Original Article

Analysis of the cobalt content in Australian foods

Bevan Hokin PhD[1], Michelle Adams PhD[2], John Ashton PhD[3], and Honway Louie PhD[4]

[1] School of Applied Science, University of Newcastle, NSW, Australia
[2] School of Applied Science, University of Newcastle, NSW, Australia
[3] Sanitarium Health Food Company, Research Laboratories, Cooranbong, NSW, Australia
[4] Australian Government Analytical Laboratories, Pymble, NSW, Australia

The cobalt content of Australian foods is unknown, and as this content is, at least in part, related to the respective concentrations in the Australian soil, data collected previously in other countries may not reflect the levels in Australian produce. To compare reported food cobalt levels to that found in Australian foods, one hundred and fifty different food and beverage items from each of the major food groups were selected for analysis, based on annual sales figures in Australia. Food digests were analysed for cobalt content using a Finnigan High Resolution Inductively Coupled Plasma Mass Spectrometer. While some variation in cobalt content was seen in a small selection of foods from different States, in general terms, the cobalt content of Australian foods is similar to that seen in data from other countries.

Key Words: cobalt, food digests, mass spectrometry, Australian foods

Introduction

A more detailed understanding of the positive biological function of essential metals is needed, not only to improve our knowledge about already established deficiency diseases, but also to be able to discover new connections between metal nutritional deficiency states and other health disturbances of yet unknown origin.

The slow progress in this area of health has been caused by: a focus on metal toxicity, particularly environmental, with the heavy metals (Cadmium, Mercury and Lead); and, until recently, a lack of technology of sufficient sensitivity to be able to measure metal ions in biological fluids. Present technology still struggles with detection limit limitations and interference correction issues.[1]

In the context of human physiology, cobalt has been seen to be of no importance other than as a component of vitamin B12.[2] However, cobalt ions are able to replace other divalent cations such as zinc, magnesium and manganese. In general terms, the cobalt-substituted enzymes show a reduced enzyme activity[3]. Cobalt ions have an inhibitory effect on RNA-polymerase.[4] So although the food authorities seem to not recognise elemental cobalt as a trace mineral (as opposed to vitamin B12-cobalt), there is evidence of biological activity in its own right.

While cobalt has been reported to have a low oral toxicity, two reports of cardiomyopathy, presumably due to excessive cobalt intake, in heavy (≥12 litres/day) beer drinkers (beer once had cobalt salts added as a foam stabiliser) were cited as the reason. Normal daily intake of cobalt is reported to be in the range 2.5 to 3.0 mg/day. Poisoning occurs within the range of greater than 23-30mg cobalt daily.[5]

Current data on the cobalt concentration in foods is from non-Australian foods (Table 3), which may in fact not represent the true levels consumed by the Australian population. Variation in soil cobalt levels may influence food concentrations, and some soils in Australia have been reported to be deficient.[6,7] The condition "Coast disease" in sheep and cattle was first described by Australians Marston and Lines[8] and found to be due to a cobalt deficiency in the soil. Furthermore disparity in the cobalt concentrations that have been previously reported from other countries (Table 3) suggests geographical, and perhaps seasonal variation does occur.

Materials and methods

Experimental design

One hundred and fifty different food and beverage items from each of the major food groups were selected for analysis. Processed foods were selected on the basis of their annual sales figures in Australia[9], to ensure that the sample of foods selected was as representative as possible. All foods were purchased from the shelves of suburban supermarkets in New South Wales, Australia. In addition, as some major food companies are known to purchase and manufacture foods on a State basis, wheat bran was sourced from Western Australia, New South Wales and South

Correspondence address: Bevan Hokin, Pathology Department, Sydney Adventist Hospital, , 185 Fox Valley Road, Wahroonga, NSW 2076, Australia
Tel: + 61 2 9487 9511; Fax: + 61 2 9487 9535
Email: bevan@sah.org.au
Accepted 24 October 2003

