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Environmental Physiology and Shelter Engineering

With Special Reference to Domestic Animals

XLIX. EFFECTS OF CONSTANT ENVIRONMENTAL TEMPERATURES OF 50° AND 80° F ON THE FEED AND WATER CONSUMPTION OF BRAHMAN, SANTA GERTRUDIS, AND SHORTHORN CALVES DURING GROWTH

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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 Brahman, Santa Gertrudis, and Shorthorn heifers during growth. Data are also presented on the effects of various other environmental temperatures on these heifers raised at 50° and 80° F. Since body weight and body weight gain are directly related to feed (TDN) and water consumption, this relationship was also analyzed.

Conclusions drawn from these data are:

1. The constant 80° F environmental temperature significantly depressed the TDN consumption of the Shorthorn and Santa Gertrudis calves. The depression of TDN consumption was much greater for the Shorthorns than for the Santa Gertrudis. The Brahmans showed no significant depression in TDN consumption at 80° F, compared to 50° F.

2. At both 50° and 80° F water consumption and frequency of drinks were greater during the day than at night for all breeds.

3. During growth the Shorthorns had a higher water consumption per unit weight or per unit surface area than the Brahmans and Santa Gertrudis at both 50° and 80° F. TDN consumption followed a pattern similar to that of water consumption, with the exception that only after eight months of age was the 80° F Shorthorns' TDN consumption per unit weight higher than that of the other breeds.

4. Relation of feed and water consumption to body weight during growth at both 50° and 80° F showed distinct "breaks" in the logarithmic regression lines at approximately 200 pounds for all animals except the 80° F Shorthorns.

5. There was an enormous difference in body weight gain of Shorthorns raised at 80° F, compared to those at 50° F. The difference for the 80° F Santa Gertrudis was less significant and there was no significant difference in body weight for the Brahmans.

6. The time required to gain an equivalent body weight was greater for the Shorthorns and Santa Gertrudis at 80° than at 50° F—five months longer for the Shorthorns and one month longer for the Santa Gertrudis. The Brahmans did as well at 80° as at 50° F.

7. Upon exposure to 90° F after the principal growth experiment had been completed, the 80° F Shorthorns and Brahmans had higher TDN and water consumption than those reared at 50° F. The 80° F Brahmans were slightly heavier than the 50° F Brahmans, but the 80° F Shorthorns were about 150 pounds lighter than the 50° F animals.

A complete discussion of the physiological effects of temperature on all measured growth responses of these Brahmans, Santa Gertrudis, and Shorthorns will be made later when all data on the various experimental phases of the project are published.

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ACKNOWLEDGMENTS

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XLIX. EFFECTS OF CONSTANT ENVIRONMENTAL TEMPERATURES OF 50° AND 80° F ON THE FEED AND WATER CONSUMPTION OF BRAHMAN, SANTA GERTRUDIS, AND SHORTHORN CALVES DURING GROWTH

INTRODUCTION

This bulletin, concerning the effects of temperature on growth of calves, is a report on one phase of the climatic laboratory project. The overall purpose of the project is to investigate the various effects of climate on growth, milk production and other physiological, physical, and/or hereditary characteristics that may be associated with an animal's adaptability to various climatic conditions, primarily high temperatures.

The objective of this report is to evaluate, quantitatively, the feed and water consumption of Brahman, Santa Gertrudis, and Shorthorn calves during growth from one to 3 months to about 18 months of age at constant 50° F, 80° F, and Missouri open shed conditions. These data were analyzed with respect to measurements reported by Ragsdale, *et al.,* 1957, and Kibler, 1957.

Included in this report are the responses in feed and water consumption of the 50° and 80° F reared calves when both groups were exposed to various higher constant environmental temperature conditions.

The function of growth is to a large extent determined by the animal's efficiency in utilizing feed which is closely correlated in turn with the ability of the animal to maintain thermal equilibrium. Normally, animals that have been adapted to a high level of feeding are those that suffer most in hot weather (Bonsma, 1947). These and other data suggest that the European-evolved Shorthorn would fall into the above category and thus be heat intolerant, while the tropic evolved Brahman should show more heat tolerance. The Santa Gertrudis which has been selected for ability to gain weight in a semitropical region of the United States may be intermediate.

Feed and water consumption varies with age, size, breed, and environmental conditions. How would a near optimum 50° F temperature (for mature cattle) or a relatively high 80° F temperature affect the feed and water intake of Shorthorn, Santa Gertrudis, and Brahman calves during growth? Does feed and water intake reflect the adaptability of the breeds to the 50° and 80° F environments? What are the differences in the conversion of feed to weight gain between calves held at high and calves held at low temperatures? These are basic questions in environmental investigations for which this report should provide some answers.

METHODS

Experimental Conditions.

This report includes two separate experiments. The major experiment covering a period from November 1954 to December 1955 was a growth experiment in which Brahman, Santa Gertrudis, and Shorthorn calves were exposed to constant environmental temperatures of 50° F, 80° F, and open shed.

Following the major experiment, the same heifer calves were exposed to temperatures varying from 65° F to approximately 110° F, with the vapor pressure relatively constant at approximately 0.43 in Hg. (55° F dewpoint temperature). In the actual experiment, however, vapor pressure increased slightly with temperature, up to 0.59 in Hg. at 110° F. This portion of the work extended from January, 1955, through April, 1955.

Three calves of each breed—Brahman, Santa Gertrudis, and Shorthorn—were placed in each chamber of the climatic laboratory for both experiments, one breed in each pen. The ages of the animals at the beginning of the experiment ranged from one to three months. Chamber I of the laboratory was kept at constant environmental conditions of about 50° F and 62 percent relative humidity. Chamber II had a constant environmental temperature of 80° F and approximately 54 percent relative humidity. For daily temperature conditions, see Yeck, 1957. Illumination was provided by one 40-watt incandescent bulb that was on at all times and six 200-watt incandescent bulbs which were on between 6 a.m. and 6 p.m. in each chamber. Air velocity was approximately 50 feet per minute.

For the first three months the pens were cleaned weekly and thereafter, daily. The pens were bedded daily throughout the experiment with straw, wood shavings, and pulverized limestone.

The open shed was single boarded with a straw loft. Windows were left partly open at all times and the inside temperature cycled with outside temperature but did not reach the extremes of the outside diurnal cycle.

Feed.

The animals were fed at approximately 7 a.m., immediately following cleaning, and again in the evening at 4 p.m. Milk was fed to all calves for about one month after they were placed in the laboratory and for about 15 days after feed and water measurements were started. Alfalfa hay of good quality was available *ad libitum* at all times. The left-over hay was weighed back and deducted from the amount fed. The grain mix was fed *ad libitum* until the calves were about eight months old. Thereafter grain was supplied at about 6 pounds per calf per day. The older calf or heifer mix (Table 1) was substituted for a calf starter ration at about four months of age. Daily records of feed consumption were kept for each breed (pen average); data were expressed as the average of three animals; that is, average per calf per day.

TABLE 1--COMPOSITION OF GRAIN RATION

Calf and Heifer Mix	
31.95%	corn
13.31%	oats
13.31%	wheat bran
3.33%	Soybean meal
3.33%	linseed meal
.67%	salt
.67%	bone meal
.17%	reinforced cod liver oil
33.26%	Foremost D & F mix

Feed consumption was expressed as TDN (total digestible nutrients). It was computed by the following formula: TDN (lbs.) = .503 x lbs. hay + .725 x lbs. grain + .163 x lbs. milk.

Water.

In the climatic chambers water at 60° to 70° F was always available in the drinking cups. The frequency of drinks and the quantity consumed were recorded automatically. (For methods see Ragsdale, *et al.,* 1950). One float-operated water cup was provided in each pen, i.e., one cup for three calves of each breed. The water consumption and frequency of drinks were not recorded in the open shed group.

Veterinary Care.

The general health of animals was observed daily by a veterinarian. Brucellosis vaccinations were given to all Shorthorn calves on March 10, 1955 (5 to 6 months of age), and to all Santa Gertrudis calves on March 15, 1955 (4 to 5 months of age). All animals were dehorned on July 28, 1955 (9 to 10 months of age).

DATA AND DISCUSSION

Effects of Temperature on Feed and Water Consumption During Growth.

The data are presented and correlated with respect to several factors, such as age, body weight, surface area, breed, and temperature since we are dealing simultaneously with the phenomena of growth, temperature effects, and breed differences.

