TEXAS AGRICULTURAL EXPERIMENT STATION
A. B. CONNER, DIRECTOR,
College Station, Texas

BULLETIN NO. 595 NOVEMBER 1940

IODINE IN DRINKING WATERS, VEGETABLES, COTTONSEED MEAL, AND ROUGHAGES

G. S. FRAPS and J. F. FUDGE

Division of Chemistry

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS
T. O. WALTON, President

A96-1140-7M-L180

[Blank Page in Original Bulletin]

Iodine was determined in nearly 500 samples of city and rural drinking waters, vegetables, cottonseed meals, roughages and grasses from various parts of Texas. Iodine was deficient in only a very few samples, and in most samples was high when compared with similar samples from areas where the iodine was sufficiently low to cause goiter.

Iodine in 103 samples of city waters ranged from 4 to 312 parts per billion, with an average of 56. Iodine in three samples of cistern water averaged only 4 parts per billion. Iodine in city waters averaged lowest in the East Texas Timber Country (24 parts per billion) and highest in the High Plains (101 parts per billion). There was good agreement between the average iodine in waters and the average iodine content of soils of the same region. The iodine content varied directly with the quantities of sodium chloride in the waters.

Iodine in 37 samples of vegetables ranged from 62 to 3502 parts per billion. Iodine in Texas vegetables was much higher than in corresponding vegetables from goitrous areas, and as high as or higher than that in vegetables reported from other non-goitrous areas.

Iodine in 235 samples of cottonseed meal ranged from 23 to 1420 parts per billion. The average iodine in samples from different geographic divisions ranged from 92 parts per billion in the West Cross Timbers to 251 parts per billion in the Rio Grande Plain. There was good agreement between the average iodine in cottonseed meal and that in soils of the same region.

Iodine in 56 samples of roughages and grasses ranged from 17 to 1125 parts per billion. There was a considerable range in the iodine content of different samples of the same type of forage and a wide range between average iodine contents of different types of forage, but iodine was deficient in only a very few cases.

The use of iodized table salt for human consumption in Texas is not advisable, except under the supervision of a competent physician. The use of iodized mineral mixtures for livestock in Texas is not recommended.

TABLE OF CONTENTS

IODINE IN DRINKING WATERS, VEGETABLES, COTTONSEED MEAL, AND ROUGHAGES IN TEXAS

G. S. Fraps, Chief, and J. F. Fudge, Chemist,
Division of Chemistry

Iodine in minute quantities has long been recognized as necessary for the health of man and animals. Where very low quantities of iodine in foods, feeds, and waters occur, there may be a high incidence of simple goiter (43, 45, 46, 49, 50, 51, 59, 60, 63). Other disturbances of health may also be due in part to insufficient iodine intake.

The quantity of iodine required daily is very small, 1 microgram of iodine per pound of animal or man being considered sufficient (48), (one microgram is about two one-billionths part of a pound). Continuous consumption of quantities of iodine considerably in excess of the quantities required may result in injury to health of animals and of man (5).

Texas is not in an area in which deficiencies of iodine for man or animals are known to occur and give rise to goiter. No instance of an animal suffering from a disease due to deficiency of iodine has heretofore been found by the Division of Veterinary Science. Nevertheless, efforts are being made commercially to promote the use of iodine in animal feeds. Iodized salt is extensively distributed in Texas, and if sufficient quantities of iodine are present in the food or water, the use of iodized salt is unnecessary and may even injure health.

A survey of the possible needs for iodine in Texas is therefore important. The need for and importance of iodine surveys in different geographical regions, in order to determine whether or not the iodine supply is sufficient for proper development and maintenance has been shown by the work of Marine (43), McClendon (49), Weston (74), and others. Such a survey of the iodine content of soils, drinking waters, vegetables, cottonseed meal, and roughages from various sections of Texas was begun by the authors a number of years ago. Work already published has shown that very few of the soils of Texas are deficient in iodine, and that some of them are relatively quite high (20), and that the iodine content of vegetables and drinking waters from various sections of Texas is also relatively high (19).

This bulletin presents in detail the results of a study of the iodine content of vegetables, cottonseed meal, and a few roughages collected from various sections of Texas, together with the iodine and mineral content of drinking waters collected from a number of cities. Cottonseed meal was selected as an indicator of the iodine taken by plants from the soil. Irish potatoes and cabbage have been used by other investigators (50, 61, 64) for the same purpose. Cotton is widely grown, and meal from the cotton seed grown in various locations of the state can easily be secured, as representative of the different localities.

Method of Analysis

In case of water, an aliquot, usually 500 cc, was treated with a slight excess of sodium hydroxide and evaporated to about 30 cc. Iodine was then estimated by the method described elsewhere in detail (21). The waters collected were also analyzed for mineral salts.

Vegetables and feeds were cut into small pieces and dried in an oven at about 45° C. The material was then ground in a Wiley mill and stored in tightly closed jars. Cottonseed meals were ground in a Quaker City mill. A portion of the sample, from 25 to 100 grams, was burned in a current of oxygen in the apparatus described by von Kolnitz and Remington (31). The combined absorbing solution and washings were then evaporated to about 30 cc and iodine estimated.

The estimation of iodine was made by a colorimetric modification of the method described by Trevorrow and Fashena (16, 72) already described in detail (21). In this procedure, iodine and residual organic matter are oxidized by chromic acid, the iodates reduced by phosphorous acid, the iodine distilled in an all-glass apparatus, the iodine in the distillate oxidized to iodic acid by the addition of bromine, the bromine boiled off, and the iodic acid reduced by potassium iodide. The liberated iodine is extracted from the aqueous solution with carbon tetrachloride, and the color produced by the iodine compared with that produced by iodine from a standard iodide solution treated in the same way. The distillation of the iodine was necessary to eliminate interfering substances.

Iodine and Salts in Drinking Waters

The quantities of iodine and mineral salts found in the drinking waters from 103 cities in Texas are shown in Table 1. The numbers given in the fourth column of Table 1 refer to the geographic division of Texas shown in Figure 1. Iodine in these city waters ranged from 4 to 312 parts per billion. The iodine content varied within a given division, and also between different divisions. With a very few exceptions, however, all of the Texas samples had a high content of iodine in comparison with waters from goitrous areas shown in Table 2. The mean iodine content, as shown in Table 3, was 56 parts per billion, with a standard deviation of 60 parts per billion. Iodine was lowest in city waters from the East Texas Timber Country and the West Cross Timbers; both of these areas are covered by sandy, noncalcareous soils low in iodine as compared with other Texas soil (20). Iodine was highest in city waters from the High Plains and the Rio Grande Plain, both of which are covered, in the main, by heavier soils, many of which are calcareous and high in iodine. However, waters containing relatively low quantities of iodine occur throughout the state, as is shown by the minimum analyses (Table 3).

In the opinion of Miss Mildred Horton, State Home Demonstration Agent, and the District Home Demonstration Agents, goiter is of very rare occurrence in all districts, with the possible exception of certain areas in the High Plains. Samples of well water from rural homes in this section (Table 4) were high in iodine with the exception of 3 samples of cistern water which were low (3 to 5 parts per billion). In many parts of the State, rain water is collected in cisterns and used for cooking and drinking, and water is also stored in earthen "tanks" for the use of farm animals. Most cistern and tank waters are probably low in iodine, and a deficiency may result if not made up in the foods or feeds.

