A MICROSCOPICAL COMPARISON OF SOME KANSAS STARCHES

by

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TABLE OF CONTENTS

INTRODUCTION 1

EXPERIMENTAL PROCEDURE 3

Outline of Investigation 3

Characterization of Blackhull Kafir Starch . 4

Determination of Gelatinization Temperatures . 12

Classification of Granules 18

DISCUSSION 25

Blackhull Kafir Starch 25

Gelatinization Temperatures 26

Effect of Growth Conditions on Granule Size . 28

CONCLUSIONS 32

ACKNOWLEDGMENTS 34

REFERENCES 35

APPENDIX 37

INTRODUCTION

The experimental investigations which resulted in this thesis were one phase of a project by the Kansas Agricultural Experiment Station to determine new uses for Kansas agricultural products. The aims and desirability of such an investigation have been stated by Kramer (8) and need not be repeated here except to say that such developments, if successful, could be of great economic importance to the Kansas people.

While it was necessary to know the quantity of starch obtainable from the different sources, it certainly must be admitted that its quality can be none the less important. The actual character of the starch granules is a certain indicator of the way in which the starch will behave when put to the various uses for which it is intended. For example, starch is used in the sizing of certain papers and textiles during the process of manufacture. In order to be used for this purpose, the starch must be made into a paste by boiling with water until a more or less homogeneous mass is formed. Now for each different type of starch there is a definite narrow range of temperature at which the granules in a water suspension of starch suddenly swell up enormously in size and change the thin watery suspension into a thick, viscous paste. It is obvious that for industrial applications it would require less heating to make a paste of a starch in which this process occurs at a relatively low temperature. Szego (17) stated that the viscosity of the paste produced was directly related to the average size of the granules present, the smaller granule size giving the more viscous paste. His work has been confirmed by Janicki (7). This property is highly desirable in certain textile sizing processes. Radley (14, p. 31) also stated that the temperature required for dextrin formation is higher for starches of a smaller granule size. This is an important factor in this type of work. Hence we see the desirability of a knowledge concerning the factors which influence granule size. It was with the purpose of determining these two important characteristics that this investigation was undertaken upon some of the more common varieties of Kansas starches.

Although this work was primarily concerned with the properties of the starches obtained from the different types of Irish and sweet potatoes, data were also taken on the starch obtained from the grain of Blackhull Kafir. This plant is being investigated as a source of commercial starch at the present time. So far as could be determined, the starch from this source has never been characterized in this manner before.

EXPERIMENTAL PROCEDURE

Outline of Investigation

The experimental work was divided into the following three parts.

(a) The characterization of the size, shape, and general properties of the granules of Black-hull Kafir starch.

(b) The determination of the temperature of gelatinization for the various samples of Irish and sweet potato starch. These included different varieties, soil types, and times of harvest.

(c) The classification of the granules in regard to average size and range of sizes included in a particular sample. This was accomplished by taking size-frequency distribution curve data on each sample. These data were then interpreted by means of a statistical analysis of variance.

Characterization of Blackhull Kafir Starch

Reichert (15) listed as some of the most important characteristics of starch granules the staining characteristics, the temperature range of gelatinization, the average size and range of sizes of the granules, and the shape and appearance under polarized and unpolarized light. These characteristics were also listed by Ellis (3).

Staining. For certain types of microscopical work with starch granules it is highly desirable to be able to stain them just the right amount in order to bring out their shapes and markings most clearly. To this end several different methods were tried. The standard procedure of mounting in Lugol's solution (H_2O--1000cc., KI--6 gm., I_2--4 gm.) proved to be wholly unsatisfactory, even at different dilutions, since the process was almost impossible to control. This method resulted in either an unstained granule or one which was stained so deeply as to cover up its markings entirely. On account of this difficulty the method was discarded and a vapor-phase staining method was tried next. This consisted in placing the starch in an open watch-glass in a vacuum desiccator in the presence of a few crystals of solid iodine. The desiccator was then closed, pumped down, and the vapor from the iodine allowed to act on the starch. Different times of exposure were tried and it was found that a period of about three hours gave very acceptable results. This method had the advantage that the granules did not have to be dried before mounting in any medium desired. However, after using this method for some time, another was found which gave superior results and which could also be used for photographic purposes. This process, described by McClung (12, p. 220), gave excellent detail of the granules in contrasting colors. Briefly, it consisted in staining the granules with an aqueous solution of crystal or gentian violet, treating with saturated picric acid solution, drying, and mounting. This resulted in a granule whose markings were stained a deep blue on a bright yellow background. The granules so stained offered high visibility and good contrast for photography. It might be remarked that different starches react differently to the various staining methods, so that a stain suitable for one type might not be satisfactory for another.

