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Environmental Physiology and Shelter Engineering

With Special Reference to Domestic Animals

LIX. The Effects of Constant Environmental Temperatures 50° or 80°F. on the Feed and Water Consumption of Holstein, Brown Swiss and Jersey Calves

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SUMMARY

Data are presented on the effects of 50° and 80°F. environmental temperatures on the feed (TDN) and water consumption of Brown Swiss, Holstein and Jersey calves during growth. The results obtained indicate that:

1. TDN consumption was greater at 50°F. than at 80°F. for all breeds, with the exception of the Brown Swiss.
2. At both 50° and 80°F. the TDN consumption per unit body weight gain increased with age for all three breeds. The differences between 50° and 80°F. are not noticeable due to lower feed intake and lower rate of gain at 80°F. and relatively higher feed intake and rate of gain at 50°F.
3. The equation or curve of diminishing increments was applied to the feed consumption and body weight data.
4. Using maintenance equation $f = aw^{2/3}$ (1 ≁ kg.) a greater estimated TDN requirement is necessary for maintenance at 50°F. than at 80°F for all three breeds.
5. Water consumption for all three breeds raised at 50° and 80°F. generally increased with age. A greater increase was observed during the day than at night in both frequency of drinking and water consumption for all breeds.
6. During growth, the gallons of water per pound of feed increased markedly in the 80°F. animals from 6-11 months, but during the same period the increase was negligible for the 50°F. animals.
7. The gallons of water per pound gain increased in both 50° and 80°F. groups from 1-10 months. The 50°F. animals increased total water consumption per pound gain from approximately 1 to 4 gallons per pound gain while the 80°F. animals increased from approximately 1.5 to 6 gallons per pound weight gain.

ACKNOWLEDGMENTS

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The Effects of Constant Environmental Temperatures 50° or 80° F. on the Feed and Water Consumption of Holstein, Brown Swiss and Jersey Calves During Growth

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With Assistance of Joan F. Jones

ORIENTATION

This report is a continuation of a series of research bulletins (Environmental Physiology Series LII, LIII, LIV, and LV) concerning the influence of 50° and 80°F. environmental temperature on growth and related physiological responses of Holstein, Brown Swiss, and Jersey dairy calves.

The general objective of the entire project, was the determination of the effects of environmental temperature on growth. The related responses considered were: water consumption, thyroid activity, heat production, vaporization, surface temperature and other physical and physiological characteristics that are associated with an animal's ability to adapt to certain environmental conditions, especially high temperatures.

INTRODUCTION

Several investigators have found that high environmental temperatures are conducive to relatively slow growth in cattle (Bonsma, 1947; Ragsdale *et al.*, 1957; and to comparatively low feed consumption and modified water intake (Johnson *et al.*, 1958; Ragsdale *et al.*, 1949, 1950, 1951).

Growth as well as milk production is an end product of countless intermediate and associated physiological reactions, each of which is influenced by environmental and shelter conditions. An understanding of the effects of environmental and shelter conditions on the proponent factors in the growth or milk producing complex is likely to lead to rational adjustment of shelter to conditions for highest productivity.

The effects of environmental temperature on the feed and water consumption of dairy calves of various breeds is of vital interest for many reasons. Foremost, perhaps, are the reasons stated by Bonsma (1949). Bonsma noted that an animal receiving sufficient feed may, nevertheless, be undernourished if the climatic conditions do not permit the effective intake and conversion of feed. An animal well adapted to the environment can effectively utilize the available forage and grow normally.

It is evident that an animal which has the ability to utilize feed efficiently during growth at cool temperature possesses a characteristic that is particularly desirable at higher environmental temperatures.

Additional insight into the mechanisms inherent in the maintenance of homeothermy and/or efficiency may be obtained by consideration of water consumption data. The actual quantity required by various breeds of cattle of different ages, of different nutritional backgrounds, and at varying environmental temperature conditions is of great importance to dairymen and engineers as well as to physiologists. With the exception of a few reports by Ragsdale et al., (1950, 1951, and 1953), Winchester and Morris, (1956), Johnson et al., (1958) and previous data by Sykes (1955), and Leitch and Thompson (1944), there is very little record of effects of environmental conditions on water consumption of cattle. The breed's comparative gains in growth under similar conditions may be an index of the effectiveness with which water serves its purpose as a cooling agent.

It is of particular importance to evaluate the ability of three of the principal U.S. dairy breeds to withstand heat and to utilize feed while they are being subjected to a high environmental temperature (80°F.) for a long period of time. The specific goal of this report is the quantitative analysis of feed and water consumption data of Holstein, Brown Swiss, and Jersey calves raised at a constant environmental temperature of either 50° or 80°F. from approximately one to twelve months of age. This time period comprises the formative ages for calves, during which one may expect particular responses and/or degrees of acclimation to occur as a result of continued exposure to high environmental temperature stresses. Although it cannot be classified as an intense stressor, an environmental temperature of 80°F. will elicit certain homeothermic adjustments in most European breeds.

In brief, this study is an attempt to provide information on several questions such as: (a) what are the comparative effects of 50° and 80°F. environmental temperature on the ability of a breed to utilize feed for growth? (b) what are the temperature effects on feed consumption when expressed per unit weight or per unit weight gain during growth? (c) will the proportions of feed expended for maintenance and growth differ in accordance with the general responses with age and with the heat tolerance of the animal? An approach to the answer of this latter question will be attempted by means of prediction equations.

EXPERIMENTAL CONDITIONS

The experiment was conducted in the climatic laboratory which consists of two independently controlled chambers, each arranged to contain three calves of each breed-a total of nine calves in each chamber. A constant temperature of 50°F. was maintained in Chamber I, and the constant temperature of Chamber II was 80°F. The respective relative humidities associated with the temperatures of 50°F. and 80°F. were 62 and 54%. The illumination in each chamber was from one 40-watt incandescent lamp, on continuously, and six 200-watt incandescent lamps, on from 6 a.m. to 6 p.m. The air velocity within the pens was approximately 50 feet per minute.

Hay and water was available *ad libitum* and the consumption was recorded. Calf and heifer concentrate was fed as described by Johnson and Ragsdale (1959).

DATA AND DISCUSSION

Presentation of Feed and Water Data:

Feed and water consumption data are presented graphically (Figures 1 to 11) and tabularly (Appendix Tables 2-8). The relationships between these data and weight and surface area measurements are also presented in order to integrate data on these interdependent variables. The interrelated phenomena of growth, other reactions to environmental temperature, and breed differences will be discussed simultaneously.

Water Consumption Vs. Age:

Figure 1 is an arithmetic plot of TDN and water consumption vs. calendar dates and approximate ages. Dehorning, modification of grain ration, milk withdrawal, and vaccinations for blackleg and brucellosis are indicated by arrows on the plot.

At 50°F., water consumption of all breeds increased with age. Generally, the Holsteins consumed the greatest quantity; the Brown Swiss consumed an intermediate amount, and the Jerseys, the least. At 80°F., water consumption increased similarly with age, although the consumption level was higher at 80°F., as contrasted to 50°F. The breed differences in water consumption at 80°F. became much greater, especially after the calves reached approximately three months of age. The similarity of the 50°F. Jersey volume to those of the other two breeds at 50°F. may have been due partially to the presence of an unusual individual (J-633) (Johnson *et al.*, 1960) which, like J-212 (reported previously by Ragsdale *et al.*, 1950) displayed an abnormally high level of water consumption, (Johnson *et al.*, unpublished).

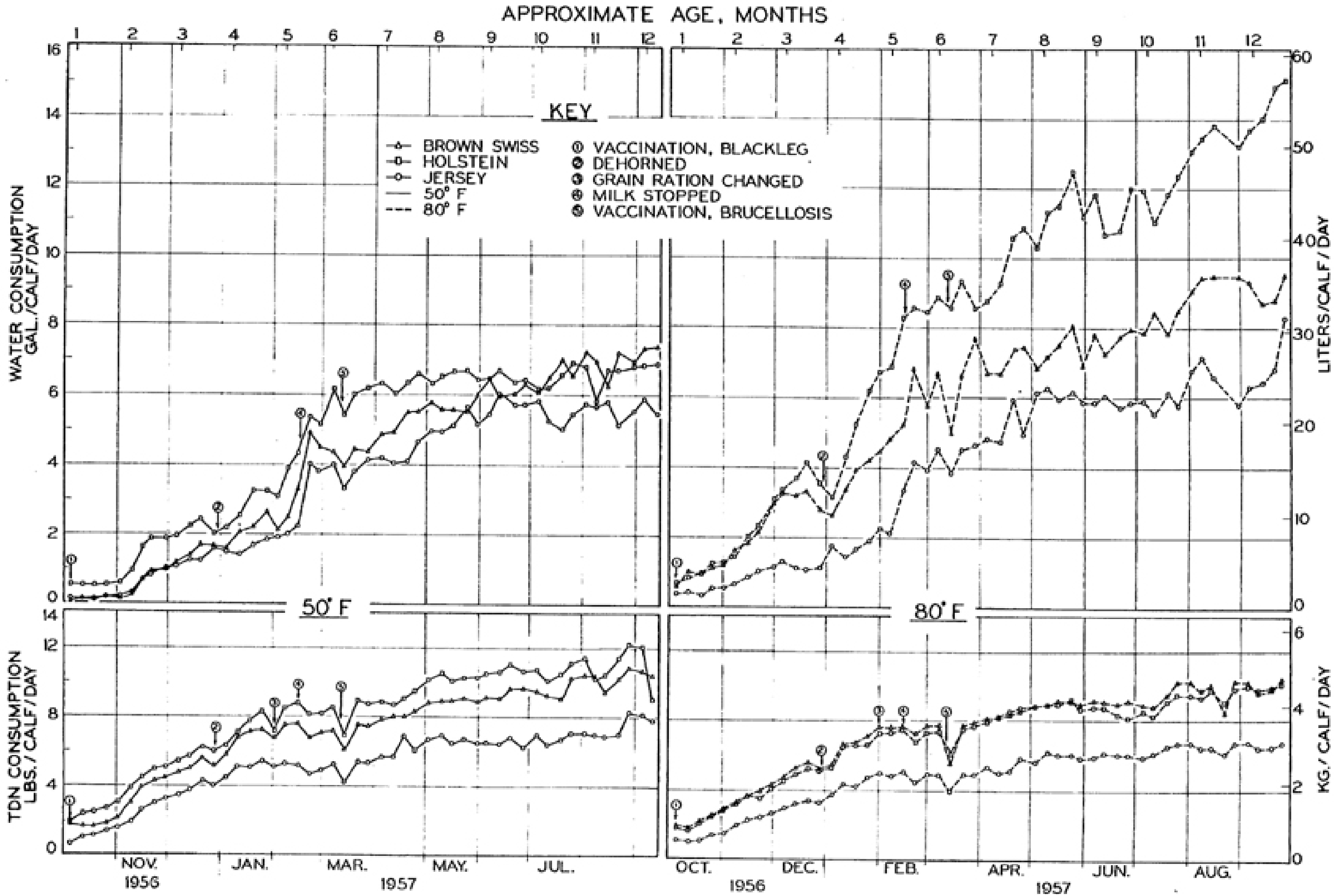

Figure 1. Water and TDN consumption of Holstein, Brown Swiss, and Jersey Calves at 50°F and 80°F. Each datum-point represents the average consumption per calf per day for one week.

TDN Consumption Vs. Age:

The lower section of Figure 1 indicates the increasing TDN consumption at both temperatures. At 50°F., the average TDN consumption (including milk values) expressed as pounds per calf per day throughout the growth period was: Holstein, 8.2; Brown Swiss, 6.9; and Jerseys, 6.4. At 80°F., the respective values for Holsteins, Brown Swiss and Jerseys were 7.1, 7.3, and 4.8. During the first four months, TDN consumption nearly tripled. It tended to level off between 5 and 6 months of age. There are obvious temperature differences in TDN consumption for the Holsteins and Jerseys, i.e., lower values at 80°F. as compared to 50°F. As shown in other physiological and physical measurements, the Brown Swiss were not adversely affected by the mild heat exposures, even though they displayed evidence of numberous compensations or adjustments to the higher temperature.