The relation of the iodine content of drinking waters to the incidence of goiter has been discussed by a number of workers. In Utah the iodine content in 5 waters (24) ranged from .018 to .216 parts per billion, and the corresponding incidence of goiter among school children ranged from 57 per cent to 6 per cent. In 4 counties in Michigan (59) the iodine content of waters was 8.7, 7.3, 0.5 and 0 parts per billion, and the incidence of goiter was 26 per cent, 32.7 per cent, 55.6 per cent, and 64.4 per cent. In Suffolk, England, (60) iodine averaged 8.2 parts per billion, and in Somerset, 2.9 parts per billion; corresponding incidences of goiter were 3 per cent and 56 per cent. In Maryland, iodine in 11 city waters from the mountainous area, where goiter is common, ranged from .06 to 1.21 parts per billion (53), while in Baltimore, where goiter is uncommon,

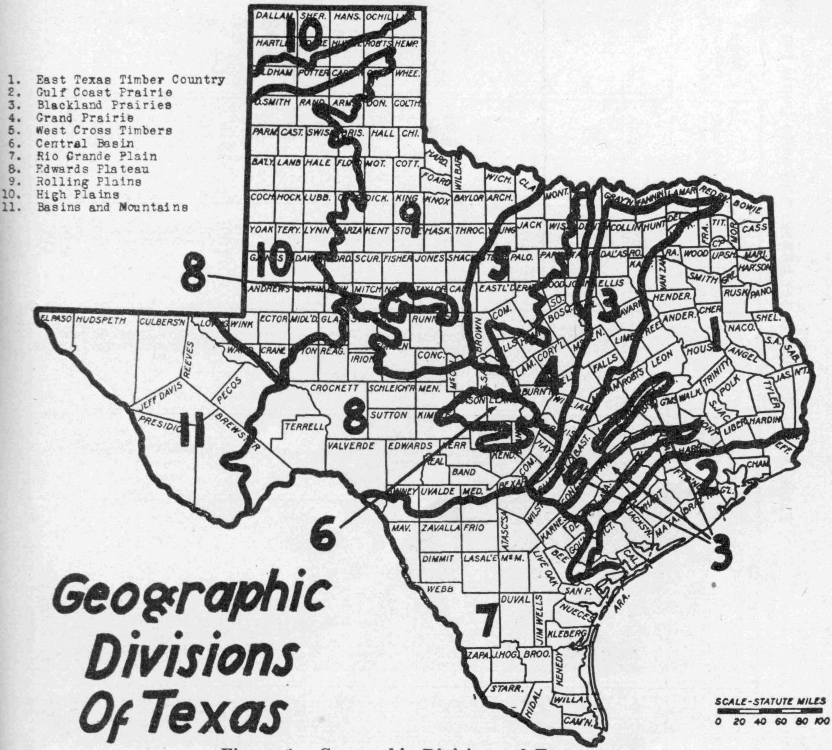

Figure 1. Geographic Divisions of Texas.

Table 1. Iodine (parts per billion) and salts (parts per million) in waters from cities in Texas

Lab. No.	City	Geo-graphic division (Fig. 1)	Iodine	Calcium carbonate	Calcium sulphate	Mag-nesium carbonate	Mag-nesium sulphate	Mag-nesium chloride	Sodium carbonate	Sodium sulphate	Sodium chloride
48406	Abilene	9	48	29	.....	22	24	.....	.....	2	35
46865	Alto	11	27	4	.....	3	.....	.....	494	9	118
48397	Amarillo	10	230	98	.....	122	39	2	.....	.....	18
46866	Anderson	1	35	225	17	.....	6	24	.....	.....	239
44516	Athens	1	18	18	.....	2	.....	.....	109	5	53
47278	Austin	3	40	30	.....	15	36	.....	.....	18	97
48401	Ballinger	9	38	145	29	.....	116	7	.....	.....	102
43629	Beaumont	2	25	31	22	.....	15	.....	.....	9	59
46052	Beeville	7	45	18	.....	2	.....	.....	456	11	792
49092	Benjamin	9	25	.....	.....	.....	.....	.....	.....	.....	.....
48402	Big Spring	10	27	178	12	.....	39	2	.....	.....	64
48403	Borger	9	38	125	.....	41	.....	35	.....	.....	.....
48405	Breckenridge	5	14	110	27	.....	69	.....	.....	20	76
46055	Brenham	3	15	105	31	.....	.....	9	.....	.....	20
46867	Buffalo	1	13	32	.....	8	.....	.....	73	25	28
48404	Canyon	10	13	21	.....	33	.....	.....	220	48	33
46681	Carrizo Springs	7	68	123	.....	46	9	.....	.....	158	234
48424	Childress	9	13	128	236	.....	117	.....	.....	4	59
48400	Cleburne	1	21	27	.....	17	.....	.....	285	172	73
39113	College Station	1	40	16	.....	10	.....	.....	508	451	406
46053	Corpus Christi	7	107	178	78	.....	90	5	.....	.....	340
46868	Corrigan	1	24	27	.....	7	3	.....	.....	66	48
39471	Corsicana	3	35	28	80	.....	63	.....	.....	44	26
43955	Corsicana	3	24	41	.....	3	60	.....	.....	112	33
46680	Cotulla	7	49	5	.....	2	.....	.....	269	119	135
46355	Crockett	1	20	16	.....	8	.....	.....	29	70	71
39311	Crowell	9	29	169	1910	.....	389	146	.....	.....	205
44519	Dallas	3	65	29	.....	1	21	.....	.....	23	54
48439	Denton	1	29	18	.....	10	.....	.....	305	174	59
48462	El Paso	11	48	95	.....	26	.....	.....	.....	50	328
46051	Falfurrias	7	191	95	.....	73	.....	.....	40	62	325
49073	Farwell	10	80	57	.....	96	.....	.....	3	37	36
48463	Fort Worth	1	42	111	.....	8	26	7	.....	.....	41
48438	Graham	5	51	28	12	.....	12	14	.....	.....	2
46144	Grand Saline	1	35	20	102	.....	60	21	.....	.....	101
44521	Greenville	3	72	112	.....	3	27	.....	.....	57	28
46353	Groesbeck	3	78	238	51	.....	51	.....	.....	57	153
48973	Harlingen	7	20	108	199	.....	167	.....	.....	69	393
43748	Hearne	1	33	11	.....	.....	.....	.....	309	7	84

46678	Hebbronville	7	179	24	...	14	...	...	116	162	551
43578	Hempstead	1	26	70	...	...	...	...	203	11	86
43954	Henderson	1	9	7	...	6	...	...	113	16	31
46147	Hillsboro	3	101	20	...	13	...	...	358	495	96
43637	Houston	2	97	...	...	56	...	...	165	11	89
44079	Huntsville	1	21	37	...	8	...	...	220	21	119
43956	Jacksonville	1	24	25	...	...	17	5	...	...	17
39556	Jasper	1	7	20	...	3	9	...	...	9	17
49074	Jayton	9	117	...	...	...	...	...	...	...	...
48482	Junction	8	42	198	...	63	18	31	...	...	...
46050	Kingsville	7	312	48	...	42	...	...	137	247	442
48477	Lamesa	10	183	86	...	172	45	...	...	222	203
48461	Lampasas	4	43	274	44	...	...	213	...	...	1064
46679	Laredo	7	34	38	330	...	72	...	...	64	348
46356	Livingston	1	30	79	...	10	...	...	169	20	64
47279	Lockhart	3	49	213	82	...	...	28	...	...	168
44520	Longview	1	12	12	...	6	3	...	...	11	36
48723	Lubbock	10	144	143	...	87	179	...	...	51	155
39555	Lufkin	1	30	6	41	...	12	...	...	...	21
44076	Lufkin	1	14	30	29	...	20	5	...	...	36
44078	Madisonville	1	13	108	68	...	72	...	...	47	483
43953	Marshall	1	11	44	12	...	27	...	...	52	35
43747	Mexia	3	113	98	...	27	...	...	163	7	290
46143	Mineola	1	16	20	...	15	...	...	55	30	28
48724	Mineral Wells	5	22	38	27	...	27	...	...	4	15
48641	Midland	10	279	165	143	...	345	5	...	...	363
49090	Montague	5	23	...	...	...	...	...	...	...	...
48967	McAllen	7	51	105	272	...	173	...	...	23	455
48743	McCamey	8	59	179	...	8	93	26	...	...	38
44077	Nacogdoches	1	10	9	...	8	...	...	81	39	26
43577	Navasota	1	49	62	...	6	...	...	343	...	140
48779	Odessa	10	70	160	27	...	114	...	...	7	109
46869	Oakwood	1	10	82	...	27	...	...	20	39	25
49185	Paducah	9	29	...	...	...	...	...	...	...	...
44400	Palacios	2	36	20	...	8	...	...	251	28	125
43754	Palestine	1	18	20	...	3	24	...	...	4	31
44517	Paris	3	46	43	10	...	15	...	...	5	21
48804	Plainview	10	4	112	...	115	38	...	...	...	45
48968	Raymondville	7	192	114	...	3	69	...	...	1634	914
44398	Refugio	7	108	34	...	15	...	...	277	94	520
47274	Rockdale	1	17	40	37	...	...	66	...	...	135
47277	Round Rock	3	52	266	...	41	38	21	...	...	23
46358	Rusk	1	32	25	7	...	15	...	...	12	21
48711	San Angelo	9	30	120	...	17	47	2	...	...	74
46683	San Antonio	7	14	152	...	32	17	9	...	...	23
46054	Schulenburg	3	65	93	...	19	...	...	183	35	167
48631	Seymour	9	27	179	...	117	18	...	...	101	168
49067	Spur	9	64	...	...	...	...	...	...	...	...

