Thyroid hormone profile in dairy cattle acclimated to cold or hot environmental temperatures

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Abstract. Milk yields and the circulating profile of T₄, T₃ and rT₃ were assessed during three different seasons of the year, in first trimester lactating (L) and in dry (D) multiparous holstein cows acclimated to distinct weather conditions. Within the thermoneutral zone (18–28°C; 40–60% RH) and regardless of their geographical location, the thyroid hormone profile in all L-cows (n = 50) resembled the so-called euthyroid sick syndrome (T₄, 43.7 ± 7.7 nmol/l; T₃, 1.31 ± 0.10 nmol/l and rT₃, 0.52 ± 0.08 nmol/l). In both groups of animals the T₃/T₄ molar ratio was similar within the entire range of climates encompassed in the study. However, both groups exhibited a significant shift in the T₃/rT₃ molar ratio during cold (10°C; 50%) or hot-dry (34°C; 40%) weather conditions. This shift reaches maximum values (L, 6.5 ± 1.2; D, 7.9 ± 1.0 nmoles/l) under hot-humid conditions (28–42°C; 60–90%). The relative increase of T₃ levels from comfortable to cold or hot environmental temperatures was significantly higher in L than D animals (30 vs 12%, respectively). Furthermore, only L-cows exhibited a significant decrease in the rT₃/T₄ molar ratio during either type of thermoregulatory demands, as well as a significant increase of T₄ values under heat-acclimation. These results suggest that heat-acclimation in dairy cattle does not depress thyroid gland activity, and lend further support to the notion that adaptive thermoregulatory mechanisms in homeothermic vertebrates, involve adjustments in the peripheral monodeiodinative pathways of thyroid hormones.

Our previous studies on thyroid physiology in dairy cattle under comfortable, natural weather conditions demonstrate that in animals undergoing early lactation, the circulating profile of thyroxine (T₄), triiodothyronine (T₃) and reverse triiodothyronine (rT₃), resemble the so-called euthyroid sick syndrome and also that environmental heat overloads induce a gradual shift in the T₃/rT₃ ratio which within certain limits seems not to affect T₄ levels or milk yield (Aceves et al. 1985a,b). The occurrence of these particular hormonal re-arrangements during certain physiological conditions, lead us to suggest that peripheral thyroid hormone metabolism may be part of the homeorhetic mechanisms that maintain energy expenditure for high priority functions in the organism (Aceves et al. 1985a; Aceves 1985).

These findings along with the well known fact that acute exposure to low or high temperature modifies thyroid activity in homeothermic vertebrates (Sterling & Lazarus 1977; Collins 1978; Mortley 1981), prompted us to study the profile exhibited by thyroid hormones in holstein cows confronting different natural weather conditions. Thus, in the present paper we extend our previous studies and present data suggesting that peri-

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1 Recipient of a postgraduate studentship from CoNaCyT-UNAM.
teral metabolism of thyroid hormones may be a major component of the homeorhetic response elicited during acclimation to cold or hot environmental weather conditions in dairy cattle.

Materials and Methods

Animals

The study includes 167 non-pregnant purebred multiparous (2 to 5 calvings) holstein cows of which 111 were lactating (L), and 56 were dry (D). All animals were born within the herds from three different university experimental farms (see below). All lactating cows were within the first trimester of lactation (early lactation). Animals were maintained in a semistabling regimen, pasturing on native grass in the morning and supplemented with corn silage, alfalfa hay and a mixture of 2% molasses/urea when housed in the barn. In addition, lactating cows received 2 kg of protein supplement (16–18%) during each mechanical milking period.

Table 1.
Climatic and weather characteristics.

