FURTHER OBSERVATIONS ON THE OCCURRENCE OF IODINE IN RELATION TO ENDEMIC GOITRE IN NEW ZEALAND AND ON IODINE METABOLISM.

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(With a Map.)

CONTENTS.

I. Introduction.

In a previous paper (Hercus and Roberts, 1927) an account was given of a comprehensive survey, which was carried out at Otago University, of the natural sources of iodine in New Zealand. This study also included observations on iodine metabolism, and on the effect of varying iodine environment on the iodine content of plant and animal products. More recently, we have carried out additional investigations with a view to further supplementing

https://doi.org/10.1017/S0022172400017691 Published online by Cambridge University Press

our knowledge of various aspects of iodine distribution. The present paper deals with these later observations, which relate mainly to the iodine content of soils from parts of Australia and some of the Pacific Islands, and of articles of diet in New Zealand and the Islands, with the relations between the intake and excretion of iodine in human beings under various conditions, and with the distribution of iodine in the animal organism.

We have to acknowledge a grant from the New Zealand Department of Health which has enabled the analytical side of the research to be carried out; also a grant from the Sir John Roberts Endowment which assisted one of us (H. M. S. T.) in carrying out a section of the research.

We are also indebted to the Director of Canterbury Agricultural College for arranging to supply us with samples of soils and pastures; and to Dr K. C. Roberts for his co-operation in connection with the proof reading.

II. Some notes on the analytical method.

Most of the analyses which are here recorded were carried out by v. Fellenberg's method as described by Hercus and Roberts (1927). Not long ago the modification of Leitch and Henderson (1926) was introduced into our laboratory by Mr W. J. Blackie, M.Sc., and found to have considerable advantages in convenience. In this method the iodine is estimated by titration with a thiosulphate solution which ordinarily requires frequent standardisation. The use of amyl alcohol as described by Meyr and Kirschbaum (1928) to stabilise the thiosulphate solution was found to be highly satisfactory, the solution maintaining its strength unchanged for months.

In the course of our analyses we have frequently had occasion to observe the contamination of reagents and vessels by minute traces of iodine. Commercial brands of purified potassium hydroxide vary from sample to sample, some samples being iodine-free and others containing measurable amounts of iodine. Likewise various metal basins, otherwise suitable for combustions, were found to yield traces of iodine from their surfaces. Typical results are given in Table I.

Table I. *Showing amount of iodine obtained from various metal surfaces.*

Type	Microgrm.
Nickel basin	0·5 (mean of 5 tests)
Cast-iron basin	1·6 (mean of 3 tests)
Iron ladle	1·4
Iron pot	0·9 (mean of 2 tests)
Monel basin (87 % nickel)	1·6
Copper basin	3·2
Platinum basin	Nil
Porcelain basin	2·4

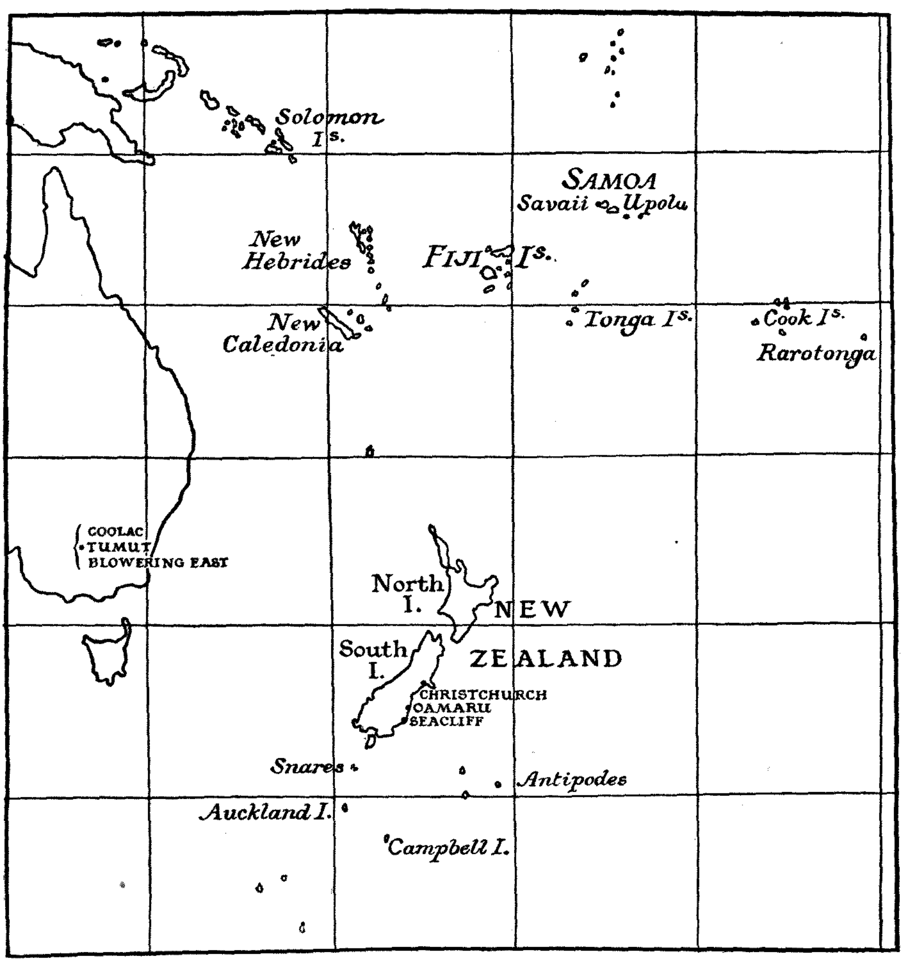
In each case the results were obtained by evaporating potassium carbonate to dryness in the basin, combusting for a short time and analysing the carbonate for iodine. Since in actual estimations organic matter is present, which might be expected to inhibit this effect of alkali in extracting iodine from the metal, similar combustions were carried out in nickel, iron and monel basins on a sample of fresh vegetable matter of known iodine content. It was found that the organic matter markedly reduced the amount of iodine given off by the metal, and that this source of error in the case of most of the nickel basins was negligible; nickel basins were, therefore, used throughout the work and any error so introduced may be assumed to be a constant one.

Another point which was investigated was the relation between the colour of the extract from combustion and the accuracy of the estimation. After a series of combustions with the same substance it was found that the most accurate results were obtained when the filtrate was straw colour.

III. IODINE IN SOILS.

(1) *Iodine content of soils from districts in Australia and the Pacific Islands adjacent to New Zealand.* (See Map.)

As comparisons of iodine contents of soils from different localities are of very great interest whether from the agricultural, the medical, or the economic



https://doi.org/10.1017/S0022172400017691 Published online by Cambridge University Press

point of view, we have taken the opportunity of supplementing our previous studies on the iodine content of New Zealand soils by obtaining specimens of soils from various Pacific Islands and from certain parts of Australia. The position of the various islands in relation to Australia and New Zealand is indicated in the Map. The iodine content of the soils and the geological formation from which they are derived are shown in Table II.

Table II. *Amount of iodine in soils of different origin and nature.*

Locality	Geological formation	Iodine in parts per 10,000,000	Goitre incidence %
Western Australia:			
Perth	Calcareous (?) sand	24	Nil
Kalgoorlie	Basic igneous rock	53	,,
Bunbury	Loam	96	,,
,,	Sand	7	,,
Freemantle	Calcareous (?) sand	24	,,
Northam	Granite sand	8	,,
New South Wales:			
Tumut	Slate?	—	—
Coolac	Slate?	15	—
Blowering East	Granite	38	—
Samoan Group:			
Savaii:			
Samatau	Basalt	351	Nil
Tuasivi	,,	72	,,
Sataua	,,	720	,,
Fagamalo	,,	270	,,
Satupaitea	,,	360	,,
Upolu:			
Vailele	Basalt	41	,,
Apia	,,	196	,,
,,	,,	291	,,
Cook Island Group:			
Rarotonga	Basalt	102	,,
Solomon Islands:			
Inland village	Probably basalt or andesite	194	,,
Coastal village		370	,,
Tonga	Basalt	91	,,
Antipodes at 400 ft.	,,	144	—
Antipodes at 10 ft.	,,	120	—
Auckland Island	,,	120	—
Campbell Islands	,,	103	—
Enderby Island	,,	198	—
Goat Island	,,	252	—
Snares Island	Granite	61	—
New Zealand:			
Canterbury:			
Christchurch	Gravel	25 (mean of 8)	55
,,	Sandy	3	—
Otago:			
Oamaru	Gravel	98	—
Seacliff	Basaltic	69 (mean of 11)	10
Waitati	Phonolite	24	—
Stewart Island:			
Pegasus Bay	Granite	90	—
Halfmoon Bay	,,	198	—

https://doi.org/10.1017/S0022172400017691 Published online by Cambridge University Press

Table II again illustrates the higher concentration of iodine obtaining in soils derived from volcanic structures, as, for example, in the completely non-goitrous region of Samoa. Similar and even higher values have been obtained in certain volcanic regions in the North Island of New Zealand.

(2) *Iodine manuring and its effect on the iodine content of plants.*

Various investigators (Scharrer and Strobel, 1927; Orr, Kelly and Stuart, 1928) have shown that crops from soils treated with manures containing iodine show a higher iodine content than controls from unmanured plots. We have again taken up this question in order to find the nature of the increase which can be produced in the iodine content of grass by the use of iodides and also what results can be expected from the use of commercial manures.

In the first experiment a dressing of potassium iodide was given to six plots and different commercial manures were added to six other plots, the plots being then sown down with grass (15. x. 1929). The grass and soil from each plot was sampled on 5. xii. 1929, when the plots were showing a vigorous growth. Further samples of the maturer grass were collected on 24. iv. 1930. The results are shown in Table III. The figures in brackets represent the iodine content of the commercial manures.

Table III.

