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Environmental Physiology and Shelter Engineering

With Special Reference to Domestic Animals

LXXIV. THERMAL REGULATION IN CATTLE AT 2° TO 35° AS INFLUENCED BY CONTROLLED FEEDING, AD LIBITUM FEEDING AND FASTING

H. H. KIBLER, H. D. JOHNSON, LEROY HAHN, AND MILTON D. SHANKLIN

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INTRODUCTION

The responses of cattle to heat and cold identify various physiological processes that are involved in opposing a deviation of deep body temperature from the normal level. Within a limited range above and below an optimal environmental temperature—the comfort zone—minor thermoregulatory accommodations may be necessary. Such minor responses tend to be masked by the effects of diurnal cycles in feeding and activity.

Outside the comfort zone, the heat production and dissipation responses to changes in temperature became more pronounced and identifiable as illustrated by heat production in Figure 1. Eventually, at extreme temperatures, regulation fails: body temperature falls at cold temperatures or rises at hot temperatures until death occurs.

The boundaries or critical temperatures are not fixed, but vary with the efficiency and capacity of the heat producing, heat dissipating, and insulating mechanisms. They may vary with changing levels of energy intake and milk or meat production.

Data are presented here to show how a number of animal functions involved in, or related to, heat production and heat dissipation change with environmental temperature during controlled feeding at a fixed level, *ad libitum* feeding, and fasting. Assessments are made of: (1) the effects of the different nutritional treatments on the magnitude of the responses to heat and cold; (2) the modifying effects of feed levels; and

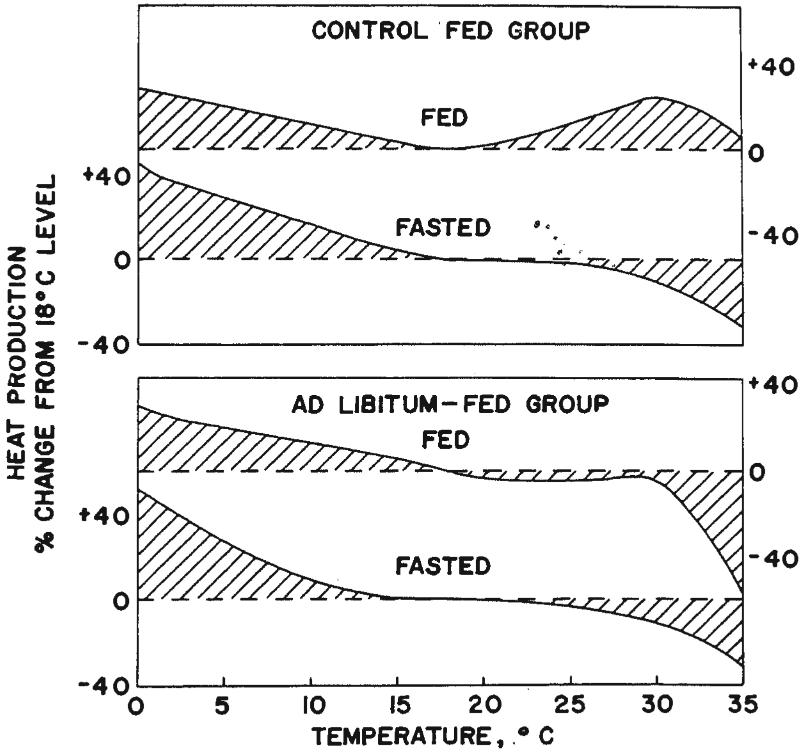

Fig. 1—Diagram of the changing levels of heat production in two groups of non-lactating Holstein cows at temperatures from 2°C to 35°C. The curves illustrate the modifying effects of controlled and ad libitum feeding, and subsequent fasting on the heat production at the different temperatures. The curves also represent heat dissipation, as the heat production and heat dissipation were in equilibrium during the measurements.

(3) the possible influence of pre-fasting feed levels on responses during fasting.

METHODS

Animals

Six non-lactating Holstein cows from 4 to 10 years of age were used in this experiment. Each was surgically fitted with a 10 cm rumen cannula so that: (1) a fasting condition could be more quickly obtained by removing the rumen contents, and (2) the feed intake could be held at a constant level at high temperatures by supplementary feeding through the cannulas. This method of rumen feeding was reported by Johnson *et al.* (1966).

Management and Experimental Procedures

After the cattle were fitted with cannulas, they were kept in one chamber at the Missouri Climatic and Shelter Engineering Laboratory for several weeks to adjust to an environment of 18°C and 50 percent relative humidity. They were then exposed for two-week periods to temperatures of 2°, 10°, 18°, 30°, and 35°C. The hair coats of all animals were clipped to 0.5 cm.