Body Weight Vs. Age:

The effects of 50° and 80°F. constant environmental temperatures upon growth of these calves have been described by Johnson and Ragsdale (1959). Since there is an intrinsic relationship between TDN and water consumption and body weight, a semi-log plot of body weight versus age, should be consulted to facilitate a discussion of this relationship. The Holsteins, in particular, and also the Jerseys, made greater gains at 50° than at 80°F. throughout the study. The 80°F. Brown Swiss, however, gained more than the 50°F. Brown Swiss during the 12 month period. At the conclusion of the experiment, the 50°F. Holsteins were approximately 76 pounds heavier than the 80°F. Holsteins, and the 50°F. Jerseys were about 20 pounds heavier than the corresponding 80°F. animals. The 80°F. Brown Swiss were 18 pounds heavier than the 50°F. group. The weight differences occurring throughout growth were significantly different (Johnson and Ragsdale, 1959).

Environmental Temperature Effects on TDN and Water Consumption:

Figure 2 is a semi-logarithmic plot which depicts the effects of a constant environmental temperature of 50° or 80°F. on the TDN and free water* consumption. Each breed consumed much more water at 80°F. than at 50°F. The water consumption of the Holsteins was affected by the higher temperature to a greater extent than that of the other breeds. The Brown Swiss were affected to a lesser degree than either of the other two breeds. The average free water consumption of

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*Note: Free water or merely water consumption is defined by water consumed from the drinking cups.

Milk water is "water estimated to be in the milk consumed by the calves." Values of 87%, 88.9%, 90.7% water were used for whole milk, half-whole and half-skim, and skim milk, respectively.

Total water refers to the addition of free water and milk water values.

the 50° and 80°F. Holsteins throughout the experiment was 17.6 liters (4.6 gal.) and 31 liters (8.2 gal.) per day respectively; that of the 50° and 80°F. Brown Swiss was 14.4 liters (3.8 gal.) 21 liters (5.5 gal.) per day, respectively; and the consumption of the 50° and 80°F. Jerseys was 13.7 liters (3.6 gal.) and 15 liters (4 gal.) per day. The corresponding values of total water (free water and the water content of the controlled amount of milk fed to the calves for the first 5-6 months) were 19.7 liters (5.2 gal.) and 33.1 liters (8.7 gal.); 16.6 liters (4.4 gal.) and 23.2 liters (6.1 gal.); 15.4 liters (4.1 gal.) and 16.8 liters (4.4 gal.) per day. The percentage difference in 50° and 80°F. Holsteins became noticeable greater after about 6 months of age. It is somewhat surprising that the water consumption of the 80°F. Jerseys paralleled that of the 50°F. Jerseys so closely. The similarity is probably due to the presence of the J-633. (Johnson et al., unpublished).

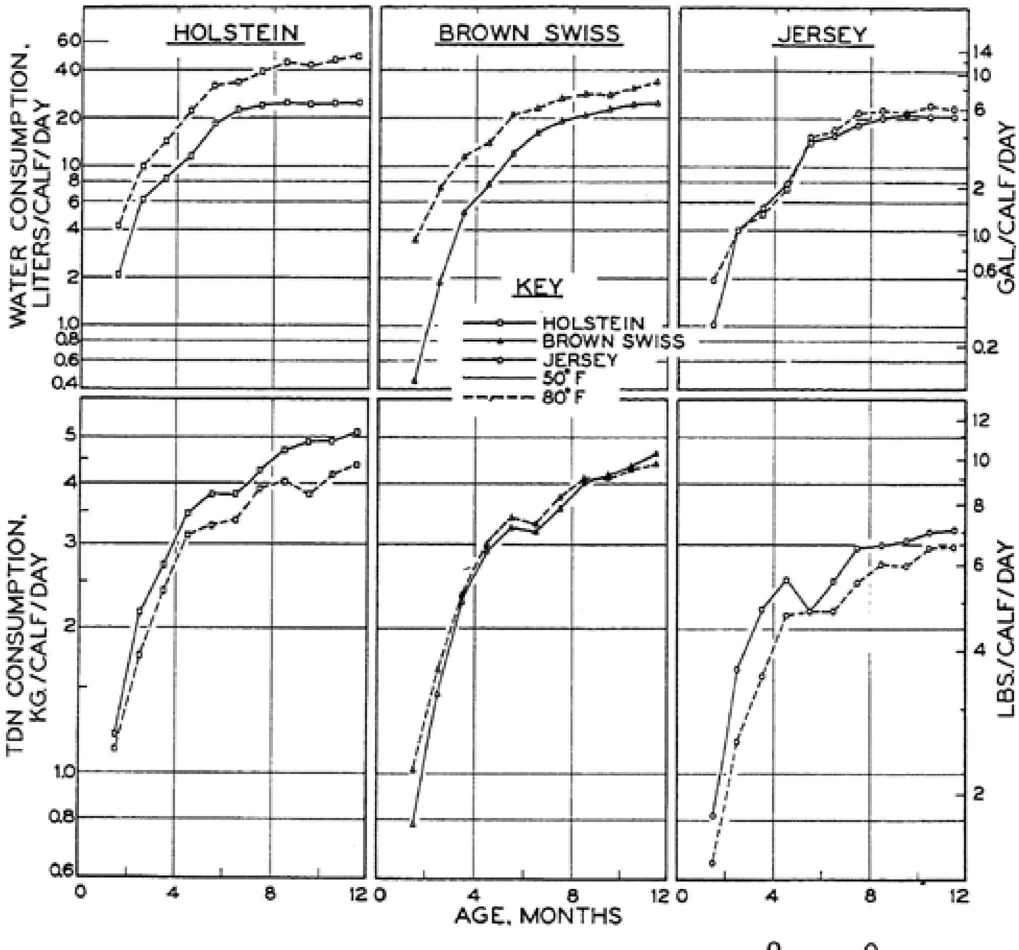

Figure 2. The effects of environmental temperature (50° or 80°F.) on TDN and free water consumption of Holstein, Brown Swiss, and Jersey calves from 1 to 12 months of age.

The TDN consumption was lower for the 80°F. Holsteins and Jerseys than for the corresponding 50°F. animals. The 50°F. Brown Swiss, in contrast consumed less than the 80°F. Brown Swiss. The 80°-50°F. differences in TDN consumption (pounds per day) throughout the experiment were approximately 1.1 for the Holsteins, 1.6 for the Jerseys, and .39 for the Brown Swiss, the 80°F. Brown Swiss consuming the greater quantity. After about 5 months of age the 50°-80°F. differences in the Holsteins' feed consumption became noticeably greater. It is of interest to observe that the 50°F. Holsteins consumed 1.3 lbs. of TDN more per day than the 50°F. Brown Swiss, but the 80°F. Brown Swiss exceeded the 80°F. Holstein in TDN consumption by approximately 0.25 lbs. day.

<u>Ratio of Water Consumption to TDN Consumption</u>:

Figure 3 is an arithmetic plot of the ratio of water consumption to TDN consumption. Although the ratios employing free water measurements increased markedly with age at 50°F., those using total water consumption remained fairly constant or increased slightly - the greatest increases occurring between 4 and 6 months of age. The Jerseys had the highest ratios and were followed by the Holsteins and the Brown Swiss. (At 80°F., however, the ratios of the Holsteins showed a definite tendency to increase with age. The greatest increase in the 80°F. Jersey ratio occurred at about 5 months of age and started to level off at about 7 months of age. The 80°F. Brown Swiss total ratios remained markedly constant after 5 months of age).

Figure 3 clearly indicates the fact that the Holsteins at 80°F. required far more water, presumably for cooling purposes, in proportion to their TDN consumption than did the other two breeds. Although the ratios of each of the other breeds were greater at 80°F. than at 50°F., the most impressive difference in ratios was that of the Holsteins. The Brown Swiss' and Jerseys' differences were of about the same magnitude between the two temperature groups.

Appendix table 2 shows the gallons of total water per pounds of TDN consumed. At the age of 1-2 months the values for the Brown Swiss, Holstein, and Jerseys at 50° and 80°F. respectively were .07, .21, .15, .41, .45, .35. At 10-11 months, the same values for the Brown Swiss, Holsteins, and Jerseys at 50° and 80°F. were .69, .61, .79, .87, 1.35, .98.

Daily total water intake (gallons) per pound TDN consumption of the Holsteins and Brown Swiss at 50°F. decreased slightly from approximately 1 to 5 months of age; thereafter it reached a peak at about 7 months of age and then declined to its initial level. At the first level, the Brown Swiss consumed about 9.7 gallons and the Holsteins about 0.65 gallons water/pound of TDN. The Jerseys' water intake rose from approximately 0.65 gallons at 1.5 months to 9.78 gallons at 11.5 months

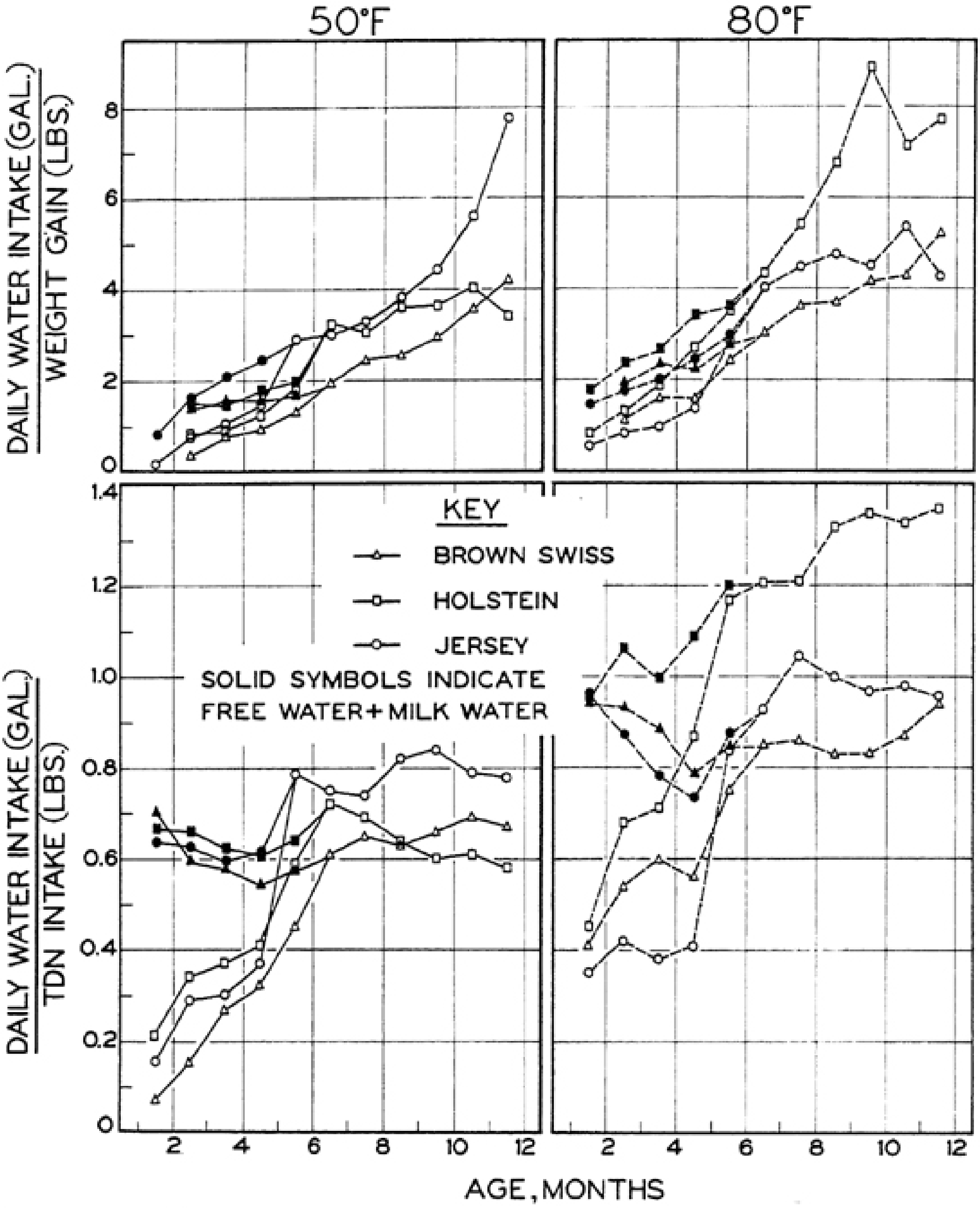

Figure 3. Relationship of water consumption to TDN consumption and daily weight gain.

at 50°F. At 80° F., on the other hand, after an initial decline up to 3 to 4 months of age, the water intake per unit TDN increased until the calves were 7.5 months old, after which the Holsteins' values increased and the Jerseys' and Brown Swiss' approached the 1.5 month level. The ratio of water to TDN consumption was higher at 80°F. than at 50°F. for all breeds. The 80°F. Holsteins displayed the highest ratio, they were followed by the Jerseys and Brown Swiss. At their highest level, the 11.5 month-old Holsteins consumed about 1.4 gallons of water per pound of TDN. The Jerseys at 7 months of age exhibited a ratio of 1.03 and the Brown Swiss ratio was .95 at 12 months.

