The Thiamin Content of Manitoba Vegetables and The Effects of Cooking, Storage and Canning on the Thiamin Content.

by

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INTRODUCTION

From a public health standpoint the nutritional deficiency diseases are not a cause for undue alarm in Canada. Cases of this nature are comparatively rare, e.g. at the Hospital for Sick Children (40) in Toronto in 1925 there were 154 cases of rickets. Ten years later, in 1935, there were only four. However, from dietary surveys made in Canada and the United States it is quite apparent that of the populations of both countries as many as one-third are receiving diets which are not in line with optimum health. The point stressed in these surveys was that the diets of the people of both countries are deficient in vitamin B_1 or thiamin. Surveys in Canada show that the average daily intake ranges from less than 0.6 to 1.2 milligrams per day (30). This is to be contrasted to a recommended daily intake of 1.8 milligrams for men and 1.5 milligrams for women, approved by the Canadian Council on Nutrition in 1942.

From the large numbers of assays which have been made of a wide variety of animal and vegetable tissues it is clear that thiamin is of nearly universal occurrence in quantities ranging from 0.1 to 2.0 micrograms per gram. In the wide variety of products in the plant world these amounts are exceeded only in seeds and yeast grown in rich media. The task of estimating the thiamin supplied by mixed diets requires accurate analysis of a large number of essential foods. Vegetables rank high in the dietaries of not only Canada but also other countries of the world. A knowledge of the amount of thiamin present in such home products is necessary in order that programs to alleviate the above mentioned lack of this factor may be initiated.

As a consequence of a "sophistication" of the modern food supply, it is becoming increasingly difficult to set up dietaries that will ensure adequate nutrition. Extensive educational programs have failed to bring about a greater appreciation and usage of the natural foodstuffs such as whole wheat flour and bread. We insist on employing methods of cooking that cause a loss of most, if not all, of the essential minerals and vitamins. A continuation and extension of the preference for nutritionally inferior foods poses a question of grave concern with respect to the effect on the public health.

This is essentially true in view of the health problem that has come to light during the past war. The medical profession and nutritionists have at the present time, and in Winnipeg, a splendid opportunity to study a nutritional disease which is relatively rare in Canada. The Winnipeg Grenadiers returned some weeks ago, and we know that these boys, having undergone untold misery, are suffering from beriberi as a result of lack of Vitamin B_1 and general malnutrition. Recently I had the opportunity of visiting one of our local military hospitals and of interviewing one of the doctors and several of the patients. The following are a few of the facts as taken from one of the hospital case histories:

> The patient was shipped out to Hong Kong in October, 1941. The Government surrendered Hong Kong December, 1941. Food in the camp in which he was placed was very poor. He was given one can of "vegetable soup" made from grass and herbs per day with two small buns made of white bread and one cup of tea, given at dinner. He had meat twice for the duration of his stay in Hong Kong (Jan. '42 - Sept. '42.)
>
> He was shipped to Japan in 1943. His feet were sore and weak and he had burning pains in his legs. Finally his feet became numb and he went blind. Shortness of breath developed in the summer of 1944 and a pain over the apex of the heart radiating to underneath the shoulder blades began in the fall of 1944. He was in Koki hospital for six months with beriberi and malnutrition. This was in November 1944 until April 1945. When taken prisoner he weighed 228 pounds. While a prisoner he came down to 98 pounds. His present weight is 198 pounds.

It is in such cases as this that as complete a knowledge as possible of the chemical composition of foodstuffs is essential.

With the availability of greatly improved methods of assay it has become a relatively simple problem to determine the vitamin supply in our foods. However, it is becoming more and more important that we determine values for foods as they are consumed. The vitamin content of the vegetables prior to cooking or processing may be affected by long periods of holding in the retail stores. There is considerable interest in improved cooking methods and evidence of this better vitamin retention through their use is now available. Losses due to home and commercial canning of vegetables have heretofore been regarded as inevitable but many of these losses may be reduced as easily as those encountered in the final cooking procedure.

It is for this reason that a study of the thiamin content of Manitoba vegetables and the effects of processing and storage on the thiamin content has been undertaken. A large representative group of vegetables has been covered and the effects of canning, storage, and cooking have been determined.

It has also been suggested that soil type and nutrient supply both have an effect on the thiamin content of vegetables. It is clear, however, that only a few of the many possible relationships have been studied. An attempt is made in these experiments to study the variation in thiamin content of Manitoba vegetables over a considerable area. Seven districts have been considered and although it was impossible to secure data on soil type, the degree of variability has to some extent been determined.

REVIEW OF LITERATURE

Although scurvy, rickets, beriberi, and pellagra are widely spread and have been known throughout recorded medical history, it is only during the most recent years that the causes of such diseases have been found to be that of dietary origin.

It was Takaki, Director-General of the Japanese Navy, who early discovered that the occurrence of beriberi could be reduced to a minimum by the addition of more meat and vegetables to the sailors' diet. Following this Dr. Christiaan Eijkman in 1897 found that fowls fed on polished rice developed convulsions and opisthotonus. This is a spastic condition characterized in birds by retraction of the head and protrusion of the abdomen.

In 1911 Funk attempted to isolate from rice polishings the substance active in the cure of beriberi, and in 1912 he assembled the facts concerning beriberi, scurvy, rickets and pellagra. He advanced the theory that other vitamins similar to his so-called "anti-beriberi vitamine" must exist and that these substances would be capable of curing these deficiency diseases. By a long and troublesome extraction Jansen and Donath (24) in 1926 isolated from rice polishings, in extremely small yields, a highly active hydrochloride which analyzed for the empirical formula $C_6H_{10}N_2O$. Application of the methods of Jansen and Donath to the extraction of yeast enabled a group of workers in the Gottingham Laboratory of Professor Windaus (46) in 1932 to isolate small amounts of a highly active material. This proved to be essentially identical with Jansen and Donath's substance, but was found to contain sulphur. Williams and his co-workers (44) in 1934 were able to devise a method for securing consistent yields of anti-neuritic vitamin hydrochloride, and in 1936 Williams (42) revised his formulation. Together with Cline, (43) he published a preliminary communication on the synthesis of the vitamin which was called thiamin.

The first systematic study of the distribution of the antiberiberi vitamin in foodstuffs was made at the Lister Institute of Preventive Medicine by Cooper (5) in 1912. This investigator used the prevention of polyneuritis in pigeons as a criterion. Not only did he deal with the quantitative determination of the preventive powers of various common foodstuffs against polyneuritis in these birds, but also he dealt with the fractionation of some of these foodstuffs. This was done in order to add further light to the subject of isolation of the active constituent or constituents.

This work was carried on during the first Great War due to war-time needs. As knowledge accumulated different techniques were devised and allowances made for the remaining factors of the vitamin B complex as they were duly discovered. Many workers began using the growth of rats as the test standard. Others have since used methods based on one of the following factors: the stimulation of growth or of the fermentation process of some specific micro-organism; the cure of polyneuritic convulsions in rats; the relief of induced bradycardia in rats; and the chemical reaction of vitamin B_1. At present the fermentation methods and the chemical thiochrome procedure are particularly adapted to routine testing of biological materials.

Although several chemical methods have been proposed for the determination of vitamin B_1 during the last few years, perhaps the most commonly used and studied is the thiochrome method. In 1923 Jendrassik (25) demonstrated that a reduction of ferric ferricyanide with the formation of a blue color was found to be the reaction always given by extracts containing vitamin B. Jansen in 1936-38 (23) devised a procedure for the chemical determination of aneurin (vitamin B_1) depending on the quantitative oxidation of the vitamin to the fluorescent thiochrome. This was followed by an extraction with isobutanol, and the intensity of the fluorescence estimated by comparison in a standardized photoelectric fluorometer.

Since this time various alternative techniques for the thiochrome test have been recommended. Hennessy and Cerecedo in 1939 (21) outlined a method based on the oxidation of thiamin by $K_3Fe(CN_6)_6$ in an alkaline medium. Previous to the writing of this latter article attempts had been made to separate the thiamin from materials interfering in the assay by adsorption on Franconite or similar adsorbents. In order to provide a more efficient purification of the thiamin it was found that a base exchange procedure allowed for a simpler isolation of thiamin. This was more effective in preparing samples for the thiochrome assay, and by means of this step, materials which interfere chemically or physically are eliminated.

As early as 1929 specific efforts were being made to assay a great number of materials for their antineuritic vitamin B content. Evans and Lepkovsky (10), using rats as the experimental animal, found that the growth obtained in the absence of the antineuritic vitamin B depended largely upon the basal diet used. Fixsen and Roscoe (15) in 1939, noting the need for a reliable reference table published data on the vitamin content of human and animal foods, including results of biological tests prior to this time. Booher, Hartzler and Hewston in their book "The Vitamin Values of Foods" (2) summarize the available data on the vitamin content of foods in relation to the variety of plant or breed of animal.

In an outline of the fungus-growth method of thiamin determination Hamner, Stewart and Matrone (19) reported results on a number of vegetables. Data on the comparison of analyses of vegetables obtained by the fungus method and the chemical assay method as directed by Dr. L. R. Cerecedo of Fordham University were taken from a paper by Heller, McCay, and Lyon (20). The agreement between the two methods on individual samples appeared remarkably close.

In order to obtain detailed data on which average values might be based a large number of different varieties of vegetables grown in the Royal Horticultural Society's gardens were analyzed for vitamin content by Pyke (38). Those richest in B_1 were found to be Jerusalem artichokes, peas, parsley, garlic and spinach. The range for these products was from 27 I.U. per gram, the lowest value for spinach, and 150 I.U. per gram, the highest value noted for Jerusalem artichokes. It was felt that although vegetables do not contain a high concentration of vitamin B_1 they do provide an amount over and above that required to meet their own metabolism needs. Therefore, they should be considered as active contributors to the diet.

The changes that may occur during storage, processing, and preservation of vegetables were described by Moyer and Tressler (32) who gave a detailed report on the comparison and specificity of the chemical and biological procedures. Eight frozen vegetables were used in the study and good agreement was found to exist between the bioassay, thiochrome, and fermentation methods. The values in µgs. per gram were --- according to the thiochrome method --- peas 2.60, asparagus 2.04, cut corn 1.17, lima beans 0.89, broccoli 0.88, snap beans 0.64, cauliflower 0.43, and spinach 0.55.

The thiamin content of asparagus has been given as 0.195 mg. per 100 grams by Fellers, Esselen and Fitzgerald (12); 0.219 by MacKinney and Sugihara (29); 0.183 to 0.174 by Moyer and Tressler (33); and 0.187 by Gleim, Tressler and Fenton (16).

Little difference was noted in three varieties of spinach by Kifer and Munsell (26). The groups of rats fed daily portions of 3 grams of Virginia Savoy, Viroflay, and Princess Juliana varieties made total gains in weight of 40.5 grams, 39.8 grams, and 37.5 grams respectively at the end of seven weeks.

The thiamin content of spinach has been presented as 0.050 mg. per 100 grams by Williams and Spies (45); 0.108 by Fellers, Esselen and Fitzgerald (12); 0.126 by Conner and Straub (4); and 0.304 by Nagel and Harris (34). The latter study was carried out under restaurant conditions and the loss of thiamin due to large cookery procedures was reported as an average of 35 percent. MacKinney and Sugihara (29) report the thiamin value of dehydrated spinach as 1.02 mg. per 100 grams.

Factors Affecting Vitamin Values of Foods.

1. Natural Variations.

It is a recognized fact that variations in the vitamin content of vegetables as harvested are bound to be present. Perhaps the factors contributing to these variations could be listed as climate and soil, variety, degree of maturity, and selective concentration in different parts of the plant. However, while soil fertility is known to affect size of harvest, flavor and mineral content of foods, there is relatively little information concerning its influence upon vitamin content.

In order to study the effect of environment on the thiamin content of peas, the same variety of pea was grown in one year by Fincke et al. (14) in three different parts of Oregon, i.e. Corvallis, Astoria, and Pendleton. In addition the same variety was raised in the same place two different years. A significant difference was found in the thiamin content of tall Alderman peas grown in one place in 1938 to the thiamin content of those grown in the same place the following year. On the other hand, certain varieties of peas grown in different parts of the state the same year contained approximately the same amounts of thiamin.

Several studies have been carried out on the vitamin A content of various vegetables as affected by different conditions of soil determinations. Swanson et al. (40) report that the application of certain specific fertilizers did not influence the relative quantity of vitamin A present in a root vegetable in Buckner soil in a section of Iowa. Whether the vitamin B_1 content of such vegetables would be similarly unaffected elsewhere is a matter requiring further investigation.

2. Effect of Cooking Procedures.

Aughey and Daniel (1) carried out an extensive study in 1940 to determine the effect of different cooking methods on the thiamin content of a representative variety of foods. The results obtained were as follows: thiamin destruction in some vegetables boiled in water amounted to as much as 22% with an additional 15% dissolved in the cooking water. However, in direct contrast to Richardson and Mayfield (39) there was found to be no loss of thiamin in carrots prepared either by the boiling or pressure cooker methods. A 33% loss of thiamin in the boiled pared potato (20% destroyed, plus 13% dissolved in the cooking liquid) was reported. Spinach lost 30% of its thiamin value (22% destroyed and 8% recovered in the cooking liquid); green peas cooked without soda lost 20% of thiamin and when cooked with soda lost 33% (11% in both cases dissolved in the cooking liquid); snap beans lost 32% of their original thiamin content (14% retained in the cooking liquid).

