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Kuwait climate and heat stress in dairy cattle

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ABSTRACT

For almost six months out of every year the temperature in Kuwait rises above the comfortable temperature for dairy cattle. Every year milk production and reproduction efficiency of dairy cows in Kuwait decrease in the summer, due to heat stress conditions.

From the several indices which have been developed to predict comfort and discomfort of environmental conditions, the temperature–humidity index (THI) is used in this study. It was found that only 44 % of the year lies in the recommended comfortable levels of THI. For the rest of the year the values of THI are higher than the comfort level and heat stress conditions exist.

INTRODUCTION

Dairy cows, as all mammals, are homeothermic; thus there exists a thermal environment in which maximum productivity occurs. This is usually measured by the efficiency of feed conversion to useful products. The limits of the comfortable levels of the environment at which maximum productivity and efficiency occur, however, will depend on the breed, age, weight and sex (ASHRAE 1981). The two environmental variables which are commonly used to evaluate the best thermal environment are the dry-bulb temperature (T) and the relative humidity (RH). The air temperature is considered the major variable describing thermal environment, since the animal's sensible heat dissipation is a function of temperature difference. Second in importance is the relative humidity. When the ambient temperature approaches the animal's surface temperature, the burden of heat dissipation is shifted to latent heat or evaporative heat loss as illustrated in Fig. 1. Appleman & Owen (1971) indicated that for mature cows, a comfort temperature zone of about 0–24°C exists for all breeds and that milk production decreases if the temperature exceeds 24°C. On the other hand, increase in relative humidity will interfere with the evaporative heat loss, which is essential at higher temperatures.

The extremes of external environmental variables cause heat stress. Heat stress occurs under any combination of environmental conditions that will cause the effective temperature of the environment to be higher than the temperature range of the animal's thermo-neutral zone. The animal responses to such environmental extremes are dramatic. Stott (1981) stated that loss of body tissue and the decline in production

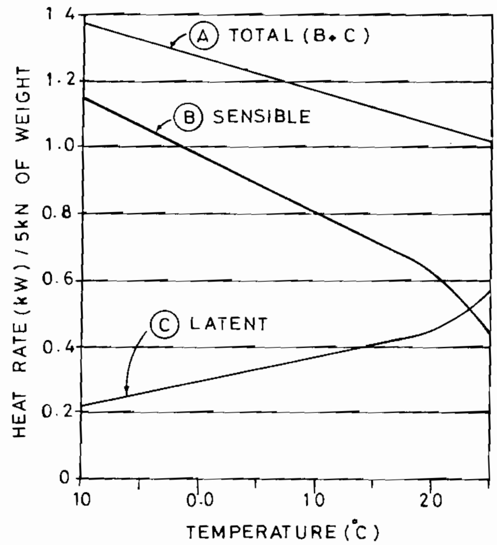

Fig. 1. The effect of temperature on the sensible and latent heat dissipation rates for rested dairy cattle (A and C, ASHRAE, 1981).

are immediately noticeable. With the prolonged exposure to extreme stress, adverse neuroendocrine activity occurs, serum adrenal steroid concentrations become subnormal, consequently affecting (directly or indirectly) the depression of serum reproductive steroids (Abilay *et al.* 1974). It was also reported that a short-term exposure to high ambient temperature at or near the time of breeding, results in reproductive suppression. Raising the ambient temperature of cows to high levels shortly after mating will have detrimental effects on embryonic survival (Stott & Wiersma 1976).

Several indices have been developed and used to predict comfort, or discomfort of environmental conditions. Buffington *et al.* (1981) stated that the most common comfort index is the temperature–humidity index (THI). One form of the THI equation is

$$THI = T + 0{\cdot}36T_{dp} + 41{\cdot}5$$

where

$$T = \text{Dry-bulb temperature (°C)}$$

$$T_{dp} = \text{Dewpoint temperature (°C)}$$

The value of THI was found to affect milk production directly. With a THI value of 70 or less, dairy cows experience little, if any, thermal discomfort (Buffington *et al.* 1981). However, when THI is 75 or higher, milk yield and feed intake are seriously depressed.