Appendix table 2 and Figure 3 also show that gallons of total water consumed for every pound gain in body weight increased with age at both temperature levels. At 50°F., the Jersey showed the greatest rise; from approximately 3/4 gallon at 1.5 months to 7.5 at 11.5 months. The Holsteins rose from about 1.5 gallons to their highest consumption of 4 gallons per pound gain at 10.5 months of age. The Brown Swiss increased their consumption from about 1.5 gallons at 1.5 months to 4.25 gallons at 11.5 months. At 80°F., the Holsteins showed the greatest increase with age, i.e., from 1.75 gallons/pound gain at 1.5 months of age to 7.75 at 11.5 months. At 1.5 and 11.5 months, respectively, the Brown Swiss rose from 1.9 to 5.25 gallons per pound weight gain, and Jerseys increased their consumption from 1.5 to 4.25 gallons.

Water and TDN Consumption Per Unit of Body Weight:

There is a close similarity in the water consumption per unit weight vs. age and the TDN consumption per unit weight vs. age. Since the metabolic rate per unit weight decreases with increments in body weight, (Kibler, 1960) a decline in water and TDN consumption per unit body weight may be expected to occur with increasing age. Until approximately 3 1/2 months of age the ratios of free water consumption to unit body weight increased. Thereafter, the ratios of each breed declined with advancing age. At 50°F. the free water consumption per unit body weight was greatest for the Jerseys*, which were followed by the Brown Swiss and the Holsteins, while at 80°F., the high to low order was Holsteins, Jerseys, and Brown Swiss. The ratios of the 80°F. animals were higher than those of the corresponding 50°F. animals. A low ratio of water consumption per unit weight may, at high temperatures, be an index of heat tolerance. (See Figure 4).

At 50°F., TDN consumption per unit body weight increased for the first 2-3 months and thereafter declined sharply. At 80°F., the initially increasing ratio continued until 4 months of age prior to the 8 month period of decline. The fact that the 80°F. animals, regardless of breed, consumed smaller quantities of TDN per unit weight than the 50°F. animals is evidenced by the lesser magnitudes of the 80°F. ratios. It should be noted that the 80°F. Brown Swiss, while consuming less per unit weight than the 50°F. Brown Swiss, nevertheless, showed equal productivity in terms of growth.

It is also apparent that, at 80°F., the Holsteins had the lowest and the Jerseys the highest TDN consumption per unit weight, whereas

*Note: J-633, one of the 3 Jerseys raised at 50°F. displayed an unusually high level of water consumption that undoubtedly influenced these 50°F. values.

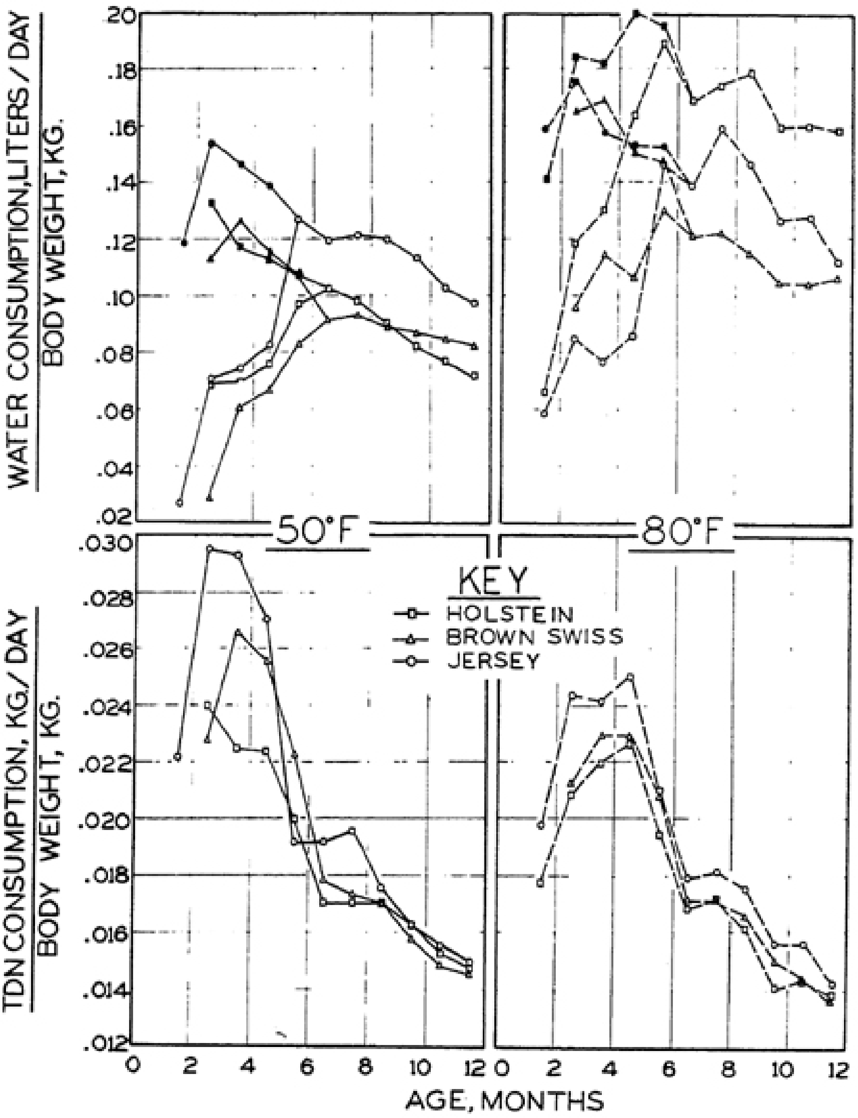

Figure 4. Ratio of TDN and Water Consumption to Body Weight. Solid Symbols represent free water plus milk water. The 80°F. Holsteins generally displayed the lowest ratio of TDN per unit weight the Jerseys, the highest. The water consumption per unit weight, on the other hand, was highest for the Holsteins, intermediate for the Jerseys, and lowest for the 80°F. Brown Swiss. At 50°F., note the relatively greater water values of the relatively smaller Jersey animals and observe how an unfavorable environment (80°F.) alters the breed equivalence of this expression.

the water consumption per unit weight was highest for the Holsteins and somewhat lower for the Jerseys. One may observe the relatively greater water consumption per unit weight of the 80°F. Holsteins and lower TDN consumption per unit weight.

Relationship of Water and TDN Consumption to Daily Weight Gain:

Water and TDN consumption per unit body weight gain are presented in Figure 5. Water consumption per unit body weight gain increased markedly with age regardless of temperature. At 50°F., the ratios of Jerseys, Holsteins, and Brown Swiss were high to low, respectively. At 80°F., the high to low ratios were Holsteins', Jerseys', and Brown Swiss', respectively. This is an apparent order of increasing "heat tolerance".* At 80°F. water consumption per gain is highest for Holstein and lowest for the apparently more heat tolerant Brown Swiss.

TDN consumption per unit body weight gain also increased with age, to a greater extent for the 50°F. animals than for the 80°F. animals. The order of magnitude of the ratios at 50°F. was Jersey, Holstein, and Brown Swiss; at 80°F., the Holsteins consumed the most feed per unit body weight gain. They were followed by the Jerseys and Brown Swiss in that order. 50°-80°F. differences in TDN per unit of gain were not

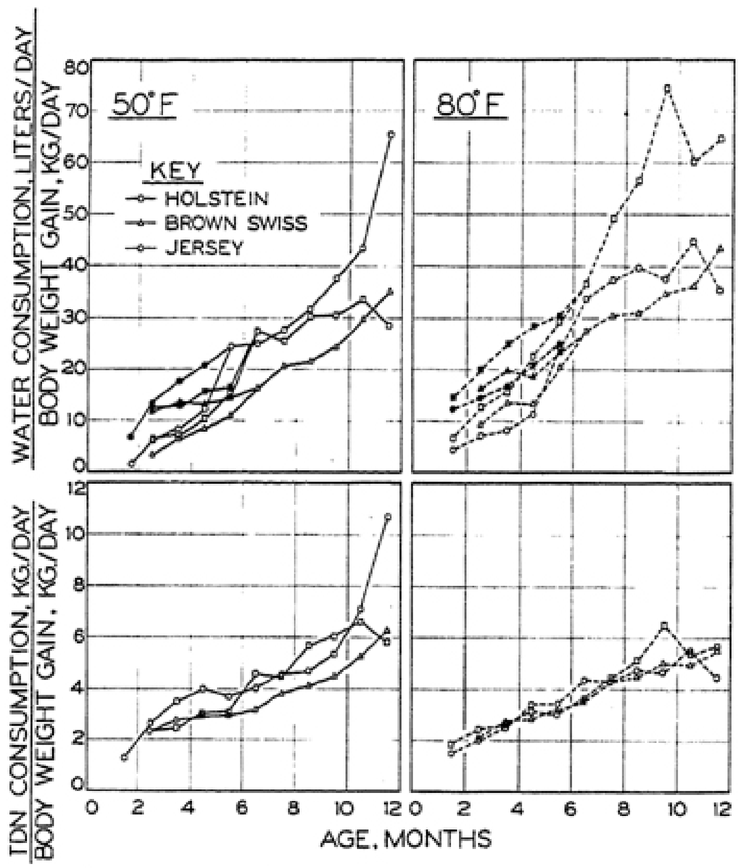

Figure 5. Ratio of Water to Body Weight Gain and TDN Consumption to Body Weight Gain at Various Ages. At 80°F. water consumption per weight gain is highest for Holstein and lowest for the apparently more heat tolerant Brown Swiss. 50° - 80°F. TDN per gain ratios are not noticeable different because of lower feed and lower gain at 80°F. and higher feed and higher gain at 50°F.

* Heat Tolerance, a term which has many meanings is in this case specifically used to describe the ability to grow at higher environmental temperatures.

noticeably present because of the relatively lower feed intake and lower body weight gain at 80°F. and the relatively higher feed and higher gain at 50°F. Probably the chief influence on the 80°F. ratios was the comparatively lower TDN consumption. The data indicate that as much or more TDN was required to maintain animals at 50° as at 80°F. A following section will discuss this topic somewhat further.

