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LXXII. HEAT AND ACCLIMATION INFLUENCES ON LACTATION OF HOLSTEIN CATTLE

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LXXII. HEAT AND ACCLIMATION INFLUENCES ON LACTATION OF HOLSTEIN CATTLE

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INTRODUCTION

Although it is well known that tropical conditions (Payne and Hancock, 1957) and high environmental temperatures (Ragsdale *et al.*, 1949, 1950, 1951 and Johnson *et al.*, 1962) will lessen the milk production of cattle, it has not been demonstrated under controlled environmental conditions whether, or to what extent, lactating cows acclimate to heat. It has been assumed that lactating Holstein cattle can acclimate to environmental temperatures above 24°C. This implies the gradual attainment of the ability to more efficiently preserve homeothermy and produce milk during a prolonged exposure to heat. Variables of advancing lactation, seasonal changes in temperature, humidity, radiation, feed, water supply, etc., have heretofore prevented valid evaluations of acclimation to temperature.

Findlay (1963a and 1963b) in reviewing results of acclimation research on cattle reported no information on acclimation effects on lactating cattle. However, he reported that Kamal *et al.* (1962) had described some evidences of acclimation in heifers.

The objectives of this experiment were to determine if lactating cattle acclimate in terms of milk production to an environmental temperature of 29°C; to evaluate (or assess) the role of heat tolerance and the level of production in the ability to acclimate; and to measure the time exposure necessary for cattle acclimated at 18°C to partially acclimate or acclimate at 29°C, i.e., the time necessary for the animal to reach a new "stabilized state" or "equilibrium" with the environment. Temperature and acclimation effects on feed, water intake, and body weight will also be reported and related to responses in lactation.

Data on metabolism, cardio-respiratory activities, skin temperature, hair density, and respiratory and total vaporization were published by Kibler *et al.* (1965). Data on thyroid and adrenal functions, and urinary and blood constituents are in preparation for publication by various authors.

Terminology

Throughout this report the term acclimation will refer to compensatory alterations in an animal during maintenance under laboratory conditions which are altered for one stressful parameter as defined by Prosser (1964).

Following the exposure of an animal to an adverse environmental factor such as heat, there is an initial displacement of functions followed by a trend toward acclimation or perhaps partial acclimation depending on the degree of displacement and compensations. Acclimation will be considered in this study as a return to the initial or estimated functional level. After the initial displacement or compensation of a function, this function may reach a "stabilized state" or equilibrium with the thermal environment. This "stabilized state," or a plateau in "heat compensation" functions, may occurr without a return to the initial environmental condition.

By these definitions an animal in a stabilized state of heat compensation is physiologically adjusted to the adverse environment and may be regarded as "partially acclimated" although the animal is different physiologically than the same animal in a less adverse environment. In this report acclimation trends or effects will refer generally to the physiological changes following exposure to the 29°C temperature.

EXPERIMENTAL PROCEDURE

Animals

Ten lactating and two dry Holstein cows were used during the two-year study. The animals were obtained from the Holstein-Jersey Farm where they were maintained under loose housing management practices. The cows housed in one chamber of the Missouri Climatic Laboratory, which provided temperature and humidity control. The same environmental conditions were used for both years (Table 1). The daily milk production per cow when entering the Climatic Laboratory was 53.6 pounds (24.3 kg.) for year 1961-1962, and 48.6 pounds (22.0 kg.) for 1962-1963. The animals were two to three months postparturition at the initiation of the experiment, and ranged from three to six years of age (most were three to four years of age).

Procedures

The animals were exposed for six weeks to an 18°C, 50% relative humidity (R.H.) condition. This temperature is within the temperature range for which cows may express their maximum milk production potential (Ragsdale *et al.,* 1949, 1950, 1951). Following the six-week exposure, the temperature was raised to 29°C, 50% R.H. for nine weeks. This is the temperature that would be tolerated safely for nine weeks by all of the lactating cows in the laboratory. Following the prolonged heat exposure, animals were returned to the 18°C base for five weeks. This procedure established a "normal" 18°C persistency or trend line for each individual animal for comparison with the measured persistency line at 29°C for each function during the heat exposure. Adjustment for persistency was made by averaging the data obtained during the fifth and sixth weeks of exposure at the first (18°C) condition for one point and the data from the third and fourth weeks at the last conditions of 18°C period for the second point. By regressing a line between these points, the expected or predicted lactation and

TABLE 1. ACTUAL ENVIRONMENTAL CONDITIONS FOR ACCLIMATION STUDIES AND TIME OF EXPOSURE.

Date	Number of Weeks	Average D. B. Temperature	Average Relative Humidity, %
12-4-61 to 1-14-62	6	65°F (18.3°C)	54
1-15-62 to 3-18-62	9 9	84°F (28.9°C) 84°F (28.9°C)	50 50
3-19-62 to 4-22-62	5	65°F (18.3°C)	51
12-17-62 to 1-27-63	6	64.8°F (18.2°C)	51.9
1-28-63 to 3-31-63	9	84.3°F (29°C)	49.3
4-2-63 to 5-5-63	5	65.5°F (18.6°C)	51.1

related functions throughout the heat exposure were obtained. With this reversal procedure, each animal was used as its own control.

Daily values were obtained on milk production, feed and water intake, and rectal temperature. Twice weekly values were obtained for body weights.

For purposes of data analysis, the actual values obtained during the exposure to heat were compared to the expected values as determined by the regression analysis. These paired values for each cow and the ten cow averages for each period or week of the heat exposure were tested for significance by the "t" test. The differences for each cow were computed for each week of the heat exposure and then pooled for mean differences for each week. These "t" tests of differences of actual from "expected" production for each cow were useful in interpolating the extent and possible mechanisms of adjustment by the animal during the nine-week heat exposure period.

The overall temperature effect of the nine-week, 29°C conditions was evaluated with covariance analysis by testing for significance of difference between the adjusted means at 18°C and 29°C. The magnitude of the acclimation trend was determined by observing the significance of the difference of the regression coefficients for 18°C and 29°C by this covariant procedure (Snedecor, 1957).

Feeding Program

A complete ration was fed consisting of 45% grain, 50% hay and 5% molasses. The use of a complete ration eliminated a changing ratio of the grain to hay at a higher temperature and throughout the heat exposure period due to the animals having different preferences for the various feed constituents at different temperatures. Animals at all times were fed *ad libitum,* and salt was available. For ration composition and proximate analysis, see Table 2. Feed and re-

TABLE 2. RATION COMPOSITION

45% Grain

900	lbs.	No. 2 Yellow Corn (coarse ground)
360	lbs.	No. 2 Oats (coarse ground)
200	lbs.	Barley (coarse ground)
150	lbs.	Wheat Bran
150	lbs.	Soybean Meal (44%)
100	lbs.	Dehydrated Alfalfa (17%)
100	lbs.	Cane (blackstrap) Molasses
25	lbs.	Iodized Trace Mineralized Salt
15	lbs.	Dicalcium Phosphate
2000	lbs.	(907.2 kg.)

50% Alfalfa Hay (coarse ground, 1/2 to 1" by hammermill)

5% Molasses

100% TOTAL

Proximate Percent Analysis on Content of Complete Rations

Water	N	Ether Extract	Crude Fiber	Ash	Na	K
11.187	2.443	1.922	18.689	7.433	0.398	1.971

Note: Proximate percent analyses were perfomed by Dr. C. W. Gehrke, Experiment Station Chemical Laboratories, University of Missouri, Columbia.

fused feed were weighed twice daily for each animal. Water was also available *ad libitum* and individual daily frequency of drinking and volume was recorded.