All cows were fed a complete high energy ration consisting of 45 percent grain, 50 percent coarsely ground alfalfa hay, and 5 percent molasses. They were fed twice daily from pre-weighed bags. Water was available at all times in drinking cups. Relative humidity and light were maintained the same at all temperatures.

Cows 909, 460, and 773 were fed *ad libitum* at all temperatures, with weighings made of amounts fed and amounts refused. Measurements were made of the feed consumed by cows 903, 201, and 46 at the base temperature, 18°C. These amounts were 15.4 kg/day for cow 903 and 16.3 kg/day each for cows 201 and 46. The specified levels of feeding were maintained the same at all temperatures for cows 903, 201, and 46 by limiting the feed at cold temperatures, and forced feeding by cannula at high temperatures.

The cows were fed as described above during the first week of each period, and fasted during part of the second week. During the fasting weeks the usual evening feeding for the cows that had their feed controlled was omitted on Tuesdays, and the mangers were emptied. No feed was given Wednesday mornings, and the rumen contents were removed and placed in insulated plastic-lined containers to maintain temperature. Approximately 12 liters of water were poured into each animal's rumen. Measurements were then made during the remainder of the day while the cows were fasting. Late in the afternoon the rumen contents were replaced, and the cows were fed at their fixed levels. The same procedure was followed with the ad libitum fed cows on Thursdays and Fridays of the fasting weeks, except they were returned to *ad libitum* feeding after their rumen contents were replaced.

Measurements

The cows were weighed before the morning feeding on Monday and Tuesday of each week. Pulse rate, respiration rate, and rectal temperature were measured at about 1 p.m., Monday through Friday. Skin and hair temperatures were measured with a touch thermocouple (by the method of Bedwell and Shanklin, 1962) during feeding periods.

Energy metabolism, pulmonary ventilation rate, and respiratory vaporization rate were determined by indirect calorimetry (by the method of Kibler, 1960) during feeding and fasting. Total vaporization was measured with a hygrometric tent (by the method of Yeck and Kibler, 1956) on Thursdays of the weeks the animals were fed. It was not possible to schedule total vaporization measurements during the brief fasting periods because of the time required for other measurements.

Analysis of data

The measurement data are summarized in Tables 4, 5, and 6 in the Appendix. The deviations from base levels at 18°C caused by higher and lower temperatures, feeding and fasting, controlled feeding at a constant level and *ad libitum* feeding, and the interactions among treatments were tested by analysis of variance. For measurements such as energy metabolism, ventilation rates, respiratory and total vaporization, percentage deviations were compared in an attempt to minimize the effects of body size. For responses less directly dependent on body size, such as respiration rate, pulse rate, rectal temperature, and skin and hair temperature, the absolute deviations from the 18°C levels were compared.

RESULTS

In the following discussion, cold temperature refers to 2° and 10°C; hot temperature to 30° and 35°C; and base temperature to 18°C. Comparisons of the effects of cold and hot temperatures, fasting, and the level of feeding on the different measurements are shown in Figures 2, 3, and 4. Differences in the measurements from their base levels during the different treatments, and their statistical significance are given in Tables 1, 2, and 3. The measurements on individual animals are given in Tables 4, 5, and 6 in the Appendix.

Temperature Effects

The physiological effects of decreases from base to cold temperatures were significantly different from the effects of increases from base to hot temperatures for all nine measurements (Table 1). Increases occurred at cold temperatures and decreases occurred at hot temperatures, in functions closely related to heat production, such as energy metabolism and pulse rate. In functions more closely related to heat dissipation, such as respiration rate, pulmonary ventilation rate, and respiratory and total vaporization rates, the reverse was true. Rectal temperatures within the 2° to 35°C range were affected only by the hot temperatures, but hair and skin temperatures were decreased significantly by cold temperatures and increased significantly by hot temperatures.