Logarithmic Relationship of Water Consumption to Body Weight:

Total water consumption increased with more than one constant power of body weight and displayed a break at the weight of approximately 400, 350, 225 pounds, respectively, for the 50°F. and 80°F. Holstein, Brown Swiss, and Jersey animals. The equation of the regression line fitted to the data was of the parabolic type ($Y=aX^b$). The equation indicates that an increase of 1% in X (body weight, kg.) is associated with an increase of b percent in Y (water consumption, Liters per day). The rate of increase of water consumption was higher before the break. For example, b values for Holsteins were .73; for the Brown Swiss, .91 and for the Jerseys, 1.17. Following the break, values were: Holsteins, .18; Brown Swiss, .8; and Jerseys .64. The rates of increase for the 80°F. Holsteins, both before the break (1.32) and after the break (.80) were greater than those of the 50°F. Holsteins, and indicate the greater effect of heat on the Holsteins. The Brown Swiss, in a manner predictable for other data, exhibited similar but lower exponents at 80°F. (.82, .66) as compared to the 50°F. values of, .91 and .80. Paradoxically, the Jerseys rates of increase in water consumption with increase in body weight were lower at 80°F. (.93, .52) than at 50°F. (1.17, .64), although these animals required a longer growth period at 80°F. to make a given weight attained at 50°F. (Johnson and Ragsdale, 1959).

Logarithmic Relationship of TDN Consumption to Body Weight:

These data were also plotted on a logarithmic scale and expressed by the equation used for the water consumption data, namely $Y = aX^b$, which states that an increase of 1% in X occurred with an increase of b percent in Y. Breaks in the regression lines occurred at both 50° and 80°F., when the Holsteins reached approximately 400 pounds; the Brown Swiss, 300 pounds; and the Jerseys approximately 200 pounds. At 50°F., the b values for the Holsteins were .79 and .65; for the Brown Swiss, .97 and .63; and for the Jerseys, 1.22 and .58. These regression coefficients indicate that the 50°F. Holsteins, in comparison to the other breeds at the same temperature, were increasing their feed consumption at a lower percentage rate per unit increase in body weight during the period of growth to 400 pounds. It may be inferred that at 50°F., the Holsteins were growing most economically. At 80°F., however, the situation was somewhat different. At 80°F. (before and after the break, respectively) the slope-values of the Holsteins were 1.12 and .48; those of the Brown Swiss were .99 and .52;

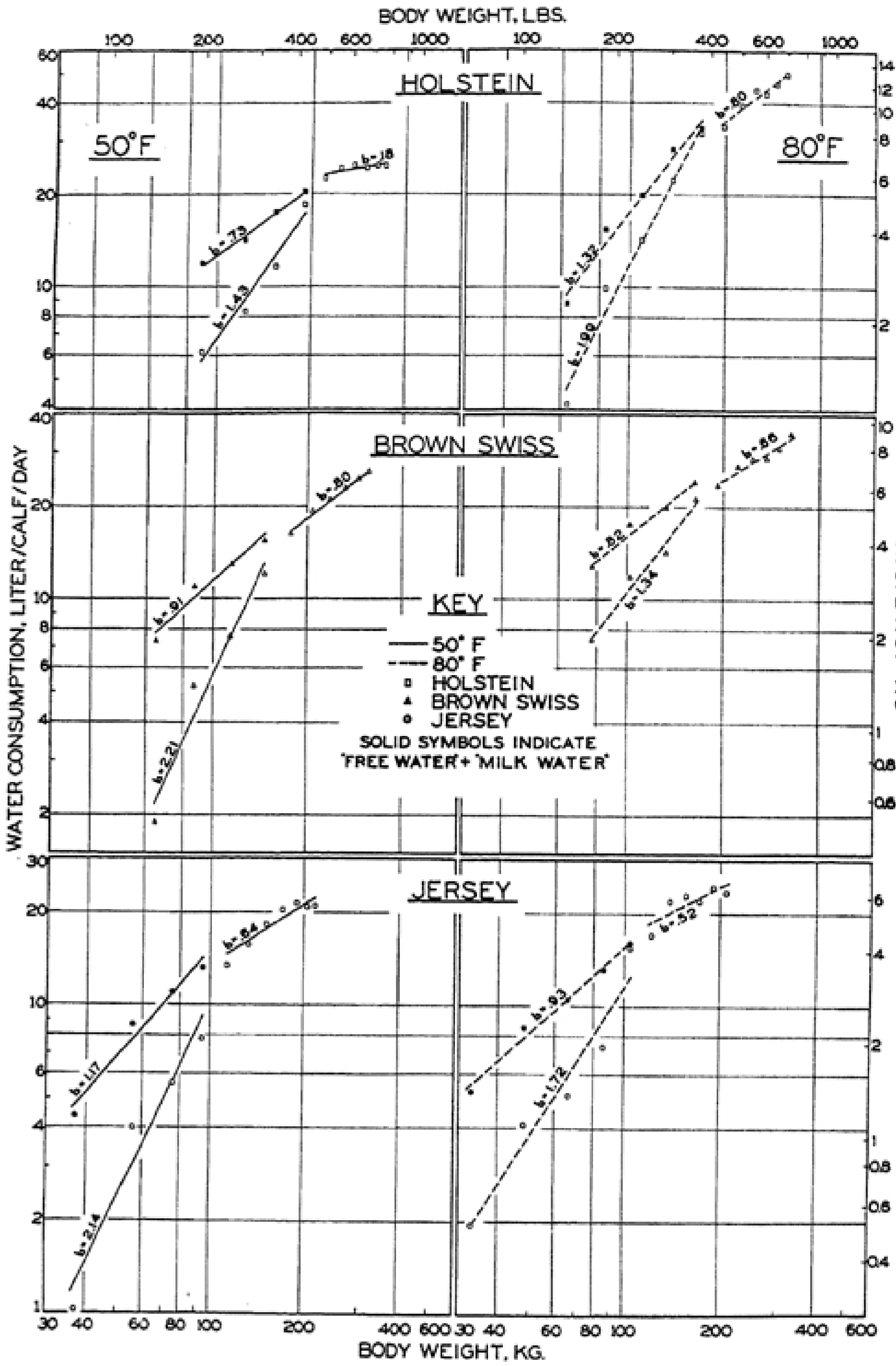

Figure 6. Logarithmic Relationship of Water Consumption to Body Weight During Growth.
Free Water = water consumed from drinking cups.
Milk Water = water estimated to be in the milk consumed by the calves. Values of 87.0 88.0 and 90.7% water were used for whole milk, half whole and half skim milk, and skim milk, respectively. "Total Water Consumption" refers to the addition of free water and milk water during period of the first 5 - 5 1/2 months.

and those of the Jerseys were 1.08 and .55. It appears that among the three breeds at 80°F., the Holsteins were gaining least economically and the Brown Swiss most economically.

To further interpret the logarithmic plot, the ratio of hay to grain consumption vs. age at 50° and 80°F. temperatures, Figure 7, is shown. In both groups, from 1 to approximately 5.5 months of age, the ratio of hay to grain increased gradually. At approximately 6 months of age, milk was withheld from the ration, although the animals were still fed grain at about the same level. Thereafter, the ratio of hay to grain continued to increase, somewhat more markedly than during the previous six months. The increase in the ratio was primarily due to increased hay consumption.

It is interesting to speculate on the mechanisms behind the changes that occur and also upon factors that may be responsible for the break in the logarithmic trends in Figure 8. It is assumed that the changing composition of TDN may influence the logarithmic exponents. It is also approximately about this age, that the metabolism, TDN,

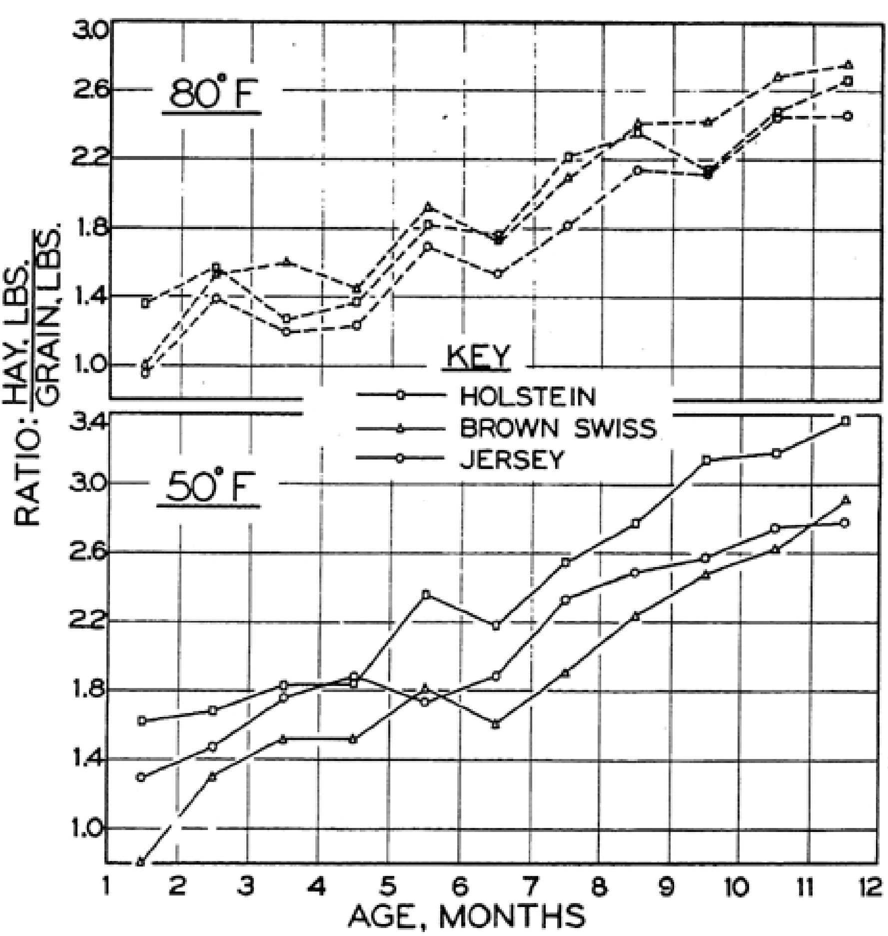

Figure 7. The ratio of hay to grain consumption during growth at 50° and 80°F.

and thyroid activity per unit surface area are apparently approaching maximum values and that the rates of increase are diminishing markedly. (Kibler, 1960; Johnson and Ragsdale, 1959).

The Curvilinear Relationship Between TDN Consumption and Body Weight:

The weight or quantity of feed consumed by a growing animal and the resulting gain in live weight is a relationship that is of both practical importance and of theoretical interest. The relationship between TDN consumption and body weight has been described (previous section) by the equation $Y = aX^b$, the equation for a parabola. This equation stated that with every increase of one percent in X, there would be an increase of b percent in Y. An examination of Figure 8 will reveal that what, presumably, would be a continuous straight line broke when the Holsteins, Brown Swiss, and Jerseys reached 400, 350, and 225 pounds, body weight respectively. The "b" (exponent) values after the break were always less than those before the break. According to the equation, one would conclude that an increase of one percent in body weight occurred with a smaller percentage increase in TDN consumption after the break. This conclusion might erroneously lead to the interpretation that growth, in terms of feed consumption, became more economical for these particular calves after the break. One factor which may influence the break is the effect of removal of skim milk from the diet of the calves at approximately 5 months of age. There may have been a time lag in the adjustment or compensation to the modification in the calves' diet.

In order to present a more thorough data analysis, which would take into consideration the probability that there is not, theoretically and as indicated by evidence from other animals (Titus, et. al., 1934; Titus, 1928), a straight, linear relationship between TDN consumption and body weight, an equation of the curve of diminishing increment was fitted to the data.

Brody (1945), in his discussion of the principle of diminishing increments, states that above the maintenance level, total food energy decreases as successive increments in food consumption occur. "The tendency for decline in utilization of successive dietary increments is an example of a ubiquitous phenomenon often generalized by the principle of diminishing returns or diminishing increments, or the Weber-Fechner law, or the law of mass action." (Brody, 1945) In application to the relationship between TDN and weight, the law would state that for successive unit increases in TDN, weight also increases but each successive increment is a certain percentage less than the immediately preceding increment.

