THE QUANTITY OF STARCH IN KANSAS IRISH AND SWEET POTATOES

by

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INTRODUCTION

Irish and sweet potatoes are pre-eminently starchy foods and, from a standpoint of value and production, they are two of the most important vegetables grown in the United States. They are placed on the market almost exclusively as the whole tuber and root, and are used largely as human food. Rigorous grading requirements for market potatoes have resulted in the rejection of a considerable part of the total white and sweet potato crop as culls, including both over-size and under-size potatoes. Most generally these culls are wasted or inadequately utilized. In the past few years, investigations (1, 7) have been reported on the possibility of utilizing the cull and excess potato crop as a source of commercial starch. Some progress has been made on the problem and, at the present time, white potato starch is produced in both Maine and Minnesota. The production of sweet potato starch is still in an experimental stage; a factory has been established in Mississippi for developing the process on an industrial scale and to be used later as a commercial plant. Total consumption of white potato starch in the United States has been increasing steadily, with textile

industries consuming most of the starch for the sizing of warp and the finishing of certain classes of textiles. Other industries, such as laundries and in the manufacture of dextrins and adhesives, utilize large quantities of potato starch, creating a rather large demand for that material. Although its total production and consumption is not as great as is that for the white potato, sweet potato starch shows possibilities of satisfactorily replacing white potato starch in some industries. This is an important item, since about half of the white potato starch used is imported.

Each year Kansas produces a large volume of white and sweet potatoes which are marketed mainly as a food crop. However, an extension of the potato starch industry in Kansas might be profitable and assist materially in stabilizing the potato crop, if it were chemically feasible to utilize the Kansas crop for that purpose. With these points in mind, Kansas Irish and sweet potatoes which were grown under different soil conditions and harvested at different stages of maturity were investigated quantitatively for starch.

SURVEY OF THE LITERATURE

A review of the literature showed that little previous work of the nature of this investigation has been done upon Kansas Irish and sweet potatoes. In 1891, Failyer and Willard (3) analyzed feeding stuffs in which two varieties of sweet potatoes were included. However, only percentages of water, ash, protein, fiber, and nitrogen free extract were reported, no figures being given as to their starch content. In a study of the Irish potato, using the crops of 1890 and 1892, Watson (9) determined the solids and starch in 12 varieties grown in states east of the Rocky Mountains. In his work were included the Early Ohio, Minister, Clark, and Triumph varieties which were grown at Edwardsville, Kansas. His results, given in Table 1, show that there is a great

Table 1. Data on Watson's work.

Variety	Per cent Water	Per cent Dry Matter	Per cent Starch
Early Ohio	83.03	16.97	12.68
Minister			14.37
Clark	81.50	18.50	10.95
Triumph	88.68	11.32	8.15

variation in the varieties that contain the highest and lowest per cent of dry matter and starch respectively. He further stated that the water content was higher in Kansas grown varieties than in any varieties examined from other states. It is interesting to note that of the varieties of Kansas potatoes studied, the Triumph was found to be consistently low in starch.

Although practically no intensive work has been done on starch content of Kansas Irish and sweet potatoes, a number of such studies have been made upon potatoes grown in other localities. In 1893, Price (8) reported on the yields of 31 varieties and the chemical composition of 21 varieties of sweet potatoes in Texas. Similar investigations have been reported by White (11) in Georgia and by Morgan and Rose (5) in Louisiana.

The aim of Watson's work (10) was to compare northern and southern grown varieties of white potatoes. The average results of solids and starch respectively were as follows: Connecticut, 22.74 and 17.06; Indiana, 18.87 and 15.13; Maine, 20.18 and 15.42; Massachusetts, 22.04 and 15.31; Michigan, 22.17 and 14.91; North Carolina, 19.98 and 15.14; Pennsylvania, 20.58 and 16.01; and Virginia, 23.06 and 15.62 per cent. Cutter (2), in the analysis of Utah potatoes, showed 29.58 per cent of solids

and over one-third more starch than eastern potatoes. He believed that this variation from Watson's data was due to methods of planting, tillage, and distance of planting of potatoes on sandy loam soil with gravelly subsoil. Idaho, also, was found to produce potatoes with a high starch content (12, p. 154). It appears from the investigations of Headden (4) that Colorado potatoes are even lower in starch content than those in the eastern section. It might be expected that these potatoes would be midway in composition between the product of regions east of the Rocky Mountains and the Utah-Idaho region, considering the geographical situation of the state.

The chemical composition of certain varieties cannot be regarded as strictly representative of the varieties, since other factors may exert a predominating influence. Possibly owing to soil conditions or climate, Watson (10) found that the variety Dakato Red grown in Virginia contained 9.75 per cent starch, while the same variety grown in Canada contained 14.29 per cent. Similarly, Winton and Winton (12, p. 156) reported that the Early Rose variety grown in Lansing, Michigan, contained 12.38 per cent of starch while potatoes from the same seed grown in Grand Rapids, a neighboring city, contained 15.31 per cent. They believe that the difference in the starch content of potatoes grown in the East, in Colorado, and in Utah is unquestionably due largely to local conditions

which tend to overcome all other factors affecting composition.

Winton and Winton (12, p. 160) state that, with regards to changes during storage, light exerts little influence and humidity is a more important factor, although not so important as temperature. When stored in a warm place (25 to 35° C.), in either moist or dry air, potatoes will lose moisture and gain in starch, but stored in a cool place, especially if the air is moist, the water and starch content change but little. These authors consider that the principal chemical changes taking place during storage are threefold: namely, (1) respiratory, (2) sugar (sucrose and reducing sugars) formation from starch, and (3) starch re-formation from sugar.