Heat stress environmental conditions exist for nearly half the year in Kuwait; in some years more drastically than others. During the more severe summers some cows cannot tolerate the continual stress and simply die. Most cows are kept in shaded areas during the summer, while a few, mainly pregnant cows and young calves are kept in evaporatively cooled sheds.

Farms in Kuwait suffer during the long summer months from a decrease in milk production, high death rates, low reproductive efficiency and other heat stress effects. In a study made by the Animal Production Division of the Kuwaiti Agricultural Affairs and Fish Resources Authority (1981), the milk production dropped down in summer to 70% of that produced in winter (Fig. 2).

It is evident that these harmful effects reduce the profitability of the farms, and make the economics of farms questionable. As a result, the Kuwaiti Government subsidizes the cost of milk to encourage farmers to continue in the production of this important source of food. Bahman (1984) reported that fresh milk production covers only 10–15% of the country's consumption, while the rest is covered by imported powdered milk.

In Kuwait (28°N, 46°E), summer weather lasts about six months, fall lasts only one month, while winter and spring last for about two-and-a-half months each (Salman & Ayyash 1981).

The purpose of this study is to identify periods when heat stress conditions exist. This is achieved by using the temperature–humidity index (THI) to predict comfort, or discomfort, of local environmental conditions.

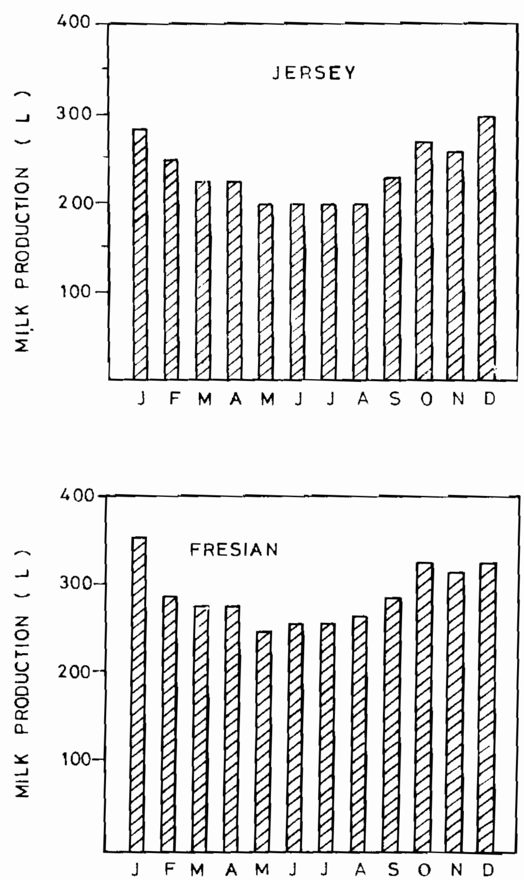

Fig. 2. The monthly milk production for dairy cattle in Kuwait.

METHODS

Weather data over a period of twenty years has been stored in the computer. For each day of the period 1961–1980, values of the various weather parameters were recorded for each one hour interval (Meteorological Department 1976–1980). These parameters include: dry and wet bulb temperatures, relative humidity, wind speed and direction, atmospheric pressure and vapor pressure. The dew point temperature was calculated by the method described by ASHRAE (1976).

The recorded weather data is used to predict the weather pattern shown in Figs 3–5. All figures are constructed using the hourly values averaged over the 20-year period. Fig. 3 shows the average maximum and minimum temperatures for a typical year. Fig. 4 shows the average temperature for typical days in each of the four seasons. The figure shows a relatively mild winter, where the temperature ranges between 8 and 16°C, although in some years it may drop at night to almost freezing. Fall and spring are usually comfortable and temperature ranges between 15 and 25°C. The summer is long and the temperature stays above the comfort level day and night, and ranges from 30–44°C. The highest recorded temperature is around 51°C.

