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Seasonal Effects on Body Temperature, Thyroid Function, Blood Glucose and Milk Production in Lactating and Dry Holstein Cows in Semi-Arid Environment[1]

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ABSTRACT. Effects of summer and winter season were studied in two groups of 15 non-pregnant Holstein cows. Each group included 5 dry cows, 5 high-yielders and 5 average-yielders. The rise in air temperature and temperature-humidity index (THI) during summer compared with winter caused a significant ($p < 0.01$) rise in rectal temperature (RT) and respiratory rate (RR) of lactating cows compared with dry cows, particularly in the late afternoon compared with the early morning, and in the high-yielders compared with the average-yielders. Diurnal rhythms in RT and RR were found in winter but not in summer. Productivity status was found to exert greater effect on plasma thyroid hormone levels than did the season. Regardless of season effect, thyroxine (T_4) and triiodothyronine (T_3) concentrations were significantly ($p < 0.01$) lower in lactating cows than in dry cows. In summer, dry cows had higher T_4:T_3 ratio and blood glucose concentration compared with winter season, meanwhile the lactating cows showed an opposite trend. Among the two lactating groups, T_3 level was significantly ($p < 0.01$) reduced in the high-yielding cows only during the winter season. The decline in the milk yield of the high producing cows for each unit rises in THI, air temperature and RT were 0.92, 0.15 and 3 kg/day, respectively.

Numerous reports have indicated that hot summer season causes a lowering of thyroid activity resulting in a low plasma concentration of thyroxine and triiodothyronine in most studied farm animals (Johnson and Vanjonack 1976, Hart *et al.* 1979, El-Nouty and Hassan 1983, Bell *et al.* 1985 and Nixon *et al.* 1988). On the other hand, lactation is also associated with a decline in plasma thyroid hormone concentrations due to its fast turnover rates which may be more enhanced in high-yielding cows in order to support high milking intensity

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(Hart *et al.* 1978, Hart *et al.* 1979, Walsh *et al.* 1980, Blum *et al.* 1983 and Hassan *et al.* 1985).

The decline in milk production of temperate-evolved Holstein cows transferred to hot regions, particularly during hot summer, has been ascribed to heat-induced suppression of thyroid activity along with many other physiological changes necessary to minimize the rise in body temperature (Johnson 1987). Previous results (El-Nouty *et al.* 1988a) indicated that the rise in temperature-humidity index above the upper critical level for lactating Holstein cows altered most blood cellular and non-cellular constituents in high-yielding cows. This study was carried out in order to assess the effect of hot summer season on rectal temperature, respiration rate and plasma T_4, T_3 and glucose concentrations of high- and average-yielding Holstein cows raised in the semi-arid environment of Saudi Arabia.

Materials and Methods

This study was carried out at Al-Kharj Agriculture Project, Al-Hassa Irrigation and Drainage Authority, Ministry of Agriculture and Water during the summer of 1987 and the winter of 1988. Experimental design and animals are described by El-Nouty *et al.* (1988a). To review briefly, 30 cows divided into two equal groups were used in the experiment. During each season, 15 non-pregnant Holstein cows including 5 dry-cows, 5 high-yielding and 5 average-yielding cows were chosen to be used in the experiment. Average daily milk yield of the high-yielding cows during the experimental periods were 24.1 ± 0.40 and 33.5 ± 0.40 kg/day during summer and winter seasons, respectively. The corresponding values for the average-yielding cows were 19.2 ± 0.40 and 18.4 ± 0.40 kg/day. All lactating cows were closely matched for parity number and stage of lactation (60-110 days). Animals were housed together in an open shaded barn and water was available at all times. They were fed on a roughage mixture composed of 80% green fodder (*Medicago sativa*) and 20% Alfalfa hay offered *adlibitum*. A commercially formulated dairy concentrate (containing 13.4% digestible protein and 72% total digestible nutrients) was offered to the animals according to their actual requirements. Experiments were started in the summer (August) and repeated in the winter (February) and lasted for two weeks during each season. The first week was considered as a preliminary period followed by a 6-day experimental period. Daily maximum and minimum ambient air temperatures (°C) and relative humidities (%) were recorded during the 6-day experimental period. Dry and wet bulb temperatures, rectal temperature (RT) and respiration rate (RR) were also recorded twice a day at 9.00 and 16.00 hr. RT was measured by a clinical thermometer inserted in the rectum, while RR was measured by counting the flank movements during one minute and was expressed as number of respirations per minute. Temperature-Humidity Index (THI) was calculated, {THI = T_{db} + 0.36 T_{dp} + 41.2°C, where: T_{db} = dry bulb temperature (°C) and T_{dp} = dew point temperature (°C)}. Vapor pressure was obtained from Psychrometric chart using dry bulb temperature (°C) and relative humidity (%).

