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# Environmental Physiology and Shelter Engineering

*With Special Reference to Domestic Animals*

## LVII. Surface Area Determinations of Beef and Dairy Calves During Growth at 50° and 80° F Environmental Temperatures

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Missouri Agricultural Experiment Station and the
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# Environmental Physiology and Shelter Engineering

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## LVII. Surface Area Determinations of Beef and Dairy Calves During Growth at 50° and 80°F. Environmental Temperatures

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(JOHN D. SIKES, JAMES I. KENNEDY, E. B. O'BANNON, JR., AND D. HARTMAN)[1]

## INTRODUCTION

This bulletin represents a coordination and comprehensive presentation of surface area data collected on calves in two major investigations of the Climatic Laboratory project. The general purposes of the climatic studies are to study the various effects of climate on growth, milk production, and other physical, physiological, and/or heredity characteristics that may be associated with an animal's adaptability to various climatic conditions, primarily high temperatures. The surface area data reported were obtained during the growth phase of the study on Shorthorns, Santa Gertrudis, and Brahman cattle, conducted from November, 1954, to January, 1956, and on Holstein, Brown Swiss, and Jerseys, investigated from September, 1956, to August, 1957. Data on other physical and physiological measurements from these studies were reported by Dale *et al.* (1959); Johnson *et al.* (1958); Johnson and Ragsdale (1959a, 1959b); Kibler and Yeck (1959); and Stewart *et al.* (1958).

## HISTORICAL

The surface area of animals has been studied extensively during the last century because of the relationship between surface area heat production and dissipation. Even when area was estimated roughly, it was apparent to physiologists that the rate of metabolism for each unit of surface was approximately similar for all species of warm-blooded animals—more similar than when metabolism was expressed per unit weight. Some differences in metabolic rate of animals of the same species have been observed with differences in sex, age and some factors of the environment.

Controversies have existed for years in regard to the reason for the relation between area and rate of metabolism, but this does not affect the experimental fact nor alter its usefulness. Murlin (1922) states that area is the best unit of reference for comparing the metabolism or factors related to metabolism of different individuals.

The formulation of the law of surface area is commonly attributed to Rubner and Richet since they were the first to submit any extensive data in support of it. Rubner (1883) and Murlin (1922) published work on the metabolism of dogs and Richet (Lusk, 1925) on rabbits, in which they showed that under similar conditions of environment, the rate of metabolism of large and small animals was different when compared for the same unit of weight, but similar when compared for the same unit of surface. Rubner found also that the average heat production per square meter of body surface per twenty-four hours for man, dog, rabbit, guinea pig and mouse was 1,008 calories, ± 10 percent. Further work by Lusk, Armsby and others has confirmed the law repeatedly.

The significance of the relation between area and metabolism is not known. The early physiologists calculated that at least 80 percent of heat loss was through the skin, and that heat was produced in the body to keep pace with heat loss. They thought of the body as surrounded by a cooler medium and tending to cool according to Newton's law. However, it has been known since the time of Rubner that the body continues to metabolize in environments warmer than body temperature. Furthermore, the heat produced as a by-product of muscular work is far in excess of that needed to maintain body temperature. The problem of most individuals in warm and temperate climates is to get rid of the excess heat inevitably produced, rather than to metabolize enough to keep warm.

Benedict was opposed to using area as a unit of reference, since he believed that it gave an impression of a causal relationship which does not exist. In his studies on normal adults, he found that surface was only slightly better than weight as a unit for comparing individuals.

Murlin's views were that humans of different size produce heat in proportion to surface rather than weight, and therefore require energy in proportion. Dubois and also Lusk express similar views. Murlin also pointed out that Benedict's subjects were very similar in weight, and therefore in surface, and that if Benedict had been comparing individuals of widely differing weight, he should have found surface distinctly better than weight as a unit of reference.

Another group of investigators (DuBois, 1927) has taken the attitude that metabolism is proportional to area because area is proportional to some more fundamental factor. For example, area is proportional to blood volume (Dreyer, *et al.,* 1912-1913; Moulton, 1960), cross-sections of the aorta and trachea (Dreyer *et al.,* 1912-1913), body nitrogen (Moulton, 1960), vital capacity (Moersch, 1926) and area of intestines (Von Pirquet, 1927), etc.

Many investigators have believed that surface area is an important factor in the maintenance of homeothermy. However, an exact, experimentally valid statement of the relationship in animals has not been made. It has been established that heat loss and heat production are proportional to surfaces and that surface area and heat production are interrelated. The laws of Newton and Stefan-Boltzmann state that the rate of cooling of a body is proportional to the surface. The importance of the external surface of cattle in heat dissipation has been proposed and disputed (Brody, 1945; Scholander, 1955; and McDowell *et al.,* 1953).

Surface area varies with the two-thirds power of body weight in geometrically similar physical bodies of constant specific gravity, but, since growing calves are not geometrically similar or constant in specific gravity, surface area will not vary with $W^{2/3}$ in these animals. Recognizing the fallacies associated with an assumption of $W^{2/3}$ as an index of metabolism, Brody (1945) concludes: "It is theoretically more logical and practically simpler to relate metabolism not to surface area or to $W^{2/3}$ or to 'active mass', . . but to the non-committal, physiologically effective body size represented symbolically by $W^b$, the value of the exponent b to be determined from actual data."

Matthews *et al.* (1928) measured 341 beef cows including all ages and all degrees of fleshiness. All points were plotted on logarithmic paper and they formed a straight line. The equation for the data was $A = .12W^{.60}$. Elting and Brody (1926) measured 96 purebred Holstein and Jersey cows and obtained similar results. When the data were plotted on logarithmic paper, they formed a straight line and the resulting equation, $A = .15W^{.56}$ expressed the relationship. Elting and Brody (1924); Matthews *et al.* (1928); and Brody (1945) found that the value of the power varied from .32 to .72 and depended upon the form of the animal. The change in form of the animal due to change in weight during growth is quite different from that during fattening or fasting of mature animals.

## OBJECTIVES

It is the purpose of this paper to describe changes in surface area as related to body weight during growth from approximately 2 to 14 months for beef animals and from 1 to 12 months for dairy animals at two constant temperatures, 50° or 80°F. Other objectives were to discover whether surface area changes would reflect adaptation to the high temperature of 80°F. Would the relationship of surface area to body weight of a breed be different from the calves raised at 50°F. than for those raised at 80°F., and what are the breed differences in surface area during growth?

It is known that the Brahman cattle can withstand tropical and subtropical climates. The effects of rising temperature on physiological reactions becomes critical (significantly changed from normal levels) at environmental temperatures between 90° and 95°F. (Kibler and Brody, 1951).

Upon exposure to high environmental temperature, recent work has shown, the Shorthorn (generally considered heat intolerant) generally develops hyperthermia; loses appetite, grows slowly and is less fertile. The tolerance of the Santa Gertrudis, a cross between the Shorthorn and Brahman, is somewhere between the two parent breeds (Johnson *et al.,* 1958, Kibler, 1957)

It has been determined that Holsteins and Jersey cows exhibit heat discomfort characteristics when environmental temperatures exceed 70° and 75°F., respectively. The critical temperature for the Brown Swiss cow is 85°F. (Worstell and Brody, 1953).

## METHODS

### Experimental Procedure

The conditions of the experiments conducted in the Climatic Laboratory were thoroughly controlled. The laboratory consisted of two chambers, each independently controlled and arranged to contain three pens. The constant temperature and relative humidity during the first experiment were 50° F. and 62% R.H. for one chamber and 80°F. and 54% R.H. for the other. Light was supplied by a 40-watt incandescent bulb (24 hours per day) and six 200-watt incandescent bulbs (6 a.m. to 6 p.m.)

For information on age and body weight of calves see Appendix Tables I and III. A description on feeding, managements and experimental conditions has been published for beef calves (Johnson *et al.,* 1958) and dairy calves (Johnson and Ragsdale, 1959a).

### Method of Measuring Surface Area

The surface integrator was used to measure surface area. The integrator was designed by Elting and Brody in 1926. Figure 1 presents a photograph of the surface area integrator.

A simple measuring technique was used. The right side of the animal was measured and the values obtained were multiplied by two. Following the dorsal median line, the roller was passed from the muzzle to the posterior of the animal. The edge of the outside path was indicated by the chalk marker. The inside edge of the roller was placed on the outside edge of the path, thereafter, and the entire surface was measured without duplication or omission. When a Brahman was measured, the dewlap was held forward and measured with the neck and shoulder portion. Measurement of the side portion of the animal was resumed and continued until the underside part, beginning with the flank, was reached. Only the outside portions of the legs were measured. The legs were remeasured so that account could be made of the inside view. The underside was measured in a manner similar to that applied to the side portion. In the study of beef breeds, the undersides of the animals were measured after the animals had been "thrown" with ropes. To allow for the inside half of the ear, the outside portion was measured twice. The animals tail was measured by traversing it twice with the integrator. The surface area measurements on both beef and dairy breeds were taken approximately once a month.