Table1. Cobalt content in Australian foods μg/kg

Food	μg/kg	SEM μg/kg	Food	μg/kg	SEM μg/kg
"VEGEMITE"*	1188	56	"WEET BIX" WA	55.6	1.4
Coffee, instant	1016	19.9	Lamb kidney	53	2.4
Brazil nuts	1001	62	"NUTRI GRAIN"	53	1.2
Multi vitamin capsule[1]	995	5.8	Chocolate milk	52	0.88
Linseeds	823	18	"TIM TAM"	49	1.1
Brewers' yeast*	547	12.2	Alfa alfa, fresh	48	1
Millet seeds	356	2.9	Pepitas	42.6	1.2
Buckwheat	275	7.1	Kidney beans	41.6	1.2
Chocolate, dark	236	5.4	Pepper, black	40	8
Bran, rice	219	1	Rock melon	40	2
Chilli powder	214	5.8	"WEET BIX" NSW	36	1
Sunflower kernels	198	2.6	"WEET BIX" SA	36	0.57
Liver, bovine	194	5.5	"GOOD START"	35	0.3
Marmite*	178	2	Apricot, fresh	34.6	3
Curry powder	172	1.2	Cashew nuts, roasted	34.6	0.6
Peanut butter[1]	169	2	Avocado	34	0.6
"MILO"	162	2.4	Bread, multigrain	33	0.66
Potato, fresh	137	2.9	Tofu, organic	32.6	0.8
ALL BRAN, original	113	2	"NUTMEAT"	31	1
Bran, processed	111	1.7	Baked beans	31	1.1
Broccoli	108	0.8	Barbecue biscuit	29	0.57
Potato crisps	107	2.8	Flour, Wholemeal	28	1.2
Peanut butter[2]	101	4.2	Peas, frozen	27	0.2
Cereal	94	1.3	Beans, green, frozen	26	2
Beef, mince-extra lean	87	2.9	Pumpkin	25.5	2.5
Brown lentils	82.6	2	Bacon	23.3	0.33
Chick peas	82	0.33	Oysters fresh	22	0.33
Tahini	80.6	2	Soy Sausage	22	0.3
"SULTANA BRAN"	73	2.9	Pizza, vegetarian	22	0.3
Liver, lamb	72.6	0.88	Bran, Oat	20	0.8
"SOY TASTY"	72.6	0.6	Tomato sauce	19.6	1.8
"SAUSAGE FILLING MIX"	68	0.6	"MAXIMIZE"	18	1
Almonds	63	1.5	Tomato, fresh	18	0.3
MCDONALDS fries	57	0.3	Soy milk	17	0.88
"WEET BIX" hi bran	57	0.3	Pizza	17	1.1
Walnuts	56	2	Prawns, fresh	16	0
Burger, whole	16	0	Salmon	3	0
Cornflakes[1]	15.6	0.6	"UP & GO" malt	3	0
Oats, rolled	15.6	0.66	Baby formula, instant	3	0.57
Capsicum, fresh	15.3	1.2	Peach slices, canned	2.6	0.3
Soymilk[1]	12.7	1.3	Cheese[1]	2.3	0.33
Bread, "WONDER WHITE"	12.6	0.66	Bream, fresh	2.3	0.3
Honey	12.33	0.66	Tuna, canned	2.3	0.33
Cornflakes[2]	11.6	0.3	Banana	1.6	0.33
Mince	11.3	0.33	Orange, fresh	1.5	0.5
Pear, fresh	11	0	Cheese[2]	1	0
Lettuce	10.3	1.2	Milk, whole	1	0
Cauliflower	10	0	Egg, fresh	1	0
Sultanas	10	.3	Steak, rump	1	0
Chicken roll	9.6	0.3	Milk, skim	1	0
Coconut, desiccated	9.3	0.33	Chicken, fresh	1	0
Peas fresh	8.3	0.3	Lamb	1	0
Milk powder, whole	8	2	"SO GOOD"	1	0
Tempeh, organic	8	0	Pineapple, canned	1	0

Table1. continued Cobalt content in Australian foods µg/kg

Food	µg/kg	SEM µg/kg	Food	µg/kg	SEM µg/kg
Rice, brown	8	0	Apple, red delicious	1	0.3
Pork sausage	7	0.58	Yoghurt[2]	0.66	0.33
Rice, white	7	0.33	Orange juice	0.66	0.33
Steak	6.3	0.3	Apple juice	0.33	0.33
“BIG MAC” burger Patti	6.3	0.3	Margarine	Bdl	0
Pasta sauce, “LEGGOS”	6	0	Butter	Bdl	0
Red wine	5	1	Olive oil	Bdl	0
Fish, canned	5	0.57	Vegetable oil blend	Bdl	0
Beans, fresh	5	0	Vegeburger	Bdl	0
Flour, plain white	5	0	“COKE”	Bdl	0
Ham, virgin	4.6	0.3	Black tea	Bdl	0
Steak, veal	4.3	0.3	Mineral water	Bdl	0
Fish, fresh	4	0	Tap water	Bdl	0
Carrot	4	0	Egg powder	Bdl	0
WomBock	4	0.3	Sugar, white	Bdl	0
Spaghetti, raw	4	0	Pork fillet	Bdl	0
Meat pie	3.3	0.3	Mushrooms, fresh	Bdl	0
Corn, frozen	3.3	0.88	Corn kernels, canned	Bdl	0
Onion, fresh	3.3	0.3	Apple golden	Bdl	0
Yoghurt [1]	3	0	Apple granny	Bdl	0
Pineapple, fresh	3	0.57			
Pork sausage	7	0.58			
Rice, white	7	0.33			
Steak	6.3	0.3			
“BIG MAC” burger Patti	6.3	0.3	Margarine	Bdl	0
Pasta sauce, “LEGGOS”	6	0	Butter	Bdl	0
Red wine	5	1	Olive oil	Bdl	0
Fish, canned	5	0.57	Vegetable oil blend	Bdl	0
Beans, fresh	5	0	Vegeburger	Bdl	0
Flour, plain white	5	0	“COKE”	Bdl	0
Ham, virgin	4.6	0.3	Black tea	Bdl	0
Steak, veal	4.3	0.3	Mineral water	Bdl	0
Fish, fresh	4	0	Tap water	Bdl	0
Carrot	4	0	Egg powder	Bdl	0
WomBock	4	0.3	Sugar, white	Bdl	0
Spaghetti, raw	4	0	Pork fillet	Bdl	0
Meat pie	3.3	0.3	Mushrooms, fresh	Bdl	0
Corn, frozen	3.3	0.88	Corn kernels, canned	Bdl	0
Onion, fresh	3.3	0.3	Apple golden	Bdl	0
Yoghurt [1]	3	0	Apple granny	Bdl	0
Pineapple, fresh	3	0.57			

