendicular sections, as illustrated in Figure 1.

(i) *The Hair Follicle*

(1) *Hair Follicle Depth.*—Hair follicle depth was defined as the shortest distance between the base of an active hair follicle and the skin surface. Resting hair follicles, although present in the skin sections, were not measured. Giant follicles seated deep in the reticular layer and representing 4–6% of the total amount present (Hayman and Nay 1961) were ignored. Depths of each of 10 follicles in each section were measured and the mean value taken as the typical follicle depth.

(2) *Hair Follicle Length.*—Hair follicle length was defined as the distance between the base of the bulb of an active hair follicle and the point where the follicle reaches the surface of the skin. The lengths of each of 10 follicles in each sample were measured and the mean value taken as the typical follicle length. Giant follicles were again ignored. The angle of slope of the hair follicle, which could be calculated from the measurements of hair follicle length and depth, was not included in the general analysis. It was, however, considered when comparing animals in different habitats.

(3) *Hair Follicle Diameter.*—The diameters of the same 10 hair follicles were measured. Follicle diameter was, for the sake of uniformity, always measured at the level of the sebaceous glands.

(ii) *The Sweat Gland*

(1) *Sweat Gland Length.*—The length ($L$) of the secretory portion of each of 10 glands per animal was measured using an eyepiece micrometer as described by Nay and Hayman (1956) and the mean value calculated.

(2) *Sweat Gland Diameter.*—The diameter ($D$) of the secretory portion of each of the same 10 glands was measured in three places. The mean of these 30 values was taken as the estimate of sweat gland diameter. From these estimates of length and diameter, sweat gland shape and sweat gland volume were calculated.

(3) *Sweat Gland Shape.*—This is expressed as $L/D$, and is a measure of the extent to which the glands are sac-like or tubular.

(4) *Sweat Gland Volume.*—By considering the sweat glands as cylinders the glandular volume was estimated using the formula $\pi(\frac{1}{2}D)^2L$.

It was not possible using the present technique to measure the sebaceous gland, arrector pili muscle, and epidermis. As the skin specimens were taken by different individuals it was not always possible to determine if the trephine had penetrated the entire skin, and hence a measure of total skin thickness could not always be obtained. Hair density (the number of hairs per square centimetre of skin) was determined from sections cut parallel to the skin surface, but preliminary analysis indicated that this measurement was not a reliable indicator of skin type and it was not included in the final analysis.

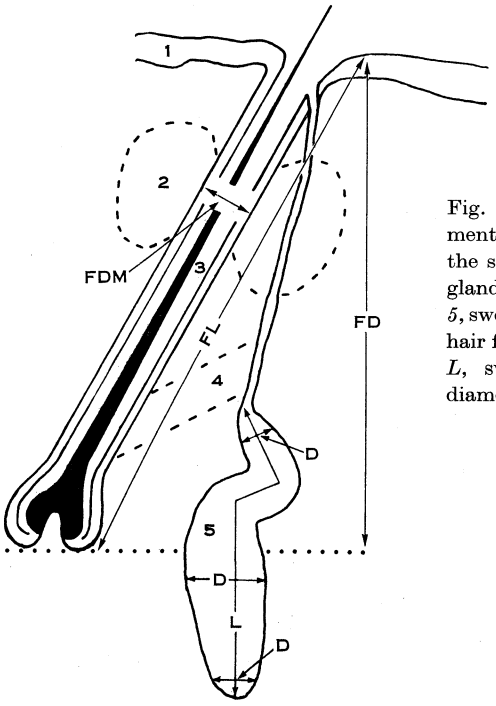


Fig. 1.—Diagram illustrating the measurements made on sections cut perpendicular to the skin surface. *1*, epidermis; *2*, sebaceous glands; *3*, hair follicle; *4*, arrector pili muscle; *5*, sweat gland. *FL*, hair follicle length; *FDM*, hair follicle diameter; *FD*, hair follicle depth; *L*, sweat gland length; *D*, sweat gland diameter.

## III. Results

### (*a*) *Effect of Age*

The correlation and regression coefficients and their significance between age and the various skin measurements are shown in Table 1 for a group of 85 British Ayrshire cows aged from 2–12 years. None of the measurements were significantly related to age within this age range. There were insufficient data on hair density and total skin thickness to permit analysis of the effect of age on these parameters.