Gelatinization Temperature. The temperature of gelatinization of this starch was determined in exactly the same way as that of the Irish and sweet potatoes and the actual method and apparatus will not be described here. This has been fully covered in the section on gelatinization temperatures. The temperatures were read to 0.1° C., although this was probably unnecessary in view of the variation in duplicate runs. The column marked Initial Temperature was the temperature at which the polarization crosses began to disappear, and the column marked Final Temperature was that at which the disappearance of the crosses was complete in a large majority of the granules. The column marked Mean Temperature was the arithmetical average of these two. The results are given in Table 1.

Table 1. Gelatinization temperature

Initial temperature	Final temperature	Mean temperature
68.5° C.	71.5° C.	70.0° C.
67.5	70.0	68.8
67.3	70.0	68.7
66.3	68.8	67.6
66.5	69.0	67.8
66.5	68.3	67.4
67.3	70.0	68.7
67.0	71.3	69.2
67.8	71.0	69.4
67.8	71.0	69.4

From this table the following results were calculated:

Range of gelatinization . . . 67.3 - 70.1° C.

Mean gelatinization temperature . 68.7° C.

Size Range and Average Size of the Granules. For this purpose the diameters of 1000 granules were measured to the nearest 2 microns (1 micron = .001 mm.) and the data thus obtained used to plot a size-frequency distribution curve. In constructing this curve, size in microns was plotted against percent of the granules falling within the indicated groupings. It will be noticed that a bar graph, or histogram, was used in place of a smooth curve. This was due to the fact that the number counted was not nearly enough to justify the drawing of a continuous smooth curve. Moreover, the histogram gave a much clearer picture of the experimental conditions. The graph was plotted from the data contained in Table 2.

Table 2. Data for the size-frequency histogram

Step interval in microns	Mid point in microns	Frequency	Percent
1 - 3	2	13	1.3
3 - 5	4	94	9.4
5 - 7	6	101	10.1
7 - 9	8	162	16.2
9 - 11	10	127	12.7
11 - 13	12	140	14.0
13 - 15	14	69	6.9
15 - 17	16	100	10.0
17 - 19	18	68	6.8
19 - 21	20	77	7.7
21 - 23	22	22	2.2
23 - 25	24	13	1.3
25 - 27	26	3	0.3
27 - 29	28	1	0.1
29 - 31	30	0	0.0
		N = 1000	

From the information given in the above table the arithmetical mean diameter of the granules of Blackhull Kafir starch was calculated to be 11.5 microns, based upon measurements of a thousand granules.

Shape and Appearance of the Granules. There was only one proper method of describing the appearance of microscopical objects, and that was by a photograph showing the granules as they appeared under actual conditions. Accordingly, photomicrographs of this starch under ordinary and polarized light are given in Plate I.