Milk Analysis

Cows were milked at 12-hour intervals and milk was recorded to the nearest tenth of a pound for each milking. Individual consecutive samples of milk (two morning and two evening samples) were collected from each cow at 6:00 a.m. and 6:00 p.m. to provide four samples per week on each cow.

Fat percentage was determined on individual samples by Babcock test and total solids by Watson-Taylor Lactometer.

RESULTS

Rectal temperatures, milk production, feed and water consumption, and body weight are shown graphically in Figure 1. The actual weekly values (solid lines) and their expected values (dotted lines) are plotted for the ten lactating cows and the two non-lactating cows for the 18°C periods and 29°C period. These values are listed for lactating cows in Appendix Table 3 with standard error of mean shown in Appendix Table 4. Values for the dry cows are given in Appendix Table 5.

Rectal Temperatures

In assessing the degree of environmental heat stress, the upper section of Figure 1 shows that the rectal temperatures of the cows upon exposure to 29°C were elevated above normal and remained that way for the nine-week period. The "t" test (Appendix Table 6) for differences of actual and expected values showed that the rectal temperatures were significantly elevated each week throughout the heat exposure period.

The extent of acclimation or lowering of body temperature toward the normal expected value as evaluated by determining the difference between the adjusted means at 18°C and at 29°C for the nine-week period was significant (Appendix Table 7). The differences between the regression coefficients at 18°C and 29°C were significant and suggested that the animals were improving their ability to control their body temperature or regulate at an elevated state of hyperthermia. The downward trend in body temperature during the 29°C heat exposure period was significantly different from the 18°C trend and appeared to relate to the similar trend in lactation, and to the downward trends in heat producing and some heat dissipating functions as discussed by Kibler *et al.* (1965).

Milk Production

Heat exposure (Figure 1) caused a sharp decline in lactation or displacement of the level of lactation with minimum values occurring during the second week. There was an apparent partial recovery or stabilization during the third and

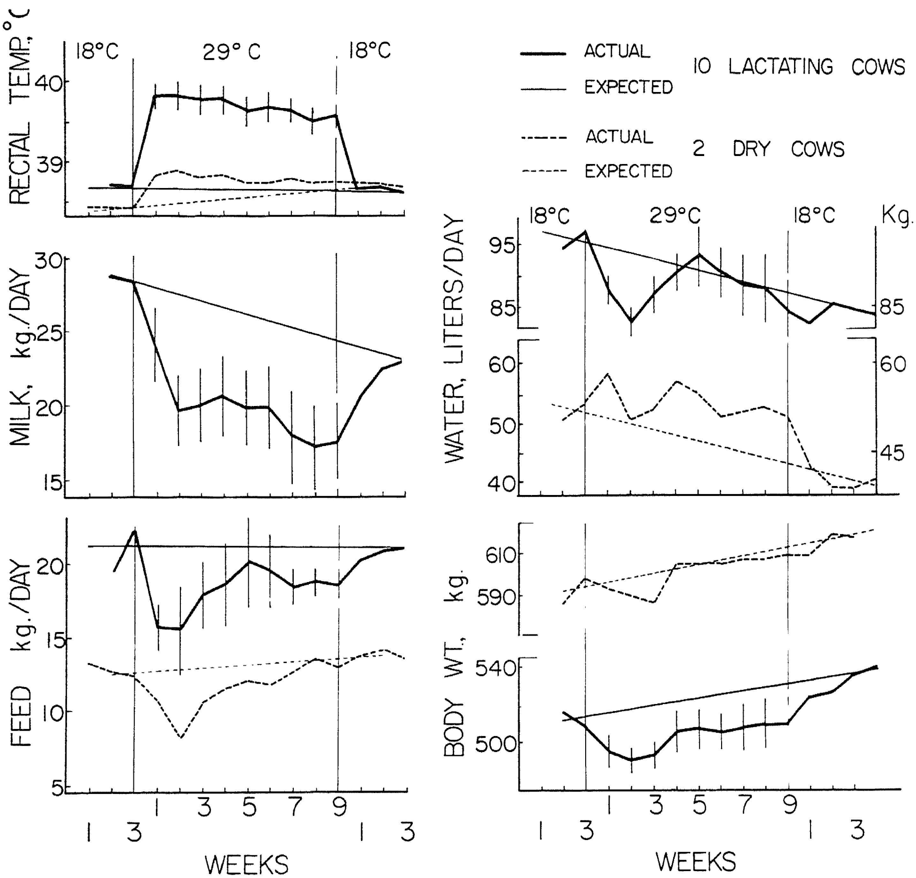

Fig. 1—Actual and expected values for 10 lactating and 2 dry cows at 65°F (18°C) and 84°F (29°C) exposure period. Expected values are based on regression of 18°C values. Each point on the figure is the weekly average of the daily values. Vertical bars represent the standard error of the mean of actual values. The actual values for the 10 lactating cows are also given in Table 5.

fourth weeks with some tendency to decline thereafter. This decline in lactation during the 29°C period resembled the trend or slope in rectal temperature. The differences from expected value in milk production for the whole nine-week period were highly significant (Appendix Table 6). The covariance analysis of differences of adjusted means at 18°C and 29°C for the heat exposure period also showed a highly significant difference or loss in lactation (Appendix Table 7).

The degree of acclimation or trend (coefficient of regression) in lactation (Figure 1 and Appendix Table 7) was not significantly different after the second week of exposure to 29°C. This indicates that the animals reached an equilibrium with the environment and continued to produce milk at a lower level of 2 to 4 kg.

Generally, the lactation by these animals declined in response to the constant 29°C temperature and the sub-normal values paralleled the expected ones after the third and fourth weeks. Full acclimation in milk production was not obtained, but a stabilized state of heat acclimation was achieved indicating considerable physiological adjustment necessary to permit these animals to lactate at this rather substantial level.

Feed Intake

Feed intake declined markedly as did milk production after exposure to the 29°C temperature.

The decline from the expected values for each of the nine-week periods for ten lactating cows was significant (Appendix Table 6 and Figure 1) except for the fifth and sixth weeks. The maximum depression occurred during the second week of exposure and there was a gradual recovery thereafter. The maximal recovery in feed intake was obtained during the fourth and fifth weeks. As shown for milk production, the values tended to decline slightly during the sixth, seventh, eighth and ninth weeks (Figure 1). Feed intake was depressed significantly for the period as a whole (Appendix Tables 6 and 7).

The regression coefficient for feed intake was significant for the period two to five weeks after exposure to heat (Appendix Table 7 and Figure 1). The regression coefficient during the heat exposure period as a whole was not significant as indicated by the "expected" trend and actual trend not being significantly different. This is due undoubtedly to the role of appetite in temperature regulation, as shown by the drastic decline in feed intake during the first and second weeks. (Feed intake at this level was insufficient to maintain lactation and body weight). Feed intake approached recovery during the first five weeks but decreased slightly thereafter. Upon return to 18°C, feed intake increased rapidly as did the lactation.

Water Intake

Water intake in the lactating cows tended to follow the milk production and feed intake curves during the first few weeks of heat exposure (Figure 1 and Appendix Tables 3, 4, 5, and 6). At the fifth week of heat exposure the water intake was at the expected level and milk production was at its highest level. As will be discussed later, the dry cows maintained an elevated water intake throughout the period to replace evaporative losses. Since depressed milk production was not a factor in these dry cows, there was no parallel loss of water in milk formation.

The departure in water consumption from the expected value in the ten lactating cows was not significant for the nine-week period (Appendix Table 6 and 7). However, examination of individual weekly periods shows that the first and second week values at 29°C were significantly lower than expected, and the regression coefficient was significant for the two to five-week period (Appendix Table 7). Following a return to 18°C, water intake increased slightly but not as much as milk yield or feed intake. The reason for this is not clear at present unless some fluid shifts are involved as factors in water balance.

