The oxalic acid content of English diets

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The dietary intake of oxalate is of interest for several reasons. It is well recognized, for example, that the calcium content of food is of little nutritional significance unless considered in conjunction with the oxalic and phytic acid contents (Fincke & Sherman, 1935; McCance & Widdowson, 1942–3; Hoover & Karunairatnam, 1945). Similarly, the availability of magnesium is influenced by any phytic acid and oxalic acid present (Wittwer & Goff, 1946; Wittwer, Albrecht & Schroeder, 1947; Roberts & Yudkin, 1960). The avoidance of a high-oxalate diet would appear to be particularly important for elderly persons, who are liable to be in negative calcium balance and can ill afford wastage of calcium from combination with oxalate (Kane & McCay, 1947; Lovelace, Liu & McCay, 1950). A diet high in oxalate is also undesirable in the treatment of states of calcium deprivation such as occur in the malabsorption syndrome and in vitamin D deficiency or vitamin D 'resistance'.

Closely associated with the problem of calcium availability is the incidence of oxaluria after ingestion of oxalate-rich foods. A diet having a preponderance of oxalate-containing vegetable foods and a deficiency of calcium-containing dairy foods favours a high urinary excretion of oxalic acid, and Grossmann (1938) considered that this type of diet was a major factor in the renal oxalate stone 'wave' occurring in Eastern Europe after the First World War. Approximately two-thirds of human renal calculi occurring in Europe and America contain calcium oxalate as a major constituent, which has prompted studies of the metabolism and excretion of oxalic acid by these subjects (Dempsey, 1957; Hodgkinson, 1958; McIntosh & Read, 1958; Dempsey, Forbes, Melick & Henneman, 1960). These studies have been further stimulated by the recent recognition of a rare inborn metabolic disorder, 'primary hyperoxaluria', in which the urinary excretion of oxalic acid is increased five to ten times above normal values (Archer, Dormer, Scowen & Watts, 1957; Pyrah, Anderson, Hodgkinson & Zarembski, 1959).

Comparatively little is known about the daily intake of oxalate, the proportion normally absorbed or the proportion of the urinary oxalate that is of dietary origin. Several extensive studies of the oxalate content of foods have been made within recent years (see Table 1), but the accuracy of the analytical procedures is sometimes open to question. The method employed by Kohman (1939) was criticized by Andrews & Viser (1951), who considered that recovery of oxalic acid was incomplete. The latter authors employed a more vigorous procedure of acid extraction to ensure fuller recovery of oxalic acid, but it may lead to erroneously high results owing to the

Table 1. *Oxalic acid, calcium, magnesium and phosphorus contents of foods*

(mg/100 g fresh material)