Plot	Manure	Total iodine in manure (grm.)	Iodine in soil (pts $I_2/10^7$)	Iodine in grass Dec. 5th (pts $I_2/10^9$)	Iodine in grass April 24th (pts $I_2/10^9$)
1	Potassium iodide	·000765	51	150	210
2	,,	·038250	67	160	220
3	,,	·076500	89	260	210
4	,,	·153000	93	270	330
5	,,	·306000	110	340	250
6	,,	·688500	131	—	390
7	20 grm. nitrate of soda (237/10^7)	·000474	51	150	200
8	20 grm. Seychelles guano (95/10^7)	·000190	42	130	190
9	20 grm. Nauru phosphate (28/10^7)	·000058	38	200	360
10	20 grm. superphosphate (152/10^7)	·000304	39	170	280
11	20 grm. special grass (76/10^7)	·000152	40	135	—
12	20 grm. blood and bone (1/10^7)	·000002	39	140	210

A study of Table III shows that in the first six plots the iodine content of the grasses reflects fairly definitely that of the dressing used. This is shown clearly in the young growth (Dec. 5th), while in the later growth (April 24th) the regular effect of increased iodine content in maturer vegetation is shown. The more even and apparently anomalous values obtained in the case of the later growth can be explained by assuming that the soils have a certain retentivity for iodine and that the excess iodine is largely washed out by the rain. Actually the soil was somewhat clayey and would have a rather low retentivity (Hercus and Roberts, 1927).

Further light was thrown on this point by testing for water-soluble iodine in the soils. For the first three plots the quantity was not measurable, while in the later plots it reached only about a quarter of the total iodine content of the soil. Since the iodine content of these soils was raised considerably as compared with the control, it follows that even in the short time which had elapsed since manuring (about 7 weeks) much of the retained iodine had gone into organic combination. This is not difficult to understand on consideration of the ease with which oxidations are carried out by soil bacteria, for example nitrifying bacteria. The iodine is probably split off by bacteria, particularly in the presence of humic acids, from the readily oxidisable iodide and forms iodo-compounds with unsaturated organic matter in the soil.

The effect of the commercial manures is also interesting (Table III). It is seen that the iodine content of the pasture is not closely correlated either with the iodine content of the soil or with the relatively small iodine content of the manure. Obviously the availability of the soil iodine must vary from plot to plot. The iodine content of this grass compares favourably with that of the first six plots, and this seems to indicate that the manures exert their effect by rendering the soil iodine available, rather than by virtue of their own iodine. Table III shows that superphosphate is most effective in this regard. This is confirmed by the results of a similar experiment which was carried out for us at Lincoln Agricultural College, through the kindness of the Director. The details are given in Table IV. The pasture consisted of grasses and clover.

Table IV.

Plot	Manure	Iodine in soil (pts $I_2/10^7$)	Iodine in pasture Aug. 1929 (pts $I_2/10^9$)	Iodine in pasture Oct. 1929 (pts $I_2/10^9$)
1	No manure for 8 years	32	220	194
2	Potash manure (30 %): 1 cwt. per acre per year for 6 years	36	248	380
3	Superphosphate (44 %): 1 cwt. per acre per year for 6 years	58	308	402
4	Lime: total of 5½ tons per acre over 6 years	22	253	378
5	Nitrate: 1 cwt. per acre per year for 4 years. Ammonium sulphate: 1 cwt. per acre per year for 2 years	20	220	—

In addition to artificial fertilisers dried seaweed and fish by-products represent sources of manure iodine. We have occasionally received samples of vegetables in which the iodine content has been increased by the use of seaweed manures. In other cases the results have been negative. This is attributed to differences in the variety of seaweed used and in the nature of the soil. The value of fish by-products as iodine manures depends upon the process of manufacture. A fish manure prepared by autoclaving refuse with steam under pressure was found to be useless as a source of iodine, most of the iodine having been volatilised.

IV. Iodine in foods.

(1) *Iodine content of edible products from districts in New Zealand and the Pacific Islands.*

Partly to complete our earlier survey of iodine in foods and partly for convenience in computing iodine intake on given diets we have made additional analyses of a number of articles of food as shown in Table V.

Table V. *The iodine content of foodstuffs and other substances.*

Substance	Source	Goitrous or Non-Goitrous	F. = Fresh D. = Dry	Iodine content in microgrm. per kg.
Cereals:				
Oatmeal	Southland	G.	D.	21
Rice starch	?	?	D.	10
Raw wheat germ	Australia	—	—	40
White bread	Otago	G.	F.	6
Root vegetables:				
Beetroot (mean of 5) without skin	Canterbury	G.	F.	5·1
Beetroot (mean of 5) with skin	,,	G.	F.	6·9
Carrot (mean of 8) without skin	,,	G.	F.	4·2
Cucumber	Samoa	Non-G.	F.	2
Parsnip (mean of 6)	Canterbury	G.	F.	5·6
Potato	Samoa	Non-G.	F.	4
Taro	Solomon Islands	Non-G.	F.	2
Turnip (mean of 7)	Canterbury	G.	F.	5·7
Leafy vegetables:				
Brussels Sprouts	Otago	G.	F.	7·3
Cabbage (mean of 5)	Canterbury	G.	F.	6·1
Cauliflower	Otago	G.	F.	4
Leek (mean of 2)	Canterbury	G.	F.	8·4
Lettuce	Otago	G.	F.	6·9
Silver beet (mean of 16)	Canterbury	G.	F.	16·7
Spinach	Samoa	Non-G.	D.	255
,,	Canterbury	G.	F.	6
Turnip top	,,	G.	F.	26
Fruits:				
Apples (mean of 5) without peel or core	,,	G.	F.	5
Apricots	,,	G.	F.	4·8
Bananas	Samoa	Non-G.	D.	6
Cocoanut (edible portion)	,,	Non-G.	F.	6
Egg fruit	,,	Non-G.	F.	2
Lemon	,,	Non-G.	F.	2
Mummy apple	,,	Non-G.	F.	9
Orange	,,	Non-G.	F.	2
Passion fruit	,,	Non-G.	F.	2
Peanuts	,,	Non-G.	F.	58
Pineapple	,,	Non-G.	F.	2
Prunes	California	—	—	10
Raisins	,,	—	—	32
Yeast	Otago	G.	D.	40
Fresh water plants:				
Watercress	,,	G.	F.	31
Grass:				
Grass (mean of 11)	Samoa	Non-G.	D.	326
Grass	Canterbury	G.	D.	309
,,	,,	G.	F.	56
Seaweeds:				
Seaweed	Pacific Ocean	—	F.	5,830
Carrageen moss	Ireland	—	D.	315,000

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Table V (*cont.*).

Substance	Source	Goitrous or Non-Goitrous	F. = Fresh D. = Dry	Iodine content in microgrm. per kg.
Plant oils:				
Cocoanut oil (edible)	Samoa	Non-G.	F.	6
Animal oils:				
Butter	Canterbury	G.	F.	6
,,	Otago	G.	F.	12
Cod-liver oil (refined)	Scandinavia	?	F.	5,000
Shell fish:				
Oysters	New Zealand	—	F.	809
Animal products:				
Eggs	Canterbury	G.	F.	52
,,	Otago	G.	F.	58
,,	Samoa	Non-G.	F.	394
Cow's milk	,,	Non-G.	F.	11
,,	Canterbury	G.	F.	7
,,	Otago	G.	F.	6
Cheese	,,	G.	F.	31
Cream	,,	G.	F.	6
Casein	New Zealand	—	D.	156
Lactose	,,	—	D.	10
Meat:				
Tripe	Otago	G.	F.	5
Meatmeal	,,	G.	D.	158
Miscellaneous:				
Marmalade (Californian oranges)	California	—	F.	10
Jam (plum)	Otago	G.	F.	12
Honey	,,	G.	F.	18
Non-edible substances:				
Oyster shell	Otago	G.	D.	38,400
Sark	India	—	—	125

Carrageen, cod-liver oil and oysters, being marine products, are particularly rich sources of iodine. It is unfortunate that the price of fish in New Zealand compares badly with that of meat, with the result that fish is by no means a staple article of diet. Also in many districts such as the endemic area of South Westland, transport difficulties are so great that fish is practically unobtainable. Among the land products given in the table Samoan eggs are noteworthy, having an iodine content of 394 microgrm. per kg.

(2) *Iodine content of New Zealand foods as compared with those of Samoa.*

We have already recorded the results of a comparative study of the iodine content of foodstuffs in goitrous and non-goitrous districts in New Zealand. It was decided to extend this investigation to the goitre-free island of Samoa for purposes of comparison with more or less endemic districts in New Zealand, such as Canterbury and Otago. Owing to transport difficulties the analytical material was narrowed down to grass, eggs and milk. The findings are shown in Table VI.

Table VI shows clearly the marked difference between Samoa and New Zealand as iodine environments, and is thus further evidence for the relation between goitre incidence and iodine deficiency.

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Table VI.

District	Goitre incidence (%)	Soils: iodine in 10^7	Grass: iodine in 10^9	Foodstuffs iodine in 10^9	
				Eggs	Milk
Samoa	Nil	285 (mean of 9)	326 (mean of 11)	394 (mean of 12)	11 (mean of 6)
Otago	19	64 (mean of 12)	68 (mean of 13)	58 (mean of 12)	8 (mean of 9)
Canterbury	64	25 (mean of 9)	67 (mean of 6)	41 (mean of 12)	6 (mean of 9)

(3) *Dietaries of institutions in relation to daily iodine intake.*

An investigation of the dietaries of fifteen residential institutions was carried out by one of us (H. M. S. T.) with a view to ascertaining to what extent the iodine content of the daily menu conformed to the accepted daily requirement of iodine. The fifteen institutions included four preparatory school hostels, seven secondary school hostels, two university residential colleges, one nurses' home and one mental hospital, the total number of residents being 1900. From data received from these institutions was compiled Table VI A, which shows the average diet for all the institutions and the corresponding iodine intake, exclusive of fish and iodised salt, which will be considered later.

Table VI A.