Body Weights

Body weights in the lactating cows (Figure 1 and Appendix Table 6) declined about 20 kg during the heat exposure period, with the exception of the fourth week. These values paralleled very closely the feed and water intake, showing maximal recovery at four to five weeks. However, the body weight compensations were not as great as other measures. Even though most of the body weight loss can be attributed to lowered feed and water intake, apparently some of the body tissues were used for the maintenance of lactation during the first and second weeks. The regression coefficient was not significant. However, as was shown for milk production, the animals reached an equilibrium or "stabilized state" level at four to five weeks. Upon return to 18°C, the body weight rapidly increased.

Efficiency of Feed Conversion to Milk During Heat Exposure Period

The amount of feed required to produce one kilogram of milk was less during the first four weeks of heat exposure (Figure 2). Since the milk quality did

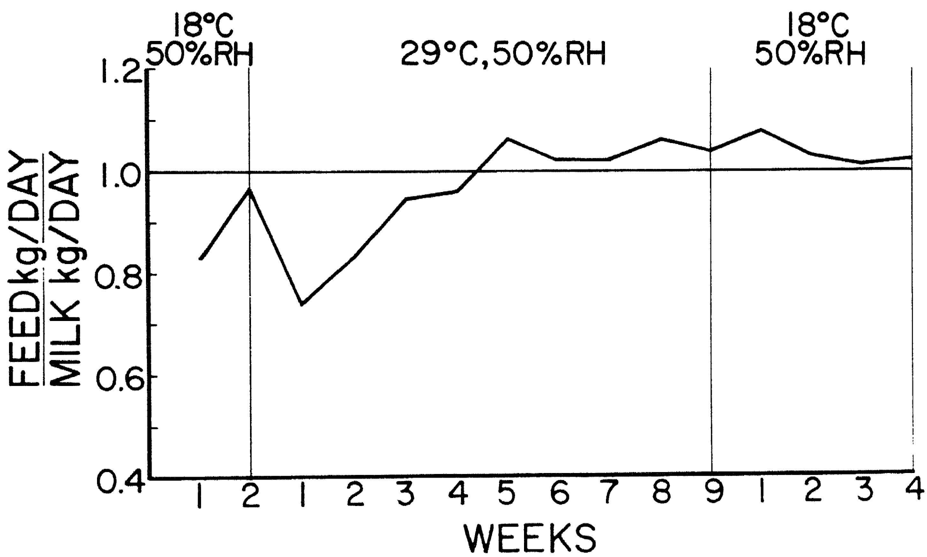

Fig. 2—Kg. of feed required to produce 1 kg. of milk.

not change greatly during this period, this further suggests the use of body tissue for production.

The ratio of kilograms of feed per kilogram of milk at two, five and nine weeks of heat exposure was 0.83, 1.06 and 1.04, indicating a greater efficiency at two weeks. As feed intake recovered to near the initial level after four to five weeks of heat exposure, the efficiency declined to the 18°C values. Thus, during early exposure to heat when the body tissues were apparently utilized for processes of lactation, the apparent efficiency of lactation was high. However, when the body weights were generally stabilized after four to five weeks of heat exposure, the efficiency of conversion of feed to milk was somewhat less than at 18°C.

Comparison of Dry and Lactating Cows

These differences in values for lactating and non-lactating cows (Figure 3 and Appendix Table 8) provide, through graphic presentation, an easier means

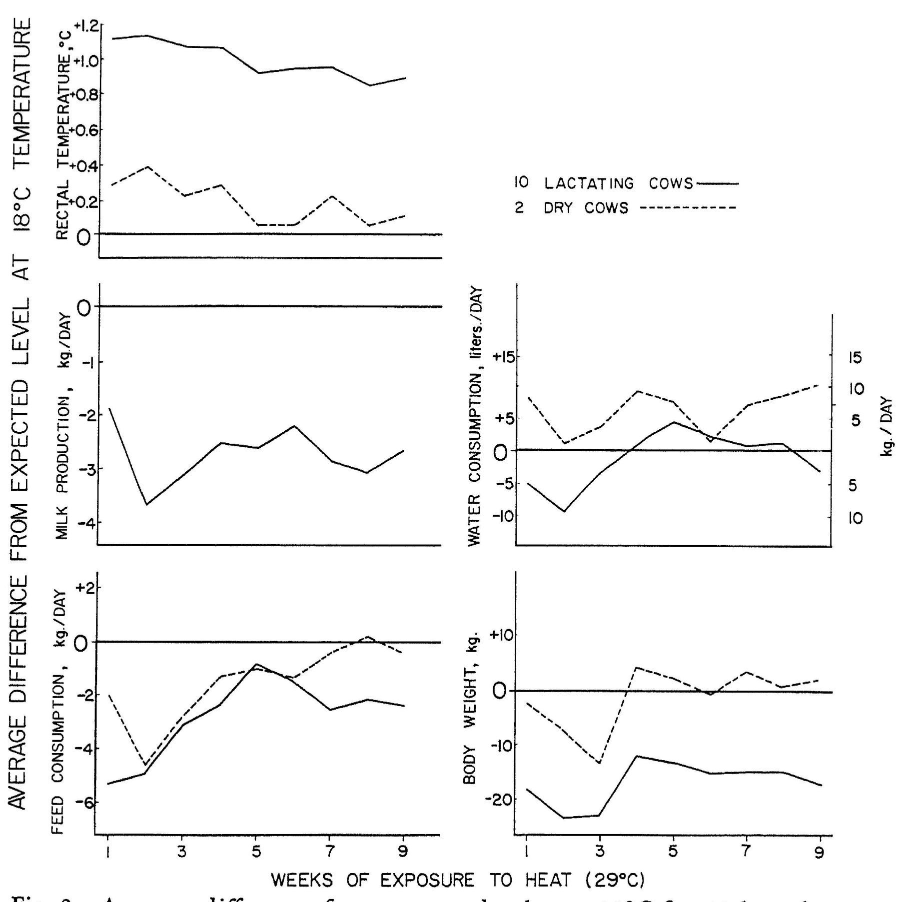

Fig. 3—Average difference from expected value at 18°C for 10 lactating cows and 2 dry cows.

of assessing the degree of physiological adjustment of the various parameters and evaluating the influence of lactation on the degree of compensation or of the various parameters.

The trends in rectal temperature, milk production, feed consumption, water consumption, and body weight for both groups of cows during the nine-week exposure were very similar. However, the departures from the expected values (zero line based on 18°C values) were considerably different. This greater difference from the expected values appeared to be the determining factor in whether the cattle acclimated or only partially acclimated during the nine-week period. For example, rectal temperatures were essentially normal for dry cows after four to five weeks (Figure 3), whereas the values for lactating cows were significantly above normal (Appendix Table 6). Similar observations were made for feed, water intake, and body weight, thereby leading to the conclusion that lactation and related factors prevented full acclimation.

Generally, one may conclude that the major difference in the responses of lactating and non-lactating cattle as suggested in Figure 3 is the magnitude of displacement of the measured function. Further, it may be interpreted that for lactating cows partial acclimation occurred and heat balance or a stabilized state was established at an elevated body temperature. Values for non-lactating animals indicated that acclimation or return to 18°C values was essentially achieved at 29°C after four to five weeks.

