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CHEMICAL AND RADIOCHEMICAL COMPOSITION OF THE RONGELAPESE DIET

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INTRODUCTION

Rongelap Atoll was contaminated with radioactive fallout resulting from the Bravo test on March 1, 1954, to the extent that it was necessary to evacuate the population of 82 Rongelapese. Some 200 Marshallese returned to Rongelap in June 1957, after the area had been declared safe for human habitation. Since 1954 there have been several surveys to determine levels of radioactive contamination at Rongelap Atoll (Dunning, 1957). In March 1958, a study of the ecology of the atoll relative to radioactive contamination was initiated at the request of the U. S. Atomic Energy Commission, Division of Biology and Medicine.

One of the objectives of this investigation was to arrive at an estimate of the amount and kinds of radionuclides and minerals ingested by the Rongelapese through foods. The fat, protein and carbohydrate were determined to provide a basis of comparison with known diets. To our knowledge there are no published data on the diet of the Rongelapese.

Rongelap Atoll lies in the northern Marshall Islands, an area of comparatively low rainfall and limited variety of agricultural products. The principal plants eaten are coconut, breadfruit, pandanus and the arrowroot or tacca; some squash and papaya are also grown. Bananas and taro have been introduced but are not yet in full production.

Fish, clams, langusta, birds, chickens and pigs are eaten. Of these fish is the most important. The coconut crab, Birgus latro, is considered a delicacy but is the one food item recommended to be excluded from the diet because of the strontium-90 content (Dunning, 1957).

The coconut, "Ni" in Marshallese, is eaten at different stages of development. The juice from the immature nut is preferred for drinking and rarely the germinated nut is eaten. Copra, the dried coconut meat, is a staple eaten alone or mixed with other foods.

The coconut sap is collected from the cut ends of inflorescences of coconut trees that have been set aside for this purpose in the village area. The fresh sap is partaken of by all age groups and the fermented sap, "jekro" or "jugaroo," is consumed by adults.

Breadfruit (Ma) is eaten either baked or boiled and also is made into a preparation which they refer to as "cheese." To make "cheese," the skin is removed and the pulp is placed in salt water for three days, then wrapped in breadfruit leaves and buried in the sand for at least one week before it is eaten. The Rongelapese claim that this "cheese" will keep for two years or more if left buried in the sand.

Pandanus (Bop) is eaten fresh, boiled, or baked. A preparation which is said to keep for more than five years is called "jenkun." This is prepared by either baking or boiling the Pandanus keys and scraping out the pulp. The pulp is dried, usually on a piece of sheet metal, over coals until it reaches the consistency of fudge. The dried pulp is pressed into a roll and wrapped in either Pandanus or coconut leaves. Slices are then cut off as needed.

Tacca or arrowroot (Mokmok) tubers are washed with sea water, then crushed and passed through a sieve into a pan of sea water and allowed to settle for three or four hours. When the starch begins to coagulate, the water is decanted. Sea water washes are repeated several times followed by one fresh-water wash. Finally the starch is dried and stored as a powder. The powder is then mixed with water for use and either eaten immediately as prepared, boiled, or baked.

The papaya is eaten fresh, sometimes mixed with rice or grated coconut.

The few banana trees present were just beginning to bear fruit in March 1961 and cannot be expected to form any significant part of the diet for some years to come.

The taro pit is very limited in size,and when visited in March 1961 fewer than a half dozen small plants in poor condition were surviving. The outlook for a significant taro crop in the future was bleak.

The fish consumed consists primarily of reef fish such as the goatfish, Mulloidicthys sp., mullet, Neomyxus sp., surgeonfish, Acanthurus sp., and the siganids. The fish are eaten baked, boiled and raw. The three fish which we have observed the Rongelapese to eat raw are goatfish, mullet and siganid. Fish are also preserved by baking and then drying in the sun. Sometimes salt is added before the fish are dried.

The langusta, spiny lobster, is eaten boiled. The clams are either boiled as a chowder or baked in the shell in a covered pit. The clam meat is sometimes also dried in the sun after baking and kept for several days.