Bdl = below detection limit; Values are means (*N*=3) and standard error of the mean
*Data for Vegemite, Marmite and Brewer’s yeast checked and confirmed; [1]Cenovis Mega Multi, containing 25 µg vitamin B12

Table 2. Cobalt content in selected Australian breakfast cereals by State µg /kg

Food /Product	State where sourced	Cobalt content µg /kg
Cereal Weet-bix (Sanitarium)	Western Australia	57 ± 1.4
	New South Wales	37[a] ± 1
	South Australia	36[a] ± 0.57
Cereal Wheat bran (Sanitarium)	Western Australia	108[b] ±3.5
	New South Wales	111[b] ±1.7
	South Australia	106[b] ±5

Values are means ± standard error of the mean (*N*=3); values within a given column with the same superscripts are not significantly different ($P > 0.05$, one way –ANOVA)

Australia. Variation in cobalt content from these three States would give some indication of the variability in cobalt content in soils and foods across Australia.

Sample preparation

Sample preparation was undertaken in the research laboratories of the Sanitarium Health Food Company. Food samples were homogenised using a nitric acid washed domestic food processor fitted with specially made titanium blades to eliminate possible cobalt contamination from stainless steel. Fruits and vegetables were washed in deionised (18MΩ) water to remove any dirt. All sample handling was undertaken in a clean room environment. Triplicate 1 gm samples were digested using 3 mL of nitric acid on a steam bath for 90 minutes, then left overnight. Digests were made up to 40 mL with deionised water and centrifuged. Ten millilitres of supernatant were provided for analysis.

Analytical methods

Analysis of samples (in triplicate) was performed by the Australian Government Analytical Laboratory using their Finnigan High Resolution Inductively Coupled Plasma Mass Spectrometer. This technology ensures that the cobalt results are free from potential matrix interferences.[10] Cobalt standard solutions with concentrations of 5, 10, 20 ppb were used to calibrate the instrument and indium was used as an internal standard for both samples and calibration solutions.

The practical quantitation limit for cobalt was 0.2µg cobalt per 100gm of sample, with a detection limit being approximately 0.1µg cobalt for 100gm of sample. However, any results less than 0.2µg/gm should be considered qualitative, and are included here for comparison purposes only.

Results

The average cobalt content was calculated for each of the food or beverage items from the results of the three separate analyses performed. Table 1 lists in descending order the average cobalt content of all the foods tested. Table 2 presents the results of cobalt content on wheat and wheat bran from three Australian States.

Discussion

There is wide variability in the cobalt content in common Australian foods and beverages, ranging from over 1000µg/kg to undetectable levels (Table 1). The results however, have not been adjusted for serving size, *and* hence total intake in some cases may be negligible, even though the relative amounts are quite high. Further, the variation in cobalt in food products produced in different States may reflect variation in soil concentrations as has

Table 3. Comparison of cobalt content in foods from several countries µg /kg

Food type	Australia	Spain [11]	Canada [12]	USA [13]	France [14]
Cereals		26	18	12	4
Cornflakes	12				
All bran	113				
Meat	86	21	8.7	12	
Poultry	1				
Fish	4		19.9		121
Oils, fats	Bdl	15		2	
Eggs	1	10		3	9
Vegetables		11	9.7	7	9
Carrot	4				
Broccoli	101				
Fruits		10	4.6		9
Pear	11				
Apple	Bdl				
Banana	2				
Nuts				26	
Brazil	998				
Peanut butter	101		35.7		
Almonds	63				
Walnuts	56				
Potato	137	19	74		
Milk, dairy products	1	4	5.2	3	
Soft drink	Bdl	7	1.1	0	
Tap water	Bdl	4		0	

previously been reported.[7] Interestingly, although the cobalt content of Western Australian Weet-bix was significantly higher than that sourced from New South Wales and South Australia ($P<0.05$), there was not a significant difference for wheat bran (Table 2). There are two possibilities for this. Firstly seasonal variation may have influenced the results. No information was available to support this, however it posses the possibility that cobalt intake may fluctuate dramatically over time. This is unlikely to exert any negative effect on health. The second possibility is that processing may influence the cobalt concentration of the wheat products.