Food	Weight in grm.	I_2 intake for non-goitrous area: Iodine in γ/kg. (Hercus and Roberts, 1927)	I_2 intake for non-goitrous area: Total I_2 in γ	I_2 intake for goitrous area: Iodine in γ/kg. (Hercus and Roberts, 1927)	I_2 intake for goitrous area: Total I_2 in γ
Meat	168	16	2·4	9·5	1·4
Eggs	20	137	2·7	56	1·1
Butter	327	12	3·9	8	2·6
Milk (c.c.)	293	25	7·3	15	4·4
White cereals	220	3	0·66	2	0·44
Whole cereals	64	40	2·5	20	1·2
Fresh fruit	100	5	0·5	3	0·3
Dried fruit	40	20	0·8	12	0·5
Root vegetables	200	9	1·8	6	1·2
Leafy vegetables	20	27	0·5	20	0·4
Water (in c.c.)	1000	2	2·0	1	1·0
Total iodine intake		—	25·06	—	14·5

The iodine intake on this diet is too close to the minimum requirement (according to Orr and Leitch (1929) 15 microgrm. for an adult, 50 microgrm. for a child) to be suitable for individuals resident in a district where goitre is endemic. However, it was found that on an average the institutions investigated used fish about once a week, though four neglected the use of fish altogether. In a total of twenty-eight meals having fish as a basis, fresh fish (generally groper) was employed in nineteen, tinned salmon in six, sardines in two, and smoked cod in one. The effect on average daily iodine intake of having a meal of fish once a week is shown in Table VI B.

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Table VI B.

Kind of fish	I_2 in γ/kg.	One serving	I_2 content	Increase in average daily I_2 intake by use once weekly
Fresh fish (Groper)	72	100 grm.	7·2	1·0
Salmon	750	50 ,,	37·5	5·3
Smoked fish (blue cod)	812	90 ,,	73	10·4
Sardines	360	25–50 ,,	9–18	1·3–2·6
Oysters	880	1 oyster	20	3·0

It is clear that the use of salmon, blue cod, or oysters twice a week in conjunction with the diet shown in Table VI A would produce an important augmentation of the daily iodine intake. As to the cooking of the fish, our experiments have shown that there is no loss of iodine by baking, steaming or frying, though there is an appreciable loss on boiling, if the cooking water is discarded.

Reference to Table VI A shows that milk is an important item in supplying iodine, a pint of milk containing from 7 to 11·6 microgrm. The standard for consumption of milk from the point of view of calcium and phosphorus requirement is generally given as $1\frac{1}{2}$ to 2 pints daily for a child and 1 pint daily for an adult. The average consumption in the institutions considered was 0·63 pints per head daily, all being below the standard, while three institutions used less than half a pint per head daily. These latter were all school hostels!

Finally, it was found that while all fifteen institutions used iodised salt at table, only eight were using it for cooking purposes as well. Investigation has shown that table salt represents about 16 per cent. of the total salt used, and that the use of iodised salt containing 1 part of iodine in 250,000 solely at table raises the daily intake by only about 5 microgrm. It is obvious that to obtain the full effects of iodised salt it should be used both for table and cooking purposes, and cooking waters in preference to being discarded should be used in the preparation of soups, sauces, etc.

V. Iodine metabolism in man.

At the present time our knowledge of iodine metabolism is extremely fragmentary. Little is known of the respective rôles of inorganic and organic iodine in nutrition, or of the relations between blood iodine, tissue iodine and thyroid iodine. Even the fundamental question of the relation between intake and excretion of iodine has received scant attention, the only experiments being one by McClendon and Hathaway (1923) and two by v. Fellenberg (1923–6). We have now carried out three studies on this subject as described below, with rather interesting results. Experiments on the effect of fasting on iodine excretion, on the iodine content of human milk, and on the effect of iodized salt on iodine excretion are also described.

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(1) *Relations between intake and excretion of iodine on diets low in iodine and on normal diets.*

In the first study three women students, whose ages were 24, 19 and 21 years, and whose weights were 11 st. 8 lb., 10 st. 10 lb. and 9 st. 7 lb. respectively, agreed to undertake a quantitative investigation of 10 days' duration. The students aged 24 and 19, who will be referred to as students A. and B., had simple goitres of medium size of some years' duration—the third student, C., had an apparently normal thyroid gland. Throughout the investigation the students carried out their usual routine of classes and social activities.

The diet adopted is detailed in the Appendix, Diet *A*.

Each day each item of the diet was accurately weighed and the iodine content was determined. The daily iodine intake of the food and water will be seen to be approximately 8 microgrm. After the diet had been in use for 4 days, in order to give an opportunity for the body to adjust itself to the low iodine intake, the total daily iodine excretion in urine and faeces was determined for each subject for a period of 6 days. The intake through the respiratory tract and the excretion by way of mucous discharge and perspiration have been neglected, being unimportant.

The results are given in Table VII.

Table VII.

Day of experiment	Daily iodine intake in microgrm. Students A.	B.	C.	Daily iodine excretion in microgrm. Students A.	B.	C.	Iodine balance in microgrm. Students A.	B.	C.
1–4	8	8	8	Preliminary period			Preliminary period		
5	8	8	8	35·8	38·0	51·0	−27·8	−30·0	−43·0
6	8	8	8	31·9	33·7	50·0	−23·9	−25·7	−42·0
7	8	8	8	35·0	29·1	48·0	−27·0	−21·1	−40·0
8	8	8	8	54·0	33·8	27·6	−46·0	−25·8	−19·6
9	8	8	8	35·4	60·0	30·0	−27·4	−52·0	−22·0
10	8	8	8	83·2	29·3	27·2	−75·2	−21·3	−19·2
Total for 6 days	48	48	48	275·3	223·9	233·8	−227·3	−175·9	−185·8

If excretion values in Table VII, differing greatly from the average of all values, are rejected it is found that the tendency is for the excretion to approximate to some 34 microgrm. per day, thus giving rise to an average balance of about −26 microgrm. per day. The excretion corresponds to that associated with the normal diet of the students before the beginning of the experiment, and it is clear from the table that, even at the end of 10 days, the iodine of the tissues is still being mobilised, and the small intake has not yet led to the inevitable lower equilibrium. Only in the case of student C. do we observe the first signs of adjustment to the lower level. Such a lag can be explained by consideration of the small ratio which the daily intake of iodine bears to the total bodily iodine, especially as compared with the corresponding ratio for a more typical food element such as nitrogen. It would

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seem that adjustments of iodine balance are mainly passive; as is to be expected, for if iodine excretion were under active control, iodine deficiency would be a rarity.

After a period of 3 weeks and 3 days had elapsed, a further study was carried out on a diet relatively rich in iodine-containing food, the total iodine content being 45 microgrm. The details of the diet are given in the Appendix, Diet *B*. After the usual 4 days on the diet, estimations of iodine excretion through the urine and faeces were determined for a further period of 6 days. The results are given in Table VIII.

Table VIII.

Day of experiment	Daily iodine intake in microgrm. Students			Daily iodine excretion in microgrm. Students			Iodine balance in microgrm. Students		
	A.	B.	C.	A.	B.	C.	A.	B.	C.
1–4	45	45	45	Preliminary period			Preliminary period		
5	45	45	45	34·4	32·0	40·0	+10·6	+13·0	+ 5·0
6	45	45	45	29·2	136·0	40·0	+15·8	−91·0	+ 5·0
7	45	45	45	30·2	78·6	45·0	+14·8	−33·6	0
8	45	45	45	32·4	56·0	36·0	+12·6	−11·0	+ 9·0
9	45	45	45	30·1	40·0	34·0	+14·9	+ 5·0	+11·0
10	45	45	45	29·6	21·4	28·2	+15·4	+23·6	+16·8
Total for 6 days	270	270	270	185·9	364·0	223·2	+84·1	−94·0	+46·8

In this table a normal excretion is found to be about 37 or 33 microgrm. higher than the normal excretion for the low iodine diet of Table VII. The figures in column B. on the sixth and seventh days are obviously anomalous, being due to effects other than dietic (excitement, menstruation, etc.). There is a definite tendency in all three cases for storage to take place towards the end of the period, the tissues being perhaps slightly depleted as a result of the earlier experiment.

The third study was carried out on two members of the teaching staff of the Home Science School in conjunction with a study as to the intake and output of calcium. The subjects will be referred to as B. and N. Both were free from goitre. Their respective weights were 143 and 156 lb. and their ages 35 and 26 years.

The diet was one based upon an enquiry by Storms and Todhunter (1928) into the exact content of some of the diets of 710 families comprising 13,099 meals. This enquiry included data from over seventy different occupations from all strata of society scattered throughout New Zealand. The diet selected, details of which are given in the Appendix, Diet *C*, was constructed to represent, as far as possible, an average of these dietaries. Diets which were of apparently identical composition appeared in a number of those collected.

Before the experiment was commenced, observations as to intake and excretion were carried out for a fortnight on a well-balanced diet to which iodised salt was added in the usual proportions. Exact weighings were not carried out with this diet, but qualitative data are given in the Appendix, Diet *D*. The diet was estimated to contain 45 microgrm. of iodine. The daily excretion for B. averaged 34 microgrm. in urine and 7 microgrm. in the faeces, which gave a positive iodine balance of 4. The daily excretion of N. averaged 28 microgrm. in the urine and 10 microgrm. in the faeces, a positive balance of 7 microgrm.

Diet *C* was now adopted on an accurate quantitative basis. For the first 4 days of the experiment the iodine excretion was not estimated. Exact data as to intake and excretion were now obtained by analysis for 6 days.

The results are given in Table IX.

Table IX.