<table>
<thead>
<tr>
<th>Experimental zone</th>
<th>Climatic classification*</th>
<th>January</th>
<th>May</th>
<th>October</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aguascalientes</td>
<td>BS1hw(w) (e)g</td>
<td>10°C: 50%</td>
<td>22°C: 40%</td>
<td>18°C: 60%</td>
</tr>
<tr>
<td>Durango</td>
<td>BS1Kw(w) (e)</td>
<td>22°C: 40%</td>
<td>34°C: 40%</td>
<td>28°C: 40%</td>
</tr>
<tr>
<td>Tabasco</td>
<td>Am(f)w&quot; (i')g</td>
<td>28°C: 70%</td>
<td>42°C: 60%</td>
<td>34°C: 90%</td>
</tr>
</tbody>
</table>


Table 2.
Milk yield and thyroid hormones under different thermoregulatory demands.

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Relative humidity (%)</th>
<th>Group (N)</th>
<th>Milk yield (l/day)</th>
<th>T₄ (nmol/l)</th>
<th>T₃ (nmol/l)</th>
<th>rT₃ (nmol/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>50</td>
<td>D (6)</td>
<td>–</td>
<td>64.3 ± 3.8</td>
<td>2.1 ± 0.14b</td>
<td>0.28 ± 0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L (14)</td>
<td>19.0 ± 3.2</td>
<td>41.8 ± 7.7A</td>
<td>1.9 ± 0.09B</td>
<td>0.35 ± 0.05B</td>
</tr>
<tr>
<td>18</td>
<td>60</td>
<td>D (7)</td>
<td>–</td>
<td>65.6 ± 5.1</td>
<td>2.0 ± 0.06</td>
<td>0.27 ± 0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L (14)</td>
<td>22.6 ± 3.1</td>
<td>41.2 ± 11.6A</td>
<td>1.3 ± 0.13A</td>
<td>0.47 ± 0.05A</td>
</tr>
<tr>
<td>22</td>
<td>40</td>
<td>D (8)</td>
<td>–</td>
<td>65.6 ± 9.0</td>
<td>1.9 ± 0.89A</td>
<td>0.29 ± 0.03A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L (12)</td>
<td>24.8 ± 2.2</td>
<td>37.3 ± 3.9A</td>
<td>1.1 ± 0.17A</td>
<td>0.57 ± 0.06A</td>
</tr>
<tr>
<td>22</td>
<td>40</td>
<td>D (5)</td>
<td>–</td>
<td>66.9 ± 3.9</td>
<td>1.8 ± 0.05A</td>
<td>0.32 ± 0.03A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L (13)</td>
<td>20.8 ± 3.8</td>
<td>39.9 ± 6.4A</td>
<td>1.3 ± 0.11A</td>
<td>0.60 ± 0.06A</td>
</tr>
<tr>
<td>28</td>
<td>40</td>
<td>D (5)</td>
<td>–</td>
<td>72.0 ± 3.9</td>
<td>1.9 ± 0.08</td>
<td>0.33 ± 0.04A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L (11)</td>
<td>20.1 ± 2.9</td>
<td>51.5 ± 6.4</td>
<td>1.5 ± 0.08A</td>
<td>0.50 ± 0.10A</td>
</tr>
<tr>
<td>28</td>
<td>70</td>
<td>D (6)</td>
<td>–</td>
<td>65.6 ± 5.1</td>
<td>2.0 ± 0.05</td>
<td>0.29 ± 0.02A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L (16)</td>
<td>18.6 ± 2.8</td>
<td>52.8 ± 3.9B</td>
<td>1.9 ± 0.06B</td>
<td>0.33 ± 0.05B</td>
</tr>
<tr>
<td>34</td>
<td>40</td>
<td>D (4)</td>
<td>–</td>
<td>64.3 ± 6.4</td>
<td>2.1 ± 0.03b</td>
<td>0.32 ± 0.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L (9)</td>
<td>18.5 ± 2.3</td>
<td>56.6 ± 5.1B</td>
<td>1.9 ± 0.09B</td>
<td>0.38 ± 0.03</td>
</tr>
<tr>
<td>34</td>
<td>90</td>
<td>D (8)</td>
<td>–</td>
<td>64.3 ± 7.7</td>
<td>2.1 ± 0.02b</td>
<td>0.27 ± 0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L (12)</td>
<td>15.8 ± 1.3</td>
<td>59.2 ± 5.1B</td>
<td>2.0 ± 0.10B</td>
<td>0.29 ± 0.03B</td>
</tr>
<tr>
<td>42</td>
<td>60</td>
<td>D (7)</td>
<td>–</td>
<td>61.7 ± 5.1</td>
<td>2.1 ± 0.05b</td>
<td>0.24 ± 0.02b</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L (10)</td>
<td>15.5 ± 1.5</td>
<td>54.1 ± 3.9B</td>
<td>2.0 ± 0.12B</td>
<td>0.25 ± 0.03B</td>
</tr>
</tbody>
</table>