Thus, as the animal grows larger, its maintenance cost in comparison to weight gain increases and, therefore, the energetic

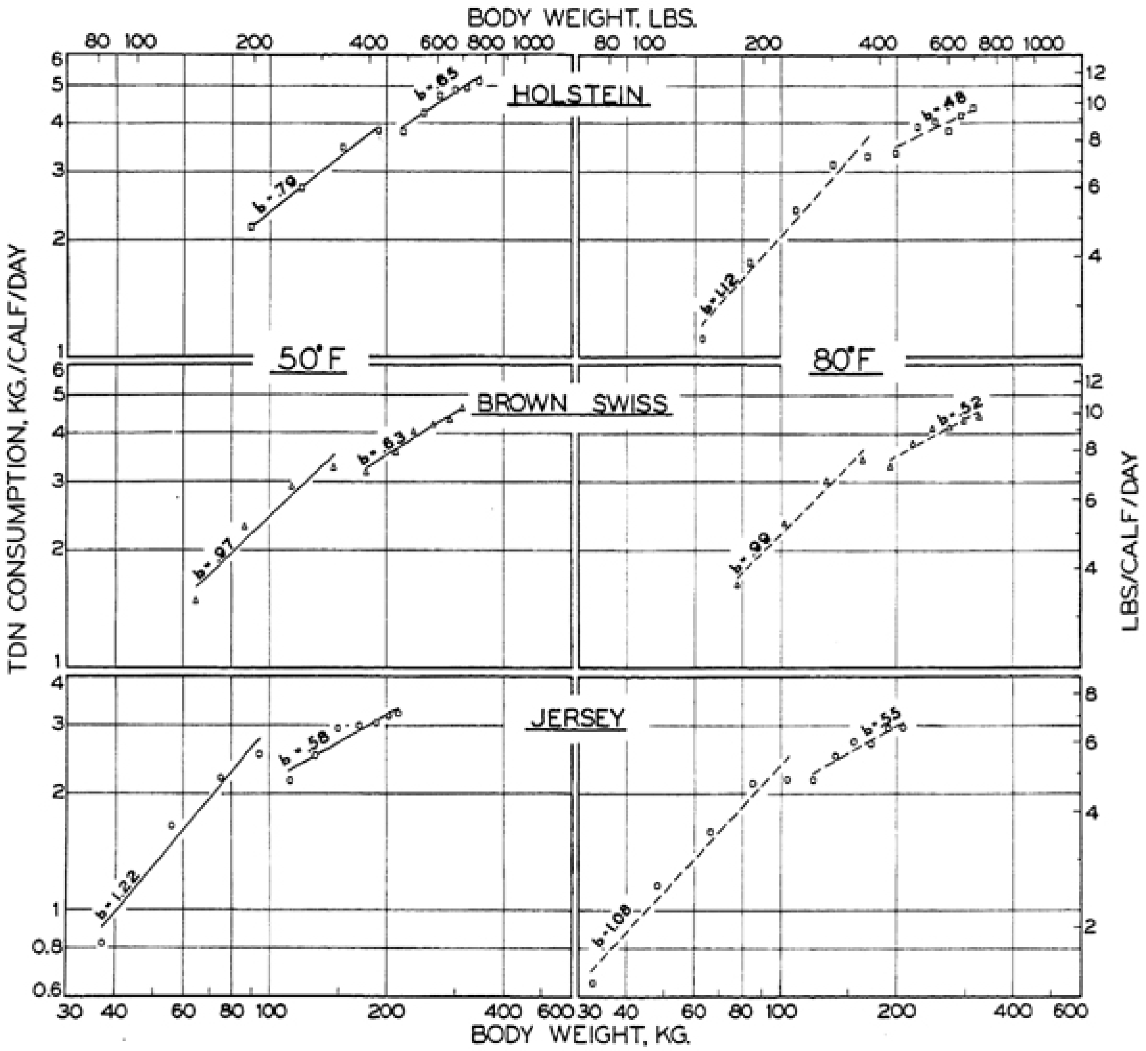

Figure 8. Logarithmic Relationship of TDN consumption to body weight.

efficiency of growth decreases; that is, as the animal approaches mature weight, the successive increments in body weight decrease per unit food intake. Finally growth virtually ceases while food consumption continues for maintenance. Winchester (1954) has more recently pointed out that restriction of feed will reduce gain and thus prolong the period required to attain a certain weight.

Apparently high temperature expresses its effect in the same manner on growing beef (Johnson et al., 1958) as on dairy calves, i.e., at high temperatures a longer time is required for the attainment of maturity.

Titus et al. (1934) have stated that "the curve of diminishing increment expresses with a high degree of accuracy the relationship between feed consumption and live weight over an appreciable period of growth". The equation $W = A - Be^{-kf}$ can be used to express the principle.

In the equation:

W = the live weight for any corresponding TDN consumption, F

A = the maximum live weight attainable on given level of feed intake

B = the difference between A and the initial live weight, i.e., the total gain in live weight possible

e = the base of the natural system of logarithms

k = a constant, the relative rate (or, when multiplied by 100, the percentage rate) of decline of the differential TDN gains in weight.

The same adjustment equations used and recommended by Titus et al., (1934) were employed to correct the approximations of the parameters of the equation. Cumulative TDN consumption was plotted against average live weight values in Figure 9. Both plotted curve and observed points are shown on the figures, and the equations from which the calculated points were derived are indicated.

The proximity of the observed and calculated points of the various curves emphasizes the high degree of accuracy with which the equation fits the data. The negative exponents (k) signify that with every unit increase in TDN, the weight increment is k percent less than the preceding increment. The percentage decline values of k are .082, .078, and .127 for the 80°F. Holsteins, Brown Swiss, and Jerseys, respectively. For the corresponding 50°F. animals, they were .092, .087, and .103.

The high degree of accuracy permitted by the use of the correction formulae and confirmed by the proximity of the calculated line and observed points would allow reasonable estimates of the mature weights of the animals based on weight and TDN consumption data. These weights are mathematically probable as valid or even more so than those based on first approximations obtained by the graphical method, previously reported (Johnson and Ragsdale, 1959).

Equations indicate that among the 50°F. Holsteins each weight gain increment per kilogram TDN is .0921 percent less than the preceding increment while at 80°F., each increment is .0820 less than the preceding one. This suggests a more rapid maturity at 50°F. and consequently progressively lower weight gain per unit TDN. Among the 50° and 80°F. Brown Swiss, the percentage decline values were .088 and .078, suggesting that the decreasing increments of weight per kg. TDN consumption were greater at 50° than at 80°F., in accordance with expectations concerning the heat tolerant Brown Swiss. The percentage decline values of the 50° and 80°F. Jerseys, .103 and .127,

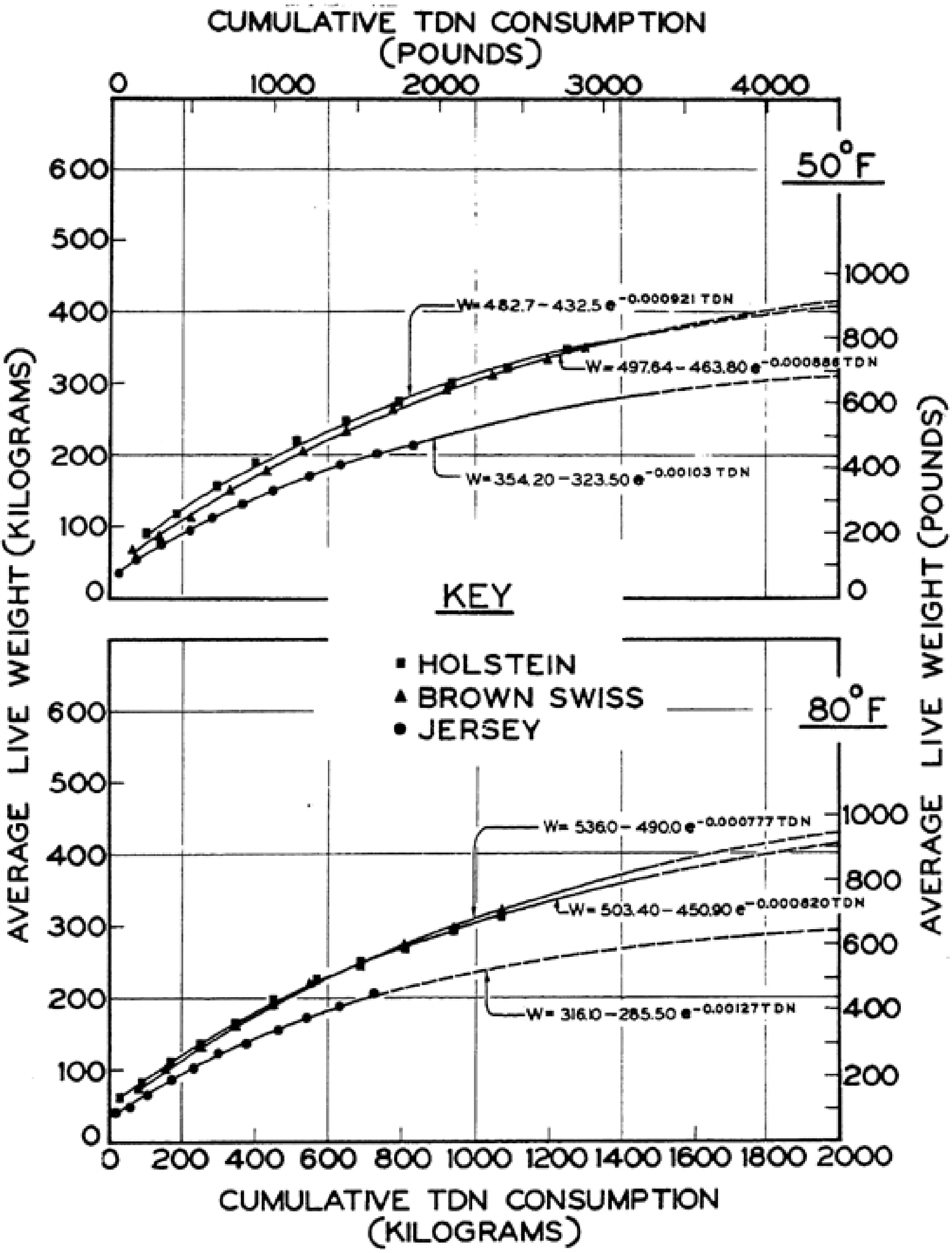

Figure 9. The relationship between TDN consumption and body weight expressed by the equation of the curve of diminishing increments. Equation is $W = A\text{-}Be^{-kf}$. Data points are calculated values. The solid lines represent the actual data and the dotted lines represent values estimated by the equation.

respectively, tend to substantiate inferences concerning the Jerseys acclimation to the 80°F. temperature during the last 3-4 months of the study. The 80°F. Jerseys adjusted to the high temperatures and the last few months of the growth experiment (Johnson and Ragsdale, 1959) were gaining more than the 50°F. Jerseys. This would cause a greater exponent (.127).

Interpretation of these data are, by necessity, tentative since the data represent only twelve months of growth and since individual variations in TDN consumption were not available. It is also necessary to consider the change in ration composition during growth.

TDN and Water Consumption Per Unit Surface Area:

The relation of TDN and water consumption to surface area (Figure 10) is important as a source of potential insight into the physical and physiological reactions of animals stressed by heat. Brody (423) has stated:

> Newton's law of cooling indicates that the larger the surface area of a given body, the greater the rate of heat transfer. . . . . Since from geometrical considerations, the larger the body, the smaller the surface area per unit volume (or per unit weight), heat dissipation becomes more difficult as the body size of the animal increases.