Day of experiment	Daily iodine intake in microgrm. Subjects		Daily iodine excretion in microgrm. Subjects						Iodine balance in microgrm. Subjects	
			B.			N.				
	B.	N.	Urine	Faeces	Total	Urine	Faeces	Total	B.	N.
1–4	24	24	Preliminary period						—	—
5	24	24	19·4	2·8	22·2	14·0	4·5	18·5	+1·8	+ 5·5
6	24	24	17·0	—	17·0	7·3	2·2	9·5	+7·0	+14·5
7	24	24	11·6	5·0	16·6	5·2	1·2	6·4	+7·4	+17·6
8	24	24	13·2	3·4	16·6	8·5	1·5	10·0	+7·4	+14·0
9	24	24	12·0	3·7	15·7	11·7	2·6	14·3	+8·3	+ 9·7
10	24	24	13·0	5·0	18·3	13·4	—	13·4	+5·7	+10·6
Total	—	—	—	—	—	—	—	—	+37·6	+66·9

In this experiment we might be led, on the basis of the previous results, to expect a balance of − 10 microgrm. on such a change of diet. Actually there is a slight but definite increase of storage. The reason for this remarkable effect must be sought among the items of the diets (Appendix). Comparing Diets *C* and *D* we observe that, in *C*, *meat* has been substituted for the fish and eggs of *D*. Hence it would appear that iodised salt is much more effective in promoting storage when associated with a meat diet than when associated with a fish diet.

(2) *Effect of fasting on iodine excretion.*

Two women students from the goitre-free district of Taranaki, aged 20 and 21 years and weighing 12 st. 13 lb. and 12 st. 5 lb. respectively, were anxious to undergo a period of fasting in order to reduce weight. These students will be referred to as Students 1 and 2. It was decided to carry out an iodine balance experiment during the fasting period. The girls were examined and found to be perfectly normal well-built girls. Their health was excellent, and they both engaged in strenuous athletics—hockey and tennis.

The diet on the day preceding the fast was accurately determined and the iodine content was estimated. A 5-day fast then followed, when 700 c.c. of water constituted the total intake of food. The total urine excreted throughout the fast period was collected and the iodine content determined. During

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this period the students attended classes and carried on their usual activities, with the exception of the substitution of walking for all strenuous exercises.

On the day following the fast a very light diet was taken. It should be noted that the diet on the day preceding the fast included 60 grm. of salmon. The detailed constituents of the diet on this day were: meat, 62 grm.; salmon, 60 grm.; turnip, 90 grm.; potatoes, 120 grm.; plums, 200 grm.; apples, 117 grm.; figs, 28 grm.; dates, 35 grm.; maizena, 70 grm.; rice, 30 grm.; white bread toast, 150 grm.; cakes, 38 grm.; butter, 9 grm.; and water, 500 c.c. The energy value was approximately 2000 calories and the iodine content 50–60 microgrm.

On the day subsequent to the fast the diet contained: soup, 150 grm.; potatoes, 75 grm.; carrots, 71 grm.; white bread toast, 64 grm.; maizena, 68 grm.; butter, 15 grm.; and water, 550 c.c., the energy value being approximately 700 calories and the iodine content less than 10 microgrm.

The results of the experiment are given in Table X.

Table X.

Day of experiment	Daily iodine intake in microgrm.		Daily iodine excretion in microgrm.		Iodine balance in microgrm.	
	Student 1	Student 2	Student 1	Student 2	Student 1	Student 2
1 (preliminary)	50–60	50–60	69·0	62·0	–9–19	–2–12
2 (fast)	1·3	1·3	23·5	22·0	–22·2	–20·7
3 (fast)	1·3	1·3	29·4	17·8	–28·1	–16·5
4 (fast)	1·3	1·3	9·0	10·6	– 7·7	– 9·3
5 (fast)	1·3	1·3	7·6	9·2	– 6·3	– 7·9
6 (fast)	1·3	1·3	16·0	12·6	–14·7	–11·3
7	10·0	10·0	8·0	14·6	—	—

It will be seen that on the day preceding the fast the iodine excretion of the urine was at the relatively high level of 69 and 62 microgrm. On the first day of fasting the iodine excretion fell suddenly to 23 and 22 microgrm. respectively, and continued to fall with minor fluctuations. Student 1 lost a total of 79 microgrm. and Student 2 65·7 during the course of the fast. The weight of Student 1 was reduced by 10 lb. and that of Student 2 by 8 lb.

(3) *Iodine excretion in human milk and urine.*

In a previous paper (Hercus and Roberts, 1927) a number of analyses are recorded showing the relationship between the iodine excretion in the milk and urine of goitrous and non-goitrous women.

It was shown that the iodine content of the milk is high immediately after parturition, and during the subsequent week falls rapidly to lower levels which are lower in goitrous subjects than in the non-goitrous.

Some further data on this subject are recorded in Table XI. The majority of the specimens were obtained from a maternity hospital in a non-endemic area. The mothers were unmarried girls of an average age of 19 years. The milk was expressed from the breasts on and after the third week after parturition.

Table XI.

Subject		Milk		Urine		Blood
Goitrous area	Non-goitrous area	Iodine in microgrm. per litre	Iodine in microgrm. per 24 hours	Iodine in microgrm. per litre	Iodine in microgrm. per 24 hours	Iodine in microgrm. per kg.
C.	—	7·0	3·3	40	73	—
R.	—	10·7	9·6	—	—	—
	N.	24·0	19·0	90	54	105
	M.[1]	9·0	10·0	12	17	—
	M.[2]	12·0	13·0	22	27	78
	F.	16·7	10·0	14	11	79
	D.	8·0	10·0	6	10	52
	L.	30·0	23·0	22	31	—

Considerable difficulty was experienced in obtaining specimens for analysis, and the number of cases from endemic areas is too small to constitute a fair sample for statistical purposes. It will be seen, however, that the amount of iodine secreted in the milk in 24 hours averages 6·4 microgrm. in the endemic areas, as compared with the average of 14 microgrm. in the non-endemic area.

By the addition of iodised salt to the diet of one mother suffering from goitre and resident in an endemic area it was found possible to raise the iodine content of the milk in the secretion of 24 hours from 12 to 25 microgrm. A definite reduction in the size of the goitre was also observed during a 6-month lactation period.

(4) *Effect of iodised salt on iodine excretion.*

Previous studies recorded in this *Journal* of the effect on urinary excretion of the addition of potassium iodide have been extended. The amount of iodine in 24-hour specimens from groups of twelve individuals at different age periods has been determined before and after the use of an iodised salt containing 0·7 parts of KI per 250,000 parts of salt. Specimens were obtained from adults in the Christchurch Mental Hospital and from the following Dunedin Institutions: two university women's colleges, a girls' school, and an orphanage. The ages of the subjects from whom the specimens were obtained were 20–40 years in the case of the mental hospital, 18–21 years in the university colleges, 12–14 years in the girls' school, and 2–8 years in the orphanage. Varying periods of time were allowed to elapse between the collection of these specimens; thus in the mental hospital iodised salt had been in constant use for 12 months, in the university colleges 8 and 12 weeks, in the girls' school 15 weeks, and in the orphanage 14 weeks.

The amount of salt consumed per day was estimated at 7·5 grm. This figure was based on the average consumption of 172 persons living in two residential colleges over a period of 6 days when the salt used for cooking purposes, on the table and any disused salt was accurately weighed.

It is evident, therefore, that each individual had his normal daily iodine intake supplemented by approximately 16 microgrm. The average daily intake of iodine in the food was estimated to be approximately 20–30 microgrm.

The results are given in Table XII.

Table XII.

Institution	Period iodised salt in use	Excretion of iodine in microgrm. per 24 hrs. Before use of iodised salt	After use of iodised salt	Increase in microgrm.	Percentage increase
Mental hospital	12 months				
Goitrous average	—	20·0	37·0	17·0	85
Non-goitrous average	—	36·0	59·0	23·0	64
Women's college X	8 weeks				
Goitrous average	—	16·0	25·2	9·2	58
Non-goitrous average	—	25·6	29·1	3·5	14
Women's college Y	12 weeks				
Goitrous average	—	18·3	25·0	6·7	37
Non-goitrous average	—	24·3	29·4	5·1	21
Girls' school	15 weeks				
Goitrous average	—	11·5	18·5	7·0	61
Non-goitrous average	—	14·1	20·0	5·9	42
Orphanage	14 weeks				
Goitrous average	—	19·3	24·1	4·8	25
Non-goitrous average	—	16·5	26·3	9·8	59

It will be seen that in each group there is a definite increase in the iodine excretion varying from 14 to 85 per cent.

It is to be noted that among adults the iodised salt has raised the excretion in each case to the non-goitrous normal, fulfilling its purpose with remarkable accuracy. Among the girls, where the difference in total iodine between goitrous and non-goitrous excretions is much less than in adults, it has the effect of raising the excretion above normal.