Comparisons of Heat Tolerant and Heat Intolerant Cows

The dry cows were also compared to lactating animals that were grouped into heat tolerant and heat intolerant animal groups on the basis of individual differences in rectal temperature responses to the high environmental temperature (Table 9). Figure 4 (upper left) represents the average rectal temperature for the three groups. Lactating heat intolerant cows had the highest elevation in body temperature. The lactating heat tolerant cows ranked next and the dry cows had the least elevation. Figure 4 also shows that milk production was depressed significantly more for the heat intolerant group than for the heat tolerant group as determined by an analysis of variance between the two groups (Appendix Table 10). Likewise, feed intake was lowered for the high rectal temperature group, though not significantly according to analysis of variance. No differences were apparent in water intake and body weight although the heat tolerant and dry cows tended to increase their water intake more at 29°C.

Comparison of High and Low Milk Producers

Again for purposes of comparison, lactating animals were divided into high and low milk production groups. Individuals in these groups were essentially the same as in the heat tolerance groups (Appendix Table 11). The groups were significantly different in their response to heat as evidenced by milk production, water intake, and rectal temperature, though not in feed intake or body weight.

These data suggested that the magnitude of response due to heat exposure

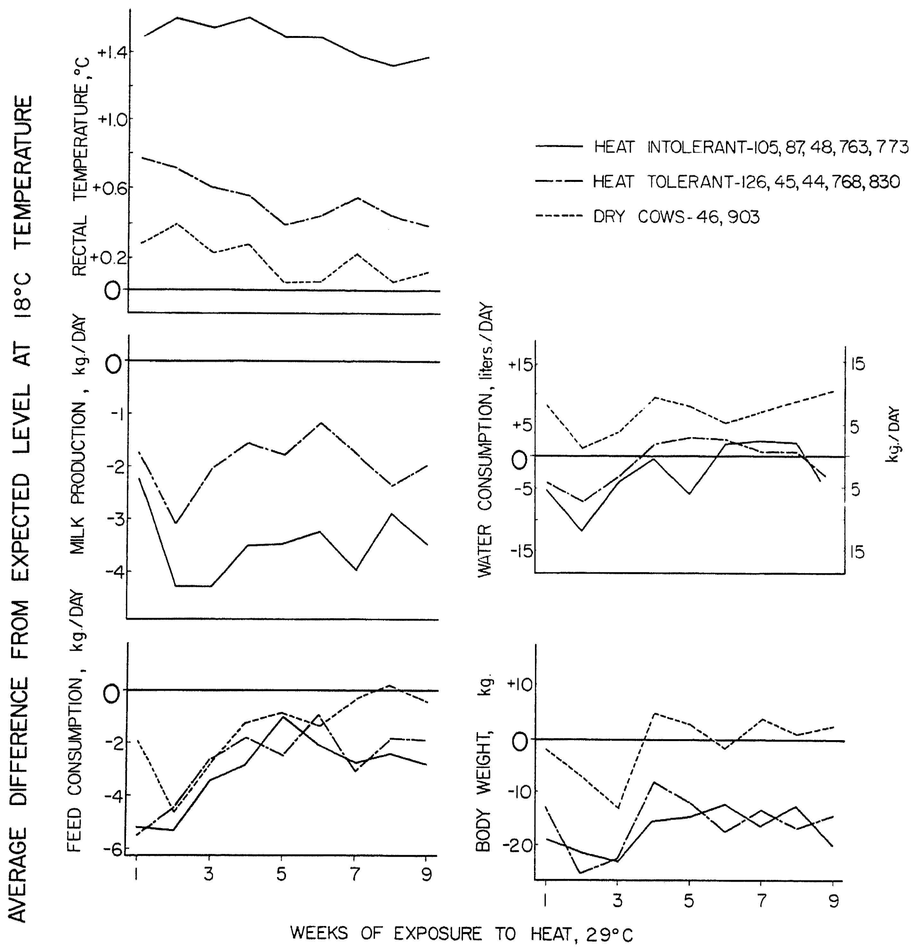

Fig. 4—Average difference from expected value at 18°C level for 10 lactating cows grouped by rectal temperatures as heat tolerant, heat intolerant, and 2 non-lactating cows.

was not significantly different except for the level of milk production. This tends to reemphasize earlier opinions stating that heat tolerant cows can produce more milk on similar amounts of feed. The nine weeks of heat exposure had no pronounced effect on the composition of the milk produced so the data will only be reported in table form (Appendix Table 12). However, there was a gradual increase in the butterfat percentage, specific gravity, and milk solids percentage normally associated with advancing lactation.

Rectal temperature data infer that if this type of experiment were to continue for many weeks with normally declining lactation, perhaps normal body temperatures might be restored eventually. To substantiate this, additional experiments with an exposure for a complete lactation period would be necessary.

Upon return to the 18°C temperature, the level of lactation increased rapidly. It seems that this "equilibrium" or stabilized state attained during the heat exposure must be regarded as "partial" acclimation in terms of lactation. The fact that lactation immediately declined upon exposure of the animals to 29°C and tended to parallel the expected (18°C) decline is evidence of heat compensation. It also indicates that lactation is one of several physiological adjustments whose change permits an animal to maintain a moderate level of lactation and survive under adverse environmental conditions. Theoretically, the animal in such a state is in the stage of resistance to a stressor, according to Selye (1955).

Weekly averages were used for most data evaluation. Tables 13 and 14 show data on the individual cows.

DISCUSSION

Although it was generally interpreted that a stabilized state or an "equilibrium" was attained in most functions of lactating cows, the data of lactating animals during the seventh, eighth, and ninth weeks suggest some lowering of feed intake and lactation. This may suggest a tendency for a deterioration of the stabilized state or lessening of resistance to stress in terms of Selye's Syndrome (Selye, 1955). However, it may be that this is actually not a decline as such but perhaps due to some "overshoot" in production at five to six weeks due to the greater depression at one, two, and three weeks of 29°C exposure.

Although a significant trend is apparent, the animals declined very little in body temperature during the nine weeks, indicating that an approximate thermal equilibrium or stabilization was achieved in milk production, feed intake, and body weight at this hyperthermic state. Acclimation in lactating cows in terms of full recovery to 18°C values was not attained except for water intake. Actually, water intake assumed a state of compensation for vaporization due to the higher temperature (Kibler *et al.,* 1965). Acclimation in terms of stabilizing to the hyperthermic state occurred in **milk production and body weight at ap-**
the hyperthermic state occurred in milk production and body weight at approximately four to five weeks.

Generally, the differences between the regression coefficients for the actual values during the 29°C periods and the expected values during the 18°C periods were not significant, indicating that physiological adjustments had been made between the animal and the environment, and that no trends were occurring that would not have occurred during normal lactation at 18°C. A stabilized state for these functions occurred usually after three weeks or more. This equilibrium attained is "acclimation" or "partial acclimation."

However, a gradual decline occurred in rectal temperatures during the 29°C period which was significantly different from the "expected values", i.e., a significant acclimation trend. Generally, after three to four weeks of exposure, lactating cows stabilized or compensated to the 29°C environmental temperature. This is definitely an excellent display of compensation to heat but when compared with values of 18°C, it may only be considered as "partial acclimation."

Since many functions were changing simultaneously and at undoubtedly differing rates, and since a dynamic steady state was not achieved during a lactation period, it was difficult to estimate when the animals had become "stabilized" or partially acclimated. It would appear, however, from data presented, that maximal recovery at the 29°C temperature occurred in lactation at about three to five weeks, and in body weight at four to five weeks.

Johnston (1958) reported that when animals were gradually exposed to heat (in July), they did not observe an initial drop in production followed by recovery as reported here and in other reports (Johnson, *et al.,* 1962). This slower exposure to heat prevents abrupt disturbance in lactation but the animals obviously must eventually arrive at a production level lower than that observed at a comfort temperature to maintain homeothermy.