Employing two cooking methods, Oser, Melnick and Oser (35) undertook a study to determine the difference in degree of retention of vitamins and minerals as affected by variations in culinary methods. Analyses were conducted for the carotene, thiamin, ascorbic acid, riboflavin, nicotinic acid, iron, calcium, and phosphorus contents of four representative vegetables, before and after cooking. By using the thiochrome procedure of Hennessy a consistent loss of thiamin was found to be significantly greater with the first method of cooking which utilized a larger amount of water than with the second. Thiamin was destroyed to an extent of approximately 8% in the new and improved method of cooking. This is to be contrasted to losses amounting to 48% which were incurred by the poorer cooking processes. It was concluded, however, that outside of a few isolated cases, if the improved methods of cooking are followed there should be no more than 10% loss in either vitamins or minerals.

Thiamin losses in large quantity cookery were investigated by Heller, McCay and Lyon (20). These experiments were conducted at one of the cafeterias feeding industrial workers at the Brooklyn Navy Yard. Although steps were not taken to determine at which stage in the cooking process the greatest amount of thiamin was lost, the losses of this vitamin during the cooking and holding processes were calculated as from 16% to 64%, with an average of 37%. Such high losses were indicative of poor cooking procedures and changes were immediately enforced.

In 1942 Lane, Johnson and Williams (27) attempted to formulate a sequence of diets which would contain all of the more important foodstuffs of the American dietary. As part of these studies, the cooking procedure, representing a common customary kitchen practice, was studied as to the effect on B_1 content of the vegetables and foods employed. The thiamin content of the cooking water was particularly stressed, to such an extent that it would be necessary to use a correction figure on the vitamin values listed as "yield as purchased" by adding the "B_1 in total liquors" or vice versa.

In the Massachusetts study (11) referred to in connection with canning losses in green snap beans it was found that very small or no losses in thiamin and riboflavin were noted as a result of cooking. The samples of frozen, canned, and dehydrated beans were 16 months old when the cooking tests were made. However, the vitamin B_1 content of the vegetable as purchased and as served did not vary to any great extent.

Several practices commonly employed in the home in cooking asparagus and spinach were investigated by Gleim, Tressler, and Fenton (16). These experiments were conducted in order to determine how these methods compared in conserving the thiamin of these vegetables during cooking. The larger amount of water in all cases increased the amount of thiamin dissolved in the cooking water and decreased the retention of thiamin in the vegetable. However, little actual destruction of thiamin because of boiling was found. Similar results occurred whether the vegetable was fresh, stored or frozen. The results of this study are summarized in Table 1.

TABLE 1.

EFFECT OF COOKING IN LARGE AND SMALL AMOUNTS OF WATER ON RETENTION OF THIAMIN IN FRESH, STORED AND FROZEN ASPARAGUS AND SPINACH.

	Asparagus					Spinach				
	Method of Cooking			Thiamin		Method of Cooking			Thiamin	
Condition of Vegetable	Weight of Water	Time to Return to Boil	Time of Boiling	Retention	Solution	Weight of Water	Time to Return to Boil	Time of Boiling	Retention	Solution
	gm.	min.	min.	pct.	pct.	gm.	min.	min.	pct.	pct.
Garden, fresh	1,200 60	2 2	8 8	71 78	20 9	600 60	2 2	6 6	50 73	43 22
Stored for 24 hours at 18.8 to 25.5°C. (66° to 78°F.)	1,200 60	2 2	8 8	83 89	12 --(1)	600 60	2 2	6 6	53 81	54 25
Stored for 1 week at 0° to 4.4° C (32° to 40° F.)	1,200 60	2 2	8 8	79 92	17 --(1)	600 60	2 2	6 6	50 82	48 28
Commercially frozen	1,200 60	3 3	4 4	74 86	33 18	600 60	3 3	3 3	61 94	39 5

(1) Cooking water not analyzed.

Although up to 1923 practically all the data bearing on the effect of cooking upon the vitamin content of cabbage were to be found in the publications of English investigators, interest was rising on this side of the ocean. In a single experiment to determine the value of cooked cabbage as a source of vitamins A and B, Eddy, Shelow, Pease, Richer, and Watkins (9) report that rats fed a diet in which 15% of the otherwise basal diet was supplied by pressure cooked cabbage in one case and open kettle cabbage in the other grew as well as those on diets adequate in all respects. In the minds of these investigators the results appeared to confirm some earlier views in that the cooking process had little if any destructive effect upon the vitamins A and B in cabbage.

Estimation of vitamin B_1 by the Phycomyces method (31) showed that when raw potato was steamed three times, and the liquid portion discarded, the loss of the vitamin was very high. This was comparable with the losses incurred when the potato was sterilized at pH 9.0. The greater part of the vitamin B_1 was washed out from the potato during steaming.

3. Effect of Common Storage.

With the shipping, storage, freezing and marketing of commercial fruit and vegetable crops, considerable delay usually occurs between the time the vegetable is harvested and when it is prepared for the table. It is even possible that long periods of time may elapse between harvesting and preparation for the table of products from the home garden. Vitamin losses do occur in these storage periods, the extent depending upon the conditions of storage and the vitamin under consideration. Although more studies have been carried out particularly with respect to ascorbic acid, a number of experimental stations have dealt specifically with storage losses of thiamin.

Employing the rat growth method of vitamin determination, Langley, Richardson and Andes (28) estimated the vitamin content of carrots as they were secured in the fall. After the carrots had been stored for four months in boxes of sand in two different storage cellars, they were again tested, when raw and cooked, to find whether storage had affected the vitamins in the carrots. There appeared to be no decrease in the potency of vitamin B_1 in raw carrots after storage in either cool or warm cellars. After cooking, either in the fall or after storage, there seemed to be a rather uniform but slight decrease in the potency of the vitamin.

Of eight vegetables grown in the region of Geneva, N.Y. peas and asparagus were found by Moyer and Tressler (33) to have thiamin contents sufficient to make a significant contribution to the daily diet. When one lot of Thomas Laxton peas were processed a delay of 16 hours occurred between the time of harvesting in the field and vining, during which time vines were spread out in a thin layer over the floor. There was a second delay of over three hours between the time of shelling and washing. There was no loss of thiamin noted in spite of these delays.

After storage for twenty-four hours at room temperature the losses of thiamin from asparagus and spinach as reported by Gleim, Tressler and Fenton (16) were negligible. Further storage for one week at 0° to 4.4° C. caused a loss of 18% thiamin in the asparagus and 15% in the spinach.

4. Effect of Canning.

Little information is available on the effects of commercial canning operations on the retention of thiamin in vegetables. Data, although still inadequate are somewhat more complete concerning the effect of home canning on the thiamin retention in vegetables. However, as the methods of treatment in both commercial and home canning vary so distinctly, only when the nature and treatment of the raw products and canning methods employed are parallel, can they be correlated. Information is also lacking on the changes in nutritive value which are likely to occur from the time the product is processed until it is consumed. Time and temperature of storage are factors which may cause significant changes in the nutritive value of canned foods. This is true particularly with reference to changes in vitamin content.

Richardson and Mayfield in 1932 (39) studied the vitamins B_1 and B (complex) content of the Netted Gem variety of potato and the Chantenay carrot. The carrots were subjected to home canning by the hot pack method in both the oven and the steam pressure cooker. No loss was noted when carrots were canned in the oven, whereas there was a slight loss due to the pressure cooker process. Oxidation of the vitamin after it had been made more available by the canning process was considered the answer to the loss of vitamin in the canned carrots after they were again tested in the spring.

Fellers, Esselen, and Fitzgerald (12) studied the effect of canning on the retention of thiamin in vegetables.

Using the bioassay method the effects of the entire canning operation were determined on four vegetables with the following results: asparagus 72%, peas 60%, lima beans 28%, and spinach 71%. As part of a study of the influence of processing on the vitamin content of green snap beans, Farrell and Fellers (11) determined the thiamin content of the beans while fresh and raw, after canning, and after storage of the canned products for 12 months at 38° F. in a dark room. A 17% loss resulted in canning at the normal pH of 5.3 and storage for twelve months resulted in a 45% loss. Thirty days after canning vitamin determinations were made separately on the solid and liquid contents of the jars with the result that 30% of the thiamin and riboflavin in the canned beans was found in the liquid portion. This particularly stresses the point that in most cases the liquid portion of canned vegetables should be utilized in order to obtain the full nutritive value of the food.

Fincke (13) observed a general trend towards lower thiamin contents of peas scalded for longer times and at higher temperatures. No significant difference was noted between peas blanched in steam or in hot water at the same temperature for the same length of time.

Surveys conducted by Clifcorn and Heberlein (7) indicate that blanching and processing are of greatest concern in the preservation of thiamin.

In 1924 about nineteen million cases (24 No. 2 cans each) of peas were canned in the United States. With so large a production and consumption of a single food stuff Eddy, Kohman, and Carlsson (8) felt that a comprehensive study of the vitamins in this product was necessary. Whereas no loss in the B value resulted in home cooking or in processing, the duration and method of blanch appeared to be an important item. It was recommended that this process be reduced as much as possible to conserve the full value of this factor.

Guerrant, Vavich, and Dutcher (18) emphasize the necessity of storing canned foods under the most favorable conditions in order to retain maximum vitamin content. It was found that although thiamin retention proved to be least affected by time of storage it was most severely influenced by the temperature of storage. At the end of a 365-day period at 30° F, all three foods studied retained essentially 100% of their original thiamin content. When stored at 110° for one year these three products, tomato juice, lima beans, and yellow corn lost 69, 50, and 70% respectively, of the original thiamin content.

Vitamin B_1 in sixteen samples of commercially canned tomato juice was estimated by the growth of rats receiving a diet deficient in vitamin B_1 by Poe in 1943 (37). The results are expressed in Sherman units as the amount of activity needed to promote 3 gm. weight increase weekly. The average was 22 of such units per 100 ml. and the range was 20.0 to 27.0 units per 100 ml.

Filtration of the juice did not alter its vitamin B_1 content.

A nutrition program sponsored jointly by the National Canners Association and the Can Manufacturers Institute and organized in early 1942 (6, 22) enabled a study to be carried on by selected universities. This study included data covering a more extensive field than anything published up to this time on the thiamin and niacin content of canned foods. The extent of the range in thiamin content was found to vary considerably from product to product; the highest values in the cases of apricots, green beans, white corn, peas, spinach, tomato juice and tomatoes being four times the lowest values. Can size, time of harvest or pH of the products had little influence on the thiamin or niacin content. Of the samples analyzed the values found ranged from 0.008 mg.% in canned beets to 0.119 mg.% in canned peas.

EXPERIMENTAL

Selection of Vegetables.

The vegetables used in this problem were all obtained either in the city of, or from the surrounding districts of Winnipeg, Manitoba, Canada. The majority of the samples were grown in the University of Manitoba Experimental gardens and are marked as having come from the Fort Garry district. All vegetables used in the canning, storage and cooking experiments came from these gardens. Care was taken to select representative samples of fresh, good-looking products.

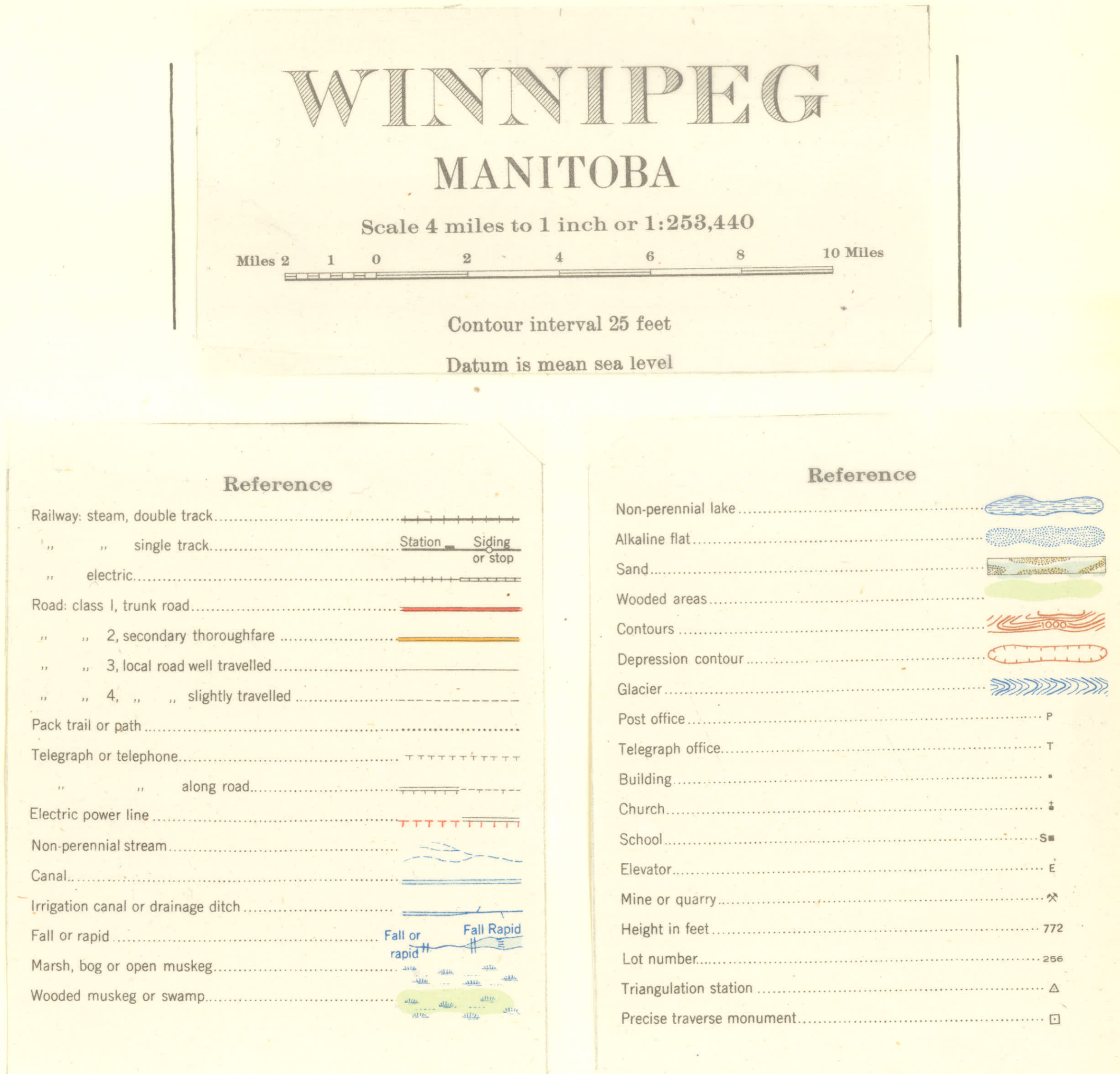
If it so happened that the product had to be purchased from the open market, the vegetable was wrapped in wax paper, stored in the refrigerator over night as it came from the market, and analyzed the following day. Such samples are distinguished by the term "market".