Basic data that were used in the subsequent analysis are presented in Figure 1. Water consumption, TDN consumption, and body weights of the calves were plotted as a function of their age. The approximate calendar dates are shown

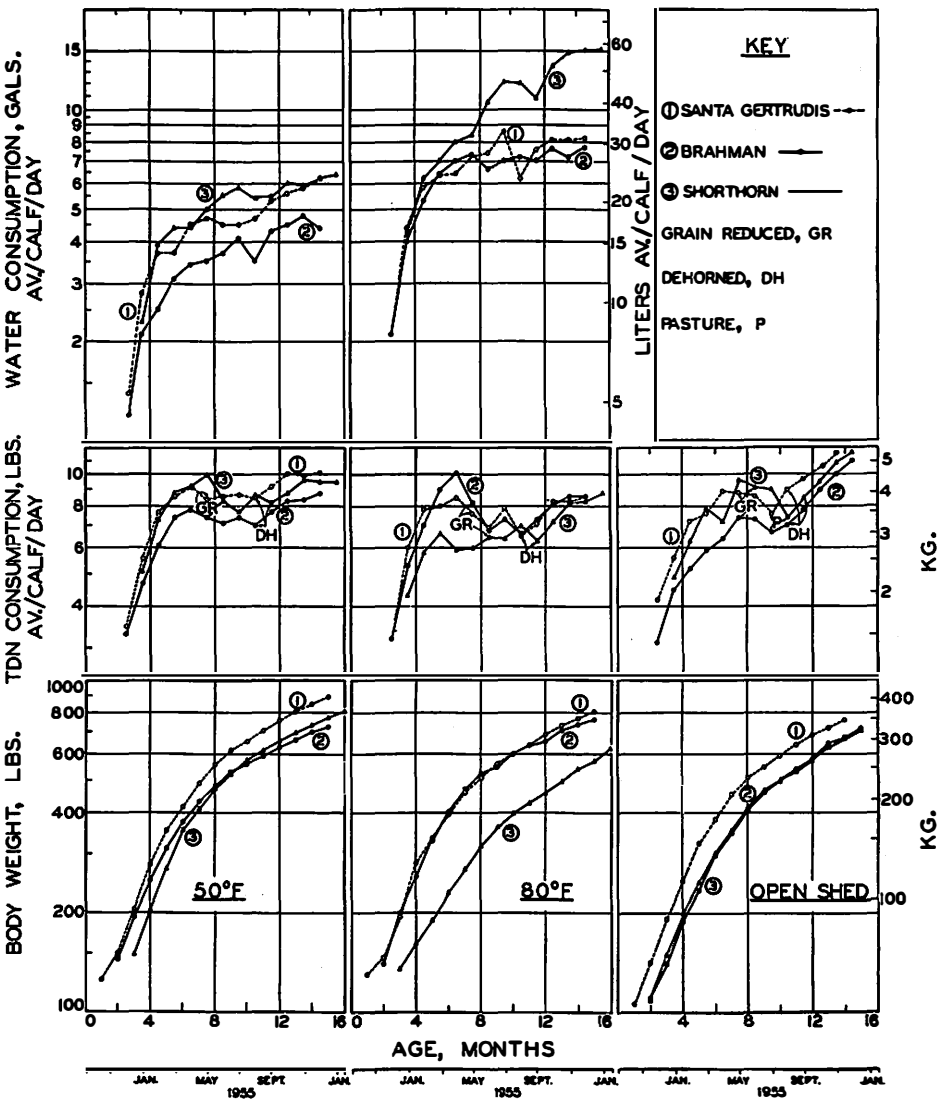

Figure 1—Breed comparisons of TDN, water consumption, and body weights of Santa Gertrudis, Brahman, and Shorthorn heifers raised at 50° F, 80° F, and open shed. The calendar at the bottom of the figure is approximate due to the age differences in the calves. Each datum point represents the monthly breed averages.

below the ages. All tests began on the same date but there was some difference in the average ages of the three breeds.

Water Consumption vs. Age. Water consumption increased with age among all animals with the greatest percentage of increase occurring during the early part of the growth period.

At 50° F the Shorthorns had the highest water consumption, Santa Gertrudis next, and Brahmans the least throughout most of the experiment. The breed differences were of the same order at 80° F except the Shorthorns consumed much more water than the other two breeds, particularly after seven months of age.

TDN Consumption vs. Age. TDN consumption increased very rapidly until about six months and thereafter tended to level off.

The TDN consumption at 50° F was approximately the same for the Santa Gertrudis and Shorthorns—about 2 pounds per day higher than for the Brahmans. At 80° F the TDN consumption of Shorthorns was lower than that of either the Santa Gertrudis or the Brahmans. Up to eight months the 80° F Shorthorns' TDN consumption was considerably lower than that of the other two breeds, but thereafter the difference was not so great. Missouri open shed conditions showed the Shorthorns and Santa Gertrudis to have a higher TDN than the Brahmans. *(Note: Recognition should be given to the probability of error among the shed data due to difficulty encountered when trying to eliminate feed wastage there.)*

Body Weight vs. Age. The greatest percentage of weight increase occurred during the earlier periods of growth. An enormous difference is shown between the weight gains of the Shorthorns raised at 50° F and those raised at 80° F. Those raised at 50° F gained approximately 147 pounds more.

There is a less striking difference between the growth of the Santa Gertrudis at 80° and 50° F (See Table 2)—a difference of approximately 71 pounds at

TABLE 2--WEIGHT GAIN COMPARISONS

	50°F			80°F			Open Shed		
	S.G.	Br.	Sh.	S.G.	Br.	Sh.	S.G.	Br.	Sh.
Weight at 4 mos. (lbs.)	278	249	205	283	257	163	249	190	202
Weight at 12 mos. (lbs.)	756	630	658	690	656	461	684	581	577
Total gain for 8 mo. period (lbs.)	478	381	445	407	399	298	435	391	375
Differences in gain from 50°F values	---	---	---	71	-18	147	43	-10	70

80° F as compared to 50° F. The tropic-evolved Brahman calves did as well at 80° F as at 50° F; i.e., no adverse effects of the 80° F temperature on their growth response were encountered.

Generally the 50° F environment was better than the 80° F or the shed environments insofar as weight gain was concerned. The Brahmans were the only

exception. They did as well or slightly better at 80° F than at 50° F. The differences were greatest for the first eight months of the test. Table 2 compares the magnitudes of the weight gains. The productive and probable financial loss on rearing Shorthorn calves at 80° F as compared with rearing them at 50° F is quite apparent. The time, financially though not physiologically important, for the various animals to reach 600 pounds body weight is indicated in Table 3 and Figure 1.

It took the 80° F Shorthorns approximately five months longer to attain the weight of the 50° F animals, while it took only one more month for the 80° F Santa Gertrudis to equal the 50° F animals' weight. The Brahmans, on the other hand, required one month longer at 50° F to reach the weight of the 80° F animals. (Table 3 and Figure 1).

TABLE 3--MONTHS REQUIRED TO REACH 600 LBS. BODY WEIGHT

	Environmental Conditions		
Breed	50°F	80°F	Open Shed
Santa Gertrudis	9.0	10.0	10.0
Brahman	11.0	10.0	12.5
Shorthorn	10.5	15.5	12.5

The comparison between the daily body weight gain (Table 4) at 50° and 80° F showed the Brahmans to be the least affected by temperature. Both the

TABLE 4--LEVEL OF SIGNIFICANCE OF DIFFERENCE BETWEEN YEARLY MEAN (AGE 4-16 MONTHS) OF DAILY BODY WEIGHT GAIN BY 50° AND 80°F ANIMALS

	Average Daily Body Weight Gain		Significance Level of
Breed	50°F	80°F	Temperature Variance
Santa Gertrudis	0.87 kg.	0.77 kg.	5%
Brahman	0.67 kg.	0.76 kg.	not significant
Shorthorn	0.76 kg.	0.58 kg.	1%

Santa Gertrudis and the Shorthorns had a significant variation with respect to temperature at the 5 percent level for the Santa Gertrudis and 1 percent for the more heat stressed Shorthorns.

The changes in body weight follow the same pattern as that of TDN and water consumption.

Effects of Environmental Temperature on Feed and Water Consumption During Growth. Figure 2 emphasizes the effects of three environments on each of the three breeds. The semi-logarithmic plot emphasizes the percentage differences rather than the absolute differences.

Water consumption at 80° F was approximately twice that at 50° F among all three breeds. Age trends were emphasized by the change in consumption from approximately 3 to 8 liters per day at two months to 10 to 25 liters per day at

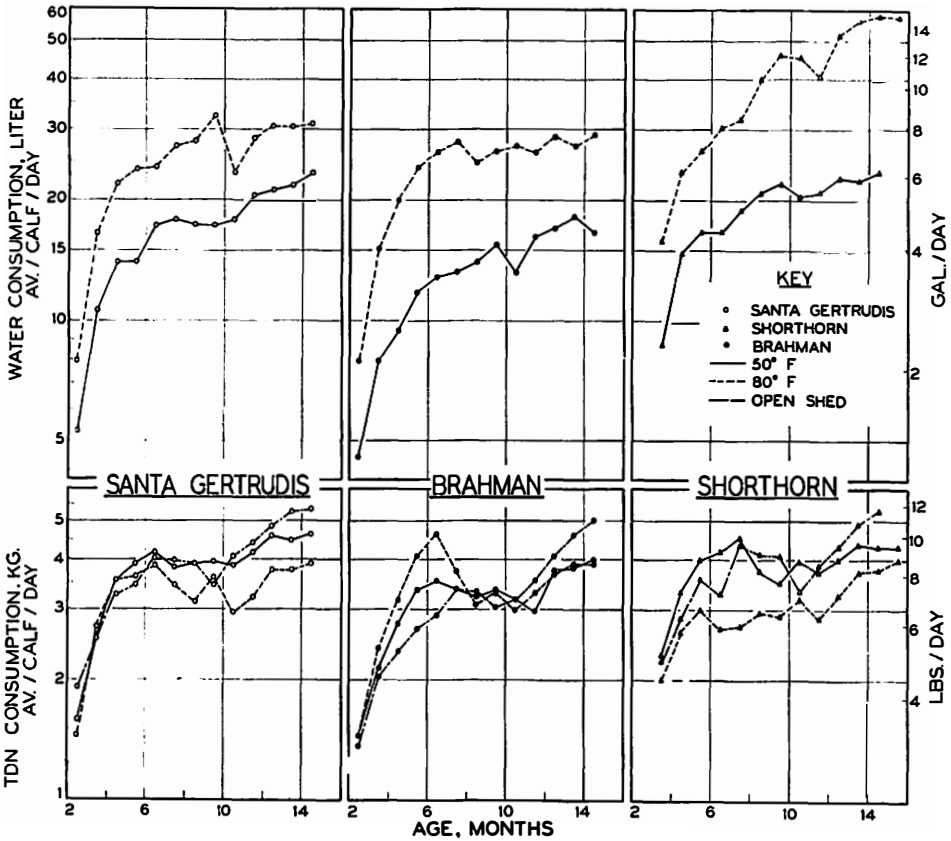

Figure 2—Effects of environmental temperature on TDN and water consumption of the Santa Gertrudis, Brahmans and Shorthorns.

one year of age. There was a greater relative rate of increase in water consumption of 80° F Shorthorns than 50° F Shorthorns.