The total surface area of the animal was obtained by means of the equation:

$$\text{Surface Area in } M^2 = 2\ (A + B) + D \times .008107$$

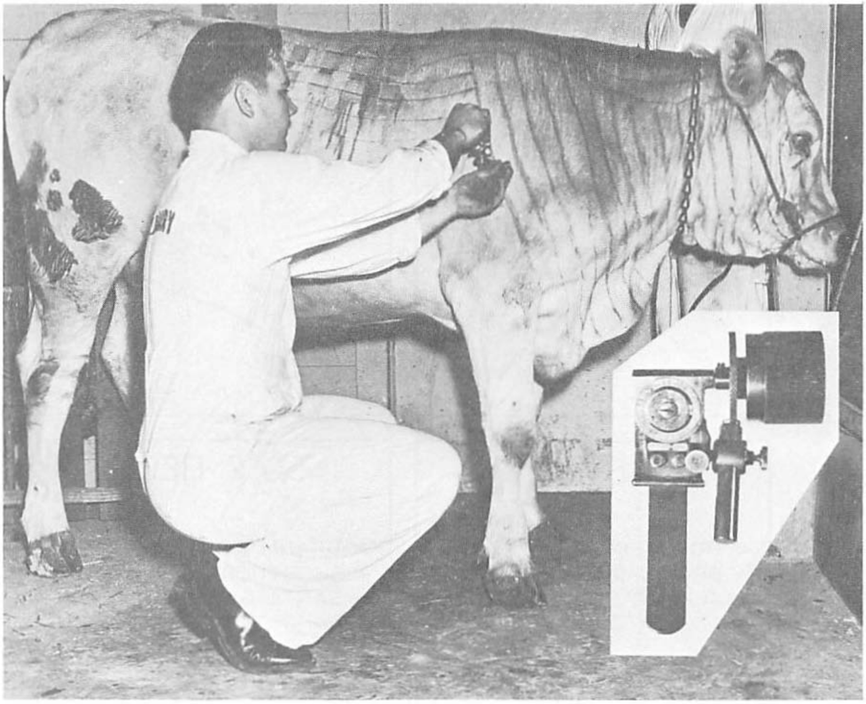

Figure 1

**Procedure for measurement of the animal's surface by the Integrator method (Elting and Brody, 1926). Insert is the surface area Integrator.**

A = revolutions obtained from measuring surface of the right side of body, neck, and head (including right ear).

B = two times the revolutions obtained by measuring the surface of one-half the right legs.

D = revolutions obtained by measuring surface of the animal's tail. .008107 = $M^2$ of the integrator drum used in measurement.

## RESULTS

### Surface Area vs. Age

Surface area vs. age for all breeds (average of three in each breed) at each temperature level is plotted arithmetically and presented in Figure 2. The surface area of each breed increased with age at a fairly constant rate. From approximately 9.5 to 11.5 months of age, however, the surface area of the dairy breeds tended to level off. The 50°F. animals from 2.5 to 12.5 months of age increased

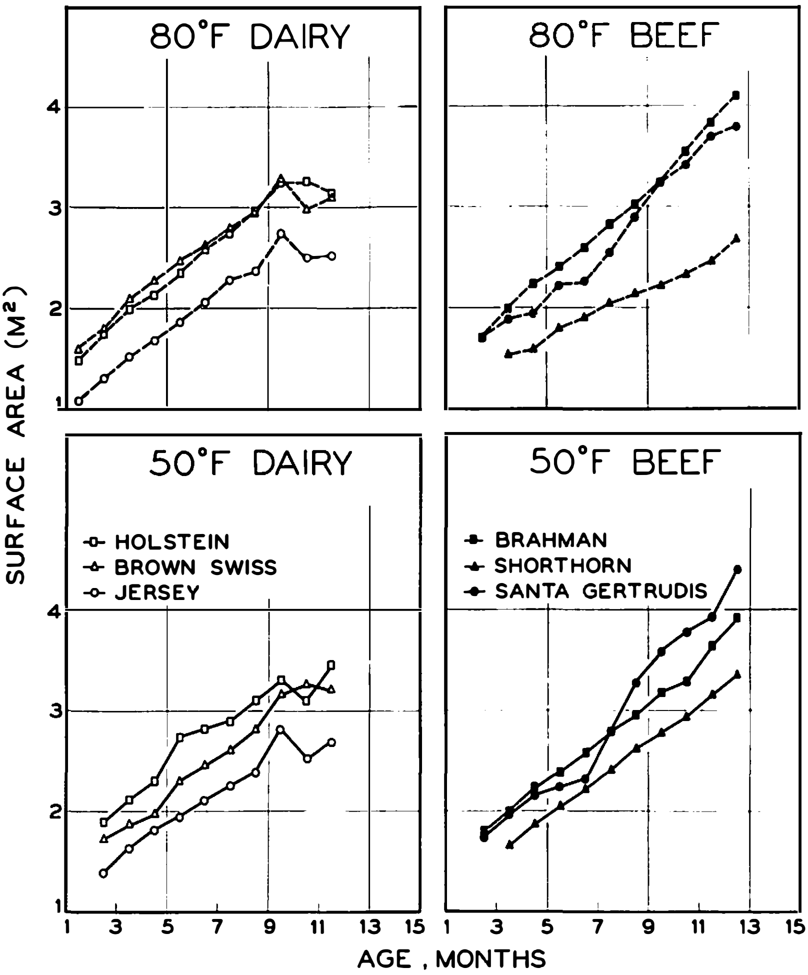


**Figure 2**

**Surface area vs. age for dairy and beef breeds during growth at 50° and 80°F. (Average of three animal measurements for each breed).**

in surface area from a low of approximately 83% (Holsteins) to 150% (Santa Gertrudis). Throughout growth the average surface area for the same ages was the greatest for the Santa Gertrudis. The other breeds generally followed, in descending order of magnitude: Brahman, Holstein, Brown Swiss, Shorthorn, and Jersey.

At 80°F. the increase in surface area was also fairly constant up to 9 months of age. This was the period of most rapid growth. Over a period of approximately 10 months, the percentage increase of surface area ranged from 75% (Shorthorn) to 140% (Brahman).

The Brahman and Brown Swiss surface area for each age was greater at 80°F. than at 50°F., but that of all other breeds tested was greater at 50°F. This was assumed to be a result of better growth at the 80°F. temperatures for these two breeds than for the other four breeds.

At approximately six months (body weight, 122 kg.) the surface area of Jerseys (2.16 $M^2$) compared favorably to findings by Elting (1926). The surface area of 50°F. reared calves (Figure 2) at 195 days (body weight, 123 kg.) was 2.12 $M^2$. The surface area of 80°F. reared calves at approximately the same age but weighing 118 kg. was 2.04 $M^2$.

At one year, a difference appears. Elting's animals measured 3.34 $M^2$ at a body weight of 272 kg. while the Jerseys at approximately one year in our investigation at 50°F. measured 2.55 $M^2$ at 209 kg. body weight. This difference was apparently caused by the heavier Jerseys in Elting's study.

Charts showing the rectal temperatures of the animals were published by Kibler, (1957 and 1960), but a brief review is necessary for a complete interpretation of the surface area data: Both the 50°F. and 80°F. beef animals showed a decrease in rectal temperature after 3 to 5 months of age. Among the 50°F. animals, breed averages, although probably insignificantly different, were highest for the Shorthorns, intermediate for the Santa Gertrudis, and lowest for the Brahmans. The 80°F. Shorthorns, had rectal temperatures about two degrees higher than the other two breeds with Brahmans slightly lower than the Santa Gertrudis. Although the difference was most pronounced for the Shorthorns, it was evident that at 80°F. all groups displayed higher rectal temperatures than at 50°F.

The differences in rectal temperatures among the dairy breeds were small at either 50° or 80°F. The environmental temperatures appeared to have the greatest effect on the Holsteins which showed the most evident 50°-80°F. differences. The Jerseys and Brown Swiss were affected to a lesser degree.

## Ratio of Surface Area to Body Weight

Figure 3 presents the ratio of surface area to body weight vs. age for beef breeds plotted on semilogarithmic paper. At both temperatures, the ratios decreased with age until they tended to level off between seven and nine months of age. Until approximately ten months of age, the ratio of the 50°F. Brahmans was higher than that of the 80°F. animals; thereafter, the positions were reversed. The Santa Gertrudis ratios were very similar at the two temperatures. (The Shorthorns, in contrast, exhibited consistently higher ratios at 80°F. than at 50°F.). At 50°F., which is within the "comfort zone", the ratios were highest for the Brahmans, intermediate for the Santa Gertrudis, and lowest for the Shorthorns. At this temperature, the relative magnitudes of the ratios appear to be consistant with the relative heat tolerance capabilities of the animals.