In order to study the variations in thiamin content of vegetables from districts outside of Winnipeg, samples of five vegetables from seven districts were chosen. The vegetables studied were beans, peas, potatoes, carrots and beets. The districts chosen were Springfield, Middlechurch, Domain, Narol, Fort Rouge, Fort Garry and St. James. (See Figure 1) Trips were made to these outlying locations the night before analyses were to be made and the vegetable treated similarly to those purchased on the open market.

Preparation of Vegetables for Fresh Analysis.

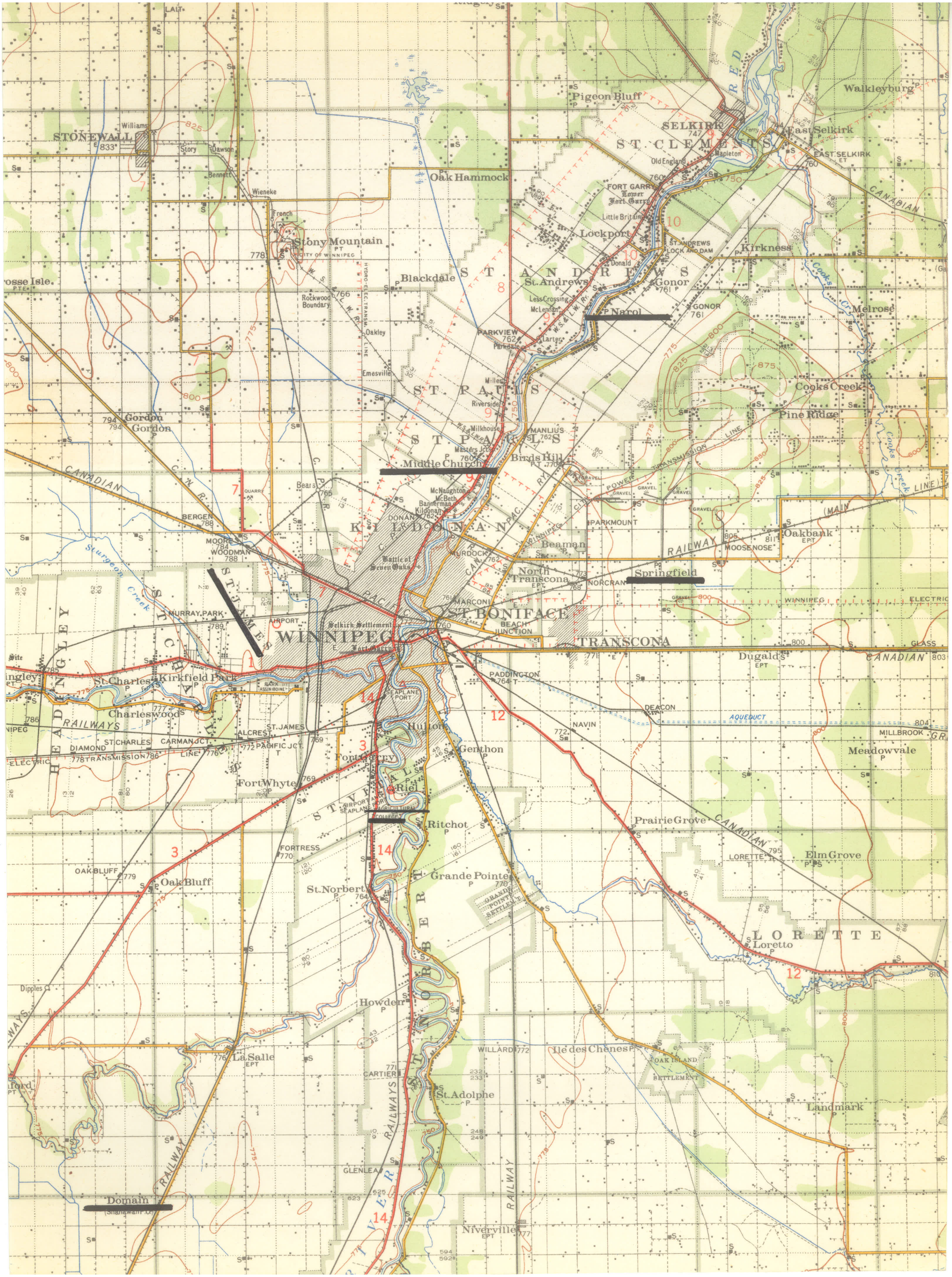
The vegetables were scrubbed and dried on paper towels in

FIGURE 1.



Taken from a map compiled, drawn and printed at the office of the Surveyor General, Ottawa, 1929. Reprinted at the office of the Sureyor General and Chief, Hydrographic Service, Ottawa 1938. Produced from field surveys and from information supplied by the Dominion and Provincial Departments and by Railway Companies.

map on next page



STONEWALL
Williams
Story
Dawson
Bennett
Wieneke
French
Stony Mountain
CITY OF WINNIPEG
Oak Hammock
Pigeon Bluff
SELKIRK
East Selkirk
EAST SELKIRK
ST. CLEMENTS
Mapleton
Old England
Walkleyburg
FORT GARRY
Lower Fort Garry
Little Britain
Lockport
ST. ANDREWS LOCK AND DAM
Kirkness
Blackdale
ST. ANDREWS
St. Andrews
Donald
Gonor
GONOR
Lower Crossing
McLennan
Narol
Melrose
Rockwood Boundary
Oakley
PARKVIEW
Parkdale
Larter
Emesville
ST. PAULS
Miller
Riverside
Cooks Creek
Pine Ridge
Gordon
Milkhouse
MANLIUS
Masters Jct.
Middle Church
Birds Hill
Bears
McNaughton
McBeth
Bannerman
Kildonan
DONAN
KILDONAN
Battle of Seven Oaks
BERGEN
MOORE
WOODMAN
PARKMOUNT
Beaman
Oakbank
MOOSENOSE
MURDOCK
North Transcona
NORCRAN
Springfield
MARCONI
ST. BONIFACE
BEACH JUNCTION
TRANSCONA
ST. JAMES
MURRAY PARK
AIRPORT
WINNIPEG
Selkirk Settlement
Fort Garry
HEADINGLEY
St. Charles
Kirkfield Park
ST. CHARLES
Charleswood
SEAPLANE PORT
Dugalds
PADDINGTON
DEACON
AQUEDUCT
NAVIN
MILLBROOK
Meadowvale
Hulton
Genthon
ALCREST
ST. JAMES
CARMAN JCT.
PACIFIC JCT.
DIAMOND
TRANSMISSION
LINE
Fort Whyte
Fort Garry
ST. VITAL
Riel
AIRPORT
SEAPLANE
AGRICULTURAL COLLEGE
Ritchot
Prairie Grove
FORTRESS
OAK BLUFF
Oak Bluff
LORETTE
Elm Grove
Grande Pointe
GRANDE POINTE SETTLEMENT
St. Norbert
ST. NORBERT
LORETTE
Loretto
Dipples
Howden
WILLARD
Ile des Chenes
OAK ISLAND SETTLEMENT
La Salle
CARTIER
St. Adolphe
Landmark
GLENLEA
Domain
(Shanawan P.O.)
Niverville
RED RIVER
CANADIAN NATIONAL RAILWAYS
CANADIAN PACIFIC RY.
WINNIPEG ELECTRIC
POWER TRANSMISSION LINE
Sturgeon Creek
Cooks Creek

order to remove any excess liquid. The whole large sample was prepared according to household usage, chopped, mixed, chopped, mixed again and a sample taken for analysis. In the case of storage vegetables the fresh sample was taken when the vegetable was stored. If both cooking and canning experiments were to be conducted the sample was divided into three parts according to the weight of the sample taken; one part was set aside for fresh analysis, the second was cooked and the third lot prepared for canning. All samples were weighed to the nearest 0.1 gram.

Preparation and Canning of Vegetables.

In order to have a broad picture of the effects of the various steps in home canning operations on the thiamin content of vegetables it would be desirable to carry such a procedure through many times. This was impossible because of the large amount of time involved. It was also necessary to limit the number of products studied. The effect of canning on the thiamin content of twelve different vegetables was determined. On the same day that samples for fresh analysis were taken, four to five jars each of asparagus, green peas, Swiss chard, beets, carrots, beans, corn, tomatoes, tomato juice, pumpkin, squash and kale were canned and set aside in a dark, clean, well-ventilated room for future reference.

Vegetables were canned according to the standard methods of canning for general household usage as outlined by the New York State College of Home Economics at Cornell University, Ithaca, New York (36). In this bulletin it was suggested that less liquid would be lost during processing if the jars were completely sealed beforehand. Accordingly, the canning process was carried out by filling the jars with boiling hot liquid and sealing at once. Although war-time rubbers were used the only trouble encountered was during the canning of kale. A first lot of six jars was completely lost due to bursting of the rubbers. However, of six jars in a second lot only one was lost. The high percentage of loss in the first case could be attributed either to too close packing of the vegetable or to a poor box of rubbers.

Sampling for Analysis of Canned Goods.

The weight of each jar prior to opening was recorded. The solids of asparagus, beets, beans, corn, carrots, kale, peas, and Swiss chard were separated from the liquids on a screen. The solids were weighed and the liquid weight determined. In all cases the whole amount of solids was mixed as well as possible without macerating the materials. Two 50 to 100 gm. samples were removed from the mixture and separately blended in the Waring Blendor with measured amounts of 0.1N sulphuric acid in preparation for the extraction of thiamin.

In the cases of pumpkin, squash and tomatoes, it was impossible to separate the solid from the liquid. Therefore, samples were weighed directly from the homogeneous material and mixed directly with the sulphuric acid.

Tomato juice was not homogenized in the Waring Blendor, but the contents of the individual jars were simply stirred, the desired aliquot was then removed and sufficient o.1N sulphuric acid added.

Preparation and Storage of Vegetables.

At the same time that samples for fresh analysis were taken, between forty to sixty pounds of beets, carrots, parsnips, turnips, potatoes, and onions, and six fruits of cabbage, pumpkin and squash were stored under appropriate storage conditions. The storage houses used were those of the Plant Science Division of the University of Manitoba. After approximately four months all vegetables appeared to be in excellent condition, and were analyzed for thiamin content. In the cases of beets, cabbage, pumpkin and squash there were definite signs of either sprouting, spoilage or a tendency to become fibrous by the end of March and accordingly a third analysis was not made. Details of storage dates and conditions are included in Table 11.

Preparation and Cooking of Vegetables.

A comprehensive study was made of the effect of cooking on vegetables when fresh and stored, and after various periods during storage. The amounts of vegetable and water used for cooking was judged in order to provide from two to four average sized servings. Raw and cooked foods as well as the liquid drained from the cooked products were assayed.

The total cooking periods were determined by removing small portions of the vegetable from the pan at intervals, and

TABLE 11.