The lower part of Figure 2 shows the TDN consumption per calf was much greater in the Shorthorns at 50° F and open shed than at 80° F—approximately 20 percent throughout most of the experiment. Somewhat less difference was observed between the Santa Gertrudis in open shed and 50° F groups, compared with the 80° F animals. The Brahman had a higher TDN consumption at 80° than at 50° F until eight months of age, but later no distinct difference was observed.

An analysis of variance (Table 5) was computed for the TDN consumption per day with respect to both age and temperature (50° and 80°F). The age differences for each of the three breeds were highly significant. The temperature contrast was highly significant for the Santa Gertrudis and the Shorthorn; how-

TABLE 5--LEVEL OF SIGNIFICANCE OF DIFFERENCE BETWEEN YEARLY MEAN (AGE 4-16 MONTHS) OF DAILY TDN CONSUMPTION BY 50° AND 80°F ANIMALS

Breed	Average TDN Consumption/Day		Significance Level of Temperature Variance
	50°F	80°F	
Santa Gertrudis	3.97 kg.	3.46 kg.	1%
Brahman	3.33 kg.	3.51 kg.	not significant
Shorthorn	3.82 kg.	2.95 kg.	1%

ever, for the Brahman cattle there was no significant difference, re-emphasizing their high heat tolerance.

Open shed values may, of course, be influenced by the season. Note that all open shed values are higher at the age of 15 months, compared to the other conditions. The cool fall and winter weather may have affected these values. (See Figure 1 for calendar.)

The Ratio of Water Consumption to TDN Consumption. Figure 3 shows an increase in the ratio of water consumption to TDN consumption with advancing age, a greater ratio occurring at 80° than at 50° F. The ratios of the heat-stressed 80° F Shorthorns increased from about 9 to 16 and were the highest ratios, while the ratios of each of the other two breeds at 80° F increased from about 6 to 8.

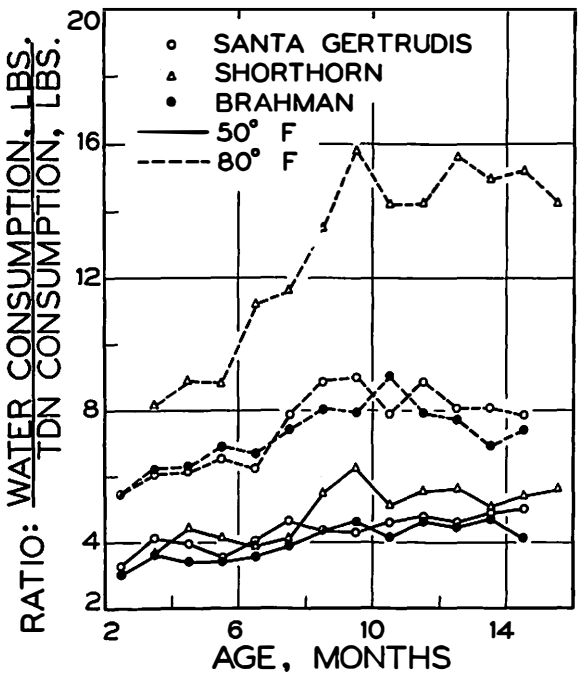

Figure 3—Ratio of water consumption to TDN consumption at 80° and 50° F.

At 50° F (solid lines) the ratios of all breeds increased from about 4 to 5, with the Shorthorns' ratios somewhat higher than those of the Brahmans and Santa Gertrudis. What was the significance of this increasing trend with age? Perhaps it was due to an increasing percentage of roughage to grain with age. The difference between the 50° and 80° F ratios was due to the increased water consumption and decreased feed consumption with increasing temperature.

Water Consumption and TDN Consumption Per Unit Body Weight. A general phenomenon among homeotherms is that metabolic rate per unit weight decreases with increasing body size. Thus, one may well expect a decrease in TDN and water consumption with increasing body weight. Figure 4 indicates that all breeds at each of the experimental temperatures showed this typical decline. The 80° F Shorthorns, while showing the trend, leveled off at a higher ratio because their attained weight was considerably lower than that of either the 80° F Santa Gertrudis or 80° F Brahmans.

The TDN per unit of body weight of the Santa Gertrudis and Brahmans at 50° F, 80° F, and open shed were about the same. However, after eight months of age the TDN per unit weight of Santa Gertrudis and Brahmans was higher at 50° F while for the Shorthorns, it was much higher at 80° F than at 50° F.

Shorthorns at both 80° and 50° F had a higher water consumption per unit body weight than either the Brahmans or Santa Gertrudis. At 80° F the water consumption per unit body weight for the Shorthorns was two to three times as high as that of the other two breeds. These data suggest that the ratio of water consumption per unit body weight under controlled experimental conditions may be an expression of heat tolerance, a low value expressing a high heat tolerance.

The lower section of Figure 4 generally indicates that the Shorthorns at 50° F, 80° F, and open shed had the highest TDN consumption per unit body weight of the three breeds. This fact was very evident at 80° F and it calls our attention to the possibility that high TDN consumption per unit body weight may be associated with intolerance to heat. Kibler's (1957) data on these animals showed that the Shorthorns also had highest values of heat production per unit body weight, Santa Gertrudis had intermediate values, and Brahmans had the lowest. Correlations between TDN consumption, heat production, and other measures will be made at a later date.

Relationship of Water and TDN Consumption Per Unit of Daily Weight Gain. Water consumption per unit of daily weight gain definitely increased with age as shown in Figure 5. The calves thus required more water for each unit of weight gain as they approached maturity. That the Shorthorns had the highest water requirement per unit of weight gain of the three breeds is in agreement with the water consumption data (Figure 4).

The TDN consumption per unit of weight gain in all experimental groups (50° F, 80° F, and open shed) followed the same trend as the water consumption per unit weight gain. However, the TDN consumption per unit of weight

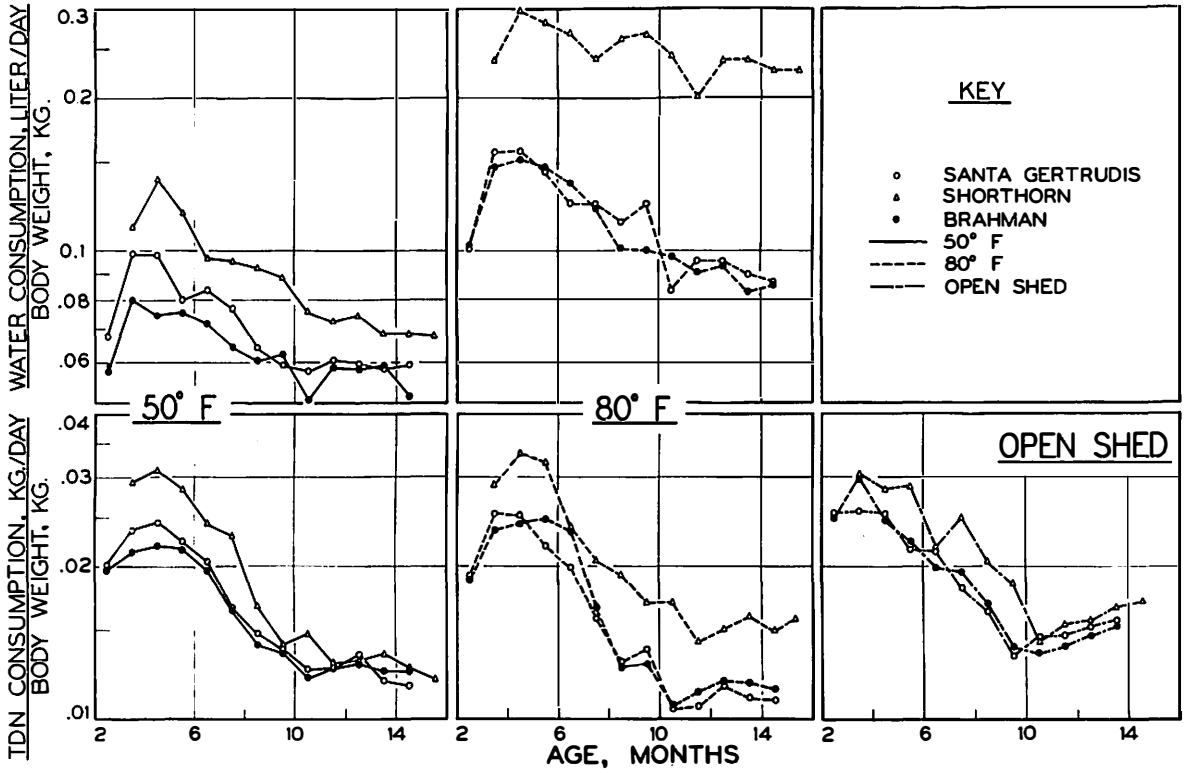

Figure 4—Age and temperature effects on TDN and water consumption expressed per unit body weight.