The question of the time required for compensation is pertinent here. If lactating animals are exposed for three weeks to a constant temperature of 29°C, when may the animals be regarded as acclimated or to at least have made major changes in most physiological and lactational adjustments? It appears that after three to four weeks of this mild 29°C heat stress, only minor changes occurred. This may indicate that the animals were partially acclimated or in a stabilized state and had by then accomplished most of the adjustment obtainable within a reasonable time.

This investigation has attempted to evaluate the time responses and the adjustments and compensations, i.e., degree of acclimation, that a lactating animal makes to a single environmental variable, such as a high environmental temperature. The magnitude of these responses of course will vary with the degree of heat stress. To quantitate the response to a multitude of environmental variables and combinations to which an animal may be subjected, at various seasons in various geographic regions and different years, requires further study.

SUMMARY

Lactating cattle continuously exposed to a constant (29°C) environmental temperature showed evidence of partial acclimation or compensation to a stabilized state in milk production at three to five weeks. This may be interpreted as the establishment of a stabilized state following compensation to heat at the 29°C environment, at a level below the animal's potential for milk production at 18°C. More complete recovery in feed intake was achieved at four to five weeks although full recovery or acclimation was not demonstrated. The cow's water intake appeared to acclimate or recover fully after four to five weeks but rectal temperature and body weight did not.

Lactating cattle apparently can partially acclimate and produce substantial amounts of milk even though their body temperature is elevated; however, the quantity of milk produced is significantly below the 18°C potential of the animal. Limited data on non-lactating cows demonstrated essentially full acclimation at 29°C, compared to values of measured functions at 18°C.

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APPENDIX

TABLE 3 - WEEKLY AVERAGE OF ACTUAL AND EXPECTED VALUES FOR 10 LACTATING COWS

Temperature and Humidity	Week	Milk, Kg/Day		Feed, Kg/Day		Water, 1./Day		Body Weight, Kg.		Rectal Temp. °C	
		Actual	Expected	Actual	Expected	Actual	Expected	Actual	Expected	Actual	Expected
18°C 50% R.H.	1	23.9	23.9	19.5	21.4	94.6	96.9	517	512	38.72	38.72
	2	23.7	23.6	22.5	21.4	93.9	95.8	510	513	38.72	38.72
29°C 50% R.H.	1	21.0	23.0	15.6	21.0	87.8	94.6	497	515	39.83	38.72
	2	18.9	22.6	15.6	21.0	82.3	93.9	493	517	39.83	39.72
	3	19.1	22.2	17.9	21.0	87.4	90.8	495	518	39.78	38.66
	4	19.4	22.0	18.5	20.9	90.8	92.0	508	519	39.78	38.66
	5	19.0	21.3	20.1	20.9	93.9	91.2	508	521	39.61	38.66
	6	19.0	21.3	19.5	20.9	90.8	90.4	507	523	39.67	38.66
	7	18.0	21.0	18.3	20.9	88.8	89.3	509	524	39.61	38.66
	8	17.6	20.8	18.7	20.8	88.4	88.6	510	525	39.50	38.61
	9	17.7	20.5	18.5	20.8	84.1	87.6	510	527	39.56	38.61
18°C 50% R.H.	1	19.3	21.2	20.1	20.8	82.2	86.7	524	528	38.61	38.61
	2	20.2	20.9	20.8	20.7	85.3	85.8	526	530	38.66	38.61
	3	20.5	20.6	21.0	20.7	84.7	84.4	535	531	38.61	38.61
	4	20.4	20.2	20.6	20.7	83.8	83.8	538	533	38.61	38.55

TABLE 4 - STANDARD ERROR OF MEAN OF ACTUAL VALUES FOR 10 LACTATING COWS DURING NINE WEEKS HEAT EXPOSURE TO 29°C

Week	Rectal Temp. °C	Milk, Kg/Day	Feed, Kg/Day	Water, 1./Day	Body Weight, Kg
1	.16	1.2	.8	1.1	8.2
2	.19	1.2	1.5	1.5	6.9
3	.19	1.3	1.2	2.3	6.9
4	.18	1.3	1.3	2.7	11.3
5	.20	1.3	1.5	3.8	10.4
6	.19	1.5	1.2	4.2	9.0
7	.17	1.6	.6	4.5	11.9
8	.17	1.5	.5	5.9	10.3
9	.16	1.5	.5	3.8	14.1

TABLE 5 - WEEKLY AVERAGE OF ACTUAL AND EXPECTED VALUES FOR TWO DRY COWS

Temperature and Humidity	Week	Rectal Temperature, °C		Feed, Kg/Day		Water, 1./Day		Body Weight, Kg	
		Actual	Expected	Actual	Expected	Actual	Expected	Actual	Expected
18°C 50% R.H.	1	38.55	38.52	12.8	12.5	50.7	52.6	582	588
	2	38.49	38.52	12.5	12.6	53.4	51.5	596	590
29°C 50% R.H.	1	38.77	38.52	10.8	12.7	59.0	50.7	590	592
	2	38.89	38.51	8.2	12.8	50.7	50.0	587	594
	3	38.72	38.51	10.8	12.9	52.6	48.8	583	596
	4	38.77	38.50	11.7	13.0	57.5	47.7	603	599
	5	38.55	38.50	12.1	13.1	55.2	46.9	604	601
	6	38.55	38.50	11.8	13.2	51.5	46.2	603	603
	7	38.66	38.49	12.8	13.3	52.2	45.0	609	605
	8	38.55	38.48	13.6	13.3	53.0	43.9	609	607
	9	38.55	38.47	12.9	13.4	51.9	43.2	612	610
18°C 50% R.H.	1	38.49	38.46	13.7	13.6	43.2	42.4	612	611
	2	38.49	38.46	14.1	13.6	39.7	41.3	617	614
	3	38.44	38.45	13.5	13.7	39.4	40.5	616	616
	4	38.44	38.45	14.1	13.8	40.9	39.4	620	618

TABLE 6 - RESULTS OF "T" TESTS* OF SIGNIFICANCE OF DIFFERENCE BETWEEN ACTUAL AND EXPECTED VALUES ON LACTATING COWS DURING THE NINE-WEEK HEAT EXPOSURE

	Rectal Temp. °C		Milk, Kg/Day		Feed, Kg/Day		Water l./Day		Body Weight, Kg	
Week	Av. Diff.	Signi.	Av. Diff.	Signi.	Av. Diff.	Signi.	Av. Diff.	Signi.	Av. Diff.	Signi.
1	1.13	.001	-1.9	.005	-5.4	.001	-5.3	.025	-18.4	
2	1.15	.001	-3.7	.001	-4.9	.005	-9.8	.05	-23.8	
3	1.09	.001	-3.2	.005	-3.1	.01	-3.6	n.s.	-23.3	
4	1.09	.001	-2.6	.01	-2.4	.05	+0.8	n.s.	-12.0	
5	.94	.001	-2.7	.005	-0.8	n.s.	+4.5	n.s.	-13.5	
6	.97	.001	-2.3	.025	-1.5	n.s.	+2.4	n.s.	-15.4	
7	.96	.001	-2.9	.001	-2.5	.001	+0.8	n.s.	-15.0	
8	.87	.001	-3.1	.001	-2.1	.001	+1.3	n.s.	-15.1	
9	.91	.001	-2.8	.001	-2.4	.005	-3.1	n.s.	-17.6	
1-9	1.00	.001	-2.8	.001	-2.8	.001	-1.3	n.s.	-17.1	

* The "t" test compared the differences of each individual cow's actual value with its own expected value. These paired values were averaged for 10 cows and tested for significance each week. A significant value was determined for the total 9-week period using the average mean deviation for each week compared to the mean deviation for the whole 9-week period as shown by Snedecor, 1957, Table 2.9.1, (p. 50).