Food	Method of cooking	Oxalic acid	Ca	Mg	P	Previously published values for oxalic acid	References
Fruit:							
Apples (*Malus silvestris* Mill.) Bramley's Seedling	Raw	1·5	3·4	5·0	6·5	0·0, 4·5, 30·0	3, 5, 6
Banana (*Musa sapientum* L.)	Raw	0·7	—	—	—	—	—
Black-currants (*Ribes nigrum* L.) Cotswold Cross	Raw	4·3	45·6	18·1	71·5	24·8, 13·5	5, 5
Gooseberries (*Ribes uva-crispa* L.) Keepsake	Stewed	2·6	19·1	8·4	21·5	88·0, 4·5, 15·7, N	3, 5, 5, 5
Grapefruit (*Citrus decumana* Murr., var.)	Raw	ND	21·0	9·1	17·5	0·0, 3·4	3, 4
Oranges (*Citrus aurantium* L.)	Raw	6·2	3·5	13·8	27·2	28·0, 24·0, 8·7	1, 3, 4
Peaches (*Prunus persica* Stokes)	Canned in syrup	1·2	3·4	5·3	10·5	0·0, 5·0	3, 3
Pears (*Pyrus communis* L.)	Canned in syrup	1·7	3·95	4·5	8·3	0·0, 3·0	1, 3
Pineapple (*Ananas sativus* Schult.)	Canned in syrup	ND	18·3	9·4	7·0	6·3, 5·8	3, 4
Plums (*Prunus domestica* L.) Jefferson's Golden Gage	Stewed	1·1	8·8	10·9	15·8	0·0	3
Plums (*Prunus domestica* L.) Giant Prune, Victoria	Stewed	3·4	14·3	8·1	9·9	0·0, 10·0, 4·5, N	1, 3, 5, 5
Raspberries (*Rubus idaeus* L.) Malling Exploit	Raw	2·2	27·2	23·7	32·6	42·0, 15·0	1, 3
Rhubarb (*Rheum* L. var.) Victoria, forced	Stewed	260·0	12·4	9·8	28·5	153·0–189·0, 275·0	5, 6
Rhubarb (*Rheum* L. var.) Victoria, end of season	Stewed	620·0	266·0	16·2	9·0	396·0–511·0, 500·0, 1336·0	1, 3, 4
Rhubarb (*Rheum* L. var.) Giant Grooveless Crimson, end of season	Stewed	460·0	91·5	14·3	18·8	—	—
Strawberries (*Fragaria* var.) Huxley	Raw	1·9	16·4	11·5	21·7	20·0, 19·0, 47·0	1, 3, 6
Vegetables:							
Asparagus (*Asparagus officinalis* L.)	Boiled	1·7	22·1	12·2	54·5	0·0, 5·2, 18·0	1, 3, 6
Beans (*Phaseolus vulgaris* L.) French, Blue Lake	Boiled	30·2	31·9	18·3	38·9	31·0, 31·2, 37·0	3, 4, 6
Beans (*Phaseolus vulgaris* L.) French, Guernsey Runner	Boiled	22·8	33·3	13·3	34·6	—	—
Beans (*Phaseolus multiflorus* Willd.) Runner, Mont d'Or	Boiled	26·6	39·0	18·3	31·0	—	—
Beans (*Phaseolus multiflorus* Willd.) Summer Runner	Boiled	7·2	24·5	18·3	28·7	—	—
Beetroot (*Beta vulgaris* L.) Ruby Globe	Boiled	121·0	18·7	37·7	47·2	138·0, 40·4, 127·0	3, 4, 6
Brussel sprouts (*Brassica oleracea* L. var. *bullata gemmifera*) Cambridge Special	Boiled	2·1	19·5	19·6	97·6	5·9, 37·0	3, 6
Cabbage (*Brassica oleracea* L. var. *capitata* L.) spring, Durham early	Boiled	1·0	65·0	20·6	72·0	—	—
Cabbage (*Brassica oleracea* L. var. *capitata* L.) summer, June Giant	Boiled	0·6	50·1	11·6	13·9	19·0, 0·0	6, 7
Cabbage (*Brassica oleracea* L. var. *capitata* L.) winter, January King	Boiled	2·0	87·7	15·4	41·0	—	—
Carrots (*Daucus carota* L.) Autumn King	Boiled	22·7	43·6	22·1	62·6	33·0, 5·6, 60·0	3, 4, 6
Carrots (*Daucus carota* L.)	Canned, Smedley's	7·4	25·2	—	17·5	—	—
Cauliflower (*Brassica oleracea* L. var. *botrytis* L.) Pioneer	Boiled	1·1	23·6	15·5	46·1	0·0, 0·0, 6·8, 25·0	1, 3, 4, 6
Celery (*Apium graveolens* L.) stems	Raw	17·5	38·5	7·3	26·4	34·0 26·0	3, 6
Chives (*Allium schoenoprasum* L.)	Raw	1·1	196·0	21·0	82·6	185·0	6
Lettuce (*Lactuca sativa* L.) Webbs Wonderful	Raw	1·7	26·0	10·0	27·2	0·0, 7·1, 13·6, 11·0, 0·0	1, 3, 4, 6, 7
Marrow (*Cucurbita pepo* L. var. *ovifera*) Mosse Cream	Raw	0·5	22·0	4·9	21·6	—	—
Onions (*Allium cepa* L.) Best of All	Raw	3·0	28·4	11·7	60·7	55·0, 23·0, 1·0, 76·0	1, 3, 4, 6
Parsley (*Petroselinum crispum* (Mill.) Nyman) Moss curled	Raw	166·0	105·8	25·2	60·5	190·0	3
Peas (*Pisum sativum* L.) fresh, Feltham First	Boiled	1·3	20·4	30·0	96·0	0·0, 6·0, 6·0	3, 4, 6
Peas (*Pisum sativum* L.)	Canned, Smedley's	0·8	34·2	16·7	92·0	—	—
Potatoes (*Solanum tuberosum* L.)	Boiled	2·3	9·0	—	38·8	0·0, 5·7, 15·0, 34·0, 64·0	1, 3, 4, 6
Radishes (*Raphanus sativus* L.) French Breakfast	Raw	0·3	34·8	17·8	19·3	0·0, 0·0, 9·2	1, 3, 4