EXPERIMENTAL PROCEDURE

Outline of Investigation

This investigation was conducted along the following general lines.

(a) Irish and sweet potatoes grown under different soil conditions and harvested at different stages of maturity were analyzed quantitatively for starch.

(b) The quantity of starch present in Irish potato samples stored over a period of six months in cold and in shed storage, with samples for analysis being taken at monthly intervals, was determined.

Collection of Potato Samples

Potato samples were taken directly from the fields and shipped to the Kansas State Agricultural Experiment Station at Manhattan, Kansas. A sample for analysis was taken immediately upon receiving the potatoes. Three varieties of Irish potato samples were collected from a fine sandy loam soil at early, regular, and late periods of harvest. These samples were taken from alternate rows within the same plot and were used for the purpose of making a comparison of the varieties, the stages of harvest and in the comparison of the types of soil. One variety of a regular harvest sample of the Irish potato was taken from each of the following soils to be used for a further correlation of soil types: loamy sand, upland, soil which had grown potatoes the previous year, and soil which had grown alfalfa the previous year. A single variety of regular harvest, graded seconds, Irish potatoes was used for both the cold storage and shed storage work. These samples had been grown on sandy loam soil.

For a comparison of varieties and the periods of harvesting, three varieties of sweet potatoes were obtained from the Kaw Valley for early harvest samples and four

varieties were taken from the same source for regular harvest samples. At the same time, other samples of these four varieties were put through the procedure of curing, samples for analysis being taken at a later date. Only three varieties of regular harvest sweet potatoes were obtained from the Arkansas Valley; they were used for data on sweet potatoes before being cured. No samples from this source were cured. A complete history of each sample collected may be found in the appendix.

Method of Handling Storage Samples

Samples of Irish Cobblers were placed in both cold storage and shed storage on July 14, 1939 for a period of six months. Three one-hundred pound sacks of these potatoes were stored in a moist room at 42° F. at the Sunflower Creamery, Manhattan, Kansas. Likewise, three sacks of the same potatoes grown on the same soil and under the same conditions, were placed in a wooded shed. This shed was elevated about five feet from the ground. On the fourteenth of each month, one of the sacks, designated as "weight sample", was weighed to determine the amount of weight loss due to shrinkage. This weight loss was recorded from month to month and the per cent

loss calculated. At the same time, a ten-pound sample was taken from one of the two remaining sacks, from which was prepared the sample for analysis. This procedure was followed with the samples in both types of storage to and including January 14, 1940.

During the six months of storage, the shed storage samples were exposed to varying degrees of temperature, and the mean monthly temperatures in degrees Fahrenheit were as follows: July, 83.75; August, 75.87; September, 76.31; October, 61.77; November, 44.83; December, 39.01; and January, 13.78. Hence, the samples were exposed to both extremes of weather conditions during the period of storage.

Method of Curing Sweet Potato Samples

Samples of regular harvest sweet potatoes were placed in a kiln at a temperature of 80 to 90° F. and held at that temperature for a period of ten days to two weeks. At the end of this time, the samples were considered completely cured. The curing procedure is expected to have a two-fold effect in that it causes a slight chemical change within the potato, presumably the conversion of some starch to sugar, and that it causes breaks on the outside of the potato to heal.

Preparation of Potato Samples for Analysis

Immediately upon receiving the potatoes, samples were prepared and stored for analysis. To obtain a representative sample, approximately ten pounds of the potatoes, as received from the field, were washed carefully to remove all foreign matter, and then they were thoroughly dried by spreading them on a wire rack before an electric fan. The ten pound sample was then ground rapidly by cutting it into small pieces with a knife and passing it through a large dry Enterprise meat grinder four times. No water was added at any time, nor was the ground sample allowed to stand, because of rapid enzymatic action and the tendency for starch to settle out. The sample was thoroughly mixed and exactly 100 gm. of the thick watery suspension was immediately weighed out. This weighed sample was added to such a quantity of hot 95 per cent alcohol that the final concentration, allowing for the water content of the potato, was approximately 80 per cent alcohol. (The alcohol had been treated with sufficient precipitated $CaCO_3$ to neutralize any acid present, after which it was redistilled.) For the white potato, 550 cc. of the 95 per cent acid-free alcohol was placed in a Ball

Ideal self-sealing quart fruit jar and heated in a water bath until it was hot; while for the sweet potato, 500 cc. of the 95 per cent alcohol was used in the same manner. After the sample had been added to the hot alcohol, the water bath was heated almost to the boiling point of the alcohol for 30 minutes, shaking the jar frequently to give thorough mixing of the contents. The jar was then sealed tightly, labeled, and the sample stored until needed for analysis.

To prepare the samples for analysis, they were removed from the alcohol by filtering them carefully on a Hirsch funnel. The sample was then washed with 150 cc. of 80 per cent acid-free alcohol and dried as much as possible by means of suction. The funnel, carrying the sample and filter paper, was then placed in the oven and dried at 80° C. for 14 hours. At the end of the drying period, the funnel was cooled and the sample transferred very carefully to a tared weighing bottle. The bottle and sample were then dried in the oven at 80° C. for 3 hours, cooled, and weighed. The weight of the dried potato sample, representing 100 grams of potato, was obtained by difference. It was ground to a fine powder by means of a glass mortar and pestle, placed in a tightly stoppered glass bottle, labeled, and set aside for analysis.