Birds are eaten either baked or boiled and are also dried following precooking. Bird eggs are usually hard boiled and form only an incidental part of the diet; they are used principally when the Rongelapese are visiting islands other than their main island or nearby Ailinginae Atoll.

Pig and chicken are eaten primarily on special occasions.

The source of fresh water in the area is cisterns. Ground water is potable in certain areas during the rainy season but is not ordinarily utilized for drinking.

Of the imported foods, rice, wheat flour and canned corned beef appear to be the most important. Many other products are imported from time to time such as sardines, C-ration, ship biscuit and candy. In 1958 large quantities of C-rations were consumed. Many individuals prefer the imported foods when they are available.

MATERIALS AND METHODS

The samples were collected during a single 24-hour period in September 1959 at Rongelap Island. Bwio Soap, former village secretary, and Neil Morris, Trust Territory Resident Agriculturalist at Rongelap Atoll at that time, or one of the authors collected each sample taking care that the composition and the amount corresponded to the composition and amount actually eaten by the individual. Wet weights of the samples were taken in the field. The samples were then dried at 90°C and shipped to the laboratory at the University of Washington, Seattle.

Caution must be used in collecting such daily rations to be reasonably sure that they are a true representation. Misunderstanding and a misguided desire to please on the part of some individual Rongelapese can easily lead to merely a collection of miscellaneous food items rather than actual daily rations of prepared food. It was felt that a few samples which were witnessed to be composed of the items and portions actually being consumed were preferable to many samples of uncertain origin. Consequently, some samples proffered by individuals were discarded.

In spite of the care used there are obvious discrepancies. Sample number 3 (Table 1), for example, appears to be ridiculously low in total amount of food consumed. There can be little doubt that there must have been some "snacking," for which there is no accounting because eating habits of the Rongelapese are irregular and it was impractical to follow each individual throughout the day. Therefore, all of the samples collected (Table 1) should probably be considered as erring toward the low side for total consumption. However, there does appear to be a reasonable agreement with quantities listed by Murai (1953) from a study at Majuro Atoll. Catala (1957) has pointed out the difficulties of obtaining quantitative data in these areas.

The components of each sample were dried to constant weight in the laboratory at Seattle (Table 1). The entire diet for each individual was then homogenized with added water in a high-speed blender, dried at 98^{o}C and pulverized to a fine powder. Subsamples of the powder were taken for fat, protein, carbohydrate and radiochemical analyses. Forty to 250-gm portions were wet ashed with HNO_3 and H_2O_2 and the ash dried in 250-ml beakers for gamma ray spectroscopy.

The gamma-counting equipment consisted of a three-inch thallium-activated sodium iodide crystal used in conjunction with a 256-channel analyzer with a digital print-out. The total counts per minute under the photopeak were calculated by summing counts per minute of all channels included in the peak and subtracting the background counts. The counting efficiency for the gamma energy measured was determined by calibrating the instrument with standards with an error of $\pm$ 10 per cent. Counts per minute were converted to disintegrations per minute by a factor derived from the counting efficiency and the fraction of disintegrations giving rise to the gamma radiation counted. The factors used for cobalt-60, zinc-65, manganese-54 and cesium-barium-137 were 27.4, 54, 18.8 and 16.5 respectively. The correction factor used for sample size as compared to a point source, determined empirically, was 1.16.

Following analysis by gamma spectroscopy, the ashed samples were dissolved in a known volume of 1N HNO_3. Strontium-90 was determined on an aliquot by the method of Kawabata and Held (1958), in which a combination of nitric acid precipitation and ion exchange procedures is used.

Calcium was determined by the permanganate titration of oxalic acid and was confirmed by flame spectrophotometry, with the internal standard technique of Chow and Thompson (1955). Potassium was determined by flame spectrophotometry at 766 mμ wave length and independently confirmed with estimation of potassium by titration of the cobaltinitrite with potassium permanganate (Hibbard and Stout, 1933). Sodium was determined at 589 mμ wave length. In making these determinations, the slit width was kept at a minimum to eliminate interference; blue-sensitive filter was used and the sensitivity set as high as possible consistent with the reproducibility. The flame spectrophotometer was a Beckman DU equipped with a vacuum tube power supply and an oxy-hydrogen flame. The standardization procedure and general function of the system has been described by Chakravarti and Joyner (1960).

