Summary

1. Calcium carbide has been studied as a reductant for sulfates. It is not as effective as calcium hydride.

2. Calcium hydride presents itself as a reagent for the quantitative reduction of alkaline earth and alkali sulfates to sulfides. From such fusion residues sulfur may be determined by iodine titration.

3. An example is given of replacement of potassium and sodium by calcium.

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THE POTATO AS AN INDEX OF IODINE DISTRIBUTION[1]

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RECEIVED MAY 6, 1929 PUBLISHED OCTOBER 5, 1929

The theory that endemic thyroid enlargement is caused primarily by lack of iodine has been quite generally accepted by American scientists, so that studies on the occurrence of iodine in human environment are of considerable interest. McClendon and Williams[2] have shown that there is a correlation between shortage of iodine in surface water supplies and the incidence of goiter.

Numerous analyses by these and other workers have established that places in the United States where the water contains more than two parts per billion of iodine are few, and more than five parts per billion exceedingly rare. Von Fellenberg[3] concluded, as the result of an extended metabolism trial on himself, that the daily iodine requirement for a man is 14 micrograms, which is a great deal less than the amount (300 to 400 milligrams per year) recommended by Kimball[4] for goiter prophylaxis in the United States. Even if inorganic compounds of iodine are efficiently utilized in the body, water alone cannot supply the requirement in more than a very restricted area. Hence McClendon[5] turned his attention to vegetable foods, and was able to show that foods from Maine and Connecticut contain more iodine than do those from Minnesota or Oregon.

The senior author of this paper[6] has called attention to the relatively large amounts of iodine present in root and leafy vegetables from South Carolina, analytical data for which are now presented in Table I, and

[1] Presented before the Division of Agricultural and Food Chemistry at the 77th meeting of the American Chemical Society, Columbus, Ohio, April 29–May 3, 1929.

[2] J. F. McClendon and Agnes Williams, *J. Am. Med. Assocn.*, **80**, 600 (1923).

[3] Th. von Fellenberg, *Biochem. Z.*, **142**, 246 (1923).

[4] O. P. Kimball, *J. Am. Med. Assocn.*, **91**, 454 (1928).

[5] J. F. McClendon and J. C. Hathaway, *ibid.*, **82**, 1668 (1924).

[6] Roe E. Remington, *Science*, **68**, 590 (1928).

TABLE I

IODINE CONTENT OF VEGETABLE FOODS FROM GOITROUS AND NON-GOITROUS REGIONS

Parts per billion, dry basis

	South Carolina Analyses by Remington	California Analyses by McClendon	Oregon Analyses by McClendon
Lettuce	761	..	..
Summer squash	716	..	..
Spinach	694	26.0	19.5
Turnip tops	433	..	..
String beans	429	..	29
Cabbage	336	..	..
Asparagus	285	12.0	..
Beets	227	8.0	..
Turnips	223	..	..
Potatoes	211	..	..
Carrots	197	8.5	2.3
Sweet potatoes	98	..	..

McClendon[7] has published analyses of vegetables from California. Mitchell[8] has also examined a number of samples of South Carolina vegetables and feeds, and finds a tendency to higher iodine content in that part of the state which is more distant from the coast and nearer the Blue Ridge of the Appalachian Mountains. He reported marked differences in the results on samples of the same product from the same general locality, which differences have been found by us to amount to two or three hundred per cent. At first we were inclined to attribute the lack of uniformity to errors in laboratory technique, but extended experimentation has convinced us that the differences actually exist in the crops as grown. So far we have no suggested explanation, although soil type, stage of maturity of the crop at harvest, fertilizer and soil treatment, and rainfall all deserve consideration.

The salt spray theory of iodine distribution seems to have gained general acceptance, but the Atlantic Ocean contains only 23 parts per billion of iodine, and five or six parts per billion in the water of streams cannot come solely from spray unless the waters contain a like proportion of the other salts of the sea, which they do not. Mitchell[8] found six parts in the water of the Broad River at a point 150 miles from the coast, but the Broad River is not brackish. Lunde[9] believes that in the cooling of the earth iodine was distributed throughout all phases, and hence is now found in rocks, soils, and in the air and sea, but has been leached out of the soils of some areas. Von Fellenberg[10] found several hundred parts per billion in igneous rocks.

[7] J. F. McClendon and Roe E. Remington, THIS JOURNAL, **51**, 394 (1929).

[8] J. H. Mitchell, Clemson College Bulletin 252, **1928**.