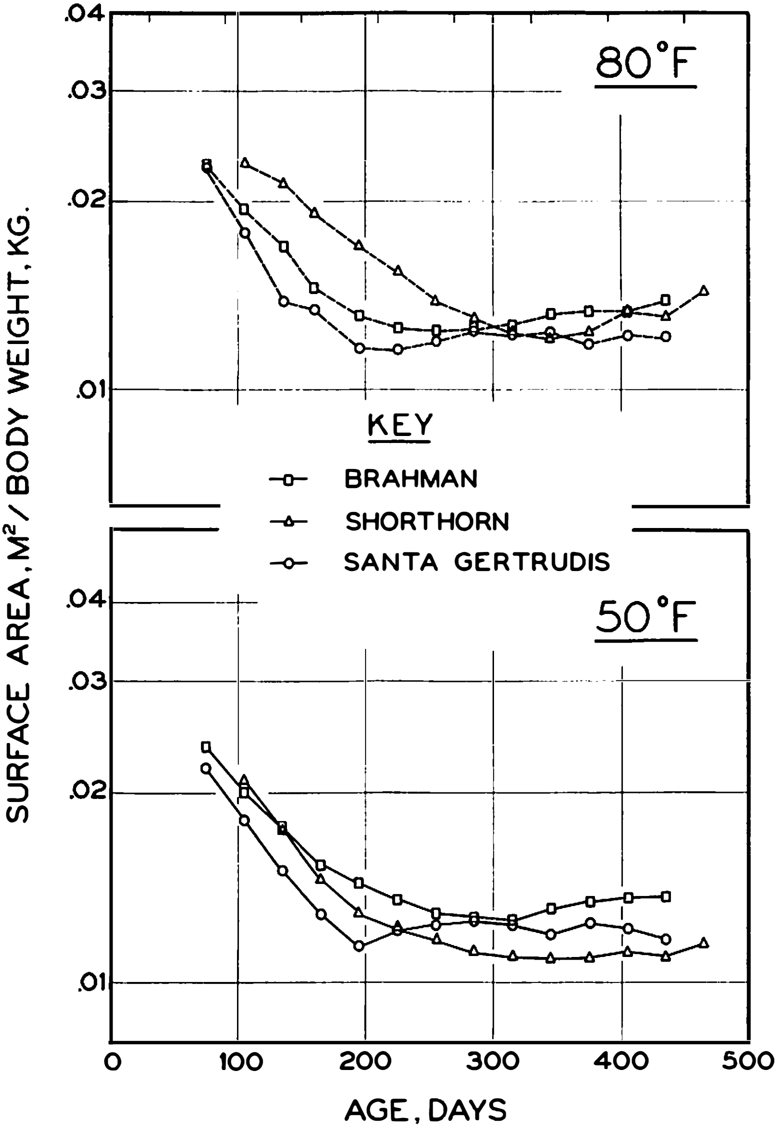


**Figure 3**

**Surface area, M²/body weight at increasing age for 50° and 80°F. Brahman, Shorthorn and Santa Gertrudis.**

At 80°F., after several months growth at the higher temperatures, values for all breeds were very similar—though Brahman tended to be highest and Santa Gertrudis lowest.

When the ratio of surface area to body weight of the dairy cattle was plotted vs. age (Figure 4), it was evident that regardless of temperature, the Jerseys

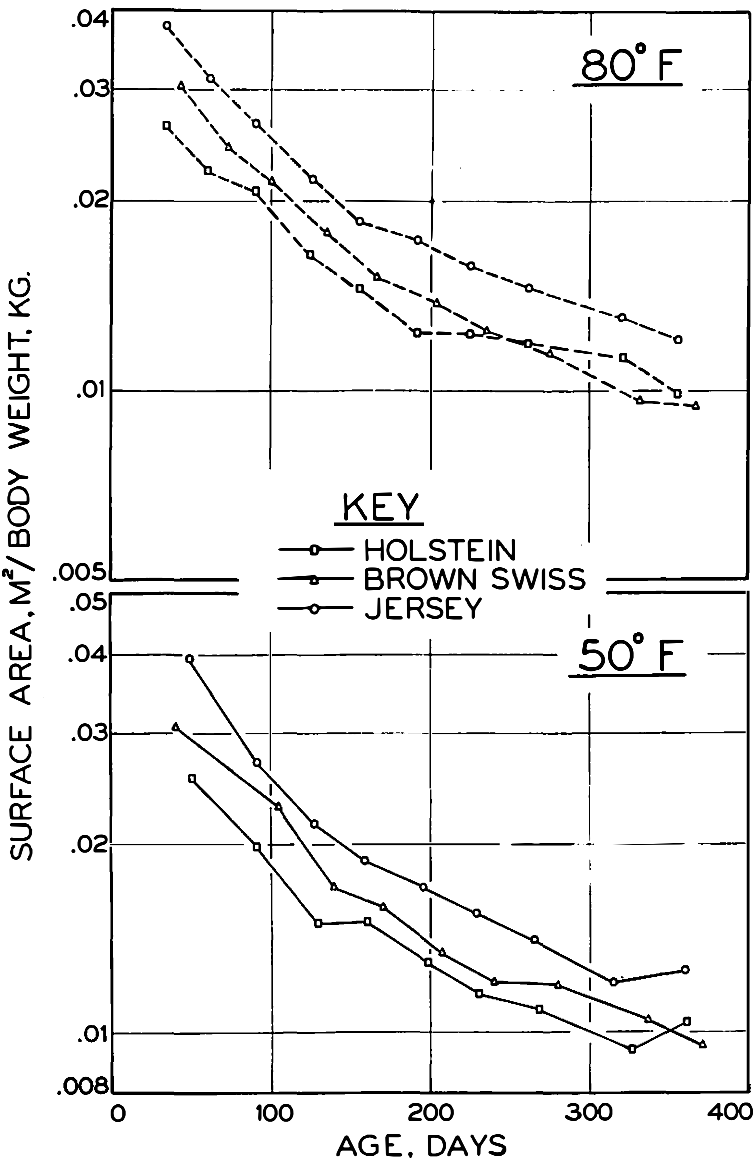


**Figure 4**

**Surface area, $M^2$/body weight at increasing age at constant environmental temperatures of 50° and 80°F. for the Holstein, Brown Swiss and Jersey (Average of three animal measurements for each breed).**

displayed the highest ratio. They were followed by the Brown Swiss and the Holsteins in that order. The surface area per unit body weight decreased with a resultant flattening of the slopes due to the fact that weight increased at a greater rate than surface area.

Statistics (F values) revealed that the surface area per unit weight of the Jerseys (50° and 80°F.) within the range of 260-325 days of age were significantly higher (.01) than the Brown Swiss, Holstein, Santa Gertrudis, Shorthorn and Brahman. Brown Swiss and Brahman were significantly different. Santa Gertrudis and Brahman differences approached significance (.01). Brahman and Shorthorn were also significantly different at this level. Other comparisons were non significant.

It was previously shown by Kibler and Brody (1951) that the Brahman cows and heifers had approximately 12% greater surface area than Jerseys and Holsteins of the same body weight—apparently in contradictation to data in Figures 3 and 4. When studying figures 3, 4, 5, and 6, it is apparent that one breed may have different body weight at comparable age which influences these surface area relationships.

With expressions of surface area per unit body weight, as in many physiological expressions vs. climate statements, one must consider the relative growth responses (Johnson *et al.,* 1958). For example, surface area per unit weight for 80°F. Shorthorn was relatively higher from 100-300 days of age, due to poor weight gains. That is, a higher surface area per unit weight may simply mean that the animal is unproductive.

Although the temperature effects were not pronounced, the 80°F. Holsteins, Brown Swiss and Jerseys ratios appeared slightly higher than those of the corresponding 50°F. animals.

## Surface Area vs. Body Weight

The logarithmic relationship of surface area and body weight is indicated in Figure 5. The equation $Y = aX^b$ was fitted on the data. At approximately 150-200 kg. body weight, considerable variation is shown in the surface area measures. These variations may be associated with changing composition of ration (Johnson *et al.,* 1958 and 1959a), due to a change in personnel responsible for the surface area, or normal physiological and physical changes.

According to the equation of the form employed, a change of one percent in X is accompanied by a change of b percent in Y. For the 50°F. Santa Gertrudis, Brahmans and Shorthorns, the exponents (b), were .66, .60, and .59, respectively. These components (Figure 5), though not greatly different, suggest that the Shorthorns made more adaptative efforts than the more heat tolerant breeds. The Shorthorns made greater gains at the older ages in contrast to the Brahman and Santa Gertrudis (Johnson *et al.,* 1958). (This would tend to lower the exponent due to the lessening of angularity per body weight). This chart emphasizes the relative effect of increasing body weight on surface area as presented previously in Figure 3.