CONDITIONS UNDER WHICH VEGETABLES WERE STORED

Vegetable	Variety	Amount Stored	Date Stored 1944	Storage Conditions
Beets	Detroit Dark Red, C.E.F. Strain	50 lbs.	Oct. 10	Cool and moist (packed in peat)
Carrots	Chantenay	50 lbs.	Oct. 12	Cool and moist (packed in peat)
Parsnips	Hollow Crown	40 lbs.	Oct. ?	Cool and moist
Turnips	Purple Top Swede	50 lbs.	Aug. 20	Cool and moist
Potatoes	Warba	50 lbs.	Aug. 30	Cool and moist
	Irish Cobbler	50 lbs.	Sept. 7	Cool and moist
Cabbage	Danish Ballhead	6 heads	Oct. 21	Cool and moist
Onions	Yellow Globe Danvers Strain #11	60 lbs.	Sept. 25	Cool and dry
Pumpkin	Sugar	6 fruits	Aug. 28	Warm and dry
Squash	Green Hubbard	6 fruits	Aug. 28	Warm and dry

tested by cutting with a fork and tasting. Cooking studies for all vegetables were carried out in the same small enamel pan and on the same electric stove. Immediately after cooking, the cooking water from each vegetable was drained off, and the weight recorded. As quickly as possible representative samples of the raw and cooked foods and of the liquid were weighed. These samples were transferred to the jar of a Waring Blendor containing 150 cc. of 0.1N H_2SO_4. Care was taken to remove all adhering vegetable particles from the inside of jars in which the vegetable sample was weighed.

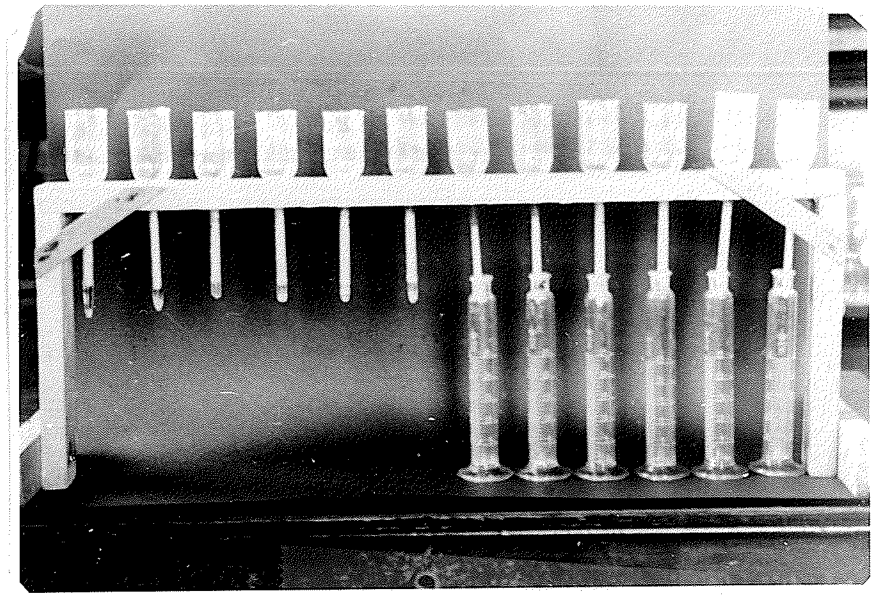
Moisture Determinations.

Duplicate two-gram portions of raw, cooked, canned and stored vegetables were weighed out immediately after sampling for moisture determinations. These portions were placed in weighed moisture pans and the pans plus the samples weighed accurately to the nearest .001 gram. The moisture pans containing the samples were then placed in a vacuum oven at 100°C. and twenty-five inches vacuum for twelve hours, after which time they were removed from the oven, cooled, and weighed again.

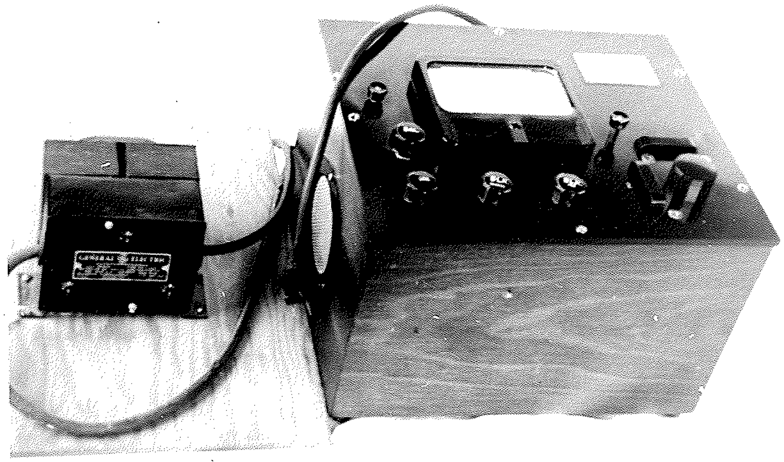
METHOD

Between 25 and 75 gram samples of the foods were weighed out for extraction with 0.1N H_2SO_4 and subsequent analysis. Thiamin was determined by the thiochrome method of Hennessy and Cerecedo (21) with slight modifications. The details of the method were: Duplicate samples of the prepared vegetable were mixed with 150 cc. of 0.1N sulfuric acid solution in the Waring Blendor. This required five minutes. It was made up to 300 cc. with more of the acid solution and was heated for one hour at 70°C. in a volumetric flask. 1.2 grams takadiastase in 20 cc. of 2.5 molar sodium acetate solution were added and the mixture heated for one hour at 50°C and twelve hours at 37°C. It was filtered and the filtrate made up to 500 cc. in a volumetric flask. An appropriate aliquot containing 0.5 to 5 micrograms of Vitamin B_1 as thiamin chloride was heated and allowed to seep through a 5 cm. column of activated 60 to 80 mesh Decalso in a base exchange tube (Figure 11). The barrel of the exchange tubes used was 0.7 x 10 cm. The reservoir which is at the upper end of the barrel had a 25 cc. capacity. The liquid was passed through the column a second time after which the vitamin was eluted from the Decalso by use of 25 cc. of a hot 25 percent solution of potassium chloride.

For the oxidation process 10 cc. of the KCl solution were put in each of two separatory centrifuge tubes. To the first, A, 3 cc. of a mixed reagent (made by diluting 1 cc. of 3% potassium ferricyanide solution to 100 cc. with 15% sodium hydroxide solution) were added quickly with mixing; to the second, B, 3 cc. of 15% NaOH were added in the same manner. 16 cc. of redistilled isobutanol were added to each. The stoppers were inserted and the tubes shaken vigorously for 1½ minutes. The tubes were centrifuged at 500-600 r.p.m. for ¾ minute, the stoppers removed and the lower layer drained off. Approximately two grams of anhydrous Na_2SO_4 were



A.



B

C.

FIGURE 11

A - SET-UP FOR ELUTION PROCESS 5 CM. COLUMNS OF 60- TO 80-MESH DECALSO

B - COLEMAN ELECTRONIC PHOTOFLUOROMETER MODEL 12.

C - WARING BLENDOR FOR SHREDDING THE TISSUE.

added to each, both vigorously shaken for twenty seconds and allowed to stand in order to ensure complete clarity.

The isobutanol layer was poured off into a cuvette. This was placed in a Coleman Electronic Photofluorometer, model 12, (Figure 11) and the fluorescence measured. The instrument was checked before each measurement with a standard quinine solution and the light intensity adjusted to the desired value by changing the setting of the iris diaphragm. A corresponding oxidation of a standard solution (1 cc. = 1 μg.) of thiamin chloride was run daily for each series of determinations. The standard solution of thiamin chloride used in all tests was made up in this laboratory from a stock standard solution. It was checked against a standard provided by Mr. A. W. Alcock, Chief Chemist of the Purity Mills Co. Ltd., and was found to agree satisfactorily.

The analytical error commonly accepted for the thiochrome method is $\pm$ 5 - 10 percent. Most of the duplicate thiamin analyses checked within $\pm$ 5 percent of one another. The results of all determinations are reported as micrograms of thiamin per 100 gms. of material and have been calculated to two places of decimals.

RESULTS AND DISCUSSION

1. General Assays.

The results of the analysis for samples of raw vegetables for moisture and thiamin are presented in Table 111. It will be noted that the data in the table include number of samples

TABLE 111

THIAMIN CONTENT OF MANITOBA VEGETABLES

Vegetable	Variety	No. of Samples	Moisture %	Thiamin, µgs./100 gms. Mean	Range
Asparagus	Mary Washington	2	91.88	63.81	63.49 - 64.12
	Market *	2	90.28	30.64	30.11 - 31.16
Beans	Round Pod Kidney Wax	4	90.39	55.42	49.39 - 61.48
	Market *	12	90.59	61.61	10.50 - 75.43
Beets	Detroit Dark Red	7	85.53	14.38	8.99 - 28.94
	Market *	12	87.38	16.69	5.66 - 31.41
Brussel Sprouts	Market *	1	81.80	87.53	
Cabbage	Danish Ball Head	4	92.01	32.52	30.45 - 37.44
Carrots	Red Cored Chantenay	6	90.48	19.70	13.37 - 25.84
	Market *	9	87.69	35.26	23.82 - 47.18
Cauliflower	Market *	2	91.17	87.45	77.80 - 97.10
Corn	Golden Bantum	2	73.43	109.60	109.0 - 110.2
Cucumber	Straight 8	2	96.54	22.30	21.89 - 22.72
Kale	Market *	2	82.15	49.50	48.82 - 50.19
Lettuce	Grand Rapids	2	93.97	30.04	29.95 - 30.09
	New York #12	4	85.63	18.09	16.73 - 18.91
Onions	Yellow Globe Danvers	6	87.56	18.52	9.33 - 28.50
Parsley	Market *	2	86.04	58.91	56.85 - 60.98
Parsnips	Hollow Crown	6	81.26	72.84	57.27 - 82.90
Peas	Laxton Progress	2	73.51	96.50	91.00 - 102.00
	Lincoln	2	80.96	174.92	166.8 - 183.0
	Homesteader	2	77.79	186.06	183.2 - 188.7
	Market *	10	77.29	211.41	175.6 - 279.5
Peppers, Green	King of the North	2	91.57	37.55	36.20 - 38.90
Pumpkin	Small Sugar	4	92.48	31.44	16.12 - 44.64
Potatoes	Irish Cobbler	6	76.41	90.32	81.29 - 102.82
	Warba	6	76.55	88.57	76.59 - 97.31
	Market *	10	81.26	68.49	51.23 - 90.05
Radish	Scarlet Globe	2	94.21	6.74	6.40 - 7.08
Squash	Golden Hubbard	4	89.78	12.81	5.92 - 17.75
Swiss Chard	Lucullus	2	93.78	24.74	23.73 - 25.76
Tomato	Market *	2	94.58	42.80	38.60 - 47.00
Tomato Juice	Market *	2		21.68	20.84 - 22.51
Turnip	Purple Top Swede	6	90.62	45.24	22.13 - 68.32

* - Bought on the open market.

and the minimum, maximum, and average quantities of the vitamin in question. Arithmetic averages based on numbers of samples were used throughout. It has been felt best to list the actual extreme values in all cases as in a few instances the number of samples was relatively small. As stated previously all thiamin values are reported as micrograms per 100 grams.

The thiamin content of average servings of Manitoba vegetables is shown in Table lV. In all cases the amounts for average servings were taken from values by Bowes and Church (3). The amount of thiamin in an average serving was calculated on the raw basis. Further studies indicate that a correction would be necessary to determine the amount as cooked and when canned.

The thiamin contents of the vegetables analyzed are of the same order as those reported by other investigators. From Table lll it can be seen that the thiamin content of all the vegetables studied varied from 6.40 µgs. per 100 grams, the lowest value for radish, to 279.5 µgs. per 100 grams, the highest value for peas. There also appears to be a wide variation within varieties. Laxton Progress peas had a low value of 91.00 µgs. per 100 grams, whereas Homesteader peas had a high value of 188.7 µgs. per 100 grams. A wide variation existed within a single variety. The highest value for pumpkin is almost three times the low value, and the same relationship would hold true for onions and beets.

The thiamin content of the potato ranges from 51 to 103

TABLE IV

THIAMIN CONTENT OF AVERAGE SERVINGS OF MANITOBA VEGETABLES (RAW BASIS)

Vegetable	Variety	Average Serving	Approximate Measure	Thiamin in Average Serving
		gm.		μgs.
Asparagus	Mary Washington	50	4 to 5 stalks, 4" long	31.90
	Market *	50	" "	15.32
Beans	Round Pod Kidney Wax	100	½ cup	55.42
	Market *	100	"	61.61
Beets	Detroit Dark Red	100	½ to 5/8 cup, diced	14.38
	Market *	100	"	16.69
Brussels Sprouts	Market *	70	6 average	61.27
Cabbage	Danish Ball Head	50	½ - ¾ cup	16.26
Carrots	Red Cored Chantenay	100	1 large	19.70
	Market *	100	"	35.26
Cauliflower	Market *	70	4 r. tbsp.	61.22
Corn	Golden Bantam	100	1 med. ear	109.60
Cucumber	Straight 8	50	8 slices, peeled	11.15
Kale	Market *	100	½ cup	49.50
Lettuce	Grand Rapids	10	1 lg. leaf	3.00
	New York #12	10	" "	1.81
Onions	Yellow Globe Danvers	100	2 to 3 small	18.52
Parsley	Market *	10	10 av. sprigs	5.89
Parsnips	Hollow Crown	100	½ large	72.84
Peas	Laxton Progress	100	½ cup, scant	96.50
	Lincoln	100	" "	174.92
	Homesteader	100	" "	186.06
	Market *	100	" "	211.41
Peppers, Green	King of the North	100	1 empty pod	37.55
Pumpkin	Small Sugar	100	½ cup	31.44
Potatoes	Irish Cobbler	150	1 medium large	135.48
	Warba	150	" "	132.85
	Market *	150	" "	102.73
Radish	Scarlet Globe	10	1, 1" in diam.	0.67
Squash	Golden Hubbard	100	½ cup	12.81
Swiss Chard	Lucullus	100	½ c leaves and stalks	24.74
Tomato	Market *	100	1 medium	42.80
Tomato Juice	Market *	100	½ cup	21.68
Turnip	Purple Top Swede	100	½ cup	45.24

* - Bought from open market.

micrograms per hundred grams, which would mean from 4 to 8% of the adult daily requirements in a 150 gm. serving (approximately the average daily consumption) if it were not for cooking losses.