Three blood samples were also collected from each animal every other day during the 6-day experimental period. Blood samples were collected from the external jugular vein using 10 ml vacutainer tubes and were placed immediately on ice. Ethylene diaminetetraacetic acid (EDTA) was used as anticoagulant to obtain plasma; in other samples it was withheld to obtain serum. Plasma and serum were stored at −20°C until analysed. Thyroxine (T_4) and triiodothyronine (T_3) were determined in the stored plasma using Sopheia solid phase enzyme immunoassay kits obtained from Diagnostic Products Corporation, Los Angeles, California. Pooled plasma samples were included routinely in each assay and revealed intra-assay and inter-assay coefficients of variation of 9.1 and 9.0% for T_4 and 8.6 and 10.9% for T_3, respectively. Serum glucose was measured by the glucose oxidase reagent kit obtained from Rimol Diagnostics, Houston, Texas.

Data were statistically analysed at King Saud University Computer Center to examine the effects of season, productivity, time (AM *vs.* PM, if present) and their various interactions according to Goodnight *et al.* (1986). The Least-Squares Means (LSMEANS) procedure was applied to the data. T_4:T_3 ratio was analysed after log transformation and normal distribution test. Overall simple correlation coefficients between milk production and various measured parameters were also calculated.

Results

The variations in ambient air temperature, relative humidity, temperature-humidity index and vapor pressure during the two experimental periods of summer (August) and winter (February) are shown in (Table 1). It is apparent that during summer season most climatic aspects were above the upper critical levels of temperate-evolved Holstein cows. The only favorable environmental factor during summer was the low relative humidity and the associated higher vapor pressure.

The RTs were significantly ($p < 0.01$) influenced by season, productivity and their interaction. The overall mean RT was higher in summer compared with winter (39.1 *vs.* 38.6°C), and in lactating cows compared with dry cows (38.9 *vs.* 38.8°C). Among the two lactating groups, RT was higher in the high-yielding cows than in the average-yielding cows (39.0 *vs.* 38.9°C). The significant interaction between season and productivity revealed that the rise of RT in lactating cows compared with dry cows occurred only during the summer season, but the two lactating groups were statistically similar in that respect. Despite the fact that no statistical difference was detected between lactating and dry cows during winter season, the high-yielders possessed higher RT compared with the average-yielders (38.7 *vs.* 38.5°C). A significant ($p < 0.01$) diurnal rhythm in RT was also noted, since RTs recorded in the late afternoon were always higher (38.9°C) than those recorded in the early morning (38.8°C). Additionally, there were significant interactions between time of the day and season where RT in summer was almost similar in the morning and in the afternoon (39.1 *vs.* 39.1°C), while in winter it was significantly lower in the morning compared with the afternoon (38.5 *vs.* 38.7°C; Fig. 1). Also, the interaction between time and productivity significantly ($p < 0.01$) affected RT where RTs recorded in the morning were similar for high- and average- yielders (38.84 *vs.* 38.86°C) but those recorded in the afternoon were significantly higher ($p < 0.05$) in the high-yielders compared with the average-yielders (39.1 *vs.* 38.9°C; Fig. 1).

