VARIATIONS IN PLASMA THYROXINE CONCENTRATIONS IN SHEEP AND THE EFFECTS OF IODINE SUPPLEMENTATION BY AN INTRA-RUMINAL DEVICE

KEITH J. ELLIS*

SUMMARY

The concentration of the thyroid hormone thyroxine (T₄) in plasma of grazing sheep varies with time, apparently in response to climatic conditions, in particular rainfall. Supplementation with intra-ruminal iodine capsules can result in large T₄ increases at times of iodine-related metabolic stress, but does not cause hyperthyroidism in times of iodine sufficiency.

INTRODUCTION

Endemic iodine deficiency in sheep is a well-recognised problem but the importance of sub-clinical iodine deficiency is difficult to assess. However, since the thyroid hormones regulate a wide variety of physiological processes (Underwood 1977), there is the potential for iodine or thyroid activity to be a limiting factor in animal production. For example, iodine or thyroid hormone supplementation to nominally iodine sufficient animals has resulted in increases in lamb growth rates (Knights et al. 1979) and wool production (Lambourne 1964). It is possible that short term production losses may occur frequently because of a sub-clinical iodine deficiency caused by seasonal variations in feed; the intake of goitrogens, or the changing physiological status resulting from pregnancy or lactation. The circulating concentration of thyroxine (T₄) is often used as an indicator of the iodine status of grazing animals. This study sought to monitor T₄ concentrations in sheep over a long period (320 days) and to observe the influence of iodine supplementation via an intra-ruminal capsule.

MATERIALS AND METHODS

A mixed flock of eighteen-month old Border Leicester x Merino ewes and wethers continuously grazed the same improved pasture at Armidale N.S.W. from December to October. They were randomly assigned to groups receiving no supplement (10 sheep), one intra-ruminal iodine capsule (5 sheep) or 5 capsules (10 sheep) per animal; all were shorn prior to the start of the experiment.

On Day 0 and at intervals thereafter, blood samples were collected from each sheep, and thyroxine assays were performed on the plasma using a radio-immunological technique (Wallace 1979). All samples from a given day were included in the one assay, and a standard plasma sample was repeatedly measured in each assay. The inter- and intra-assay coefficients of variation were 13% and no more than 7% respectively. The thiocyanate concentration in plasma was determined using a colorimetric autoanalyser method (Pettigrew and Fell 1972).

One-way analysis of variance was used to test for significance between sexes and between groups. Canonical correlation analysis was used to identify associations between T₄ levels and climatic conditions. Among the variables considered were rainfall, average maximum and minimum temperatures, the greatest difference between highest and lowest minimum temperatures in a set period, and the maximum difference between the minimum temperatures on any two successive days. This group of variables was tested for any association at times from 1 to 12 weeks prior to the date of sample collection.

* CSIRO, Division of Animal Production, Armidale, N.S.W. 2350.
† Capsules were prototypes according to Australian Patent No. PB3671/73.
RESULTS

There were no significant differences between sexes in any group at any sampling. Hence all of the $T_4$ data have been pooled. Mean values for each treatment group are presented in Fig. 1.

Fig. 1. Variations of plasma $T_4$ concentrations with time. Each point represents a mean of at least 4 animals.

Influence of iodine supplementation

During the first 56 days of the experiment and then again from Day 177 to Day 260 there were no significant differences between the circulating $T_4$ concentrations in the control and treatment groups, but in the period from Day 77 to Day 129, and again at the end of the experiment, both the supplemented groups showed highly significant increases ($P<0.01$) compared with the control group.

At no time was the mean for the 5-capsule group significantly higher than that for the 1-capsule group. Despite the 5-fold greater supplementation, the increase in the circulating $T_4$ concentration above that of the control group did not exceed one and a half times that of the 1-capsule group.

Variations within the unsupplemented group

The observed changes with time (Fig. 1, solid line) are real and significant since the coefficient of variation of the mean $T_4$ value of the control group during the whole of the experiment was more than three times the inter-assay coefficient of variation of the internal standard sample. Indeed, if a correction is made for the between assay variations (Wallace et al. 1978) the differences become even more pronounced.

Since environmental factors can affect thyroid metabolism (Dill 1964), canonical correlation analysis was used to establish any association between
Animal production in Australia

climatic conditions at varying times and T4 concentrations in the plasma of these sheep. The only significant correlation found was with the total rainfall during the interval from 5 to 8 weeks prior to each sampling. The correlation coefficient of -0.9 suggests that the T4 level fell several weeks after periods of rain, although this does not imply that rainfall directly caused the change.