(5) *Observations on the iodine content of blood, excreta and thyroid gland in different types of goitre occurring in New Zealand.*

Tables XIII (A–D) give the results of iodine estimations of the blood, urine and faeces of a number of patients treated for goitre in the Dunedin Public

Table XIII A. *Simple colloid goitre.*

Patient	No.	Sex	Age	Basal metabolic rate (mean value)	Iodine content of blood (microgrm. per kg.)	Iodine excreted in urine (microgrm. per 24 hrs.)	Iodine excreted in faeces (microgrm. per 24 hrs.)	Total iodine excreted per 24 hrs.	Observations on iodine treatment, if any, and iodine content of gland in cases of operation (dried gland)
H. A.*	1	M.	21	+20	133	98	13	111	Iodised salt. Wt. of gland 301 grm. *Iodine content* 0·11 *mg./grm.*
O'G. J.	2	F.	28	− 6	400	15	5	20	Iodine content of gland 0·06 mg./grm.
B. B.*	3	M.	15	+10	173	22	—	—	Thyroid extract 1 grain thrice daily
R. S.	4	F.	36	+13	150	—	—	—	— —
R. E.*	5	F.	38	+20	357	—	—	—	Iodised salt tincture 1 minim T.D.S.
E. A.	6	F.	19	− 7	57	19	22	41	— —
S. A.*	7	M.	21	+20	405	319	112	431	Mis. pot. iod. 10 grain T.D.S. Thyroid extract 1 grain T.D.S
R. R.	8	F.	27	+ 3	56	19	4	23	— —
L. M.	9	M.	20	+ 6	67	31	—	—	—
H. W.	10	M.	24	+ 7	110	48	22	70	—

* Indicates iodine treatment.

https://doi.org/10.1017/S0022172400017691 Published online by Cambridge University Press

Table XIII B. *Simple nodular goitre.*

Patient	No.	Sex	Age	Basal metabolic rate (mean value)	Iodine content of blood (microgrm. per kg.)	Iodine excreted in urine (microgrm. per 24 hrs.)	Iodine excreted in faeces (microgrm. per 24 hrs.)	Total iodine excreted per 24 hrs. (microgrm.)	Observations on iodine treatment, if any, and iodine content of gland in cases of operation (dried gland)
O'G. V.	1	F.	34	+17	169	—	—	—	— —
McK. I.	2	F.	44	+ 9	—	—	—	—	Iodine content of normal tissue 0·23 mg./grm. of adenoma 0·20 mg./grm.
H. G.	3	F.	23	+ 7	149	31	11	42	— —
M. H.	4	F.	45	+30	—	—	—	—	Gland weighed 96 grm. A small nodule contained 0·16 mg./grm.; large nodule 0·14 mg./grm.
L. J.	5	F.	40	− 3	294	46	12	58	— —
K. L.	6	F.	30	+ 7	50	19	—	—	Gland weighed 162 grm. and contained 0·13 mg./grm.
H. P.	7	F.	26	+27	—	—	—	—	Small nodule 0·11 mg./grm.; large nodule 0·10 mg./grm.
B. E.	8	F.	39	+ 8	115	28	—	—	— —
C. L.	9	F.	25	+10	—	35	29	64	— —
S. C.	10	F.	20	+ 0	—	36	32	68	— —
R. M.	11	F.	35	+ 5	107	79	28	107	— —
G. P.	12	F.	20	+20	176	9	2	11	Gland weighed 225 grm.: iodine content 0·11 mg./grm.
M. M.	13	F.	43	+14	100	65	—	—	Gland weighed 69 grm.: a large gelatinous nodule contained 0·16 mg./grm.: a red granular nodule 0·11 mg./grm.
T. M.	14	F.	30	+14	180	20	18	38	— —
M. C.	15	F.	38	+ 0	53	20	13	33	— —
H. M.	16	F.	23	+10	411	53	—	—	— —
D. M.	17	F.	26	+30	106	—	—	—	— —
R. M.	18	F.	25	+17	140	—	—	—	Normal tissue 0·40 mg./grm.: nodule 0·13 mg./grm.
C. E.	19	F.	38	+ 5	24	11	1	12	— —
M. M.	20	F.	26	+20	143	—	—	—	— —
C. E.	21	F.	21	− 7	374	26	—	—	Nodule 0·42 mg./grm.: adjacent tissue 0·152 mg./grm.
T. R.	22	F.	29	+ 7	23	—	—	—	— —
S. M.	23	F.	34	+ 6	33	—	—	—	Gland contained 0·15 mg./grm.
C. H.	24	F.	35	+24	101	—	—	24	Gland weighed 76 grm.: iodine content 0·355 mg./grm.
S. S.	25	F.	20	+ 2	145	—	—	—	— —
P. M.	26	F.	49	+12	128	34	11	45	— —
J. J.	27	F.	42	+12	95	—	—	—	Nodule contained 0·24 mg./grm.: left lobe 0·32 mg./grm.; right lobe 0·23 mg./grm.
R. E.	28	F.	62	+27	—	—	—	—	Normal tissue 1·28 mg./grm.: nodule 0·24 mg./grm.
L. A.	29	F.	29	+14	—	98	22	120	Gland contained 0·14 mg./grm.
B. T.	30	M.	62	+22	118	84	4	88	Normal tissue 2·18 mg./grm.: nodule 2·12 mg./grm. (after treatment with Lugol)
M. A.*	31	F.	36	+20	328	199	43	242	Iodised salt
T. A.	32	M.	25	+ 7	134	38	—	—	Gland contained 0·42 mg./grm.
P. C.	33	M.	40	+ 5	158	35	9	44	Gland contained 0·53 mg./grm.

* Indicates iodine treatment.

https://doi.org/10.1017/S0022172400017691 Published online by Cambridge University Press

Hospital. The data were collected and the classification adopted in connection with the Goitre Clinic, Otago Medical School, whose complete findings will be published elsewhere. In the case of those patients who underwent operation, the iodine content of the thyroid gland is given. The basal metabolic rate of all patients is also recorded. Complete analytical data could not be obtained in all cases, on account of difficulties in obtaining specimens for analysis. As regards iodine intake apart from treatment, the patients, while in hospital, received a well-balanced diet which would provide on an average about 50 microgrm. of iodine per day.

Table XIII A gives the data for a group of simple colloid goitre. The average age is 25 years, the average basal metabolic rate + 9; if cases receiving iodine, together with the anomalous value for patient no. 2 are excluded, the average value for blood iodine is 81 microgrm. per kg., and the average daily excretion is 39 microgrm. Non-goitrous human blood normally contains about 130 microgrm. per kg. The iodine content of the glands in cases 1 and 2 is seen to be very low; according to Marine (1927) a normal gland should contain at least 1 mg. of iodine per grm. of dried gland.

In Table XIII B showing simple nodular goitre which is prevalent in New Zealand, the average age is 34 years and the average basal metabolic rate +12. Blood iodines above 200 microgrm. per kg. are rare and obviously exceptional. If these are excluded the average blood iodine is then about 110 microgrm. per kg. Similarly the average value of daily excretions below 100 microgrm. is 44 microgrm. The iodine content of the gland is distinctly

Table XIII C. *Primary Graves' disease.*

Patient	No.	Sex	Age	Basal metabolic rate (mean value)	Iodine content of blood (microgrm. per kg.)	Iodine excreted in urine (microgrm. per 24 hrs.)	Iodine excreted in faeces (microgrm. per 24 hrs.)	Total iodine excreted per 24 hrs. (microgrm.)	Observations on iodine treatment, if any, and iodine content of gland in cases of operation (dried gland)
McA. G.*	1	M.	28	+60	150	322	121	443	Received Lugol's solution 10 minims T.D.S. Gland weighed 145 grm.: right lobe contained 1·03 mg./grm.; left lobe 1·14 mg./grm.
McI.*	2	F.	21	+42	130	163	50	213	Received Lugol's solution: gland contained 0·717 mg./grm.
C. R.	3	M.	40	+42	136	188	94	282	— —
E. M.	4	F.	49	+69	135	270	120	390	— —
H. S.	5	F.	48	+39	—	27	9	36	— —
D. C.*	6	F.	48	+52	876	3384	107	3491	Received Lugol's solution: gland contained 1·81 mg./grm.
R. A.*	7	F.	42	+38	333	54	77	131	Received Lugol's solution
M. B.	8	F.	15	+43	73	18	24	42	Gland contained 0·37 mg./grm.: adenoma 0·13 mg./grm.
R. M.	9	F.	41	+47	—	—	—	—	Gland weighed 43 grm.: normal tissue 0·49 mg./grm.: nodule 0·47 mg./grm.
S. J.	10	F.	32	+55	30	20	13	33	— —
S. S.*	11	F.	55	+74	677	4941	64	5005	Received Lugol's solution
B. L.	12	F.	57	+96	54	—	—	—	— —

* Indicates iodine treatment.

https://doi.org/10.1017/S0022172400017691 Published online by Cambridge University Press

Table XIII D. *Secondary Graves' disease ("toxic adenoma").*

Patient	No.	Sex	Age	Basal metabolic rate (mean value)	Iodine content of blood (microgrm. per kg.)	Iodine excreted in urine (microgrm. per 24 hrs.)	Iodine excreted in faeces (microgrm. per 24 hrs.)	Total iodine excreted per 24 hrs. (microgrm.)	Observations on iodine treatment, if any, and iodine content of gland in cases of operation (dried gland)
N. A.	1	F.	32	+20	118	—	—	—	— —
H. R.	2	F.	39	+35	181	—	—	—	Gland weighed 165 grm.: normal tissue 0·27 mg./grm.: nodule 0·02 mg./grm.
G. E.	3	F.	37	+53	29	—	—	—	— —
F. J.	4	F.	32	+46	246	36	—	—	Gland weighed 101 grm.: colloid (granular) 0·54 mg./grm.: nodule (degenerated) 0·25 mg./grm.
W. E.	5	F.	36	+69	102	—	—	—	— —
P. E.	6	F.	43	+41	31	23	31	54	— —
M. M.	7	F.	30	+28	68	—	—	23	Gland contained 3·26 mg./grm. (after pre-operative Lugol administration)
F. A.	8	F.	51	+37	56	—	—	—	— —
S. L.	9	F.	23	+77	237	—	—	—	— —
D. V.	10	F.	45	+26	105	912	49	961	— —
M. I.	11	F.	52	+42	174	26	8	34	Gland contained 0·82 mg./grm. and nodule 0·56 mg./grm. (after pre-operative Lugol administration)
T. K.*	12	F.	36	+53	82	423	37	460	Receiving iodine unction: gland contained 0·87 mg./grm. and nodule 1·23 mg./grm.

* Indicates iodine treatment.

low, most frequently lying between 0·11 and 0·20 mg./grm. The nodules, as a general rule, contain a lower concentration of iodine than the normal tissue.