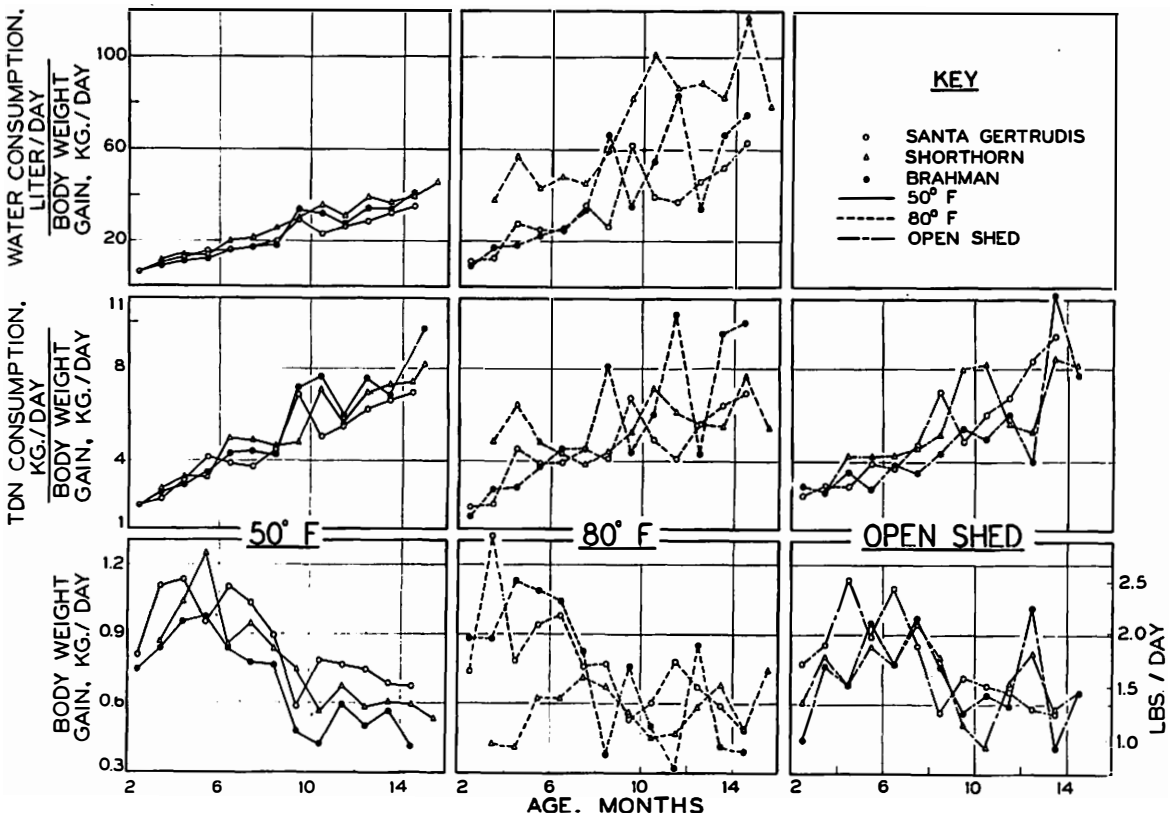

Figure 5—TDN and water consumption expressed per unit body weight gain.

gain increased much less with increasing age for the Shorthorns than for the other breeds at 80° F. From 3 to 6 months of age the 80° F Shorthorns consumed more TDN per unit of weight gain than the other breeds, although the daily weight gain of the Shorthorns was much less during this period.

When the variance of the ratio of TDN consumption per gain in body weight was analyzed, the increase due to age was highly significant for the Santa Gertrudis and significant for the Brahmans and the Shorthorns. However, no significant difference between the two temperature groups was determined for any breed.

These data do not suggest that temperature has no influence on efficiency of gain under all experimental conditions. The relatively long-term acclimation (growth) at a moderately high temperature (80°F) also resulted in less 50° and 80° F difference in other physiological responses than observed when animals were exposed progressively (short term) to higher environmental temperatures (Ragsdale, *et al.,* 1949).

This slower growth and depressed TDN consumption of the animals at 80° F as compared to 50° F is a dual compensatory response to the heat stress. Thus, the ratio may change little; however, there was an enormous difference in body weight gains (Figure 1).

These data emphasize the concept that under controlled environmental conditions the cost of growth (TDN/unit of weight gain) becomes higher. Specifically, as the rate of daily gain in body weight declined with advancing age (approaching maturity), the maintenance factor increased. For more details on growth rate see Ragsdale, *et al.,* 1957.

Logarithmic Relationship of TDN and Water Consumption vs. Body Weight. Feed and water consumption increased with various powers of body weight in this logarithmic plot (Figure 6). Due to the complexity of growth, TDN consumption did not increase with one fixed power of body weight—such as ¾ power as suggested by Kleiber (1933) for several species of mature animals. The TDN consumption (Figure 6), with the exception of 80° F Shorthorns, generally increased with a 0.7 to 1.2 power of body weight or higher until approximately 200 kg. of body weight was obtained. Thereafter the rate of increase was considerably less (.33 to .44). The completely different response of the 80° F Shorthorns as compared to the Santa Gertrudis and Brahmans and to all the animals in the 50° F room should be noted. Even though the TDN consumption was high for the Shorthorns up to a body weight of 200 kg., the Shorthorns made the poorest gains (see Figure 5) during this period (3 to 6 months).

After the eighth month of the experiment it became necessary to reduce the quantity of grain that was fed to the animals. This is indicated in Figure 6 as the point where all regression lines are broken. The change in slope of the regression lines may be due to a shift in the quality of the ration or possibly due to a normal growth trend.

This same trend was generally indicated by the water consumption (upper curves) at both 50° and 80° F conditions. For this particular chart, the water

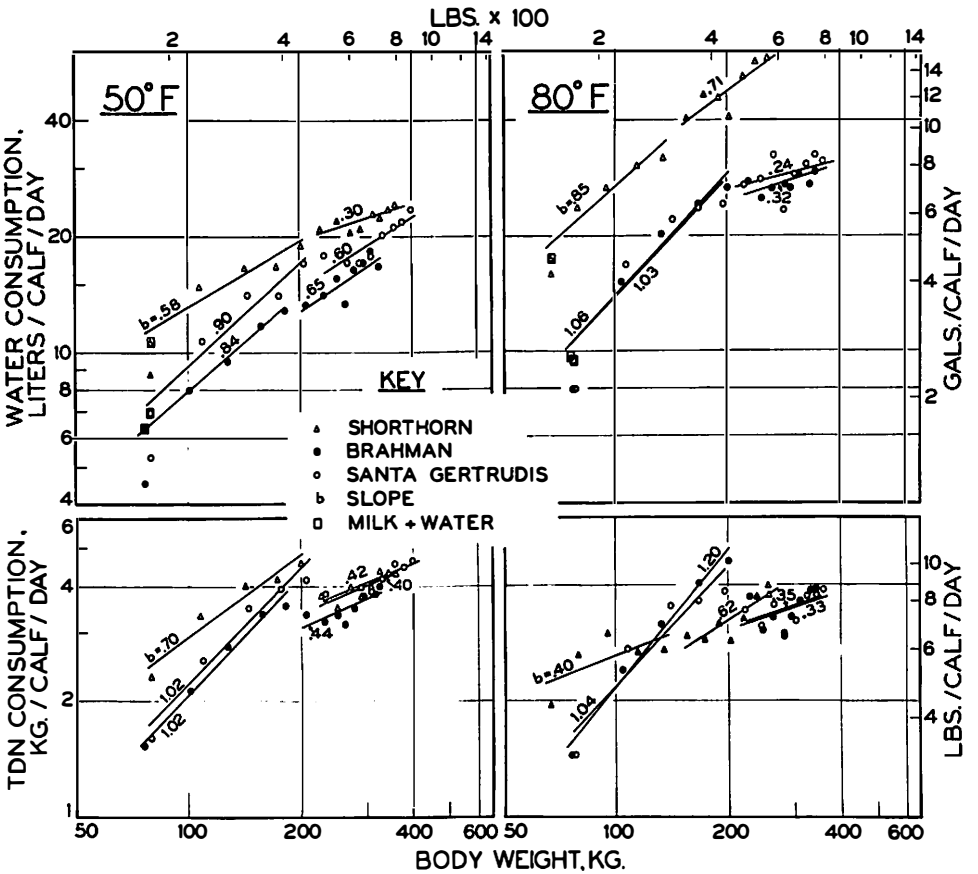

Figure 6—Logarithmic relationship of TDN and water consumption vs. body weight. Each datum point represents an average of 30 daily records from a pen of three calves. The regression lines were calculated from these average values.

content of milk (approximately 87%) given the calves until two to three months of age was added to the water consumption. These points (square symbols on the chart), rather than the water data points included for comparison, were used in determining the regression lines. The regression lines for water consumption with respect to body weight are also broken at the point of grain reduction.

