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Field investigation of the iodine status of farms in the North Island of New Zealand

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Abstract

Over a 10-year period 104 farms in the North Island were attended on a consultancy basis, and of these, 29 farms were identified as having clinical signs associated with iodine deficiency (high peri-natal calf mortality, poor conception rate and/or low pregnancy rate). Mean pasture iodine concentrations (n=24) were 0.28 mg/kg (SD=0.16) ('adequate' range: 0.40-0.80 mg/kg). Mean animal plasma inorganic iodine (PII) concentrations (n=17) were 40.6 µg/L (SD=16.28) ('inadequate' range <45 µg/L). Marginally low iodine status (20-45 µg/L) was present in 13.5% of farms (14 of 104). The overall average deficit for the farms with low pasture iodine (n=19) was calculated to be 3.0 mg iodine per cow per day. Corrective treatment was computed for each farm and made primarily through weekly addition of iodine to the drinking water. Following iodine supplementation, mean animal PII was 60.8 µg/L (SD=19.50), a 50% increase over initial values. For individual cattle, there was a significant reduction in the proportion (73.5% to 23.5%) whose PII was marginally low (P=0.001). Clinical responses in livestock were monitored, and on the iodine supplemented farms there was some evidence for a reduction in peri-natal calf mortality and an increase in conception rates, but the amount of data was limited. Iodine supplementation was seen to contribute to an overall increase in pregnancy rates on ten farms (from 79.4% to 91.1%). It is concluded that iodine deficiency is common in North Island pasture-based livestock farms, that it is responsive to dietary supplementation, and that supplementation may be associated with improved reproductive performance.

Keywords: iodine; supplementation; clinical; response

Introduction

The clinical presentations of iodine deficiency in livestock in the North Island of New Zealand have not been well described. Reproductive problems, such as an absence of visible oestrus, irregular interoestrus intervals, increased incidence of retained foetal membranes, stillbirths and birth of weak calves, have been described in association with iodine deficiency (Allcroft et al 1954; Rogers 1999; McDowell 2003; Suttle 2003). Likewise, goitre is considered a cardinal manifestation of iodine deficiency (Radostits et al, 2000), which was recognised in New Zealand by Gilruth in 1901 (see Sinclair & Andrews 1954).

Over a period from 1985 to 1992, the prevalence of farms with low iodine status in the Rotorua district, was estimated from the presence of serum thyroxine concentrations <45 nmol/L, in 18% of herds (10/54) and 40% of cattle (114/337). Herds with low thyroxine had clinical syndromes that included anoestrus, suboestrus, stillbirth and weak calves, whilst clinical observation of one dairy herd indicated a 16% improvement in first service conception rate when half the herd was injected with iodised oil (PD Anderson; unpublished).

In a cross-sectional study of farms suspected of being iodine deficient (e.g., with a previous history of low serum thyroxine concentrations), 44 stillborn calves were collected from 12 Manawatu dairy herds (Anderson et al 2007). A high rate of goitre was present in both calves (16%) and herds (42%). The conclusion of that study was that there is evidence that iodine deficiency is present in Manawatu dairy herds. Similar conclusions have been drawn from previous studies of sheep (Sargison et al. 1997, 1998; Clarke et al. 1998; Grace et al. 2001).

Measurement of plasma inorganic iodine (PII) was introduced into New Zealand in 2006 and has subsequently displaced the use of thyroxine as an assessment of iodine status. Plasma inorganic iodine represents current dietary iodine intake, responding within a few days to any changes in iodine in the diet (Rogers & Mee, 1996). There was some difficulty in establishing a reference range: initially this was considered to be 60-200 µg/L. Extensive work in Ireland had indicated that a result >60 µg/L was adequate (Rogers 1999). The reference range has now been revised to 'adequate' >45 µg/L; 'marginal' 20-45 µg/L; 'deficient' <20 µg/L (Gribbles Veterinary Laboratory). This reference range for inorganic iodine has not been substantiated by production data.

The first aim of this study was to establish an iodine status for pasture-based farms in the North Island, where Brassica crops were not being fed (so that the goitrogen effect on iodine metabolism was minimised). The second aim was to correlate the iodine status with appropriate reproductive data following iodine supplementation. The clinical entities of early conception rate, peri-natal mortality and pregnancy rate were chosen as the best indicators of iodine deficiency in cattle, as described above.

Methods and materials

Over a 10-year consultancy period (2004 to 2014), 104 farmer clients, mainly in the Taranaki and Manawatu regions of the North Island were attended (Peter D. Anderson). Of these, twenty-nine farms were identified as having clinical signs that could putatively be attributed to iodine deficiency; namely, either high peri-natal mortality (>5%), poor conception rate (<60% non-return rate to first service) or low pregnancy rate (<85%). The iodine status of these 29 farms (20 dairy and 9 sheep & beef) was investigated. Selenium estimations were undertaken to ensure that selenium deficiency was not a confounding factor.