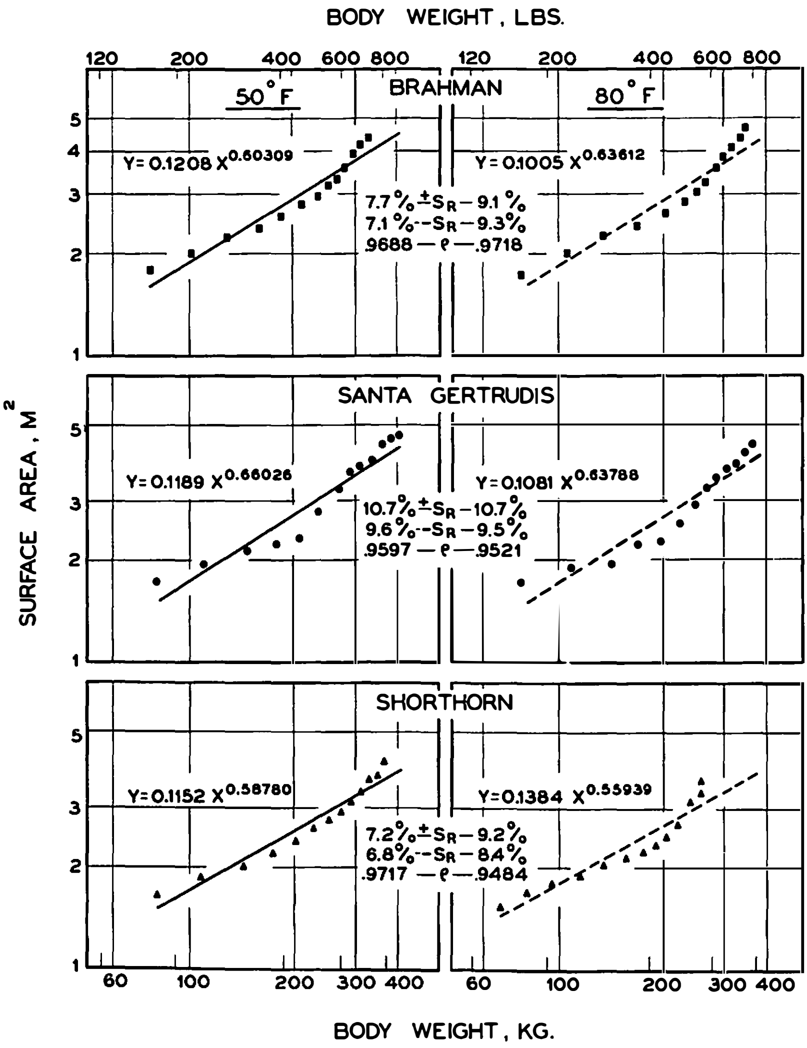


**Figure 5**

**Logarithmic relationship of surface area and body weight for Brahman, Santa Gertrudis, and Shorthorn at 50° and 80°F. (Points are average of three animal measurements for each breed).**

Data collected from the dairy breeds were represented in a similar manner on logarithmic paper and regression lines fitted by the method of least squares. (See Figure 6). The data were expressed by the parabola, $Y = aX^b$. The range of the exponent b, for the animals raised at 50°F., was from .40 to .44, while

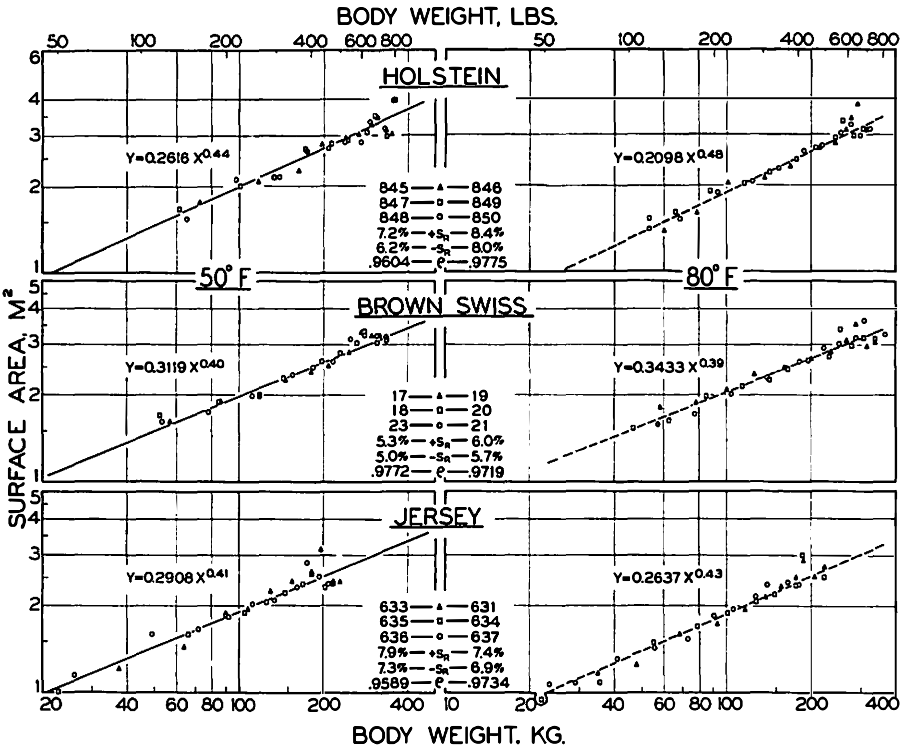


**Figure 6**

**Logarithmic relationship of surface area and body weight for Brown Swiss, Holstein, and Jersey during growth at 50° and 80°F. (Individual data points are used for each breed).**

the 80°F. animals ranged from .39 to .48. With the exception of the Brown Swiss, the exponent representing increase in surface area per unit change in body weight appeared slightly greater in the 80°F. animals than in the 50°F. groups. The exponent of the 50°F. Brown Swiss was .40 while that of the 80°F. Brown Swiss was .39. The rate of gain was also greater for the 80°F. Brown Swiss. The Holsteins, generally believed to be the least heat tolerant, exhibited an exponent .04 higher at 80° than at 50°F.

## Data on Surface Area of Specific Regions of Body

Although the beef and dairy experiments were comparable in many respects, each study included different measurements. These aspects will be discussed individually.

*Local Heat Dissipating Areas in Beef Cattle:* The ears, dewlap, navel flap, and vulva are believed by some to be very important heat dissipating surfaces. In the

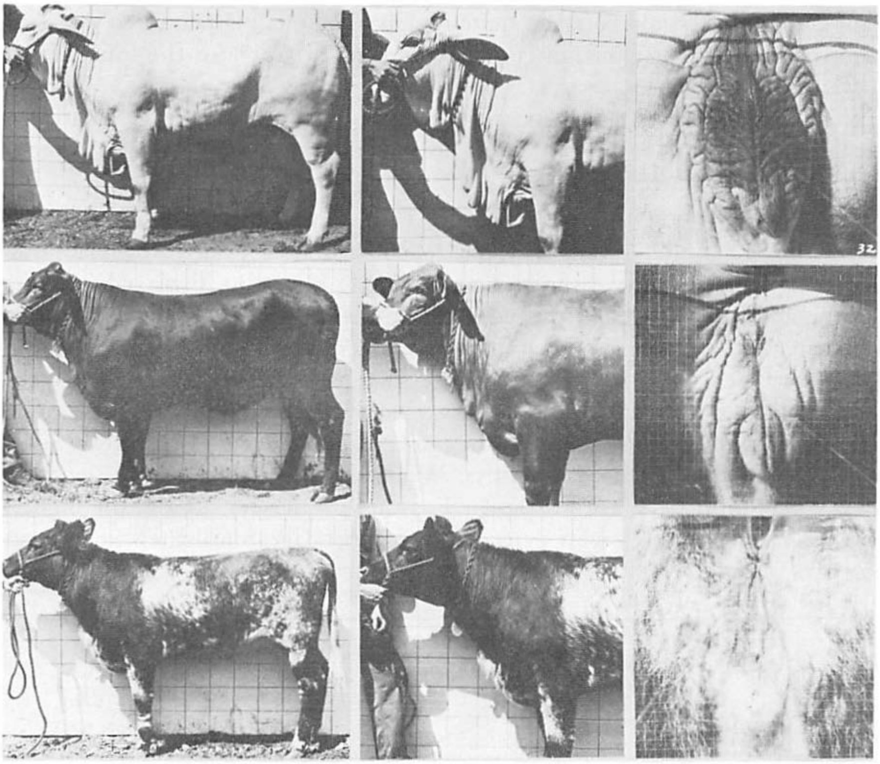

**Figure 7**

**Views showing relative differences in size of dewlap, navel flap and vulva. Some investigators believe these to be important areas of heat dissipation.**

Brahmans, these features are the largest; somewhat less impressive in the Santa Gertrudis, and much less pronounced in the Shorthorns. (See Figure 7). The ears, dewlap, and navel-flap, were measured at various ages. These features of the Brahman represent about 11% of the total surface area. In the Santa Gertrudis and Shorthorns, the areas mentioned equal about 9% and 6%, respectively, of the total surface area.