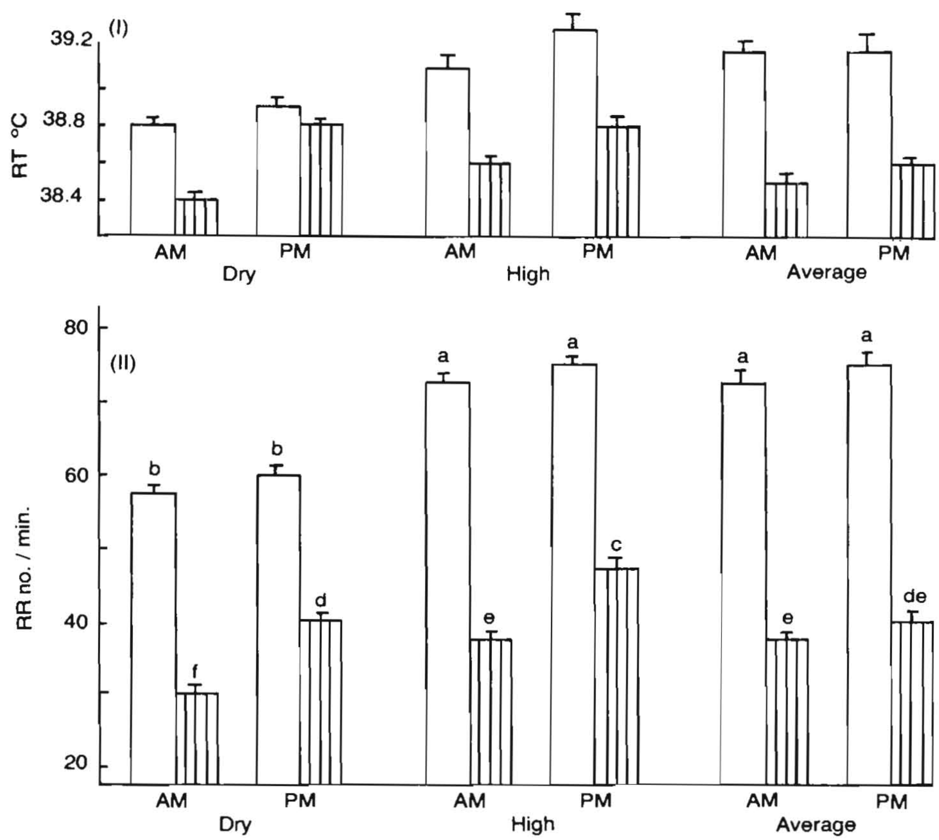

Fig. 1. (I) rectal temperature and (II) respiration rate in dry, high- and average-yielding Holstein cows during summer ▭ and winter ▥ in morning (AM) and afternoon (PM). [a,b,c,d,e,f]Columns bearing different superscripts differ ($P < 0.05$).

Table 1. Means and standard errors for the climatological parameters recorded during the summer and winter experimental periods

Parameters	August	February
Air temperature		
Maximum	38.7 ± 0.51	24.2 ± 1.20
Minimum	20.7 ± 0.66	12.1 ± 1.11
Relative humidity		
Maximum	48.8 ± 0.75	78.2 ± 4.06
Minimum	27.5 ± 0.45	30.0 ± 3.84
Vapor pressure		
AM	16.4 ± 1.53	12.6 ± 0.90
PM	15.8 ± 1.61	13.3 ± 0.48
Average THI*	81.9 ± 0.51	66.6 ± 1.25

* Temperature- humidity index.

Respiration rate showed a trend almost similar to that observed for RT. RR in summer was almost double ($p < 0.01$) that observed in winter (68 *vs.* 38 no./min.). It was also enhanced ($p < 0.01$) in lactating cows compared with dry ones (56 *vs.* 47 no./min.) and in the high-yielders than in the average-yielders (57 *vs.* 54 no./min.). Also time of the day exerted a significant influence ($p < 0.01$) on RR, and RR recorded in the late afternoon was always higher than that recorded in the morning (55 *vs.* 50 no./min.). There were significant interactions between season and time ($p < 0.01$) and season × productivity × time ($p < 0.05$). It can be seen from Fig. 1 that RR during summer was of almost similar frequency in the morning and in late-afternoon, while in winter it was significantly lower in the morning compared with the afternoon (33 *vs.* 41 no./min.).

The rise in RT and PR of cows during hot summer season was associated with a significant decline ($p < 0.01$) in the overall mean plasma T_4 level compared with its level in winter (57.1 ± 1.37 *vs.* 66.1 ± 1.37 ng/ml), but no significant changes were noted in the overall means of T_3 and glucose concentrations. The calculated ratio of T_4:T_3 was higher in winter ($p < 0.01$) than in summer. Dry cows possessed higher means of plasma T_4 and T_3 ($p < 0.01$) and non-significantly lower glucose concentration compared with lactating cows. Among the two lactating groups, the high-yielders had a significantly lower plasma T_3 concentration and consequently a higher T_4:T_3 ratio compared with the average-yielders (Table 2). Therefore, the correlation between milk production and T_4:T_3 ratio was positive ($r = 0.47$; $P < 0.01$).