The total surface area per unit weight was highest for the Jerseys, intermediate for the Brown Swiss, and lowest for the Holsteins at both temperatures (Johnson et al., 1960). The TDN consumption per unit surface area at 50°F. was high for the Holsteins, intermediate for the Brown Swiss, and low for the Jerseys. The ratio increased until the animals reached about five months of age. At 80°F., the ratios also increased for the first five months and leveled off somewhat shortly afterward. Through the first seven months, the Holsteins had the highest ratios and were followed by the Brown Swiss and Jerseys, but after seven months of age, the Brown Swiss ratios rose above those of the Holsteins. Perhaps, in order to reduce the heat produced but ineffectively dissipated because of the low ratio of surface area to unit weight, the Holsteins relatively decreased their TDN consumption. With the exception of the Brown Swiss ratio, the 80°F. animals' ratios were slightly lower than the 50°F. animals' ratios.

The total water consumption per unit surface area was quite constant at 50°F. The Holsteins' ratios were highest. They were very closely followed by the Jerseys' and the Brown Swiss'. At 80°F., the Holsteins' tremendously higher water consumption and comparatively small surface area per unit weight resulted in an notable difference in the ratios, the Holsteins' being the highest, Brown Swiss', intermediate, and the Jerseys', lowest. The 80°F. Holstein ratios were considerably higher than the 50°F. Holstein ratios. Support of the heat tolerance

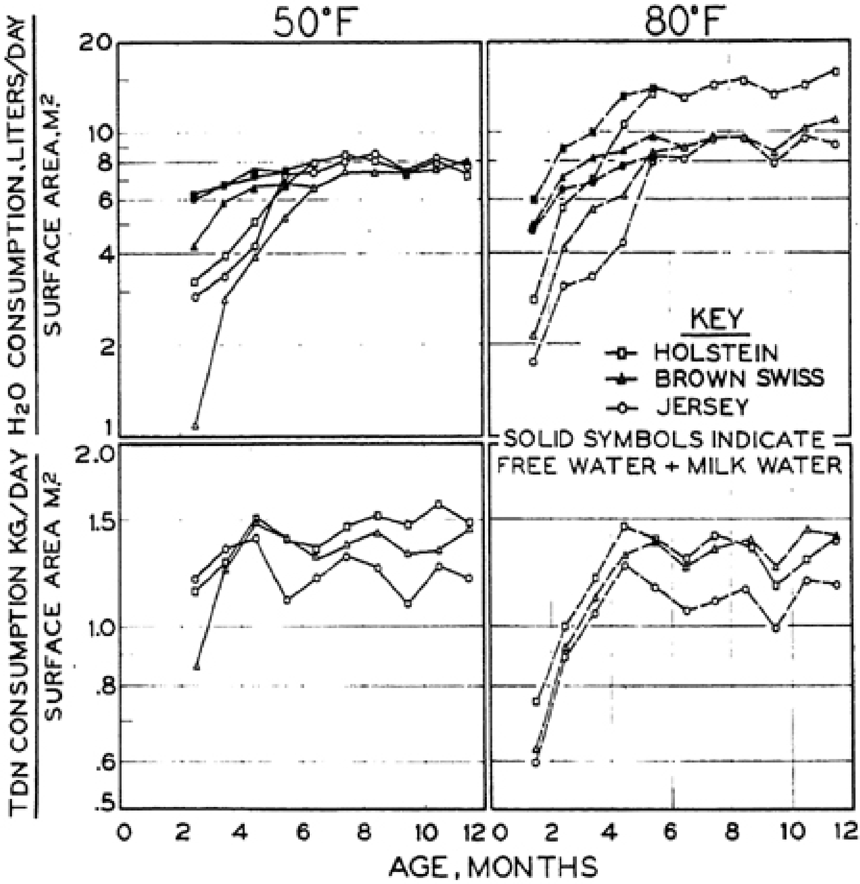

Figure 10. The relationship of TDN and water consumption to surface area. One may observe that the TDN per surface area values are highest for the Holstein, intermediate for the Brown Swiss, and lowest for the Jersey and that the apparent Holstein and Brown Swiss difference diminshes at 80°F.

ability of the Brown Swiss is provided by the fact that the ratio was moderately higher at 80°F. than at 50°F., and that the surface area measurements of the 80°F. Brown Swiss were higher than those of the 50 F. Brown Swiss for the first ten months of growth. (Johnson et al., 1960). The Jerseys' surface area was slightly lower at 80° than at 50°F., although it was high in comparison to those of the other calves in proportion to body weight. Again we are confronted with the fact that one of the individuals chosen at random in 50°F. Jersey group had an abnormally high water intake so data must be interpreted accordingly.

Discussion of Maintenance and Growth:

One of the purposes of this study was to determine the effect of environmental temperature on the energy requirements of maintenance and growth. In order to estimate the requirements, an equation developed by Winchester and Hendricks (1953) was fitted to the TDN consumption and body weight data. In the equation, $f = aw^{2/3}(1 \neq kg)$, f = energy requirement in kg. TDN, w = body weight of the animal in kg., g = daily gain in kg., and a and k were constants computed from the actual data.

Proceeding on the assumption that the "feed used for maintenance is essentially the amount needed to compensate for the energy loss equivalent to basal metabolism," which is approximately proportional to the two-thirds power of body weight, the quantity $aw^{2/3}$ was used to estimate the maintenance requirement (TDN necessary to maintain constant body weight).

The following equations were obtained:

50°F. Holstein:	$f = .0877w^{2/3}\ (1 + .2599g)$
80°F. Holstein:	$f = .0615w^{2/3}\ (1 + .7483g)$
50°F. Brown Swiss;	$f = .0733w^{2/3}\ (1 + .4684g)$
80°F. Brown Swiss:	$f = .0289w2/3\ (1 + 2.8955g)$
50°F. Jersey:	$f = .0725w2/3\ (1 + .6491g)$
80°F. Jersey:	$f = .0716w2/3\ (1 + .4661g)$

The daily TDN requirements for maintenance at 2.5, 4.5, 6.5, 8.5, and 10.5 months of age are shown in Appendix Table 6. This table also presents the TDN requirements for daily weight gains of .23, .34, .45, .68, and .91 kg. (1/2, 3/4, 1, 1 1/2, and 2 pounds) at the several ages.

An excerpt of the data (See Table 1) indicated that the total TDN requirements (maintenance plus growth) for approximately 1 pound gain per day were slightly greater for the 50°F. than for the 80°F. Holsteins, Jersey, and Brown Swiss. This is a fairly close agreement between the calculated TDN requirements and the observed TDN consumption, at least for the first half of growth measured. (Appendix Table 6).

It is interesting to note that while the TDN requirement for maintenance and growth, occurring simultaneously, was higher at 50° than at 80°F. for the Brown Swiss, the difference between TDN requirement for maintenance and daily requirement for weight gain of two pounds (.91 kg.) was greater at 80° than at 50°F., indicating that greater relative amounts of TDN were being utilized for growth (if growth can be logically separated from maintenance) at 80° than at 50°F. Among the Holsteins as well, relatively more of the TDN consumed was spent on growth at 80° than at 50°F. Among the Jerseys, however, the maintenance requirements of which were almost equal for the two temperature groups, apparently a relatively lesser quantity of TDN was expended for growth at 80° in comparison to 50°F. These observations also hold in a comparison between actual TDN consumption and TDN maintenance requirement.

There is greater estimated TDN requirement for maintenance at 50°F. than 80°F. for all three breeds. Theoretically the Brown Swiss, Holstein and Jerseys have a greater estimated TDN requirement for 1 lb. gain at 50° than at 80°F. These theoretical physiological occurrences are suggested by the equation $f = aw^{2/3}$ (1 ≠ kg.).

Therefore, these data suggest that moderately high environmental temperatures may have some physiological merits (i.e., more efficiency, less feed/lb. gain). Though the longevity of the animals may be adversely affected which is of particular concern in the raising of breeding stock and dairy cow replacements. Furthermore, it is important to recall that the volume of saleable product is reduced at 80°F. particularly in the Holstein animals and shown by earlier data on Shorthorn Calves (Johnson et al., 1958) as compared to 50°F.

Diurnal Trends in Frequency and Volume of Water Consumption During Growth:

Water consumption (Figure 11) was much greater during the day than at night throughout the growth study. The values were also greater at 80°F. than at 50°F. throughout growth. At 80°F., the Holsteins displayed the greatest water consumption and were followed by the Brown Swiss and Jerseys, and at 50°F., the relative positions of the three breeds were identical. With increasing age, the 50° and 80°F. day consumption values increased much more than the night consumption values, especially for the Holsteins and Brown Swiss.

After about eight months of age, the 50°F. animals displayed day consumption values almost always three to four times as great as night values. At 80°F., the day-night differences increased until the animals reached about 11 months of age; day consumption was two to three times greater than night consumption.

Among the 50°F. Holsteins, day consumption leveled off when the animals reached about 7 months of age; generally, it was more than three times as great as night consumption. A leveling off trend was not evident for the 80°F. Holsteins, in fact they continued to increase consumption.

Both 50° and 80°F. Jerseys exhibited fairly level trends after nine months of age. The day consumption was 3 to 4 times greater than the night consumption for both groups.

These data express a very definite daily rhythm in the water consumption for the animals under these constant environmental conditions and they are similar to data on beef calves. The rhythm may be inherent or may be associated with feeding or other managerial rhythms. Critical studies are needed for complete understanding of these basic mechanisms.

The lower section of Figure 12 shows the total frequency of drinks for each breed at both 50° and 80°F. The curves are similar in shape though the frequencies have previously been shown for volume, are higher at 80°F. than at 50°F. throughout growth.

Each breed's frequency of drinks, an increasing function of age for approximately the first eight months, was two to three times greater