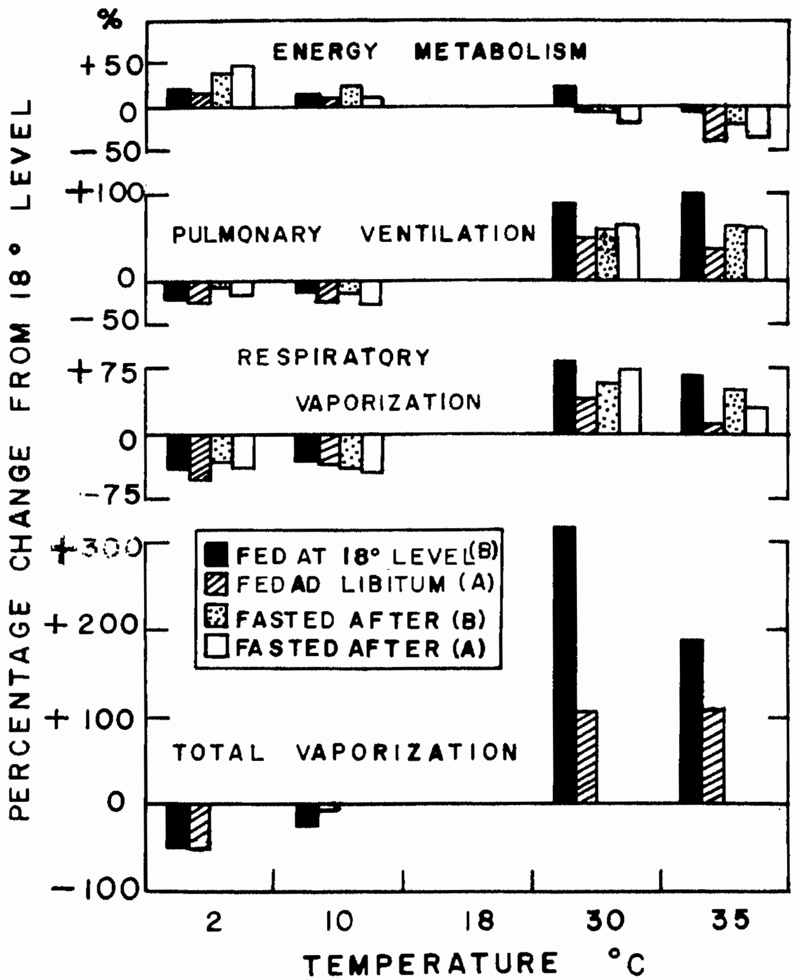

Fig. 2–Percentage changes in four measurements from normal levels at 18° C to temperatures from 2° to 35° C during feeding and fasting.

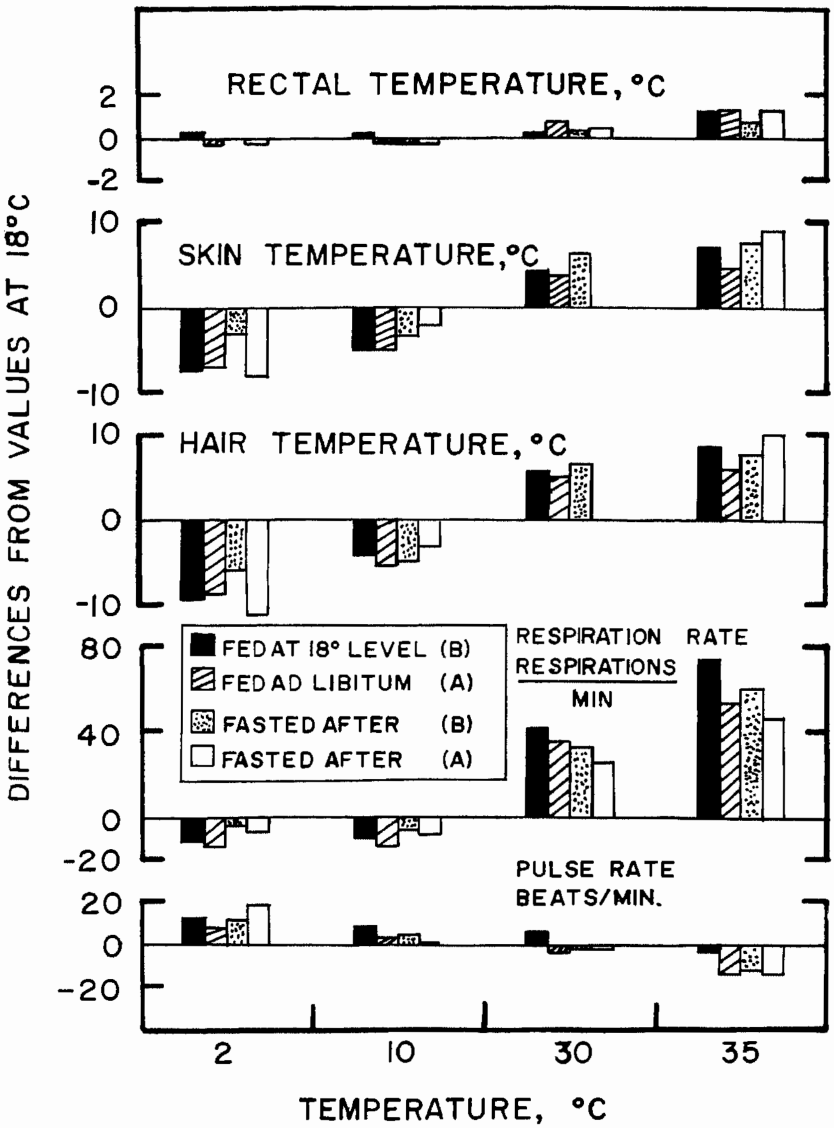

Fig. 3—Differences from levels at 18°C temperature in five measurements at temperatures from 2° to 35°C during feeding and fasting.