In determining magnesium, an aliquot of the ashed sample was dissolved in 0.1N HCl and the solution passed through a

Dowex-50 X8 100-200 resin column of precalculated capacity. Interfering anions were removed by elution with two-column volumes of distilled water. The resin was then stripped of cations with three-column volumes of 2N HCl and the eluate neutralized to methyl orange with concentrated NH_4OH. Calcium was removed by precipitation with ammonium oxalate followed by boiling and filtration. The filtrate was made basic with 1N NH_4OH; 5 per cent $(NH_4)_2 PO_4$ was added until a precipitate formed, and an excess of NH_4OH was then added while stirring constantly. The precipitate, magnesium ammonium phosphate, was allowed to settle overnight, removed by filtering, dissolved in 6 drops of concentrated H_2SO_4 and made to volume with water. Magnesium was determined by titrating an aliquot of this solution against a standard EDTA solution in which Eriochrome Black T was used as the indicator.

Total phosphorous was determined by the colorimetric method of Fleischer et al. (1958). The ash was converted to the nitrate form and diluted with water. The colorimetric reagent consisted of aqueous solution of 2.5 per cent ammonium molybdate, 1 per cent bismuth subcarbonate in 7N H_2SO_4 and crystals of ascorbic acid. Color transmittance at 660 millimicrons was read on a Bausch and Lomb "Spectronic 20" colorimeter and compared against a known standard.

The transition elements, nickel, manganese, cobalt, copper, iron and zinc, were determined colorimetrically by methods described by Sandell (1959). The elements were initially separated by the selective elution of their chloride complexes from an anion exchange resin. Kraus and Moore (1953) have shown that the chloride complexes of the transition elements, nickel through zinc, are adsorbed onto a strongly basic anion exchange resin (Dowex 1) and are selectively eluted at different molarities of HCl. Following the same principle, Joyner and Chakravarti (1960) have suggested techniques which were applied to these samples.

Light transmission of the solutions containing each of the separated ions was compared against sets of standards with a Bausch and Lomb "Spectronic 20" adjusted to specific wave lengths.

Protein nitrogen was determined by the Kjeldahl method.

Fat was determined by a modification of the Johnson method (Winton and Winton, 1945). Methylene chloride was the extracting solvent.

Ash content was determined as the nitrate form by drying an aliquot of the ashed sample to constant weight.

The moisture content of the sample was calculated from the wet weight to dry weight ratios.

The total carbohydrate and like substances were estimated by subtracting the moisture, fat, protein and ash from the total solids and calculating the carbohydrate content by difference.

RESULTS AND DISCUSSION

The components of the 24-hour food rations collected at Rongelap Island are presented in Table 1. Proximate composition and the trace element content of the rations are given in Tables 2 and 3, and levels of radioisotopes in the rations are presented in Tables 4 and 5. Results are given both on a percentage or unit weight basis (Tables 2 and 4) and as amount for total diet (Tables 3 and 5). The former to permit comparison of the relative composition of individual rations and to facilitate evaluation of the contributions made by specific items in each diet; and the latter to show the actual amounts consumed in a 24-hour period.

In evaluating the chemical constituents consumed by an individual in a 24-hour period, the gross weight of the total diet is of much importance. Comparing the proximate chemical composition on a percentage basis with the published chemical composition of some of the items which constituted the samples, it is possible to account for the variation in moisture, fat, protein, carbohydrate and ash content of the different diets.

Since the information on the nutritional aspects of the Rongelapese diet is limited, comparison of the data with that of other areas is probably not meaningful. The gross percentage composition indicates that the diets are generally low in fat, protein and ash but fairly high in carbohydrate content.