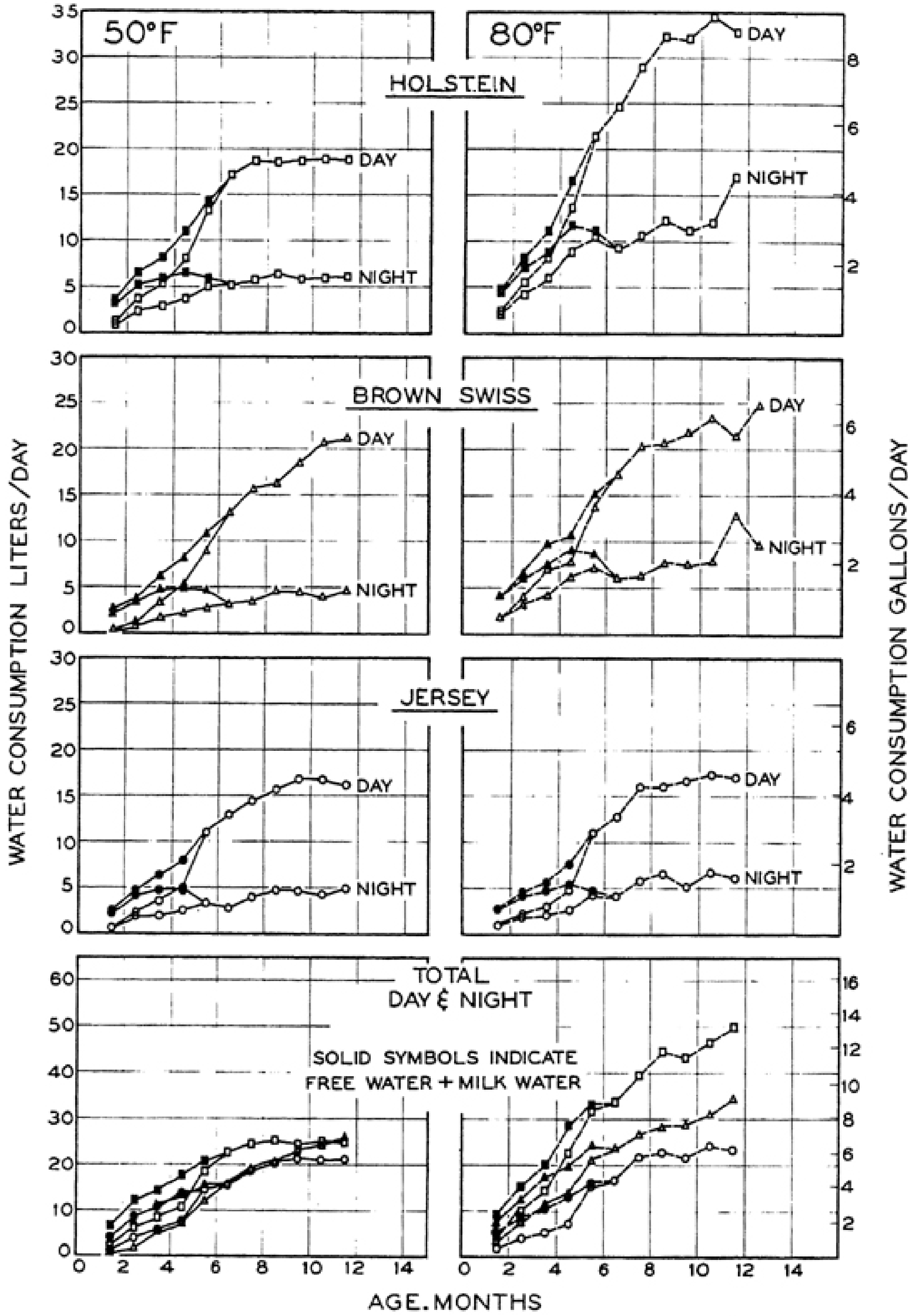

Figure 11. Changes in water consumption during growth at 50^{O} and 80^{O}F. Day values are based on consumption from 6 A.M. to 6 P.M. and night, from 6 P.M. to 6 A.M.

in the day than at night at both temperature levels. Both day and night frequencies of the 80°F. Holsteins and Jerseys were greater than those of the 50°F. animals. At 80°F., the Brown Swiss drank more frequently than the 50°F. Brown Swiss at night but not during the day. At both temperatures, the frequency of drinks was usually greatest for the Holsteins, intermediate for the Brown Swiss, and lowest for the Jerseys.

In general, the data suggest that the animals were drinking more per drink, i.e., a greater quantity per drink, during the day than at night. The data are similar to data on beef calves (Johnson et al., 1958) in that animals such as the Holsteins or the Shorthorns, which consumed the most water during the 24 hours, displayed the least difference between day and night frequency.

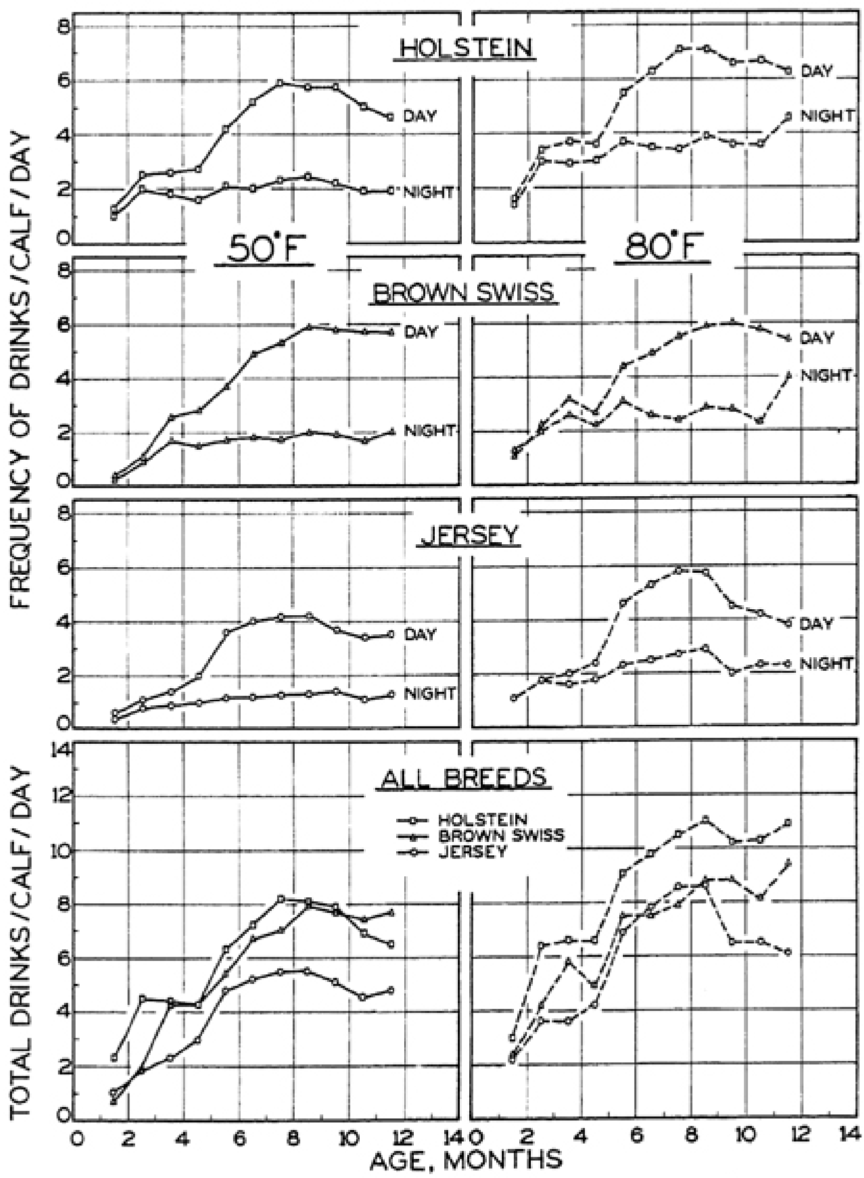

Figure 12. Frequency of drinks during growth at 50° and 80°F.

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APPENDIX TABLE 1 - TDN REQUIREMENTS FOR MAINTENANCE AND GAIN FROM FORMULA:
$f = aw^{2/3} (1 \neq \text{kg.})$

	50°F.			80°F.		
Age	Brown Swiss	Holstein	Jersey	Brown Swiss	Holstein	Jersey
	Daily TDN Requirement for Maintenance (Pounds)					
2.5	2.6	4.0	2.4	1.1	2.6	2.0
4.5	3.7	5.5	3.3	1.5	3.5	3.1
6.5	5.1	7.1	4.2	2.2	4.6	4.0
8.5	6.2	8.2	4.8	2.4	5.3	4.6
10.5	7.1	9.1	5.5	2.9	6.0	5.3
Daily TDN Required for One Pound Weight Gain (Maintenance and Gain)						
2.5	3.2	4.4	3.1	2.5	3.6	2.4
4.5	4.5	6.2	4.3	3.6	4.7	3.7
6.5	6.1	7.9	5.4	5.1	6.2	4.8
8.5	7.5	9.1	6.3	5.6	7.1	5.6
10.5	8.5	10.1	7.1	6.6	8.0	6.4

Data taken from Appendix Table 6.

APPENDIX TABLE 2 - GALLONS OF WATER CONSUMED PER POUND GAIN AND GALLONS WATER CONSUMED PER POUND TDN CONSUMED FOR BROWN SWISS, HOLSTEIN AND JERSEY CALVES AT 50°F AND 80°F FROM 1 TO 12 MONTHS

	50°F			80°F		
Age Months	Brown Swiss	Holstein	Jersey	Brown Swiss	Holstein	Jersey
	(Water Consumption, gal/calf/day) (Av. Daily Gain in Weight, lbs/calf/day)					
1-2	--	--	0.19	--	0.83	0.54
2-3	0.36	0.80	0.76	1.13	1.33	0.84
3-4	0.76	0.89	1.06	1.60	1.89	0.97
4-5	0.91	1.23	1.45	1.59	2.73	1.40
5-6	1.32	1.80	2.92	2.47	3.52	2.88
6-7	1.95	3.27	2.99	3.05	4.38	4.06
7-8	2.47	3.04	3.32	3.66	5.44	4.46
8-9	2.55	3.61	3.83	3.71	6.80	4.78
9-10	2.95	3.63	4.49	4.19	8.93	4.52
10-11	3.57	4.04	5.59	4.32	7.19	5.39
11-12	4.21	3.40	7.80	5.24	7.77	4.30

APPENDIX TABLE 2 CONTINUED

Age Months	50°F Brown Swiss	50°F Holstein	50°F Jersey	80°F Brown Swiss	80°F Holstein	80°F Jersey
	(Water Consumption, gal/calf/day)					
	(TDN Consumption, lbs/calf/day)					
1-2	.07	.21	.15	.41	.45	.35
2-3	.15	.34	.29	.54	.68	.42
3-4	.27	.37	.30	.60	.71	.38
4-5	.32	.41	.37	.56	.87	.41
5-6	.45	.59	.79	.75	1.17	.84
6-7	.61	.72	.75	.85	1.21	.93
7-8	.65	.69	.74	.86	1.21	1.05
8-9	.63	.64	.82	.83	1.33	1.00
9-10	.66	.60	.84	.83	1.36	.97
10-11	.69	.61	.79	.87	1.34	.98
11-12	.67	.58	.78	.94	1.37	.96

APPENDIX TABLE 3 - TDN CONSUMPTION OF BROWN SWISS, HOLSTEIN AND JERSEY CALVES AT 50^{o}F AND 80^{o}F FROM 1 TO 12 MONTHS

Age	50^{o}F						80^{o}F					
Months	Brown Swiss		Holstein		Jersey		Brown Swiss		Holstein		Jersey	
	lbs	kg.	lbs	kg.	lbs	kg.	lbs	kg.	lbs	kg.	lbs.	kg.
	TDN/calf/day											
1-2	1.71	0.78	2.63	1.19	1.80	0.82	2.22	1.01	2.46	1.12	1.44	0.65
2-3	3.26	1.48	4.75	2.15	3.64	1.65	3.61	1.64	3.86	1.75	2.58	1.17
3-4	5.08	2.30	5.97	2.71	4.85	2.20	5.17	2.35	5.28	2.39	3.53	1.60
4-5	6.43	2.92	7.62	3.46	5.61	2.54	6.65	3.02	6.87	3.12	4.71	2.14
5-6	7.16	3.25	8.39	3.81	4.79	2.17	7.51	3.41	7.24	3.28	4.82	2.19
6-7	7.00	3.18	8.35	3.79	5.55	2.52	7.27	3.30	7.38	3.35	4.83	2.19
7-8	7.89	3.57	9.36	4.25	6.50	2.95	8.30	3.76	8.60	3.90	5.54	2.51
8-9	8.87	4.02	10.37	4.70	6.59	2.99	9.04	4.10	8.91	4.04	6.01	2.73
9-10	9.21	4.18	10.75	4.88	6.74	3.06	9.08	4.12	8.41	3.81	5.98	2.71
10-11	9.54	4.33	10.84	4.92	7.02	3.18	9.48	4.30	9.23	4.19	6.53	2.96
11.12	10.20	4.63	11.28	5.12	7.10	3.22	9.70	4.40	9.64	4.38	6.55	2.97

APPENDIX TABLE 4 - AVERAGE DAILY GAIN IN WEIGHT (LBS) FOR BROWN SWISS, HOLSTEIN AND JERSEY CALVES AT 50°F AND 80°F FROM 1 TO 12 MONTHS

Age	50°F			80°F		
Months	Brown Swiss	Holstein	Jersey	Brown Swiss	Holstein	Jersey
1-2	--	--	1.41	--	1.34	.95
2-3	1.37	2.05	1.39	1.74	1.72	1.28
3-4	1.83	2.47	1.39	1.94	1.98	1.39
4-5	2.23	2.53	1.41	2.34	2.18	1.39
5-6	2.43	2.73	1.30	2.27	2.40	1.41
6-7	2.20	1.83	1.39	2.03	2.03	1.10
7-8	2.07	2.12	1.46	1.94	1.92	1.30
8-9	2.18	1.83	1.41	2.03	1.74	1.26
9-10	2.07	1.79	1.26	1.81	1.28	1.28
10-11	1.83	1.63	.99	1.90	1.72	1.19
11-12	1.63	1.94	.71	1.74	1.70	1.46