The interaction between season and productivity exerted a significant influence ($p < 0.01$) on plasma T_3, T_4:T_3 and serum glucose. Dry cows in summer

Table 2. Least -squares means and standard errors for milk production, plasma levels of thyroxine (T_4), triiodothyronine (T_3), T_4:T_3 ratio and serum glucose concentration in Holstein cows as influenced by season and level of milk production

Parameters	Overall season average			Overall production average		
	Summer	Winter	Dry	High-yielders	Average-yielders	Mean for lactating[#]
Milk production (kg/day)	21.7^{B} ± 0.28	26.0^{A} ± 0.28	–	28.8^{a} ± 0.28	18.8^{b} ± 0.28	23.8 ± 0.43
T_4 (ng/ml)	57.1^{B} ± 1.37	66.1^{A} ± 1.37	74.4^{aA} ± 1.68	54.0^{b} ± 1.68	56.4^{b} ± 1.68	55.2^{B} ± 1.46
T_3 (ng/ml)	0.59 ±0.01	0.58 ±0.01	0.70^{aA} ±0.02	0.49^{c} ±0.02	0.56^{b} ±0.02	0.53^{B} ±0.01
*T_4:T_3 (ratio)	79.4^{B} ± 3.06	126.9^{A} ± 3.06	109.7 ± 3.76	124.4 ± 3.76	102.3 ± 3.76	113.4 ± 4.53
Glucose (mg/100ml)	31.3 ± 2.37	35.8 ± 2.37	29.0 ± 2.90	35.1 ± 2.90	36.5 ± 2.90	35.8 ± 1.90

a,b,c; A,B Means in the same row bearing different superscripts differ ($p < 0.05$); small letters are used to compare dry, high- and average-yielders; capital letters are used for comparing dry versus lactating cows and summer versus winter.

[#] Pooled means of high- and average-producers.

* T_4:T_3 is the least square means of the individual T_4/T_3 values.

showed significantly ($P < 0.05$) lower T_3 and higher glucose than in winter. They also had lower plasma T_4 and higher T_4:T_3 ratio in summer compared with winter but the differences were statistically non-significant (Table 3). This trend was somewhat different in lactating cows, since they had significantly lower T_4:T_3 ratio and glucose concentration in summer compared with winter. Comparisons between the two lactating groups across seasons showed that both high- and average-yielders in summer as well as the average-yielders in winter possessed significantly higher plasma T_3 than that in the high-yielders during winter.

Discussion

The rise in ambient temperature during summer resulted in an elevation in RT which in turn caused the observed respiratory enhancement. The correlation coefficient between RT and RR was positive and highly significant ($r = 0.8$), this because the rise in deep body temperature is the main stimulus to panting (Terrill 1968). The rise in RT and RR with elevated air temperature agrees with previous reports on dairy cattle (Lee *et al.* 1976, Holmes *et al.* 1980 and Ludri 1985), sheep and goats (Joshi *et al.* 1977 and El-Nouty *et al.* 1988b). The recorded higher RT and RR in lactating cows compared with dry cows and in the high-yielders relative to the average-yielders can be ascribed to the high metabolic rate of the lactating cows, particularly the high-yielders. In summer season, the combined effects of high ambient temperature and high metabolic rate was apparently the cause of the observed higher RT and RR in lactating cows compared with dry cows. Monty and Wolf (1974) reported that the body temperature of heat stressed lactating cows began to increase when the environmental temperature exceeded 30°C, but a similar increase did not occur in heat stressed non-lactating cows. The absence of significant differences in RT and RR between high- and average-yielders during summer season and their presence during winter may indicate that RTs are more affected by the high environmental temperature in summer rather than by the high metabolic heat production associated with greater milk production. The energy expenditure for respiratory enhancement in summer resulted in a remarkable decline in the milk yield of the high producing, but not of the average-producing, cows (Table 2). Thus, the correlation coefficient between milk yield and RR was negative ($r = 0.18$; $p < 0.05$). The decline in the milk yield of the high producing cows for each unit rises in THI, air temperature and RT were 0.92, 0.15 and 3 kg/day, respectively.