Comparing the data in Table 3 with recommended daily dietary allowances as published by the Food and Nutrition Board of the National Research Council it appears that the 24-hour food rations of the Rongelapese are generally below the recommended level for protein. Since fat allowances are based at present more on food habits than on physiological requirements, no definite conclusion can be drawn regarding the apparently low fat content of these diets. The habitat of the Rongelapese probably does not demand a high-energy diet, which may partially justify the lower fat intake.

The calcium content of the 24-hour ration seems to be much lower than the suggested normal requirement (National Data, 1958). On the same basis, the magnesium levels seem to be adequate but the phosphorous levels are far below what is necessary to maintain a proper calcium-phosphorous balance in a good diet. The sodium levels appear to be slightly below the normal suggested intake levels, although no information is available as to the minimum daily requirement of sodium. The potassium level is lower than the sodium content, which is generally the case in most diets.

Kent and McCance (1941) have suggested that an ordinary adult diet will supply 0.3-0.5 mg of nickel daily. On the basis of these values, the nickel content of the 24-hour Rongelapese rations appears to be higher than usual in some cases. Nickel salts frequently gain access to food from corrosion of nickel vessels, and small quantities of nickel may also be found in various manufactured foods. It also may be that some of the native food components are high in nickel content.

Basu and Malakar (1940) have suggested that 4.6 mg of manganese are required per day to keep an adult male in manganese balance. On this basis, the Rongelapese food appears to be low in manganese. The average adult diet of good quality supplies between 0.005-0.008 mg of cobalt daily (Harp et al. 1952); in comparison the Rongelapese food appears to be fairly high in cobalt content. Tompsett's (1934) balance experiments with adult humans indicate a minimum copper requirement as low as 0.6 mg daily. The estimate of Chou and Adolph (1935) is 1 to 2 mg daily. The Rongelapese diet is definitely above the experimental minimum requirements given. The iron in the diet appears to compare favorably with the minimum daily requirement as suggested by the National Research Council. Eggleton (1939) has given normal daily intake of zinc through food as 12 mg.

The Rongelapese food appears to have large variation in the zinc content and on the average is less than 8 mg daily.

The higher levels of cobalt-60 and zinc-65 are associated with each other and with those rations which contained local fish. This is to be expected since these isotopes are primarily found in marine organisms (Dunning, 1957). The higher levels of strontium-90 and cesium-137 are found where local fruit was consumed. In general, higher levels of strontium-90 are coincident with higher levels of cesium-137. Coconut contributes little strontium-90 and pandanus the most.

Those rations with the higher levels of zinc-65 also contain the higher levels of stable zinc, indicating that local sea foods may be the main source of zinc in the diet. Cesium-137, strontium-90, and cobalt-60 show no definite correlation with potassium, calcium and cobalt respectively, indicating that these elements are in large measure supplied from imported foods.

With the current means of sanitation, utilization of pit toilets and burial of garbage on Rongelap and Eniaetok Islets there must be a net addition of minerals. The chief export, copra, is low in ash content as compared with the imported foods. A quantitative evaluation of the addition would require comparison of export and import records.

Table 1. Description of Food Rations Collected at Rongelap Island September 1959.
(Each sample is a 24-hour ration)

Sample number	Contributor	Description of food items	Wet wt. grams	Total wt.dry
1	Berberin	a) Pandanus paste, boiled rice and baked fish (mixed)	253	374.68
		b) Partly baked bread dough with bully beef	252	
		c) Bully beef sandwiches	195	
2	Paul	a) Coconut meat (green)	30	175.85
		b) Pandanus "pie"	16	
		c) Baked fish	23	
		d) Sardines, canned	20	
		e) Boiled rice w/coconut milk	249	
3	No name	a) Breadfruit, baked	41	87.12
		b) Coconut and bread dough, baked	24	
		c) Bread	31	
		d) Bully beef	17	
		e) Ship's biscuit	13	
		f) Rice w/coconut milk, boiled	49	
4	Bwio	a) Coconut, ripe	72	321.69
		b) 1/2 papaya	57	
		c) Rice and fish (mixed)	306	
		d) Bread, local (coconut milk, not saved)	81	
5	Altha	a) Rice and fish mixed	243	203.16
		b) Bread, local	80	
		c) Rice	197	