Fig. 5 shows the average relative humidity for typical days in fall, winter, spring and summer. For almost all the days in the year, the average humidity drops significantly during the middle of the day from its higher values in the morning and evening hours. Comparing the relative humidity figures with the temperature figures and with the help of the psychrometric chart, it is clear that the amount of vapor in the air is almost constant during the course of the day. In other words, the humidity ratio remains almost constant. The drop in relative humidity at midday allows the use of evaporative cooling to lower dry bulb temperature and consequently lower the periods of heat stress on the animals.

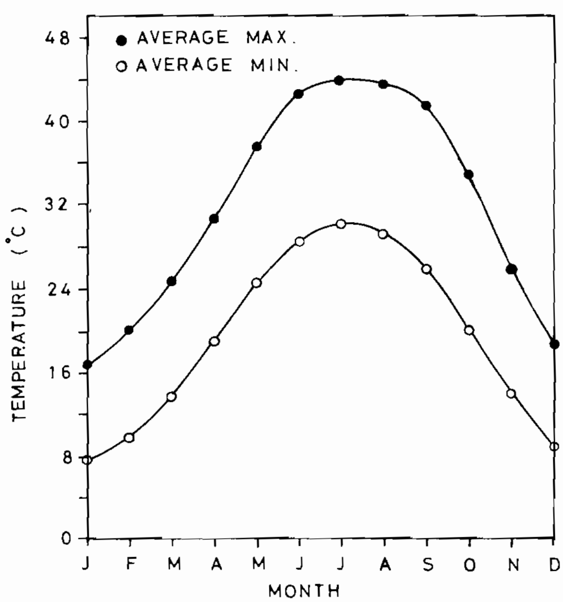

Fig. 3. The average maximum and minimum temperatures for a typical year.

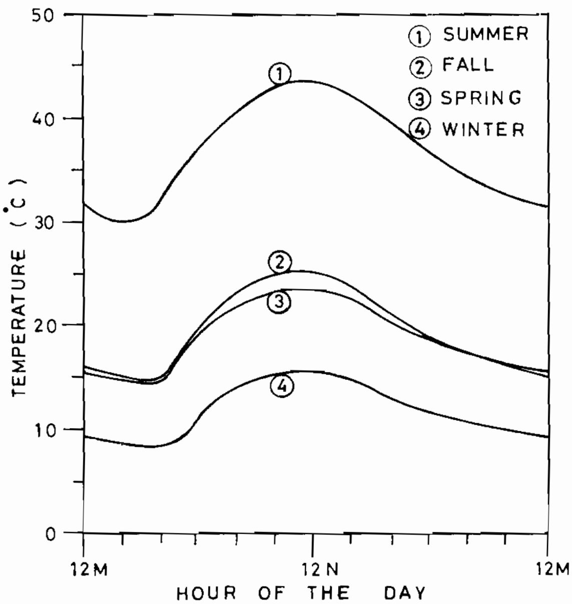

Fig. 4. The average temperature for typical days in the four seasons.

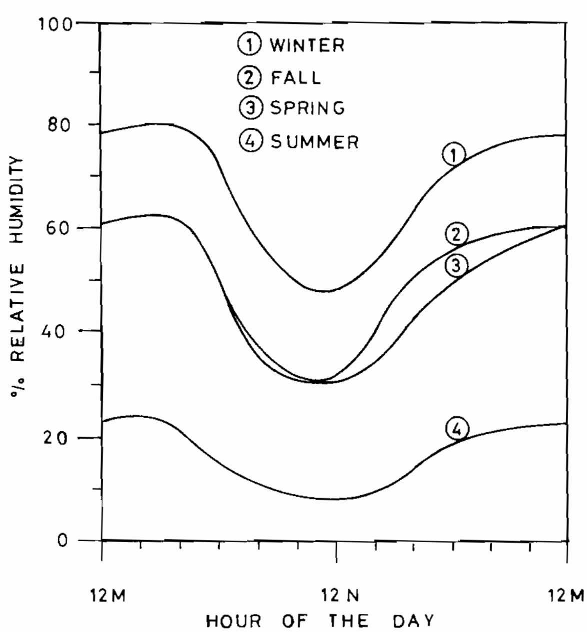

Fig. 5. The average relative humidity for typical days in the four seasons.