Iodine status

Pasture samples were collected from 24 of the 29 farms for iodine analysis (Appendix 1). Samples were collected from most (64%) of the farms between the months of August and November, with the balance of the farms being sampled at other times of the year.

Blood samples were collected from 17 of the 29 farms for measuring iodine (PII) concentrations and 12 of the 29 farms for measuring selenium (as glutathione peroxidase: GPX) (Appendix 1). These blood samples were collected either concurrently with the pasture samples or within a month of the pasture sampling. Blood samples (heparin and EDTA anticoagulant) were collected by caudal venepuncture from three randomly-selected cattle from each farm. Mostly these were two-year-olds (N=34) or yearling cattle (N=18), but some mixed-aged cows were also sampled (N=10).

Iodine supplementation

Iodine supplementation was thereafter initiated for 13 of the 29 farms to meet the calculated deficit of the farm. Iodine supplementation was initiated 3-4 weeks before the next calving season and continued throughout mating. The iodine deficit per cow per day was calculated for each farm from the pasture iodine concentration, as follows:

Deficit = [Desired Iodine Concentration – Measured Iodine Concentration] x Dry Matter Requirement per Day

The lower figure (0.40 mg/kg) of the reference range (0.40 to 0.80 mg/kg) was used as the desired concentration.

The primary means of meeting the iodine deficit was by providing the calculated deficit through the addition of iodine to the drinking water. The supplement was added to the water supply once per week. The amount of supplement was calculated using the following formula:

Dose = [Deficit per cow per day / Iodine content of supplement (mg/mL)] x herd size x 7 days

Supplement was given as Stock Iodine (Bomac Laboratories Ltd: 63 mg Iodine/mL: 8 farms; or FIL New Zealand: 25 iodine/mL: 3 farms). Potassium iodide (50mg/mL) was incorporated into a daily drench on a further farm. One farm only used an iodised salt lick. A secondary source of iodine was also recommended, although (except for the final farm mentioned above), no allowance was made for its contribution to the overall iodine intake of the cows. Various supplementary sources were supplied, including iodised salt (in a 'mineral lick'), iodised anthelmintic, iodine teat spray and seaweed extract.

Post–supplementation sampling

In the following spring (July to September) after supplementation with iodine (i.e. 12 months later), samples were collected from seven farms in Taranaki. Blood samples were again collected from 3 cows per herd, to allow a comparison to be made of iodine concentrations before and after supplementation. Clinical findings for two of the syndromes that are commonly associated with iodine deficiency (i.e. neonatal mortality and conception rate to first service) were recorded. In addition, data on overall pregnancy rate was also sourced from these farms.

Assay methods

Pasture iodine concentrations were determined by extracting the iodine using an alkaline ashing procedure, followed by iodine determination using inductivelycoupled plasma mass spectroscopy (Fecher et al. 1998).

Concentrations of PII were measured according to the method described by Aumont and Tressol (1987). PII is separated from other iodine compounds by protein precipitation in ethanol, followed by ion-exchange chromatography. After alkaline ashing at 600^{o}C, the iodine content is determined colorimetrically by the Sandell and Kolthoff reaction. Results are given as µg/L.

The test method for glutathione peroxidise (GPx) was described by Thompson et al. (1980). Blood is haemolysed and diluted in water. GPx in the haemolysate is determined enzymatically in a phosphate buffer by the rate of NADPH oxidation after the oxidation/reduction of GSH and peroxide. The units of measurement for GPx are KU/L.

Results

Initial iodine and selenium results

Pasture and animal iodine data and animal selenium data are summarised in Table 1 (see also Appendix 1). The mean pasture iodine concentration at the start of the study was 0.28 (SD 0.16) mg/kg. Five farms had iodine concentrations within the reference range (0.40-0.80 mg/kg), while the remaining 19 farms were below the reference range. The mean pasture iodine concentration of these 19 farms was 0.20 mg/kg.

Mean PII concentrations were 40.6 (SD 16.3) µg/L. Blood samples from three farms were in the adequate range (>45 µg/L). The remaining 14 farms had a mean plasma inorganic iodine concentration of 34.5 µg/L, which is around the middle of the marginal range (20-45 µg/L). No farms in this study had plasma inorganic iodine concentrations below 20 µg/L (i.e. none were in the 'deficiency' range). The farms with marginally low animal iodine tests were widespread throughout the North Island study area. Mean plasma GPX concentrations were 8.6 KU/L, which was within the reference range (2-50 KU/L). Two samples were low (<1.0 and 1.7 KU/L).