The tomato is one of the most important protective foods because of its ascorbic acid content. However, on the basis of the available figures, tomatoes in amounts consumed cannot be considered as an important source of thiamin.

On the average it would appear that the soil vegetables contain a smaller amount of thiamin than those which grow above the ground. The thiamin content of the green vegetables such as peas and beans is particularly high. Some vegetables such as asparagus, beans and peas have relatively high vitamin B_1 content, but this is in contrast to that of root vegetables such as beets, onions and turnips. Potatoes are the exception in this case. Of the twenty-two samples analyzed all possessed a high thiamin content.

The high water content and great bulk of leaves, roots, and stems of plants prevent them from playing an outstanding role as sources of thiamin. However, the large amounts of vegetables consumed in the average American and European diet make these products of importance as dietary sources of vitamin B_1. Dried leaves, roots and fruits, moreover, often approach the value of whole seeds in their thiamin content.

The thiamin contents of five vegetables, beans, peas, potatoes, carrots, and beets, obtained from seven districts (see Figure 1) are included in Table V. The two values reported for an individual vegetable represent assays run on duplicate samples taken from one large representative sample. It is thereby possible to determine any error that might be present due to laboratory technique.

An examination of the data revealed that the thiamin values for the two samples of potatoes obtained from Springfield were completely out of line, as the difference between the two exceeded all other differences for any other vegetable. Due to the lateness of season and the inability to obtain another set of samples from this district it was felt that new values should be estimated. The method of estimating these values was that of Yates, as described by Goulden (17)[1]. The process was repeated several times until the values of 60.42 and 58.74 μgs. per 100 grams became constant.

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1. The mathematical basis for estimating values for missing plots is that by substituting another value the sum of the squares of the deviations from the mean will be a minimum. The following formula was used to estimate the missing values.

$$x = \frac{pP + qQ - T}{(p-1)\ (q-1)}$$

where p = number of vegetables.
q = number of districts.
P = total of all the districts for the one vegetable in which the missing value is found.
Q = total of all the vegetables in the same district as the missing value.
T = total of all plots.

TABLE V.

VARIABILITY IN THIAMIN CONTENT OF VEGETABLES OBTAINED FROM VARIOUS DISTRICTS

Districts	Vegetables, Thiamin Content, μgs./100 gms.									
	Beans		Beets		Carrots		Peas		Potatoes	
Springfield	62.12	61.72	23.44	25.67	24.39	24.99	175.60	168.69	60.42	58.74
Middlechurch	65.03	55.59	17.37	20.10	47.18	43.08	191.79	195.90	68.31	60.72
Domain	74.54	66.99	13.65	10.50	42.52	35.18	239.37	230.97	51.23	54.80
Narol	72.68	75.43	30.81	31.41	36.93	39.30	279.51	279.51	66.94	64.97
Fort Rouge	35.35	42.27	7.21	7.41	39.20	36.50	173.43	179.36	79.20	72.30
Fort Garry	59.68	61.48	8.99	9.17	38.40	37.20	183.01	166.83	71.60	72.40
St. James	64.34	63.25	5.66	7.01	23.82	23.82	188.76	183.37	82.68	84.48

The analysis of variance was applied to these data (Table VI) and the F values were found to equal 105.12 and 1.57 for vegetables and districts respectively. Referring to Snedecor's table (17) of F values for the five percent and one percent points it is noted that the F value for vegetables exceeds the five percent value of 2.78. This was to be expected as the thiamin content for different vegetables was found to vary to a great extent.

However, the experiment was designed to test whether there was a significant variation in the thiamin content of a single vegetable over various districts in and surrounding Winnipeg. The interaction variance was used in testing the significance of the districts and vegetables. Tested against error it obviously represents a fairly large effect and is taken as an indication of an interaction between the two factors that are concerned. The variance represented by error is determined from differences between the results for duplicate determinations and measures error arising merely from sampling and laboratory technique. Due to the estimation of two missing values for the set of results two degrees of freedom had to be removed from the total.

TABLE VI.

ANALYSIS OF VARIANCE FOR THE THIAMIN CONTENT OF VEGETABLES OBTAINED FROM DIFFERENT DISTRICTS IN MANITOBA

Sources of Variation	D.F.	Mean Square	F	5% Point
Vegetables	4	75650.237	105.12	2.78
Districts	6	1127.066	1.57	2.51
Interaction	24	719.638		
Error	33	13.726		

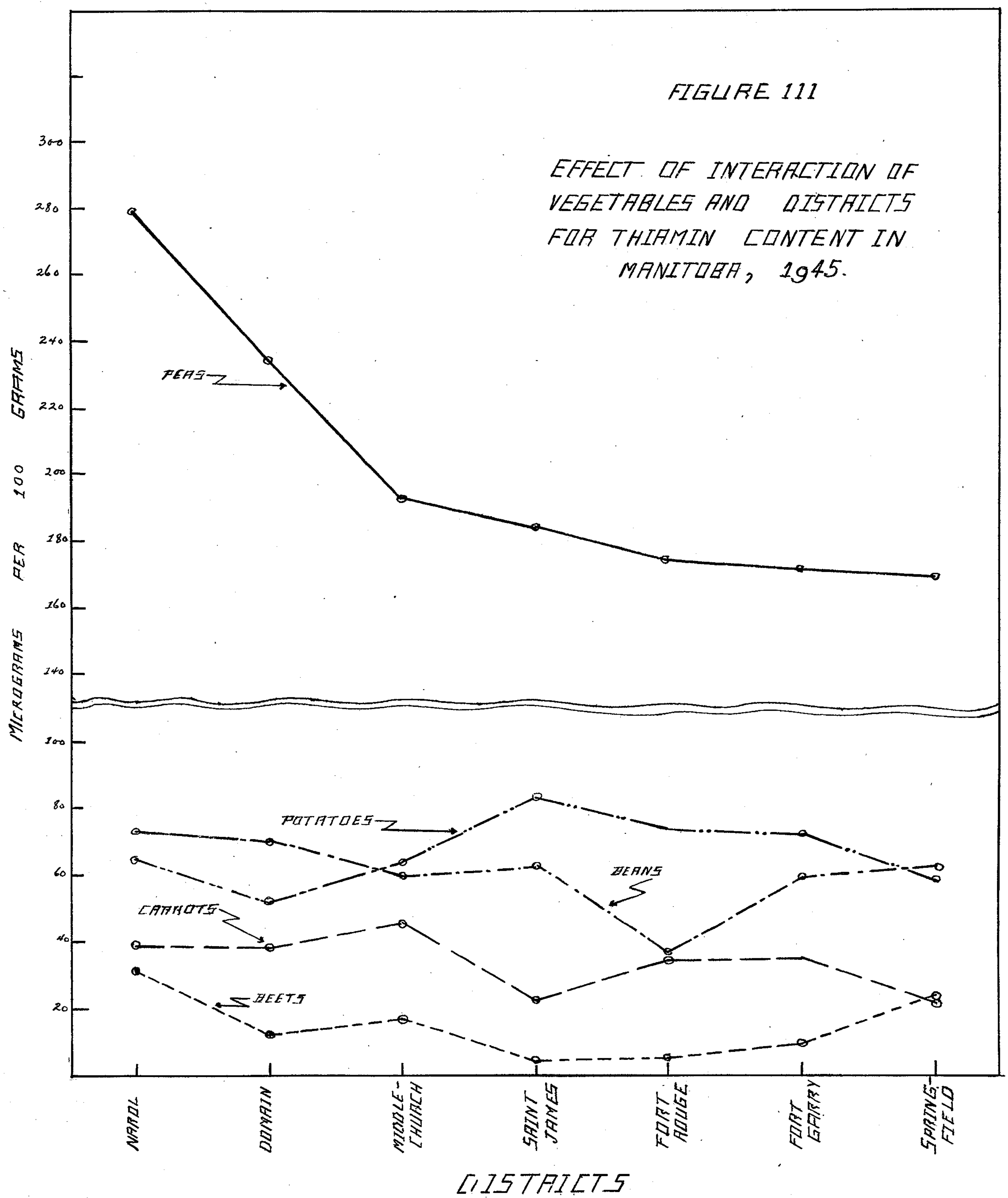


FIGURE 111
EFFECT OF INTERACTION OF VEGETABLES AND DISTRICTS FOR THIAMIN CONTENT IN MANITOBA, 1945.
MICROGRAMS PER 100 GRAMS
300
280
260
240
220
200
180
160
140
100
80
60
40
20
PEAS
POTATOES
BEANS
CARROTS
BEETS
NARDL
DOMAIN
MIDDLE-CHURCH
SAINT JAMES
FORT ROUGE
FORT GARRY
SPRING-FIELD
DISTRICTS

From the analysis of variance it would appear that the thiamin content of the vegetables does not vary significantly over a large area. An F value of 1.57 does not reach the five percent point, 2.51. However, other experiments on the thiamin content of vegetables over a wide area have led to the belief that the thiamin content does vary. Although not significant in this experiment further work should be carried out on these vegetables in order to determine whether a significant variation does exist.

The effect of the interaction of vegetables and districts for thiamin content is illustrated in Figure 111. Arranged in order of thiamin concentration, from high to low, the vegetables would be peas, potatoes, beans, carrots and beets. The thiamin content of vegetables from the Fort Rouge district would appear to be particularly low, whereas those from Narol would be considered relatively high.

2. <u>Results and Discussion of Cooking Tests</u>.

The thiamin retention values of the vegetables cooked when fresh, stored and at various periods during storage are given in Table VII. The analytical data and figures used in making up this table are to be found in Table XVII included in the appendix.

An examination of the data reveals that there was relatively little loss of thiamin during the cooking of fresh potatoes (variety, Irish Cobbler). However, later studies indicated a loss of 38% during the cooking of the same

TABLE VII.

THIAMIN RETENTION DURING COOKING OF VEGETABLES

Vegetable	Condition of Vegetable	Sample No.	Weight of Sample	Cooking Time	Distribution of Thiamin: Total Amount in Sample	Retained by Cooked Sample	Total Amount in Cooking Liquid	Dissolved in Cooking Liquid	Destroyed During Cooking
			gms.	mins.	µgs.	%	µgs.	%	%
Asparagus	Fresh, raw	10			70.19				
	Fresh, cooked	11	110	15	38.35	55	17.22	24	21
	Fresh, raw	12			118.00				
	Fresh, cooked	13	385	15	98.94	84	9.67	8	8
Beets	Fresh, raw	20			148.26				
	Fresh, cooked	21	600	20	32.22	22	(1)	(1)	
Beans	Fresh, raw	30			201.08				
	Fresh, cooked	31	400	20	111.24	55	86.79	43	2
Brussel Sprouts	Fresh, raw	40			262.59				
	Fresh, cooked	41	300	20	140.58	54	55.76	21	25
Cauliflower	Fresh, raw	50			262.50				
	Fresh, cooked	51	300	15	93.90	36	42.62	16	48
Cabbage	Fresh, raw	60			121.80				
	Fresh, cooked	61	400	20	45.00	37	44.13	36	27
	Storage 4 mo. raw	62			83.57				
	Storage 4 mo. cooked	63	340	25	42.53	51	36.76	44	5
Corn	Fresh, raw	80			438.40				
	Fresh, cooked	81	400	10	418.40	95	19.15	4	1
Carrots	Fresh, raw	90			68.35				
	Fresh, cooked	91	500	15	35.05	51	30.41	44	5
	Storage 6 mo. raw	95			124.55				
	Storage 6 mo. cooked	96	500	20	111.80	90	45.55	37	-

THIAMIN RETENTION DURING COOKING OF VEGETABLES (cont'd.)

Vegetable	Condition of Vegetable	Sample No.	Weight of Sample	Cooking Time	Distribution of Thiamin: Total Amount in Sample	Retained by Cooked Sample	Total Amount in Cooking Liquid	Dissolved in Cooking Liquid	Destroyed During Cooking
			gms.	mins.	µgs.	%	µgs.	%	%
Carrots (cont.)	Storage 10 mo. raw	97			61.53				
	Storage 10 mo. cooked	98	300	20	41.31	67	27.26	44	-
Kale	Fresh, raw	101			148.53				
	Fresh, cooked	102	300	30	108.30	73	38.30	26	1
Onions	Storage 3 mo. raw	123			84.51				
	Storage 3 mo. cooked	124	300	15	64.80	77	32.83	39	-
	Storage 8 mo. raw	125			53.34				
	Storage 8 mo. cooked	126	300	15	30.63	57	17.29	32	11
Parsnips	Fresh, raw	130			237.63				
	Fresh, cooked	131	300	10	148.77	63	81.73	34	3
	Storage 5 mo. raw	132			173.01				
	Storage 5 mo. cooked	133	300	15	106.71	62	47.38	27	11
	Storage 8 mo. raw	134			245.10				
	Storage 8 mo. cooked	135	300	15	191.31	78	47.98	19	3

THIAMIN RETENTION DURING COOKING OF VEGETABLES (cont'd.)