The higher RT recorded in the late afternoon as compared with that obtained in the early morning reflects animal activity and feeding during the day and rest during the night (Andersson 1982). This hyperthermia was apparently the cause of the observed rise in RR during the late afternoon. Amakiri and Funsho (1979) concluded that the changes in RT and RR between morning and afternoon periods parallel the daily air temperature and relative humidity. An interesting

Table 3. Least -squares means and standard errors for milk production, plasma levels of thyroxine (T_4), triiodothyronine (T_3), T_4:T_3 ratio and glucose concentration during summer and winter seaons for dry, high- and average-yielding Holstein cows

Parameters	Summer				Winter			
	Dry	High-yielders	Average-yielders	Mean for lactating#	Dry	High-yielders	Average-yielders	Mean for lactating#
Milk production (kg/day)	–	24.1^{b} ± 0.40	19.2^{c} ± 0.40	21.7 ± 0.61	–	33.5^{a} ± 0.40	18.4^{c} ± 0.40	26.0 ± 0.61
T_4 (ng/ml)	71.2 ± 2.37	49.9 ± 2.37	50.2 ± 2.37	50.1 ± 2.06	77.6 ± 2.37	58.2 ± 2.37	62.6 ± 2.37	60.4 ± 2.06
T_3 (ng/ml)	0.65^{bB} ± 0.02	0.57^{c} ± 0.02	0.57^{c} ± 0.02	0.57^{C} ± 0.02	0.75^{aA} ± 0.02	0.42^{d} ± 0.02	0.55^{c} ± 0.02	0.49^{D} ± 0.02
*T_4:T_3 (ratio)	112.3^{bA} ± 5.31	92.4^{c} ± 5.31	87.5^{c} ± 5.31	89.9^{B} ± 6.40	107.1^{bA} ± 5.31	156.4^{a} ± 5.31	117.2^{ab} ± 5.31	136.8^{A} ± 6.40
Glucose (mg/100ml)	36.4^{abAB} ± 4.11	28.3^{bc} ± 4.11	29.0^{bc} ± 4.11	28.7^{BC} ± 2.77	21.6^{cC} ± 4.11	41.9^{a} ± 4.11	43.9^{a} ± 4.11	42.9^{A} ± 2.77

a,b,c,d; A,B,C,D Means in the same row bearing different superscripts differ ($p < 0.05$); small letters are used to compare dry, high- and average-yielders; capital letters are used for comparing dry versus lactating cows.

Pooled means of high- and average-producers.

* T_4:T_3 is the least square means of the individual T_4/T_3 values.

finding was the absence of the diurnal rhythms in RT and RR in summer and its presence in winter. This phenomenon can be explained by the observed change in animal's activity and feeding behavior which increased during night time. Hafez (1982) reported that high environmental temperature alter feeding and activity of the animals to increase during night. Finally, the significantly higher RT of the high-yielders recorded in the late afternoon relative to the average-yielders may reflect the combined effect of the hottest time of the day and the greater metabolic heat production of the high-yielders.

Several factors have been reported to cause changes in plasma level of thyroid hormones and/or thyroid hormones secretion rate. Hot summer season as well as exposure of dry cows to high temperature in climatic chambers depress thyroid activity resulting in a lowering of thyroid hormones (Johnson and Vanjonack 1976, Christopherson *et al.* 1979 and El-Nouty and Hassan 1983). Data of the present study agree with previous results since T_4 and particularly T_3 were reduced in dry cows during hot summer compared with moderate winter. Several investigators related the decline in thyroid hormones level during heat exposure to the direct effect of heat on hypothalamic-pituitary axis to cause reduction in TSH which enables the animal to reduce basal metabolism (El-Nouty and Hassan 1983 and Johnson 1987). Lactation is also known to cause a reduction in thyroid hormone concentrations of dairy cattle in proportion to milking intensity. The lactation-induced depression of plasma thyroid hormones is not caused by a lowering of thyroid activity. On the contrary, the secretion rate of thyroid hormones is known to be elevated in lactating cows, but owing to increased tissue utilization of these hormones during lactation, their levels decline proportionally to milk yield (Hart *et al.* 1978, Hassan *et al.* 1985 and Nixon *et al.* 1988). This may explain the higher levels of T_4 and T_3 in dry cows compared with lactating cows in the present study (Table 2). Similar observations were reported recently by Aceves *et al.* (1985, 1987).