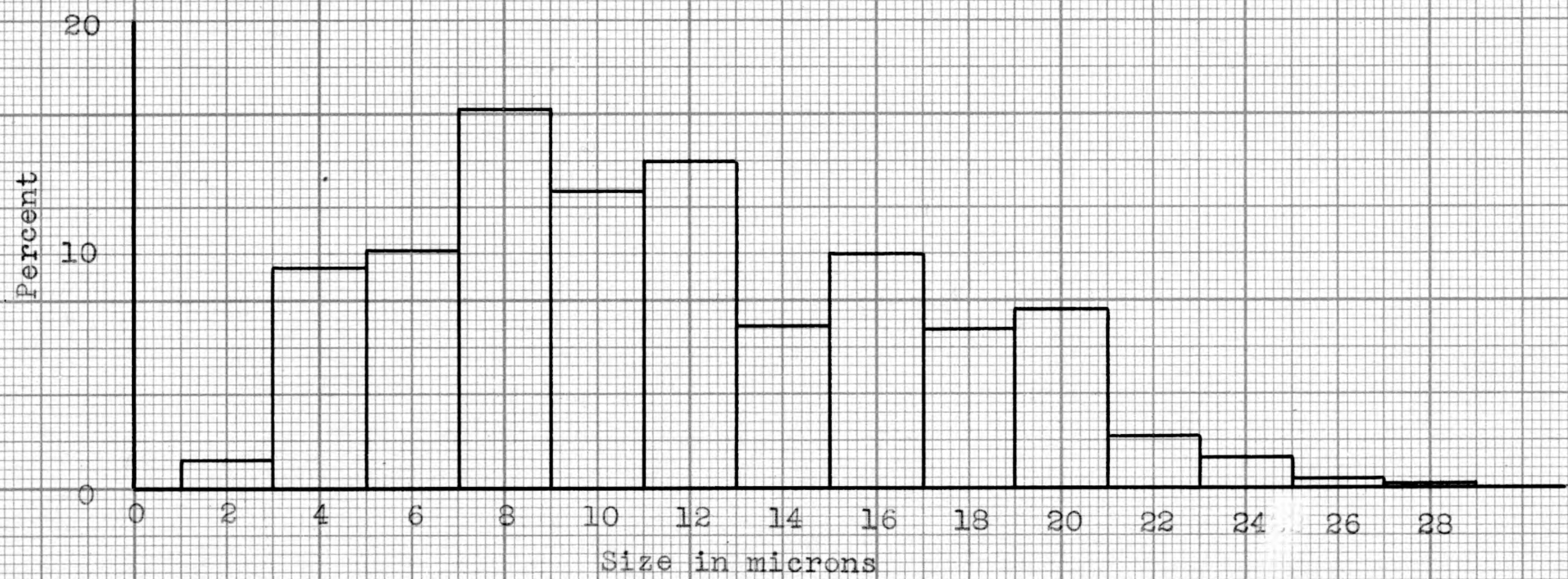

Fig. 1. Size-frequency histogram of Blackhull Kafir starch.

EXPLANATION OF PLATE I

Fig. 2. Blackhull Kafir starch with ordinary light.

Fig. 3. Blackhull Kafir starch with polarized light.