It should be kept in mind that the following analysis assumes that the cows are shaded and only the effect of THI is considered. The analysis does not include the effect of radiation from the sun nor from the surrounding surfaces. Exposure of cows to the direct sun's radiation will cause a significant rise in rectal and surface temperatures, in addition to the increase in respiration rates. This in fact decreases their milk production and reproductive efficiency.

RESULTS

In an attempt to define the heat stress periods for a typical year in Kuwait, the THI was calculated for each one-hour interval from estimated values of temperature and relative humidity. Each value of THI, for example, THI = 75, will cover the range between $74{\cdot}5 < \text{THI} < 75{\cdot}5$.

Table 1 shows the percentage of occurrence of the different values of THI averaged for hourly values for different months of a typical year. The table shows the percentage of time within each month in which the average values fall in the specified THI range. For example the THI average values for May will be 65 or less for 1·4% of the hours of the month, and the average value of THI will be 75, for 6·9% and so on. Table 2 shows the average daily values of THI. From these data the year can be divided into three sections: (a) 44% of the year where $\text{THI} \leqslant 70$, no heat stress; (b) 15% of the year where $70 > \text{THI} \leqslant 75$, some discomfort; (c) 41% of the year where $(75 < \text{THI})$, heat stress conditions existing.

Table 3 shows the percentage of time for each day of the year when the THI value is less than or equal to 70, and these are the periods of no heat stress. The annual pattern of no heat stress conditions is shown in Fig. 6. It is clear that there will be no heat stress in the months of January, February, and December, and for most of March and November. On the other hand, heat stress conditions exist in the months of May through September and for about half of both April and October.

Table 1. The monthly percentage of occurrence of the different values of THI

THI / Month	≤ 65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	≥ 80
JAN	96.6	0.8	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FEB	91.1	3.3	2.1	1.5	0.8	0.5	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MAR	62.8	8.5	6.8	5.8	4.2	4.0	2.6	1.9	1.4	0.9	0.7	0.4	0.0	0.0	0.0	0.0
APR	16.4	6.0	6.9	7.8	8.2	8.9	7.9	7.7	7.0	6.0	4.4	3.8	2.9	2.5	1.6	2.0
MAY	1.4	1.1	1.4	2.2	2.8	3.6	4.6	4.9	6.1	7.3	6.9	7.8	7.3	7.4	6.7	28.5
JUN	0.0	0.0	0.1	0.3	0.7	1.0	1.4	2.4	3.1	4.4	4.9	4.9	6.0	5.9	6.4	58.5
JUL	0.0	0.0	0.0	0.0	0.1	0.3	0.5	1.2	1.7	2.6	3.5	4.0	5.1	5.2	5.8	70.0
AUG	0.0	0.0	0.1	0.1	0.1	0.5	0.6	1.5	2.2	2.9	3.6	4.5	5.2	5.7	5.4	67.6
SEP	0.7	0.5	0.7	1.2	1.8	2.4	3.1	3.6	4.2	4.1	5.0	5.3	5.7	5.7	5.4	50.6
OCT	14.3	3.6	3.8	4.0	5.2	4.8	5.2	5.0	5.5	5.5	5.8	5.8	5.9	5.8	4.8	15.0
NOV	53.4	5.8	6.0	6.0	5.5	5.0	4.3	4.0	3.6	2.4	1.6	1.0	0.7	0.4	0.2	0.2
DEC	90.4	2.9	2.2	1.9	1.3	0.8	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 2. The average daily value of THI