Table 1. Iodine (parts per billion) and salts (parts per million) in waters from cities in Texas—Continued

Lab. No.	City	Geographic division (Fig. 1)	Iodine	Calcium carbonate	Calcium sulphate	Magnesium carbonate	Magnesium sulphate	Magnesium chloride	Sodium carbonate	Sodium sulphate	Sodium chloride
44518	Sulphur Springs	3	62	35	10	...	21	...	...	18	28
48742	Sweetwater	8	63	170	15	...	36	28	...	...	3
47276	Taylor	3	171	43	...	15	...	...	307	580	361
46357	Teague	1	43	39	...	13	9	...	...	27	54
48801	Temple	3	15	130	44	...	17	28	...	...	20
46145	Terrell	3	37	55	27	...	27	...	...	11	25
44515	Texarkana	1	44	43	19	...	...	33	...	...	7
47275	Thorndale	3	210	55	...	13	18	...	...	14	50
46354	Trinity	1	127	29	...	8	...	...	21	11	393
44514	Tyler	1	21	23	15	...	...	26	...	...	...
46682	Uvalde	7	15	202	...	7	19	19	...	...	15
49187	Vernon	9	22	...	...	...	...	...	...	...	...
44401	Victoria	2	102	79	...	42	...	...	154	23	162
46148	Waco	3	52	130	32	...	11	21	...	...	31
46146	Waxahachie	3	51	12	...	10	...	...	406	160	480
44399	Wharton	2	28	161	...	20	23	7	...	...	83
48710	Wichita Falls	9	23	45	194	...	...	71	...	...	410

Table 2. Iodine (parts per billion) in some city waters from goitrous areas

Region	Reference	Iodine		
		Low	High	Average
Illinois	6, 7	.13	1.33	....
Maryland	8, 53	.06	5.0	....
Massachussets	10, 11	0	6.3	2.14
Michigan	14, 59	0	8.7	....
Minnesota (Duluth)	6	....	....	.014
Nebraska	6	.005	.30	....
North Dakota	69	Too small to determine		
Utah	24	.18	2.16	....
Poland	32	1.1	12.4	....
England (Suffolk)	60	....	....	8.2
England (Somerset)	60	....	....	2.9
Norway	40	1.5	2.0	....
Germany (Westphalia)	3, 4	.12	19.6	....
New Zealand	68	.4	15.0	....
Average for Texas	....	4	312	56

the water contained 5 parts per billion of iodine. In Poland, iodine in 56 waters (71) ranged from 46 parts per billion in northern Poland, where no goiter occurs, to .05 parts per billion in the southern mountainous region, where goiter frequently occurs.

The lowest quantity of iodine in drinking waters required for good health is estimated differently by different workers. Broll (8) recommends that iodine be added to the drinking water supply whenever the iodine content falls below .3 parts per billion. Little (36) states that the addition of 169 micrograms of sodium iodide to a gallon of water, equivalent to 44.6 parts per billion of iodine, for 2 weeks in the spring and 2 weeks in the fall, cured or prevented common goiter. This would average less than 4 parts per billion for the entire year. Rogers (66) states that when the iodine content of the water exceeds 2 parts per billion, goiter incidence is reduced; however, Lunde (40) reported 1.5 to 2 parts per billion of iodine in drinking water in Norway when the incidence of goiter was about 70 per cent. McClendon (47) states that 10 parts per billion or over of iodine in water is sufficient to prevent goiter, even though the diet is deficient in iodine. This seems to be a liberal allowance.

Only 3 of the waters from Texas cities contained less than 10 parts per billion of iodine (Table 1); it may therefore be concluded that city waters in Texas usually contain sufficient quantities of iodine.

The quantities of the mineral salts in the waters analyzed are given in Table 1. Excessive quantities of salts are not contained in any of these waters.

The relation between the iodine and the other salts in drinking water is of interest. Throughout the Middle West, where the incidence of goiter is much higher than it is in Texas (37), waters are in most cases high in calcium and low in sodium. Many Texas waters contain considerable quantities of sodium and in many, the quantity of sodium greatly exceeds the quantity of calcium (Table 1). The coefficient of correlation

Table 3. Average iodine (parts per billion) in city waters in Texas

Geographic Division	Number in Fig. 1	Total	Frequency Iodine by groups					Mean	Standard deviation	Minimum
			0–25	25–50	51–75	76–100	101 +			
East Texas Timber Country	1	33	19	14	0	0	0	24	12	9
West Cross Timbers	5	4	3	0	1	0	0	28	16	14
Rolling Plains	8	13	5	6	1	0	1	38	27	13
Grand Prairie	4	1	0	1	0	0	0	43	....	43
Basins and Mountains	10	1	0	1	0	0	0	48	....	48
Edwards Plateau	7	3	0	1	2	0	0	55	11	49
Gulf Coast Prairie	2	5	1	2	0	1	1	58	37	25
Blackland Prairies	3	20	3	5	7	1	4	68	49	15
Rio Grande Plain	6	14	3	3	2	0	6	99	89	14
High Plains	9	9	2	1	1	1	4	114	101	4
All Divisions	....	103	36	34	14	3	16	56	60	4

Table 4. Iodine (parts per billion) in waters from farms in Northwest Texas

Locality	County	Depth of well feet	Iodine
Lamesa	Dawson	80	213
Lamesa	Dawson	50	223
Lamesa	Dawson	Unknown	196
Lamesa	Dawson	Unknown	97
Spur	Dickens	Cistern	4
Dickens	Dickens	50	40
Dickens	Dickens	55	42
Clairmont	Kent	Cistern	3
Clairmont	Kent	Cistern	5
Clairmont	Kent	200	31
Farwell	Parmer	200	76
Farwell	Parmer	200	64

between iodine and calcium salts was + .0335, and is not significant, while that for iodine and sodium salts was + .4099, and is highly significant. The coefficient of correlation between iodine and calcium carbonate, the principal calcium salt, was + .1007, and is not significant; that between iodine and sodium chloride, the principal sodium salt, was + .8131, and is highly significant. The iodine is probably derived from the sea water contained in the deposits when they were laid down under the sea.