Difference °C x 1.8 = Difference in °F
kg x 2.2046 = lbs.
liters x .2642 = gallons

TABLE 7 - EFFECT OF HEAT EXPOSURE PERIOD ON LACTATING COWS AS EVALUATED BY SIGNIFICANCE OF ADJUSTED MEAN VALUE AND SIGNIFICANCE OF DIFFERENCE OF TRENDS IN ACCLIMATION BY COVARIANCE ANALYSIS*

Measurement**		Significance of Difference Between Adjusted Means at 18°C and 29°C	Significance Between Regression Coefficients at 18°C and 29°C
Rectal Temperature (2-9 weeks)		.01	.01
Milk Production (2-9 weeks)		.01	n.s.
Feed Intake			
	(2-9 weeks)	.05	n.s.
	(2-5 weeks)	n.s.	.05
	(6-9 weeks)	.05	n.s.
Water Intake			
	(2-9 weeks)	n.s.	n.s.
	(2-5 weeks)	n.s.	.01
	(6-9 weeks)	n.s.	n.s.
Body Weight	(2-9 weeks)	.01	n.s.

* Snedecor, G. W., Statistical Methods, p. 408-409.

** Periods of exposure were selected which were most meaningful in interpretation of possible acclimation trends.

TABLE 8. AVERAGE DIFFERENCE* FROM EXPECTED VALUE AT 18°C FOR 10 LACTATING AND TWO DRY COWS DURING HEAT EXPOSURE

Weeks	Milk, Kg/Day		Feed, Kg/Day		Water, 1./Day		Body Weight, Kg		Rectal Temp. °C	
	Lactating	Dry	Lactating	Dry	Lactating	Dry	Lactating	Dry	Lactating	Dry
1	-1.9		-5.4	-2.0	-5.2	+8.3	-18.4	-2.3	1.13	.28
2	-3.7		-4.9	-4.6	-9.7	+1.1	-23.9	-7.3	1.15	.39
3	-3.2		-3.1	-2.8	-3.6	+3.8	-23.4	-13.6	1.09	.22
4	-2.6		-2.3	-1.3	+0.8	+9.5	-12.1	+4.5	1.08	.28
5	-2.7		-0.8	-1.0	+4.5	+8.0	-13.5	+2.7	0.94	.05
6	-2.2		-1.4	-1.4	+2.4	+5.3	-15.4	-0.5	0.97	.05
7	-2.9		-2.5	-0.4	+0.8	+7.2	-15.0	+3.6	0.96	.22
8	-3.1		-2.1	+0.2	+1.3	+8.7	-15.1	+0.9	0.87	.05
9	-2.8		-2.4	-0.5	-3.1	+10.6	-17.6	+2.3	0.91	.11

* Average difference is the group average of each cow's individual weekly difference of actual from expected values.

TABLE 9 - AVERAGE DIFFERENCE* FROM EXPECTED VALUE AT 18°C DURING HEAT EXPOSURE FOR HIGH AND LOW RECTAL TEMPERATURE COWS

Heat Tolerant Cows 126, 45, 44, 768, 830
Heat Intolerant Cows 105, 87, 48, 763, 773

	Milk, Kg/Day		Feed, Kg/Day		Water, 1./Day		Body Weight, Kg		Rectal Temp. °C	
Weeks	Heat Tolerant	Heat Intolerant	Heat Tolerant	Heat Intolerant	Heat Tolerant	Heat Intolerant	Heat Tolerant	Heat Intolerant	Heat Tolerant	Heat Intolerant
1	-1.7	-2.3	-5.5	-5.2	-4.2	-5.3	-17.7	-19.0	.78	1.50
2	-3.1	-4.4	-4.5	-5.4	-7.2	-12.1	-25.8	-21.8	.72	1.61
3	-2.1	-4.4	-2.7	-3.5	-3.4	-4.2	-23.1	-23.6	.61	1.55
4	-1.6	-3.6	-1.8	-2.9	+1.9	-0.4	- 8.2	-15.9	.55	1.61
5	-1.8	-3.5	-2.5	-0.9	+3.0	-6.1	-12.2	-15.0	.39	1.50
6	-1.2	-3.3	-0.8	-2.1	+2.7	+1.9	-18.1	-12.7	.44	1.50
7	-1.8	-4.0	-3.1	-2.8	+0.8	+2.3	-13.6	-16.8	.55	1.39
8	-2.4	-3.0	-1.8	-2.5	+0.8	+1.9	-17.2	-13.1	.44	1.33
9	-2.0	-3.5	-1.9	-2.9	-2.3	-3.8	-14.5	-20.4	.39	1.39

* Average difference is the group average of each cow's individual weekly difference of actual from expected values.

TABLE 10. ANALYSIS OF VARIANCE OF LACTATING COWS DURING 9 WEEK HEAT EXPOSURE WHEN GROUPED BY HEAT TOLERANCE AND LEVEL OF MILK PRODUCTION.†

	Probability				
	Milk	Feed	Water	Rectal Temp.	Body Weight
Grouping Based on Rectal Temperature* (Heat Tolerant vs. Heat Intolerant Cows)	.01	n.s.	n.s.	.01***	n.s.
Grouping Based on Milk Production Level** (High: 126, 105, 87, 763, 768. Low: 45, 48, 44, 773, 830.)	.01	n.s.	.01	.05	.05

* Values used are average kg/week differences from expected values. (Obtained by subtracting actual kg/day from expected kgs/day and multiplying by 7.)

** Percent of expected values were used in analysis.

*** Actual rectal temperature values were used in analysis.

† Snedecor, G. W., Statistical Methods, p. 237-240, (1957).

TABLE 1.1 - AVERAGE DIFFERENCE* FROM EXPECTED VALUE AT 18°C DURING HEAT EXPOSURE FOR HIGH AND LOW PRODUCERS OF MILK

High Producers--Cow 87, 105, 126, 763, 768.
Low Producers--Cow 44, 48, 45, 773, 830.

Weeks	Milk, Kg/Day		Feed, Kg/Day		Water, 1./Day		Body Weight Kg		Rectal Temp. °C	
	High	Low	High	Low	High	Low	High	Low	High	Low
1	-3.1	-0.7	-5.80	-4.9	-7.2	-1.5	-22.7	-14.1	1.28	.94
2	-5.3	-2.2	-5.76	-4.1	-16.7	+1.1	-23.1	-24.5	1.39	.89
3	-4.6	-1.8	-3.45	-2.7	-8.7	+1.5	-25.4	-21.3	1.28	.94
4	-4.0	-1.2	-2.22	-2.5	-4.2	+5.7	-18.6	- 5.4	1.17	1.00
5	-4.0	-1.3	-1.77	+0.2	+0.4	+8.7	-19.0	- 8.2	1.17	.78
6	-3.6	-0.9	-2.09	-0.8	-1.1	+5.7	-14.0	-16.8	1.11	.83
7	-3.8	-2.5	-3.36	-1.7	-1.5	+3.0	-20.4	- 9.5	1.00	.89
8	-3.1	-2.2	-2.40	-1.9	-0.8	+3.0	-17.2	-12.7	.94	.67
9	-3.6	-2.0	-3.17	-1.6	-11.4	-1.1	-24.5	-10.9	1.11	.72

* Average difference is the group average of each cow's individual weekly difference of actual from expected values.