Tables XIII C, D, give observations on cases of Primary and Secondary Graves' disease. The average age for the primary cases is 40 years and the average basal metabolic rate is +55; for the secondary 38 years and +44. The natural iodine content of the blood in cases shown in Table XIII C is too frequently obscured by the effects of iodine treatment for its value to be estimated. In Table XIII D the average blood iodine is not far from normal, but it will be seen that there are several cases in which the blood iodine is abnormally high. This accords with the observations of Veil and Sturm (1925) that the blood iodine is raised in Graves' disease. On the other hand, it is noteworthy that in both tables there are cases in which the blood iodine is distinctly low. Such cases seem to support the theory of a "dys-thyroidism" or qualitative change in the thyroid secretion advanced by Williamson, Plummer, De Quervain and others (1927). The analyses of glands recorded in Tables XIII C, D, show that the untreated gland is always low in iodine, but in cases which have received iodine the iodine content is generally raised above normal. It has been shown that the thryoid gland in Graves' disease, though low in iodine, is extremely active in producing metamorphosis in tadpoles, and this is supposed to be further evidence for the existence of a dys-function (Müller, 1927).

https://doi.org/10.1017/S0022172400017691 Published online by Cambridge University Press

VI. Miscellaneous.

(1) *Distribution of iodine in the organs and tissues of the white rat.*

An investigation of the distribution of iodine in the different organs and tissues of the white rat was carried out by one of us (H. M. S. T.). One object of the experiment was to determine the normal ratio of the thyroid iodine to the total bodily iodine of the rat. Fellenberg (1926), from a detailed examination of the iodine distribution in guinea-pigs on normal and iodine-rich diets, concluded that the thyroid iodine ordinarily constitutes less than 1 per cent. of the total bodily iodine. The bulk of additional diet iodine was found to be distributed in the skin, hair, flesh and lungs of the animals, though high concentrations were found in the organs, particularly the spleen.

Studies of the thyroids and bloods of various animals have led us to the conclusion that the guinea-pig is an exceptional animal in this respect when compared with rats, hares, rabbits, etc.; and, indeed, in a much later publication Fellenberg (1930) states that thyroid iodine may normally constitute 5–20 per cent. of the total bodily iodine for certain animals.

The present experiments were carried out on three litters of rats, *A*, *B* and *C*. All three groups were fed on white bread and milk for 8 weeks (Period I), their daily iodine intake being 0·33 microgrm. per rat. During the next period of 5 weeks (Period II) *B* and *C* had a daily addition to their diet of 1 microgrm. of iodine in the form of potassium iodide and thyroid extract respectively, which raised their intake to 1·33 microgrm. per rat per day. The ordinary diet was then resumed in all groups for 8 weeks (Period III), and this was followed by another 5-week period with an additional microgrm. of iodine, but in this case *B* received thyroid extract and *C* potassium iodide (Period IV). Finally, there followed a 7-week period on the ordinary diet (Period V). Group *A* was kept on ordinary diet throughout.

At the end of the second and succeeding periods a rat from each group was killed and a partition analysis carried out. The results are shown in Tables XIV a, b, c.

Table XIV a contains the data for rats at different ages on a diet rather low in iodine. It is seen that thyroid iodine for these rats averages 10 per cent. of the total bodily iodine, which has an average value of 10 microgrm. Examination of Table XIV b shows that, in rats which received additional iodine, the thyroid iodine represents on an average 17 per cent. of the total bodily iodine which itself averages 23 microgrm. Administration of iodide leads to slightly greater storage as compared with thyroid extract; otherwise the two substances are similar in their effects. Finally Table XIV c shows that, for rats on a low iodine diet, following a diet higher in iodine, thryoid iodine averages 12 per cent. of the total bodily iodine, which has an average value of 17 microgrm. These last results may be taken as normal values of thyroid percentage and total iodine for the adult white rat.

Table XIV A. *Group A receiving* 0·33 *microgrm. per rat per day.*

Period ...	End of II (age 19 weeks)			End of III (age 27 weeks)			End of IV (age 32 weeks)			End of V (age 39 weeks)		
Sex	F.			F.			F.			M.		
Weight (grm.)	133			144			148			213		
	Iodine in organs.											
Organ	I Total iodine in organ (micro-grm.)	II % of bodily iodine	III Conc. in micro-grm. per grm.	I Total iodine in organ (micro-grm.)	II % of bodily iodine	III Conc. in micro-grm. per grm.	I Total iodine in organ (micro-grm.)	II % of bodily iodine	III Conc. in micro-grm. per grm.	I Total iodine in organ (micro-grm.)	II % of bodily iodine	III Conc. in micro-grm. per grm.
Thyroid	1·2	13	80	1·6	14	90	0·6	5	38	0·8	9	30
Skin	2·7	28	0·1	5·2	45	0·2	2·2	20	0·1	2·1	24	0·1
Carcase	2·2	28	<0·1	2·4	21	<0·1	2·6	24	<0·1	1·9	21	<0·1
Liver	1·3	1·4	0·2	0	0	0	0	0	0	1·3	14	0·1
Spleen	0·4	5	1·0	0	0	0	0	0	0	0	0	0
Genitals	0	0	0	0·7	6	0·2	2·6	24	0·6	1·7	19	0·2
Heart and lungs	1·3	14	0·5	0·8	7	0·4	0·9	8	0·2	0·5	6	0·1
Kidneys and suprarenals	0	0	0	0	0	0	1·3	12	0·8	0	0	0
Alimentary tract	0·4	4	<0·1	0·8	7	0·1	0·7	6	<0·1	0·7	8	<0·1
Total	9·5	—	—	11·5	—	—	10·9	—	—	9·0	—	—

Table XIV B. *Rats receiving* 1 *microgrm. additional iodine as potassium iodide or thyroid extract* (1·33 *microgrm. per rat per day*).

Group ...	*B* (KI)			*C* (thyroid extract)			*B* (thyroid extract)			*C* (KI)		
Period ...	End of II (age 19 weeks)			End of II (age 19 weeks)			End of IV (age 32 weeks)			End of IV (age 32 weeks)		
Sex	F.			F.			F.			F.		
Weight (grm.)	125			144			144			160		
	Iodine in organs.											
Organ	I Total iodine in organ (micro-grm.)	II % of bodily iodine	III Conc. in micro-grm. per grm.	I Total iodine in organ (micro-grm.)	II % of bodily iodine	III Conc. in micro-grm. per grm.	I Total iodine in organ (micro-grm.)	II % of bodily iodine	III Conc. in micro-grm. per grm.	I Total iodine in organ (micro-grm.)	II % of bodily iodine	III Conc. in micro-grm. per grm.
Thyroid	4·3	20	350	3·6	22	250	3·3	12	270	3·5	13	320
Skin	1·8	9	0·1	2·9	18	0·1	7·1	25	0·3	3·6	14	0·1
Carcase	7·7	36	0·1	4·2	25	0·1	4·8	17	0·1	2·5	10	<0·1
Liver	1·8	9	0·2	0·8	5	0·2	1·8	6	0·3	1·0	4	0·1
Spleen	1·9	10	8·0	0·8	5	3·6	2·0	7	8·0	1·6	6	4·2
Genitals	0·7	<1	0·3	1·3	8	0·6	3·2	11	1·0	5·1	20	1·1
Heart and lungs	1·8	9	1·0	1·7	10	0·6	2·2	8	0·6	2·2	8	0·5
Kidneys and suprarenals	0·6	3	0·4	0·5	3	0·4	3·3	12	2·3	4·8	18	3·0
Alimentary tract	0·9	4	0·1	0·7	4	<0·1	1·0	4	0·1	1·7	7	0·1
Total	20·5	—	—	16·5	—	—	28·7	—	—	26·0	—	—

Examination of the other details of distribution in Tables XIV A, B shows that the largest proportion of the total iodine in the case of six rats out of twelve was located in the skin and hair, in four in the carcase, and in two in the genital organs. The highest concentration of iodine apart from the thyroid is found in the spleen.

In earlier experiments with rats under conditions of iodine intake further removed from the normal than those just described we obtained somewhat

Table XIV c. *Rats receiving* 0·33 *microgrm. per rat per day, subsequent to a higher iodine diet of* 1·33 *microgrm. per rat per day.*

Group ...	*B*			*C*			*B*			*C*		
Period ...	End of III (age 27 weeks)			End of III (age 27 weeks)			End of V (age 39 weeks)			End of V (age 39 weeks)		
Sex	F.			F.			M.			M.		
Weight (grm.)	133			140			226			226		
	Iodine in organs.											
Organ	I Total iodine in organ (microgrm.)	II % of bodily iodine	III Conc. in microgrm. per grm.	I Total iodine in organ (microgrm.)	II % of bodily iodine	III Conc. in microgrm. per grm.	I Total iodine in organ (microgrm.)	II % of bodily iodine	III Conc. in microgrm. per grm.	I Total iodine in organ (microgrm.)	II % of bodily iodine	III Conc. in microgrm. per grm.
Thyroid	3·0	18	170	2·4	14	150	1·6	10	70	1·2	7	50
Skin	6·1	36	0·2	6·1	36	0·2	2·0	12	0·1	2·8	16	0·1
Carcase	3·0	18	<0·1	3·1	18	<0·1	2·4	15	<0·1	4·0	22	<0·1
Liver	0	0	0	1·7	10	0·3	1·4	8	0·1	2·1	12	0·2
Spleen	0·4	3	1·1	0·4	2	1·3	2·5	15	6·0	1·2	7	2·4
Genitals	1·4	8	0·4	1·3	8	0·4	2·8	17	0·4	2·4	14	0·3
Heart and lungs	0·9	5	0·4	0·9	5	0·4	0·7	4	0·2	0·8.	5	0·1
Kidneys and suprarenals	0·5	3	0·3	0·5	3	0·3	2·0	12	0·7	2·0	11	0·8
Alimentary tract	1·7	10	0·2	0·8	5	0·1	1·2	7	<0·1	1·2	7	<0·1
Total	17·0	—	—	17·2	—	—	16·6	—	—	17·7	—	—

different results. Thus with a group of immature rats on a low iodine diet (determined as 0·2 microgrm. per rat per day) the values shown in Tables XV A, B, were obtained.

Table XV A. *Rats on low iodine diet* (0·2 *microgrm. per rat per day*).