Vegetable	Condition of Vegetable	Sample No.	Weight of Sample	Cooking Time	Distribution of Thiamin: Total Amount in Sample	Retained by Cooked Sample	Total Amount in Cooking Liquid	Dissolved in Cooking Liquid	Destroyed During Cooking
			gms.	mins.	μgs.	%	μgs.	%	%
Pumpkin	Fresh, raw	150			97.15				
	Fresh, cooked	151	500	15	83.35	85	14.71	15	0
	Storage 5 mo. raw	154			217.30				
	Storage 5 mo. cooked	155	500	20	74.30	34	38.02	17	49
Peas	Fresh, raw	170			612.77				
	Fresh, cooked	171	635	20	315.15	51	119.97	19	30
Potatoes Irish Cobbler	Fresh, raw	180			296.64				
	Fresh, cooked	181	300	15	235.41	79	77.80	26	-
	Storage 4 mo. raw	182			258.30				
	Storage 4 mo. cooked	183	300	17	160.95	62	37.81	15	23
	Storage 6 mo. raw	184			257.91				
	Storage 6 mo. cooked	185	300	17	226.38	88	27.97	11	1
Potatoes Warba	Fresh, raw	190			233.46				
	Fresh, cooked	191	300	15	121.59	52	31.57	13	35
	Storage 3 mo. raw	193			273.48				
	Storage 3 mo. cooked	194	300	20	136.23	50	29.90	11	39
	Storage 6 mo. raw	195			290.13				
	Storage 6 mo. cooked	196	300	20	242.67	84	24.59	8	8

THIAMIN RETENTION DURING COOKING OF VEGETABLES (cont'd)

Vegetable	Condition of Vegetable	Sample No.	Weight of Sample	Cooking Time	Distribution of Thiamin: Total Amount in Sample	Retained by Cooked Sample	Total Amount in Cooking Liquid	Dissolved in Cooking Liquid	Destroyed During Cooking
			gms.	mins.	µgs.	%	µgs.	%	%
Squash	Fresh, raw	210			70.32				
	Fresh, cooked	211	400	10	49.72	71	13.01	18	11
	Storage 5 mo. raw	214			24.15				
	Storage 5 mo. cooked	215	300	10	25.50	105	1.16	5	-
Swiss Chard	Fresh, raw	220			99.00				
	Fresh, cooked	221	400	10	70.40	70	37.65	38	-
Turnips	Fresh, raw	240			201.72				
	Fresh, cooked	241	300	15	81.84	40	41.43	20	40
	Storage 4 mo. raw	242			68.19				
	Storage 4 mo. cooked	243	300	15	60.75	89	(2)	(2)	
	Storage 6 mo. raw	244			137.31				
	Storage 6 mo. cooked	245	300	20	51.15	37	31.93	23	40

(1) Cooking water not analyzed.
(2) Result discarded.

variety of potatoes after only four months of storage. Of this, 23% had been destroyed while 15% had been dissolved in the cooking liquid. Such findings are comparable to those of Aughey and Daniel (1) who reported a 33% loss of thiamin in boiled pared potato.

The greatest loss of thiamin was encountered during the cooking of pumpkin after storage for four months. The loss amounted to 66%, 17% being retained in the cooking liquid. This is to be contrasted to the cooking of pumpkin immediately after harvesting when 15% of the vitamin was found in the cooking liquid with no loss as a result of the cooking procedure.

Golden Bantam Corn lost the least amount of thiamin as the result of cooking. Only 1% was destroyed by cooking and 4% was dissolved in the cooking liquid.

An average loss of thiamin of 43% was observed for the cooking of carrots. Aughey and Daniel (1) found no loss of thiamin in carrots prepared either by the boiling or pressure cooker methods.

Taking all the cooking tests into consideration an average of 37% of thiamin was destroyed during the cooking procedure. Of this 37%, 23% was dissolved in the cooking liquid. Such a fact emphasizes the importance of saving all cooking liquids and using them in such products as gravies, sauces, soups, etc.

In a few of the cooking tests there appeared to be a little over 100% retention. This apparent gain in thiamin content may be attributed to the same three factors that may have caused the discrepancy in the canning tests.

Of the nine vegetables stored, it was only possible to do cooking tests for the three periods of storage on five, i.e. carrots, parsnips, potatoes (varieties, Irish Cobbler and Warba) and turnips. It was impossible to do a third series of tests on the other storage vegetables as by March they were either spoiled, musty or fibrous. Table VIII shows the results of these cooking tests for the five vegetables listed above. The effects of cooking on the thiamin content

TABLE VIII. EFFECT OF COOKING ON THE THIAMIN CONTENT OF VEGETABLES WHEN FRESH AND AFTER STORAGE FOR APPROXIMATELY FOUR AND SEVEN MONTHS

	Thiamin Content, ugs./100 gms.					
	Fresh		4 Months Storage		7 Months Storage	
Vegetable	Raw	Cooked	Raw	Cooked	Raw	Cooked
Carrots	13.67	7.01	24.91	22.36	20.51	13.77
Parsnips	79.21	49.59	57.67	35.57	81.70	63.77
Potato, Irish Cobbler	98.88	78.47	86.10	53.65	85.97	75.46
Potato, Warba	77.82	40.53	91.16	45.41	96.61	80.89
Turnip	67.24	27.28	22.73	20.25	45.77	17.05

of the other four when freshly harvested and after storage are included in Table VII. The primary object of the experiment was to study the differences in thiamin content due to the cooking treatment (methods of treatment: raw, cooked) and the differential responses due to this same treatment. Due to the method in which the thiamin values are reported, there is no real measure of the error in the technique, but it was felt that the triple interaction would be the most logical error to use in testing the significance of the variance due to cooking. The problem is not to study the interaction of the methods of treatment with the vegetables, but to determine the significance of the methods of treatment at the various storage times. Therefore, a measure of significance must be based on the usual experimental error of technique. The triple interaction represents an effect that is the least likely to be significant and will probably be equal to or greater than the error due to differences between duplicate analyses.

TABLE IX.

ANALYSIS OF VARIANCE FOR THE EFFECT OF COOKING ON THE THIAMIN CONTENT OF STORAGE VEGETABLES.

Sources of Variation	D.F.	Mean Square	F	5% Point
Vegetables (1-5)	4	4238.559	54.48	3.84
Storage Times (XYZ)	2	382.847	4.92	4.46
Interaction (1-5 x XYZ)	8	259.480	3.34	3.44
[1]Methods of Treatment (RC)	1	3391.821	43.60	5.32
Interaction (RC x XYZ)	2	73.570	.94	4.46
Interaction (1-5 x RC)	4	150.308	1.93	3.84
Interaction (1-5 x RC x XYZ)	8	77.802		

[1] Effect of cooking; raw and cooked.

An analysis of variance as applied to the data in Table VIII is summarized in Table IX. The F values with their five percent points are given in the analysis. The vegetable and storage time differences are significant in comparison with the experimental error but the interaction between them is barely significant.

However, we are mainly interested here in the methods of treatment (effect of cooking) and its interaction with the other factors. For this reason the analysis of variance has been separated into two sections. The methods of treatment are very significant and this is explained by the fact that the values for the cooked samples are lower than the raw in every instance. This would indicate that cooking has a very definite effect on the thiamin content of vegetables. That part of this loss is found in the cooking liquid has been demonstrated. The interaction of methods of treatment with storage time is not significant, indicating that the effect of cooking is the same whether the vegetables are freshly harvested or stored for a period of almost a year. The interaction of vegetables with methods of treatment is not significant, and we can conclude that the effect of cooking is the same for all the vegetables concerned.

It is of interest to note that although storage time is significant, the interaction of vegetables with storage time is barely significant. Glancing at Figure IV, and at the totals for methods of treatment, it would appear that there is a trend for the thiamin content to fall during the first four months of storage and to rise during the next six or seven months of storage. Splitting up the degrees of freedom for storage and interaction (1-5 x XYZ) into linear and quadratic effects we obtain the results in Table X.

TABLE X.

A PARTIAL ANALYSIS OF VARIANCE FOR THE EFFECT OF COOKING ON THE THIAMIN CONTENT OF STORAGE VEGETABLES

Sources of Variation	D.F.	Mean Square	F	5% Point
Vegetables (1-5)	4	4238.559	54.48	3.84
Storage Times (XYZ)				
a. Linear effect	1	87.780	1.13	5.32
b. Quadratic effect	1	677.914	8.71	5.32
Interaction (1-5 x XYZ)				
a. Linear x Vegs.	4	305.039	3.92	3.84
b. Quadratic x Vegs.	4	213.921	2.75	3.84

All effect are tested against the error as given in Table IX.

That there is no linear trend indicated by any of the vegetables studied in this instance, is obvious from the F value of 1.13. However, by breaking up the interaction effect (1-5 with XYZ) which almost reaches the 5 percent point, into two parts of four degrees of freedom each, it is possible to measure the inconsistency (or vice versa) of linear and quadratic effects. The analysis indicates a significant F value (3.92) for the interaction of linear effect and vegetables. It is concluded that although there is not a significant linear trend in the data for the vegetables included here it would not necessarily hold true for all vegetables at all times.

The reaction of thiamin to heat has been the subject of inquiry almost since the biological discovery of thiamin. We know that certain chemicals such as sulfites, nitrites, and acetates can split the thiamin molecule into fragments and that high acidity tends to protect against such disintegration. According to Williams (45) the effect of heat on thiamin is serious only in neutral or in alkaline solutions and probably merely aggravates the splitting tendency. He states that sterilization of solutions of pure thiamin chloride at 120°C for thirty minutes or more has little effect on the stability of the vitamin and that this stability is probably due to the acidity of the salt which gives solutions of approximately pH 3.5.

On the other hand, Elvehjem has shown that in cooking of meats there are relatively large losses of vitamin B_1 and Aughey and Daniel (1) report that thiamin destruction amounted to as much as 22% in some vegetables boiled in water. It is evident that generalizations as to the effect of heat on vitamin B_1 potency are impossible. The effects of cooking operations on particular foodstuffs awaits actual assay determinations such as those cited above.

That oxidation can convert thiamin to the physiologically inactive thiochrome has been noted. To what extent this occurs in cooking operations is almost, if not totally, unknown at present.

3. <u>Results and Discussion of Storage Tests.</u>

As soon as the carrots were secured in the fall tests were carried on to determine the vitamin B_1 content when both raw and cooked. After the vegetables had been stored for approximately four and seven months in the storage cellars,

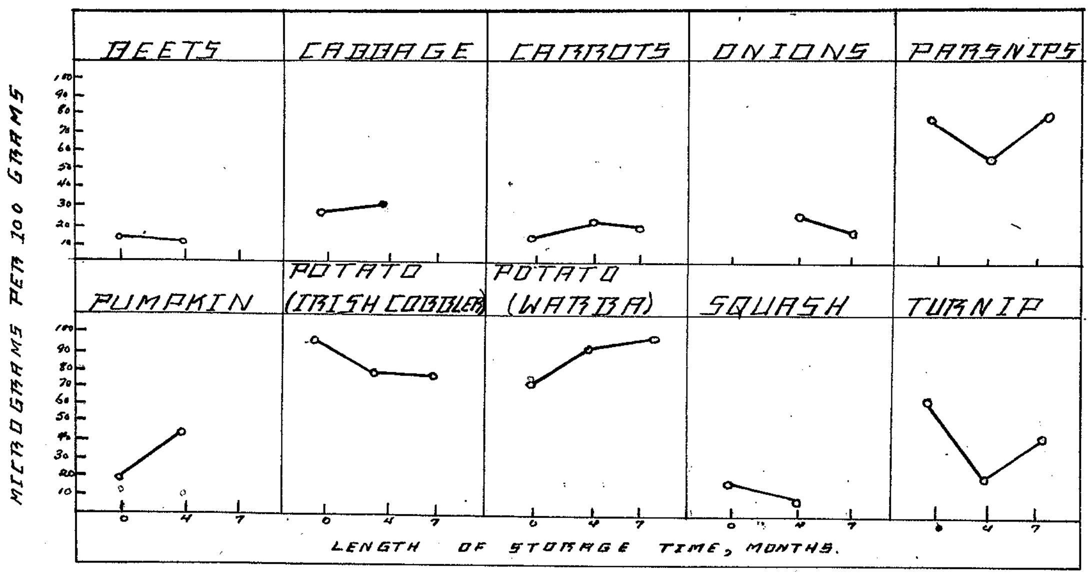


FIGURE IV. - EFFECT OF COMMON STORAGE ON THE THIAMIN CONTENT OF VEGETABLES

as described in Table 11, they were again tested, when raw and cooked to find whether storage had affected the vitamin B_1 content of the products.

Table XI shows the average results of duplicate samples assayed for thiamin content in the fall, winter and early spring after the vegetables had been kept under appropriate storage conditions. Figure IV gives a graphical presentation of the vitamin B_1 contents before and after storage. Upon examining these data, it is noted that while there are evidences of seasonal variation, there are also evidences of

TABLE XI.