PLATE I

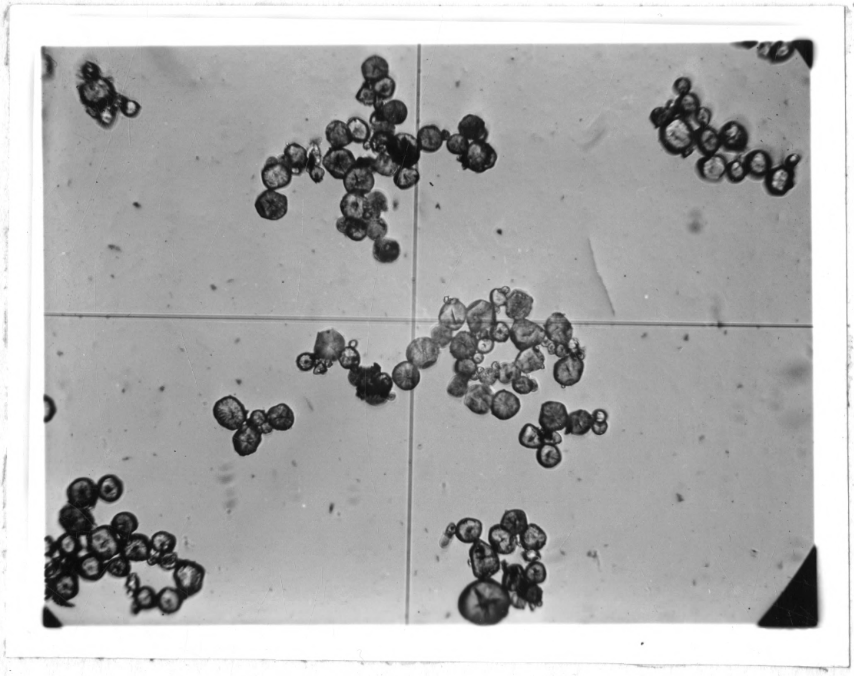

Fig. 2

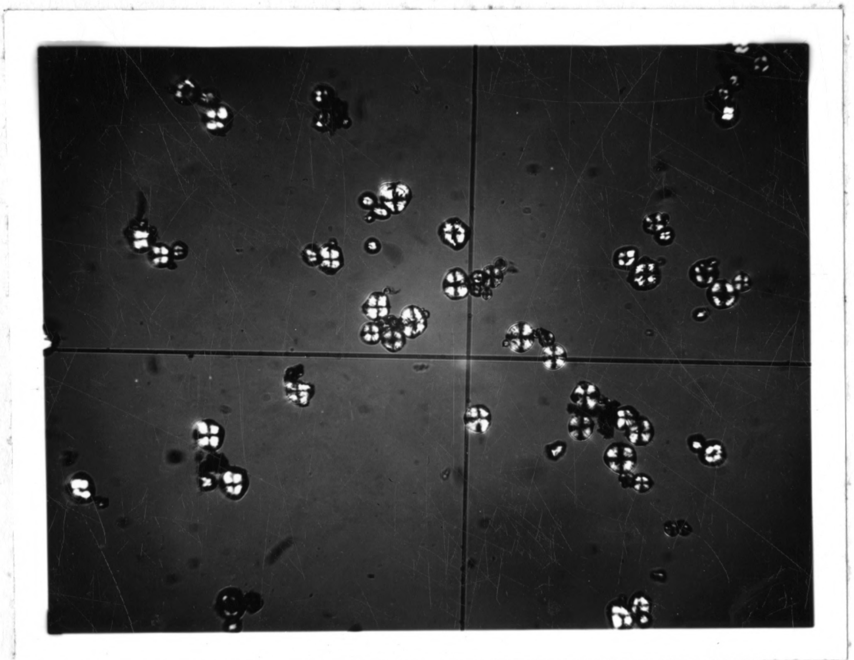

Fig. 3

Determination of Gelatinization Temperatures

As it was stated before, there is a certain definite temperature, or range of temperature, at which the granules of a given starch suddenly swell up when heated with water. This is characteristic of a certain starch and is constant for that one. McNair (13) made use of this fact in his rearrangement of Reichert's (15) data. It was used as one of the qualitative tests in the determination of the source of a particular starch. However, Reichert's method was time-consuming and involved the use of comparatively large quantities of the starch, and McNair suggested that there should be a better method. Such a method was worked out by Francis and Smith (4), and it was their method that was used in this investigation.

The principal part of the apparatus as used by Francis and Smith was a brass cell which they referred to as a thermoslide. This cell consisted of two glass microscope slides mounted in a brass holder so as to leave a space between them. The apparatus was so arranged that the heating liquid was run between the two slides, while the illumination came from the bottom and through the transparent windows. This whole apparatus was placed on the stage of the polarizing microscope and its top window was used just as an ordinary slide would be used. This enabled the temperature of the material under observation to be controlled very closely by controlling the rate of flow of the heating liquid through the cell. Since it would not be possible to place a thermometer at the actual point where the substance being observed was located, other means of measuring it had to be used. This was accomplished by mounting one of two identical thermometers on the inlet side and the other on the outlet side of the cell. The temperature at the center of the cell was taken as the mean of these two readings taken simultaneously. In order to check the accuracy of this method p-dibromo benzene was recrystallized three times from hot benzene and thoroughly dried. The apparatus was used to determine the melting point of this substance in exactly the same way that a gelatinization temperature would be determined except that the actual change from solid to liquid of the crystals was observed instead of the swelling which was noted with the starch granules. At the instant of melting, as observed through the microscope, both thermometers were read and their readings recorded. The results are given in Table 3. The melting point of p-dibromo benzene was given in the literature (9) as 87-88° C.

Table 3. Check on thermoslide reading

Inlet temperature	Outlet temperature	Mean temperature
91.5° C.	84.0° C.	87.8° C.

It should be mentioned that this represented the average of several determinations made under identical conditions. The reason for the selection of p-dibromo benzene was that its melting point lay in the range desired for use.

It is known that while any one observer may become very proficient in reproducing his own results on gelatinization temperatures, the readings of different observers upon identical samples will not necessarily agree within the expected limits of error. This is caused by the facts that the point of disappearance of the polarization crosses is not as exact as the melting point of a crystalline solid and there is a personal factor entering into the determination. With this in mind, it was decided not to attempt to read the temperatures closer than 0.5° C.

The procedure in making a determination follows. Some sort of a reservoir containing the liquid heating medium was connected to the thermoslide by means of small rubber tubing. A three liter Pyrex flask was found to work very well for this purpose. Another similar flask was connected in the same manner to the other side of the thermoslide and placed on a lower level. The liquid was forced through the entire apparatus so as to establish an unbroken column and produce a siphoning action. The flow of the liquid through the apparatus was controlled by means of a small screw clamp located somewhere on the tubing. The heating liquid, which was a concentrated solution of calcium chloride in this investigation, was kept just at the boiling point by means of a Bunsen burner. The temperature and rate of change of temperature of the thermoslide was controlled by controlling the rate of flow of the liquid. Two drops of distilled water were placed in the exact center of the upper window, the surface sprinkled with the starch to be tested, and the whole covered with a thin cover glass. Next the polarizing microscope was focused on the preparation, using a medium-power objective. The polarizer and analyzer were set at right angles to each other and the granules appeared as small bright crosses on a dark background. It was these small crosses which were observed as the heating progressed. The field was kept under constant observation while the screw clamp was opened slightly until a slow, steady rate of heating was attained. The rate of heating used in these determinations was approximately 8° C. per minute. When the polarization crosses just began to fade out, both thermometers were read and the mean of these two readings is the first number given in the column headed <u>Range of Gelatinization</u> in Table 4. The heating was continued at the same rate until the crosses disappeared from the majority of the granules in the field of view. It was sometimes necessary to add a drop of water to the edge of the cover glass to replace the water lost by evaporation during the heating. Both thermometers were again read upon the disappearance of the crosses from the majority of the granules. This gave the upper temperature in the column mentioned above. Considerable practice was necessary before check results were secured.

The results of the determinations upon the various types of Irish and sweet potato starches are given in Table 4. Each of these represents the average of five determinations upon a single sample.