Rat No. ...	1		2		3		4	
	grm.	microgrm.	grm.	microgrm.	grm.	microgrm.	grm.	microgrm.
Thyroid wt.	0·011	—	0·014	—	0·0089	—	0·014	—
Iodine content (microgrm./grm.)	—	170	—	83	—	180	—	99
Iodine in thyroid	—	1·87	—	1·2	—	1·60	—	1·38
Body weight	101	—	123	—	92	—	86	—
Iodine in body	—	1·33	—	2·1	—	3·15	—	1·36
Total iodine in gland and body	—	3·20	—	3·3	—	4·75	—	2·74
Thyroid iodine as percentage of total iodine	58		37		34		50	

Table XV B. *Details of distribution for rat* 4 *in Table XV A.*

Tissue	Weight in grm.	Total iodine in microgrm.	% of total bodily iodine	Conc. of iodine (microgrm./grm.)
Thyroid	0·014	1·38	50	99
Skin	15	0·25	9	0·017
Carcase	56	0·40	15	0·007
Liver	6	0·24	9	0·04
Alimentary tract	8·5	0·24	9	0·021
Spleen	0·5	0·23	8	0·46
Total	86	2·74	—	—

Here the thyroid iodine averages 45 per cent. of the total bodily iodine which itself has the very low average figure of 3·5 microgrm.

A group of rats on a high iodine diet (about 5 microgrm. per rat per day) yielded the results shown in Tables XV C, D, where the thyroid iodine averages 27 per cent. of the total iodine, and the total iodine averages 28 microgrm.

Table XV C. *Rats on high iodine diet* (5 *microgrm. per day*).

Rat No. ...	1		2		3		4	
	grm.	microgrm.	grm.	microgrm.	grm.	microgrm.	grm.	microgrm.
Thyroid weight	0·01	—	0·0078	—	0·0065	—	0·0072	—
Iodine content (microgrm./grm.)	—	470	—	1070	—	1140	—	1400
Iodine in thyroid	—	4·7	—	8·35	—	7·4	—	10·1
Body weight	120	—	152	—	139	—	143	—
Iodine in body	—	16·0	—	17·1	—	27·9	—	20·0
Total iodine in gland and body	—	20·7	—	25·5	—	35·3	—	30·1
Thyroid iodine as percentage of total iodine	22		33		21		33	

Table XV D. *Details of distribution for Rat* 3 *in Table XV C.*

Tissue	Weight in grm.	Total iodine in microgrm.	% of total bodily iodine	Conc. of iodine (microgrm./grm.)
Thyroid	0·0065	7·4	21	1140
Skin	28	18·0	51	0·65
Carcase	89	6·7	19	0·075
Liver	8	0·3	0·8	0·037
Alimentary tract	13·5	2·7	7·6	0·20
Spleen	0·5	0·2	0·6	0·40
Total	139	35·3	—	—

Finally, with a group of rats on a very high iodine intake (100 microgrm. or more per rat per day) the values given in Table XV E were obtained. Here the thyroid iodine averaged 1 per cent. of the total iodine which itself averaged 2060 microgrm.

Table XV E. *Rats on diet very high in iodine* (100 *microgrm. or more per rat per day*).

Rat No. ...	1		2		3	
	grm.	microgrm.	grm.	microgrm.	grm.	microgrm.
Thyroid weight	0·012	—	0·0085	—	0·013	—
Iodine content (microgrm./grm.)	—	1240	—	2250	—	1600
Iodine in thyroid	—	14·9	—	19·1	—	20·8
Body weight	137	—	153	—	162	—
Iodine in body	—	1500	—	2110	—	2520
Total iodine in gland and body	—	1515	—	2129	—	2541
Thyroid iodine as percentage of total iodine	1		0·9		0·8	

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Hence, apart from the apparently anomalous results observed in the case of the immature rats, we may conclude that in general the percentage of thyroid iodine varies with the value for total iodine in the rat. The percentage has a minimal value where the total bodily iodine is in the neighbourhood of 10 microgrm., it increases with the total iodine to a normal value of about 12 per cent. where the total iodine is about 17 microgrm., it rises to a maximum when the total iodine is in the neighbourhood of 30 microgrm., and then falls off with greatly increased values of total iodine to about 1 per cent., where it remains approximately constant.

(2) *Iodine content of animal thyroids.*

The iodine content of the thyroid glands of various animals is recorded in Table XVI. The glands were dissected out soon after death and weighed immediately. The iodine is expressed in mg. per grm. of fresh substance.

Table XVI.

Animal	Weight of gland in grm.	Iodine content in mg. per grm.	Weight of animal, with remarks
Monkey (*Macacus rhesus*)	0·49 (mean of 10 monkeys)	0·55 (mean of 10)	Average weight of monkeys 3175 grm.
Dog	3·6 (mean of 2 dogs)	0·37 (mean of 2)	Average weight of dogs 4082 grm.
Dog (*A*)	4·86	0·003	Exhausted condition at death from hydatid toxaemia. Weight of dog 4082 grm.
Lamb	0·85	0·96	Weight 6804 grm. Normal lamb
Lamb (*B*)	354	0·001	Weight 5443 grm. Large congested goitre
Rabbit	0·095	0·25	Weight 1100 grm. Wild brown rabbit
Rabbit (*C*)	0·27	0·02	Weight 1200 grm. Laboratory white rabbit
Hare	0·22	0·63	Weight 1500 grm.
Hare (*D*)	0·18	0·11	Weight 1450 grm.
Rats	0·0140 (mean of 6 rats)	0·136 (mean of 6)	Average weight 200 grm. Low iodine intake
Rats (*E*)	0·0087 (mean of 6 rats)	0·99 (mean of 6)	Average weight 180 grm. High iodine intake

The weight of the thyroid gland of the dog relative to the weight of the body is worthy of note, it being much greater in the dog than in the monkey. In the case of dog (*A*) which was in an extreme condition of exhaustion at death from hydatid toxaemia, the gland was of large size and its iodine store was practically depleted. The lamb (*B*) had a huge congenital goitre which weighed over 350 times more than a normal lamb's thyroid. The thyroid constituted approximately one-fifteenth of the total weight of the animal. It was one of a series of lambs with congenital goitre (forty) born in Otautau in the endemic area of Southland. There is a striking difference in the weight and iodine content of a wild rabbit and a laboratory reared rabbit. The hare thyroids were obtained at a hare drive in Otago at mid-winter. It will be seen that hare (*D*) contained less than one-fifth the amount of iodine per unit

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weight of gland as compared with the other, and histologically it presented the typical appearance of the secretory phase of Williamson and Pearce (1928). It is possible that one animal may have been shot early in the drive and the other towards the end, and that the factors of fear and exhaustion may have been responsible for the striking difference in histology and iodine content. This subject is receiving further consideration. It will be seen that the rats on low iodine diet (bread and milk) show thyroids of nearly twice the weight and of approximately one-seventh the iodine content.

(3) *Variations in the iodine content of iodised salts.*

Previous studies on the iodine content of domestic salt as used in New Zealand have shown that it has an extremely low iodine content. Several samples contained less than one microgrm. per kg. One sample of Fijian marine salt contained 20 microgrm. per kg., but it was not in general domestic use. Crude Rock Salt was also found to have a low content varying from 0 to 10 microgrm. per kg. The only samples which were uniformly high were obtained from naturally occurring salt licks which were eagerly sought after by sheep and cattle in the endemic areas of Otago and Marlborough. These salts contained as much as 9000 microgrm. per kg. The introduction of artificially iodised salts into the country standardised officially to contain one part of potassium iodide per 250,000 parts prompted us to carry out a series of tests on various samples of iodised salts to determine to what extent it is possible for the manufacturers to conform to the standard. In addition to the extraction method of analysis titration was carried out by the usual method, viz. the potassium iodide was oxidised to iodate in acid solution with bromine and the iodine titrated with thiosulphate solution after its liberation by the addition of iodide and phosphoric acid. The results are shown in Table XVII.

Table XVII. *Iodine content of iodised salts.*

	Parts of KI per 250,000 parts of salt	
Specimen	Extraction method	Titration method
Union iodised salt (average of 8 samples)	0·6	0·7
Imperial brand (average of 2 samples)	0·9	1·1
Cerebos iodised salt (average of 6 samples)	0·5	0·7
Windsor iodised salt (average of 8 samples)	0·5	0·6
Salodine iodised salt (average of 2 samples)	0·8	0·8

It will be seen that practically all the samples are fluctuating below the standard. During the course of the analyses two samples of different salts were found to contain 2·5 and 6·9 parts respectively per 250,000, thus indicating the need for careful analytical control.

An investigation was therefore undertaken to determine to what extent the potassium iodide was distributed uniformly throughout samples of salt supplied in bags. Samples of iodised salt containing 1·23 parts of KI per 250,000 stored in corked bottles in the laboratory had previously been found to have the same iodine content at the end of 12 months' storage. Samples of salt were obtained from various positions in various sized bags and the findings are shown in Table XVIII.

Table XVIII. *Distribution of iodine in various portions of bulk samples of iodised salt.*

No.	Specimen	Wt. of bag (lb.)	Region of bag	Parts KI per 250,000 salt
1	Windsor iodised salt	5	Top	0·47
			Bottom	0·24
2	Windsor iodised salt	5	Top	0·46
			Bottom	0·49
3	Windsor iodised bakers' salt	112	Top	0·51
			Side halfway down	0·53
			Side near bottom	0·96
			Bottom corner	0·40

It will be seen from Table XVIII that in one 5 lb. bag the top sample contained twice as much iodine as the sample from the bottom, whereas in another similar bag the samples from top and bottom were practically identical. A large 112 lb. bag of bakers' iodised salt showed significant variation; a sample from the bottom corner of the bag having half the iodine content of an adjacent sample situated 4 inches further in and above. This finding suggests that the variation may be due to some factor other than the uneven distribution of the potassium iodide during manufacture. V. Fellenberg (1926) has shown that traces of water in conjunction with the extreme solubility of potassium iodide may cause re-distribution of the iodide both by gravitational and capillary processes. Johnson and Herrington (1927) concluded that considerable loss of iodine occurred if free circulation of air was permitted by storing in sacking. The minimum loss occurred when storage was carried out in an atmosphere of relative humidity of 50 per cent. Iodised salt rendered alkaline by the addition of sodium bicarbonate (1 per cent.) loses only insignificant amounts of iodine on prolonged exposure to sunlight and to heat (80° C.). Neutral or slightly acid specimens under these conditions lose relatively large quantities of iodine.