Chemical Analysis

All of the samples were analyzed by the following two official methods of analysis:

(a) A.O.A.C.[1] Official Diastase Method with Subsequent Acid Hydrolysis, XXVII 32 and 33.

(b) A.O.A.C. Official Direct Acid Hydrolysis Method, XXVII 31.

Description of Malt Diastase

For the enzymic hydrolysis, Diastatic Spray Dried Malt No. 25 was used. This material was an aqueous extract of highly enzymatic pure barley malt, the extract being dehydrated by a special process down to 2 per cent moisture. This dried malt was obtained from Eimer and Amend of New York, and recommended by them for the purpose desired. It was claimed by the manufacturers that this product would form at least twenty five times its own weight of maltose, using a 3 per cent Arrow Root Starch Paste at 99 to 100° F., in exactly thirty minutes.

RESULTS

The results of the experimental procedure upon the Irish potatoes are given in Table 2. The samples are

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1. Association of Official Agricultural Chemists. (6)

Table 2. Data on the Irish potatoes.

Number	Variety	Stage of Harvest	Type of Soil	Per cent Starch		Remarks
				Acid Hydrolysis	Diastase Hydrolysis	
A-1	Irish Cobbler	Early	Sandy Loam	13.26*	11.77*	Unsatisfactory
A-1	Irish Cobbler	Early	Sandy Loam	11.59*	10.56*	Unsatisfactory (extra)
A-4	Irish Cobbler	Early	Fine Sandy Loam	14.67	13.40	Potatoes after potatoes
A-5	Irish Cobbler	Regular	Fine Sandy Loam	14.31	12.55	Variety comparison
A-8	Irish Cobbler	Regular	Fine Sandy Loam	15.41	13.84	Potatoes after potatoes
A-9	Irish Cobbler	Regular	Fine Sandy Loam	14.64	13.22	Potatoes after alfalfa
A-10	Irish Cobbler	Regular	Loamy Sand	13.28	11.86	Potatoes after potatoes
A-11	Irish Cobbler	Regular	Sandy Loam	14.67	13.28	Storage sample
A-13	Irish Cobbler	Late	Sandy Loam	12.18	10.99	
A-16	Irish Cobbler	Late	Fine Sandy Loam	13.30	11.98	
A-17	Irish Cobbler	Late	Loamy Sand	12.46	11,15	
A-18	Irish Cobbler	Late	Upland	15.19	13.25	
A-2	Bliss Triumph	Early	Sandy Loam	10.99	9.90	
A-6	Bliss Triumph	Regular	Fine Sandy Loam	11.45	9.90	Variety comparison
A-15	Bliss Triumph	Late	Sandy Loam	9.81	8.80	
A-3	Warba	Early	Sandy Loam	12.59	11.17	
A-7	Warba	Regular	Fine Sandy Loam	13.56	11.90	Variety comparison
A-14	Warba	Late	Sandy Loam	11.82	10.51	

* Due to unsatisfactory handling of these two samples, they will be disregarded in the discussion.

grouped according to variety and time of harvest. The data for number A-12, the shed storage sample, is the same as that for number A-11. Since the potatoes were the same and were divided equally for both types of storage, only one sample was taken for analysis.

It can be observed that the Irish Cobbler contains the greatest percentage of starch, the Warba next, and the Bliss Triumph the least. In each variety, regular harvest potatoes show the maximum amount of starch, having increased slightly over the early harvest potatoes; late harvest potatoes, on the other hand, show a decided decrease in starch content. The types of soil may have an effect on the starch content. These variations will be taken up in the discussion of the results.

Data on the starch content of sweet potatoes according to variety and period of harvesting are shown in Table 3. There seems to be little significant difference in the starch content of varieties obtained from the Kaw and Arkansas Valleys. The Little Stem Jersey sweet potato from the Arkansas Valley does run slightly higher in starch than does the same variety from the Kaw Valley. However, this is based on the results from only a few samples.

Table 3. Data on the sweet potatoes.

Number	Variety	Stage of Harvest	Source	Per cent starch in the potato	
				Acid Hydrolysis	Diastase Hydrolysis
B-1	Little Stem Jersey	Early	Kaw Valley	15.21	13.44
B-4	Little Stem Jersey	Regular	Kaw Valley	16.88	15.13
B-5	Little Stem Jersey	Regular	Kaw Valley	16.57	14.78
B-16	Little Stem Jersey	Regular**	Kaw Valley	15.19	13.17
B-17	Little Stem Jersey	Regular**	Kaw Valley	15.33	13.13
B-8	Little Stem Jersey	Regular	Arkansas Valley	17.39	15.45
B-11	Little Stem Jersey	Regular	Arkansas Valley	18.84	16.74
B-2	Nancy Hall	Early	Kaw Valley	21.06	19.45
B-13	Nancy Hall	Regular	Kaw Valley	21.59	19.42
B-18	Nancy Hall	Regular**	Kaw Valley	18.96	16.59
B-7	Nancy Hall	Regular	Arkansas Valley	21.49	19.73
B-9	Nancy Hall	Regular	Arkansas Valley	19.69	17.93
B-3	Red Bermuda	Early	Kaw Valley	13.84	12.85
B-12	Red Bermuda	Regular	Kaw Valley	14.50	13.57
B-14	Red Bermuda	Regular**	Kaw Valley	14.87	13.42
B-6	Improved Big Stem Jersey	Regular	Kaw Valley	18.69	16.79
B-15	Improved Big Stem Jersey	Regular**	Kaw Valley	17.83	15.60
B-10	Regular Big Stem	Regular	Arkansas Valley	18.94	17.14

** Cured sample

Results of the work done on the storage samples of Irish potatoes are given in Table 4. The two samples were Irish Cobblers taken from sandy loam soil at the regular harvest period. They were stored July 14, 1939, and samples for analysis were taken at monthly intervals thereafter, to and including January 14, 1940. The cold storage samples show a gradual decrease in starch content while the shed storage samples show a tendency for an increase in starch content. In the discussion of the results this will be taken up.