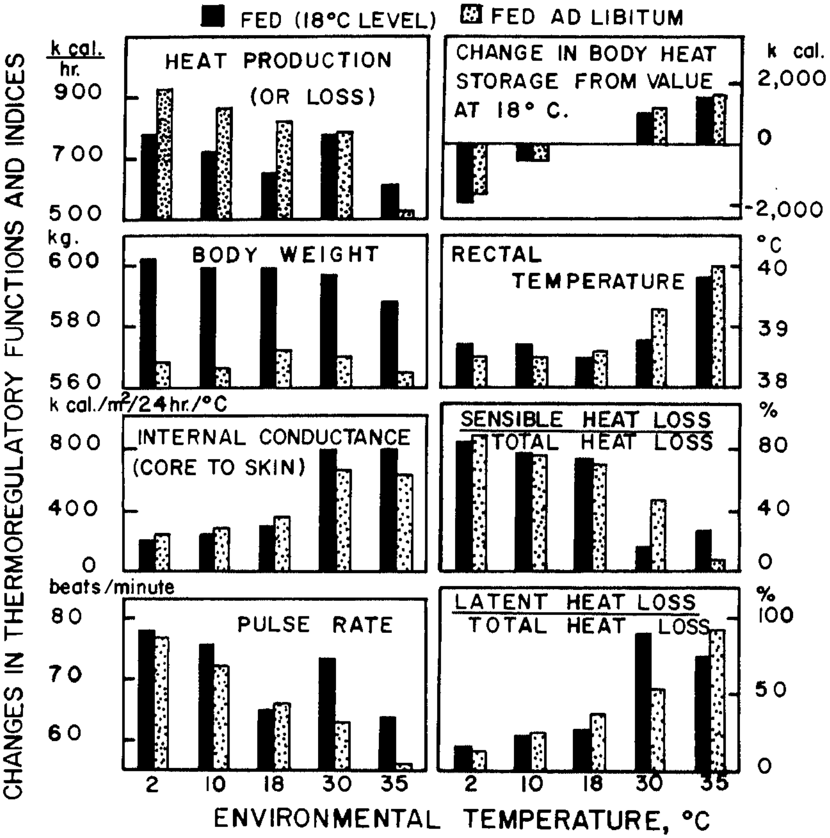

Fig. 4—Effects of temperatures, 2° to 35°C, and controlled and ad libitum feeding on several thermoregulatory activities. Heat production values were obtained by indirect calorimetry (oxygen consumption) and were assumed to equal total heat loss values as body temperatures had reached equilibrium values at the time of measurements.

TABLE 1. EFFECTS OF FEEDING AND FASTING ON NINE PHYSIOLOGICAL MEASURES DURING EXPOSURES TO COLD, 2 TO 10°C AND HEAT, 30 TO 35°C

(C = controlled feeding at the 18°C level; A = ad libitum feeding; * = significant at P<.05; ** = significant at P<.01)

Source of variation from 18°C level		Mean differences from 18°C base levels at 2° to 35°C								
		Energy metabolism	Ventilation rate	Vaporization		Respiration rate	Pulse rate	Temperature		
				Respiratory	Total			Rectal	Skin	Hair
		%	%	%	%	r/m	b/m	°C	°C	°C
Temperature	cold	+21	-18	- 40	- 25	-10	+ 8	0.0	-5	-6
	hot	-12**	+66**	+102**	+188**	+48**	- 2**	+0.7**	+7**	+8**
Feed	feed	+ 4	+24	+ 5	+ 81	+19	+ 3	+0.4	-1	0
	fasted	+ 5	+24	+ 5		+19	+ 4	+0.2	+2	+1
Temperature X Feed		*								
Cold	2°C	+19	-22	- 46	- 43	-14	+10	0.0	-7	-9
	10°C	+11	-18	- 34*	- 8	-12	+ 6	+0.1	-5**	-5**
Feeding	C	+16	-16	- 36	- 35	-12	+11	+0.2	-6	-7
	A	+14	-23	- 44	- 16	-14	+ 5	-0.1	-6	-7
Cold X Feed										*
Heat	30°C	+ 8	+68	+ 61	+212	+38	+ 3	+0.4	+4	+5
	35°C	-22**	+69	+ 39	+164	+63**	- 8**	+1.3*	+6**	+7**
Feeding	C	+ 8	+95	+ 76	+253	+56	+ 1	+0.7	+6	+7
	A	-22**	+42**	+ 25**	+123	+45*	- 6	+1.0	+4**	+5**