To further interpret the logarithmic plot (Figure 6), the ratios of hay and grain consumption with respect to age at 50° and 80° F temperatures are shown in Figure 6a. The ratio was low (less than 1 lb. of hay per lb. of grain) and remained nearly constant until shortly after 7 months of age. This was the period during which *both* hay and grain were fed *ad libitum.* After this period, when the grain ration was reduced to a fixed amount (6 lbs./calf/day), the ratio of hay to

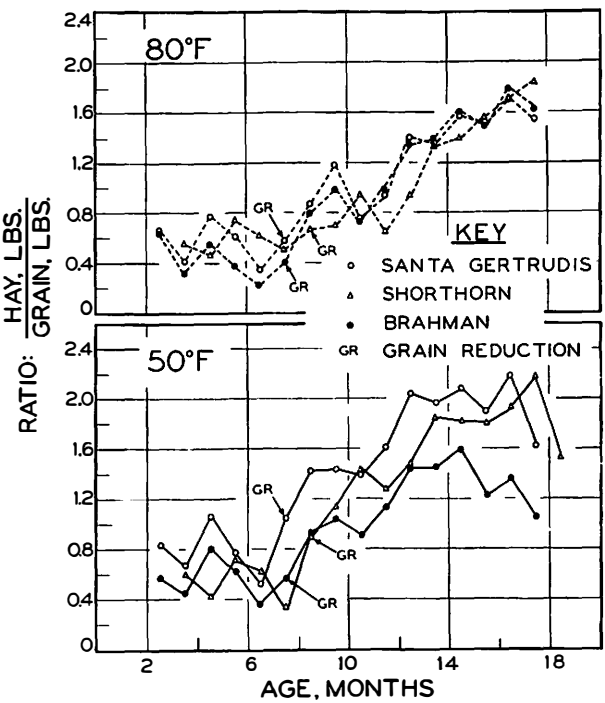

Figure 6a—Ratio of hay consumed to grain consumed at 50° and 80° F. (See Appendix, Table 9, for actual hay and grain data).

grain consumption began to increase rather markedly with age. The increased ratio would then be due to increased hay consumption only. It is interesting to note that at 50° F the ratio after 7 months of age was greatest for Santa Gertrudis, but at 80° F all three breeds had about the same ratio of hay to grain. The Shorthorns and Santa Gertrudis over 7 months of age consumed more hay at 50° F than at 80° F, but the Brahmans consumed as much at 80° as at 50° F.

TDN and Water Consumption vs. Unit Surface Area. Figure 7 presents the relationship of feed and water consumption to the measured surface area of the animals at different ages. At approximately six months of age all breeds at all conditions (50° F, 80° F, and open shed) had the highest water and feed consumption per unit of surface area. As in previous relationships of TDN and water consumption with age and body weight, the Shorthorns had the highest values, Santa Gertrudis next, and the Brahmans the lowest. These growing calves showed the highest water and TDN consumption levels per unit surface area at five to six months. This observation is in excellent agreement with their heat production per unit surface area at five to six months (Kibler, 1957).

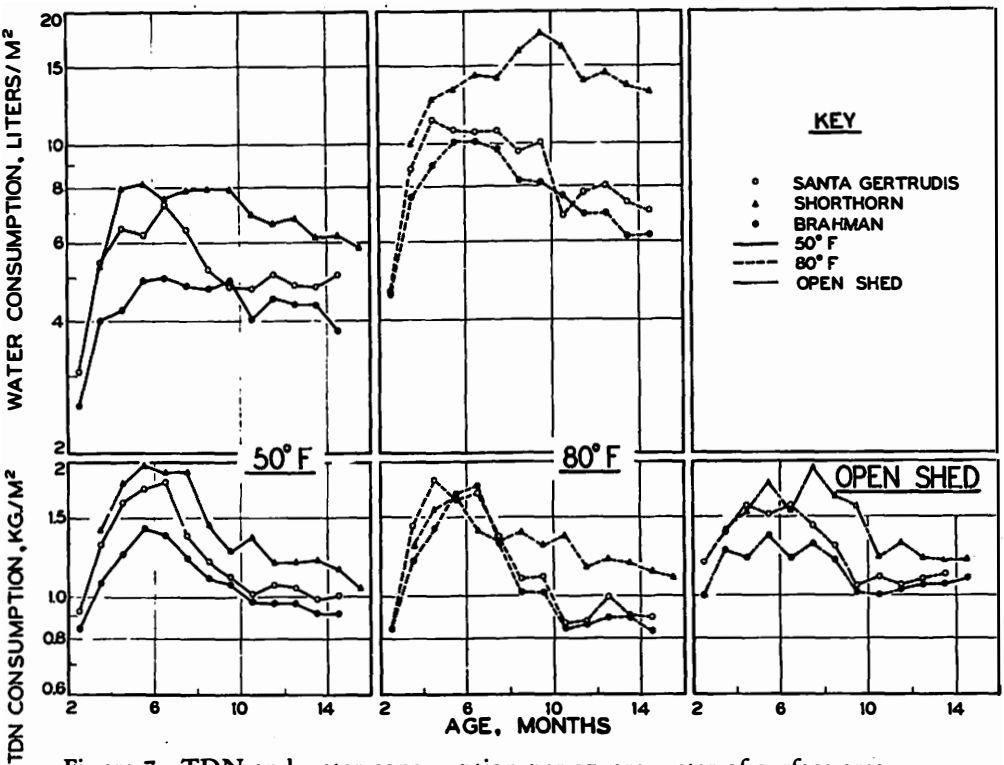

Figure 7—TDN and water consumption per square meter of surface area.

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

Day and Night Water Consumption. At both 50° and 80° F the day (6 a.m. to 6 p.m.) water consumption was two to three times as great as the night (6 p.m. to 6 a.m.) water consumption (Figure 8). This definite rhythm in daily water consumption may be inherent or may be associated with illumination. Each test room had six 200-watt incandescent lamps that were on from 5 a.m. to 6 p.m. and off at night, leaving only one 40-watt incandescent lamp which was on during both day and night.

Both the 50° and 80° F growing calves (all breeds) drank two to three times as much during the day as at night. This quantitative difference in water consumption persisted with advancing age.

In summary, the data expressed a very definite daily rhythm in water consumption when animals were under constant temperature conditions—a rhythm that may be inherent or may be associated with feeding and other managerial rhythms.

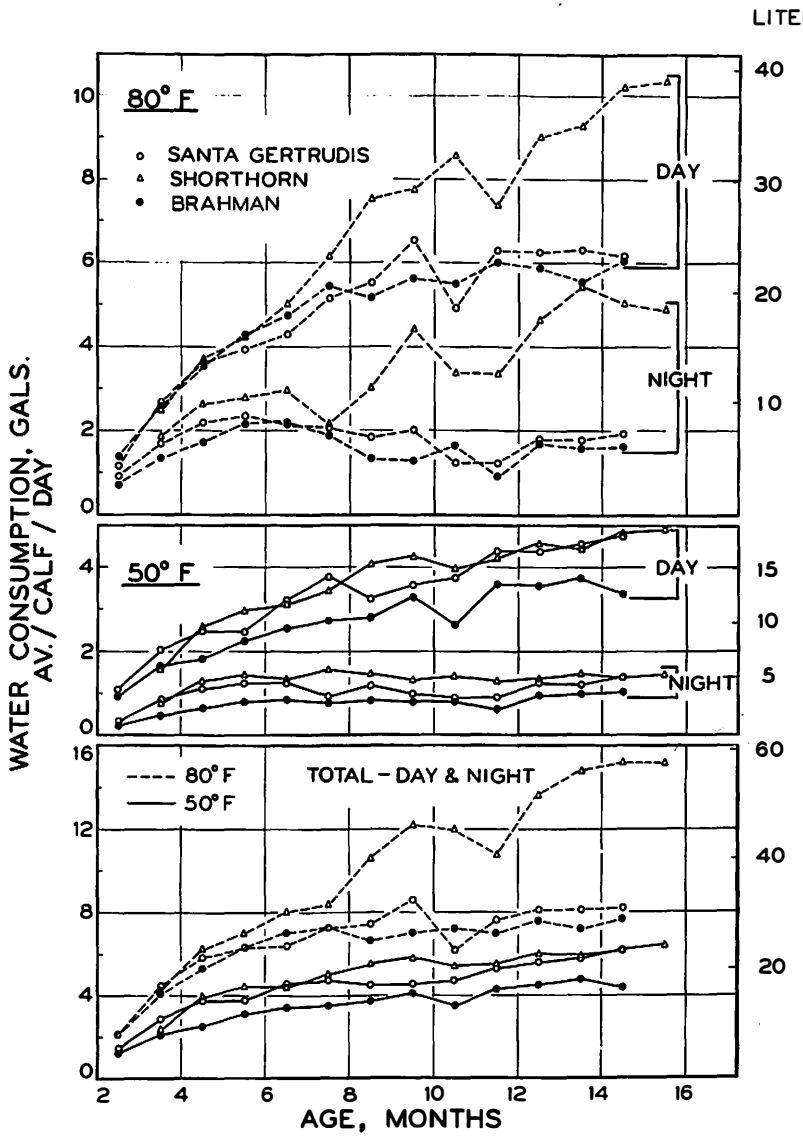

Figure 8—Day water consumption, night water consumption, and total water consumption at 80° and 50° F.