THIAMIN CONTENT OF VEGETABLES WHEN FRESH AND AFTER VARIOUS PERIODS OF STORAGE

Vegetable	Variety	Sample No.	Days Between Fresh And First Set of Storage Assays	Days Between Fresh And Second Set of Storage Assays	Thiamin, Micrograms /100 gms.** Thiamin Content Prior to Storage	Thiamin Content After Approx. Four Months Storage	Thiamin Content After Approx. Seven Months Storage
Beets	Detroit Dark Red	24	128		11.50	10.12	
Cabbage	Danish Ball Head	60	121		30.45	34.58	
Carrots	Red Cored Chantenay	90	201	292	13.67	24.91	20.51
Onions	Yellow Globe Danvers	123	*	*	*	28.17	17.78
Parsnips	Hollow Crown	130	142	218	79.21	57.67	81.70
Pumpkin	Small Sugar	150	147		19.43	43.46	
Potato	Irish Cobbler	180	121	183	98.88	86.10	85.97
	Warba	190	107	176	77.82	91.16	96.71
Squash	Golden Hubbard	210	148		17.58	8.05	
Turnip	Purple Top Swede	240	120	182	67.24	22.73	45.77

* A fresh analysis was not run.
** Each value is the average of two samples.

some general trends. This fact is further enlarged upon in the section covering the effect of cooking on storage vegetables. Although there is a general trend for the vitamin content to fall during the first few months of storage, there appears to be no decrease in the potency of the vitamin B_1 in raw vegetables after storage for over eight months.

These results show agreement with the conclusion reached by Langley, Richardson, and Andes (28) that winter storage of carrots for four months in either cool, damp or warm, dry cellars, had no deteriorating effect on vitamin A, B_1 and C.

4. Results and Discussion of Canning Tests.

The retention of thiamin after blanching and processing is summarized in Tables XII, XIII, and XIV. The values are expressed as micrograms of the vitamin per 100 grams of the solids, of the liquid portions of the jar and of the entire original contents of the jar. Table XIII includes the overall retentions of thiamin in the products for the entire canning operations. Outside of asparagus, tomatoes and kale which were purchased on the open market, the varieties of the products studied are as follows: Detroit Dark Red beets, Round Pod Kidney Wax beans, Golden Bantam corn, Red Cored Chantenay carrots, Small Sugar pumpkin, Golden Hubbard squash, Laxton Progress peas, and Lucullus Swiss chard.

The results in Table XIV are expressed as over-all retentions of thiamin from the fresh to the canned products after the various periods of storage. Lack of information on the canning procedure made it impossible to run retention studies on pumpkin, squash, tomatoes and tomato juice. The

TABLE XII.

THIAMIN CONTENT OF CANNED FOODS

		Water Blanch		Process		Thiamin, μgs./100 g.			
						Fresh	Canned		Days Between Canning and Analysis
Product	Variety	Mins.	°F.	Mins.	°F.		Solids	Total Amount in Jar	
Pumpkin	Small Sugar	12	212	60	250	19.43	5.01	21.64	139
						19.43	28.00	120.96	267
Squash	Golden Hubbard	12	212	60	250	17.58	3.03	14.30	121
						17.58	2.63	12.22	261
Tomatoes	Market	½	212	35	212	4.28	29.64	137.53	120
						4.28	14.94	68.72	267
Tomato Juice	Market	10	212	10	212	4.28	21.68	89.32	120
						4.28	15.64	66.78	267

thiamin contents of these products, before and after canning, and after various periods of storage are included in Table XII. The calculations for over-all thiamin retentions during canning and after storage for approximately three and nine months are included in the appendix (Table XVIII). The thiamin content of the canned solids, of the respective canning liquids and of the entire contents of the jar after storage for approximately 0, 3, and 9 months is illustrated graphically in Figure V.

Thiamin retention values ranging from 13% to 61% were

TABLE X111.

OVER-ALL RETENTION OF THIAMIN IN VEGETABLES DURING PREPARATION AND CANNING

Product	Water Blanch		Process		Thiamin, Micrograms /100 gms. Fresh	Canned		Total in Jar	Days Between Canning and Assay	Reten-tion %
	Min.	°F.	Min.	°F.		Solids	Liquid			
Asparagus	3½	212	30	240	30.65	19.29	8.04	57.87	98	93
Beets	17	212	30	240	24.71	2.23	3.45	12.97	109	19
Beans	3	212	30	240	46.90	11.65	14.42	63.63	111	57
Corn	2	212	60	240	109.6	8.38	11.59	44.61	125	13
Carrots	3	212	30	240	13.67	7.44	8.06	39.44	104	109
Kale	3	212	60	250	49.51	13.34	3.92	30.77	111	40
Peas	3	212	45	240	96.50	23.78	27.70	100.18	104	29
Swiss Chard	3	212	60	250	24.75	3.17	7.36	16.85	98	28

TABLE XIV.

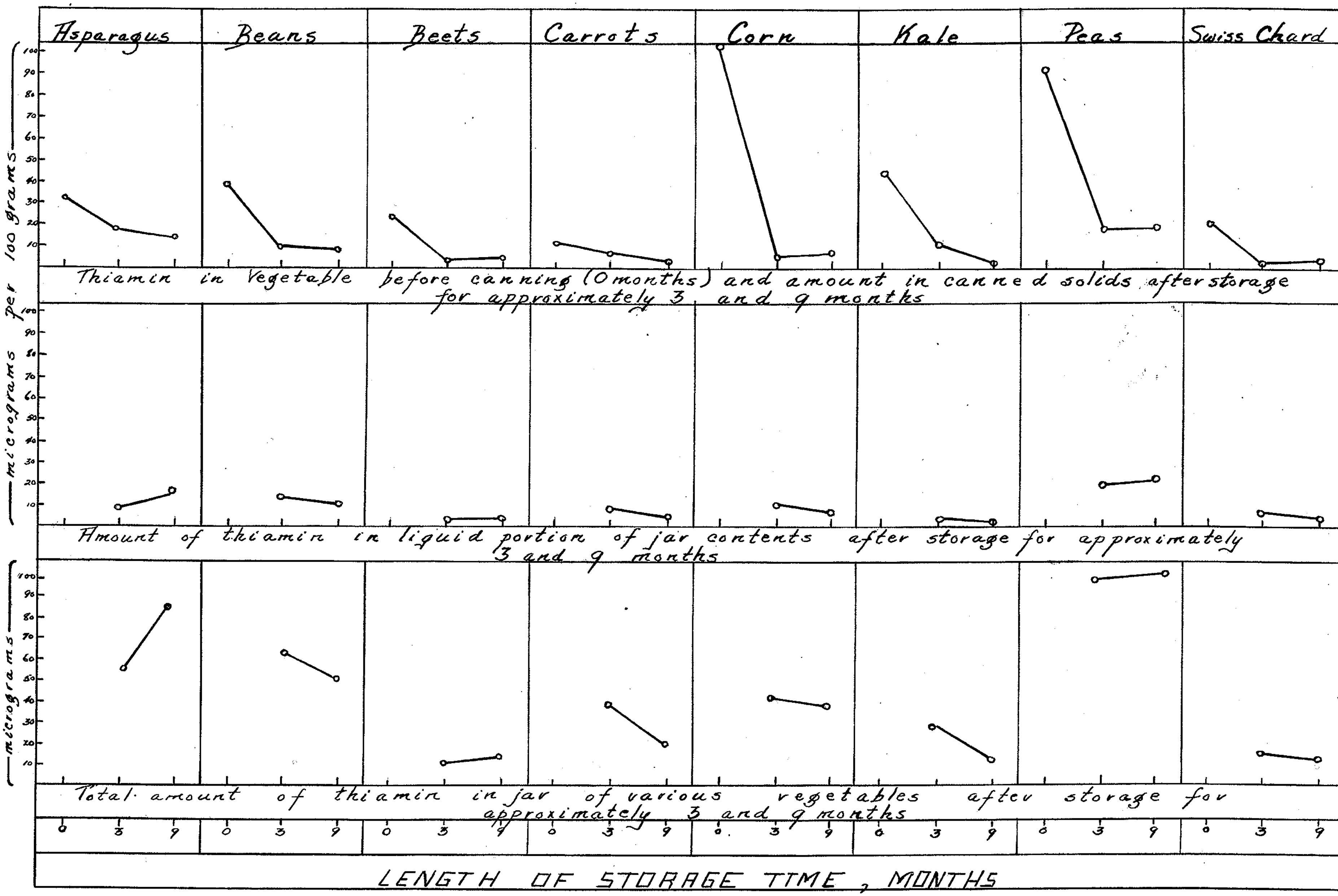
EFFECT OF STORAGE ON THIAMIN CONTENT OF CANNED VEGETABLES

Product	Thiamin, Micrograms /100 grams. Fresh	Canned Solids	Canned Liquid	Total in Jar	Days Between Canning and Assay	Over-all Retention %	Loss Referred to First Analysis after Canning %
Asparagus	30.65	19.29	8.04	57.87	98	93	---
	30.65	16.32	19.71	84.97	321	137	---
Beets	24.71	2.23	3.45	12.97	109	19	---
	24.71	2.86	3.51	14.80	305	21	---
Beans	46.9	11.65	14.42	63.63	111	57	---
	46.9	10.71	10.15	51.73	291	47	10
Corn	109.6	8.38	11.59	44.81	125	13	---
	109.6	9.93	7.63	42.41	271	13	0
Carrots	13.67	7.44	8.06	39.44	104	109	---
	13.67	4.19	4.84	22.15	306	61	39 *
Kale	49.51	13.34	3.92	30.77	111	40	---
	49.51	3.36	2.83	13.49	250	18	22
Peas	96.50	23.78	27.70	100.18	104	29	---
	96.50	23.84	31.89	102.26	307	30	---
Swiss Chard	24.75	3.17	7.36	16.85	98	28	---
	24.75	3.23	5.87	14.63	309	24	4

* Taken from 100%.

FIGURE V.

EFFECT OF CANNING AND STORAGE ON THE THIAMIN CONTENT OF VEGETABLES



found with the exception of asparagus, which was 93%. These figures agree fairly well with those obtained by Clifcorn and Heberlein (7) who found the over-all thiamin retention for the nine vegetables studied, based on the total contents of the can to range from 31% to 89% with an average over-all retention of 57%.

In the present study fourteen cases out of sixteen showed a considerable drop in thiamin from the fresh to the canned solids. In the other two instances, asparagus 321 days after canning and carrots 104 days after canning, the total yield of thiamin in the canned product appeared to be greater than that initially present in the raw state. This apparent discrepancy is attributed to three factors: first, limitation in the precision of the analytical methods employed; second, the greater difficulty experienced in extracting the vitamin for analysis from the raw state; and third, the probable action of destructive enzymes in raw vegetables released during homogenization. These enzymes are, of course, inactivated when vegetables are processed. The conclusion has been drawn in these instances that the vitamin was completely retained.

Williams and Spies in 1938 (44) state that the amino group of the pyrimidine nucleus of vitamin B_1 (thiamin) is said to be capable of reacting readily with aldehydes. Inasmuch as the amino group is essential to physiological activity, this possibility cannot be ignored as a factor in the thermolability of vitamin B_1. Aldehydes are of very common occurrence in foods. It has been found that thiamin occurs in tissues partly in the free form and partly as the pyrophosphate and it may be that a difference between the thermolability of the two may exist. That the stability of vitamin B_1 in vegetables during canning may be tied up with the form in which it exists in the vegetable and the amount of aldehydes in the vegetable is quite possible.

Comparative Concentrations of Thiamin in Solids and Liquids.

After storage for three months the concentration of thiamin in the solid ran higher than in the liquid in fifty percent of the cases, i.e., in asparagus, corn, kale, peas. (Tables XV and XVI). After storage for nine months the concentration of thiamin was still higher than in the liquid in the case of corn and peas. The concentration of thiamin in the solids of asparagus and kale was considerably higher after three months, but the longer period of storage caused an increased seepage of the thiamin to the liquid. Beets exhibited a higher concentration after nine months whereas the thiamin content of the solids of beans, carrots, Swiss chard was lower than the liquid throughout. The variations between thiamin values for solids and liquids was most pronounced in the determinations on peas in which the relatively lower liquid content of the canned product probably explains the exaggerated difference in the amount of thiamin dissolved in the two phases.

TABLE XV.

DISTRIBUTION OF THIAMIN IN CANNED VEGETABLES AFTER STORAGE FOR THREE MONTHS

Vegetable		Weight: Total per Jar gm.	Weight: Distribution %	Thiamin: Concentration µgs/100 gm.	Thiamin: Concentration µgs/Tot. Amount	Thiamin: Distribution %
Asparagus	Solid	175	37	19.29	33.75	58
	Liquid	300	63	8.04	24.12	42
Beets	Solid	257	55	2.23	5.73	44
	Liquid	210	45	3.45	7.24	56
Beans	Solid	212	44	11.65	24.70	39
	Liquid	270	56	14.42	38.93	61
Corn	Solid	283	59	8.38	23.72	53
	Liquid	192	41	11.59	21.09	47
Carrots	Solid	243	48	7.44	18.08	46
	Liquid	265	52	8.06	21.36	54
Kale	Solid	131	28	13.34	17.48	57
	Liquid	339	72	3.92	13.29	43
Peas	Solid	330	80	23.78	78.47	78
	Liquid	82	20	27.70	21.71	22
Swiss Chard	Solid	160	50	3.17	5.07	30
	Liquid	160	50	7.36	11.78	70
Pumpkin	Solid	432	100	5.01	21.64	100
Squash	Solid	472	100	3.03	14.30	100
Tomatoes	Solid	464	100	29.64	137.53	100
Tomato Juice	Liquid	412	100	21.68	89.32	100

Distribution of Weight and Thiamin between Solids and Liquid.

