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Trace Element Concentrations in the Liver, Kidney, and Muscle of Queensland Cattle

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All heavy metals are toxic at certain levels of intake. However, in contrast to elements such as arsenic, chromium, copper, selenium and zinc that have useful biological functions, cadmium, lead and mercury as far as we know play no useful role and their intake should be limited to the unavoidable minimum. In attempts to achieve this, the World Health Organisation has recommended maximum weekly intakes and the National Health and Medical Research Council of Australia has specified the maximum permitted concentrations of heavy metals in food.

Since meat, particularly beef, is a significant part of the Australian diet, its heavy metal content may contribute significantly to the heavy metal intake of the consumer. FLANJAK & LEE (1979) surveyed the trace element content of liver and kidney tissue of New South Wales cattle and the data obtained was used in the compilation of food standards by the National Health and Medical Research Council of Australia (1980). However, no information was presented on the trace element concentration of muscle tissue, the type of meat most commonly consumed. The Australian Government Analytical Laboratories have carried out a limited pilot survey of liver and muscle samples (DEPARTMENT OF PRIMARY INDUSTRY 1976) and annually analyse a small number of liver, kidney and muscle samples from all Australian States but no comprehensive survey of trace elements in Queensland beef has been done.

The purpose of the work described in this paper was to provide information on trace element concentrations in Queensland cattle. In addition, this work was designed to provide some indication of the effect that various major industries might have on trace element concentrations in beef.

MATERIALS AND METHODS

Liver, kidney and muscle samples (ca 500 g) were taken from cattle selected at random from abattoirs in ten selected 100km square areas of Queensland. These areas represented a cross-section of industries in the State (Table 1). Animals were identified from a tailtag to ensure that they originated from the specified areas. Samples were submitted in polyethylene bags and stored at $-18^{\circ}C$.

TABLE 1. Major industries in the sampling areas.

Area	Industry
Brisbane	Urban industrial, dairy, small crops
Charleville	Cattle, sheep
Dalby	Wheat
Emerald	Grain, mining (coal), cattle
Gympie	Dairying
Hughenden	Cattle, sheep
Lowood	Intensive agriculture
Mackay	Sugar
Mareeba	Tobacco, maize, peanuts, small crops
Mt. Isa	Mining (zinc, copper, lead)

Tissues were subsampled on a polypropylene board covered with fresh polyethylene bags. Glassware and sampling instruments (stainless steel forceps and carbon steel scalpel blades) were soaked in a dilute surfactant (*Decon 90, Decon Laboratories Ltd.*) overnight and rinsed thoroughly with glass-distilled water. Muscle and liver tissues were subsampled after the surface layer of tissue had been removed. Kidney cortex was subsampled and visible fat deposits were avoided.

Samples were prepared for cadmium, chromium, copper, mercury, lead and zinc analyses using the digestion method of SHUM et al (1977). An aliquot of tissue (3 g wet weight) was digested in 5 mL of concentrated nitric acid for 4 hours at 80°C. Digested samples were then diluted to 25 mL. Two blanks and two aliquots of the United States National Bureau of Standards, Standard Reference Material 1577 bovine liver (SRM 1577) were included in each batch of 18 analyses. Copper and zinc were determined by flame atomic absorption, mercury by flameless atomic absorption and cadmium, chromium and lead by a modified carbon rod atomic absorption technique (Steiner and Kramer, unpublished data 1981).

Samples were analyzed for arsenic and selenium by digesting 5 g of tissue in 6.5 mL of a solution containing 2 mL each of nitric and perchloric acids and 2.5 mL of sulphuric acid. Nitric acid was added during the digestion to prevent charring. A blank and two aliquots of SRM 1577 bovine liver were included in each batch of 18 samples. Selenium and arsenic were determined by hydride generation atomic absorption using a technique similar to that of FIORINO et al (1976).

The accuracy and precision of the methods of analysis were checked by analysis of SRM 1577 (Table 2). Since the level of arsenic in the reference material (0.055 mg/kg dry weight) was less than the limit of detection of our method, arsenic recoveries were determined by the technique of standard additions. Eight liver samples were each spiked with 1 ug arsenic and the average recovery was 99.5 ± 12.9%.

TABLE 2. Analysis of SRM 1577 bovine liver (mg/kg dry weight).

Element	Certified concentration (mean ± 95% C.L.†)	Number of determinations	Found (mean ± 95% C.L.)
Cadmium	0.27 ± 0.04	5	0.26 ± 0.02
Chromium	0.088 ± 0.012	4	0.07 ± 0.02
Copper	193 ± 10	5	189 ± 10
Lead	0.34 ± 0.08	5	0.33 ± 0.06
Mercury	0.016 ± 0.002	4	0.022 ± 0.002
Selenium	1.1 ± 0.1	5	1.1 ± 0.2
Zinc	130 ± 13	5	140 ± 4

† C.L. - confidence limit.

Statistical analyses of the results of this survey were done by parametric, restricted parametric and non-parametric (median test) testing; the type of analysis depending on the number of samples containing less than the limit of detection.