TABLE 12 - ACCLIMATION EFFECTS ON MILK PRODUCTION, BUTTERFAT; SPECIFIC GRAVITY; AND PERCENT TOTAL SOLIDS

Weeks	Temp. Humid.	Cow Number 44	45	48	87	105	126	763	768	773	Average
					Milk Production, Kg/Day						
6	18°-50	23.5	19.8	21.5	28.3	27.2	26.7	26.3	19.6	25.7	24.3
9	29°-50	21.0	16.4	17.7	23.3	22.3	22.4	17.3	17.0	22.1	19.9
5	18°-50	22.3	12.9	14.9	23.9	23.2	22.6	19.2	17.9	23.7	20.0
					Percent Butterfat						
6	18°-50	3.6	4.3	3.5	3.5	3.6	3.5	4.0	3.8	3.7	3.7
9	29°-50	3.6	3.7	3.2	3.8	4.2	4.3	4.3	3.8	3.4	3.8
5	18°-50	4.1	4.9	3.0	3.7	3.8	4.1	3.6	3.7	3.3	3.8
					Specific Gravity*						
6	18°-50	1.0321	1.0323	1.0290	1.0308	1.0304	1.0317	1.0304	1.0314	1.0325	1.0312
9	29°-50	1.0325	1.0314	1.0298	1.0314	1.0305	1.0305	1.0305	1.0312	1.0329	1.0314
5	18°-50	1.0336	1.0328	1.0321	1.0337	1.0341	1.0337	1.0311	1.0314	1.0340	1.0329
					Percent Total Solids*						
6	18°-50	13.27	13.87	12.32	12.44	12.56	12.61	12.99	12.98	13.12	12.90
9	29°-50	13.02	14.24	11.82	12.93	13.35	13.34	12.41	12.90	12.88	13.01
5	18°-50	13.65	14.74	11.64	13.29	13.62	13.76	12.58	12.82	13.04	13.15

*Four consecutive samples per week - 2 morning - 2 evening.
In scattered cases, 3 samples per week when cow in clinic or sample was sour.
In rare cases, 2 samples per week used.

Note: Solids appear as measured by Watson Taylor Lactometer & Babcock Fat Test.

TABLE 13--INDIVIDUAL COW AVERAGE FOR NINE WEEK HEAT ACCLIMATION PERIOD

Cow No.	Rectal Temp. °C		Milk, Kg/Day		Feed, Kg/Day		Water, l./Day		Body Weight, Kg	
	Actual	Expected	Actual	Expected	Actual	Expected	Actual	Expected	Actual	Expected
87	40.11	38.72	23.2	29.4	21.6	24.2	93.1	99.5	482	480
105	40.06	38.72	22.2	25.3	20.1	22.1	108.3	96.5	508	526
48	40.11	38.38	17.7	19.1	20.5	22.0	93.5	87.1	541	562
763	40.67	38.89	17.2	24.4	14.0	20.6	85.2	104.8	450	481
773	39.78	38.61	17.0	19.2	15.1	18.5	83.3	84.0	464	484
768	39.39	38.66	22.0	25.2	16.3	20.1	90.1	100.7	523	557
830	39.11	38.72	*9.7	12.4	*13.7	17.9	*66.2	73.1	498	*493
126	39.11	38.61	22.4	24.8	19.3	20.9	85.5	86.3	522	542
44	39.17	38.61	21.0	22.6	19.8	21.5	90.8	87.4	531	538
45	39.22	38.77	16.3	16.4	20.5	21.4	87.1	74.9	524	537
46	38.55	38.44	dry	dry	8.7	8.2	41.6	34.1	611	615
903	38.77	38.55	dry	dry	14.4	17.9	65.5	60.2	591	588

*Cow injured leg, removed from laboratory.

TABLE 14--RECTAL TEMPERATURE; MILK PRODUCTION; FEED CONSUMPTION; WATER CONSUMPTION; AND BODY WEIGHT (WEEKLY AVERAGES)

Temperature		1961-1962 Cow Number						1962-1963 Cow Number					
°C.	%R.H.	87	105	48	126	44	45	763	773	768	830	46	903
		Rectal Temperature, °C											
18°	50	38.66	38.72	38.38	38.38	38.49	38.66	38.83	38.72	38.44	38.55	38.49	38.44
18°	50	38.61	38.77	38.89	38.44	38.55	38.72	39.05	38.61	38.72	38.66	38.55	38.61
18°	50	38.77	38.66	38.77	38.49	38.55	38.72	38.83	38.66	38.83	38.61	38.49	38.49
18°	50	38.72	38.66	38.49	38.49	38.33	38.66	39.28	38.66	38.77	38.77	38.55	38.61
18°	50	38.72	38.94	38.44	38.55	38.61	38.77	39.00	38.72	38.66	38.77	38.44	38.61
18°	50	38.72	38.66	38.49	38.66	38.61	38.77	39.00	38.72	38.72	38.72	38.44	38.55
29°	50	40.16	40.11	40.11	39.50	39.72	39.39	40.89	39.72	39.61	39.11	38.55	39.00
29°	50	40.50	39.89	39.89	39.44	39.17	39.33	40.94	40.28	39.94	39.11	38.49	39.28
29°	50	40.33	40.16	40.11	39.22	39.56	39.39	40.78	40.00	39.50	38.77	38.61	38.83
29°	50	40.06	40.06	40.28	39.05	39.39	39.33	40.83	40.00	39.39	39.11	38.72	38.83
29°	50	40.11	40.22	40.11	39.00	38.94	39.11	40.67	39.61	39.17	39.11	38.44	38.66
29°	50	40.06	40.22	40.11	39.00	38.89	39.22	40.56	39.89	39.33	39.11	38.55	38.55
29°	50	39.89	39.94	40.16	39.00	39.05	39.22	40.56	39.61	39.17	39.44*	38.55	38.77
29°	50	39.72	39.89	40.00	38.94	38.89	39.05	40.50	39.61	39.05	39.39*	38.38	38.66
29°	50	40.11	40.11	40.00	39.00	38.94	39.17	40.39	39.39	39.17	39.00*	38.49	38.66
18°	50	38.89	38.94	38.49	38.33	38.61	38.77	38.72	38.61	38.38	38.55*	38.44	38.55
18°	50	38.77	39.00	38.38	38.61	38.44	38.83	38.94	38.55	38.66	38.72*	38.49	38.49
18°	50	38.72	38.55	38.33	38.55	38.55	38.77	38.72	38.44	38.72	38.55*	38.38	38.49
18°	50	38.61	38.77	38.33	38.49	38.49	38.77	38.77	38.44	38.61	38.72*	38.38	38.55

		Milk Production, Kg/Day									
18°	50	27.2	25.1	21.0	25.3	24.9	20.9	21.3	17.8	24.6	15.5
18°	50	26.9	27.6	18.2	27.8	24.0	20.4	25.9	19.9	26.0	16.3
18°	50	27.4	28.6	21.8	28.1	24.9	20.3	27.1	20.2	26.1	15.8
18°	50	28.6	28.6	24.1	26.4	21.3	19.4	27.4	19.8	25.6	14.5
18°	50	30.6	25.6	22.1	25.9	23.0	19.4	28.1	19.8	25.9	14.4
18°	50	28.7	27.2	21.8	26.1	22.6	18.1	27.9	20.0	25.9	13.9
29°	50	26.0	24.0	21.7	22.5	21.1	17.1	21.7	19.7	23.9	12.4
29°	50	23.1	22.4	19.7	21.2	20.5	16.1	17.9	16.6	20.7	10.3
29°	50	22.4	23.1	18.7	22.8	20.8	17.1	16.9	16.4	21.8	10.5
29°	50	23.0	23.2	19.1	24.0	21.0	17.5	17.3	16.8	21.6	10.2
29°	50	23.3	21.8	17.7	22.4	20.6	17.3	17.3	17.4	22.1	9.8
29°	50	23.1	22.1	17.7	23.6	22.3	17.5	16.8	16.9	21.7	8.2
29°	50	22.7	21.0	15.1	22.5	20.8	15.6	16.4	16.1	22.3	7.1
29°	50	22.7	21.1	14.3	20.6	20.7	14.2	15.9	16.5	22.0	4.6
29°	50	22.6	21.4	14.7	21.8	20.5	14.8	15.2	16.4	22.0	3.1
18°	50	23.2	23.1	14.5	22.4	20.8	13.7	16.9	17.4	22.5	3.2
18°	50	22.4	22.4	16.0	22.6	22.1	13.3	19.6	18.6	25.0	3.3
18°	50	23.9	24.0	15.1	23.3	23.0	13.3	19.2	18.4	24.2	2.9
18°	50	25.0	23.6	14.7	22.7	22.9	12.8	20.1	17.9	24.2	2.9