Although the value of the ears, dewlap, navel-flap, and vulva as heat dissipating mechanisms is a subject of great controversy, the relative extent of any importance may be indicated by a table showing the relation to the total surface area.

The vulva of various individuals within each breed was photographed at various stages of growth. The photographs were taken against an eight by twelve inch plastic grid marked in one-quarter inch squares. The grid was attached to a frame and attached to a Graflex camera. The depth of field was constant and pictures could be taken quite rapidly. The method permitted measurement of the perimeter but, of course, could not account for the folds of the vulva or any difference in vascularity of this structure.

More suitable tests must be devised in order to thoroughly evaluate the heat dissipating effectiveness of these areas, although Figure 7 clearly demonstates the relative breed differences.

*Dairy Calves: Ratio of Appendages* to Total Surface Area:* Surface area of an animal may be more meaningful when appendages are considered in relation to the total surface. Figure 8 shows that the 80°F. Holsteins displayed a higher percentage of surface area in appendages than than 50°F. Holsteins. Perhaps the Holsteins at the higher temperature were endeavoring to adjust surface area in a manner that would facilitate better heat dissipation. This was accomplished with a depressed growth rate. The Jerseys showed the least difference among the breeds with respect to total surface area in appendages. The Brown Swiss were not much different than Jerseys. When the breed averages for the three breeds were plotted vs. age for the 50°F. group the Jerseys showed the highest and the Holsteins the lowest percentage of appendages until they were about 265 days old.

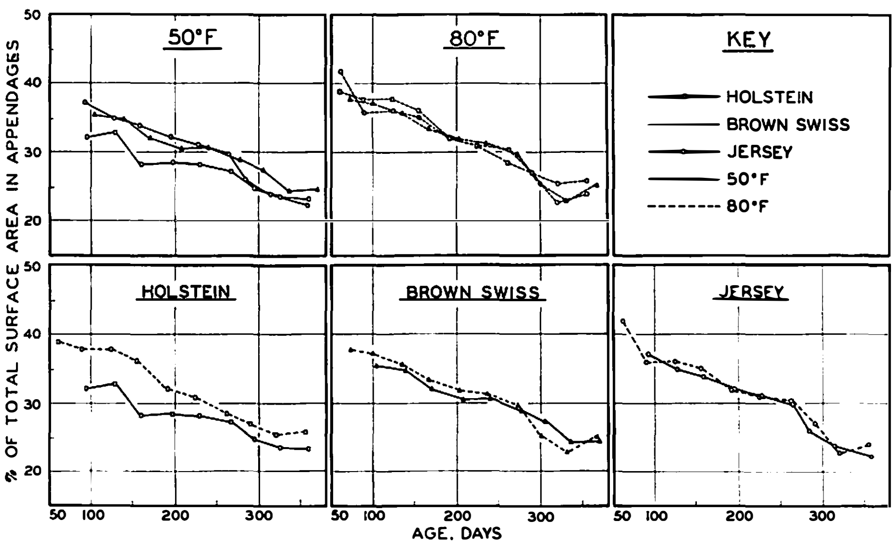


**Figure 8**

**Percent changes of Appendage area (legs, tail) in the total animal surface with increasing age, during growth at constant environmental temperatures of 50° and 80°F.**

The obvious decrease in ratio of appendage area to total surface area during growth suggests that small calves should be more heat tolerant, but they have a higher heat production (See the following discussion section).

TABLE I. PERCENTAGE OF SURFACE AREA IN HEAT DISSIPATING AREAS
(Ears, Dewlap, and Navel-flap)

| | Brahman | Santa Gertrudis | Shorthorn |
|---|---|---|---|
| Ears | 3.0% | 3.0% | 3.1% |
| Dewlap | 6.6% | 4.6% | 1.9% |
| Navel-flap | 1.2% | 1.2% | .8% |
| Total Surface (Represented by 3 Features) | 10.8% | 8.8% | 5.8% |

The following table indicates the area of various components or appendages of the body and the percentage of total surface area in various appendages.

TABLE 2-TOTAL BODY SURFACE AREAS# AND THAT OF VARIOUS COMPONENTS ($M^2$) (Breed Average)

| Breed | Total Surface Area ($M^2$) | Dewlap ($M^2$) | Legs and Tail ($M^2$) | Ears ($M^2$) |
|---|---|---|---|---|
| Holstein | 3.9427 | .0575 | .9924 | .7654 |
| Brown Swiss | 4.0184 | .1555 | .9287 | .7950 |
| Jersey | 3.1806 | .0504 | .7688 | .5394 |

PERCENT OF TOTAL BODY SURFACE AREA IN VARIOUS APPENDAGES## OF DAIRY CALVES
(Breed Average)

| Breed | Dewlap | Legs and Tail | Ears |
|---|---|---|---|
| Holstein | 1.45% | 25.17% | 1.99% |
| Brown Swiss | 3.87% | 23.11% | 2.06% |
| Jersey | 1.58% | 24.17% | 1.76% |

# Measures made at conclusion of growth study.
## Ears and dewlap were determined by covering the regions with paper tape then calculating the areas mathematically.

Brown Swiss had apparently greater surface in dewlap and ears than Holstein or Jersey, though less in legs and tail than the Jersey or Holstein.

The above table on proportional parts of the total surface area express the actual measured areas. These values of course also reflect the size of the animal.

## DISCUSSION

There are two schools of thought on the subject of surface area and heat tolerance. (1) Surface area is not an important factor in heat tolerances as indicated by McDowell et al., (1953). (2) Surface area may be an important factor. According to the law of Newton and Stefan-Boltzman the rate of cooling of the body is proportional to its surface. Since heat loss should equal heat production and since surface is one of the major sites of heat dissipation the surface area may determine the adaptability of animals to the environment.

Whatever the surface area of an animal may be, we know that heat dissipation from its surface must balance heat production. (Scholander, 1955). It is conceivable that greater appendages such as dewlap, ears, vulva, etc., may effectively dissipate much of the body heat without necessitating greater dissipation of heat by other areas of the body. For example, if an animal has more dewlap, ear surface, etc., theoretically less diffusion or sweating of the main body surface would be necessary for a given condition. This theory requires intensive "critical studies" such as blockage or stimulation of heat dissipation in the dewlap or ears coupled with circulation studies and simultaneously observe the effects on dissipation (surface temperatures, vaporization) on other areas of the body. At extremely high environmental temperatures (approximately 100°F.), the Brahman excel in heat tolerance apparently due to a lower level of heat production and ability to vaporize moisture (Kibler and Yeck, 1959). It is not inconceivable that a greater area of dewlaps, ears, vulva may be of some importance in heat balance.

It is difficult to conceive that the greater surface, particularly of appendages, is of no importance in heat dissipation. They may have among other attributes, energy-conserving characteristics which have permitted the successful adaptation of these animals in the tropics. It is obvious from data presented in this paper that total surfaces between most breeds do not differ greatly—though some of the appendages, ear, dewlap, etc., are more pronounced in animals of Indian origin.

It may be recalled that surface area and characteristics of surfaces are only one factor in the complex phenomena of heat balance; the heat production/unit weight and efficiency of energy transformation play important roles (Ragsdale *et al.,* 1957, Kibler, 1957, Johnson *et al.,* 1959).

This greater surface area per unit weight would be of particular significance unless the metabolism per unit weight and the vaporization per unit weight increased with the same magnitudes. Data from Kibler (1957, 1960) and Kibler and Yeck (1959) show the following heat production and vaporization values.

In comparing Figure 3 and Table 3, we see that, in first considering 50°F. beef calves, the Shorthorns have the highest heat production per unit weight and a lower surface area per unit weight. The Santa Gertrudis have intermediate values whereas the Brahmans have the highest surface area per unit weight and the lowest heat production per unit weight.

Thus, this is a conceivable reason for greater ability of Brahman to withstand high temperatures (dissipate their heat) and the inability of the Shorthorns with less surface to dissipate a greater level of heat production per unit weight.

The 80°F. reared beef calves generally have the same situation, however, surface area per unit weight shows a reversal (Shorthorn higher than Santa Gertrudis). However, this may be largely due to a greater productivity of the Santa Gertrudis (heavier) as contrasted to the poor gains and, thus, more angularity, etc., of the 80°F. Shorthorns. These observations are further supported by

TABLE 3-VALUES OF METABOLISM AND VAPORIZATION DURING GROWTH AT 50° AND 80°F.