Means in the same column bearing different superscript letters (within the same group), differ significantly (P < 0.05). a, b: dry animals; A, B: lactating animals.
Throughout the entire study body weight in both groups of cows varied from 415 to 560 kg.

**Lactic conditions and study protocol**

The study was conducted in animals from three different climatic zones: temperate (Aguascalientes); hot-dry (Durango) and hot-humid (Tabasco). All animals were sampled during three different seasons of the year thus covering different weather conditions in each zone (see Table 1). All sampling periods began at 10.00 h. Blood was obtained by caudal puncture, and the serum from each animal was divided in suitable aliquots and frozen at −20°C until assayed.

**Radioimmunoassay**

Serum levels of T₄, T₃ and rT₃ were assessed by specific radioimmunoassay (RIA) procedures as previously reported (Aceves et al. 1982; Ruiz-J et al. 1984). Each hormone was quantified in all samples in consecutive RIA's. The intra- and inter-assay coefficients of variation (n = 16) were 8.5 and 11.5% for T₄; 9.6 and 13.6% for T₃ and 9.2 and 12.5% for rT₃, respectively.

Results are expressed as the mean ± sd. Statistical methods included variance analysis and when appropriate Student's t-test. A P-value of less than or equal to 0.05 was considered to be statistically significant.

**Results**

Table 2 summarizes the results obtained in the present study. Data are ordered according to the average temperature (°C) and relative humidity (%) registered at the corresponding experimental
without elevated in case or values occurred simultaneously to lower location, within obtained.
pared type in the 34°C temperatures, farm
As Fig. both climates both when lactating animals
molar of values of thermoneutral and environmental or lactating animals
the of thermoregulatory production of animals revealed significant
temperature exceeded 60%. In the case of lactating animals under conditions of up to 34°C and 40%, this re-arrangement occurred without a significant decrease in milk yield. Above these values milk production dropped.

Fig. 1 shows the effect of the different weather conditions on the molar ratios among thyroid hormones. The molar ratio of T₃ to T₄ was similar in both groups of animals within the entire range of climates encompassed in the study. In contrast, the molar ratio of T₃/rT₃ was significantly higher in both dry and lactating animals during either type of thermoregulatory demand when compared with animals in the thermoneutral zone. This shift in the T₃/rT₃ molar ratio was much greater in lactating animals.

Furthermore, only in this group of cows, the molar ratio of rT₃/T₄ exhibits a significant decrease during cold or heat overloads.

Table 3 summarizes milk yields and hormonal values of animals in the climatic ranges encompassed in this study: cold (10°C:50%); temperate (18–28°C:40–60%); hot-dry (34°C:40%) and hot-humid (28–42°C:60–90%). It is clear that, regardless of the type of thermoregulatory stress, increased T₃ circulating levels reach similar values in both groups of cows. However, the relative increase of T₃ from comfortable to cold or hot environmental temperatures, was significantly higher in lactating than in dry animals (30% vs 12%, respectively). Besides this T₃ increase, lactating animals exhibit a significant elevation of T₄ values under heat stress. A comparison of hormone molar ratios in these climatic ranges reveals that the maximum shift in T₃/rT₃ ratio, for both groups of cows, occurs during hot-humid stress.