Heat X Feed									
Cold 2°C	+41	-12	- 38	NO	- 6	+14	-0.1	-6	-8
Cold 10°C	+15	-20	- 43		- 8	+ 2*	-0.2	-1**	-4**
Fasting after C	+27	-10	- 39	FASTING	- 6	+ 7	-0.1	-2	-5
Fasting after A	+28	-22	- 43		- 8	+ 9	-0.2	-5**	-7**
Cold X Feed								*	**
Heat 30°C	- 9	+62	+ 67	DATA	+32	+ 3	+0.3		
Heat 35°C	-26*	+65	+ 36		+57**	- 4*	+0.8	+8	+9
Fasting after C	-13	+60	+ 55		+49	+ 1	+0.3	+7	+7
Fasting after A	-22	+66	+ 48		+40	- 3	+0.8		
Heat X Feed									

TABLE 2. EFFECTS OF CONTROLLED AND AD LIBITUM FEEDING ON NINE THERMOREGULATORY FUNCTIONS, DURING EXPOSURES TO 2°C AND 10°C ENVIRONMENTAL TEMPERATURES

(C = controlled feeding at the 18°C level; A = ad libitum feeding; * = significant at P< .05; ** = significant at P< .01)

Temperature effects	Mean differences from 18°C base levels at 2° to 35°C								
	Energy metabolism	Ventilation rate	Vaporization		Respiration rate	Pulse rate	Temperature		
			Respiratory	Total			Rectal	Skin	Hair
	%	%	%	%	r/m	b/m	°C	°C	°C
Fed									
C at 2°C	+19	-18*	-41**	-48**	-14**	+12**	+0.2	-7.6**	- 9.2**
A at 2°C	+18	-25	-52*	-49	-14**	+ 8**	-0.1	-7.2**	- 8.7**
Temp X Feed									
C at 10°C	+11	-13	-33*	-23	-11**	+10**	+0.3	-4.9**	- 4.0**
A at 10°C	+10	-21	-36	- 7	-14**	+ 3	-0.1	-5.0**	- 5.3**
Temp X Feed									
Fasting									
After C at 2°C	+39	- 7	-36	NO	- 5**	+11**	0.0	-3.6**	- 5.9**
After A at 2°C	+46	-18	-43	FASTING	- 8**	+18**	-0.1	-8.1**	-11.2**
Temp X Feed				DATA				**	**
After C at 10°C	+14	-13	-41*		- 6*	+ 4	-0.2	-3.5**	- 4.8**
After A at 10°C	+11	-27	-45		- 8*	0	-0.2	-2.0**	- 3.0**
Temp X Feed									*

TABLE 3. EFFECTS OF CONTROLLED AND AD LIBITUM FEEDING ON NINE THERMOREGULATORY FUNCTIONS DURING EXPOSURES TO 30° AND 35° C ENVIRONMENTAL TEMPERATURES AND FASTING

(C = controlled feeding at 18° C level; A = ad libitum feeding; * = significant at $P < .05$; ** = significant at $P < .01$)

	Mean difference from 18° C base levels at 30° C and 35° C								
	Energy	Ventilation	Vaporization		Respiration	Pulse	Temperature		
Temperature	metabolism	rate	Respiratory	Total	rate	rate	Rectal	Skin	Hair
Effects	%	%	%	%	r/m	b/m	°C	°C	°C
Fed									
C at 30° C	+21	+ 85**	+79**	+303**	+42**	+ 6*	+0.2	+4.4**	+5.7**
A at 30° C	- 5	+ 48	+38	+ 77	+35**	- 3	+0.7	+3.8*	+5.1**
Temp X Feed				*					
C at 35° C	- 5	+102**	+67**	+182**	+73**	- 3	+1.2*	+6.9**	+8.4**
A at 35° C	-36	+ 34	+11	+103	+53**	-14	+1.3	+4.6**	+5.9**
Temp X Feed									
Fasting									
After C at 30° C	- 6	+57**	+56**		+33**	- 1	+0.3	+6.3**	+6.6**
After A at 30° C	-16	+61	+70*	NO	+30*	- 1	+0.4		
Temp X Feed				FASTING					
After C at 35° C	-21	+63*	+50*	DATA	+59**	- 7	+0.7*	+7.5**	+7.6**
After A at 35° C	-30	+60	+17		+46**	-10	+1.2	+8.9**	+9.7**
Temp X Feed									*