Table 4. Data on the storage samples.

Number	Per cent Starch	
	Acid Hydrolysis	Diastase Hydrolysis
	Cold Storage Samples A-11	
A-11	14.67	13.28
Aug.	13.00	11.77
Sept.	12.86	11.53
Oct.	12.72	11.23
Nov.	11.93	10.67
Dec.	11.06	9.59
Jan.	10.68	9.56
	Shed Storage Samples A-12	
A-12	14.67	13.28
Aug.	14.55	13.34
Sept.	15.63	14.17
Oct.	15.11	13.56
Nov.	14.66	13.24
Dec.	15.35	13.86
Jan.	15.79	14.20

To determine the amount of shrinkage and loss due to evaporation of the water from the storage samples, a weight record, as shown in Table 5, was kept on each sample. The weight record was taken at the same time the sample for analysis was collected. The cold storage samples lost weight very gradually, ending with a total loss of about 11 per cent of the original weight. The shed storage samples, on the other hand, lost weight rapidly during the first three months and showed a total loss of practically one-third of the original weight at the end of six months.

Table 5. Weight record on storage samples.

A-XI (42° storage)				A-XII (Shed storage)			
Date	Wt. (lbs.)	Total Loss	% Loss	Date	Wt. (lbs.)	Total Loss	% Loss
July	90.0	----	-----	July	89.5	----	-----
Aug.	86.0	4.0	4.44	Aug.	77.5	12.0	13.41
Sept.	83.5	6.5	6.22	Sept.	69.0	20.5	22.90
Oct.	83.0	7.0	7.78	Oct.	62.5	27.0	30.27
Nov.	82.5	7.5	8.33	Nov.	60.5	29.0	33.63
Dec.	81.5	8.5	9.44	Dec.	59.0	30.5	34.08
Jan.	80.0	10.0	11.11	Jan.	58.5	31.0	34.64

DISCUSSION OF RESULTS

Methods of Analysis

There is no one procedure which can be said to give an accurate measure of the starch present. There are a number of methods by which starch may be determined, and although these methods will give good checks within themselves, they do not check each other with a good degree of accuracy. The two methods used were recommended for the chemical analysis as being the best methods available for this work, and in order to gain a truer representation of the starch present and a better comparison of the potato samples, data was collected by both methods.

The results obtained by the acid hydrolysis method generally are higher than results by the diastase hydrolysis method. It is generally accepted that the former method may act upon substances other than the starch present, giving rise to an increased amount of reducing compounds. The enzymic procedure is thought to act more specifically upon the starch itself and have very little action upon the non-starches present. Hence, it might be expected that the results by the diastase method would be lower in value than those by the other method.

During the work of this investigation, it was found that a fairly constant difference in starch percentages always existed between the two methods used. Although satisfactory results were obtained within one method, at no time did the results accurately check between the two methods. The percentages obtained by both methods did parallel each other in most cases; that is, when a decrease (or an increase) was found by one method, a corresponding difference was found by the other method. On analyzing the Irish potatoes and calculating to the per cent of starch in the potato, an average difference of 1.39 per cent was found between the values obtained by the two methods. The greatest difference was 1.94 per cent and the least was 1.01 per cent. The differences between the values for the cold storage samples ranged from 1.12 to 1.49 per cent and gave an average of 1.33 per cent. The range of the differences between the values for the shed storage samples was from 1.21 to 1.59 per cent, giving an average difference between the two methods of 1.43 per cent. The average difference between the two methods for all Irish potatoes analyzed was approximately 1.4 per cent. For the sweet potatoes, the average difference between the two methods was noticeably higher than it was for the Irish potatoes, being 1.81 per cent with a range of 0.93 to 2.37 per cent.

This difference may be attributed to two factors: (1) an actual difference arising from the technique and procedure of the two methods, and (2) the hydrolysis of non-starches present in the fibrous material of the sample. To secure more evidence upon the matter, samples of quite pure sweet potato and Irish potato starch were analyzed by both methods and the results compared with those obtained from the corresponding potato sample. The pure starch was collected from the potatoes which were left after a sample had been taken for anlaysis. In Table 6 are given the percentages of starch in the samples analyzed, and they are not to be confused with percentages of starch in the potato.

Table 6. Data for a comparison of the methods of analysis.

Sample	Acid Hydrolysis	Diastase Hydrolysis	Difference
Sweet potato (B-13)			
Pure starch	86.50	81.05	5.45
Potato sample	78.20	70.64	7.56
White potato (A-11)			
Pure starch	79.57	75.09	4.48
Potato sample	76.42	69.14	7.28

It can be seen that, with samples of pure starch, there actually does exist a very appreciable difference between the two methods of procedure. A greater difference was found between the methods when the potato samples were used. It would seem probable, therefore, that other substances besides the starch have been hydrolyzed in the acid hydrolysis method, and that it appears that the greatest difference is due principally to the methods themselves.