[9] G. Lunde, *Tids. Kemi Bergvesen*, **7**, 61, 67 (1927).

[10] Th. von Fellenberg, *Biochem. Z.*, **152**, 132 (1924).

Examination of a large number of samples has heretofore been difficult owing to the intricate and laborious technique of the oxygen combustion method of McClendon, which has been the most reliable method in use up to the present time. It has been found in this Laboratory, however,[7] that if the organic matter were destroyed by simple ignition in a porcelain dish at a temperature which did not exceed 450°, 95% of the iodine in sodium iodide added to potatoes could be recovered, and we have since obtained as good or better recovery when 0.1 g. of dried thyroid is added to 100 g. of dried potatoes; hence we conclude that organic as well as inorganic iodine is retained by the ash of vegetables when ignited at this temperature. The method is so simple that a good technician can now make six to eight determinations per day if laboratory facilities are adequate.

In order to compare the iodine content of foods in maritime and non-maritime regions, it seemed desirable to choose a crop which is universally grown, largely used as food, and can be readily obtained and transported without spoilage. Cereal grains are not suitable because their iodine content is very low, regardless of where grown. Since we have found that Irish potatoes from South Carolina contain as much iodine as any other root crops which we have examined, the potato was chosen as the basis of our survey. Samples in South Carolina were collected by county agricultural agents; those from other states were furnished us through the courtesy of the directors of the several agricultural experiment stations.

On receipt the samples were washed, cut into small cubes without peeling, dried first for twenty-four hours or more by a current of air at room temperature blown upward through the screen wire bottoms of trays in which the samples were placed, and finally for twenty-four hours in an oven at 80°, after which they were ground and bottled. The moisture content of the dried samples ranged from 1 to 3%. The loss in drying varied in different samples between 75 and 80%. Results are given in Table II.

The Idaho samples were all produced on wind-borne silt loam soils of volcanic origin, fertilized with liberal quantities of stable compost but no commercial fertilizer. Mixed commercial fertilizers are extensively used in Michigan, Maine and South Carolina, but not in Minnesota nor North Dakota.

With regard to South Carolina, while 72 is probably not a sufficient number of samples on which to base an accurate study, it has seemed worth while to analyze the data, first with reference to distance from the sea and second with regard to soil types. If we draw lines across the map of the state at intervals of fifty miles from the coast, and average the samples within each belt, we obtain the values in Table III. There is a regular progressive increase in iodine content as we go from the coast toward the mountains.

TABLE II

IODINE CONTENT OF POTATOES FROM DIFFERENT REGIONS

Sample no.	Source	Locality	Iodine in parts per billion, dry basis
212	Idaho	Twin Falls	160
294	Idaho	Moscow	125
306	Idaho	Hansen	45
		Average	110
129	Maine	Monmouth	203
133	Maine	Brunswick	283
137	Maine	Orono	188
138	Maine	Presque Isle	105
		Average	195
195	Michigan	Pontiac	120
161	Michigan	Greenville	110
168	Michigan	Manton	69
297	Michigan	Chatham	75
		Average	97
139	Minnesota	Grand Rapids	67
140	Minnesota	Grand Rapids	117
141	Minnesota	Grand Rapids	75
143	Minnesota	Grand Rapids	26
144	Minnesota	Grand Rapids	70
145	Minnesota	Grand Rapids	109
146	Minnesota	Grand Rapids	125
147	Minnesota	Grand Rapids	98
		Average	86
148	North Dakota	Fargo	78
	South Carolina	72 samples	87 to 544
		Average	211

TABLE III

IODINE CONTENT OF POTATOES IN RELATION TO DISTANCE FROM THE SEA

Parts per billion, dry basis

Distance from sea, miles	0–50	50–100	100–150	150–200	200
Number of samples	19	18	15	16	4
Iodine content, average	180	213	223	249	266

With regard to soil types, the state is roughly bisected by the "fall line," which marks a prehistoric coast (Fig. 1). Below the fall line the soils are predominantly sand or sandy loam, and have come up out of the sea in comparatively recent geologic time. Above the fall line the predominating type is a red clay loam, brought down by erosion from the granite rocks of the Appalachian system. The differentiation is not sharp, and some areas of clay have been washed clear down into the lower pine belt. It is rational to expect that the remains of marine plants and animals which are incorporated in the soils below the fall line will have an effect on the iodine content of crops raised thereon. It will be noted, however, that