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	51.7	48.6	63.2	74.8	71.2	79.1	85.3	82.3	79.7	77.3	71.7	58.9
2	53.9	48.5	60.1	74.8	71.8	79.8	82.6	83.7	81.5	78.2	70.0	56.3
3	54.2	48.8	56.7	76.1	70.8	82.3	80.3	83.2	81.2	77.9	66.1	54.4
4	56.0	54.4	54.0	72.9	75.4	82.3	82.6	82.7	80.3	78.3	66.9	53.9
5	59.4	59.3	55.8	69.8	75.1	82.5	83.5	84.0	81.7	73.0	56.6	56.3
6	59.1	57.5	57.0	70.5	74.1	83.7	81.7	81.6	81.3	71.0	69.7	59.4
7	53.1	56.6	57.4	69.6	72.3	82.6	82.1	79.1	81.0	72.3	69.7	60.2
8	52.0	57.3	59.3	70.0	74.7	78.7	82.2	82.1	78.0	72.0	70.6	59.1
9	53.8	57.5	64.3	73.2	76.5	77.6	81.6	79.2	77.9	74.2	72.0	56.7
10	55.5	64.4	64.6	73.9	76.2	76.9	82.4	80.4	78.8	73.2	70.4	55.5
11	55.0	62.6	64.4	74.6	73.7	77.3	82.9	84.2	78.9	74.1	70.9	60.4
12	59.0	57.9	67.6	75.6	75.5	78.6	82.9	85.4	82.8	73.3	70.3	57.3
13	60.6	58.8	66.1	75.4	76.4	81.3	84.3	82.6	78.3	71.0	70.8	52.0
14	57.9	60.1	67.0	67.4	77.9	81.9	83.7	81.5	78.6	72.8	71.1	53.6
15	56.3	59.6	68.3	69.8	73.0	81.3	86.7	78.9	77.2	69.8	67.5	57.7
16	53.5	59.5	63.1	61.1	72.8	84.2	86.8	80.3	76.2	68.3	65.7	58.8
17	48.7	59.4	62.0	60.4	73.2	83.8	85.2	81.6	76.2	69.8	65.9	57.9
18	50.7	59.6	65.2	62.2	75.6	79.8	86.1	81.6	75.5	70.1	66.5	53.9
19	53.9	58.1	61.8	65.5	76.5	78.7	85.4	80.7	76.5	71.1	68.8	54.0
20	60.8	58.1	62.1	68.7	78.	80.0	87.4	82.2	75.5	71.9	68.9	54.4
21	61.8	57.2	64.8	71.2	79.5	80.2	84.4	82.2	77.3	70.6	66.1	54.1
22	56.1	57.1	67.4	74.0	81.8	81.0	86.9	82.2	72.7	69.2	70.6	54.9
23	61.8	59.5	69.2	73.4	81.5	78.8	88.1	80.8	69.0	68.1	62.2	55.4
24	56.6	62.1	69.2	74.8	75.0	81.4	87.1	81.2	68.8	73.0	60.7	56.7
25	56.7	58.9	71.0	77.1	75.4	81.8	86.4	81.2	74.2	72.9	58.7	58.7
26	56.1	60.4	71.2	68.9	76.9	80.6	87.6	79.9	76.7	69.1	55.9	60.2
27	56.8	61.8	70.9	68.1	78.6	79.8	82.7	80.2	76.5	68.0	60.6	62.4
28	58.0	63.7	72.8	68.8	79.6	81.6	81.6	79.9	76.7	68.0	61.6	61.0
29	60.2	63.8	73.3	73.9	78.1	84.2	82.9	79.7	76.0	65.9	59.4	57.2
30	54.9	-	73.0	72.9	77.2	85.5	82.6	79.1	76.0	62.6	58.5	57.4
31	46.2	-	72.6	-	77.8	-	82.6	77.9	-	64.7	-	59.4

SUMMARY

The results show that for almost half of the year, dairy cattle in Kuwait suffer from excessive heat stress, and for only 44% of the year the environmental conditions are within the recommended range for dairy cattle. The subjection of cattle to heat stress conditions will seriously affect their milk production, reproduction efficiency and successful pregnancies. One can correlate the reduction in milk production in the summer months with the subjection of cows to excessive heat stress. Also, the extended