It is commonly assumed that the hydrolysis of starch leads to the formation of dextrose which is usually identified by its reducing characteristics. It would seem logical that reducing substances such as maltose and other disaccharides could be formed, and that these substances would not have the same reducing index as dextrose. Since the diastase method gave lower percentages on pure starch samples, it appears that the starch is not being completely hydrolyzed with this treatment and hence, a low representation of the starch content results. Therefore, the acid hydrolysis method, which apparently gave a more complete hydrolysis of a pure starch sample, would give more accurate values representing the minimum starch present.

After completing the analysis of all samples, attempts were made to check some of the results, and it was found that better checks were obtained with the acid hydrolysis method. By using this method, checks were obtained within one-tenth of one per cent while the diastase method proved to check mostly at about two-tenths of one per cent.

In the diastase procedure, a blank was determined on the diastase and used for about eight samples before a new and separate check was made. For each determination, a fresh diastase preparation was made in exactly the same way as it was prepared for the blank. It is believed that the principal error with the diastase method lies in the determination of this blank. This error would probably be decreased by carrying a blank with each analysis of a sample, since small differences in treatment could mean considerable differences in the degree of hydrolysis.

As to the manipulation of the two methods, the direct acid hydrolysis method involves less steps and can be carried out more quickly with more consistent checks.

For the reasons discussed above, the acid hydrolysis data was considered to represent more acurately the true

starch content of the samples, and this data will be used in making the correlations and comparisons.

Irish Potatoes

For a comparison of the varieties of Irish potatoes, samples A-6, A-7, and A-8 show a noticeable high and low percentage of starch. These samples (Table 7) were grown under the same conditions on fine sandy loam soil, and were collected at the regular period of harvest. Throughout these three samples as well as all others analyzed,

Table 7. Data for variety comparison.

Number	Variety	Per cent starch in the potato
A-8	Irish Cobbler	15.41
A-7	Warba	13.56
A-6	Bliss Triumph	11.45

the Irish Cobbler contained the greatest amount of starch, the Warba ranked next, and the Bliss Triumph was consistently the variety with the lowest starch content. A further comparison (Table 8) of the varieties at early, regular, and late harvest periods shows that this is the existing trend of starch content within the varieties.

The regular harvest potatoes seem to contain the maximum amount of starch, having increased slightly over the early harvest potatoes. Although variations are

Table 8. Starch content at different harvest periods.

Variety	Early Harvest	Regular Harvest	Late Harvest
Irish Cobbler	14.67	15.41	13.30
Warba	12.59	13.56	11.82
Bliss Triumph	10.99	11.45	9.81

noticeable, it could be said generally that there is not a great significant difference in starch content over the three periods of harvest. However, late harvest potatoes show a drop in their starch content, going to a value below that of the early harvest samples. Apparently, in harvesting a potato crop for starch, the harvest period might be started during early harvest in the latter part of June, and continued possibly for two weeks past the regular harvest period of July 3-11, but it would seem inadvisable to leave the potatoes in the soil longer than necessary. In this connection, it must be remembered that there is a great loss in yield per acre the earlier the harvest. A maximum yield and a maximum starch content

would both be attained at the regular harvest period.

The types of the soil upon which the potatoes were grown are important to the potato crop and the amount of starch which will be manufactured by the plant. In this work, the number of samples collected was not enough to make any definite statements as to the effect of the soil upon starch production, as in some cases only one or two samples form the basis for possible conclusions. It would appear from the data on hand, however, that upland soil and fine sandy loam soil would grow potatoes containing the highest percentage of starch. Upland soil produced a sample of Irish Cobblers containing 15.19 per cent starch and fine sandy loam soil, which had grown potatoes the previous year, produced potatoes ranging from 14.67 per cent to 15.41 per cent in starch. As compared with these, loamy sand soil yielded potatoes containing 13.28 per cent starch. Soil which had grown potatoes the previous year produced potatoes with about the same or a slightly higher starch content than soil which had grown alfalfa the previous year. But, it was observed that potatoes following alfalfa were more uniformly solid and had less rotten spots than when potatoes followed potatoes. It must be remembered, however, that the differences in starch content are not entirely due to varieties, times of harvest, and soil conditions but

also to the climatic conditions and the variability of the localities from which the samples were taken.

Sweet Potatoes

Variety differences were quite prominent in the samples of sweet potatoes taken for analysis. In all cases, as shown in Table 9, it was observed that the Nancy Hall contained the greatest percentage of starch

Table 9. Data for variety comparison.

Variety (Regular harvest before curing)	Per cent starch in the potato	
	Kaw Valley	Arkansas Valley
Nancy Hall	21.59	21.49
Nancy Hall		19.69
Improved Big Stem Jersey	18.69	
Regular Big Stem Jersey		18.94
Little Stem Jersey	16.88	18.84
Little Stem Jersey	16.57	17.39
Red Bermuda	14.50	

with the Red Bermuda showing the lowest value. Intermediate between these were the Little Stem Jerseys and the Big Stem Jerseys with about the same starch content, although the Big Stem Jerseys appeared to be of a slightly higher value.

Samples were taken from both the Kaw Valley and the Arkansas Valley, but there was no significant difference in the starch content of potatoes of the same variety from these two sources.

From Table 10, it can be noticed that the regular harvest samples showed a slight increase in starch content over the early harvest potatoes. After the regular harvest potatoes had been cured, a decrease in starch was found. This would support the theory of a probable change of some of the starch to sugar within the potato during the process of curing. The increase observed in the Red Bermuda is only very slight and probably is due to experimental error in the analysis of the samples either before or after curing.