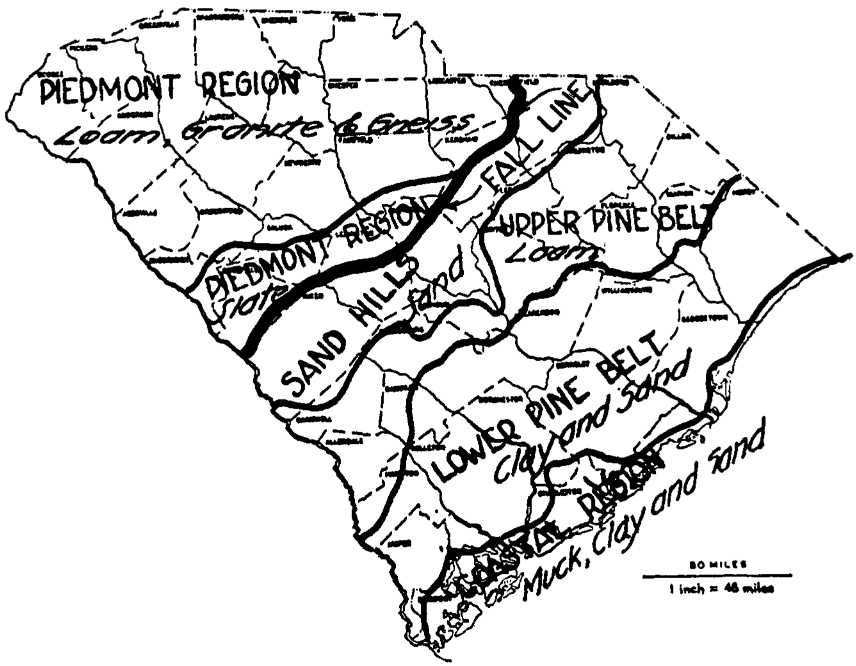

Fig. 1.—General topographic and soil areas of South Carolina.

the samples from the Piedmont (Table IV) (above the fall line) are richer in iodine than those from any of the lower areas, not excepting the coast

Table IV

Iodine Content of Potatoes in Relation to Soil Areas

Parts per billion, dry basis

Soil-area	Number of samples	Iodine content, av.
Coastal Region	7	198
Lower Pine Belt	18	164
Upper Pine Belt	12	234
Sand Hills	7	191
Piedmont	28	249

itself. In fact, were it not for the sand hill section and the narrow coastal belt, the order would be the same as that of the previous table. The soil of the sand hills is particularly barren, and presents an agricultural problem of its own, while we can believe that the higher values along the coast (as compared with the lower pine) are due to the immediate effect of the sea, in that marsh grass is used as feed for live stock and for fertilizer, seaweed is blown ashore and finds its way into the soil, and the possible effect of sea spray. It is a matter of common agricultural knowledge that the clay soils of the Piedmont not only hold water better, but also retain mineral salts, so that only one-fourth to one-half as much fertilizer is used to make a crop as is required in the sandy soils of the low country.

Commercial fertilizers have probably been used for a longer time, and more abundantly in South Carolina than in any of the interior states. Chilean nitrate may carry as high as 0.02% of iodine[11] but the amounts reported for other usual fertilizer materials are not higher than have been found in many soils. As previously noted, fertilizers were used in producing all the samples from Michigan, where lower amounts of iodine were found. We believe that the main source of iodine in South Carolina vegetation lies in the disintegration of the granitic rocks of the Blue Ridge, and that this has been supplemented by the liberal use of commercial fertilizers over a period of years. This supply of iodine is being conserved by the return of vegetable matter and animal wastes to the soil.

Summary

Analyses of 72 samples of Irish potatoes from different parts of South Carolina, as well as of samples from Maine, Michigan, Minnesota, North Dakota and Idaho, are presented and discussed in relation to various factors which have been supposed to influence the iodine content of plants. Average values are: South Carolina 211, Maine 195, Idaho 110, Michigan 94, Minnesota 86.

Large variations are found in samples from the same area and identical soil type, the variations, however, not being confined to South Carolina. Average values increase progressively from the sea to the Appalachian Mountains, but the relative amount of clay in the soil increases in the same manner. It is suggested that the principal source of the iodine is from the disintegration of granite rocks, supplemented by the use of commercial fertilizers. The immediate influence of the sea is not seen beyond a very narrow belt along the coast.

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[11] Th. von Fellenberg, *Mitt. Lebenson. Hyg.*, **15**, 247 (1924).