Table 1 Iodine and selenium status of study farms

	Adequate (Number)	Low (Number)	Cut-off Value	% farms in low or marginal ranges	
				Study farms (n=29)	All farms (N=104)
Pasture iodine	5	19	0.4mg/kg	65.5	18.3
Animal iodine [PII]	3	14	45.0 µg/L	48.3	13.5
Animal selenium [GPX]	10	2	2.0 KU/L	6.9	1.9

Iodine deficit

Calculations of the iodine deficit were carried out for each individual farm from the pasture test result, in order to determine the required supplementation rate. When this calculation was applied to the mean pasture iodine concentration (0.28 mg/kg), the overall mean deficit was 1.8 mg iodine per cow per day. This was assuming a dry matter requirement of 15 kg per cow per day and a desired iodine concentration of 0.40 mg/kg. When the five farms with adequate pasture iodine concentrations were excluded, the average for the remaining 19 low farms was 0.20 mg/kg, which equated to a deficit of 3.0 mg iodine per cow per day.

Post-supplementation iodine

After supplementation (Table 2), average pasture iodine concentrations (5 farms) was more than double the initial concentration (0.28 mg/kg) and within the 'adequate' range (0.40-0.80 mg/kg). Likewise, mean PII concentrations had also substantially increased, such that they were now within the adequate range (>45 µg/L). Selenium concentrations were in the adequate range before and after iodine supplementation.

Analysis of individual PII concentrations showed that the number of animals with low PII had been improved by the supplementation. Before supplementation, 73.5% of tests (36/49) were within the marginally low range (20-45 µg/L), while 26.5% (13/49) were adequate (>45 µg/L). Following supplementation with iodine, only 23.5% of tests (4/17) were marginally low. The reduction in the number of cattle in the marginally low category was significant (χ^2=22.3: P=0.001).

Perinatal mortality was reduced on two farms after iodine supplementation (12.3 and 10.8% versus 4.8 and 4.2%). CIDR usage was reduced on two farms after iodine supplementation (53.9 and 22.0% versus 10.2 and 4.0%). Mean pregnancy rate increased on 10 farms after iodine supplementation (79.4% prior to supplementation versus 91.1% after supplementation). The mean PII of the cows in these herds increased from 36.3 µg/L to 52.0 µg/L.

Discussion

The original selection process, using three measures of reproductive performance, was applied to the 104 farms with the aim of finding a group with low iodine status. Two of the criteria used (low conception rate and high peri-natal mortality) are commonly found in iodine deficiency, while the third (low pregnancy rate) is the end result of many aspects of reproduction. This selection process resulted in a group of 29 farms, of which almost two thirds (65.5%) had low (<0.40 mg/kg) pasture iodine concentrations and approximately half (48.3%) had marginally low (<45 µg/L) animal PII concentrations. This rate was similar to a Manawatu study where, in stillborn calves from herds selected on the basis of low thyroxine concentrations, goitre was evident in 42% of herds. It therefore appears that the selection process for the study group was successful in capturing the farms with low iodine status.

As a proportion of the 104 farms in the consultancy database, 18.3% farms had low pasture iodine status. Moreover, on the basis of PII, 13.5% of farms in the database had animals with marginally low iodine concentrations. Furthermore, an 8-year period of observation of the prevalence of farms with low iodine status in the Rotorua District (Anderson, unpublished), 18% had low serum thyroxine concentrations. Hemingway et al. (2001) have shown that thyroxine is a relatively sluggish measure of iodine status, whereas PII is associated with current dietary intake (Rogers and Mee, 1996). Therefore, the presence of low PII concentrations on 13.5% of farms in the present study gives confidence that this is a realistic indicator that iodine deficiency occurs in the North Island. Of course, a field investigation such as the present study cannot provide definitive evidence of the presence of such a deficiency, but it does provide sufficient preliminary data about the prevalence of low iodine status on North Island farms, to warrant further formal investigation.

The iodine supplements used in this study (stock iodine and iodised salt) were chosen because they were widely available and of low cost, especially in comparison with the injectable form. Results indicated that a simple means of application (weekly stock iodine via the water supply and iodised salt as a mineral lick) could be used successfully to lift the farms from a marginally low to an adequate iodine status (36.3 µg/L to 52.0 µg/L PII). Moreover, there was a significant reduction in the number of animals with marginally low iodine (PII) concentrations after supplementation (before: 73.5%, after: 23.5%).