Clearly the best dietary sources of cobalt from the Australian diet include yeast products and yeast, coffee, nuts, seeds and grains, chocolate and condiments. These results are comparable data from studies in other countries, which are summarised in Table 3.

Considerable differences in the food cobalt levels between countries are evident, in particular for meat. Although variations in analytical methods could provide a partial explanation, the latter two studies by Dabeka *et al.,* (1995)[12] and Biego *et al.,* (1998),[14] use similar methods to those described in this study. The variation in reported cobalt content of meat between the Dabeka *et al.,* study (1995)[12] (8.7 µg/kg) and this study (86 µg/kg), exemplifies the influence of geographical location on the cobalt concentration.

Conclusion

This is the first reported study on the cobalt levels in Australian foods. Although the results were comparable to those reported for other countries, clear disparity for some foods highlights the geographical influence on food cobalt levels. Seasonal variation may also play a major role in food cobalt levels, although this variation may not exert a negative influence on the well being of individuals.

Acknowledgement

This research was supported by contributions from the Australian Government Analytical Laboratories, Pymble, Sydney, and the Sanitarium Health Food Company, Cooranbong, NSW Australia.

References

1. Favaro DIT, Hui MLT, Cozzolino SMF, Maihara VA, Armelin MJ, Vasconcellos MB, Yuyama LK, Boaventura GT, Tramonte VL. Determination of various nutrients and toxic elements in different Brazilin regional diets by neutron activation analysis. J Trace elements Med Biol 1997; 11: 129-136.
2. WHO Codex General Standard for Contaminants and toxins in foods. World Health Organisation, The Netherlands: Codex Alimentarius Commission, 1996.
3. Lindskog S. Co (II) in metaloenzymes. Structure and Bonding. Vol 8. Berlin: Springer Verlag, 1970; 153-196. cited by Hellsten E, Henriksson-Enflo A, Sundbom M, Vokal H. Cobalt. In: University of Stockholm Institute of Physics report, 76-11 March, University of Stockholm 1976.
4. Eichhorn GL.In: GL Eichhorn, ed. Inorganic biochemistry. Vols 1 & 2. Amsterdam: Elsevier Scientific Publishing Company, 1973; 1215.
5. Hellsten E, Henriksson-Enflo A, Sundbom M, Vokal H. Cobalt. In: University of Stockholm Institute of Physics report, 76-11 March, University of Stockholm 1976.
6. Lee J, Masters DG, White CL, Grace ND, Judson GL. Current issues in trace element nutrition of grazing livestock in Australia and New Zealand. Australian J Agri Research 1999; 50 (8):1341-64.
7. Imberger R. Cobalt in the ruminant. rohini@cleo.murdoch.edu.au Sept 1995
8 Underwood EJ, Hedly Ralph Marston (1900-1965). A biographical memoir. Records of the Australian Academy of Science. Vol 1, No 2. Published by the Australian Science Archives Canberra, 1967. www.asap.unimelb.edu.au/bsparcs/aasmemoirs/marston.htm
9. Nielson AC. Annual report. Retail market share figures 1999 Barry Flannagan Publisher, Sydney 1999
10. Reed NM, Cairns RO, Hutton RC. Characterisation of polyatomic ion interferences in inductively coupled plasma mass spectrometry using a high-resolution mass spectrometer. J Analytical atomic spectrometry 1994; 9: 881-896.
11. Barbera R, Farre R. Cobalt content of foods and diets in a Spanish population. Die Nahrung 1986; 30 (5): 565-7.
12. Dabeka RW, McKenzie AD. Survey of lead, cadmium, fluoride, nickel and cobalt in food composites and estimation of dietary intakes of these elements by Canadians in 1986-1988. J AOAC International 1995; 78 (4): 897-909.
13. Pennington JA, Jones JW. Molybdenum, nickel, cobalt, vanadium and strontium in total diets. J Am Diet Assoc 1987; 87 (12): 1644-50.
14. Biego GH, Joyeux M, Hartemann P, Debry G. Daily intake of essential minerals and metallic micro-pollutants from foods in France. Sci Total Environ 1998; 217(1-2):27-36.