Table 3. The daily percentage of occurrence where THI ≤ 70

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	100	100	99	77	33	2	2	0	5	20	64	100
2	100	100	97	73	36	2	2	2	4	21	68	100
3	100	100	92	65	27	5	1	0	2	25	58	100
4	99	100	98	64	18	7	0	0	4	24	57	98
5	99	100	99	71	15	5	0	0	2	18	76	97
6	100	100	99	68	28	4	2	0	3	21	78	100
7	100	100	100	69	27	3	3	0	2	28	83	98
8	100	98	98	65	24	3	3	0	1	35	77	99
9	100	100	100	62	17	3	2	0	3	33	70	98
10	100	98	98	50	15	3	0	0	2	30	74	98
11	100	100	97	55	15	3	0	0	3	29	77	98
12	100	100	95	53	10	1	0	0	6	30	80	100
13	100	100	96	49	10	2	0	1	5	29	81	100
14	100	100	94	49	7	3	0	0	3	27	78	98
15	100	99	94	53	12	2	0	2	5	33	78	100
16	100	98	93	55	14	1	0	0	6	39	82	100
17	100	100	92	59	7	0	1	0	6	30	83	100
18	100	98	94	61	5	0	0	1	7	35	86	100
19	100	97	93	53	10	1	1	0	6	40	85	100
20	100	99	91	46	9	0	0	2	6	40	90	100
21	100	98	91	51	6	0	0	2	7	42	92	100
22	100	95	94	38	5	0	0	1	11	48	92	99
23	100	99	85	35	5	2	0	0	13	51	87	100
24	100	100	91	46	7	0	0	0	15	48	90	100
25	100	100	83	60	8	2	0	1	13	42	93	100
26	100	100	84	57	4	3	0	1	15	46	99	99
27	100	100	84	45	5	2	0	0	14	44	89	100
28	100	100	80	42	0	2	0	0	15	47	96	100
29	100	100	81	29	3	0	0	1	18	46	99	100
30	100		82	28	4	1	0	4	17	55	100	100
31	100		82		3		0	3		57		100

heat stress periods cause a high death rate. This, together with the low milk production, decreases the profitability of dairy farms in the country. Consequently, the owners are reluctant to pay for improving the housing facilities for the animals, thus perpetuating the harmful effects of heat stress.

At present, the Government subsidizes about 25% of the cost of milk. It is thus recommended to improve the environmental conditions of the cattle shelters in order to improve production and reduce the need for subsidy. One method to achieve this is the use of evaporative cooling for the purpose of establishing better living conditions.

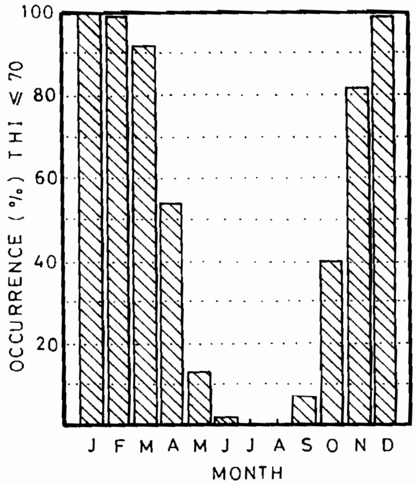

Fig. 6. The monthly percentage of occurrence where THI < 70.

Studies are now under way to investigate the effectiveness of this method in reducing the heat stress periods.

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تعرض الأبقار الحلوب للإجهاد الحراري تحت الظروف الجوية في الكويت

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الصفاة ١٣٠٦٠ ، الكويت

خلاصة

ترتفع درجات الحرارة في الكويت لمدة لا تقل عن ستة أشهر سنويا الى مستوى أعلى من المستويات المريحة للأبقار الحلوب . وفي فصل الصيف من كل عام ينخفض انتاج الحليب وكذلك كفاءة التكاثر عند هذه الأبقار نتيجة تعرضها للإجهاد الحراري .

ولتحديد المستويات المريحة للعوامل الجوية المختلفة بالنسبة للأبقار الحلوب فقد استعمل في هذه الدراسة معامل الحرارة والرطوبة من بين عدة مقاييس وضعت لهذا الغرض . وقد تبين أن الفترة الزمنية التي لا تعاني الأبقار فيها من أي إجهاد حراري لا تتعدى ٤٤٪ من السنة ، بينما ترتفع القيمة العددية لمعامل الحرارة والرطوبة الى أعلى من المستويات المريحة للأبقار الحلوب لبقية السنة .