Table 10. Kaw Valley sweet potatoes.

Variety	Early Harvest Before Curing	Regular Harvest Before Curing	Regular Harvest After Curing
Nancy Hall	21.06	21.59	18.96
Improved Big Stem Jersey		18.69	17.83
Little Stem Jersey	15.21	16.57	15.33
Red Bermuda	13.84	14.50	14.87

It is interesting to note that the 21.5 per cent starch in the Nancy Hall variety corresponds very closely to the value of 22 per cent for the same variety as found by the Mississippi Agricultural Experiment Station at Laurel, Mississippi in 1936 (7).

Storage Potatoes

Potatoes placed in storage undergo a gradual chemical change -- through the slight conversion of starch to sugar -- that results in a decrease in starch content. At the same time, there is a decrease in weight due to the evaporation of water from the potatoes. Since both of these effects are taking place at the same time, they must be considered in discussing the data on storage samples.

From Table 4, it can be noticed that the cold storage samples undergo a gradual loss in weight; however, it is not as great a loss as is that for shed storage samples. About 11 per cent of the original weight was lost by the former, and about 34 per cent lost for the latter. This means a weight loss of about one-third of the crop placed in shed storage. Such an item would be a very important factor considering that potatoes are marketed, in bulk, by weight instead of measure. Further-

more, it was noticed that there was practically no rot loss by cold storage potatoes, while with shed storage potatoes this was quite considerable.

Enzymic action probably occurs when potatoes are placed in either shed or cold storage. From the original data on cold storage samples, the decrease in starch content was 4 per cent over the period of six months. With the shed storage sample, the original data appears to indicate an increase in starch content at the end of the six months. This would be logical for the evaporation of the water would tend to concentrate the starch in the smaller weight of potato. Therefore, the effect of the loss in weight due to evaporation and shrinkage must be eliminated. In Table 11 are recalculated the percentages of starch in the potato samples of both cold and shed storage on the basis of the original weights. It was assumed that the entire loss was due to evaporation of water. These values still show a gradual decrease in

Table 11. Data on the recalculation of storage samples.

Month	% starch in the potato	
	A-11, Cold Storage	A-12, Shed Storage
July	14.67	14.67
August	12.43	12.60
September	12.06	12.05
October	11.73	10.54
November	10.93	9.73
December	10.04	10.12
January	9.57	10.32

the amount of starch when the potatoes have been stored in a cool moist place. The total decrease in starch was a little over 5 per cent, going from 14.67 per cent to 9.57 per cent during the six months period. With the other kind of storage, these calculations show a decrease in starch content also, reaching what appears to be a minimum in the fourth month (November). The minimum is about a 5 per cent decrease from the original percentage of 14.67 in the month of July. It can be observed that with shed storage samples, the drop in starch to 9.73 per cent took place in four months. On the other hand, cold storage samples dropped to 9.57 per cent starch during a period of six months, thus requiring two months longer to reach approximately the same per cent of starch

in the sample. During the last two months of shed storage a slight increase in starch content occurs. This increase could be due to a possible re-formation of starch from the sugar that is present. Another possible explanation might be that the per cent of starch has reached a constant minimum level and would tend to stay at approximately this level through the equilibrium between sugar formation from starch and the starch re-formation from sugar. Regardless of what the cause is for this phenomena, it must be observed that the overall decrease in starch of the potatoes for the two types of storage is practically the same. The greatest difference lies in the enormous weight loss of shed storage potatoes as compared with cold storage potatoes.

SUMMARY

Several common varieties of Kansas Irish and sweet potatoes, which were grown under different soil conditions and harvested at varying stages of harvest, were collected and analyzed quantitatively for starch by two official methods. Irish potatoes were stored in both shed storage and cold storage, and samples for analysis were taken at regular monthly intervals for six months. At the same time, weight loss due to shrinkage and evaporation of water was recorded.

In the analysis of the samples, it was found that the direct acid hydrolysis method gave the most accurate results.

The Irish potatoes were collected at periods of early, regular, and late harvest from sandy loam, loamy sand, fine sandy loam, and upland soil, as well as soil which had grown potatoes the previous year and soil which had grown alfalfa the previous year. A very noticeable difference in varieties was found and, although there is a slight increase in starch of regular harvest potatoes over early harvest potatoes, the greatest change in starch content appeared in the late harvest samples. Soil conditions also produced an appreciable difference in the starch content of the potatoes.

Sweet potatoes were collected from the Kaw and Arkansas Valleys at stages of early and regular harvest and were analyzed before and after curing. Although no great difference was observed in the starch content of the same variety from the two sources, a large difference was found in the varieties from one source. Regular harvest samples contained a higher percentage of starch than did early harvest samples, and curing caused a decrease in starch content.

Shed storage samples suffered a much greater weight loss than did cold storage samples. Calculated on the

basis of the original weights, a gradual decrease in starch occurred with both types of storage, amounting to practically the same total loss over the six months period. However, the shed storage samples reached a minimum starch content in four months, while the cold storage samples fell to approximately the same level in six months. During the last two months of shed storage, a slight increase in starch occurred which might possibly be due to re-formation of starch from sugar.

CONCLUSIONS

1. The A. O. A. C. Direct Acid Hydrolysis Method for the analysis of starch gives more accurate results and more consistent checks than does the A.O.A.C. Diastase Method.

2. Among the varieties of Irish potatoes, the Irish Cobbler contains the greatest percentage of starch, the Warba next, and the Bliss Triumph contains the least.