50°F.

| Dairy Breed | (kg.) Body Weight | Month Age | Cal/hr/calf | cal/hr/ Sq. Meter | cal/hr/calf / Body Weight, kg. |
|---|---|---|---|---|---|
| Holstein | 150 | 4.5 | 425 | 179 | 2.83 |
| Brown Swiss | 100 | 4.3 | 250 | 126 | 2.50 |
| Jersey | 80 | 4.1 | 236 | 135 | 2.95 |
| Holstein | 300 | 9.6 | 552 | 171 | 1.84 |
| Brown Swiss | 250 | 9.1 | 467 | 164 | 1.87 |
| Jersey | 175 | 9.1 | 367 | 152 | 2.10 |

80°F.

| Dairy Breed | (kg.) Body Weight | Month Age | Cal/hr/calf | cal/hr/ Sq. Meter | cal/hr/calf / Body Weight, kg. |
|---|---|---|---|---|---|
| Holstein | 125 | 4.2 | 302 | 142 | 2.42 |
| Brown Swiss | 125 | 4.4 | 298 | 132 | 1.68 |
| Jersey | 80 | 4.3 | 214 | 124 | 2.68 |
| Holstein | 275 | 9.8 | 498 | 160 | 1.81 |
| Brown Swiss | 275 | 9.7 | 486 | 159 | 1.77 |
| Jersey | 175 | 9.8 | 337 | 139 | 1.93 |

50°F.

| Dairy Breed | (kg.) Body Weight | Month Age | Cal/hr/calf | cal/hr/ Sq. Meter | cal/hr/calf / Body Weight, kg. |
|---|---|---|---|---|---|
| Brahman | 125 | 4.5 | 242 | 111 | 1.94 |
| Santa Gertrudis | 125 | 4.0 | 343 | 144 | 2.75 |
| Shorthorn | 100 | 4.3 | 286 | 155 | 2.86 |
| Brahman | 250 | 10.1 | 352 | 110 | 1.41 |
| Santa Gertrudis | 300 | 10.1 | 463 | 139 | 1.54 |
| Shorthorn | 250 | 9.5 | 426 | 153 | 1.70 |

80°F.

| Dairy Breed | (kg.) Body Weight | Month Age | Cal/hr/calf | cal/hr/ Sq. Meter | cal/hr/calf / Body Weight, kg. |
|---|---|---|---|---|---|
| Brahman | 125 | 4.3 | 261 | 119 | 2.09 |
| Santa Gertrudis | 125 | 4.2 | 291 | 139 | 2.33 |
| Shorthorn | 80 | 4.5 | 215 | 128 | 2.69 |
| Brahman | 275 | 10.1 | 381 | 109 | 1.38 |
| Santa Gertrudis | 275 | 10.1 | 416 | 122 | 1.51 |
| Shorthorn | 175 | 10.2 | 341 | 152 | 1.95 |

50°F.

| Breed | (kg.) Body Weight | Month Age | Skin Vaporization Per Hour /calf | $g/m^2$ | Body Weight, kg. |
|---|---|---|---|---|---|
| Brahman | 113 | 4 | 55 | 26 | .487 |
| Santa Gertrudis | 126 | 4 | 79 | 37 | .627 |
| Shorthorn | 124 | 5 | 93 | 48 | .750 |
| Brahman | 225 | 10 | 73 | 22 | .286 |
| Santa Gertrudis | 297 | 10 | 102 | 31 | .343 |
| Shorthorn | 262 | 10 | 107 | 37 | .408 |

80°F.

| Breed | (kg.) Body Weight | Month Age | Skin Vaporization Per Hour /calf | $g/M^2$ | Body Weight, kg. |
|---|---|---|---|---|---|
| Brahman | 117 | 4 | 200 | 93 | 1.71 |
| Santa Gertrudis | 128 | 4 | 238 | 113 | 1.86 |
| Shorthorn | 86 | 5 | 135 | 79 | 1.57 |
| Brahman | 273 | 10 | 232 | 67 | .850 |
| Santa Gertrudis | 271 | 10 | 288 | 86 | 1.06 |
| Shorthorn | 181 | 10 | 205 | 89 | 1.13 |

the reversal of the heat production per $M^2$ at approximately 8 months in the 80°F. reared Santa Gertrudis and Shorthorns (Kibler, 1957).

In agreement with the heat production per unit weight, the Shorthorns display a greater skin vaporization per unit weight. These discussions, in conclusion, are evident in the expressions of heat production and heat vaporization per $M^2$ surface area (Kibler and Yeck, 1959).

In comparing the 50°F. reared dairy calves, the Jerseys have the highest heat production per unit weight and also the highest surface area per unit weight. The Brown Swiss have the lower heat production per unit weight with an intermediate surface area particularly at four months. Therefore, relatively speaking, they have a greater surface per level of heat production. The Holsteins have the lowest surface area per unit weight and intermediate level of heat production. These facts may account for some of the relatively superior heat tolerance of the Brown Swiss and less heat tolerance of the Holstein. The values of heat production per unit surface area point this out. That is, the Jerseys having less heat production per square meter of surface area than tht Holsteins and the Brown Swiss are intermediate except at four months when Jerseys are intermediate and Brown Swiss lowest. (See Table 3).

The 80°F. reared Jersey animals have the highest heat production and surface area per unit weight. The 80°F. reared calves show a reversal (See Figure 4 at 250 days) of the Brown Swiss and Holstein animals at 80°F. in surface area per unit weight. However, this is largely due to less weight gain of the Holsteins at 80°F. The relative comparisons of heat production and surface area are similar to the 50°F. values. The skin vaporization data are not presently available for a comparison of the dairy animals, however, one may logically expect the level of vaporization to parallel the level of heat production.

In continuation of this discussion we might ask the question, "Are young calves more heat tolerant since they have a greater surface area per unit weight?" On the contrary, they seem to be less heat tolerant. Kibler (1957) suggested that young calves may be less heat tolerant than cows because they have greater heat production per unit surface area. However, he also showed that younger calves have a greater heat production per unit weight. Similar views are apparently shared by Kennedy and Turner (1959). However, there are apparent inconsistencies when considering the fact that Brahman cattle have greater surface area and less heat production per unit weight or unit surface area and that young calves with greater surface area per unit weight are less heat tolerant than mature animals. These inconsistencies are eliminated if we consider the ratio of heat production per unit surface area and body weight. This relative comparison became interesting when we asked the question "Why are *small* Holstein calves apparently still less heat tolerant than Jerseys, following the same relationship as shown in large mature animals?" Though this leads one to believe that surface area is an important factor, there are perhaps more important invisible factors.

McDowell *et al.* (1953) has reported essentially the same surface area per unit body weight in Jersey and Jersey-Sindhi Crosses but definite differences in heat tolerance. Though not necessarily discounting any possible advantage of a greater surface area, this further emphasizes the need for other physiological measures and indices to explain the heat tolerance complex.

## SUMMARY

1. Changes in surface area during growth and with increasing body weight are described.

2. Differences in surface area of Jerseys and the other five breeds are highly significant. Some surface area comparisons of the various breeds are significant.

3. For prediction purposes surface area and body weight is expressed logarithmically. The parabola $Y = aX^b$ was fitted to the data. Exponent values for each breed at 50°F. and 80°F. respectively, were Holstein 44, 48; Brown Swiss 40, 39; Jersey 41, 43; Santa Gertrudis 66, 64; Brahman 60, 64; and Shorthorn 59, 55.

4. Temperature effects on total surface areas were not significant.

5. Information is presented on the relative percentage of appendage surface area to total surface area by comparison of data on ears, dewlap, legs and tail.

**APPENDIX TABLE I - BODY WEIGHT FOR INDIVIDUAL HOLSTEIN, BROWN SWISS AND JERSEY CALVES RAISED AT 50° AND 80° F ENVIRONMENTAL TEMPERATURES**

**Holstein**

| | 50°F Calf Number | | | | | 80°F Calf Number | | | |
|---|---|---|---|---|---|---|---|---|---|
| Age Days | 845 | 847 | 848 | Average | Age Days | 846 | 849 | 850 | Average |
| | (kg.) | | | | | (kg.) | | | |
| 51 | 72 | 61 | 61 | 65 | 33 | 60 | 53 | 53 | 55 |
| 94 | 118 | 101 | 98 | 105 | 61 | 79 | 66 | 69 | 71 |
| 129 | 164 | 134 | 140 | 146 | 89 | 103 | 87 | 93 | 94 |
| 160 | 197 | 173 | 174 | 181 | 124 | 138 | 116 | 124 | 126 |
| 197 | 238 | 213 | 207 | 219 | 155 | 169 | 143 | 154 | 155 |
| 229 | 265 | 243 | 237 | 248 | 192 | 215 | 179 | 190 | 195 |
| 267 | 295 | 284 | 271 | 283 | 224 | 244 | 209 | 221 | 225 |
| 295 | 308 | 304 | 292 | 301 | 262 | 267 | 244 | 256 | 256 |
| 326 | 332 | 336 | 330 | 333 | 290 | 279 | 260 | 276 | 272 |
| 360 | 350 | 360 | 357 | 356 | 321 | 292 | 283 | 300 | 292 |
| | | | | | 355 | 318 | 309 | 323 | 317 |