(4) *Amount of iodine returned to the soil by rain water.*

In a previous study (Hercus, Benson and Carter, 1925) the extent to which the soil of coastal districts might obtain iodine from rain and from sea spray was discussed. Regular samples of rain water were obtained from Hokitika, which is situated on a narrow coastal plain of the South Island of New Zealand, at the foot of the Southern Alps facing the rain-bearing winds of the Tasman Sea, and has an annual rainfall of 200 inches, and from Central Otago, which is an inland plateau 50 miles distant from the sea, and with an annual rainfall of 13–20 inches.

The iodine and chloride contents of the various samples were determined and the findings are given in Table XIX.

Table XIX.

Place	Date	Rainfall in inches	Chloride $NaCl/10^6$ mg.	Iodine in microgrm. per litre
Hokitika	27. vii.–11. ix. 26	—	15·4	—
	12. ix.–15. x. 26	—	18·4	—
	16. x.–1. xi. 26	—	8·4	—
	2–14. xi. 26	8·07	9·6	6·8
	15. xi.–6. xii. 26	7·56	—	—
	7. xii. 26–15. i. 27	8·11	15·8	1·8
	16. i.–2. ii. 27	7·96	—	2·5
	3. ii.–15. iii. 27	8·14	—	3·0
	16. iii.–27. iii. 27	8·54	—	1·8
	28. iii.–23. iv. 27	8·44	14·4	3·4
	24. iv.–19. v. 27	7·49	13·9	3·1
	20–28. v. 27	8·29	10·3	0·9
	29. v.–25. vi. 27	4·14	9·1	1·6
Weraroa (Central Development Farm)	3. x.–4. xi. 26	8·38	1·18	—
	4. xi. 26–1. ii. 27	8·05	11·5	4·8
	1. ii.–24. iv. 27	8·70	25·0	2·1
	24. iv.–9. vi. 27	8·86	6·2	2·4
Ophir	23. vi.–5. xii. 26	6·94	1·4	1·2
	7. xii. 26–25. iii. 27	8·20	—	—
	26. iii.–7. xii. 27	7·76	1·0	—

From Table XIX it will be seen that the iodine content of all the samples is appreciable and in some samples relatively high. The average ratio of iodine to chlorine is about 1 to 2500 which is of a distinctly higher order than the ratios determined by McClendon and Hathaway (1924) and Fellenberg (1924). There is, however, no indication of even approximate constancy in the iodine-chlorine ratio.

VII. Summary.

1. Most artificial manures are found to have some effect in increasing the iodine content of crops, particularly superphosphate.

2. Marked differences are found between the iodine contents of Samoan and New Zealand foodstuffs corresponding to the non-goitrous condition of Samoa and the partial endemicity of New Zealand.

3. Investigation of the dietaries of fifteen residential institutions showed that improvement in provision of iodine was necessary in many cases by using fish at least twice a week, raising the daily ration of milk to 1 pint per head, and employing iodised salt for table and culinary purposes.

4. Dietetic experiments indicate (i) that on a change of diet adjustment of iodine metabolism may take a considerable time, (ii) that iodised salt is most effective in promoting storage of iodine when associated with a meat diet.

5. Iodine excretion is found to decrease much more rapidly under fasting than on a diet very low in iodine.

6. Iodised salt has the effect of adjusting the excretion of goitrous adults to the normal non-goitrous value.

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7. The iodine content of the blood is found to be lower than normal in cases of simple colloid and simple nodular goitre, though it may range from low to abnormally high in cases of Graves' disease. In all types of goitre the thyroid gland is low in iodine.

8. The ratio of thyroid iodine to total bodily iodine is about 12 per cent. in the case of the white rat under ordinary conditions, but the ratio is found to vary considerably with the iodine intake.

9. Great differences in the ratio of the weight of the thyroid gland to that of the whole body are found among different species of animals, the ratio being higher for the dog than for the monkey.

10. Variations in commercial samples of iodised salts are recorded and discussed.

11. Data are given in regard to the iodine and chlorine content of rain-water in different localities.

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Appendix.

Diet A.

Food	Weight in grm.	Calories	Protein in grm.	CaO in grm.	P_2O_5 in grm.	Fe in grm.	Iodine in microgrm. per kg.	Iodine in microgrm.
Milk	80 c.c.	55	2·70	0·134	0·169	0·00019	15	1·20
Meat	60	200	11·40	0·009	0·276	0·00170	9·5	0·57
Butter	54	415	0·54	0·012	0·021	0·00012	5	0·27
White bread	180	474	16·60	0·071	0·384	0·00166	2	0·36
Sugar	25	100	0	0	0	0	0	0
Rice	18	62	1·44	0·002	0·039	0·00016	2	0·04
Kornies	10	37	1·05	0·006	0·075	0·00046	20	0·20
Biscuit	12	50	1·80	0·004	0·028	0·00018	2	0·02
Potatoes	90	75	1·98	0·021	0·142	0·00140	6	0·54
Cabbage	130	41	2·08	0·080	0·084	0·00139	20	2·60
Carrots	42	19	0·46	0·035	0·046	0·00027	6	0·25
Apples	108	68	0·43	0·011	0·031	0·00033	3	0·32
Pears	83	53	0·50	0·018	0·049	0·00025	3	0·25
Peaches	75	31	0·53	0·016	0·040	0·00023	3	0·23
Banana	73	72	0·95	0·009	0·052	0·00044	3	0·22
Jam	30	100	0·20	0·028	0·089	0·00069	6	0·18
Marmalade	30	100	0·16	0·082	0·061	0·00026	6	0·18
Water	675 c.c.	—	—	—	—	—	1	0·68
Total	—	1952	42·82	0·538	1·596	0·00973	—	8·11

Diet B.

Food	Weight in grm.	Calories	Protein in grm.	CaO in grm.	P_2O_5 in grm.	Fe in grm.	Iodine in microgrm. per kg.	Iodine in microgrm.
Milk	475 c.c.	327	16·10	0·795	1·007	0·00114	15	7·13
Meat	60	200	11·40	0·009	0·276	0·00170	9·5	0·57
Tinned fish	55	112	12·10	0·017	0·301	0·00065	500	27·50
Butter	48	369	0·48	0·001	0·002	0·00001	5	0·24
Custard	36	50	4·80	0·031	0·139	0·00102	30	1·08
Brown bread	180	530	16·00	0·148	1·010	0·00508	10	1·80
Sugar	25	100	0	0	0	0	0	0
Kornies	10	37	1·05	0·006	0·075	0·00046	20	0·20
Potatoes	100	83	2·20	0·023	0·158	0·00150	6	0·60
Cabbage	155	49	2·48	0·098	0·103	0·00171	20	3·10
Lettuce	40	8	0·48	0·026	0·043	0·00066	12	0·48
Pears	90	57	0·54	0·018	0·057	0·00026	3	0·27
Dates	36	124	0·76	0·032	0·046	0·00107	12	0·43
Figs	65	200	2·79	0·047	0·054	0·00062	12	0·78
Banana	63	62	0·82	0·007	0·045	0·00038	3	0·19
Marmalade	30	100	0·16	0·082	0·061	0·00026	6	0·18
Water	500 c.c.	—	—	—	—	—	1	0·50
Total	—	2408	72·16	1·340	3·377	0·01652	—	45·05

https://doi.org/10.1017/S0022172400017691 Published online by Cambridge University Press

Diet C.

Food	Weight in grm.	Calories	Protein in grm.	CaO in grm.	P_2O_5 in grm.	Fe in grm.	Iodine in microgrm. per kg.	Iodine in microgrm.
Milk	125 c.c.	86	4·24	0·209	0·265	0·00030	15	1·89
Meat	150	500	28·50	0·022	0·690	0·00425	8	1·20
Butter	55	423	0·55	0·012	0·021	0·00012	12	0·66
White bread	153	403	14·11	0·061	0·326	0·00141	2	0·31
Sugar	25	100	0	0	0	0	0	0
Sago	13	45	0·05	0·003	0·026	0·00020	2	0·03
Porridge	25	100	4·20	0·024	0·226	0·00096	30	0·75
Potatoes*	200	166	4·40	0·046	0·316	0·00300	9	1·80
Cabbage*	100	33	1·60	0·066	0·070	0·00107	7·5	0·75
Apples	60	43	0·27	0·0068	0·019	0·00021	4	0·24
Jam	45	150	0·30	0·042	0·133	0·00103	10	0·45
Water	500 c.c.	—	—	—	—	—	0	0
Iodised salt	7·5	—	—	—	—	—	—	16
Totals	—	2049	58·22	0·4918	2·092	0·01255	—	24·08

* Water discarded; I_2 lost from salt and from vegetables.

Diet D.

Food	Weight in grm.	Calories	Iodine in microgrm. per kg.	Iodine in microgrm.
Milk	306 c.c.	210	15	4·59
Fish	25	—	500	12·5
Butter	52	400	5	0·260
Cheese	5	20	30	0·15
Eggs	30	44	56	1·68
White bread	79	208	2	0·158
Brown bread	95	250	10	0·950
Sugar	36	144	0	0
Rice	30	133	2	0·300
Kornies	20	74	20	0·400
White flour	53	189	2	0·106
Potatoes	140	117	6	0·280
Spinach	100	24	20	2·000
Lettuce	42	8	12	0·504
Apple	170	107	3	0·510
Pear	135	86	3	0·405
Banana	162	159	3	0·486
Iodised salt	7·5	—	—	20·000
Total	—	2173	—	45·379

(*MS. received for publication* 7. xi. 1930.—Ed.)

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