*Cow injured

TABLE 14. (Cont'd)

Temperature °C	%R.H.	1961-1962 Cow Number 87	105	48	126	44	45	1962-1963 Cow Number 763	773	768	830	46	903
							Feed Consumption, Kg/Day						
18°	50	25.2	24.4	25.7	23.8	23.8	23.6	19.1	17.3	21.1	18.2	12.1	16.9
18°	50	21.2	23.0	23.0	25.5	20.2	22.3	22.7	17.5	23.0	19.0	13.1	17.2
18°	50	23.6	23.3	23.0	24.3	21.2	22.0	21.0	18.0	20.6	18.1	9.0	16.8
18°	50	19.7	18.8	18.2	19.9	17.9	20.0	21.0	17.9	20.7	17.1	9.2	17.4
18°	50	20.5	20.0	20.6	17.9	20.7	20.2	20.7	17.4	19.7	17.6	7.8	17.7
18°	50	30.6	24.7	23.7	23.5	21.5	23.8	20.6	18.1	20.3	18.3	7.4	17.4
29.5°	50	20.7	16.9	18.2	14.5	16.6	15.3	13.0	13.5	14.8	13.0	7.7	13.8
29.5°	50	20.2	18.9	16.3	19.0	19.6	20.3	10.5	10.5	11.1	9.4	6.3	10.0
29.5°	50	21.0	22.1	21.2	20.3	19.8	20.1	12.1	14.1	15.7	12.4	6.1	14.0
29.5°	50	23.0	23.2	19.8	21.8	19.5	22.6	13.2	13.7	15.5	13.2	8.7	14.7
29.5°	50	25.4	22.5	25.8	20.7	23.1	24.6	14.4	14.7	16.1	13.7	9.5	14.7
29.5°	50	24.2	20.8	21.4	20.1	22.6	24.0	15.4	15.0	16.8	13.6*	9.0	14.7
29.5°	50	20.0	18.5	21.2	18.5	19.4	19.5	15.6	17.3	18.0	9.4*	9.7	16.0
29.5°	50	20.5	19.6	19.7	19.6	18.9	19.2	16.1	18.5	19.3	7.9*	11.0	16.1
29.5°	50	19.4	18.1	21.1	19.2	18.6	18.7	15.1	18.6	19.2	9.6*	10.1	15.8
18°	50	21.4	19.6	21.1	20.4	20.5	20.3	17.7	19.3	20.9	10.0*	9.5	18.1
18°	50	21.5	21.1	22.0	21.6	21.5	21.2	18.8	19.0	20.2	10.7*	9.8	18.5
18°	50	22.3	21.6	21.3	20.6	21.1	21.3	20.5	19.5	20.4	9.9*	8.5	18.3
18°	50	22.0	22.0	22.2	21.9	22.4	19.2	20.6	19.4	20.0	10.5*	9.6	18.6

		Water Consumption, 1./Day											
18°	50	95.8	87.4	82.9	86.7	85.2	82.5	86.3	79.5	88.2	73.8	40.1	71.2
18°	50	95.8	92.4	70.0	90.5	87.1	84.4	101.1	77.6	104.8	85.5	39.4	69.6
18°	50	101.1	97.7	94.6	94.2	99.9	92.0	110.9	83.3	106.7	69.3	35.2	64.7
18°	50	100.3	101.1	106.4	94.6	87.8	87.4	107.5	83.3	98.4	70.0	41.3	68.9
18°	50	108.6	94.6	96.5	89.7	94.6	80.6	116.9	88.2	104.1	74.2	34.8	67.0
18°	50	101.1	97.7	89.6	92.4	88.6	78.0	115.0	88.2	107.1	81.8	38.6	67.7
29.5°	50	91.6	96.9	85.9	82.9	87.4	78.7	97.3	85.5	94.6	77.2	45.4	72.3
29.5°	50	78.3	87.4	95.0	84.8	77.2	88.2	85.5	79.1	82.1	66.6	39.4	62.4
29.5°	50	88.9	104.8	92.7	81.4	86.7	87.1	85.9	88.2	92.0	66.6	39.0	66.2
29.5°	50	91.2	112.8	93.9	90.5	96.9	87.8	86.3	90.1	90.5	70.8	43.9	70.8
29.5°	50	98.4	118.4	104.1	88.2	90.5	90.5	85.9	94.6	98.4	70.4	43.2	67.0
29.5°	50	97.7	115.0	95.8	89.7	98.8	89.7	83.3	84.8	92.0	62.4*	41.3	61.3
29.5°	50	97.3	119.6	93.5	85.9	92.7	86.3	81.0	82.1	87.4	48.8*	39.0	65.5
29.5°	50	101.4	117.7	95.0	85.2	95.4	86.7	83.3	71.9	87.1	46.9*	44.3	61.3
29.5°	50	93.1	103.0	85.5	82.5	92.4	88.9	79.1	73.1	85.9	45.4*	42.4	61.3
18°	50	94.2	97.3	96.5	75.3	58.3	75.3	80.2	73.1	90.5	44.3*	34.8	51.5
18°	50	91.6	95.0	87.8	83.3	86.3	78.3	81.4	75.3	89.3	37.9*	31.0	48.5
18°	50	92.7	97.3	79.1	82.9	79.1	67.7	88.2	80.2	95.4	42.0*	30.3	48.5
18°	50	95.0	95.4	77.2	76.1	85.2	67.7	91.2	75.7	92.7	43.9*	30.3	51.5

*Cow injured

TABLE 14. (Cont'd)

Temperature		1961-1962 Cow Number						1962-1963 Cow Number					
°C	%R.H.	87	105	48	126	44	45	763	773	768	830	46	903
						Body Weight, Kg							
18°	50	456	494	519	508	517	494	472	451	517	492	615	527
18°	50	460	505	486	494	515	504	466	442	527	527	624	531
18°	50	484	500	527	525	527	504	477	461	534	512	621	550
18°	50	478	513	536	526	518	517	-	-	-	-	-	-
18°	50	490	501	556	536	532	520	487	482	543	522	601	563
18°	50	424	517	536	532	523	521	495	493	545	514	621	570
29.5°	50	474	494	525	513	521	516	452	461	503	505	609	571
29.5°	50	471	487	518	504	514	493	463	461	517	498	603	571
29.5°	50	468	494	526	513	519	517	457	454	509	490	601	565
29.5°	50	488	516	541	526	547	532	434	465	520	504	616	591
29.5°	50	484	513	551	530	531	523	443	469	523	508	612	596
29.5°	50	481	513	547	528	529	517	471	465	535	494	605	601
29.5°	50	484	520	554	529	543	540	442	466	528	483	610	608
29.5°	50	490	516	550	528	538	536	465	470	529	*	610	607
29.5°	50	502	518	555	528	539	547	425	469	538		618	606
18°	50	509	533	585	537	542	539	451	472	548		614	610
18°	50	502	518	577	538	544	546	469	474	566		620	615
18°	50	523	546	579	551	557	557	462	478	571		619	611
18°	50	501	552	585	558	543	561	473	483	575		621	618

*Cow injured - Weights not taken