Table 1 (*cont.*)

Food	Method of cooking	Oxalic acid	Ca	Mg	P	Previously published values for oxalic acid	References
Vegetables (*cont.*)							
Spinach (*Spinacia oleracea* L.) frozen	Boiled	458·0	—	—	—	364·0	3
Spinach (*Spinacia oleracea* L.) Long-standing, round	Boiled	780·0	110·9	76·7	88·0	837·0, 797·0–870·0, 892·0, 658·0, 1050·0	1, 2, 3, 4, 6
Spinach beet (*Beta vulgaris* L. var. *Cicla* L.) Beet Perpetual	Boiled	692·0	49·6	71·4	28·4	—	—
Tomatoes (*Lycopersicum esculentum* Mill.) J.R. 6	Raw	5·3	10·0	10·0	26·0	0·0, 7·5, 3·6, 4·5, 13·0	1, 3, 4, 5, 6
Turnip (*Brassica rapa* L.) Early Snowball, white	Boiled	0·8	42·4	17·9	54·5	0·0	3
Meat:							
Bacon, streaky	Fried	0·6	—	—	—	—	—
Beef, corned, Fray Bentos	Canned	0·2	14·1	31·8	119·0	—	—
Beef	Roasted	0·4	7·7	28·6	16·2	—	—
Chicken	Boiled	0·3	7·8	27·5	240·0	—	—
Ham	Boiled	0·4	8·2	25·7	245·0	—	—
Fish:							
Haddock (*Gadus aeglefinis*)	Boiled	0·2	16·9	28·1	175·0	—	—
Plaice (*Pleuronectes platessa*)	Boiled	0·3	27·5	26·4	185·0	—	—
Cereals and cereal foods:							
Biscuits, Marie	—	4·5	138·0	26·3	104·0	—	—
Bread, Allinson's	—	20·7	24·6	94·3	245·0	—	—
Bread, white	—	4·9	108·0	24·3	100·0	—	—
Cake, fruit	—	11·8	—	—	—	—	—
Cake, sponge	—	7·4	—	—	—	—	—
Cornflakes	—	5·6	8·8	36·0	44·0	—	—
Oatmeal porridge	—	1·0	10·2	16·6	58·8	—	—
Dairy products:							
Milk, fresh* sp.gr. 1·034	—	0·5	115·0	10·4	91·0	1·9, 20·9–21·4	4, 8
Butter, fresh	—	ND	17·0	2·1	26·0	—	—
Cheese, Cheshire	—	ND	—	—	—	—	—
Eggs, fresh, whole	Boiled	ND	47·0	11·4	98·0	—	—
Fats:							
Margarine	—	ND	3·9	0·8	11·0	—	—
Preserves:							
Jam, red plum	—	0·5	8·6	2·6	5·5	—	—
Marmalade, shredless	—	10·8	27·7	4·5	4·5	—	—
Beverages:							
Cocoa (*Theobroma cacao* L.) powder, Rowntree's	—	623·0	—	—	—	645·0, 442·0, 908·0	1, 4, 6
Coffee (*Coffea arabica* L.) ground, containing 5 % chicory, Kardomah†	2 g in 100 ml water, infused for 5 min	1·0	—	—	—	15·4 mg per 100 g of coffee powder	4
Coffee (*Coffea arabica* L.) Nescafé powder	—	57·0	—	—	—	—	—
Horlicks, powder	—	4·1	256·0	21·7	300·0	—	—
Lucozade*	—	0·1	13·7	6·1	3·0	—	—
Ovaltine, powder	—	45·9	126·0	33·0	335·0	—	—
Oxo cubes	—	1·6	2840·0	621·0	5740·0	—	—
Tea (*Thea sinensis* L.) Indian, blended, dry leaves	—	375·0–1450·0	—	—	—	1386·0, 730·0–2030·0	1, 9
Tea (*Thea sinensis* L.) Indian, infusion†	1 g in 100 ml water, infused for 2 min	4·6	0·3	0·6	1·2	219·2‡	4
Tea (*Thea sinensis* L.) Indian, infusion†	2 g in 100 ml water, infused for 2 min	7·0	—	—	—	—	—
Tea (*Thea sinensis* L.) Indian, infusion†	2 g in 100 ml water, infused for 5 min	10·1	—	—	—	—	—
Tea (*Thea sinensis* L.) Indian, infusion†	2 g in 100 ml water, infused for 10 min	11·5	—	—	—	—	—
Tea (*Thea sinensis* L.) Indian, infusion†	2 g in 100 ml water, infused for 15 min	12·6	—	—	—	—	—
Puddings:							
Rice (*Oryza sativa* L.)	—	ND	80·0	10·4	74·0	4·6	4
Soups:							
Chicken, Fray Bentos	Canned	3·0	29·0	6·3	160·0	—	—
Oxtail, Fray Bentos	Canned	1·0	28·0	6·5	120·0	—	—