Even smaller increases in environmental temperature within the cold and hot ranges caused significant changes in some measurements (Tables 2 and 3). During the periods in which the animals were fed, skin and hair temperatures were significantly lower at 2°C than at 10°C; and were significantly higher at 35°C than at 30°C. Rectal temperature and respiration rate were significantly higher, and energy metabolism and pulse rate were significantly lower at 35°C than at 30°C. During fasting, increases in pulse rate and decreases in skin and hair temperature were significantly greater at 2°C than at 10°C. During fasting at high temperature, respiration rate increased significantly more at 35° than at 30°C. Pulse rate and energy metabolism were significantly lower at 35°C than at 30°C.

Feeding and Fasting Effects.

The responses to cold and hot temperatures followed similar patterns for both feeding and fasting (Table 1). A significant interaction among these factors occurred in only one function: The percentage decrease in energy metabolism from cold to hot temperatures was significantly greater in fed than in fasted animals. However, the various measurement levels at the different temperatures were lower in the fasted than in the fed animals except for respiration rate at 2°C. At this low temperature both groups had low rates of only 12 respirations per minute.

Controlled and Ad Libitum Feeding Effects.

The changes in the nine functions from their 18°C levels during controlled feeding were not significantly different from the corresponding changes during *ad libitum* feeding at 2°C and 10°C (Table 1). At high temperatures, however, the responses were affected by feeding. The decrease in energy metabolism from the 18°C level was significantly greater for *ad libitum* feeding than for controlled feeding. The increases in respiratory rate, respiratory vaporization, pulmonary ventilation, and skin and hair temperature were significantly greater for controlled feeding than for ad libitum feeding.

In two measures, the prior level of feeding seemed to influence the response to temperature during subsequent fasts. Skin and hair temperatures were significantly lower after *ad libitum* feeding than after controlled feeding during fasting at cold temperatures (Table 1). It appeared that an adjustment to a reduced energy intake had occurred which increased the efficiency of energy conversion. This result needs to be verified with larger groups of animals.

Compensations in the Comfort Zone.

Earlier work at the Missouri Climatic Laboratory indicated that lactating Holstein cows could maintain normal deep body temperatures at an environmental temperature of 10°C, but not at 30°C. It was of interest to know if this were true also for non-lactating Holstein cows, and if their thermoregulatory responses were significantly affected by controlled feeding, *ad libitum* feeding, or fasting within these temperature limits.

Tables 2 and 3 show that rectal temperature was not significantly different at either 10°C or 30°C from base level values at 18°C. This was true regardless of controlled-feeding, *ad libitum*-feeding, or fasting. This maintenance of a constant deep body temperature, of necessity, required compensatory changes in heat producing and/or heat dissipating functions.

Energy metabolism did not decrease significantly at 30°C, but significant increases occurred in ventilation rate, vaporization, pulse rate, respiration rate, and skin and hair temperatures in the group with controlled-feeding. Significant increases in respiration rate and hair and skin temperatures also occurred at 30°C in the group fed *ad libitum.*

At 10°C significant decreases occurred in respiration rate and skin and hair temperatures for all treatments. Figure 2 indicates that energy metabolism tends to increase at 10°C, but not by a statistically significant amount. Pulse rate and respiratory vaporization, however, increased significantly in the controlled-feeding group.

DISCUSSION

The constancy of deep body temperature during moderate changes in environmental temperature tends to mask the changes in activities concerned with thermal regulation. Strictly speaking, the range of environmental temperatures within which regulatory processes are minimal must be narrow. Although deep body temperature may remain constant, peripheral temperatures will rise or fall with varying environmental temperature. The widening differential in temperature between core and periphery will in turn initiate circulatory adjustments, and alter the thermal conductivity of the tissues. The changes in average body temperature will cause heat storage or heat loss even though the rectal temperature remains constant.

These thermal effects of environmental temperature and feed levels are shown in Figure 4. Internal conductance and heat storage were calculated from the basic measurements given in Tables 4, 5, and 6.

Internal Conductance.

The internal conductance, C, from core to skin was computed as follows:

$$C = \frac{24(H-H_{rv}) - H_w}{A(T_r - T_s)} = \text{kcal/m}^2\text{/24 hr/°C}$$

Where H = heat production, kcal/hr

H_{rv} = respiratory vaporization, kcal/hr

H_W = heat to warm consumed water to body temperature, kcal/24 hr

A = surface area of animal, m^2

T_r = rectal temperature,°C

T_s = skin temperature,°C

The internal conductance increased with rising temperature. However, since cattle normally reduce their feed consumption with rising temperature, the feed factor may partially compensate for the temperature factor.