**Brown Siwss**

| | 50°F Calf Number | | | | | 80°F Calf Number | | | |
|---|---|---|---|---|---|---|---|---|---|
| Age Days | 17 | 18 | 23 | Average | Age Days | 19 | 20 | 21 | Average |
| | (kg.) | | | | | (kg.) | | | |
| 61 | 57 | 53 | 54 | 54 | 44 | 58 | 47 | 57 | 54 |
| 104 | 87 | 85 | 78 | 83 | 73 | 78 | 63 | 77 | 73 |
| 139 | 119 | 119 | 112 | 116 | 100 | 100 | 85 | 104 | 96 |
| 170 | 146 | 155 | 144 | 148 | 135 | 127 | 114 | 140 | 127 |
| 207 | 181 | 196 | 183 | 187 | 166 | 161 | 142 | 182 | 162 |
| 239 | 208 | 229 | 216 | 218 | 203 | 200 | 166 | 222 | 196 |
| 277 | 248 | 261 | 249 | 253 | 235 | 234 | 194 | 250 | 226 |
| 305 | 272 | 279 | 280 | 277 | 273 | 266 | 232 | 287 | 262 |
| 336 | 296 | 308 | 308 | 304 | 301 | 286 | 252 | 309 | 282 |
| 370 | 316 | 337 | 332 | 328 | 331 | 314 | 278 | 338 | 310 |
| | | | | | 367 | 337 | 305 | 366 | 336 |

**Jersey**

| | 50°F Calf Number | | | | | 80°F Calf Number | | | |
|---|---|---|---|---|---|---|---|---|---|
| Age Days | 633 | 635 | 636 | Average | Age Days | 631 | 635 | 637 | Average |
| | (kg.) | | | | | (kg.) | | | |
| 49 | 38 | 25 | 26 | 29 | 34 | 35 | 24 | 24 | 28 |
| 92 | 64 | 66 | 49 | 60 | 62 | 48 | 36 | 29 | 37 |
| 127 | 90 | 89 | 72 | 83 | 90 | 68 | 55 | 41 | 55 |
| 158 | 108 | 105 | 91 | 101 | 125 | 93 | 79 | 56 | 76 |
| 195 | 130 | 126 | 112 | 123 | 155 | 117 | 101 | 73 | 97 |
| 227 | 154 | 147 | 134 | 145 | 192 | 138 | 127 | 90 | 118 |
| 264 | 181 | 169 | 162 | 171 | 224 | 156 | 148 | 106 | 137 |
| 284 | 195 | 181 | 174 | 183 | 262 | 176 | 176 | 127 | 160 |
| 314 | 216 | 202 | 192 | 203 | 290 | 187 | 186 | 139 | 171 |
| 358 | 229 | 217 | 207 | 218 | 320 | 204 | 207 | 163 | 191 |
| | | | | | 355 | 224 | 223 | 180 | 209 |

APPENDIX TABLE II-SURFACE AREA (M²) OF INDIVIDUAL HOLSTEIN BROWN SWISS AND JERSEY CALVES RAISED AT 50° AND 80°F ENVIRONMENTAL TEMPERATURES

**Holstein**

| | 50°F Calf Number | | | | | 80°F Calf Number | | | |
|---|---|---|---|---|---|---|---|---|---|
| Age Days | 845 | 847 | 848 | Average | Age Days | 846 | 849 | 850 | Average |
| 51 | 1.75 | 1.65 | 1.54 | 1.65 | 33 | 1.39 | 1.54 | 1.41 | 1.45 |
| 94 | 2.08 | 1.98 | 2.18 | 2.08 | 61 | 1.61 | 1.61 | 1.53 | 1.58 |
| 129 | 2.25 | 2.14 | 2.15 | 2.18 | 89 | 2.03 | 1.92 | 1.89 | 1.95 |
| 160 | 2.80 | 2.70 | 2.64 | 2.71 | 124 | 2.12 | 2.03 | 2.07 | 2.08 |
| 197 | 2.93 | 2.80 | 2.72 | 2.82 | 155 | 2.33 | 2.21 | 2.29 | 2.28 |
| 229 | 3.04 | 2.88 | 2.84 | 2.89 | 192 | 2.71 | 2.46 | 2.64 | 2.61 |
| 267 | 3.26 | 3.07 | 2.83 | 3.05 | 224 | 2.84 | 2.71 | 2.77 | 2.77 |
| 295 | 3.48 | 3.50 | 3.35 | 3.44 | 262 | 3.13 | 2.95 | 3.06 | 3.05 |
| 326 | 3.13 | 2.97 | 3.15 | 3.08 | 290 | 3.47 | 3.35 | 3.29 | 3.37 |
| 360 | 3.03 | 4.00 | 4.00 | 3.68 | 321 | 3.87 | 3.00 | 3.00 | 3.29 |
| | | | | | 355 | 3.12 | 3.16 | 3.12 | 3.13 |

**Brown Swiss**

| | 50°F Calf Number | | | | | 80°F Calf Number | | | |
|---|---|---|---|---|---|---|---|---|---|
| Age Days | 17 | 18 | 23 | Average | Age Days | 19 | 20 | 21 | Average |
| 61 | 1.64 | 1.70 | 1.62 | 1.65 | 44 | 1.82 | 1.54 | 1.59 | 1.65 |
| 104 | 1.91 | 1.91 | 1.75 | 1.86 | 73 | 1.89 | 1.65 | 1.73 | 1.75 |
| 139 | 1.98 | 2.01 | 1.98 | 1.99 | 100 | 2.20 | 1.99 | 2.03 | 2.07 |
| 170 | 2.29 | 2.38 | 2.30 | 2.32 | 135 | 2.35 | 2.16 | 2.30 | 2.27 |
| 207 | 2.41 | 2.62 | 2.50 | 2.51 | 166 | 2.49 | 2.27 | 2.62 | 2.46 |
| 239 | 2.54 | 2.81 | 2.63 | 2.66 | 203 | 2.69 | 2.46 | 2.94 | 2.70 |
| 277 | 2.83 | 3.05 | 3.15 | 3.01 | 235 | 2.83 | 2.62 | 3.05 | 2.83 |
| 305 | 3.32 | 3.32 | 3.25 | 3.30 | 273 | 3.10 | 2.75 | 3.19 | 3.02 |
| 336 | 3.22 | 3.09 | 3.20 | 3.17 | 301 | 3.53 | 3.40 | 3.63 | 3.52 |
| 370 | 3.22 | 3.13 | 3.14 | 3.16 | 331 | 2.95 | 2.90 | 3.12 | 2.99 |
| | | | | | 367 | 3.09 | 3.19 | 3.29 | 3.19 |

**Jersey**

| | 50°F Calf Number | | | | | 80°F Calf Number | | | |
|---|---|---|---|---|---|---|---|---|---|
| Age Days | 633 | 635 | 636 | Average | Age Days | 631 | 634 | 637 | Average |
| 49 | 1.22 | 1.05 | 1.15 | 1.14 | 34 | 1.17 | .94 | 1.07 | 1.06 |
| 92 | 1.43 | 1.60 | 1.60 | 1.54 | 62 | 1.31 | 1.09 | 1.09 | 1.16 |
| 127 | 1.89 | 1.86 | 1.65 | 1.80 | 90 | 1.60 | 1.50 | 1.31 | 1.47 |
| 158 | 1.95 | 1.90 | 1.84 | 1.89 | 125 | 1.74 | 1.71 | 1.43 | 1.63 |
| 195 | 2.25 | 2.06 | 2.03 | 2.12 | 155 | 1.96 | 1.90 | 1.55 | 1.80 |
| 227 | 2.43 | 2.21 | 2.10 | 2.24 | 192 | 2.16 | 2.09 | 1.86 | 2.04 |
| 264 | 2.61 | 2.38 | 2.30 | 2.43 | 224 | 2.34 | 2.21 | 1.96 | 2.17 |
| 284 | 3.14 | 2.60 | 2.83 | 2.86 | 262 | 2.52 | 2.37 | 2.17 | 2.35 |
| 314 | 2.41 | 2.33 | 2.54 | 2.43 | 290 | 2.89 | 2.02 | 2.38 | 2.76 |
| 358 | 3.42 | 2.41 | 2.39 | 2.74 | 320 | 2.56 | 2.51 | 2.42 | 2.50 |
| | | | | | 355 | 2.73 | 2.54 | 2.38 | 2.55 |