3. Irish potatoes left in the ground after the regular harvest period show a decided decrease in starch content. There is only a slight increase in starch with regular harvest potatoes over early harvest potatoes.

4. From the data at hand, fine sandy loam soil produces potatoes with a higher starch content than does loamy sand soil.

5. In the varieties of sweet potatoes, Nancy Hall contains the greatest amount of starch and the Red Bermuda contains the least amount. Big Stem Jerseys and Little Stem Jerseys rank in between these two.

6. No important difference in starch content of varieties of sweet potatoes obtained from the Kaw and the Arkansas Valleys was observed.

7. Regular harvest sweet potatoes contain a slightly higher percentage of starch than do early harvest potatoes, and curing causes a decrease in starch content.

8. Potatoes placed in shed storage undergo a much greater weight loss than do cold storage potatoes.

9. Cold storage potatoes decrease gradually in starch content while with shed storage potatoes there is an apparent increase. However, when calculated on the basis of original weights a gradual decrease occurs in both types of storage resulting in about the same total loss for both. The same minimum starch content is attained by cold storage potatoes during a longer period of time than is required by the shed storage potatoes.

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APPENDIX

HISTORY OF SAMPLES COLLECTED

Irish Potatoes

A-1 IRISH COBBLER - EARLY HARVEST.
This sample was grown on sandy loam soil by Paul Mellott, Edwardsville, Kansas. It was dug July 6, and received July 8, 1939. The sample was clean, irregular in shape, non-uniform in size, and consisted mainly of small potatoes.

A-2 BLISS TRIUMPH - EARLY HARVEST.
This sample was grown on sandy loam soil by O. Browning, Linwood, Kansas. It was dug July 5, and received July 8, 1939. The sample was clean, highly uniform in size, and regular in shape.

A-3 WARBA - EARLY HARVEST.
This sample was grown on sandy loam soil by Paul Mellott, Edwardsville, Kansas. It was dug July 6, and received July 8, 1939. The sample was clean, uniform, and regular in size and shape.

A-4 IRISH COBBLER - EARLY HARVEST.
This sample was grown on fine sandy loam soil at Newman Plots, Newman, Kansas. It was dug July 7, and received July 8, 1939. The sample was clean, fairly uniform, large, and regular in size and shape. It was grown on soil that had grown potatoes following potatoes.

A-5 IRISH COBBLER - REGULAR HARVEST.
This sample was grown on fine sandy loam soil at Newman Plots, Newman, Kansas. It was dug July 11, and received July 14, 1939. The sample was clean, large, fairly uniform and regular. It was taken for variety comparison and was grown on the same soil as were A-6 and A-7.

A-6 BLISS TRIUMPH - REGULAR HARVEST.
This sample was grown on fine sandy loam soil at Newman Plots, Newman, Kansas. It was dug July 11, and received July 14, 1939. It was clean, fairly large, and regular in size and shape. It was taken for variety comparison and was grown on the same soil as were A-5 and A-7.

A-7 WARBA - REGULAR HARVEST.
This sample was grown on fine sandy loam soil at Newman Plots, Newman, Kansas. It was dug July 11, and was received July 14, 1939. The sample was clean, non-uniform in size, regular in shape, and contained many bad spots. It was taken for variety comparison and was grown on the same soil as were A-5 and A-6.

A-8 IRISH COBBLER - REGULAR HARVEST.
This sample was grown on fine sandy loam soil at Newman Plots, Newman, Kansas. The soil had grown potatoes the previous year. The sample was dug July 12, and received July 14, 1939. It was clean, not very uniform in size, fairly regular in shape, and contained a number of bad spots.

A-9 IRISH COBBLER - REGULAR HARVEST.
This sample was grown on fine sandy loam soil at Newman Plots, Newman, Kansas. The soil had grown good alfalfa the previous year. The sample was dug July 12, and received July 14, 1939. The sample was clean and fairly uniform in size and shape.

A-10 IRISH COBBLER - REGULAR HARVEST.
This sample was grown on loamy sand soil by Mr. Malone, Loring, Kansas. It was dug July 14, and received July 15, 1939. The sample was clean, fairly uniform in size and shape, and of a rather small size. The soil had grown potatoes in 1938.

A-11 IRISH COBBLER - REGULAR HARVEST.
This sample was grown on sandy loam soil by A. W. Travis, Manhattan, Kansas. It was dug July 14, and received July 14, 1939. The sample was clean, fairly uniform in size and shape, but was small. They were grade 2. The sample was stored at 42°F., July 14, 1939.

A-12 IRISH COBBLER - REGULAR HARVEST.
This sample was grown on sandy loam soil by A. W. Travis, Manhattan, Kansas. It was dug July 14, and received July 14, 1939. A-11 and A-12 came in together and were put through a grader. Grade 1 was removed and the remainder used for the sample. Hence, only one sample was used for starch analysis for both of these. The sample was put in shed storage July 14, 1939.

A-13 IRISH COBBLER - LATE HARVEST.
This sample was grown on sandy loam soil by Paul Mellott, Edwardsville, Kansas. It was dug July 19, and received July 19, 1939. The sample was clean, large, and fairly uniform in shape. Some had rotten spots inside the potatoes while others showed external rotting.

A-14 WARBA - LATE HARVEST.
This sample was grown on sandy loam soil by Paul Mellott, Edwardsville, Kansas. It was dug July 19, and received July 19, 1939. The sample was clean, fairly large, and rather irregular in shape. There was some internal rotting of the potatoes.