Evidence for goitrogen intake

Table 1 contains some of the data from a separate study of the relationship between white clover and the anionic goitrogen, thiocyanate.

Table 1: Thiocyanate concentrations in plasma (means of 6 sheep)

<table>
<thead>
<tr>
<th>Type of feed</th>
<th>Lucerne chaff</th>
<th>Phalaris/ryegrass (some white clover present)</th>
<th>Partially improved pasture containing large amounts of white clover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date (day/month)</td>
<td>25/1</td>
<td>3/1</td>
<td>29/8 3/1 15/1</td>
</tr>
<tr>
<td>Thiocyanate (ppm)</td>
<td>0.53(0.1)</td>
<td>4.95(0.51)</td>
<td>0.73(0.1) 9.48(1.6) 1.58(0.64)</td>
</tr>
</tbody>
</table>

DISCUSSION

Although consistent with other reports on sheep (Sutherland and Irvine 1974), cattle (Shoda and Ishii 1976) and deer (Bubenik and Bubenik 1978), the magnitude of the apparent seasonality of T4 concentrations in sheep plasma reported here is in marked contrast to the study using penned sheep with fixed feed intake (Wallace 1979) and to the survey of lactating grazing ewes (Wallace et al. 1978). It appears likely then that the amount of circulating T4 in grazing animals can be affected both by the amount and type of feed available, and by seasonal or climatic factors. The practical relationship between T4 level, hypothyroidism and an iodine responsive condition, together with the practice of adopting a "normal" range of T4 values, can therefore be questioned.

In the Northern Tablelands of N.S.W. a fine balance may exist between factors relating to iodine metabolism. The geology of the area, the altitude and the distance from the sea predetermine that iodine is not always in abundant supply. White clover is a common component of the highly improved pastures and so relatively high concentrations of thiocyanate, (a known anionic goitrogen) are often present in the blood of grazing animals. It has been established (Ellis unpublished) that sheep grazing improved pastures can show a very wide range of plasma thiocyanate concentrations depending on the plant species present, and that even within the same paddock almost ten-fold changes can be seen within a period of two weeks. In addition, the climatic conditions can be extreme, and place. additional "iodine stress" on the animal in order to maintain a constant body temperature and metabolic rate. Thus any changes in feed availability, type of pasture or weather may upset the balance, causing changes in the circulating T4 concentrations as seen in this study. The data, although limited, are consistent with the known seasonal trends, and the negative correlation with rainfall might be explained by the promotion of white clover growth and the subsequent elevation of thiocyanate in the blood.

Each capsule released only about 400 µg of iodine each day (Laby personal communication) and it was therefore expected that some time would elapse before sufficient iodide accumulated in the rumen to cause a subsequent elevation of circulating thyroid hormones. However, once the additional iodide began to affect production of T4, there was little difference between those animals which
were supplemented with either one or five capsules. That there are times when no significant difference is observed between supplemented and unsupplemented animals, and that this occurs even when the circulating $T_4$ is relatively low (for example in July), confirm the hypothesis that the amount of iodine released by one capsule is sufficient to supply most of the animal's requirements. Furthermore, the normal homeostatic processes ensure that hyperthyroidism does not result either from overdosing or from unnecessary supplementation.

On the basis that supplementation with iodine results in an increased $T_4$ level only when the animal has a requirement for additional iodine, it is concluded that the control animals in this study were exhibiting some degree of "iodine stress" or sub-clinical hypothyroidism during the period from February to May, and again from August until the termination of the experiment. The data in Fig. 1 are also consistent with the hypothesis that large changes in the circulating amounts of $T_4$ can be caused by a combination of factors, but that a low $T_4$ value does not necessarily indicate an iodine responsive condition.

These conclusions are supported by the sporadic nature of outbreaks of goitre, and by the uncertainty of consistently identifying iodine deficiency and/or responsive areas of grazing country. Furthermore, they suggest that periods of "sub-clinical hypothyroidism" may frequently occur. The economic impact of such events should be investigated.

Being a long acting and metabolically safe form of supplementation, the intra-ruminal iodine capsule presents a practical means of prophylaxis against production losses due to long or short term periods of iodine related stress.

ACKNOWLEDGEMENTS

Drs H.I. Davies and V. Bofinger are sincerely thanked for their assistance with the analysis of data. The capable technical assistance of Mrs J. Gregson and Mr R. Young is gratefully acknowledged.

REFERENCES