In this experiment, the cows under controlled feeding were prevented from reducing their feed consumption at temperatures above 18°C. As a result, this group which had a relatively low level of heat production at 18°C (Figure 3) attained the *ad libitum* group's level at 30°C, and exceeded that group's level at 35°C. As a consequence, the internal conductance increased more in the control-fed than in the *ad libitum*-fed cows at 30 and 35°C. At low temperatures, however, the cows under controlled feeding were prevented from increasing their feed consumption above the level established at 18°C. Consequently, the internal conductance was lower in cows under controlled feeding than in the *ad libitum*-fed cows at 2° and 10°C.

Heat Storage

The time required to store or dissipate heat from the outer shell of the body tends to prevent or delay changes in deep body temperature. During a preceding experiment (Kibler and Brody, 1956) the environmental controls were set to simulate a 16° to 43°C diurnal temperature rhythm. For these constantly changing conditions it was found that the changes in rectal temperature lagged behind the changes in environmental temperature by approximately two hours.

During the two-week exposure periods of this experiment, the heat storage displacements (Fig. 4) had time to reach equilibrium values. Body heat content was computed by use of the equation used for sheep by Blaxter *et al.* (1959):

$$\text{Body heat content} = 0.83\ W(0.2T_S \ @\ 0.8T_R)$$

Where 0.83 is the specific heat of body tissue

W is body weight, kg

T_S is skin temperature, °C

T_R is rectal temperature, °C

Values were computed for temperatures, 2, 10, 18, 30, and 35°C. The results shown in Figure 3 are the plus and minus differences from the 18°C level. These differences ranged from -1900 kcal at 2°C to +1600 kcal at 35°C. The total difference from 2 to 35°C thus amounted to 3500 kcal, or as much heat as one of these animals produced in four or five hours.

CONCLUSIONS

Exposures of Holstein cows to cold temperatures (2 and 10°C) tended to increase energy metabolism and pulse rate, and to decrease functions involved in heat dissipation such as ventilation rate, vaporization rates, respiration rate, and skin and hair temperatures. Exposures to hot temperatures (30 and 35°C) tended to produce reverse effects.

Fasting lowered the functional levels under all conditions. However, the changes from the 18° base levels were essentially parallel in the fed and fasted animals.

Restricted feeding at low temperatures lowered the functional levels, but to a lesser degree than fasting. The changes from the base levels at 18°C were very similar for both control fed and *ad libitum* fed animals. At high temperatures, however, energy metabolism decreased significantly more in the cows that were allowed to adjust their own feed intake than in those that were control-fed at the normal 18°C level. Vaporization rates, respiration rate, and skin and hair temperatures were significantly greater in the control-fed than in the *ad libitum* fed cows at high temperatures.

The level of prior feeding appeared to affect skin and hair temperatures during fasting at cold temperatures, but further confirmation of this effect is needed with greater numbers of animals.

The progressive changes in heat storage and tissue conductivity with increasing environmental temperature indicates that thermal regulation occurs even within the comfort zone.

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APPENDIX

TABLE 4. ENERGY METABOLISM, PULMONARY VENTILATION AND VAPORIZATION IN HOLSTEIN COWS AT ENVIRONMENTAL TEMPERATURES, 2 TO 35°C, AS MODIFIED BY FEEDING LEVELS AND FASTING

(Means for 2 to 4 observations on each animal)

Temperature °C	Fed						Fasted					
	Control fed			Ad libitum fed			After controlled feeding			After ad libitum feeding		
	903	201	46	907	460	773	903	201	46	907	460	773
	Energy metabolism, kcal/hr											
18	581	730	632	930	731	692	508	508	430	569	422	457
2	790	868	652	1084	982	715	639	921	444	801	540	768
10	752	753	652	1134	740	733	593	638	476	680	508	434
18	590	760	582	967	820	687	473	520	380	689	471	451
30	762	886	688	938	775	647	444	458	393	458	457	433
35	586	675	565	665	619	290	353	406	321	473	381	269
	Pulmonary ventilation rate, liters/min											
18	82	73	75	125	81	96	62	56	48	88	57	56
2	67	66	55	96	64	65	47	69	38	68	43	54
10	68	62	68	102	61	76	50	45	48	61	42	42
18	71	93	75	125	86	102	53	59	54	87	46	56
30	146	147	149	190	141	132	85	82	94	115	98	91
35	154	183	146	177	150	93	81	99	90	126	104	72
	Respiratory vaporization rate, grams/hr											
18	113	104	89	190	116	126	86	77	57	106	61	60
2	67	61	54	97	54	58	39	70	32	51	36	43
10	66	64	73	136	77	69	40	36	47	48	35	37
18	92	124	92	173	124	101	63	74	59	86	51	62
30	193	171	186	236	164	151	99	96	111	127	108	104
35	174	194	147	184	165	92	119	90	86	95	84	53