Iodine in Vegetables

Iodine was determined in a small number of vegetables secured from Weslaco in the Rio Grande Valley, Winter Haven in the western part of the Rio Grande Plain, Sugar Land and Prairie View in the Gulf Coast Prairie, and College Station in the East Texas Timber Country (Table 5). The limited number of vegetables analyzed is, of course, not sufficient to represent all parts of the vast area of Texas, but the results secured indicate that the vegetables from all of the areas sampled are relatively high in iodine (Tables 5 and 6).

While iodine in most of the vegetables was high, it varied considerably with the portion of the plant used as food, the variety, location, and soil. The effect of the season upon the iodine content of the vegetables was not determined. Leafy vegetables contained much more iodine than root or fruit vegetables. Greens from beets and turnips contained about 75 per cent more iodine than roots from the same plants. Copenhagen Market cabbage from Weslaco contained over four times as much iodine as All Head cabbage collected at the same time and place. A sample of Italian Green Sprouting broccoli grown on a Brennan fine sandy loam at Weslaco contained over eight times as much iodine as the same vegetable grown on a Duval fine sandy loam at Winter Haven. Other comparisons may be made from the data presented in Table 5.

The vegetables analyzed contained quantities of iodine which are in most cases as high as, or higher than, amounts reported for similar vegetables from other states (Table 6). The averages for carrots, okra, and tomatoes

Table 5. Iodine (parts per billion) in vegetables grown in Texas

Vegetable	Variety	Location	Soil Type	Iodine
Beans	Bountiful	Weslaco	Victoria sandy loam	955
Beets, leaves	Unknown	Sugar Land	Miller silt loam	915
Beets, leaves	Unknown	Prairie View	Hockley fine sandy loam	702
Beets, leaves	Unknown	College Station	Lufkin fine sandy loam	369
Beets, leaves	Dark Red Turnip	College Station	Lufkin fine sandy loam	1030
Beets, roots	Unknown	Sugar Land	Miller silt loam	588
Beets, roots	Unknown	Prairie View	Hockley fine sandy loam	431
Beets, roots	Unknown	College Station	Lufkin fine sandy loam	180
Beets, roots	Dark Red Turnip	College Station	Lufkin fine sandy loam	308
Broccoli	Italian Green Sprouting	Winter Haven	Duval fine sandy loam	429
Broccoli	Italian Green Sprouting	Weslaco	Brennan fine sandy loam	3502
Broccoli	Glory of Calabria	Weslaco	Brennan fine sandy loam	521
Brussels Sprouts	Long Island Improved	Winter Haven	Duval fine sandy loam	62
Cabbage	Unknown	Sugar Land	Miller silt loam	1208
Cabbage	Marion Market	Sugar Land	Miller silt loam	2163
Cabbage	Enkhuizen	Weslaco	Victoria sandy loam	370
Cabbage	All Head	Weslaco	Victoria fine sandy loam	153
Cabbage	Copenhagen Market	Weslaco	Victoria fine sandy loam	667
Carrots	Danver's	Weslaco	Victoria fine sandy loam	233
Eggplant	Imperial Black Beauty	Weslaco	Webb fine sandy loam	112
Endive	Green Curled	Weslaco	Brennan fine sandy loam	559
Mustard	Southern Giant Curled	Weslaco	Brennan fine sandy loam	498
Mustard	Tender green	Weslaco	Webb fine sandy loam	1071
Mustard	Unknown	Sugar Land	Miller silt loam	510
Mustard	Southern Giant Curled	Weslaco	Victoria fine sandy loam	866
Mustard	Southern Giant Curled	College Station	Lufkin fine sandy loam	1185
Okra	White Velvet	Weslaco	Webb fine sandy loam	251
Pepper	California Wonder	Weslaco	Webb fine sandy loam	312
Potatoes, Irish	Early Triumph	Sugar Land	Miller silt loam	220
Potatoes, Irish	Bliss Triumph	Weslaco	Victoria sandy loam	347
Potatoes, Irish	Triumph	Weslaco	Victoria fine sandy loam	162
Potatoes, Irish	Irish Cobbler	Sugar Land	Lake Charles clay loam	160
Potatoes, Irish	Triumph	Sugar Land	Lake Charles clay loam	1045
Spinach	Unknown	Sugar Land	Miller silt loam	821
Spinach	Bloomsdale Savoy	Weslaco	Brennan fine sandy loam	679
Squash	Giant Summer Straightener	Weslaco	Webb fine sandy loam	290
Swiss Chard	Giant Lucullus	College Station	Lufkin fine sandy loam	2088
Tomato	Bonny Best	Weslaco	Webb fine sandy loam	351
Tomato	Marglobe	Weslaco	Brennan fine sandy loam	339
Turnips, leaves	Shogoin	Weslaco	Webb fine sandy loam	723
Turnips, leaves	Purple Top White Globe	College Station	Lufkin fine sandy loam	1525
Turnips, roots	Shogoin	Weslaco	Webb fine sandy loam	460
Turnips, roots	Purple Top Globe	Weslaco	Victoria fine sandy loam	705
Turnips, roots	Purple Top White Globe	College Station	Lufkin fine sandy loam	833

Table 6. A comparison of the iodine (parts per billion) in vegetables from different states

	Texas	Oklahoma*	Georgia†	South Carolina‡	Calif.‡
Beans	955	501	...	...	...
Beets, roots	377	245	...	...	...
Beets, leaves	854	651	...	...	8
Cabbage	912	286	...	...	...
Carrots	233	507	...	...	8
Mustard	826	561	...	...	...
Okra	251	777	...	412	...
Potatoes	387	210	54	333	...
Spinach	750	483	567	...	32
Tomato	345	379	...	...	20
Turnip greens	1124	676	226	...	...

*See Literature cited, 25
†See Literature cited, 27
‡See Literature cited, 52

are lower than the averages reported for Oklahoma (25), but for carrots and tomatoes are very much higher than those reported for California (52). Conner (12) states that vegetables grown in Florida contain about the same quantities of iodine as similar crops grown in South Carolina. Potatoes from Michigan contained 94 parts per billion of iodine (64), from Minnesota, 86 parts per billion (64), from Pennsylvania, 78 parts per billion (23), from the eastern section of Minnesota, 85 parts per billion (50), and from the western section of Minnesota, 226 parts per billion (50), while the average of 5 samples of potatoes grown in Texas was 387 parts per billion (Table 6). Cabbage from the east-northeast section of Minnesota contained 111 parts per billion of iodine, and from the southwest section of Minnesota, 174 parts per billion (51), while the average of the Texas samples (Table 6) was 912 parts per billion. McClendon and his associates are of the opinion that the lower occurrence in goiter in the western sections of Minnesota, as compared with the eastern section of the state, is largely attributable to the higher iodine content of the vegetables. Cabbage grown in Texas contained 912 parts per billion of iodine, compared with 174 parts per billion in the less goitrous part of Minnesota; potatoes grown in Texas contained 387 parts per billion of iodine, compared with 226 parts per billion in the less goitrous parts of Minnesota. If McClendon and his associates are correct, the comparatively high iodine content of Texas vegetables should be sufficient to preclude the probability of the development of goiter in Texas because of an insufficient supply of iodine in vegetables.

The limited number of vegetables analyzed is of course not sufficient to represent all parts of the vast area of Texas.