As far as the relation between milk yield and thyroid hormone levels, the high-yielders showed significantly lower T_3 compared with the average-yielders (Table 2). This finding can be explained on the basis of the known fact that T_3 is more potent than T_4 and the latter has to be transformed to T_3 in tissues before it becomes biologically active (Boonnamsiri *et al.* 1979). The higher T_4:T_3 ratio found in the high-yielders compared with average-yielders (Table 2) along with the significantly negative correlation between milk yield and T_3 ($r = 0.27$; $P < 0.05$) support this explanation.

In an attempt to answer the question whether season of the year or productivity level exert the greater influence on the changes in plasma thyroid hormones, regression analysis was applied to the pooled T_4 and T_3 values of lactating cows. The obtained R^2 values revealed that the contribution of the season of the year relative to the total variations in T_4 and T_3, were 4 and 0.5%, respectively. The corresponding values for productivity were 14 and 31%, indicating that productivity status had a greater influence on T_4 and T_3 levels than did the season. This finding agrees with that of Nixon *et al.* (1988), who concluded that stage of lactation (milking intensity) had a much greater influence on thyroid hormones level than did the season. In the present study, dry cows in summer showed lower T_3 and higher T_4:T_3 ratio and blood glucose compared with winter (Table 3). This may be a physiological adjustment to reduce the heat stress on the animal by lowering the potent thyroid hormone T_3. Meanwhile, the rise in blood glucose of dry cows in summer may be ascribed to heat-induced lesser glucose utilization as a result of decreased heat production and the decline in blood glucose turnover and oxidation rates (Patterson 1963). The lower T_4:T_3 ratio of lactating cows during summer compared with winter may be explained at least in part, on the basis of the combined effect of heat stress and less milk production (Table 3) on T_3 turnover rate. On the other hand, the low blood glucose concentration of lactating cows during summer can be ascribed to the additive effects of heat-induced depression of feed intake along with the higher glucose expenditure for respiratory enhancement in summer (Shaffer *et al.* 1981). Additionally, the significantly lower T_3 in the high-yielding cattle in winter indicates the opposing effect of summer high-temperature on T_3 utilization which may be necessary for sustained milk production. This view agrees with the finding of Refsal *et al.* (1984), who concluded that high milk production in early lactation may result in a reduction of T_4 and T_3 that is independent of seasonal effects.

In conclusion the rise in THI during summer season to exceed the upper critical level for temperate-evolved Holstein cattle was associated with a rise in RT and RR of lactating cows compared with dry cows and was of greater magnitude in the high-yielders than in the average-yielders. This was accompanied in the high-yielders with less T_3 utilization and a 28% less milk production in summer.

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تأثير فصل السنة على درجة حرارة الجسم ، هرمونات الغدة الدرقية ، جلوكوز الدم وانتاج اللبن في أبقار الهولشتين الحلابة والجافة في البيئة شبه الجافة

فرحات الدسوقي النوتي و أحمد إبراهيم الحيدري و محمود سيد صلاح

قسم الانتاج الحيواني ـ كلية الزراعة ـ جامعة الملك سعود
ص . ب ٢٤٦٠ ـ الرياض ١١٤٥١ ـ المملكة العربية السعودية

اتضح من البحوث التي أجريت على الحيوانات الزراعية أن ارتفاع درجة حرارة الجو خلال فصل الصيف يؤدي إلى إنخفاض نشاط الغدة الدرقية وبالتالي إنخفاض مستوى كل من هرموني الثيروكسين والتراي ـ ايودوثيرونين في الدم . ومن المعروف أن انتاج الحليب يؤدي إلى انخفاض مستوى هرمونات الغدة الدرقية بالدم نتيجة لزيادة معدل استخدام هذه الهرمونات في الجسم ، مما يجعل هذا الانخفاض أكثر وضوحاً في الأبقار عالية الانتاج .

وعند نقل أبقار الحليب التي نشأت في المناطق الباردة إلى المناطق الحارة ينخفض انتاجها من الحليب خاصة خلال فصل الصيف . هذا الانخفاض قد يكون راجعاً إلى عدة عوامل من أهمها انخفاض نشاط الغدة الدرقية بالاضافة إلى بعض التغيرات الفسيولوجية والتي تساعد الحيوان على الحد من الارتفاع في درجة حرارة الجسم .

وقد أجريت هذه الدراسة لمعرفة تأثير فصل الصيف الحار على درجة حرارة المستقيم ـ معدل التنفس ـ مستوى هرمونات الغدة الدرقية وجلوكوز الدم في أبقار الهولشتين العالية ومتوسطة الانتاج في البيئة شبه الجافة في المملكة العربية السعودية .