### Table 3.
Milk yields and hormone values under different climatic conditions.

<table>
<thead>
<tr>
<th>Climatic condition</th>
<th>Group (N)</th>
<th>Milk yield</th>
<th>T₄ (nmol/l)</th>
<th>T₃ (nmol/l)</th>
<th>rT₃ (nmol/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold</td>
<td>D (6)</td>
<td>--</td>
<td>64.3 ± 3.8</td>
<td>2.1 ± 0.14a</td>
<td>0.28 ± 0.03</td>
</tr>
<tr>
<td></td>
<td>L (14)</td>
<td>19.0 ± 3.2</td>
<td>41.8 ± 7.7A</td>
<td>1.9 ± 0.09A</td>
<td>0.35 ± 0.05A</td>
</tr>
<tr>
<td>Temperate</td>
<td>D (25)</td>
<td>--</td>
<td>66.9 ± 6.4</td>
<td>1.0 ± 0.11b</td>
<td>0.30 ± 0.04</td>
</tr>
<tr>
<td></td>
<td>L (50)</td>
<td>22.1 ± 3.9</td>
<td>43.8 ± 7.7A</td>
<td>1.3 ± 0.10B</td>
<td>0.52 ± 0.08B</td>
</tr>
<tr>
<td>Hot-dry</td>
<td>D (4)</td>
<td>--</td>
<td>64.3 ± 6.4</td>
<td>2.1 ± 0.03a</td>
<td>0.27 ± 0.02</td>
</tr>
<tr>
<td></td>
<td>L (9)</td>
<td>18.5 ± 1.3</td>
<td>59.2 ± 5.1B</td>
<td>2.0 ± 0.12A</td>
<td>0.29 ± 0.03A</td>
</tr>
<tr>
<td>Hot-humid</td>
<td>D (21)</td>
<td>--</td>
<td>64.3 ± 5.1</td>
<td>2.1 ± 0.10a</td>
<td>0.27 ± 0.03</td>
</tr>
<tr>
<td></td>
<td>L (38)</td>
<td>16.9 ± 2.1</td>
<td>52.8 ± 5.1B</td>
<td>1.9 ± 0.10A</td>
<td>0.30 ± 0.05A</td>
</tr>
</tbody>
</table>

Means in the same column bearing different superscript letters (within the same group), differ significantly (P < 0.05). a, b: dry animals; A, B: lactating animals.

farm during the month in which samples were obtained.

As previously reported (Aceves et al. 1985a), within the thermoneutral zone (18°C:60% to 28°C:40%) and regardless of their geographical location, all lactating animals exhibit significantly lower levels of T₄ and T₃ as well as significantly elevated values of rT₃ when compared to dry animals of the same herd. However and in sharp contrast, when either group of animals confronted chronic thermoregulatory demands due to exposure to low or high environmental temperatures, there was a shift in the T₃/rT₃ ratio. This shift, characterized by elevated T₃ levels and a simultaneous decrease in rT₃ concentration, occurred when environmental temperature attained values below or above 18°C or 28°C, respectively, or when relative humidity exceeded 60%. In the case of lactating animals under conditions of up to 34°C and 40%, this re-arrangement occurred without a significant decrease in milk yield. Above these values milk production dropped.

Discussion

The effect of chronic exposure to low or high temperatures on thyroid hormone metabolism is not well understood. Most experiments in different species chronically exposed to a cold environ-
ment have shown a significant rise in plasma T3 levels without changes in either TSH or T4 circulating values (Sterling & Lazarus 1977; Collins 1978; Morley 1981). In rats, acclimation to cold is associated with increased synthesis, secretion and faecal loss of thyroid hormones and recent findings demonstrate an increased rate of monodeiodination of T4 to T3 in liver and kidney (Scammell et al. 1981). However, to our knowledge there are no similar studies in dairy cattle, and most of the information showing an acute and sustained increase in PBI or T4 values has been obtained from short-term experiments conducted in climatic chambers (Thompson 1973; Johnson & Vanjnock 1976). The results reported in the present study extend these observations and demonstrate that in dry cows chronically exposed to natural mild cold weather conditions (10–18°C), there is a gradual and sustained increase in T3 without significant changes in T4 circulating values.