### (b) *Sex Difference*

The means and standard deviations for each of the measurements on the 90 bulls, 52 cows, and 39 steers of the Friesian breed are given in Table 2, together with the results of the analysis of variance for differences in the skin measurements between these means. All the measurements except hair follicle depth and sweat gland shape varied significantly between bulls, cows, and steers. When *t*-tests were applied it was found that sweat gland length, diameter, and volume, and hair follicle diameter were all larger in bulls than in cows and steers, and that all were also significantly larger in cows than in steers ($P < 0{\cdot}01$). Hair follicle length was also larger in bulls and cows than in steers ($P < 0{\cdot}01$ and $P < 0{\cdot}05$ respectively) but there was no significant difference in this measurement between bulls and cows.

TABLE 1

CORRELATION AND REGRESSION COEFFICIENTS OF EACH OF THE SKIN MEASUREMENTS WITH AGE

Measurements taken from 85 Ayrshire females aged from 2 to 12 years

| Measurements | Correlation Coefficient | Regression Coefficient (± S.E.) |
|---|---|---|
| Hair follicle | | |
| Depth | −0·106 (n.s.) | −0·0008±0·0008 (n.s.) |
| Length | −0·196 (n.s.) | −0·001 ±0·0007 (n.s.) |
| Diameter | 0·033 (n.s.) | 0·008 ±0·0260 (n.s.) |
| Sweat gland | | |
| Length | −0·032 (n.s.) | −0·328 ±1·1031 (n.s.) |
| Diameter | 0·172 (n.s.) | 0·105 ±0·0655 (n.s.) |
| Length/diameter | −0·106 (n.s.) | −0·008 ±0·0080 (n.s.) |
| Volume | 0·055 (n.s.) | 1·118 ±2·2240 (n.s.) |

### (c) *Effect of Habitat*

The means and standard deviations of the skin measurements for six cattle breeds sampled in Australia and for their counterparts sampled in Britain are shown in Table 3, together with the results of the analysis of the data and subsequent *t*-tests. Only two of the measurements, hair follicle depth and hair follicle diameter, were significantly different between the Australian animals and their British counterparts. The hair follicles tended to be deeper and thinner in the samples obtained in Britain than in those obtained in Australia from cattle of the same breed. Although differences in the skin measurements occurred between the different cattle breeds, these were not considered in the present work and will form part of a world survey of bovine skin types.

### (d) *Relationship between Measurements*

The mean correlation coefficients between the skin parameters for 332 animals from 9 British breeds sampled in Britain are shown in Table 4. It is evident from the high correlations between hair follicle depth, hair follicle length, and sweat gland length that animals with a greater hair follicle depth tend to have longer hair follicles and longer sweat glands. The diameter of the sweat gland, however, appears

TABLE 2

MEAN VALUES AND STANDARD DEVIATIONS OF SKIN MEASUREMENTS IN 181 FRIESIAN CATTLE (90 BULLS, 52 COWS, 39 STEERS) AND THE ANALYSIS OF VARIANCE OF THESE DATA

M.S., mean square; d.f., degrees of freedom

| | Hair follicle | | | Sweat Gland | | | |
|---|---|---|---|---|---|---|---|
| | Depth (mm) | Length (mm) | Diameter ($\mu$) | Length ($\mu$) | Diameter ($\mu$) | Length/Diam. | $10^{-6} \times$ Vol. ($\mu^3$) |
| | Mean Values and Standard Deviations | | | | | | |
| Bulls | 1·64±0·24 | 1·90±0·30 | 52·5 ±7·49 | 1151·0±262·0 | 139·0±18·8 | 8·3±2·2 | 18·2±7·2 |
| Cows | 1·69±0·13 | 1·85±0·14 | 45·91±6·77 | 1034·0±231·0 | 125·0±14·7 | 8·3±1·9 | 13·2±4·8 |
| Steers | 1·60±0·23 | 1·75±0·22 | 40·62±5·97 | 913·0±184·0 | 110·0±10·2 | 8·3±1·9 | 8·8±2·3 |

Analysis of Variance

| | M.S. | F | M.S. | F | M.S. | F | M.S. | F | M.S. | F | M.S. | F | M.S. | F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variation between groups (d.f. 2) | 0·101 | 2·20† | 0·286 | 4·69* | 2089·0 | 42·72** | 809,700·8 | 14·21** | 12,418·3 | 47·63** | 0·048 | 0·01† | 1,291·6 | 38·10** |
| Error (d.f. 178) | 0·046 | | 0·061 | | 48·9 | | 56,987·8 | | 260·7 | | 4·2 | | 33·9 | |

* $P < 0·05$. ** $P < 0·01$. † Not significant.