RESULTS

A summary of the trace element concentrations in the liver, kidney and muscle tissues of Queensland cattle is given in Table 3. Where the trace element concentration was less than the limit of detection, a value of half the limit of detection was assigned for the purpose of calculating the mean.

TABLE 3. Trace element concentrations in bovine liver (L), kidney (K) and muscle (M) (mg/kg fresh weight)

Element	Number of Samples	Samples containing < limit of detection	Range	Mean ± S.D.
Arsenic	L 179	141	<0.02-0.09	*
	K 177	117	<0.02-0.20	0.03 ± 0.04
	M 181	144	<0.02-0.20	*
Cadmium	L 179	0	0.005-0.57	0.06 ± 0.09
	K 174	0	0.005-2.60	0.37 ± 0.52
	M 181	158	<0.001-0.04	0.001 ± 0.003
Chromium	L 175	166	<0.01-0.91	0.01 ± 0.07
	K 172	162	<0.01-0.03	*
	M 176	166	<0.01-0.10	*
Copper	L 180	0	1.4-134.5	33.8 ± 25.2
	K 178	1	<1.0-14.0	4.9 ± 1.5
	M 181	35	<1.0-9.3	1.9 ± 1.2

TABLE 3. (Continued)

Element	Number of Samples	Samples containing < limit of detection	Range	Mean ± S.D.
Lead	L 180	82	<0.02-0.53	0.05 ± 0.07
	K 178	114	<0.02-0.71	0.04 ± 0.08
	M 181	180	<0.02-0.06	*
Mercury	L 180	178	<0.01-0.03	*
	K 178	135	<0.01-0.15	*
	M 181	181	<0.01-0.02	*
Selenium	L 178	0	0.02-0.55	0.23 ± 0.10
	K 178	0	0.73-3.20	1.52 ± 0.40
	M 180	8	<0.02-0.30	0.12 ± 0.17
Zinc	L 180	0	14.3-125.6	50.9 ± 17.3
	K 178	0	16.2-60.9	25.1 ± 6.3
	M 181	0	16.1-106.7	61.9 ± 13.0

* Mean < limit of detection.

Table 4 compares the mean and standard deviation of trace element concentrations in the tissues of cattle from various areas of Queensland.

The mean concentration of arsenic in the kidneys of cattle from Mt. Isa was significantly higher ($P < 0.01$) than it was in the kidneys of cattle from the other nine areas. The mean concentrations of arsenic in liver and muscle tissues were higher in this area than in the other areas, but were not significantly different from the limit of detection.

The mean kidney cadmium concentration of Mareeba cattle was significantly higher ($P < 0.01$) than it was in all other areas. Liver cadmium concentrations in the Mareeba and Mt. Isa areas were significantly higher than they were in the Lowood, Emerald, Hughenden and Dalby areas ($P < 0.01$) and in the Gympie and Brisbane areas ($P < 0.05$). No significant differences were detected in muscle cadmium levels.

Liver and kidney lead levels were highest in the Mt. Isa and Brisbane areas. Lead was detected in only one muscle sample (0.06 mg/kg) and this sample originated from the Lowood area.

No significant differences between areas were found for mercury and chromium levels.

Copper, selenium and zinc levels in muscle, liver and kidney varied at random between all areas.

TABLE 4. Mean (± S.D.) trace element concentrations in bovine liver (L), kidney (K) and muscle (M) from various areas (mg/kg fresh weight)