N, negligible; ND, not detected.
* mg/100 ml.
† mg/100 ml infusion.
‡ 'Liptons dust', 10 g in 200 ml infused for 5 min.

References: 1, Widmark & Ahldin (1933); 2, Hammarsten (1937); 3, Kohman (1939); 4, Majumdar & De (1938); 5, Bryan (1946); 6, Andrews & Viser (1951); 7, Lehmann & Grütz (1953); 8, Grütz, Sengbusch & Timmermann (1957); 9, Pritzker & Jungkunz (1939).

conversion of 'oxalogenic' compounds into oxalic acid (Zarembski & Hodgkinson, 1962). A further limitation is the frequent absence of information on the calcium and magnesium content of the foodstuffs. Moreover, no detailed survey has been made of foods commonly found in English diets.

We have therefore carried out a comprehensive analysis of foods commonly used in English homes and hospitals throughout the year; when possible the results are compared with data previously published. Besides oxalic acid, calcium, magnesium and phosphorus in the foods have been determined.

EXPERIMENTAL

Material

Fruit and vegetables were supplied by the Ministry of Agriculture Experimental Horticultural Station, Cawood, Yorks., and by a local wholesaler (J. Huddlestone (Whitley Bridge) Ltd). Care was taken to obtain freshly harvested samples which were stored in Polythene bags for not longer than 24 h before analysis so as to avoid loss of moisture. Other foods were supplied by Oxo Ltd, London, and the Catering Department, United Leeds Hospitals. Cooked foods and beverages were in general prepared by the procedures of McCance & Widdowson (1960).

The six diets referred to in Table 2 were freely chosen by patients in the metabolic ward from among the following foods: tea, milk, boiled eggs, cornflakes, butter, marmalade, boiled potatoes, ham, carrots, peas, white or brown bread, plum jam, tinned pears, peaches or grapefruit, fresh tomatoes, boiled chicken, fresh oranges, and Marie biscuits. The composition of the six diets, on a 1-day basis, was as follows:

	Diet no.					
	1	2	3	4	5	6
Calorific value (kcal)*	1406	1236	1579	1419	2505	1111
Protein (g)*	74·5	68·6	69·3	70·0	85·8	115·5
Fat (g)*	63·3	63·2	67·4	76·8	83·6	55·9
Available carbohydrate (g)*	185·2	142·8	226·8	232·2	410·4	135·5
Calcium (g)†	0·845	0·873	0·800	0·967	0·882	0·892
Magnesium (g)†	0·311	—	0·187	0·192	0·408	0·216
Phosphorus (g)†	1·385	1·171	1·268	1·100	—	—
Nitrogen (g)†	12·2	—	11·9	9·7	14·5	10·8

* Calculated from tables (McCance & Widdowson, 1960).
† By analysis.