Frequency of Water Consumption. The frequency of water consumption followed the same pattern as the quantity of water consumed at 50° and 80° F; that is, a greater number of drinks during the day than during the night (See Figure 9). It was somewhat surprising to see that those Shorthorns which consumed the most water during the 24 hours had the least difference between their

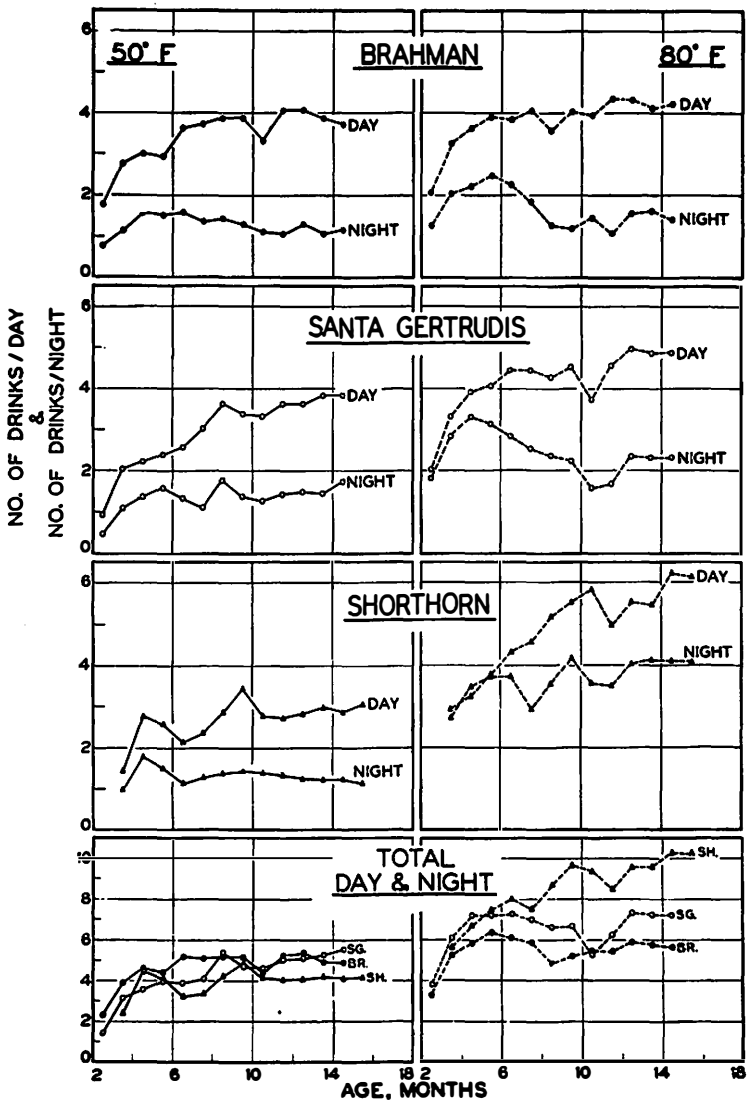

Figure 9—Frequency of water consumption at 80° and 50° F. The upper three sections show the number of drinks per day and the number of drinks per night. The lower section shows the total (24-hour) frequency.

day and night frequency, while the Brahmans and Santa Gertrudis drank relatively more frequently during the day than at night. At 50° F the breeds drank with approximately the same frequency during the day but at 80° F the heat-stressed Shorthorns drank far more frequently than the Santa Gertrudis or Brahmans. At 80° F the Brahman calves, which had the greatest apparent heat tolerance, drank less water and less frequently than the other breeds. Of the three breeds the Shorthorns showed the greatest 80°-50° F difference in frequency of drinks, a fact which may be associated with heat intolerance.

The lower section of Figure 9 shows the total frequency of drinks for each breed at both 50° and 80° F.

Effects of Varying Temperature on Feed and Water Consumption, Body Weight Gain, and Rectal Temperature at the Conclusion of the Growth Experiment.

At the conclusion of the growth experiment, the heifers raised at the two different environmental temperatures were exposed progressively to various higher temperatures within the range of 65° to 110° F. Various other physiological measurements were made as well as the following: body weight, water consumption, TDN consumption, and rectal temperature. These data are presented in Figures 10 and 11.

This series of tests provided additional data on the three breeds for further interpretation of the various breed reactions to environmental temperature.

Rectal Temperature. The rectal temperature data shown in Figure 10 were obtained before the 6 a.m. feeding. The environmental temperature was lowered during the night (see lower section, Figures 10 and 11) at the high ambient temperatures of 100° F and above. Therefore, the morning rectal temperatures did not reflect the maximum environmental heat stresses. Rectal temperature measurements for afternoon conditions were reported by Kibler, 1957.

The rectal temperatures of the Brahman heifers reared at 80° F were the least affected by the varying environmental temperatures; there was little rise in rectal temperature, even at 105° F. However, the rectal temperatures of the 50° F-reared Brahman heifers increased about 0.8 F° at 105° F, compared with the 65° F environmental temperature which produced an average rectal temperature of 101.0° F.

The Santa Gertrudis showed a moderate increase in rectal temperatures as the environmental temperature increased. The rectal temperatures of the 50° F-reared heifers averaged about 0.2° F lower than the temperature of those reared at 80° F. At 105° F both groups of animals had average daily rectal temperatures of 102.7° F.

The Shorthorns were affected most by the higher environmental temperatures. The Shorthorns raised at 50° F, when exposed to 65° F conditions, averaged 101.4° F rectal temperatures and the 80° F-reared Shorthorns averaged 102.5° F. Indeed, the Shorthorns' rectal temperatures did not return to normal even

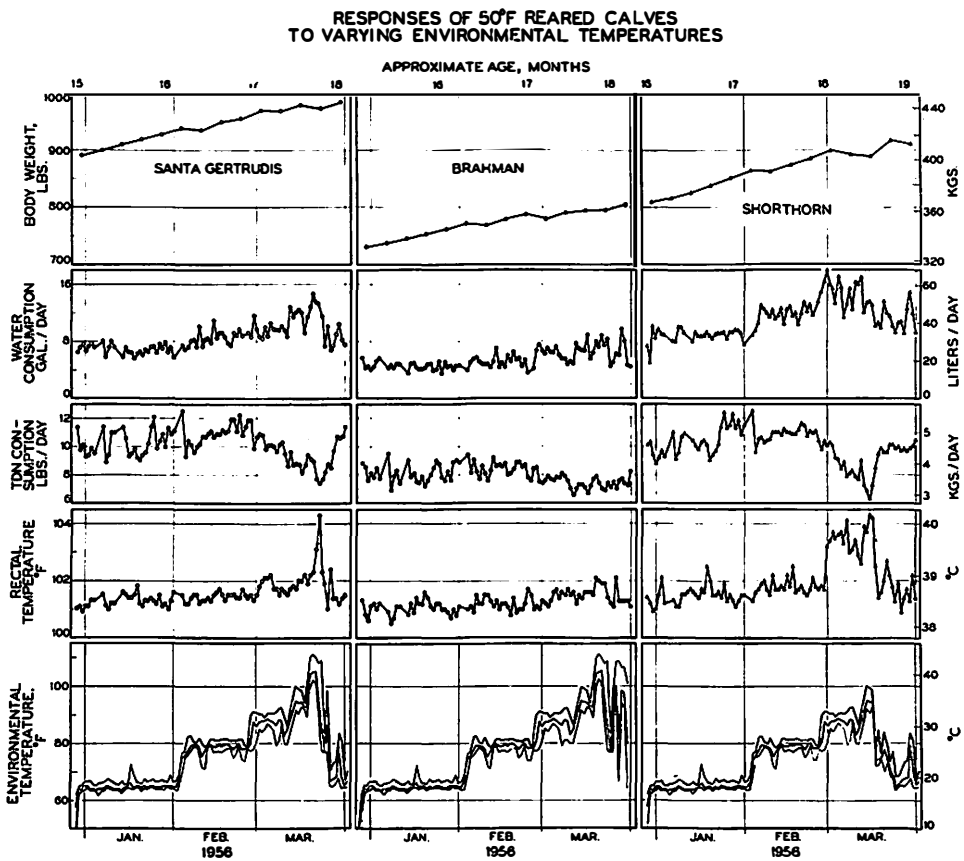

Figure 10—Curves showing the effects of varying environmental temperatures on the calves reared at 50° F. The environmental temperature curves (lower section) show the maximum temperature (top curve), average temperature (middle curve), and minimum temperature (lower curve).

after 5 weeks exposure to 65° F. When the environmental temperature was increased to 90° F the 50° F-reared Shorthorns had a rise in rectal temperature of 2° F (from 101.4° to 103.4° F), while the 80° F-reared Shorthorns showed an increase in rectal temperature of 1.6° F (from 102.5° to 104.1° F).

TDN Consumption. At an environmental temperature of 65° F the daily TDN consumption of the 80° F-reared Santa Gertrudis, Brahman, and Shorthorn heifers was 9.3, 9.4, and 10.1 pounds per day, respectively. There was a noticeable decline in TDN consumption with increase in temperature above 90° F by the Santa Gertrudis and the Brahmans. At 105° F the TDN consumption of both these breeds decreased about one pound per day.