APPENDIX TABLE 5 - DAY AND NIGHT CONSUMPTION (LITERS) AND FREQUENCY OF DRINKS FOR BROWN SWISS, HOLSTEIN AND JERSEY CALVES AT 50°F AND 80°F FROM 1 TO 12 MONTHS

Age Months	50°F Brown Swiss day	50°F Brown Swiss night	50°F Holstein day	50°F Holstein night	50°F Jersey day	50°F Jersey night	80°F Brown Swiss day	80°F Brown Swiss night	80°F Holstein day	80°F Holstein night	80°F Jersey day	80°F Jersey night
	Water Consumption (Liters/calf/day and night)											
	*(2.51)	(2.15)	(3.54)	(3.07)	(2.42)	(2.25)	(3.95)	(4.01)	(4.53)	(4.37)	(2.71)	(2.51)
1-2	.30	.15	1.21	.87	.57	.45	1.70	1.82	2.16	2.08	1.02	.91
	(3.87)	(3.49)	(6.65)	(5.28)	(4.68)	(4.04)	(6.84)	(5.94)	(8.31)	(7.21)	(4.40)	(4.03)
2-3	1.14	.76	3.79	2.42	2.31	1.67	4.16	3.26	5.53	4.43	2.27	1.82
	(6.36)	(4.66)	(8.26)	(5.83)	(6.38)	(4.68)	(9.84)	(7.53)	(11.09)	(8.86)	(5.79)	(4.70)
3-4	3.48	1.78	5.38	2.95	3.63	1.93	7.00	4.77	8.21	5.98	3.10	2.01
	(8.19)	(4.98)	(10.94)	(6.59)	(7.91)	(5.19)	(10.64)	(9.13)	(16.51)	(11.78)	(7.61)	(5.49)
4-5	5.41	2.27	8.06	3.71	5.22	2.50	7.84	6.25	13.63	8.90	4.73	2.61
	(10.97)	(4.65)	(14.41)	(6.00)			(15.29)	(8.82)	(21.89)	(11.11)	(11.36)	(4.69)
5-6	9.20	2.88	13.48	5.07	11.13	3.26	13.85	7.38	21.38	10.60	11.02	4.35
6-7	13.06	3.22	17.37	5.22	12.91	2.80	17.41	6.06	24.64	9.05	12.83	4.09
7-8	15.78	3.60	18.74	5.72	14.38	3.94	20.44	6.44	28.92	10.60	16.16	5.83
8-9	16.39	4.66	18.59	6.44	15.74	4.69	20.71	7.80	32.48	12.34	16.09	6.70
9-10	18.59	4.50	18.81	5.79	16.88	4.54	21.69	7.00	32.06	11.20	16.69	5.19
10-11	20.82	3.97	19.00	5.94	16.84	4.09	23.62	7.46	34.64	12.19	17.41	6.85
11-12	21.12	4.85	18.89	6.06	16.05	4.92	21.64	13.02	32.86	17.15	17.11	6.17

* Parentheses indicates numbers are “free water” + “mild water”.

APPENDIX TABLE 5 CONTINUED

Age	$50^{o}F$						$80^{o}F$					
	Brown Swiss		Holstein		Jersey		Brown Swiss		Holstein		Jersey	
Months	day	night	day	night	day	night	day	night	day	night	day	night
					Frequency of Drinks							
1-2	0.4	0.3	1.3	0.9	0.5	0.4	1.1	1.3	1.5	1.4	1.1	1.1
2-3	1.1	0.9	2.5	2.0	1.1	0.9	2.2	1.9	3.4	2.9	1.8	1.8
3-4	2.5	1.7	2.5	1.9	1.4	0.9	3.2	2.6	3.6	3.0	2.0	1.7
4-5	3.1	1.7	3.0	1.8	2.4	1.4	2.8	2.5	3.8	3.4	2.7	2.2
5-6	4.3	2.2	4.7	2.4	4.4	1.9	5.0	3.3	6.2	4.4	5.7	3.4
6-7	5.9	2.4	6.0	2.5	4.9	1.7	5.7	2.9	7.5	4.3	6.8	3.2
7-8	6.3	2.2	6.7	2.8	4.9	1.8	6.1	2.8	7.7	4.0	7.3	3.6
8-9	6.5	2.2	6.2	2.8	4.3	1.5	6.4	3.3	8.0	4.9	6.5	3.5
9-10	6.2	2.2	6.1	2.6	3.9	1.4	6.0	2.9	7.0	3.7	4.6	2.1
10-11	5.7	1.7	4.9	1.9	3.4	1.2	5.8	2.3	6.7	3.5	4.2	2.2
11-12	5.8	2.0	4.7	1.9	3.5	1.3	5.4	4.0	6.3	4.7	3.8	2.3

APPENDIX TABLE 6 - MAINTENANCE AND GROWTH TABLES FOR BROWN SWISS, HOLSTEIN AND JERSEY CALVES AT 50°F AND 80°F FROM 1 TO 12 MONTHS

Age Months	Obs. TDN Cons.	Body Weight	TDN Required to Maintain Body Weight	TDN Required for the Following Daily Weight Gains				
	kg.	kg.	kg.	.23 kg.	.34 kg.	.45 kg.	.68 kg.	.91 kg.
	50°F Brown Swiss $f = .0733w^{2/3}(1 \neq .4684g)$							
2.5	1.48	64.84	1.2	1.3	1.4	1.4	1.6	1.7
4.5	2.92	114.17	1.7	1.9	2.0	2.1	2.2	2.4
6.5	3.18	177.33	2.3	2.6	2.7	2.8	3.0	3.3
8.5	4.02	235.34	2.8	3.1	3.2	3.4	3.7	4.0
10.5	4.33	290.83	3.2	3.6	3.7	3.9	4.2	4.6
	80°F Brown Swiss $f = .0289w^{2/3}(1 \neq 2.8955g)$							
2.5	1.64	77.17	.5	.8	1.0	1.2	1.5	1.8
4.5	3.02	131.42	.7	1.2	1.4	1.6	2.1	2.5
6.5	3.30	192.15	1.0	1.7	2.0	2.3	3.0	3.6
8.5	4.10	246.17	1.1	1.8	2.2	2.5	3.3	4.0
10.5	4.30	297.33	1.3	2.2	2.6	3.0	3.9	4.7
	50°F Holstein $f = 0.0877w^{2/3}(1 \neq .2599g)$							
2.5	2.15	89.50	1.8	1.9	2.0	2.0	2.1	2.2
4.5	3.46	154.25	2.5	2.6	2.7	2.8	3.0	3.1
6.5	3.79	221.16	3.2	3.4	3.5	3.6	3.8	4.0
8.5	4.70	274.92	3.7	3.9	4.0	4.1	4.4	4.6
10.5	4.92	322.75	4.1	4.4	4.5	4.6	4.8	5.1
	80°F Holstein $f = .0615w^{2/3}(1 \neq .7483g)$							
2.5	1.75	83.67	1.2	1.4	1.5	1.6	1.8	2.0
4.5	3.12	137.17	1.6	1.9	2.0	2.1	2.4	2.7
6.5	3.35	198.42	2.1	2.4	2.6	2.8	3.2	3.5
8.5	4.04	250.00	2.4	2.8	3.0	3.2	3.6	4.0
10.5	4.19	290.92	2.7	3.2	3.4	3.6	4.1	4.5
	50°F Jersey $f = .0725w^{2/3}(1 \neq .6491g)$							
2.5	1.65	56.00	1.1	1.3	1.3	1.4	1.6	1.8
4.5	2.54	94.17	1.5	1.7	1.8	1.9	2.2	2.4
6.5	2.52	131.09	1.9	2.2	2.3	2.4	2.7	3.0
8.5	2.99	169.92	2.2	2.5	2.7	2.8	3.2	3.5
10.5	3.18	203.25	2.5	2.9	3.1	3.2	3.6	4.0
	80°F Jersey $f = .0716w^{2/3}(1 \neq .4661g)$							
2.5	1.17	48.00	.9	1.0	1.4	1.1	1.2	1.3
4.5	2.14	85.17	1.4	1.6	1.6	1.7	1.9	2.0
6.5	2.19	121.42	1.8	2.0	2.1	2.2	2.4	2.6
8.5	2.73	155.17	2.1	2.3	2.4	2.5	2.8	3.0
10.5	2.96	189.17	2.4	2.7	2.8	2.9	3.2	3.4

f = energy requirement in Kg. TDN, w = body weight of animal in Kg., g = daily gain in Kg.

APPENDIX TABLE 7 - GRAIN AND HAY CONSUMPTION (LBS/CALF/DAY) OF BROWN SWISS, HOLSTEIN AND JERSEY CALVES AT 50^oF AND 80^oF FROM 1 TO 12 MONTHS

Age	50^oF			80^oF		
Months	Brown Swiss	Holstein	Jersey	Brown Swiss	Holstein	Jersey
			Grain, lbs.			
1-2	.50	1.09	.64	.85	1.03	.62
2-3	1.52	2.25	1.60	1.64	1.77	1.15
3-4	2.59	2.89	2.08	2.61	2.97	1.80
4-5	3.54	3.88	2.48	3.73	4.00	2.59
5-6	3.91	4.19	2.99	4.07	4.29	2.97
6-7	4.55	4.59	3.31	4.55	4.58	3.22
7-8	4.67	4.67	3.42	4.67	4.67	3.38
8-9	4.67	4.67	3.33	4.67	4.67	3.33
9-10	4.67	4.67	3.33	4.67	4.67	3.33
10-11	4.66	4.67	3.33	4.34	4.67	3.33
11-12	4.67	4.67	3.33	4.34	4.67	3.33
			Hay, lbs.			
1-2	.40	1.57	.82	.87	1.41	.59
2-3	1.99	3.78	2.36	2.55	2.78	1.61
3-4	3.94	5.29	3.65	4.18	3.78	2.17
4-5	5.37	7.14	4.65	5.42	5.47	3.20
5-6	7.12	9.87	5.22	7.86	7.78	5.05
6-7	7.34	9.98	6.26	7.89	8.06	4.96
7-8	8.92	11.89	7.99	9.78	10.38	6.15
8-9	10.90	13.89	8.30	11.24	10.99	7.14
9-10	11.58	14.64	8.59	11.32	10.00	8.08
10-11	12.26	14.83	9.15	12.11	11.63	8.17
11-12	13.56	15.71	9.30	12.55	12.44	8.22

APPENDIX TABLE 8 - TDN CONSUMPTION, KG./DAY/SURFACE AREA (M^2) FOR BROWN SWISS, HOLSTEIN AND JERSEY CALVES AT 50°F AND 80°F FROM 1 TO 12 MONTHS

Age	50°F			80°F		
Months	Brown Swiss	Holstein	Jersey	Brown Swiss	Holstein	Jersey
1-2	--	--	--	.63	.75	.60
2-3	.86	1.14	1.20	.92	1.00	.89
3-4	1.24	1.28	1.34	1.12	1.20	1.05
4-5	1.48	1.50	1.40	1.32	1.46	1.27
5-6	1.41	1.39	1.11	1.38	1.39	1.16
6-7	1.30	1.34	1.19	1.25	1.29	1.06
7-8	1.37	1.47	1.31	1.34	1.41	1.10
8-9	1.43	1.52	1.25	1.39	1.35	1.15
9-10	1.32	1.47	1.09	1.25	1.17	.99
10-11	1.33	1.59	1.26	1.44	1.29	1.18
11-12	1.45	1.48	1.20	1.41	1.39	1.17