Furthermore, in first trimester lactating animals, the conspicuous increase in T3 levels is accompanied by a significant shift in the T3/rT3 ratio that characterizes this stage of lactation under comfortable conditions. Thus, although not strictly comparable, these findings suggest that, as in other homeothermic vertebrates, cold acclimation in dairy cattle may involve peripheral metabolic adjustments in T4 monodeiodination.

Information regarding thyroid hormone adjustments during heat-acclimation in dairy cattle is scarce, and its interpretation remains controversial. Most studies have been conducted in climatic chambers and include cows (Yousef et al. 1967; Magdub et al. 1982) and sheep (Valtorta et al. 1982). In general these reports have led to the conclusion that heat exposure reduces thyroid gland activity (Thompson 1973; Johnson & Vanjnock 1976; Johnson 1980). However, a detailed analysis of these studies suggests the occurrence of a sequential adjustment in thyroid metabolism characterized by an initial decrease in T4 circulating values which is followed by a return to control levels and that not necessarily involves a decrease in thyroid gland activity. Furthermore, the finding that in heifers and mature holstein cows, a 2 week period of artificial diurnal heat-stress (30°C–35°C; 60% RH) did not significantly affect circulating TSH levels, suggests that the pituitary-thyroid axis is not a major component of the thyroid response observed in dairy cattle during heat-acclimation (Schams et al. 1980).

This temporal sequence of events in animals confined to climatic chambers may help explain the apparent contradictory results observed under natural weather conditions in dairy cattle and other heat-acclimated homeothermic vertebrates (Collins & Weiner 1968). In lactating cows studied under mild heat-stress (September, 22 to 29°C) and thermoneutral temperature (December, 20 to 25°C), the effective T4 ratio (T4 CBPA/T3 uptake) was similar in shaded and non-shaded animals, and in both groups there was a non-significant trend of increased values as the weather became cooler (Ingraham et al. 1979). More recent studies in pregnant-lactating shaded (29.8°C) and non-shaded (37.5°C) holstein cows, demonstrate that besides the lower levels of radioimmunoassayed circulating T4, non-shaded animals exhibit significantly elevated T3 values (Collier et al. 1982).

In accordance with these data, results in the present study show that dairy cattle acclimated to natural hot weather conditions present a significant increase in circulating levels of T3, which we interpret as suggestive of an increase in the peripheral monodeiodination of T4 to T3. Moreover, results in heat-acclimated lactating cows demonstrate that besides this T3 elevation, the re-arrangement resembling euthyroid sick syndrome disappears, and that under temperatures up to 34°C this group of animals also exhibits a significant increase in T4 values. Thus and in opposition to classical interpretations (Thompson 1973; Johnson & Vanjnock 1976; Johnson 1980), these observations suggest that heat-acclimation in dairy cattle does not depress thyroid gland activity. Furthermore, recent findings in other species strengthen this suggestion. In quail, exposure to chronic warmth (35°C) is accompanied by a sustained decrease in blood supplied to the gland and in T4 circulating levels, while T3 concentration exhibits a significant increase (Bobek et al. 1980). Growth-selected lines of chicken during heat-stress also show a sustained increase in T3 values (Bowen & Washburn 1985). A similar sustained elevation in T3 circulating values has been documented in studies conducted under natural environmental hot conditions in humans (Rastogi & Sawhney 1976; Gertner et al. 1983), and in some species of desert rodents (Lachiver et al. 1978).

Recent reports suggest that in a variety of non-thyroidal illnesses, rises FFA levels may interfere with thyroid hormone RIA's (Chopra et
References


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