TABLE 3

MEANS AND STANDARD DEVIATIONS OF SKIN MEASUREMENTS IN SIX CATTLE BREEDS SAMPLED BOTH IN AUSTRALIA AND IN BRITAIN

Number of cattle sampled given in parenthesis

| Breed | Hair Follicle | | | Sweat Gland | | | |
|---|---|---|---|---|---|---|---|
| | Depth (mm) | Length (mm) | Diameter ($\mu$) | Length ($\mu$) | Diameter ($\mu$) | Length/Diam. | $10^{-6} \times$ Vol. ($\mu^3$) |
| Ayrshire | | | | | | | |
| Australian (18) | 1·56±0·14 | 1·91±0·11 | 49·8±5·6 | 912·0±163·4 | 122·0±10·6 | 7·5±1·4 | 10·8±2·7 |
| British (85) | 1·70±0·23 | 1·93±0·20 | 42·4±6·8 | 953·5±288·8 | 125·9±17·4 | 7·6±2·2 | 12·4±5·8 |
| Shorthorn‡ | | | | | | | |
| Australian (20) | 1·53±0·13 | 1·76±0·11 | 45·7±4·1 | 1023·8±140·2 | 102·5± 9·8 | 10·1±1·7 | 8·5±1·9 |
| British (45) | 1·82±0·19 | 1·98±0·19 | 38·2±6·0 | 983·3±205·4 | 108·9±11·8 | 9·0±1·7 | 9·5±3·9 |
| Friesian | | | | | | | |
| Australian (17) | 1·30±0·16 | 1·67±0·12 | 44·5±5·7 | 938·6±190·8 | 101·0±11·3 | 9·3±1·6 | 7·8±2·7 |
| British (52) | 1·70±0·13 | 1·86±0·14 | 45·9±6·8 | 1034·1±231·1 | 125·5±14·7 | 8·3±1·9 | 13·1±4·8 |
| Galloway | | | | | | | |
| Australian (28) | 1·86±0·25 | 2·41±0·17 | 42·6±5·5 | 1110·0±259·3 | 111·3±11·8 | 10·0±2·0 | 11·2±4·3 |
| British (30) | 1·84±0·15 | 2·13±0·17 | 30·6±3·6 | 1060·8±150·6 | 103·4±12·1 | 10·4±1·9 | 9·0±2·5 |
| Guernsey | | | | | | | |
| Australian (19) | 1·46±0·13 | 1·79±0·15 | 50·9±4·1 | 893·7±162·4 | 109·3± 9·8 | 8·2±1·2 | 8·6±2·8 |
| British (17) | 1·55±0·20 | 1·92±0·30 | 45·6±4·5 | 829·6±180·8 | 124·4±19·3 | 6·8±1·6 | 10·6±5·1 |
| Jersey | | | | | | | |
| Australian (41) | 1·28±0·18 | 1·71±0·12 | 41·9±6·5 | 741·5±133·0 | 95·5± 9·3 | 7·8±1·3 | 5·4±1·7 |
| British (44) | 1·40±0·11 | 1·52±0·12 | 38·6±4·9 | 745·1±134·3 | 115·0±11·4 | 6·5±1·2 | 7·9±2·2 |
| Differences in skin measurements between habitats ($t$ ratio) | 2·89** | 0·33† | 4·89*** | 0·76† | 1·11† | 0·23† | 1·56† |

** $P < 0·01$. *** $P < 0·001$. † Not significant.

‡ Illawarra Shorthorn used for Australian samples, Dairy Shorthorn for British samples.

to be independent of hair follicle depth and length, yet the results indicate that longer glands tend to have wider diameters. This apparently anomalous result is probably due to differences in sweat gland dimensions between breeds and future investigation of the glands in different breeds may provide an explanation of it. The biological meaning of some of the other correlations is also, as yet, obscure and they are probably complex multiple correlations which reflect breed differences in skin dimensions.