Table 1 (continued)

Sample number	Contributor	Description of food items	Wet wt. grams	Total wt. dry
6	Mellelon	a) Breadfruit, baked	203	484.10
		b) Coconut w/baked dough	203	
		c) Fish, baked	126	
		d) Bread, local	75	
		e) Coconut, entire	50	
		f) Rice, boiled	291	
		g) Sardines, canned	154	
7	Manana	a) Pandanus keys, raw	115	314.90
		b) Goatfish, baked	26	
		c) Sardines, canned	101	
		d) Rice, boiled	721	
8	Lisie	a) Fish, baked	155	440.50
		b) Bread, local	145	
		c) Bully beef	66	
		d) Sardines, canned	94	
		e) Rice, boiled	622	
9	Kaser	a) Rice and fish mixed	421	262.30
		b) Rice and fish mixed	64	

Table 2. Composition of Food Rations from Rongelap Island.
(Dry weight basis)

Constituent \ Sample no.	1	2	3	4	5	6	7	8	9
Proximate analyses, percentage									
Moisture	46.47	47.99	50.23	37.66	60.92	59.69	67.30	59.29	45.92
Fat	3.73	1.64	1.35	1.34	4.35	8.47	2.80	3.60	2.82
Protein	15.10	10.70	11.55	9.65	7.65	23.65	14.45	25.85	8.65
Carbohydrate	30.53	37.80	32.74	49.16	21.25	3.57	10.91	6.98	38.90
Ash	4.17	1.87	4.13	2.19	5.83	4.62	4.54	4.28	3.71
Chemical composition									
Calcium mg/g	0.761	0.593	0.920	0.571	0.381	2.128	1.291	0.624	0.455
Magnesium "	0.804	0.797	1.128	0.938	0.777	1.097	0.657	0.760	0.814
Sodium "	3.420	2.440	6.200	1.970	2.590	4.570	7.320	3.220	2.770
Potassium "	2.280	1.390	3.120	3.340	1.120	4.600	2.550	2.950	1.520
Phosphorus "	0.134	0.061	0.024	0.119	0.056	0.358	0.203	0.823	0.102
Nitrogen "	24.180	17.120	18.500	15.500	12.260	37.850	23.880	41.330	13.800
Nickel ppm(mg/kg)	0.000	24.400	4.630	1.660	33.000	5.360	24.610	3.200	1.710
Manganese " "	0.714	1.000	0.220	2.660	2.480	2.880	3.330	2.250	1.710
Cobalt " "	2.100	0.800	0.300	0.628	0.00	0.268	0.330	0.125	0.286
Copper " "	14.200	26.600	8.900	19.600	5.600	22.000	7.500	6.800	2.800
Iron " "	66.000	69.100	44.400	34.070	33.080	46.670	33.300	71.000	28.570
Zinc " "	23.800	13.900	15.800	13.500	15.900	48.000	37.200	41.000	29.200