The binominal classification employed in Table 1 is based on the *List of British Vascular Plants* edited by J. E. Dandy for the British Museum (Natural History) and The Botanical Society of the British Isles, London, 1958. Other sources are:

(1) *Flora of the British Isles*, by Clapham, A. R., Tutin, T. G. & Warburg, E. F. Cambridge University Press, 1952.

(2) *A Dictionary of the Flowering Plants and Ferns*, 6th ed., by Willis, J. C. Cambridge University Press, 1951.

(3) *Cambridge Natural History*, Vol. 7, edited by Harmer, S. F. & Shipley, A. E. London: Macmillan & Co. Ltd, 1904.

Analytical methods

Oxalic acid. Different foods required some variation in initial treatment according to the nature of the interfering constituents, such as fats and proteins (Zarembski & Hodgkinson, 1962). The method, which is based on that of Hodgkinson & Zarembski (1961), involved the isolation of oxalic acid by treating a suitably prepared sample with 33% (v/v) HCl, with subsequent diethyl ether extraction, precipitation of the extracted oxalic acid as the calcium salt and final reduction and colorimetric determination of the 'reduced oxalic acid'. Oxalic acid is expressed as mg anhydrous acid/100 g fresh material.

Calcium and magnesium. The food was homogenized and diluted to a suitable volume with water, and duplicate samples were transferred to Vitreosil crucibles. The contents of the crucibles were dried overnight on an electrically heated sand-tray and ashed for 16 h at 500° in an electric muffle furnace, and the ash was dissolved in 2 N-HCl. Calcium was determined by permanganate titration (Hawk, Oser & Summerson, 1954) and magnesium by the phosphate-precipitation method (Heaton, 1960).

Phosphorus. Duplicate samples of homogenized food were mixed with 2 ml of 10% (v/v) magnesium nitrate solution in a Vitreosil crucible, and the contents were carefully ashed over an Amal bunsen burner (A. Gallenkamp & Co Ltd, London) so as to avoid loss of phosphorus. The white ash was dissolved in 2 N-HCl, and the phosphorus content was determined by the method of Fiske & Subbarow (1925).

The recoveries of oxalic acid, calcium, magnesium and phosphate added to selected samples of food were within the range 96–100%.

RESULTS

Eighty food samples were analysed; the results are summarized in Table 1, together with previously published values, when available. The foods are classified from a 'practical' rather than a 'scientific' viewpoint (McCance & Widdowson, 1960).

Table 2. *Oxalic acid contents (mg/day) of hospital diets: comparison of analytical and computed values*

Diet no.*	By analysis	Computed from Table 1	Difference (%)
1	84·2	90·1	−6·5
2	70·8	62·0	+14·2
3	82·6	78·0	+5·9
4	150·0	139·0	+7·9
5	115·0	120·0	−4·2
6	82·0	82·0	0

* See p. 630.

The oxalic acid content of six hospital diets was determined; the results are summarized in Table 2 (column 2). The values give the oxalic acid in 1 day's food. The oxalic acid contents of these six diets, computed from Table 1, showed reasonable agreement with the values obtained by analysis.

DISCUSSION

In agreement with the results reported by previous workers, the highest concentrations of oxalic acid were found in spinach, rhubarb, parsley, beetroot, cocoa and tea leaves. Appreciable quantities were also found in Ovaltine, Allinson's bread, beans, carrots and celery.

Considerable variations can occur in the oxalic acid content of plants, depending on the inherited characteristics of a species or variety, the season, the age of the plant and the form and quantity of nutrients present in the soil. These factors, which we hope to consider in greater detail in a further communication, account for some of the discrepancies between our results and those of previous workers. Some discrepancies, however, appear to be due to differences in analytical technique, and they are particularly noticeable with foods containing large amounts of galactose and other 'oxalogenic' compounds. For such foods vigorous acid hydrolysis yields appreciably higher values for 'oxalic acid' (Zarembski & Hodgkinson, 1962), and this effect is thought to account for the lower values found in many instances on comparing our results with previous ones.