Iodine in Cottonseed Meal

Cottonseed meal was analyzed for iodine in order to compare the quantities of iodine which could be taken up by the cotton plant from soils in different parts of the State. Since cottonseed meal could be readily secured and represents a single kind of plant grown on different soils

Table 7. Iodine (parts per billion) in samples of cottonseed meal

County	Primary geographic division (Fig. 1)	Number of samples	High	Low	Average
Anderson	1	4	166	52	98
Bastrop	3, 1	5	218	60	109
Bee	7	2	998	65	532
Bell	3	1	....	....	253
Bexar	7	3	140	65	108
Bosque	5	1	....	....	27
Bowie	1	3	201	102	150
Brazos	1	1	....	....	73
Brown	5	2	144	67	106
Caldwell	1, 3	4	203	92	156
Camp	1	3	157	89	132
Childress	9	5	534	94	217
Coleman	9	2	120	102	111
Collin	3	3	121	77	99
Colorado	3, 1	1	....	....	104
Cooke	5	1	....	....	146
Coryell	5	1	....	....	98
Crosby	10	1	....	....	42
Dallas	3	2	200	111	156
Delta	3	5	371	56	223
De Witt	3, 1	4	513	46	212
Ellis	3	7	475	50	155
El Paso	11	4	441	153	241
Erath	5	2	41	39	40
Falls	3, 1	4	807	79	341
Fannin	3, 1	3	214	61	120
Fayette	3, 1	2	84	55	70
Floyd	10	2	372	138	255
Fort Bend	2	2	93	40	67
Gonzales	3, 1	4	151	48	104
Grayson	1, 3	5	346	95	197
Gregg	1	1	....	....	139
Grimes	1	1	....	....	48
Guadalupe	3, 1	3	132	48	98
Hale	10	2	78	44	61
Hamilton	5	2	207	56	132
Hardeman	9	4	156	41	88
Harris	2	2	210	176	193
Harrison	1	1	....	....	189
Haskell	9	2	145	125	135
Henderson	1	4	184	42	119
Hill	3	7	194	65	151
Hopkins	1, 3	5	576	81	222
Houston	1	1	....	....	105
Hunt	3, 1	8	478	68	200
Jim Wells	7	2	216	91	154
Jones	9	3	140	42	91
Karnes	7	3	910	48	353
Kaufman	3, 1	7	230	23	77
Kent	9	2	163	56	110
Knox	9	2	76	67	72
Lamar	3	1	....	....	117
Lamb	10	1	....	....	249
Lavaca	3	2	899	708	804
Lubbock	10	5	223	50	125
McCulloch	9	3	265	132	199
McLennan	3, 1	6	437	59	164
Maverick	7	2	110	82	96
Milam	3, 1	3	587	77	282
Mitchell	9	1	....	....	131
Nacogdoches	1	2	504	232	368
Navarro	3	5	255	59	125
Nolan	9	2	129	95	112
Nueces	7	4	1420	29	465
Parker	10	1	....	....	48
Potter	10	4	105	55	81
Red River	1	2	83	64	74
Robertson	1, 3	1	....	....	511
Runnels	9	5	327	45	124
Rusk	1	2	262	71	167

Table 7. Iodine (parts per billion) in samples of cottonseed meal—Continued

County	Primary geographic division (Fig. 1)	Number of samples	High	Low	Average
San Patricio	7	1			115
Scurry	9	1			86
Smith	1	1			156
Tarrant	5	1			128
Taylor	9	1			156
Titus	1	1			67
Tom Green	3	2	241	37	139
Travis	3	2	235	159	197
Upshur	1	1			166
Victoria	7	6	291	32	142
Walker	1	1			170
Wharton	2	3	200	87	133
Wheeler	9	2	211	61	136
Wilbarger	9	1			512
Williamson	3, 1	4	405	61	173
Wood	1	2	42	33	38
Young	5	1			52

Table 8. Distribution of samples of cottonseed meal from different geographic divisions in various ranges of iodine content (parts per billion)

Geographic division	Average iodine p. p. b.	Distribution: Below 50	50-100	101-150	151-200	Above 200	Total
West Cross Timbers	92	3	4	3	0	1	11
East Texas Timber Country	96	11	33	12	8	3	67
Gulf Coast Prairie	131	1	2	1	2	1	7
Rolling Plains	141	5	12	10	4	7	38
High Plains	144	3	6	3	4	4	20
Blackland Prairies	240	0	12	16	14	27	69
Rio Grande Plain	251	3	5	7	1	7	23
Total		26	74	52	33	50	235
As percentage of all samples		11	31	22	14	22	100

Table 9. Mean iodine content of cottonseed meals (parts per billion) and of soils (parts per million) for various geographic divisions

Geographic Division	Iodine in cottonseed meal p. p. b.: Mean	High	Low	Standard deviation	Number of samples	Average iodine in soils p. p. m.
West Cross Timbers	92	207	27	6	11	5.0
East Texas Timber Country	96	262	23	5	67	2.2
Gulf Coast Prairie	131	210	40	6	7	3.5
Rolling Plains	141	534	41	11	38	7.1
High Plains	144	441	42	10	20	3.9
Blackland Prairies	240	899	50	19	69	5.8
Rio Grande Plain	251	1420	29	19	23	8.0

in a variety of climatic conditions, it is a good means of comparing the possibility of the soils to furnish iodine to plants. Iodine was determined in 235 samples of cottonseed meal sent in by inspectors of the Feed Control Service. Samples were used only from mills located in smaller towns; these were probably from seed produced in the locality of the mills, whereas samples from large mills in the larger cities might have come from seed from much larger areas.

The analyses of the cottonseed meals are summarized by counties in Table 7. The iodine content of different cottonseed meal samples ranged from 23 to 1420 parts per billion. Considerable differences occur in different samples from the same county. The data for variation and distribution, and the variation in the different sections of the state (see Fig. 1), are summarized in Table 8. Of the 235 samples, 26 contained less than 50 parts per billion of iodine, 126 contained between 51 and 150 parts per billion of iodine, and 50 contained more than 200 parts per billion. In the different geographic divisions, however, the relative proportion of samples in the different iodine groups varied considerably. For example, 84 per cent of the samples from the East Texas Timber Country contained less than 150 parts per billion, while 60 per cent of the samples from the Blackland Prairies contained over 150 parts per billion.

The mean iodine content, high and low analyses, and standard deviation of cottonseed meals from the different geographic divisions (Fig. 1) are shown in Table 9. The average iodine content of samples from the different divisions ranged from 92 to 251 parts per billion but in no case was it low. The average iodine content of the soils of the geographic divisions (20) is also shown in Table 9. The relative standing of the different divisions with respect to the iodine content of the meals is about the same as it is with respect to the iodine in the soils, with the exceptions that the iodine in the samples from the West Cross Timbers and Rolling Plains is comparatively low and that in the samples from the Blackland Prairies comparatively high. In general, however, there is a close relation between the iodine content of the meals and that of the soils.

The iodine content of cottonseed meal can contribute effectively to the needs of animals for iodine.

Iodine in Roughages and Grasses

The iodine content of 20 samples of roughages and grasses is shown in Table 10. Iodine in 6 samples of coarse roughage (fodders, silage, and stover) ranged from 53 to 115 parts per billion, with an average of 74 parts per billion. One sample of sumac silage, however, contained 835 parts per billion of iodine. Iodine in 5 samples of hay varied from 90 to 550 parts per billion, with an average of 271 parts per billion. Iodine in 6 samples of grass varied from 92 to 1086 parts per billion with an average of 492 parts per billion. A sample of chapparo prieto (Condalia obtusiflora) contained only 21 parts per billion, while a sample of prickly pear (Opuntia sp.) tips contained 1125 parts per billion. There was thus a