Table 3. Composition of Food Rations for a 24-hour Period from Rongelap Island*

Constituent \ Sample no.		1	2	3	4	5	6	7	8	9
Wet Wts.	(gms)	700.0	338.0	175.0	516.0	520.0	1201.0	963.0	1082.0	485.0
Moisture	"	325.30	162.20	87.90	194.30	316.80	716.90	648.10	641.50	222.70
Fat	"	13.96	2.88	1.17	43.16	8.84	40.98	8.82	15.84	7.38
Protein	"	56.58	18.82	10.06	31.04	15.54	114.50	45.50	113.90	22.69
Ash	"	15.613	3.29	3.59	7.06	11.84	22.37	14.30	18.83	9.74
Carbohydrate	"	288.55	150.81	72.28	240.44	166.98	306.25	246.28	291.93	222.49
Calcium	"	0.285	0.104	0.080	0.184	0.077	1.031	0.407	0.275	0.119
Magnesium	"	0.301	0.141	0.088	0.302	0.158	0.531	0.207	0.335	0.214
Sodium	"	1.281	0.429	0.540	0.634	0.526	2.212	2.305	1.418	0.727
Potassium	"	0.854	0.244	0.272	1.074	0.228	2.227	0.803	1.300	0.399
Phosphorus	"	0.036	0.012	0.002	0.038	0.011	0.173	0.064	0.080	0.027
Nitrogen	"	9.058	3.001	1.612	4.986	2.490	18.320	7.520	18.200	3.620
Nickel	(mg)	0.0	0.914	0.403	0.515	6.704	2.595	7.750	1.410	0.449
Manganese	"	0.268	0.176	0.019	0.856	0.504	1.394	1.049	0.991	0.447
Cobalt	"	0.780	0.141	0.026	0.202	0.0	0.130	0.104	0.055	0.075
Copper	"	5.321	4.678	0.775	6.305	1.138	10.650	2.362	2.995	0.734
Iron	"	24.729	12.150	3.868	10.960	6.721	22.593	10.486	31.276	7.494
Zinc	"	8.917	2.444	1.377	4.343	3.230	23.237	11.714	18.061	7.659

*Calculated from Table 2, wet to dry ratio and weight of total sample

Table 4. Radioisotopes in Food Rations from Rongelap Island.
(Dry weight basis)

Sample number \ Isotope	Co^{60} d/m/g	Zn^{65} d/m/g	Mn^{54} d/m/g	Cs^{137} d/m/g	Sr^{90} d/m/g
1	0.35 ± .12*	0.40 ± 0.29	-0.04 ± 0.09	61.4 ± 0.60	0.84 ± 0.07
2	0.52 ± .25	-1.03 ± 0.53	0.11 ± 0.20	14.1 ± 0.50	1.63 ± 0.16
3	0.12 ± .52	-2.40 ± 1.0	-0.49 ± 0.39	21.1 ± 0.87	1.25 ± 0.25
4	0.23 ± .13	-0.76 ± 0.28	-0.07 ± 0.10	17.6 ± 0.38	0.43 ± 0.06
5	0.43 ± .22	-0.67 ± 0.45	-0.11 ± 0.16	3.6 ± 0.28	0.21 ± 0.09
6	0.90 ± .13	1.70 ± 0.30	-0.23 ± 0.09	16.1 ± 0.29	0.66 ± 0.06
7	0.56 ± .14	0.87 ± 0.35	-0.19 ± 0.10	20.0 ± 0.38	0.86 ± 0.08
8	1.20 ± .15	2.50 ± 0.41	-0.21 ± 0.11	3.0 ± 0.17	0.22 ± 0.05
9	0.33 ± .16	0.05 ± 0.36	-0.003 ± 0.13	2.6 ± 0.21	0.32 ± 0.08

*0.95 counting error

Table 5. Radioisotopes in 24-hour Food Rations from Rongelap Island*

Sample number \ Isotope	Co^{60}	Zn^{65}	Cs^{137}	Sr^{90}	
	μμc	μμc	μμc	μμc	μμc/gmCa
1	59 ± 20**	67 ± 49	10000 ± 100	142 ± 11.8	497 ± 41.4
2	42 ± 20		1100 ± 40	129 ± 12.7	1239 ±121.6
3			830 ± 34	49 ± 9.8	613 ±122.5
4	33 ± 19		2600 ± 55	62 ± 8.7	339 ± 47.3
5	39 ± 20		330 ± 26	19.2± 8.2	248 ±106.5
6	200 ± 48	370 ± 65	3500 ± 63	144 ± 13.1	140 ± 12.7
7	79 ± 20	120 ± 50	2800 ± 54	122 ± 11.4	300 ± 27.9
8	240 ± 30	500 ± 82	590 ± 34	43.6± 9.9	159 ± 36.1
9	39 ± 19		310 ± 25	37.8± 9.5	331 ± 82.8