Oxalic acid is widely distributed in the plant kingdom, sometimes as the free acid, but more commonly as the salt of potassium, sodium, calcium, magnesium or iron. For the purposes of this study, however, the free acid and its salts are expressed collectively as 'oxalic acid'.

Fruits were in general found to contain only small quantities of oxalic acid. No oxalic acid could be detected in the pulps of grapefruit and pineapple, although Bravermann (1949) reported traces of the acid in grapefruit. In citrus fruits oxalic acid appears to be concentrated in the peel rather than the pulp, the concentration being higher than that of citrate (Sinclair & Eny, 1947).

Vegetables can be divided fairly readily into those containing high concentrations of oxalic acid and those containing small or negligible amounts. No close correlation was found between the oxalic acid content and the content of calcium, magnesium or phosphorus, although the concentrations of calcium and magnesium tend to be high in those plants or parts of plants that contain large amounts of oxalate, for example, parsley, spinach and rhubarb. The nutritional availability of calcium and magnesium in these foodstuffs is thought to be low (Hoover & Karunairatnam, 1945). The influence of the age of a plant on its oxalate content is clearly illustrated by comparing the value found in forced rhubarb with that found at the end of the growing season (Table 1).

Since oxalic acid is a relatively toxic substance, it might be expected that foodstuffs of animal origin would contain only small quantities, and that it is so is borne out by the results summarized in Table 1. Thus, meat, fish, milk, eggs and butter were found to contain negligible quantities. Prepared foods contain varying quantities of oxalic acid, depending on their plant or animal origin and on the degree of conversion of 'oxalogenic' compounds into oxalic acid during their preparation.

Although the highest concentrations of oxalic acid occur in foods such as spinach and rhubarb, these foods are not necessarily the most important sources of oxalic acid in the average diet. Tea constitutes the principal source of oxalic acid in a typical

English diet, such as that shown in Table 3, other important sources being bread, cocoa and potatoes.

Analysis of six hospital diets yielded values ranging from 70 to 150 mg oxalic acid daily, with a mean value of 97 mg (Table 2). These values differ considerably from those published by Archer *et al.* (1957), who determined the oxalate content of ten normal English diets from which foods containing much oxalate were excluded, the foods excluded being rhubarb, strawberries, chocolate, cocoa, beets and spinach.

Table 3. *Distribution of oxalic acid and calcium among the component foods of a typical English diet on a 1-day basis*

Food			Oxalic acid†		
Description	Weight (g)	Calorific value* (kcal)	mg	% of total day's intake	Calcium† (mg)
Tea (five cups)	750	0	75·0	63·5	2·7
Cake, plain, fruit	100	378	11·4	9·6	293·0
Bread	150	367	7·3	6·2	162·0
Potatoes, boiled	200	160	4·6	3·9	18·0
Soup	150	105	4·5	3·8	45·0
Marmalade	30	78	3·2	2·7	8·3
Canned pears	150	94	2·5	2·1	7·9
Biscuits	50	217	2·2	1·9	69·0
Milk	300	198	1·5	1·3	345·0
Apple (raw, peeled)	100	47	1·5	1·3	3·6
Porridge	150	67	1·5	1·3	15·3
Coffee (one cup)	150	7	1·5	1·3	5·8
Cabbage	60	5	0·6	0·5	3·7
Mutton, roast	100	292	0·4	0·3	4·3
Bacon, fried	50	263	0·3	0·2	26·1
Jam	30	78	0·1	0·1	2·6
Eggs, boiled	120	192	0	0	56·0
Rice pudding	90	130	0	0	72·0
Butter	30	237	0	0	5·1
Sugar	30	118	0	0	1·0
Total		3033	118·1	100·0	1146·4

* From McCance & Widdowson (1960).
† From Table 1.

The values obtained by these authors ranged from 1190 to 1370 mg oxalic acid dihydrate/day (850–980 mg anhydrous oxalic acid/day). Although considerable differences in oxalic acid intake can occur as a result of variations in the amount of tea consumed and in the manner of its preparation, such variations do not explain the large difference between our results and those of Archer *et al.* (1957). The reason for the discrepancy is not entirely clear, but it would appear to be due mainly to differences in analytical procedure.