After three months storage: For all vegetables except asparagus and kale the solid weight was in the range of 50% to 80%. Canned asparagus had solid weight of 37% and kale had solid weight of 28%.

For all vegetables except beets, Swiss chard and peas, the solids carried from 44% to 58% of the thiamin. The solids of beets and Swiss chard carried 30% and 39% of the thiamin respectively, and the solids of peas contained 78% of the vitamin.

After nine months storage: For all vegetables except kale the solid weight was in the range of 52% to 84%, the solid weight of kale being 32%. In beans, beets, carrots, Swiss chard and corn the solid carried 47% to 70% of the thiamin; whereas in asparagus and kale the solid carried 38% and 35% of the thiamin and the concentration for peas was 80%.

TABLE XVl.

DISTRIBUTION OF THIAMIN IN CANNED VEGETABLES AFTER STORAGE FOR NINE MONTHS

Vegetable		Weight: Total per Jar gm.	Weight: Distribution %	Thiamin: Concentration µgs./100 gm.	Thiamin: Concentration µgs./Tot. Amount	Thiamin: Distribution %
Asparagus	Solids	197	42	16.32	32.15	38
	Liquid	268	58	19.71	52.82	62
Beets	Solid	272	58	2.86	7.78	52
	Liquid	200	42	3.51	7.02	48
Beans	Solid	230	46	10.71	24.63	48
	Liquid	267	54	10.15	27.10	52
Corn	Solid	298	64	9.93	29.59	70
	Liquid	168	36	7.63	12.82	30
Carrots	Solid	255	52	4.19	10.68	48
	Liquid	237	48	4.84	11.47	52
Kale	Solid	142	32	3.36	4.77	35
	Liquid	308	68	2.83	8.72	65
Peas	Solid	342	84	23.84	81.53	80
	Liquid	65	16	31.89	20.73	20
Swiss Chard	Solid	213	62	3.23	6.88	47
	Liquid	132	38	5.87	7.75	53
Pumpkin	Solid	432	100	28.00	120.96	100
Squash	Solid	465	100	2.63	12.22	100
Tomatoes	Solid	460	100	14.94	68.72	100
Tomato Juice	Solid	427	100	15.64	66.78	100

SUMMARY

1. Average values and ranges for thiamin content are reported for a large number of Manitoba vegetables. Considerable variation has been found, the values ranging from 6.40 micrograms per 100 grams, the lowest value for radish, to 279.5 micrograms per 100 grams, the highest value for peas. This would mean that from 1% to 16% of the adult daily requirements of thiamin would be supplied in a 100 gram serving of vegetables, if it were not for cooking and processing losses. Although the high water content and great bulk of leaves, roots, and stems of plants prevent them from supplying an outstanding amount of thiamin, they are nevertheless significant contributors to the diet due to the large amounts consumed. The thiamin contents of the vegetables analyzed are of the same order as those reported by other investigators.

2. A significant variation in thiamin content of five vegetables over a considerable area was not found to exist. However, there appeared to be a considerable range within values for an individual vegetable over the particular area studied.

3. The effects of cooking on thiamin retention was studied for fresh and stored vegetables. Taking all the cooking tests into consideration an average of 37% of thiamin was destroyed during the cooking procedure.

Of this 37%, 23% was dissolved in the cooking liquid. The greatest loss of thiamin (66%) was encountered during the cooking of pumpkin after it had been stored for five months. Golden Bantam Corn retained the greatest percentage of thiamin during the cooking procedure (1% destroyed, 4% dissolved in the cooking liquid).

4. Cooking was found to have a serious significant effect upon the thiamin content of storage vegetables. In all cases the values for the cooked samples were lower than the raw. This conclusion was substantiated by an analysis of variance in that the calculated F value (43.60, Table IX) far exceeded the five percent point of 5.32. Part of this loss was found in the cooking liquid. However, this effect was found to hold true whether the vegetable was fresh or had been stored for a definite time interval. It was concluded that although there was not a significant downward linear trend in the data for the vegetables included in this study it would not necessarily hold true for all vegetables at all times.

5. Home storage of vegetables did not appear to have any deteriorating effect on the thiamin content of vegetables. A trend for the thiamin content to fall during the first three months of storage and to rise during the next six or seven months seemed to exist. However, there was no decrease in the potency of the vitamin B_1 in raw vegetables after storage for over eight months.

6. The over-all thiamin retention during canning for the eight products studied based on the total contents of the jar, was found to range from 13% to 61%, with the exception of asparagus, which was 93%. In fourteen cases out of sixteen there was a considerable drop of thiamin from the fresh to the canned solids. There was also a decrease in the thiamin content of canned vegetables upon storage.

7. A comparison of the concentrations of thiamin in solids and liquids was made, and regarding the over-all distributions, the observations led to the following general conclusions: in most canned vegetables the solid weight, being 50% to 84% of the total jar contents, carried 44% to 70% of the thiamin. Peas were the outstanding exception to these ranges, for with solid weights ranging from 80% to 84% of the total, the thiamin content of the solids was correspondingly higher.

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APPENDIX

TABLE XVII. DATA FOR CALCULATION OF THIAMIN RETENTION DURING COOKING OF VEGETABLES

Vegetable	Condition of Vegetable	Sample No.	Weight of Vegetable Cooked	Amount of Thiamin in Veg. Solids	Weight of Liquid after Cooking	Amount of Thiamin in Cooking Liquid
(1)	(2)	(3)	(4)	(5)	(6)	(7)
			gms.	µgs./ 100 gms.	gms.	µgs./ 100 gms.
Asparagus	Fresh, raw	10		63.81		
	Fresh, cooked	11	110	34.86	111	15.51
	Fresh, raw	12		30.65		
	Fresh, cooked	13	385	25.70	387	2.50
Beets	Fresh, raw	20		24.71		
	Fresh, cooked	21	600	5.37		
Beans	Fresh, raw	30		50.27		
	Fresh, cooked	31	400	27.81	380	22.84
Brussels Sprouts	Fresh, raw	40		87.53		
	Fresh, cooked	41	300	46.86	370	15.07
Cauliflower	Fresh, raw	50		87.50		
	Fresh, cooked	51	300	31.30	417	10.22
Cabbage	Fresh, raw	60		30.45		
	Fresh, cooked	61	400	11.25	515	8.57
	Storage 3 mo. raw	62		34.58		
	Storage 3 mo. cooked	63	340	12.51	292	12.59
Corn	Fresh, raw	80		109.60		
	Fresh, cooked	81	400	104.60	925	2.07
Carrots	Fresh, raw	90		13.67		
	Fresh, cooked	91	500	7.01	230	13.22
	Storage 3 mo. raw	95		24.91		
	Storage 3 mo. cooked	96	500	22.36	205	22.22

DATA FOR CALCULATION OF THIAMIN
RETENTION DURING COOKING OF VEGETABLES (cont.)

(1)	(2)	(3)	(4) gms.	(5) µgs./100 gms.	(6) gms.	(7) µgs./100 gms.
Carrots	Storage 8 mo. raw	97		20.51		
	Storage 8 mo. cooked	98	300	13.77	287	9.50
Kale	Fresh, raw	101		49.51		
	Fresh, cooked	102	300	36.10	320	11.97
Onions	Storage 3 mo. raw	123		28.17		
	Storage 3 mo. cooked	124	300	21.60	268	12.25
	Storage 8 mo. raw	125		17.78		
	Storage 8 mo. cooked	126	300	10.21	217	7.97
Parsnips	Fresh, raw	130		79.21		
	Fresh, cooked	131	300	49.59	529	15.45
	Storage 3 mo. raw	132		57.67		
	Storage 3 mo. cooked	133	300	35.57	230	20.60
	Storage 8 mo. raw	134		81.70		
	Storage 8 mo. cooked	135	300	63.77	407	11.79
Pumpkin	Fresh, raw	150		19.43		
	Fresh, cooked	151	500	16.67	335	4.39
	Storage 3 mo. raw	154		43.46		
	Storage 3 mo. cooked	155	500	14.86	358	10.62
Peas	Fresh, raw	170		96.50		
	Fresh, cooked	171	635	49.63	447	26.84
Potatoes Irish Cobbler	Fresh, raw	180		98.88		
	Fresh, cooked	181	300	78.47	500	15.56
	Storage 3 mo. raw	182		86.10		
	Storage 3 mo. cooked	183	300	53.65	422	8.96

DATA FOR CALCULATION OF THIAMIN
RETENTION DURING COOKING OF VEGETABLES (cont.)

(1)	(2)	(3)	(4) gms.	(5) µgs./ 100 gms.	(6) gms.	(7) µgs./ 100 gms.
Potatoes Irish Cobbler	Storage 8 mo. raw	184		85.97		
	Storage 8 mo. cooked	185	300	75.46	284	9.85
Potatoes Warba	Fresh, raw	190		77.82		
	Fresh, cooked	191	300	40.53	225	14.03
	Storage 3 mo. raw	193		91.16		
	Storage 3 mo. cooked	194	300	45.41	117	25.56
	Storage 8 mo. raw	195		96.71		
	Storage 8 mo. cooked	196	300	80.89	284	8.66
Squash	Fresh, raw	210		17.58		
	Fresh, cooked	211	400	12.43	345	3.77
	Storage 3 mo. raw	214		8.05		
	Storage 3 mo. cooked	215	300	8.50	315	.37
Swiss Chard	Fresh, raw	220		24.75		
	Fresh, cooked	221	400	17.60	195	19.31
Turnips	Fresh, raw	240		67.24		
	Fresh, cooked	241	300	27.28	385	10.76
	Storage 3 mo. raw	242		22.73		
	Storage 3 mo. cooked	243	300	20.25	435	12.78
	Storage 8 mo. raw	244		45.77		
	Storage 8 mo. cooked	245	300	17.05	225	14.19

TABLE XVIII.

CALCULATION OF THIAMIN RETENTION DURING PROCESSING AND AFTER STORAGE FOR 3 MONTHS

	Before Processing			After Processing							
Vegetable	Thiamin Content When Filled Into Jar	Weight of Product Put Into Jar	Total Amount of Thiamin in Jar	Weight of Drained Solids	Thiamin Content of Solids	Weight of Liquid	Thiamin Content of Liquid	Total Amount of B_1 in Solids	Total Amount of B_1 in Liquid	Total Amount of Thiamin in Jar	Retention
	µgs./100 gms.	gms.	µgs.	gms.	µgs./100 gms.	gms.	µgs./100 gms.	µgs.	µgs.	µgs.	%
Asparagus	30.65	203	62.22	175	19.29	300	8.04	33.75	24.12	57.87	93
Beets	24.71	281	69.44	257	2.23	210	3.45	5.73	7.24	12.97	19
Beans	46.90	236	110.68	212	11.65	270	14.42	24.70	38.93	63.63	57
Corn	109.6	305	334.28	283	8.38	182	11.59	23.72	21.09	44.81	13
Carrots	13.67	265	36.22	243	7.44	265	8.06	18.08	21.36	39.44	109
Kale	49.51	154	76.24	131	13.34	339	3.92	17.48	13.29	30.77	40
Pumpkin	19.43			432	5.01						
Peas	96.50	353	340.64	330	23.78	82	27.70	78.47	21.71	100.18	29
Squash	17.58				3.03						
Swiss Chard	24.75	222	54.94	160	3.17	160	7.36	5.07	11.78	16.85	31
Tomatoes	42.8				29.64						
Tomato Juice	42.8				21.68						

CALCULATION OF THIAMIN RETENTION DURING PROCESSING AND AFTER STORAGE FOR 9 MONTHS

	Before Processing			After Processing							
Vegetable	Thiamin Content When Filled Into Jar	Weight of Product Put Into Jar	Total Amount of Thiamin in Jar	Weight of Drained Solids	Thiamin Content of Solids	Weight of Liquid	Thiamin Content of Liquid	Total Amount of B_1 in Solids	Total Amount of B_1 in Liquid	Total Amount of Thiamin in Jar	Retention
	µgs./100 gms.	gms.	µgs.	gms.	µgs./100 gms.	gms.	µgs./100 gms.	µgs.	µgs.	µgs.	%
Asparagus	30.65	203	62.22	197	16.32	268	19.71	32.15	52.82	84.97	137
Beets	24.71	281	69.44	272	2.86	200	3.51	7.78	7.02	14.80	21
Beans	46.90	236	110.68	230	10.71	267	10.15	24.63	27.10	51.73	47
Corn	109.6	305	334.28	298	9.93	168	7.63	29.59	12.82	42.41	13
Carrots	13.67	265	36.22	255	4.19	237	4.84	10.68	11.47	22.15	61
Kale	49.51	154	76.24	142	3.36	308	2.83	4.77	8.72	13.49	18
Pumpkin	19.43										
Peas	96.50	353	340.64	342	23.84	65	31.89	81.53	20.73	102.26	30
Squash	17.58										
Swiss Chard	24.75	222	54.94	213	3.23	132[1]	5.87	6.88	7.75	14.63	27
Tomatoes	42.8										
Tomato Juice	42.8										

1 - Sufficient only for one sample.