APPENDIX TABLE III-BODY WEIGHT (KG) OF BRAHMAN, SANTA GERTRUDIS AND SHORTHORN CALVES RAISED AT ENVIRONMENTAL TEMPERATURES OF 50° AND 80°F

| Age | 50°F | | | 80°F | | |
|---|---|---|---|---|---|---|
| Months | Brahman | Santa Gertrudis | Shorthorn | Brahman | Santa Gertrudis | Shorthorn |
| 1- 2 | --- | 62 | --- | --- | 63 | --- |
| 2- 3 | 76 | 79 | --- | 76 | 77 | --- |
| 3- 4 | 100 | 108 | 79 | 103 | 107 | 67 |
| 4- 5 | 127 | 143 | 107 | 132 | 141 | 79 |
| 5- 6 | 156 | 175 | 141 | 166 | 166 | 94 |
| 6- 7 | 181 | 204 | 172 | 199 | 194 | 113 |
| 7- 8 | 206 | 231 | 199 | 227 | 220 | 133 |
| 8- 9 | 230 | 266 | 225 | 245 | 244 | 154 |
| 9-10 | 249 | 288 | 249 | 261 | 264 | 172 |
| 10-11 | 262 | 308 | 270 | 281 | 281 | 188 |
| 11-12 | 277 | 331 | 288 | 293 | 301 | 202 |
| 12-13 | 293 | 354 | 306 | 309 | 322 | 218 |
| 13-14 | 308 | 375 | 324 | 330 | 341 | 236 |
| 14-15 | 323 | 396 | 342 | 340 | 358 | 254 |
| 15-16 | --- | --- | 358 | --- | --- | 254 |

APPENDIX TABLE IV-SURFACE AREA ($M^2$) OF BRAHMAN, SANTA GERTRUDIS AND SHORTHORN CALVES RAISED AT CONSTANT ENVIRONMENTAL TEMPERATURES OF 50° AND 80° F

| Age | 50°F | | | 80°F | | |
|---|---|---|---|---|---|---|
| Months | Brahman | Santa Gertrudis | Shorthorn | Brahman | Santa Gertrudis | Shorthorn |
| 1- 2 | --- | --- | --- | --- | --- | --- |
| 2- 3 | 1.79 | 1.73 | --- | 1.73 | 1.73 | --- |
| 3- 4 | 1.99 | 1.95 | 1.65 | 2.00 | 1.90 | 1.54 |
| 4- 5 | 2.23 | 2.15 | 1.86 | 2.24 | 1.95 | 1.69 |
| 5- 6 | 2.38 | 2.24 | 2.04 | 2.41 | 2.23 | 1.80 |
| 6- 7 | 2.58 | 2.32 | 2.21 | 2.63 | 2.27 | 1.91 |
| 7- 8 | 2.78 | 2.78 | 2.40 | 2.84 | 2.56 | 2.05 |
| 8- 9 | 2.95 | 3.28 | 2.63 | 3.03 | 2.90 | 2.14 |
| 9-10 | 3.17 | 3.59 | 2.77 | 3.25 | 3.25 | 2.23 |
| 10-11 | 3.28 | 3.78 | 2.93 | 3.56 | 3.43 | 2.34 |
| 11-12 | 3.64 | 3.93 | 3.15 | 3.85 | 3.70 | 2.47 |
| 12-13 | 3.92 | 4.40 | 3.35 | 4.12 | 3.80 | 2.70 |
| 13-14 | 4.19 | 4.58 | 3.63 | 4.38 | 4.18 | 3.15 |
| 14-15 | 4.38 | 4.63 | 3.75 | 4.70 | 4.38 | 3.33 |
| 15-16 | --- | --- | 4.14 | --- | --- | 3.63 |

APPENDIX TABLE V-PERCENT OF TOTAL SURFACE AREA IN APPENDAGES (LEGS AND TAIL) OF THE HOLSTEIN, BROWN SWISS AND JERSEY CALVES RAISED AT 50° AND 80° F ENVIRONMENTAL TEMPERATURES

| 50°F | | | | | | |
|---|---|---|---|---|---|---|
| | Holstein | | Brown Swiss | | Jersey | |
| Date Measured | Breed Age | Average % | Breed Age | Average % | Breed Age | Average % |
| 12-8-56 | 94 | 32.17 | 104 | 35.45 | 92 | 37.25 |
| 1-12-57 | 129 | 32.83 | 139 | 34.77 | 127 | 35.00 |
| 2-12-57 | 160 | 28.26 | 170 | 32.02 | 158 | 33.79 |
| 3-21-57 | 197 | 28.53 | 207 | 30.63 | 195 | 32.21 |
| 4-22-57 | 229 | 28.34 | 239 | 30.70 | 227 | 31.13 |
| 5-30-57 | 267 | 27.33 | 277 | 28.97 | 264 | 29.77 |
| 6-27-57 | 295 | 24.88 | 305 | 27.21 | 284 | 26.09 |
| 7-28-57 | 326 | 23.67 | 336 | 24.45 | 314 | 23.82 |
| 8-31-57 | 360 | 23.34 | 370 | 24.60 | 358 | 22.33 |

| 80°F | | | | | | |
|---|---|---|---|---|---|---|
| | Holstein | | Brown Swiss | | Jersey | |
| Date Measured | Breed Age | Average % | Breed Age | Average % | Breed Age | Average % |
| 11-10-56 | 61 | 38.88 | 73 | 37.77 | 62 | 41.81 |
| 12-8-56 | 89 | 37.86 | 100 | 37.17 | 90 | 35.89 |
| 1-12-57 | 124 | 37.75 | 135 | 35.72 | 125 | 36.09 |
| 2-12-57 | 155 | 36.17 | 166 | 33.45 | 155 | 35.22 |
| 3-21-57 | 192 | 32.16 | 203 | 31.89 | 192 | 31.87 |
| 4-22-57 | 224 | 30.98 | 235 | 31.30 | 224 | 31.02 |
| 5-30-57 | 262 | 28.55 | 273 | 29.80 | 262 | 30.46 |
| 6-27-57 | 290 | 27.06 | 301 | 25.31 | 290 | 27.18 |
| 7-27-57 | 321 | 25.42 | 331 | 22.84 | 320 | 22.73 |
| 8-31-57 | 355 | 25.86 | 367 | 25.18 | 355 | 23.90 |

APPENDIX TABLE VI-SURFACE AREA OF EARS OF HOLSTEIN, BROWN SWISS AND JERSEY CALVES RAISED AT 50° AND 80°F ENVIRONMENTAL TEMPERATURE (AVERAGE OF THREE FOR EACH BREED)

| Holstein | | | | |
|---|---|---|---|---|
| | 50°F | | 80°F | |
| Date | Average Age | Area cm.$^2$ | Average Age | Area cm.$^2$ |
| 10-19-56 | 42.6 | 72.9 | 38.6 | 69.1 |
| 11-27-56 | 81.6 | 92.4 | 77.6 | 90.6 |
| 1-14-57 | 129.6 | 101.3 | 125.6 | 99.1 |
| 2-21-57 | 167.6 | 125.7 | 163.6 | 122.3 |
| 4-10-57 | 215.6 | 138.9 | 211.6 | 141.4 |
| 7-15-57 | 310.6 | 149.2 | 307.6 | 159.9 |
| 9-5-57 | 363.77 | 155.8 | 359.6 | ----- |
| 3-13-58 | 547.6 | 183.3 | 543.6 | 199.4 |

Brown Swiss

| | 50°F | | 80°F | |
|---|---|---|---|---|
| Date | Average Age | Area cm.$^2$ | Average Age | Area cm.$^2$ |
| 10-19-56 | 52.6 | 80.4 | 49.3 | 74.9 |
| 11-27-56 | 91.6 | 96.8 | 88.3 | 108.1 |
| 1-14-57 | 139.6 | 110.8 | 136.3 | 112.8 |
| 2-21-57 | 177.6 | 140.8 | 174.3 | 143.2 |
| 4-10-57 | 225.6 | 136.3 | 222.3 | 162.7 |
| 7-15-57 | 321.6 | 157.0 | 318.3 | 165.7 |
| 9-5-57 | 373.6 | 188.8 | 370.3 | 179.8 |
| 3-13-58 | 557.6 | 192.5 | 554.3 | 205.0 |

Jersey

| | 50°F | | 80°F | |
|---|---|---|---|---|
| Date | Average Age | Area cm.$^2$ | Average Age | Area cm.$^2$ |
| 10-19-56 | 38.3 | 48.4 | 32.3 | 46.1 |
| 11-27-56 | 77.3 | 69.8 | 80.3 | 65.3 |
| 1-14-57 | 125.3 | 77.0 | 128.3 | 68.2 |
| 2-21-57 | 163.3 | 98.4 | 166.3 | 90.4 |
| 4-10-57 | 211.3 | 108.2 | 214.3 | 95.1 |
| 7-15-57 | 307.3 | 112.8 | 310.0 | 102.7 |
| 9-5-57 | 359.3 | 116.1 | 362.6 | 108.4 |
| 3-13-58 | 543.3 | 140.5 | 546.6 | 129.2 |

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[1]These authors were responsible for surface area measurements.

*Appendages included only area of legs and tail.