TABLE 4

CORRELATION COEFFICIENTS BETWEEN THE COMPONENTS OF SKIN TYPE
Samples were taken in Britain from 332 females of 9 breeds

| | Hair Follicle | | | Sweat Gland | | | |
|---|---|---|---|---|---|---|---|
| | Depth | Length | Diam. | Length | Diam. | Length/Diam. | Volume |
| Hair follicle | | | | | | | |
| Depth | 1·0000 | | | | | | |
| Length | 0·8467*** | 1·0000 | | | | | |
| Diam. | 0·2737** | 0·3273*** | 1·0000 | | | | |
| Sweat gland | | | | | | | |
| Length | 0·4380*** | 0·3898*** | 0·2286* | 1·0000 | | | |
| Diam. | 0·1141 | 0·2044* | 0·3101** | 0·3226*** | 1·0000 | | |
| Length/ diam. | 0·3874*** | 0·2899** | 0·0636 | | | 1·0000 | |
| Volume | 0·3101** | 0·3473*** | 0·3218*** | | | | 1·0000 |

* $P < 0·05$. ** $P < 0·01$. *** $P < 0·001$.

## IV. DISCUSSION

### (*a*) *Effect of Age*

Measurements of the skin characters vary between young calves and adult cattle. For example, skin thickness and sweat gland size are greater in the adult animal (Schotterer 1932; Hafez, Badreldin, and Shafei 1955) while hair density is less (Carter and Dowling 1954; Turner, Nay, and French 1962). However, although such age differences occur between young and adult animals, it would seem from the present results that the skin measurements do not vary appreciably with age in cattle over 2 years old. It seems reasonable to conclude, therefore, that cattle skin has an adult structure by the time the animal is 2 years old. This conclusion is in general agreement with the results of Dowling (1955*a*) and Walker (1960) who found skin thickness and the relative thickness of the papillary layer to be independent of age in animals over 2 years old. The present findings, however, differ from those of Barker and Nay (1964) who, in a study of 285 adult Jerseys, found that sweat gland size increased with age. Hair density has been shown previously to vary considerably with age and with body weight (Turner, Nay, and French 1962) and the effect of age is important up to the age of 3 years (Carter and Dowling 1954).

It seems, therefore, that in skin from cattle over 2 years old only hair density is appreciably affected by increasing age although sweat gland length, diameter, and volume may in certain breeds vary slightly with age.

### (*b*) *Sex Differences*

The present results show that steers have smaller sweat glands than cows which in turn have smaller glands than bulls. The shape of the gland, however, is the same in bulls, steers, and cows. The hair follicles are apparently situated at the same depth in bulls, steers, and cows, but are longer and thicker in the male than in the castrate. The hair follicle in the female is thicker and longer than that of the castrate but thinner and the same length as that in the male. On the other hand, Peters and Slen (1964) found no significant difference in hair fibre length or thickness or in hair density between Hereford heifer and steer calves. Turner, Nay, and French (1962) concluded that hair density is higher in male than in female calves and Schotterer (1932), studying a number of breeds, concluded that although papillary thickness did not vary between bulls and cows it was thicker in steers. Goldsberry and Calhoun (1959) concluded that the male Aberdeen Angus has a thicker skin than the female.

It seems, therefore, that follicle depth and sweat gland shape are the only two measurements which do not vary appreciably between bulls, cows, and steers.

### (*c*) *Effect of Habitat*

The present results show that animals of a known breed reared in two different habitats differ only in the depth and diameter of the hair follicle. This indicates that the hair follicles in the Australian animals grow at a more acute angle since follicle length does not vary significantly.

### (*d*) *Body Area*

Differences in sweat gland density and size and in skin thickness between different body areas have been reported (Dowling 1955*a*; Nay and Hayman 1956; Patel and Anderson 1958). Pan (1963) concluded from a study of four Jersey and four Sahiwal animals that there was a significant difference in sweat gland density, length, diameter, and volume, and in skin thickness and skin shrinkage between different body regions. He found, however, that these characters did not vary significantly within a given body position, and concluded that the value obtained for the midside position for any of the above characters was within 10% of the mean value for all positions. Pan (1964) also found that hair characters varied between different body regions and that the percentage of medullated fibres was the only hair character for which the midside sample provided estimates which were within 10% of the mean overall positions for each breed. Pan (1963) also concluded that sweat gland shape varied considerably between different body areas, although he found this measurement to be relatively constant within a position. However, as no multiple-range test of the data on sweat gland shape is presented and the most extreme cases are illustrated, the between-area results are open to an alternative interpretation. Study of this information indicates that the largest variation in sweat gland shape is limited to the cheek and ventral surface of the animal. Over the rest of the body the values obtained all fall well within the limits of the error of measurement reported for sweat gland size (Nay and Dowling 1957) and may not, therefore, be significantly different. The results could be interpreted as indicating that sweat gland shape does not vary appreciably

between body areas apart from the ventral surface and extremities of the animal. Values of sweat gland shape obtained from the neck or midside of an animal would seem, therefore, to be suitable estimates of sweat gland and hence skin type.