Table 10. Iodine (parts per billion) in various roughages and grasses

Laboratory Number	Forage	Locality	Geographic division (Fig. 1)	Iodine
37753	Sumac fodder	Big Spring	10	53
37618	Kafir fodder	Spur	9	55
37615	Red Top fodder	Spur	9	58
37617	Hegari fodder	Spur	9	69
37600	Silage	East Texas	1	95
39323	Sumac silage	Spur	9	835
39064	Hegari stover	Beeville	7	115
37731	Sorgo hay	East Texas	1	90
37512	Alfalfa hay	Rosser	3	92
37732	Alfalfa hay	East Texas	1	168
37645	Alfalfa hay (medium)	Balmorhea	11	455
37644	Alfalfa hay (grassy)	Balmorhea	11	550
34277	Buffalo grass	Sonora	8	92
40607	Dallis grass	Tyler	1	303
40611	Dallis grass	Angleton	2	336
37784	Sudan grass	Beeville	7	358
40609	Bermuda grass	Tyler	1	778
40606	Carpet grass	Tyler	1	1086
33419	Chaparro prieta	Laredo	7	21
39334	Prickly pear tips	Sonora	8	1125

Table 11. Iodine content (parts per billion) of young Bermuda and young and mature little bluestem grasses

Soil type	Bermuda	Bluestem young	Bluestem mature
Susquehanna silt loam	124	120	20
Lufkin fine sandy loam	120	123	24
Susquehanna fine sandy loam	78	44	25
Ochlockonee fine sandy loam	35	35	31
Victoria clay loam	387	35	33
Ruston fine sandy loam	162	347	34
Susquehanna fine sandy loam	121	61	40
Susquehanna fine sandy loam	521	254	52
Norfolk fine sandy loam	126	789	53
Nacogdoches gravelly fine sandy loam	17	465	61
Susquehanna fine sandy loam	161	151	90
Bowie fine sandy loam	34	209	173
Average	157	220	53

considerable range in the iodine content of different samples of the same type of forage, and a large range in the average iodine content of different types of forage.

The influence of the species and age of grass upon the average iodine content of some grasses is shown in Table 11. The results are somewhat erratic, but the average iodine content of young bluestem was appreciably higher than that of young Bermuda and about four times as high as that of mature bluestem.

Discussion of Results

While the necessity for small amounts of iodine in the development and healthful maintenance of the body has long been recognized, the quantities required have only recently been estimated. The requirements may be increased by certain unfavorable physiological, dietary, and environmental conditions. Under normal conditions, however, the quantity required is very small.

The daily iodine requirements for humans has been estimated by Marine, Lenhart, and Kimball (44) to be about 85 micrograms (a microgram is one one-millionth of a gram, or about two one-billionths of a pound), by Meerburg (54) from 80 to 100 micrograms, by Hercus and Purves (26), from 120 to 160 micrograms, by Cameron (9) from 35 to 70 micrograms, by Orr and Leitch (61), 45 micrograms for an adult male and 150 micrograms for a child, and by Levine, Remington, and von Kolnitz (35) and Mitchell and McClure (55) from 60 to 120 micrograms. McClendon (48) states that if the daily intake is less than 1 microgram per kilogram (2.2 pounds) of weight, danger of goiter in man exists; if it is near or above 2 micrograms, there is no danger of goiter, even though the susceptibility to goiter is increased by infectious disease or high fat or high cabbage diet. Remington and Levine (65) state that a diet probably does not produce goiter if it contains more than 35 parts per billion of iodine.

The daily iodine requirement for farm animals has been estimated by Levine, Remington, and von Kolnitz (35) to be from 20 to 40 micrograms per 1000 Calories of the ration. Using this estimate as a basis, Mitchell and McClure (55) estimate that the daily iodine requirement of a chicken is from 4.5 to 9 micrograms, of a sheep from 50 to 100 micrograms, of a pig from 80 to 160 micrograms, and of a cow giving 40 pounds of milk from 400 to 800 micrograms. Orr and Leitch (61) estimate that in non-goitrous regions the daily iodine intake of a fowl is 5 micrograms, of a sheep from 120 to 2,000, of a pig from 40 to 80, of a sow, about 200, and of a cow, from 3,000 to 30,000 micrograms; evidently, there may be considerable excess iodine at the higher levels, but the lower figures given by Orr and Leitch are in fair agreement with the estimates of Mitchell and McClure.

The iodine required by the body comes both from the water and from the food ingested. The mean iodine content of the 103 samples of water (Table 3) from cities in Texas was 56 parts per billion. Two quarts of average Texas city water would thus contain about 100 micrograms of iodine, or sufficient iodine for a day's requirement without including the iodine in the food consumed. Most people in Texas probably drink considerably more than that quantity per day and in so doing ingest in their drinking water alone, sufficient iodine for proper development and maintenance. Iodine in Texas vegetables has also been shown to be high, and in addition, people in many parts of Texas consume considerable quantities of sea food, which is very high in iodine. Very few of the roughages, grasses, and cottonseed meals contained less than 35 parts per billion; most of them contained much more than this amount. It seems highly probable, therefore, that in very few areas in Texas is the supply of iodine in drinking waters, foods, and feeds sufficiently low to be a dietary problem, and that goiter produced by an insufficient supply of iodine is of comparatively rare occurrence in Texas.

That this conclusion is warranted is shown by a survey of goiter among men drafted during the World War (37). The incidence of goiter among these men ranged from 2.691 per cent among men from Idaho to .025 per cent among men from Florida; Texas was second from the bottom of the list, with a goiter incidence of only .030 per cent. Reports of later goiter surveys in the United States (57, 58) corroborated these results; goiter among Texas school children (58) in Austin, Denton, El Paso, and Hidalgo was extremely rare. Since it is well known that mature individuals are much more resistant to the development of simple goiter than are children, it may safely be concluded that iodine deficiency in Texas is of comparatively minor importance and rare occurrence.

Goiter among animals in Texas is also comparatively rare. In cases where iodine is markedly deficient, pigs and lambs are often born hairless; no cases of hairless pigs or lambs have been reported from Texas. Goiter in cattle is extremely noticeable, the enlargement in the throat being very marked; this condition is not known among Texas cattle. Fenger, Andrew, and Vollertsen (17) reported that the yearly average iodine content of thyroid glands from hogs from North Dakota was 0.32 per cent on the desiccated, fat-free basis, while that in thyroids from hogs from Texas was 0.60 per cent, or nearly twice as great. The seasonal variations in the iodine content of the thyroid was much greater in the hogs from North Dakota, as compared with those from Texas.

Throughout Texas, the iodine content of waters, foods, and feeds is sufficiently high to insure that the occurrence of simple goiter, due to a deficiency of iodine, will be extremely rare. In cases where it does occur, it seems probable that simple adjustments of the diet will provide sufficient iodine.

The Use of Iodine in Table Salt and in Mineral Mixtures

During recent years, considerable interest has arisen concerning the use of iodized table salt for human consumption and iodized mineral mixtures for livestock. The use of iodized table salt and the addition of iodine to water supplies has been recommended by a number of investigators (8, 36, 42, 43, 44, 45, 47, 48, 49) in areas where a deficiency of iodine is definitely known to exist. However, there may be some danger from excess iodine, even in these deficient areas, when too much iodine is used (5).

The value of iodine in mineral mixtures for animals is doubtful, even in areas which are known to be deficient in iodine. Fairbanks and Curzon (15A) concluded that, except in special cases, it was uneconomical to supplement rations with iodine. The majority of the work done on this question indicates either that no beneficial effects were secured from its use, or that detrimental results were secured.

With poultry, the use of iodine salts greatly increased the iodine content of the eggs (62, 67, 70, 75) but did not improve the nutritive value of the ration (28), egg production, or rate of mortality (18, 29, 33). Iodine in feeds containing high amounts of iodine was considerably better than iodine in mineral mixtures (2, 75). The iodine in the eggs immediately decreased upon discontinuance of the iodine feeding, indicating that the bird was simply using the egg as an outlet from the body for excess iodine (75). The size and calcium content of the eggs may be decreased by iodine feeding (62). Goiter in poultry is exceedingly rare (30), except in certain minor areas (73).