Total (whole animal) vaporization, grams/hr							
18	417	308	349	572	231	277	
2	186	204	168	168	177	209	
10	240	304	263	404	367	254	NO DATA DURING FASTING
18	231	331	263	689	227	308	
30	1343	1056	930	916	365	621	
35	753	785	785	1057	870	567	

TABLE 5. PULSE RATE, RESPIRATORY RATE, AND BODY WEIGHT IN HOLSTEIN COWS AT ENVIRONMENTAL TEMPERATURES, 2° TO 35°C, AS MODIFIED BY FEEDING LEVELS AND FASTING

(Means for 3 to 5 observations on each animal)

Temperature	Fed						Fasted					
	Control fed			Ad libitum fed			Control fed			Ad libitum fed		
°C	903	201	46	907	460	773	903	201	46	907	460	773
						Pulse beats/minute						
18	66	64	67	74	67	66	60	62	50	54	48	54
2	79	75	79	77	72	81	68	72	64	64	68	80
10	81	74	72	78	67	71	72	56	56	52	52	52
30	66	66	68	73	62	64	54	55	47	51	48	49
30	70	73	75	63	66	62	56	44	52	48	50	48
35	61	63	67	60	52	46	48	44	44	48	40	30
						Respirations/minute						
18	29	16	28	32	24	28	25	16	10	22	18	19
2	11	10	11	16	11	14	10	16	10	14	10	12
10	14	12	15	16	12	14	11	12	9	12	12	10
18	14	21	22	38	24	24	10	12	14	26	12	14
30	62	56	64	75	56	60	52	40	42	60	36	44
35	93	90	92	99	80	66	68	60	100	78	60	60
						Body weight, kg						
18	540	645	610	592	636	463						
2	548	651	611	606	636	467						
10	561	642	594	622	614	463	NOT WEIGHED DURING FASTING					
18	560	642	595	622	622	470						
30	556	638	595	626	620	464						
35	547	629	588	616	620	459						

TABLE 6. SKIN TEMPERATURE, HAIR TEMPERATURE, AND RECTAL TEMPERATURE IN HOLSTEIN COWS AT ENVIRONMENTAL TEMPERATURES, 2° TO 35°C, AS MODIFIED BY FEEDING LEVELS AND FASTING

(Means for 1 to 5 observations on each animal)

Temperature	Fed						Fasted					
	Control fed			Ad libitum fed			Control fed			Ad libitum fed		
°C	903	201	46	907	460	773	903	201	46	907	460	773
						Skin temperature, °C						
2	23.5	23.0	22.7	25.1	23.7	23.5	24.5	24.7	23.6	21.1	19.3	18.7
10	26.3	26.0	25.0	27.5	25.5	25.8	24.2	25.0	23.9	26.4	25.2	25.9
18	31.1	30.5	30.4	33.1	30.1	30.8	28.2	28.3	27.2	27.8	28.7	26.9
30	35.7	35.2	34.2	35.9	34.8	34.6	35.0	34.2	33.3			
35	38.1	37.7	36.9	36.6	35.7	35.6	35.6	35.5	35.1	36.2	36.8	37.2
						Hair temperature, °C						
2	19.8	20.2	18.8	22.0	20.4	20.3	23.0	22.1	20.2	16.7	16.5	13.3
10	25.8	25.2	23.6	26.2	23.5	23.3	23.0	23.2	22.6	23.5	23.6	24.1
18	29.1	29.2	28.3	31.6	28.7	28.6	28.1	28.1	26.8	26.6	27.7	25.7
30	35.0	34.9	33.9	35.5	34.5	34.3	35.1	34.2	33.4			
35	37.8	37.5	36.6	36.5	35.4	34.8	35.5	35.3	35.1	35.7	36.5	37.1
						Rectal temperature, °C						
2	38.7	38.8	38.6	38.7	38.1	38.7	38.6	39.2	38.0	37.9	38.6	38.2
10	38.8	38.9	38.6	38.4	38.6	38.6	38.5	38.6	38.2	38.4	37.8	38.2
18	38.5	38.7	38.4	38.7	38.6	38.6	38.6	38.7	38.5	38.5	38.1	38.4
30	38.7	38.8	38.7	40.4	38.8	38.7	39.6	38.6	38.5	38.9	38.6	38.6
35	40.1	40.2	39.0	41.0	39.9	38.9	39.2	39.8	39.0	40.9	39.1	38.7