*Calculated from Table 4, wet to dry ratio and weight of total sample
**0.95 counting error

CONCLUSIONS

The gross chemical composition of the Rongelapese diet indicates that it is low in fat, protein and ash but fairly high in carbohydrate. The variation in gross chemical composition of the diets examined may be accounted for by the broad variability of the items constituting the different diets. The habitat of the Rongelapese probably does not demand a high-energy diet which may partially justify the lower fat intake. Levels of calcium and phosphorous seem to be below the minimum required for maintenance of a proper calcium-phosphorous balance in a good diet. The diet seems to be adequate in magnesium and potassium but slightly low in sodium. Compared to the minimum daily requirements of human adults for nickel, manganese, cobalt, copper, iron and zinc, the nickel, cobalt and copper contents seem to be high in the 24-hour Rongelap rations. The manganese content is low but the iron and zinc contents compare favorably with the minimum daily requirements.

The higher levels of cobalt-60 and zinc-65 are associated with each other and with those rations which contained local fish. The higher levels of strontium-90 and cesium-137 are found where local fruit was consumed. Coconut contributes little strontium-90 and pandanus the most. Those rations with higher zinc-65 also contain higher levels of stable zinc, indicating that local sea foods may be the main source of zinc in the diet. Cesium-137, strontium-90 and cobalt-60 show no definite correlation with stable potassium, calcium and cobalt respectively. There is probably a net addition of minerals to Rongelap soils from imported foods.

LITERATURE CITED

Basu, K. P. and M. C. Malakar. 1940. Iron and manganese requirements of the human adult. J. Indian Chem. Soc. 17: 317-325.

Catala, Rene L. A. 1957. Report on the Gilbert Islands: Some aspects of human ecology. Atoll Research Bulletin No. 59. The Pacific Science Board, National Academy of Sciences, National Research Council, Washington, D. C. 197 pp.

Chakravarti, D. and T. Joyner. 1960. Potassium as an index of naturally occurring radioactivity in tuna muscle. Trans. Am. Fish. Soc. 89: 312-314

Chakravarti, D. and R. Eisler. 1961. Strontium-90 and gross beta activity in the fat and non-fat fractions of the liver of the coconut crab (Birgus latro) collected at Rongelap Atoll during March 1958. Pacific Sci. 15: 155-159.

Chou, T. P. and W. H. Adolph. 1935. Copper metabolism in man. Biochem. J. 29: 476-479.

Chow, T. J. and T. G. Thompson. 1955. Flame photometric determination of calcium in sea water and marine organisms. Anal. Chem. 27: 910.

Dunning, G. M. 1957. Radioactive contamination of certain areas in the Pacific Ocean from nuclear tests. U. S. Atomic Energy Commission report, U. S. Government Printing Office, Washington, D. C.

Eggleton, W. G. E. 1939. The zinc content of epidermal structures in beriberi. Biochem. J. 33: 403-406.

Fleischer, K. D., B. C. Southworth, J. H. Hodecker and M. M. Tuckerman. 1958. Determination of phosphorous in organic compounds. Rapid micro and semi-micro method. Anal. Chem. 30: 152-153.

Harp, M. J. and F. I. Scoular. 1952. Cobalt metabolism of young college women on self-selected diets. J. Nutrition 47: 67-72.

LITERATURE CITED

Basu, K. P. and M. C. Malakar. 1940. Iron and manganese requirements of the human adult. J. Indian Chem. Soc. 17: 317-325.

Catala, Rene L. A. 1957. Report on the Gilbert Islands: Some aspects of human ecology. Atoll Research Bulletin No. 59. The Pacific Science Board. National Academy of Sciences, National Research Council, Washington, D. C. 197 pp.

Chakravarti, D. and T. Joyner. 1960. Potassium as an index of naturally occurring radioactivity in tuna muscle. Trans. Amer. Fish. Soc. 89: 312-314.

Chakravarti, D. and R. Eisler. 1961. Strontium-90 and gross beta activity in the fat and non-fat fractions of the liver of the coconut crab (Birgus latro) collected at Rongelap Atoll during March 1958. Pacif. Sci. 15: 155-159.