The TDN consumption of the heifers reared at 50° F decreased as the tem-

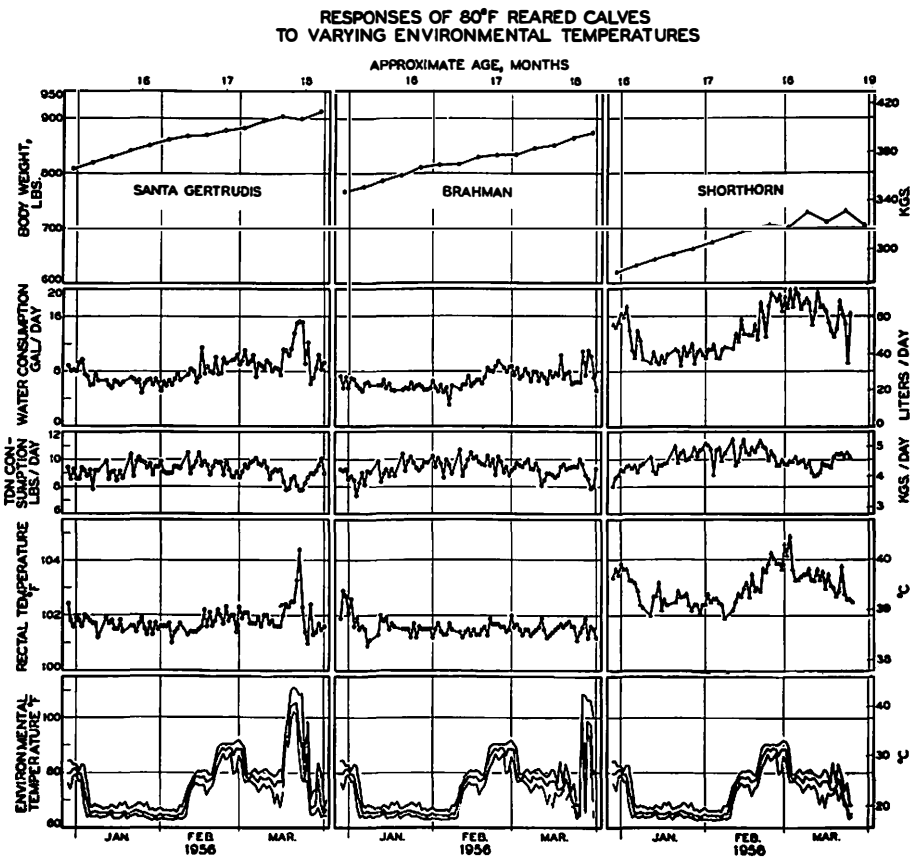

Figure 11—Curves showing the effects of varying environmental temperatures on the calves reared at 80° F. The environmental temperature curves (lower section) show the maximum temperature (top curve), average temperature (middle curve), and minimum temperature (lower curve).

perature increased. At 65° F, the Santa Gertrudis had an average TDN consumption of 10.2 pounds per day which decreased to 8.4 pounds per day when the environmental temperature increased to 105° F. The TDN consumption of the Brahmans also decreased from 8.1 pounds per day at 65° F to 7.4 pounds per day at 105° F. The Shorthorns were apparently affected most by the high temperatures. Their TDN consumption at 65° F was 10.4 pounds per day and at 90° F dropped to 8.7 pounds per day.

In general, the TDN consumption of the animals which were raised at 50° F was affected more by the higher temperatures than that of the animals raised at 80° F.

Water Consumption. The 50° and 80° F Santa Gertrudis increased water

intake at about the same rates when exposed progressively to the 65°, 80°, 90°, and 105° F temperatures. The rate of increase in water intake of the Brahmans and the Shorthorns, however, was greater for the 80° F animals than for those raised at 50° F when subjected to these same temperatures. In accordance with observations from the growth studies, Shorthorns drank the most water at all temperatures, the Santa Gertrudis, next most and the Brahmans, least.

Both the 50° and 80° F Shorthorns drank more water than the other breeds which may have been due partially to the higher body temperature and resultant increase in vaporization (Kibler, 1957). The water consumption of the Shorthorns reared at 80° F increased from 10.8 gallons per day at 65° F to 17.8 gallons per day at 90° F. The water consumption of the 50° F reared Shorthorns was 8.9 gallons per day at 65° F and 14.6 gallons per day at 90° F.

Both the 50° and 80° F Brahmans and Santa Gertrudis made less striking increases in water consumption.

Body Weight. Since the duration of exposure to these changing temperatures was variable (5 weeks at 65° F to 5 days at 105° F), it would not be valid to make a close evaluation of the effects of varying temperature on gain in body weight.

However, the body weight gains of all the heifers fluctuated with the changes in environmental temperature, generally decreasing as the temperature increased. The body weight curves of the 50° and 80° F reared Shorthorns showed a greater depression in body weight gains at 90° F than the Brahmans and Santa Gertrudis.

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APPENDIX

TABLE 6--WATER CONSUMPTION (GALS/CALF/DAY) OF SANTA GERTRUDIS, BRAHMAN, AND SHORTHORN CALVES REARED AT CONSTANT ENVIRONMENTAL TEMPERATURES OF 50° AND 80°F

Age (Months)	50°F			80°F		
	Santa Gertrudis	Brahman	Shorthorn	Santa Gertrudis	Brahman	Shorthorn
1-2	--	--	--	--	--	---
2-3	1.4 (1.8)*	1.2 (1.7)*	--	2.1 (2.5)*	2.1 (2.5)*	---
3-4	2.8	2.1	2.3 (2.8)*	4.4	4.0	4.2 (4.6)*
4-5	3.7	2.5	3.9	5.8	5.3	6.2
5-6	3.7	3.1	4.4	6.3	6.4	7.0
6-7	4.5	3.4	4.4	6.4	7.0	8.0
7-8	4.7	3.5	5.0	7.2	7.3	8.4
8-9	4.5	3.7	5.5	7.4	6.6	10.6
9-10	4.5	4.1	5.8	8.6	7.0	12.2
10-11	4.7	3.5	5.4	6.2	7.2	10.0
11-12	5.3	4.3	5.5	7.6	7.0	10.8
12-13	5.6	4.5	6.0	8.1	7.6	13.6
13-14	5.8	4.8	5.9	8.1	7.2	14.8
14-15	6.2	4.4	6.2	8.2	7.7	15.2
15-16	6.4	4.6	6.4	6.9	6.5	15.2

*Includes water content of milk.

TABLE 7--DAY AND NIGHT WATER CONSUMPTION (GALS/CALF/DAY) AND NUMBER OF DRINKS (AV/CALF/DAY) OF SANTA GERTRUDIS, BRAHMAN, AND SHORTHORN CALVES REARED AT CONSTANT ENVIRONMENTAL TEMPERATURES OF 50° AND 80°F

Age (Months)	50°F						80°F					
	Santa Gertrudis		Brahman		Shorthorn		Santa Gertrudis		Brahman		Shorthorn	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
	Water Consumption, gals.											
2-3	1.08	0.32	0.95	0.25	---	---	1.16	0.93	1.39	0.74	---	---
3-4	2.01	0.83	1.64	0.47	1.56	0.80	2.66	1.71	2.61	1.37	2.50	1.86
4-5	2.53	1.11	1.03	0.66	2.60	1.29	3.59	2.22	3.58	1.74	3.66	2.63
5-6	2.48	1.24	2.25	0.81	2.96	1.42	3.95	2.35	4.31	2.17	4.27	2.76
6-7	3.20	1.26	2.56	0.85	3.13	1.31	4.30	2.13	4.78	2.21	5.04	2.94
7-8	3.79	0.92	2.73	0.80	3.43	1.56	5.16	2.08	5.46	1.88	6.17	2.17
8-9	3.29	1.19	2.82	0.85	4.07	1.46	5.51	1.85	5.19	1.35	7.54	3.02
9-10	3.55	0.99	3.26	0.84	4.26	1.32	6.55	2.02	5.67	1.30	7.76	4.42
10-11	3.76	0.89	2.66	0.84	3.96	1.40	4.92	1.24	5.53	1.65	8.58	3.37
11-12	4.39	0.92	3.63	0.65	4.26	1.28	6.31	1.25	6.04	0.93	7.40	3.36
12-13	4.40	1.24	3.58	0.96	4.69	1.34	6.28	1.82	5.91	1.71	9.04	4.65
13-14	4.55	1.21	3.74	1.01	4.43	1.47	6.34	1.80	5.58	1.60	9.31	5.48
14-15	4.78	1.42	3.36	1.04	4.80	1.41	6.20	1.94	6.08	1.64	10.20	5.06
15-16	---	---	---	---	4.90	1.46	---	---	---	---	10.34	4.91
	Number of Drinks											
2-3	0.93	0.47	1.78	0.77	---	---	2.01	1.80	2.06	1.26	---	---
3-4	2.02	1.08	2.77	1.14	1.44	0.98	3.32	2.82	3.27	2.03	2.72	2.94
4-5	2.21	1.36	3.00	1.58	2.77	1.77	3.92	3.30	3.62	2.22	3.48	3.22
5-6	2.39	1.57	2.93	1.52	2.56	1.50	4.08	3.13	3.92	2.48	3.74	3.75
6-7	2.56	1.34	3.61	1.59	2.14	1.12	4.49	2.84	3.86	2.27	4.32	3.72
7-8	3.02	1.10	3.71	1.37	2.35	1.27	4.47	2.52	4.07	1.85	4.57	2.94
8-9	3.61	1.77	3.87	1.43	2.86	1.36	4.29	2.35	3.57	1.29	5.17	3.53
9-10	3.38	1.38	3.88	1.30	3.41	1.42	4.51	2.24	4.06	1.20	5.54	4.17
10-11	3.34	1.28	3.31	1.13	2.78	1.39	3.72	1.58	3.97	1.47	5.81	3.59
11-12	3.64	1.42	4.06	1.08	2.74	1.32	4.56	1.68	4.36	1.08	4.99	3.50
12-13	3.61	1.48	4.06	1.30	2.84	1.24	4.97	2.37	4.34	1.56	5.52	4.04
13-14	3.82	1.45	3.88	1.08	2.98	1.22	4.88	2.34	4.14	1.61	5.46	4.12
14-15	3.84	1.73	3.72	1.19	2.87	1.22	4.89	2.31	4.24	1.41	6.22	4.10
15-16	---	---	---	---	3.04	1.13	---	---	---	---	6.14	4.08