Table 4. Gelatinization temperatures of Irish and sweet potato starches

Sample	Temperature range of gelatinization	Mean gelatinization temperature
A- 1	67.0 - 73.0° C.	70.0° C.
A- 2	66.5 - 71.5	69.0
A- 3	70.0 - 74.5	72.5
A- 4	66.5 - 72.5	69.5
A-11	66.0 - 76.0	71.0
A-12		
A-13	69.0 - 75.0	72.0
A-14	69.5 - 75.0	72.5
A-15	70.0 - 75.0	72.5
A-16	67.0 - 73.0	70.0
B- 4	70.5 - 76.5	73.5
B- 5	70.5 - 77.0	74.0
B- 6	70.0 - 79.5	75.0
B- 9	69.5 - 77.5	73.5
B-10	70.5 - 80.5	75.5
B-11	72.5 - 79.5	76.0
B-12	66.5 - 76.5	71.5
B-13	67.0 - 72.5	70.0
B-14	66.0 - 72.5	69.5
B-15	68.0 - 78.0	73.0
B-16	68.5 - 77.5	73.0
B-17	68.5 - 76.0	72.5

In order to give a better idea of the apparatus used in determining these gelatinization temperatures, a photograph of the apparatus as used is shown in Fig. 4.

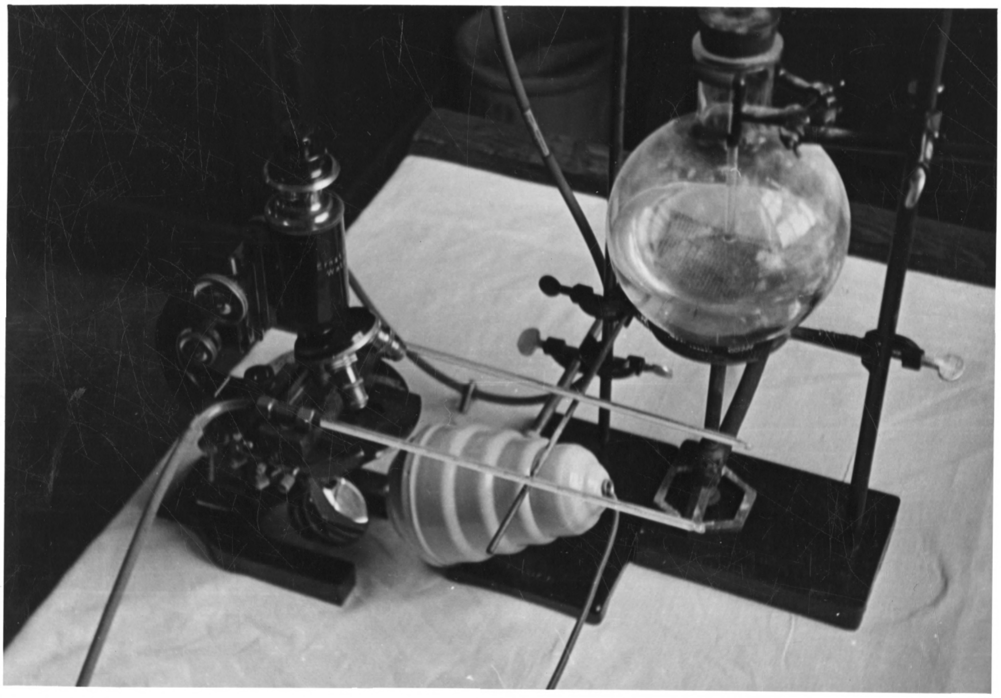

Fig. 4. Gelatinization apparatus.

Classification of Granules

A statistical analysis of any sort is usually very time-consuming and requires the taking of much data. However, it was decided that this was the only practical way in which certain questions regarding the factors influencing the average size of the granules could be answered. Accordingly, it was decided to attempt such an analysis upon the samples of this investigation.

Lindet and Nottin (10) stated that a starch could be characterized with sufficient accuracy if 150 to 200 of the granules were measured. This was practically the only information of this type that could be found on the number of granules which should be taken for measurement. But it was decided that in order to make the results more conclusive, 500 granules from each sample would be measured. Accordingly, this number of granules was carefully measured by means of the microscope equipped with an ocular micrometer which had been previously calibrated against a standard stage micrometer.

The method of taking the measurements was somewhat as follows: Two drops of glycerol were placed upon a glossy black glass plate and a very small portion of the starch to be measured was thoroughly mixed with it. A small portion of this mixture was transferred to another drop of glycerol on a slide, thoroughly mixed, and a cover glass placed over it. The purpose of this procedure was to dilute the mixture and give a more uniform field by avoiding clumps of granules. The slide was then placed on the stage of the microscope and the field and the scale of the ocular micrometer brought into focus. Care was taken to see that the same objective and draw-tube length were used each time as were used when the ocular micrometer was calibrated. By means of the mechanical stage, a uniform path of observation was taken across the slide, each granule being measured as it passed beneath the micrometer scale. These measurements were made to the nearest two microns in this case. The process was stopped as soon as a total of 500 granules had been measured.