### (*e*) *Nutrition*

Little is known about the effect of nutrition on skin measurements in cattle. It is known, however, that some skin measurements can vary depending on the nutritional status of the animal. Dowling (1955*b*) and Carter and Dowling (1954) concluded that there is a denser hair population in animals which have been on a poor diet or subjected to drought conditions. Dowling (1955*a*) also concluded that there was a significant difference in both the thickness of the skin and that of the papillary layer between 50 Shorthorns on a high plane of nutrition compared with 50 others on a low one. However, Tulloh (1960) found little difference in skin thickness between animals on different diets. In the present study all the animals were in a good nutritional state when sampled.

### (*f*) *Season and Exercise*

Some of the skin measurements have been shown to be influenced by season and exercise. Skin thickness and follicle depth are larger in winter than in summer and do not appear to be associated with body weight changes (Nay and Hayman 1963; Dowling 1964). Hayman and Nay (1958) concluded that sweat gland volume was minimal in summer and maximal in spring and autumn, and could be reduced in size after exercise. Nay and Hayman (1963) confirmed that sweat gland volume can change with season, but noted that sweat gland shape does not alter with season. Hayman and Nay (1961) and Berman and Volcani (1961) concluded that hair fibre diameter can be larger in summer than in winter in tropical cattle although the former authors failed to find a difference in this parameter in European cattle. Hair length also varies with season. However, although seasonal changes occur in most of the skin parameters, sweat gland shape appears to be independent of seasonal variation.

Schleger (1966) from a study of two animals maintains that in cattle the sweat glands undergo cyclic changes in morphology in association with the hair-growth cycle and completely disappear during the telogen or resting phase of the hair. These findings are not substantiated by the present experiments in which full-sized sweat glands were observed associated with hair follicles in all stages of the hair cycle in all instances where the gland was complete and undamaged by cutting and processing. Schleger's claim is surprising because about 60% of the hair follicles in cattle are in the resting phase during the summer (Dowling and Nay 1960; Hayman and Nay 1961) and it would follow that the capacity of cattle to sweat at the warmest time of the year would be drastically reduced.

Total skin thickness was not studied in great detail in this work as the sampling error of this measurement is large, and more material is at present being collected to enable its detailed study. The ratio of follicle depth to total skin thickness was not studied due to the measurement errors of total skin thickness and to the variations in follicle depth with season, nutrition, and habitat. Differences in this ratio between breeds have, however, been reported (Dowling 1955*a*; Nay and Hayman 1963).

Correlations between some of the skin measurements have been previously reported. Nay and Hayman (1963) found a correlation between sweat gland shape and sweat gland volume and between sweat gland shape and papillary layer depth. These results are in general agreement with the present findings. Comparison of such correlations in different breeds and in different habitats will be required before the mathematical relationships between the different skin characters can be completely explained biologically.

It appears from the evidence at present available that sweat gland shape is a reliable indicator of basic skin type in cattle if taken from the neck or midside of adult animals in a good state of nutrition. Under such conditions this parameter is not appreciably influenced by age, sex, season, or habitat, or by the hair follicle cycle. Follicle depth may also prove to be a useful associate measurement under the same conditions for animals in a known habitat if a seasonal correction is applied. Hair density is not a good index of skin type as it is affected by a number of factors. Of the remaining sweat gland measurements, volume is dependent on sex. Length, diameter, and volume vary with season and exercise. The season and physical activity of the animal would have to be taken into account before a knowledge of these parameters would be of value. The hair follicle characteristics are also only of restricted value as indicators of skin type since, for example, follicle diameter varies in different habitats and between sexes and in different seasons. Follicle length appears to be the most reliable of these hair follicle measurements.

It is concluded, therefore, that sweat gland shape (length: diameter ratio) is a suitable indicator for use in the comparison of the skin of different breeds of cattle throughout the world. Other skin parameters such as follicle depth, with suitable corrections, could possibly be used to subdivide the skin types based on the index of sweat gland shape.

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