TABLE 8--TDN CONSUMPTION (LBS/CALF/DAY) OF SANTA GERTRUDIS, BRAHMAN, AND SHORTHORN CALVES REARED AT CONSTANT ENVIRONMENTAL TEMPERATURES OF 50°F, 80°F, AND OPEN SHED

Age (Months)	50°F			80°F			Open Shed		
	Santa Gertrudis	Brahman	Shorthorn	Santa Gertrudis	Brahman	Shorthorn	Santa Gertrudis	Brahman	Shorthorn
1-2	--	--	--	--	--	--	--	--	--
2-3	3.5	3.3	--	3.2	3.2	--	4.2	3.1	--
3-4	5.6	4.7	5.1	6.0	5.3	4.3	5.6	4.5	4.9
4-5	7.7	6.1	7.3	7.8	7.0	5.8	7.2	5.2	6.3
5-6	8.6	7.4	8.8	8.0	9.0	6.6	7.6	5.9	7.9
6-7	9.2	7.8	9.2	8.5	10.2	5.9	8.9	6.4	7.2
7-8	8.4	7.4	10.0	7.6	8.2	6.0	8.8	7.4	9.6
8-9	8.6	7.1	8.3	6.9	6.8	6.5	8.6	7.3	9.1
9-10	8.7	7.4	7.7	7.9	7.3	6.4	7.6*	6.7*	9.0
10-11	8.5	7.0	8.7	6.5	6.6	7.0	9.0	7.0	7.4*
11-12	9.2	7.7	8.2	7.1	7.3	6.3	9.7	7.8	8.5
12-13	10.1	8.3	8.8	8.3	8.1	7.2	10.7	9.0	9.5
13-14	9.9	8.4	9.6	8.3	8.6	8.2	11.6	10.1	10.8
14-15	10.2	8.8	9.5	8.6	8.6	8.3	11.7	11.0	11.7
15-16	9.4	7.5	9.5	8.4	8.3	8.8	10.6	--	--
16-17	10.6	8.2	9.5	9.2	9.4	9.2	10.4	--	--
17-18	9.2	7.5	10.6	9.0	9.3	10.2	--	--	--
18-19	--	--	8.9	--	--	9.4	--	--	--

Grain was fed ad libitum until May 7, 1955, when it was reduced to 6 lbs./calf/day (7-8 months in Santa Gertrudis and Brahman, and Shorthorns 8-9 months).

*Calves turned out to pasture lot by shed in daytime.

TABLE 9--GRAIN AND HAY CONSUMPTION (LBS/CALF/DAY) OF SANTA GERTRUDIS, BRAHMAN, AND SHORTHORN CALVES REARED AT CONSTANT ENVIRONMENTAL TEMPERATURES OF 50° AND 80°F

Age (Months)	50°F			80°F		
	Santa Gertrudis	Brahman	Shorthorn	Santa Gertrudis	Brahman	Shorthorn
			Grain, lbs.			
2-3	2.5	2.5	--	2.2	2.4	--
3-4	5.4	5.0	4.3	6.5	6.0	3.7
4-5	5.9	5.5	7.8	7.0	7.0	6.0
5-6	7.7	7.2	8.2	7.8	9.9	6.1
6-7	9.4	8.6	9.0	9.5	12.2	5.7
7-8	6.8	7.3	11.2	7.5	8.8	6.1
8-9	6.0	6.0	7.0	6.0	6.0	6.1
9-10	6.0	6.0	6.0	6.0	6.0	6.0
10-11	6.0	5.9	6.0	5.8	6.0	5.9
11-12	6.0	6.0	6.0	6.0	6.0	6.0
12-13	5.8	5.8	6.0	5.8	5.8	6.0
13-14	5.8	5.8	5.8	5.9	6.0	5.8
14-15	5.8	5.8	5.8	5.7	5.6	5.8
15-16	5.6	5.6	5.8	5.6	5.6	5.8
			Hay, lbs.			
2-3	2.1	1.5	--	1.4	1.6	--
3-4	3.6	2.2	2.6	2.7	1.9	2.1
4-5	6.3	4.4	3.3	5.4	3.8	2.8
5-6	5.9	4.5	5.7	4.8	3.8	4.5
6-7	4.9	3.1	5.5	3.3	2.8	3.5
7-8	7.1	4.1	3.8	4.4	3.6	3.1
8-9	8.5	5.4	6.4	5.2	4.8	4.1
9-10	8.7	6.2	6.8	7.2	6.0	4.2
10-11	8.4	5.4	8.7	4.5	4.6	5.6
11-12	9.7	6.8	7.7	5.6	6.0	3.9
12-13	11.8	8.3	8.9	8.1	7.8	5.7
13-14	11.4	8.4	10.7	8.1	8.5	7.9
14-15	11.7	9.3	10.6	9.0	9.0	8.2
15-16	10.7	6.9	10.6	8.6	8.5	9.1

TABLE 10--BODY WEIGHT (LBS) AND BODY WEIGHT GAIN (LBS/CALF/DAY) OF SANTA GERTRUDIS, BRAHMAN, AND SHORTHORN CALVES REARED AT CONSTANT ENVIRONMENTAL TEMPERATURES OF 50°F, 80°F, AND OPEN SHED

Age (Months)	50°F			80°F			Open Shed		
	Santa Gertrudis	Brahman	Shorthorn	Santa Gertrudis	Brahman	Shorthorn	Santa Gertrudis	Brahman	Shorthorn
	Body Weight, lbs.								
1-2	137	---	---	138	---	---	123	---	---
2-3	175	167	---	169	168	---	165	124	127
3-4	237	220	175	236	228	148	218	153	162
4-5	315	280	235	310	290	175	285	211	222
5-6	385	344	310	366	367	208	353	265	275
6-7	450	400	380	427	438	249	419	322	328
7-8	510	455	438	485	500	293	485	380	385
8-9	586	506	495	539	540	340	530	435	444
9-10	635	548	550	583	576	380	570	480	487
10-11	680	578	596	620	619	415	620	521	519
11-12	730	610	636	664	646	445	664	560	554
12-13	780	646	675	710	681	480	705	613	603
13-14	827	680	715	752	727	520	740	660	650
14-15	873	713	755	790	750	559	---	695	690
15-16	---	---	790	---	---	600	---	---	---
	Body Weight Gain, lbs./calf/day								
1-2	0.87	---	---	0.57	---	---	1.17	---	---
2-3	1.77	1.63	---	1.63	1.93	---	1.70	0.97	1.33
3-4	2.43	1.83	1.90	2.90	1.93	0.93	1.87	1.67	1.77
4-5	2.50	2.10	2.27	1.73	2.50	0.90	2.50	1.50	1.50
5-6	2.10	2.13	2.73	2.07	2.40	1.37	1.97	2.10	1.87
6-7	2.43	1.83	1.87	2.17	2.30	1.37	2.43	1.70	1.70
7-8	2.27	1.70	2.07	1.67	1.80	1.57	1.87	2.13	2.10
8-9	1.97	1.67	1.83	1.70	0.83	1.47	1.23	1.67	1.77
9-10	1.27	1.03	1.63	1.17	1.67	1.23	1.57	1.23	1.13
10-11	1.73	0.93	1.23	1.33	1.10	1.00	1.50	1.40	0.90
11-12	1.67	1.30	1.47	1.73	0.70	1.03	1.43	1.30	1.53
12-13	1.63	1.10	1.27	1.47	1.87	1.27	1.27	2.23	1.80
13-14	1.50	1.23	1.33	1.30	0.90	1.50	1.23	0.90	1.27
14-15	1.47	0.90	1.30	1.07	0.87	1.07	1.07	1.43	1.43
15-16	1.27	1.00	1.17	1.60	1.30	1.63	1.50	---	---

TABLE 11--SURFACE AREA (M^2) OF SANTA GERTRUDIS, BRAHMAN, AND SHORTHORN CALVES REARED AT CONSTANT ENVIRONMENTAL TEMPERATURES OF 50°F, 80°F, AND OPEN SHED

Age (Months)	50°F			80°F			Open Shed		
	Santa Gertrudis	Brahman	Shorthorn	Santa Gertrudis	Brahman	Shorthorn	Santa Gertrudis	Brahman	Shorthorn
1-2	---	---	---	---	---	---	---	---	---
2-3	1.73	1.79	---	1.73	1.73	---	1.61	1.41	---
3-4	1.95	1.99	1.65	1.90	2.00	1.54	1.84	1.62	1.60
4-5	2.15	2.23	1.86	1.95	2.24	1.69	2.06	1.93	1.86
5-6	2.24	2.38	2.04	2.23	2.41	1.80	2.27	1.97	2.00
6-7	2.32	2.58	2.21	2.27	2.63	1.91	2.54	2.38	2.11
7-8	2.78	2.78	2.40	2.56	2.84	2.05	2.79	2.58	2.25
8-9	3.28	2.95	2.63	2.90	3.03	2.14	3.02	2.76	2.47
9-10	3.59	3.17	2.77	3.25	3.25	2.23	3.29	2.98	2.58
10-11	3.78	3.28	2.93	3.43	3.56	2.34	3.71	3.18	2.75
11-12	3.93	3.64	3.15	3.70	3.85	2.47	4.15	3.44	2.95
12-13	4.40	3.92	3.35	3.80	4.12	2.70	4.45	3.85	3.53
13-14	4.58	4.19	3.63	4.18	4.38	3.15	4.70	4.32	4.08
14-15	4.63	4.38	3.75	4.38	4.70	3.33	---	4.58	4.39
15-16	---	---	4.14	---	---	3.63	---	---	---