No difficulty was experienced in the case of sweet potato starch since the granules were approximately circular in outline. However, the granules of white potato starch offered considerable difficulty because they were elliptical in outline and it was desired to measure the longer dimension. This was overcome by the mounting of an aluminum diaphragm stop in the ocular so as to limit the field of view to the portion covered by the micrometer scale. Before a reading could be taken, the granules were moved beneath the scale and measured as before, except that the scale had to be twisted around until it ran in the same direction as the long axis of the granule. Garner (5) stated that it was this measurement of the long axis that was the most useful.

To serve as a check on the reliability of the method and also for use in the statistical computations, it was decided to count a larger number from one single sample. For this purpose 5000 granules were measured from the B-5 sweet potato sample. The results of this were used in the plotting of the size-frequency histogram of Fig. 5. This, together with Fig. 6 for white potato starch sample A-1, is given in order to show the general character of the size range and amounts of the various sizes to be expected in these two types of starch. It was at first planned to include histograms of this type for all of the samples, but the differences were not clearly shown by this method. The data for the histogram of sample B-5 are given in Table 5.

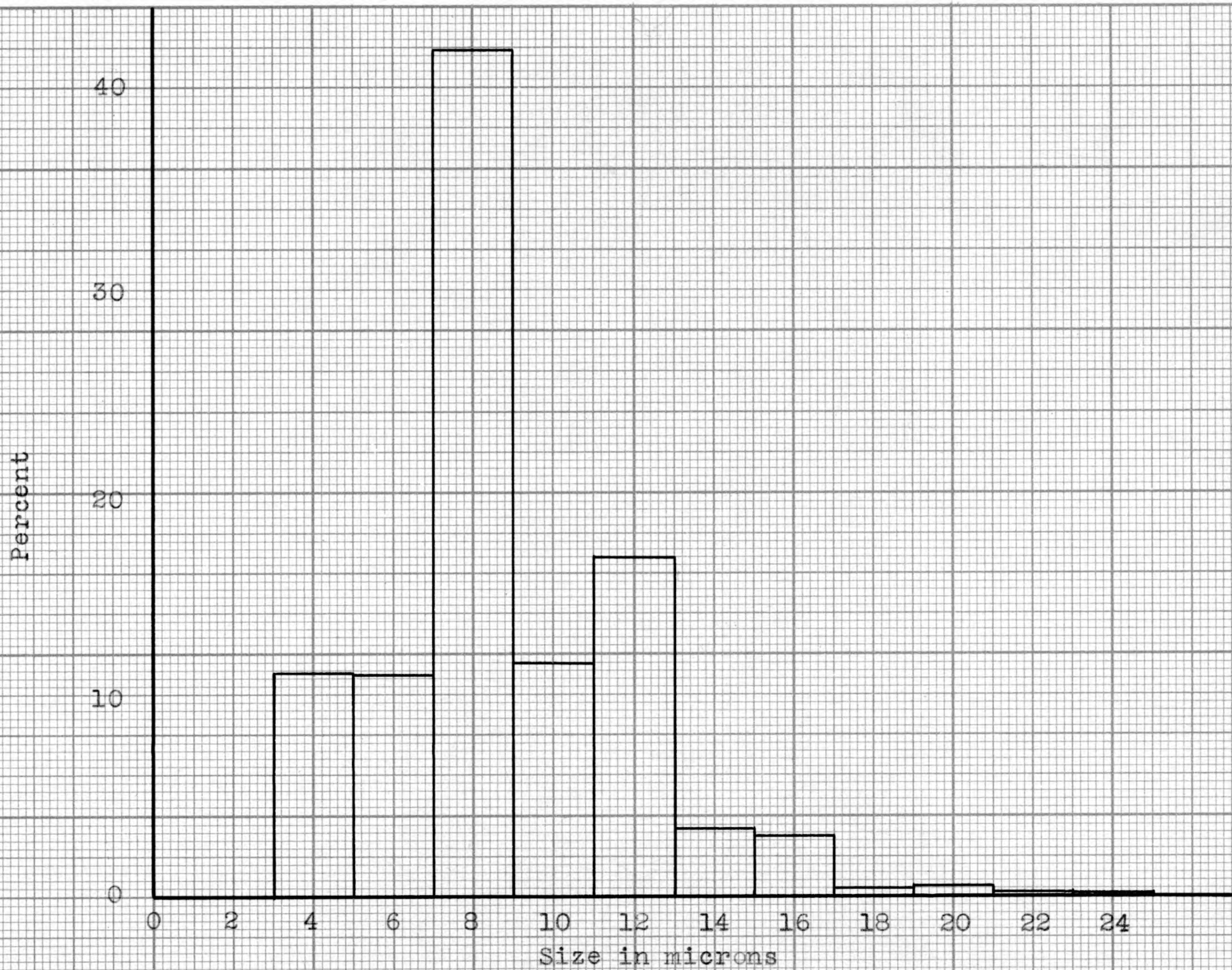

Fig. 5. Size-frequency histogram of Sample B-5.