Chou, T. P. and W. H. Adolph. 1935. Copper metabolism in man. Biochem. J. 29: 476-479.

Chow, T. J. and T. G. Thompson. 1955. Flame photometric determination of calcium in sea water and marine organisms. Analyt. Chem. 27: 910.

Dunning, G. M. 1957. Radioactive contamination of certain areas in the Pacific Ocean from nuclear tests. U. S. Atomic Energy Commission report, U. S. Government Printing Office, Washington, D. C.

Eggleton, W. G. E. 1939. The zinc content of epidermal structures in beriberi. Biochem. J. 33: 403-406.

Fleischer, K. D., B. C. Southworth, J. H. Hodecker and M. M. Tuckerman. 1958. Determination of phosphorous in organic compounds. Rapid micro and semi-micro method. Analyt. Chem. 30: 152-153.

Harp, M. J. and F. I. Scoular. 1952. Cobalt metabolism of young college women on self-selected diets. J. Nutr. 47: 67-72.

Hibbard, P. L. and P. R. Stout. 1933. The estimation of potassium by titration of the cobaltinitrite with potassium permanganate. J. Ass. Off. Agric. Chem. 16: 137-140.

Joyner, T. and D. Chakravarti. 1960. The analysis of some trace elements in fish tissues. U. S. Atomic Energy Commission report No. UWFL-68. Laboratory of Radiation Biology, University of Washington. 14 pp.

Kawabata, T. and E. E. Held. 1958. A method for the determination of strontium-90 in biological materials. Applied Fisheries Laboratory*, University of Washington. Unpublished.

Kent, N. L. and R. A. McCance. 1941. The absorption and excretion of "minor" elements by man (2) Cobalt, Nickel, Tin and Manganese. Biochem. J. 35: 877-883.

Kraus, K. A. and G. E. Moore. 1953. Anion-exchange studies VI. The divalent transition elements manganese to zinc in hydrochloric acid. J. Amer. Chem. Soc. 15: 1460-1462.

Murai, Mary. 1954. Nutrition study in Micronesia. Atoll Research Bulletin No. 27. The Pacific Science Board, National Academy of Sciences, National Research Council, Washington, D. C. 239 pp.

Nutritional Data. 1958. Third Edition. H. J. Heinz Company, Pittsburg, Pennsylvania.

Sandell, E. B. 1959. Colorimetric Determination of Traces of Metals. Third Edition. Interscience Publishers, Inc., New York. 1032 pp.

Tompsett, S. L. 1934. The copper content of blood. Biochem. J. 28: 1544-1549.

Winton, A. L. and K. B. Winton. 1945. The Analysis of Foods. John Wiley and Sons, New York. 999 pp.

---

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Hibbard, P. L. and P. R. Stout. 1933. The estimation of potassium by titration of the cobaltinitrite with potassium permanganate. J. Assoc. Offc. Agr. Chemists 16: 137-140.

Joyner, T. and D. Chakravarti. 1960. The analysis of some trace elements in fish tissues. U. S. Atomic Energy Commission Report No. UWFL-68. Laboratory of Radiation Biology, University of Washington. 14 pp.

Kawabata, T. and E. E. Held. 1958. A method for the determination of strontium-90 in biological materials. Applied Fisheries Laboratory,* University of Washington. Unpublished.

Kent, N. L. and R. A. McCance. 1941. The absorption and excretion of "minor" elements by man. Cobalt, nickel, tin and manganese. Biochem. J. 35: 877-883.

Kraus, K. A. and G. E. Moore. 1953. Anion-exchange studies VI. The divalent transition elements manganese to zinc in hydrochloric acid. J. Am. Chem. Soc. 15: 1460-1462.

Murai, Mary. 1954. Nutrition study in Micronesia. Atoll Research Bulletin No. 27. The Pacific Science Board, National Academy of Sciences, National Research Council, Washington, D. C. 239 pp.

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