Area	No. of Samples	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Selenium	Zinc
Brisbane	L 18	*	0.06 ± 0.03	*	30.3 ± 32.6	0.08 ± 0.09	*	0.17 ± 0.11	40.7 ± 13.2
	K 18	*	0.61 ± 0.72	*	5.0 ± 0.7	0.07 ± 0.16	*	1.31 ± 0.23	23.6 ± 3.5
	M 18	*	*	*	2.4 ± 1.3	*	*	0.06 ± 0.06	67.4 ± 12.8
Charleville	L 12	*	0.06 ± 0.04	*	59.1 ± 29.9	0.03 ± 0.02	*	0.25 ± 0.09	62.8 ± 11.4
	K 12	*	0.30 ± 0.27	*	5.3 ± 1.0	*	*	1.50 ± 0.37	30.7 ± 10.8
	M 13	*	0.002 ± 0.003	*	3.2 ± 2.7	*	*	0.13 ± 0.06	65.1 ± 5.0
Dalby	L 15	*	0.01 ± 0.01	0.07 ± 0.23	18.5 ± 17.4	0.02 ± 0.02	*	0.24 ± 0.12	48.3 ± 12.4
	K 13	0.02 ± 0.02	0.06 ± 0.05	*	5.8 ± 1.5	0.04 ± 0.03	0.02 ± 0.04	1.55 ± 0.35	28.8 ± 5.9
	M 16	*	*	*	2.1 ± 0.8	*	*	0.12 ± 0.06	64.2 ± 11.3
Emerald	L 19	*	0.02 ± 0.01	*	32.4 ± 19.5	*	*	0.23 ± 0.10	38.8 ± 7.5
	K 19	*	0.09 ± 0.12	*	5.1 ± 1.4	*	*	1.59 ± 0.46	21.3 ± 2.1
	M 19	*	*	*	2.4 ± 0.7	*	*	0.11 ± 0.05	59.9 ± 5.4
Gympie	L 24	*	0.06 ± 0.04	*	37.5 ± 25.4	0.05 ± 0.04	*	0.21 ± 0.10	51.1 ± 21.0
	K 24	0.02 ± 0.02	0.35 ± 0.34	*	5.7 ± 1.0	0.03 ± 0.02	*	1.49 ± 0.29	24.3 ± 3.0
	M 24	*	0.002 ± 0.004	0.01 ± 0.02	2.2 ± 0.7	*	*	0.08 ± 0.04	52.0 ± 7.4
Hughenden	L 12	*	0.01 ± 0.01	*	20.8 ± 17.2	*	*	0.30 ± 0.11	44.1 ± 9.2
	K 12	0.02 ± 0.02	0.06 ± 0.04	*	4.3 ± 1.1	*	*	1.85 ± 0.40	25.8 ± 6.9
	M 12	*	*	*	*	*	*	0.13 ± 0.03	85.5 ± 14.0
Lowood	L 17	*	0.03 ± 0.02	*	22.5 ± 17.2	0.05 ± 0.03	*	0.27 ± 0.08	44.9 ± 17.2
	K 17	*	0.16 ± 0.12	*	4.5 ± 1.0	0.03 ± 0.04	*	1.59 ± 0.50	22.9 ± 4.2
	M 17	*	0.003 ± 0.010	*	2.3 ± 0.7	*	*	0.12 ± 0.05	56.6 ± 12.8
Mackay	L 18	*	0.08 ± 0.13	*	37.5 ± 19.7	*	*	0.21 ± 0.11	49.5 ± 16.3
	K 18	*	0.41 ± 0.36	*	4.8 ± 1.1	*	*	1.79 ± 0.47	24.0 ± 6.5
	M 18	*	*	*	1.5 ± 0.7	*	*	0.10 ± 0.05	58.9 ± 7.4
Mareeba	L 19	*	0.12 ± 0.11	*	34.9 ± 29.4	0.03 ± 0.02	*	0.23 ± 0.11	59.8 ± 16.0
	K 19	*	1.18 ± 0.81	*	5.5 ± 2.3	*	0.01 ± 0.01	1.37 ± 0.40	26.5 ± 4.1
	M 19	*	0.001 ± 0.001	*	2.0 ± 0.4	*	*	0.11 ± 0.03	54.6 ± 4.0
Mt. Isa	L 25	0.04 ± 0.02	0.12 ± 0.17	*	40.3 ± 21.3	0.12 ± 0.14	*	0.22 ± 0.08	64.0 ± 17.3
	K 25	0.10 ± 0.05	0.33 ± 0.43	*	3.6 ± 1.3	0.09 ± 0.13	*	1.33 ± 0.29	26.0 ± 8.5
	M 25	0.04 ± 0.06		*	*	*	*	0.21 ± 0.44	65.5 ± 15.4

* Mean < limit of detection (see Table 3).

DISCUSSION

In this survey no trace element concentration significantly exceeded the maximum permitted concentration (MPC) specified by the National Health and Medical Research Council of Australia (1980).

Muscle tissue contained the lowest concentrations of all elements except zinc. Arsenic, chromium, mercury and lead were not detected in the majority of samples. Lead and cadmium levels in the liver and lead levels in the kidney were lower than those reported by FLANJAK & LEE (1979) and by the Australian Government Analytical Laboratory (1981). This laboratory also reported substantially higher lead and cadmium levels in muscle than those found in our survey. Concentrations of all other elements were similar to those reported by the above workers.

Three samples from different properties in the Mareeba area contained 2.5, 2.5 and 2.6 mg/kg cadmium on a fresh weight basis, compared with the MPC of 2.5 mg/kg. The mean cadmium concentration in the kidneys of cattle from this area was 1.2 mg/kg, which was the closest any mean tissue concentration came to the MPC. By comparison, liver and muscle cadmium concentrations were much lower than the MPC's of 2.5 and 0.05 mg/kg, respectively. In general, where kidney cadmium levels were elevated, the corresponding liver cadmium levels were also elevated while the muscle cadmium levels remained unaffected. The cause of the higher tissue cadmium levels in the Mareeba area is not apparent and will be further investigated.

The elevated tissue arsenic levels in the Mt. Isa area may be attributable to the local smelter since the zinc, copper and lead ores mined there contain arsenic (R.J. Allen, personal communication). However, the arsenic levels detected in cattle from this area were well below the MPC of 1 mg/kg.

Liver and kidney selenium levels were highest in the Hughenden area. McCRAY & HURWOOD (1963) reported on a seleniferous zone in north-western Queensland with extensive outcrops occurring in the Hughenden-Richmond area.

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