Table 5. Data for the size-frequency histogram of sample B-5

Step interval in microns	Mid point in microns	Frequency	Percent
1 - 3	2	0	0.00
3 - 5	4	556	11.12
5 - 7	6	554	11.08
7 - 9	8	2096	41.92
9 - 11	10	583	11.66
11 - 13	12	840	16.80
13 - 15	14	169	3.38
15 - 17	16	149	2.98
17 - 19	18	20	0.40
19 - 21	20	27	0.54
21 - 23	22	4	0.08
23 - 25	24	2	0.04
25 - 27	26	0	0.00
		N = 5000	

Only 500 granule measurements were available for the construction of Fig. 6. The corresponding data for this figure are given in Table 6.

Table 6. Data for the size-frequency histogram of sample A-1

Step interval in microns	Mid point in microns	Frequency	Percent
2 - 6	4	0	0.0
6 - 10	8	24	4.8
10 - 14	12	64	12.8
14 - 18	16	87	17.4
18 - 22	20	102	20.4
22 - 26	24	67	13.4
26 - 30	28	40	8.0
30 - 34	32	27	5.4
34 - 38	36	25	5.0
38 - 42	40	23	4.6
42 - 46	44	15	3.0
46 - 50	48	13	2.6
50 - 54	52	3	0.6
54 - 58	56	5	1.0
58 - 62	60	3	0.6
62 - 66	64	1	0.2
66 - 70	68	1	0.2
70 - 74	72	0	0.0
		N = 500	

On account of the decision not to include all of the histograms as planned at first, it was thought that some data should be given for all the samples examined to serve as a basis for comparisons. A table of average sizes of the granules, based upon measurements of 500 granules served this purpose. These average sizes for each sample were the first step in the statistical analysis. The arithmetical average sizes of the various samples are shown in Table 7.

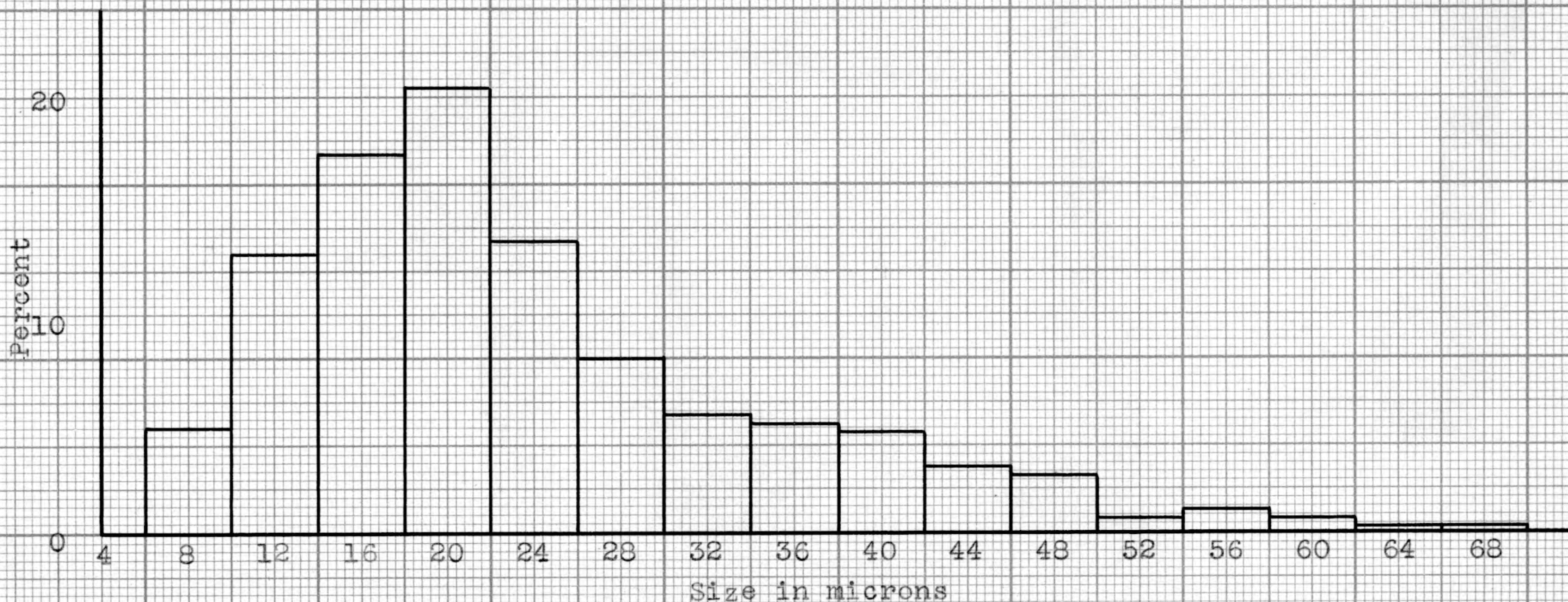

Fig. 6. Size-frequency histogram of Sample A-1.