A-15 BLISS TRIUMPH - LATE HARVEST.
This sample was grown on sandy loam soil by O. Browning, Linwood, Kansas. The sample was dug July 19, and received July 24, 1939. It was clean, uniform in size and shape, but contained considerable rot throughout. The sample had been misplaced in storage and was not found for several days.

A-16 IRISH COBBLER - LATE HARVEST.
This sample was grown on fine sandy loam soil at Newman Plots, Newman, Kansas. It was dug July 25, and received July 25, 1939. The sample was clean, uniform in size and shape, and was rather large in size.

A-17 IRISH COBBLER - LATE HARVEST.
This sample was grown on loamy sand soil by Maney Aufrey, Newman, Kansas. It was dug July 19, and received July 26, 1939. The sample was clean, non-uniform in size and shape, and contained considerable rot. It had been misplaced in storage and was not found for several days.

A-18 IRISH COBBLER - LATE HARVEST.
This sample was grown on upland soil by Erwin Abmeier, Atchison, Kansas. It was dug July 29, and received July 30, 1939. The sample was clean, uniform in shape, and rather small in size. There were a few rots in the sample.

Sweet Potatoes

B-1 LITTLE STEM YELLOW JERSEY.
Early Harvest - Before Curing. This sample was grown by A. W. Travis, Manhattan, Kansas. It was dug September 15, and was received September 15, 1939.

B-2 NANCY HALL.
Early Harvest - Before Curing. This sample was grown by A. W. Travis, Manhattan, Kansas. It was dug September 15, and was received September 15, 1939.

B-3 RED BERMUDA.
Early Harvest - Before Curing. This sample was grown by A. W. Travis, Manhattan, Kansas. It was dug September 15, and received September 15, 1939.

B-4 LITTLE STEM JERSEY.
Mature (Priestleys) - Before Curing. This sample was grown by R. Skinner, Topeka, Kansas. It was dug September 27, and was received September 27, 1939. The sample was not very clean; it was uniform in size and shape.

B-5 LITTLE STEM JERSEY.
Regular Harvest - Before Curing. This sample was grown by A. W. Travis, Manhattan, Kansas. It was dug October 2, and was received October 3, 1939. The sample was clean, fairly large size, and was uniform in size and shape.

B-6 IMPROVED BIG STEM JERSEY.
Regular Harvest - Before Curing. This sample was grown by A. W. Travis, Manhattan, Kansas. It was dug October 2, and was received October 3, 1939. The sample was clean, uniform in shape, but irregular in shape.

B-7 NANCY HALL.
Regular Harvest - Before Curing. This sample was grown by Mr. Might, Hutchinson, Kansas. It was dug October 7, and was received October 9, 1939. The sample was not very clean, rather large, and irregular in size and shape. It was grown on sandy soil.

B-8 LITTLE STEM JERSEY.
Regular Harvest - Before Curing. This sample was grown by Mr. Might, Hutchinson, Kansas. It was dug October 8, and was received October 9, 1939. The potatoes were fairly large and were of regular shape.

B-9 NANCY HALL.
Regular Harvest - Before Curing. This sample was grown by Kirby Brothers, R.F.D. 6, Wichita, Kansas. It was dug October 6, and was received October 9, 1939. The sample was clean, medium size but regular, and uniform in shape.

B-10 REGULAR BIG STEM.
Regular Harvest - Before Curing. This sample was grown by F. B. Farber, R.F.D. 2, Mulvane, Kansas. It was dug October 6, and was received October 9, 1939. The sample was clean and of a good size and shape.

B-11 LITTLE STEM JERSEY.
Regular Harvest - Before Curing. This sample was grown by Kirby Bros., R.F.D. 6, Wichita, Kansas. It was dug October 6, and was received October 9, 1939. The sample was of a small size, uniform in shape, and clean.

B-12 RED BERMUDA.
Regular Harvest - Before Curing. This sample was grown by A. W. Travis, Manhattan, Kansas. It was dug October 13, and was received October 16, 1939. The sample was of a large size, uniform in shape, and fairly clean.

B-13 NANCY HALL.
Regular Harvest - Before Curing. This sample was grown by A. W. Travis, Manhattan, Kansas. It was dug October 13, and was received October 16, 1939. The sample was fairly clean and was of a large and uniform size and shape.

B-14 RED BERMUDA.
Regular Harvest - After Curing. This sample was grown by A. W. Travis, Manhattan, Kansas. It was dug October 13, and was received November 13, 1939. The sample was clean, large, and uniform in size.

B-15 IMPROVED BIG STEM JERSEY.
Regular Harvest - After Curing. This sample was grown by A. W. Travis, Manhattan, Kansas. It was dug October 2, and was received November 13, 1939. The potatoes were of a medium size, fairly clean, and uniform in size and shape.

B-16 LITTLE STEM JERSEY.
Regular Harvest - After Curing. This sample was grown by A. W. Travis, Manhattan, Kansas. It was dug October 2, and was received November 13, 1939. The sample was of a medium size, fairly clean, uniform in size and shape, and the potatoes were quite solid.

B-17 LITTLE STEM JERSEY.
Regular Harvest - After Curing. This sample was grown by A. W. Travis, Manhattan, Kansas. It was dug October 13, and was received November 13, 1939. The potatoes were medium sized, clean, uniform in size and shape, and were solid.

B-18 NANCY HALL.
Regular Harvest - After Curing. This sample was grown by A. W. Travis, Manhattan, Kansas. It was dug October 13, and was received December 13, 1939. The potatoes were large size, clean, and uniform.