This study has been based on biochemical measurement of iodine in pasture and animal (PII) samples. For pasture iodine, the current reference range indicated by Hill Laboratories, Hamilton was 0.40-0.80 mg/kg). The Nutrient Requirements of Dairy Cattle (NRC: 7th Edition 2001) have stated that the dietary iodine requirements for cattle are 0.40-0.60 mg/kg. In calculating the deficit of iodine in pasture from each farm in the study group, the lower figure stated by both Hills and NRC (0.4 mg/kg) was used, providing a robust figure for the desired iodine concentration. The mean deficit for the low-iodine-status farms was derived from pasture iodine concentrations. This was one of the main reasons for the collection of pasture. The deficit was calculated to be 3.0 mg iodine per cow per day, which could possibly be applied to other North Island farms where the iodine status had been established as marginally low (20-45 µg/L PII). It is notable that only 1.9% of farms in the present investigation had a low selenium status, which indicates that selenium deficiency was only involved to a minor degree in this study.

Table 2 Pasture and animal iodine concentrations: before and after iodine supplementation for 7 farms in Taranaki: Mean (SE)

	Pasture iodine (mg/Kg)	PII (µg/L)
Before supplementation	0.24 (0.06)	38.4 (3.8)
After supplementation	0.60 (0.12)	60.8 (7.7)

Results of this study provided support for an association between animal iodine concentrations (i.e. PII concentrations) and changes in reproductive performance. Although clinical data on reproduction was not extensive, all of the improvements recorded after supplementation for each of the clinical entities (neonatal loss, conception and CIDR use and pregnancy rate) were mirrored by a shift in animal iodine concentrations from marginal to adequate in the reference range. However, the number of farms sampled after iodine supplementation were small and all from Taranaki, so a more extensive study would be required to confirm these findings. The 11.7% mean increase in pregnancy rate seen in this study was unexpected, but may not be exclusively due to the improved iodine status. There is a need for more research into iodine in grazing livestock using iodine supplementation and animal reproductive performance protocols and coupling these with the results in changes in plasma inorganic iodine.

The farms in the study were pasture-based and did not grow Brassica species as crops, as is common in the South Island, especially for winter fodder. This eliminated the problem of goitrogens from the Brassica crops, which have an impact on iodine status.

This study indicates that there can be a problem of low iodine concentrations in livestock on farms during the spring period, when parturition, initiation of lactation and early reproductive activity is taking place, especially with cattle. These activities put a huge demand on the animal for adequate thyroid hormone production, so that when iodine is limiting, reproduction is likely to suffer. Taken together, the widespread distribution of farms with low pasture iodine concentrations and low animal plasma inorganic iodine, suggests that marginal iodine deficiency may well be widespread in the North Island of New Zealand.

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Appendix 1 Initial Results (before iodine supplementation)

Farm Number	Farm Type	Area (District)	Pasture Iodine (ICP-MS mg/kg)	Animal Iodine* (PII ug/L)	Animal Selenium* (GPx KU/L)
1	D	Hawera	0.17	23.0	9.2
2	S & B	Hawera	0.17	31.0	-
3	D	Bell Block	0.13	50.3	-
4	D	Omata	0.32	-	-
5	D	Stratford	0.15	-	-
6	D	Stratford	0.13	36.3	-
7	D	Rahotu	0.75	-	-
8	D	Opunake	0.56	-	-
9	D	Opunake	-	43.0	20.7
10	D	Rahotu	0.32	-	-
11	D	Okato	0.28	40.3	23.0
12	D	Inglewood	0.21	-	-
13	S & B	Taihape	-	82.3	12.9
14	S & B	Taihape	0.17	24.7	
15	S & B	Hunterville	0.29	25.7	3.6
16	D	Whanganui	-	36.7	1.0
17	D	Opunake	0.15	35.3	6.7
18	D	Opunake	0.26	40.7	-
19	D	Foxton	0.19	-	-
20	D	Marton	0.17	-	-
21	S & B	Kimbolton	0.10	-	-
22	S & B	Apiti	0.24	-	-
23	S & B	Feilding	0.14	74.0	1.7
24	D	Apiti	0.46	37.0	8.0
25	S & B	Apiti	0.14	-	-
26	D	Eketahuna	0.43	-	-
27	D	Dargaville	-	44.3	10.9
28	D	Waihue	-	28.7	3.2
29	S & B	Aria	-	36.7	2.5
Overall mean			0.28	40.6	8.6
N=29			24	17	12

Legend: D: Dairy, S & B: Sheep and Beef, ICP-MS: Inductively Coupled Mass Spectrometry, PII: Plasma Inorganic Iodine; GPx: Glutathione Peroxidase, *: Mean value