With sheep, Malan, DuToit, and Groenewald (41) report that among ewes fed 50 milligrams of potassium iodide daily, only slightly more than the quantity recommended by Nichols (56), reproduction was abnormal; the condition was aggravated by feed low in carotene and was not overcome by more protein. Forbes and his associates (18) found no significant difference, except that the lambs fed iodine required more feed per 100 pounds of gain than did the lambs which received no additional iodine.

With hogs, Forbes and others (18) obtained no beneficial results with the use of iodine, while McClure and Mitchell (55) found no effect of iodine on the weight of the pigs but some indication that the retention of calcium was adversely affected. Evvard (15) recommends the use of iodine for hogs in goitrous regions.

With cattle (18), milk and cream from cows fed iodine had an objectionable odor and contained very large amounts of iodine. Calves that received iodine ate less hay and made appreciably less gains in weight than did those receiving no iodine.

All of the work discussed above, in which the use of iodine rarely gave any beneficial results and sometimes gave detrimental ones, was done in areas in which the iodine supply is known to be low and goiter is of considerable importance. In Texas, where the iodine content of waters, foods, and feeds has been shown by the work here reported to be high, and where goiter is of rare occurrence, it is certainly not to be expected that favorable results would be secured from the feeding of iodine in table salt or mineral mixtures. The addition of iodine to a diet already high in iodine results in more iodine being excreted in the urine (38, 39).

The use of iodized table salt for human consumption in Texas is not recommended, except under the supervision of a competent physician. The use of iodized mineral mixtures for livestock in Texas is not recommended.

SUMMARY

This bulletin presents the results of a study of the iodine content of vegetables, cottonseed meals, and roughages grown in Texas, and the iodine and salt content of 103 samples of city waters and 12 rural waters in Texas.

Iodine in city waters varied from 4 to 312 parts per billion, with an average of 56 parts per billion and a standard deviation of 60 parts per billion. Only 3 samples of city water contained less than 10 parts per billion iodine, the quantity thought by some investigators to be sufficient. Water from 3 cisterns contained from 3 to 5 parts per billion, and is comparatively low. Compared with waters from other areas, city and well waters in Texas are high in iodine.

Iodine in 37 samples of vegetables varied from 112 to 3502 parts per billion. Leafy vegetables contained much more iodine than root or fruit vegetables. Iodine varied with the part of the plant used for food, the variety, location, and soil. Compared with vegetables from other areas, vegetables grown in Texas are high in iodine.

Iodine in 235 samples of cottonseed meal varied from 32 to 1420 parts per billion. Twenty-six samples contained less than 50 parts per billion, 126 contained from 51 to 150 parts per billion, and 50 contained more than 200 parts per billion iodine. Iodine in cottonseed meals varied considerably in the different geographical divisions of the state; in general, there was good agreement between average iodine in cottonseed meal and average iodine in the soils of the several divisions.

Iodine in 6 samples of coarse roughage varied from 53 to 835 parts per billion; in 5 samples of hay, from 90 to 550 parts per billion, and in 42 samples of grass, from 17 to 1086 parts per billion. The average iodine content of young bluestem was higher than that of young Bermuda and mature bluestem grasses.

Iodine in Texas city waters, well waters, vegetables, cottonseed meals, roughages, and grasses is sufficiently high to insure adequate iodine intake by man and animals under ordinary conditions. In most cases, much more iodine is present than is required. Iodine in Texas foods, feeds, and waters is much higher than in similar material from goitrous areas.

The use of iodized table salt for human consumption in Texas is not recommended, except under the supervision of a competent physician. The use of iodized mineral mixtures for livestock in Texas is not recommended.

LITERATURE CITED

1. Adolph, W. H., and Prochaska, F. J. 1929. An iodine survey of Nebraska. J. Amer. Med. Assoc. 92:2158.
2. Almquist, H. J., and Givens, J. W. 1935. Effects of common feed ingredients on the iodine content of hen eggs. Poultry Sci. 14:182.
3. Balks, Rudolf. 1936. The iodine question in Westphalia. (Landw. Jahib. 81, 939-1002). C. A. 30:408.
4. Balks, Rudolf. 1936. Iodine content of foodstuffs. Z. Untersuch. Lebensm. 71:76-93.
5. Bechet, P. E. 1934. Iodized table salt as an etiologic factor in iododerma. (Arch. Dermatol. Syphilol. 29:529) C. A. 28:7354.
6. Beckwith, G. H. 1927. Iodine content of some water supplies in goitrous regions. Soc. Biol. and Med. Proc. 25:117.
7. Beckwith, G. H. 1928. The iodine content of tap-waters in goitrous districts. Zentr. ges. Hyg. 17:878.
8. Broll, H. R. 1931. Iodine in Baltimore city water in relation to goiter. Baltimore Health News, Monthly Bul. April, 1931, 106-107. C. A. 26:1366.
9. Cameron, A. T. 1931. Textbook of Biochemistry, Ed. 3,274. Macmillan and Company, New York.
10. Clark, H. W. 1925. Iodine and water supplies. Eng. News Rec. 95:470.
11. Clark, H. W. 1928. Iodine in the public water supplies of Massachusetts. J. New Eng. Water Works Assoc. 42:132-136.
12. Conner, W. H. 1931. Iodine content of Florida-grown crops. Fla. Agr. Expt. Sta. 45th Ann. Rept., 65.
13. Dietz, Carl. 1938. Iodine content of some Ohio vegetables. Proc. 23rd Ann. Meeting Ohio Vegetable Growers Assoc., 57-61.
14. Eldridge, E. F. 1924. The iodine content of Michigan water supplies. J. Amer. Public Health Assoc. 14:750-754.
15. Evvard, John M., and Culbertson, C. C. 1925. Studies in iodine feeding. I. Potassium iodide feeding beneficial to young swine. Iowa Agr. Exp. Sta. Res. Bul. 86.
15A. Fairbanks, B. W., and Curzon, E. 1940. Iodine in animal nutrition. North Amer. Veterinarian 21:81-89.
16. Fashena, G. J., and Trevorrow, V. 1936. A note on the determination of iodine in biological material. J. Biol. Chem. 114:351-355.
17. Fenger, F., Andrew, R. H., and Vollertsen, J. J. 1931. Geographic location and the iodine content of the thyroid gland. J. Amer. Chem. Soc. 53:237-239.
18. Forbes, E. G., et al. 1932. The value of iodine for livestock in Central Pennsylvania. J. Agr. Res. 45:115-128.
19. Fraps, G. S., and Fudge, J. F. 1939. Iodine in city waters and vegetables in Texas. Food Research 4:355-362.
20. Fraps, G. S., and Fudge, J. F. 1939. Iodine in Texas soils. Texas Agr. Exp. Sta. Bul. 579.
21. Fraps, G. S., and Fudge, J. F. 1940. Estimation of iodine in soils, plant material, and waters. J. A. O. A. C. 23:164-171.
22. Fraps, G. S., Fudge, J. F., and Carlyle, E. C. 1935. Estimation of iodine in soils. J. A. O. A. C. 18:314-315.
23. Frear, Donald E. H. 1934. A study of the iodine content of Pennsylvania potatoes. J. Agr. Res. 48:171.
24. Hathaway, J. C. 1924. The inverse relation of iodine and goiter in Utah. Soc. Expt. Biol. and Med. Proc. 22:183.
25. Heller, V. G., Jones, M., Pursell, L. 1935. Iodine content of Oklahoma vegetables. Okla. Agr. Expt. Sta. Bul. 229:2.
26. Hercus, C. E., and Purves, H. D. 1936. Studies on endemic and experimental goiter. J. Hyg. 36:182-203.
27. Holley, K. T., Pickett, T. A., and Brown, W. L. 1935. Iodine content of some Georgia vegetables and water as a factor in its variation. Ga. Agr. Exp. Sta. Bul. 190.
28. Holmes, A. D., Pigott, M. G., and Packard, W. H. 1934. The effect of supplementary iodine on the nutritive value of chick rations. J. Nutrition 8:583-595.
29. Johnson, E. A., Pilkey, A. M., and Edson, A. W. 1935. Effect of supplementary iodine on reproduction in the fowl. Poultry Sci. 14:16-23.
30. Kernkamp, H. C. H. 1925. Goiter in poultry. J. Amer. Vet. Med. Assoc. 67:223.
31. von Kolnitz, Harry, and Remington, Roe E. 1933. A simplified Karns technic for the micro-estimation of iodine. Ind. Eng. Chem., Anal. Ed., 5, 38.
32. Krauze, Stanislaw. The iodine content of some Polish waters. (Wiadomosci Farm. 62:85-88) C. A. 29:3077.
33. Lee, C. E., Hamilton, S. W., and Henry, C. L. 1936. The effect of supplementary iodine on egg production and mortality in the laying flock. Poultry Sci. 15, 4:307-310.
34. Levine, H., and Remington, R. E. 1933. Is goiter due to an iodine deficiency per se? J. Chem. Education 10:649-59.
35. Levine, Harold, Remington, Roe E., and von Kolnitz, Harry. 1933. Studies on the relation of iodine to goiter. II. Iodine requirement of the rat. J. Nutrition 6:345-354.
36. Little, B. C. 1923. Iodine treatment of water for prevention of goiter. J. Amer. Water Works Asoc. 10:556-558.
37. Love, A. G., and Davenport, C. B. 1920. Defects found in drafted men. U. S. War Department, Washington, D. C.
38. Lunde, G. 1927. The iodine elimination in the urine and the goiter prophylaxis with sea fish. Ber. Intern. Kropfkonferenz Bern.