في هذه الدراسة استخدمت مجموعتان من الأبقار كل مجموعة تتكون من ١٥ بقرة هولشتين غير حامل، مجموعة استخدمت صيفاً والأخرى شتاءاً، اشتملت كل مجموعة على ٥ أبقار جافة و٥ أبقار عالية الانتاج و٥ أبقار متوسطة الانتاج. وكان متوسط انتاج الحليب للأبقار العالية الانتاج ٢٤,١ ± ٠,٤ خلال فصل الصيف و ٣٣,٥ ± ٠,٤ كجم / يوم خلال فصل الشتاء، والأبقار المتوسطة الانتاج ١٩,٢ ± ٠,٤ خلال فصل الصيف و ١٨,٤ ± ٠,٤ كجم / يوم خلال فصل الشتاء وكانت جميع الأبقار الحلابة في الموسم الثالث إلى الرابع ومتقاربة في مرحلة الحليب.

أجريت هذه التجربة في صيف ١٩٨٧م واستمرت لمدة أسبوعين، كان الأسبوع الأول عبارة عن فترة تمهيدية وتم في الأسبوع الثاني أخذ القياسات التالية: درجة الحرارة اليومية العظمى والصغرى المحيطة بالحيوان، الرطوبة النسبية، درجة حرارة المستقيم ومعدل التنفس، كما تم أخذ ٣ عينات دم من كل حيوان خلال فترة التجربة وتم تقدير كلا من تركيز هرموني الثيروكسين والتراي ـ أيودوثيرونين بالبلازما وجلوكوز الدم في السيرم. أدى الارتفاع في درجة الحرارة المحيطة بالحيوان ودليل الحرارة والرطوبة خلال فصل الصيف مقارنة بالشتاء إلى ارتفاع واضح في درجة حرارة المستقيم ومعدل التنفس للأبقار الحلابة خاصة في وقت ما بعد الظهر مقارنة بالصباح الباكر، كما كانت في الأبقار عالية الانتاج أعلى من المتوسطة الانتاج.

الاختلافات اليومية في درجة حرارة المستقيم ومعدل التنفس كانت واضحة في فصل الشتاء وليس في فصل الصيف، تركيز هرمونات الغدة الدرقية في بلازما الدم وجد أنها تكون أكثر تأثراً بالحالة الانتاجية للأبقار مقارنة بتأثير فصل السنة. وبصرف النظر عن تأثير موسم السنة، وجد أن تأثير هرموني الثيروكسين والتراي ـ أيودوثيرونين كانت أقل بشكل واضح في الأبقار الحلابة مقارنة بالأبقار الجافة. نسبة هرمون الثيروكسين وهرمون التراي ـ أيودوثيرونين وكذلك تركيز الجلوكوز كانت أعلى خلال فصل الصيف في الأبقار الجافة مقارنة بالأبقار الحلابة بينما وجد العكس تماماً في الأبقار الحلابة وبمقارنة الأبقار الحلابة ببعضها البعض لوحظ أن

هرمون التراي ـ أيودوثيرونين كان منخفضاً معنوياً في الأبقـار عاليـة الانتاج فقط خلال فصل الشتاء. وقد اتضح من الحسابات أن إنتاج الحليب في الأبقـار عاليـة الإنتـاج ينخفض بمقدار ٩٢,٠، ١٥,٠، ٣,٠ كجم / يـوم لكل وحـدة واحـدة في دليل الحرارة والرطوبة ـ درجة حرارة الجو ودرجة حرارة المستقيم على التوالي.

ويستخلص مما سبق أن ارتفاع دليل الحرارة والرطوبـة خلال فصـل الصيف الحـار أعلى من المستـوى الحرج لأبقـار الهولشتـين أدى إلى ارتفـاع درجـة حـرارة الجسم ومعدل التنفس في الأبقار الحلابة عنه في الأبقار الجافة، وبـالنسبة لـلأبقار الحلابة يكون هذا الارتفاع أكثر وضوحاً في الأبقار عالية الإنتاج عنه في المتوسـطة الإنتاج، ويصاحب هذا نقص في معدل استخدام هرمون التراي ـ أيـودوثيرونـين في الأبقار عالية الإنتاج ونقص إنتاجها من الحليب بنسبة ٢٨٪ في فصل الصيف.