SUMMARY

1. Oxalic acid, calcium, magnesium and phosphorus have been determined in eighty samples of foods commonly found in English diets.

2. The results were generally found to be in reasonable agreement with previously

published data when they were available, but significantly lower values for oxalic acid were sometimes observed. The reasons for these discrepancies are discussed.

3. The mean daily intake of oxalic acid was found to be 97 mg (range 70–150 mg). Tea appears to be the largest single source of oxalic acid in English diets, with bread and potatoes as other major sources.

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REFERENCES

Andrews, J. C. & Viser, E. T. (1951). *Food Res.* **16**, 306.
Archer, H. E., Dormer, A. E., Scowen, E. F. & Watts, R. W. E. (1957). *Clin. Sci.* **16**, 405.
Bravermann, J. B. S. (1949). *Citrus Products, Chemical Composition and Chemical Technology*. New York: Interscience.
Bryan, J. D. (1946). *Rep. agric. hort. Res. Sta. Bristol*, p. 138.
Dempsey, E. F. (1957). *J. clin. Invest.* **36**, 882.
Dempsey, E. F., Forbes, A. P., Melick, R. A. & Henneman, P. H. (1960). *Metabolism*, **9**, 52.
Fincke, M. L. & Sherman, H. C. (1935). *J. biol. Chem.* **110**, 421.
Fiske, C. H. & Subbarow, Y. (1925). *J. biol. Chem.* **66**, 375.
Grossmann, W. (1938). *Brit. J. Urol.* **10**, 46.
Grütz, W., Sengbusch, R. & Timmermann, A. (1957). *Landw. Forsch.* **10**, 186.
Hammarsten, G. (1937). Eine Experimentelle Studie über Calciumoxalat als Steinbildner in den Harnwegen. Lund: Universitets Årsskrift. N.F.
Hawk, P. B., Oser, B. L. & Summerson, W. H. (1954). *Practical Physiological Chemistry*, 13th ed. New York: McGraw-Hill.
Heaton, F. W. (1960). *J. clin. Path.* **13**, 358.
Hodgkinson, A. (1958). *Proc. R. Soc. Med.* **51**, 44.
Hodgkinson, A. & Zarembski, P. M. (1961). *Analyst*, **86**, 16.
Hoover, A. A. & Karunairatnam, M. C. (1945). *Biochem. J.* **39**, 237.
Kane, G. G. & McCay, C. M. (1947). *J. Geront.* **2**, 244.
Kohman, E. F. (1939). *J. Nutr.* **18**, 233.
Lehmann, E. & Grütz, W. (1953). *Z. PflErnähr. Düng.* **61**, 77.
Lovelace, F. E., Liu, C. H. & McCay, C. M. (1950). *Arch. Biochem.* **27**, 48.
McCance, R. A. & Widdowson, E. M. (1942–3). *J. Physiol.* **101**, 304.
McCance, R. A. & Widdowson, E. M. (1960). *Spec. Rep. Ser. med. Res. Coun., Lond.*, no. 297.
McIntosh, J. F. & Read, M. K. (1958). *J. Urol.* **80**, 272.
Majumdar, B. N. & De, N. K. (1938). *Indian J. med. Res.* **25**, 671.
Pritzker, J. & Jungkunz, R. (1939). *Mitt. Lebensm. Hyg. Bern*, **30**, 256.
Pyrah, L. N., Anderson, C. K., Hodgkinson, A. & Zarembski, P. M. (1959). *Brit. J. Urol.* **31**, 235.
Roberts, A. H. & Yudkin, J. (1960). *Nature, Lond.*, **185**, 823.
Sinclair, W. B. & Eny, D. M. (1947). *Bot. Gaz.* **108**, 398.
Widmark, E. M. P. & Ahldin, G. (1933). *Biochem. Z.* **265**, 241.
Wittwer, S. H., Albrecht, W. A. & Schroeder, R. A. (1947). *Food Res.* **12**, 405.
Wittwer, S. H. & Goff, H. R. (1946). *J. Nutr.* **31**, 59.
Zarembski, P. M. & Hodgkinson, A. (1962). *Analyst*, **87**, 698.

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