39. Lunde, G. 1928. Studies on iodine metabolism. I. The iodine excretion in the urine of inhabitants of Norwegian goiter regions. Biochem. Z. 193:94-104.
40. Lunde, G. 1936. An inland goiter region without iodine deficiency. Ber. II, Intern. Kropfkonferenz Bern.
41. Malan, A. I., DuToit, P. J., and Groenewald, J. W. 1936. Mineral Metabolism. XXXV. The role of iodine in the nutritition of sheep. (Onderstepoort J. Vet. Sci. Animal Ind. 7:523-32) C. A. 31:7487.
42. Marine, D. 1933. The importance of relative iodine deficiencies in certain forms of goiter. J. Amer. Dietet. Assoc. 9:1-5.
43. Marine, David. 1935. The pathogenesis and prevention of simple or endemic goiter. Glandular Physiology and Therapy, Chap. 22. Amer. Med. Assoc. Chicago.
44. Marine, David, Lenhart, C. H., and Kimball, O. P. 1923. Studies on the prevalence of simple goiter. Western Reserve Univ. Bul. No. 7.
45. McCarrison, R. 1936. Recent researches on the etiology of goiter. (Int. Conf. Goitre, 1933.) C. A. 30:6433.
46. McCarrison, R. 1937. The problem of endemic goitre. The endocrines in theory and practice. H. K. Lewis and Co., Ltd., London, 96-105.
47. McClendon, J. F. 1926. Prevalence of simple goiter and its relation to iodine content of water and foods. J. Amer. Water Works Assoc. 15:222-3.
48. McClendon, J. F. 1935. Results of goiter prophylaxis with iodized salt. Science, 81:2103.
49. McClendon, J. F. 1939. Iodine and the incidence of goiter. Univ. of Minn. Press, Minneapolis.
50. McClendon, J. F., Barrett, Earl, and Canniff, Thomas. 1934. The iodine content of potatoes. Biochem. J. 28:1209-1211.
51. McClendon, J. F., and Holdridge, C. E. 1935. Iodine in cabbage. Biochem. J. 29:272-274.
52. McClendon, J. F., and Remington, R. E. 1929. The determination of traces of iodine. II. Iodine in vegetables. J. Amer. Chem. Soc. 51:394.
53. McClendon, J. F., and Sanford, J. R. 1928. Iodine in Maryland waters in relation to goiter. Soc. Expt. Biol. and Med. Proc. 26:263-264.
54. Meerburg, P. A. 1935. The iodine content of food in its relation to goiter. (Nederlands. Tijdschr. Geneeskunde 79, 3289-93) C. A. 29:8103.
55. Mitchell, H. H., and McClure, F. J. 1937. Mineral nutrition of farm animals. Bul. 90, National Research Council, Washington, D. C.
56. Nichols, J. J. 1938. The need for iodine in present day feed formulas. Mimeographed advertising publication of the Iodine Educational Bureau, Inc., New York.
57. Olesen, R. 1926. Distribution of endemic goiter in the United States as shown by thyroid surveys. U. S. Public Health Rept. 41:2691-2703.
58. Olesen, R. 1929. Distribution of endemic goiter in the United States as shown by thyroid surveys. U. S. Public Health Rept. 44:1463-1487.
59. Olin, R. M. 1924. Iodine deficiency and prevalence of simple goiter in Michigan. J. Amer. Med. Assoc. 82:1328-1332.
60. Orr, J. B., et al. 1936. Relation of the iodine contents of water, milk and pasture in the occurrence of endemic goiter in two districts of England. Med. Research Council (Brit.), Special Report Series 217:5-20.
61. Orr, J. B., and Leitch, I. 1929. Iodine in nutrition. Medical Research Council, London. Special Report Series No. 123.
62. Peano Eduardo, and Pissaro, Irene. 1935. Halogenized eggs. I. Iodized eggs. (Rev. sudamericana endocrinal inmunol. quimioterap. 18, 85-106) C. A. 29:3387.
63. Reith, J. F. 1933. Goiter and water supplies in Holland. Water 17:1-13.
64. Remington, Roe E., Culp, Bartow, and von Kolnitz, Harry. 1929. The potato as an index of iodine distribution. J. Amer. Chem. Soc. 51:2942.
65. Remington, Roe E., and Levine, Harold. 1936. Studies on the relation of diet to goiter. III. Further observations of a goitrogenic diet. J. Nutrition 11:343-357.
66. Rogers, M. N. 1927. An examination of the radon and iodine content of certain Christchurch artesian and other waters, with respect to the incidence of goiter. Proc. New Zealand Inst. 57:893-899.
67. Scharrer, K., and Schropp, W. 1932. Feeding of iodine to chickens. (Biedermanns Zentr. B., Tierernahr. 4:249-264) C. A. 26:4631.
68. Shore, R. A., and Andrew, R. L. 1934. Goiter in school children. The incidence of goiter in school children in relation to the amount of iodine in soil and water in certain districts of the North Island of New Zealand. New Zealand Dept. Sci. Ind. Research, Dept. of Health Bul. 45.
69. Stone, C. B. 1927. The iodine content of some waters of eastern South Dakota. Proc. S. Dakota Acad. Sci. 10:35-45.
70. Straub, J. 1933. Iodine content of iodine eggs. (Z. Untersuch. Lebensm. 65:97-100). C. A. 27:4597.
71. Szniolis, A., and Marcinkowska-Lapienska, H. 1935. The iodine content of Polish waters in connection with goiter. (Arch. Chem. Farm. 1:52-63) C. A. 29:3717.
72. Trevorrow, Virginia, and Fashena, Gladys J. 1935. The determination of iodine in biological material. J. Biol. Chem. 110:29-38.
73. Welch, H. 1928. Goiter in farm animals. Mont. Agr. Exp. Sta. Bul. 214.
74. Weston, William. 1933. Studies in the prevention of goiter. Trans. Amer. Assoc. for the Study of Goiter.
75. Wilder, O. H. M., Bethke, R. M., and Record, P. R. 1933. The iodine content of hens' eggs as affected by the ration. J. Nutrition 6:407-412.