Table 7. Average size and growth data for white and sweet potato starches

Sample:	Variety	: Harvest	:Treatment:	Source	:Average diameter in microns
A-1	Irish Cobbler	Early		Edwardsville, Kansas	23.67
A-4	Irish Cobbler	Early		Newman, Kansas	24.26
A-13	Irish Cobbler	Late		Edwardsville, Kansas	26.06
A-16	Irish Cobbler	Late		Newman, Kansas	26.08
A-2	Bliss Triumph	Early		Linwood, Kansas	22.64
A-15	Bliss Triumph	Late		Linwood, Kansas	22.40
A-3	Warba	Early		Edwardsville, Kansas	33.91
A-14	Warba	Late		Edwardsville, Kansas	28.28
B-11	Little Stem Jersey	Regular		Arkansas Valley	9.13
B-4	Little Stem Jersey	Regular		Kaw Valley	9.88
B-5	Little Stem Jersey	Regular		Kaw Valley	9.10
B-16	Little Stem Jersey	Regular	Cured	Kaw Valley	8.27
B-17	Little Stem Jersey	Regular	Cured	Kaw Valley	8.87
B-13	Nancy Hall	Regular		Kaw Valley	8.49
B-9	Nancy Hall	Regular		Arkansas Valley	10.11
B-12	Red Bermuda	Regular		Kaw Valley	9.50
B-14	Red Bermuda	Regular	Cured	Kaw Valley	8.96
B-6	Improved Big Stem	Regular		Kaw Valley	9.78
B-15	Improved Big Stem	Regular	Cured	Kaw Valley	8.69
B-10	Regular Big Stem	Regular		Arkansas Valley	9.12

DISCUSSION

The three phases of this problem will be taken up in the order in which the experimental procedure was given.

Blackhull Kafir Starch

The staining reactions of this particular starch were not abnormal and there was no evidence from the results obtained that it behaved differently from other starches of this same general type. The main purpose of the staining investigation was to find a staining technique suitable for some of the later studies.

There can be no doubt as to the value of a knowledge of the gelatinization temperature of an uninvestigated starch. This enables one to predict many things about its probable behavior on heating. A knowledge of the range of gelatinization may give one a knowledge of the range of temperatures over which one might expect maximum changes of viscosity to occur.

The size-frequency histogram for Blackhull Kafir starch proved to be very interesting, since it indicated great irregularity. Most curves of this type followed the general shape of a normal distribution curve and it was very unusual to obtain one which had more than one definite peak. This was at first thought to be due to experimental difficulties, but duplicate samples definitely showed the curve to be of this general form. This fact may be very useful in explaining the behavior of Kafir starch, since from some work that is being done on another part of this project, this starch seems to behave very irregularly during viscosity-heating determinations.

It might be mentioned that the gelatinization temperature for Blackhull Kafir starch fell within the group of gelatinization temperatures given for different types of Kafir by Francis and Smith (4).

Gelatinization Temperatures

Much has been written on the subject of gelatinization temperatures of the various starches and there is still controversy in this field concerning the mechanism and probable significance of gelatinization. From the data gathered in this investigation, it would seem that there is a difference within any one general class, such as white potatoes. It will usually be noticed in the literature that only one temperature is given for white or sweet potato starch and usually no mention is made of the particular variety upon which the determination was run. It may be that this is not important, but the findings of this study would seem to indicate that it is of some significance, since a variation of 5.5° C. was found between two of the varieties of sweet potatoes.

Even though no statistical treatment of these data was made, a rearrangement of a portion of the information given in Table 4 definitely leads to the conclusion that the temperature of gelatinization is somewhat lowered by the curing process for sweet potatoes. This can readily be seen by an examination of Table 8.

Table 8. Effect of curing upon the gelatinization temperatures of sweet potato starches

Sample	Variety	Treatment	Gelatinization temperature
B-4	Little Stem Jersey		73.5
B-5	Little Stem Jersey		74.0
B-16	Little Stem Jersey	Cured	73.0
B-17	Little Stem Jersey	Cured	72.5
B-12	Red Bermuda		71.5
B-14	Red Bermuda	Cured	69.5
B-6	Improved Big Stem		75.0
B-15	Improved Big Stem	Cured	73.0

Variety considerations are eliminated from this conclusion by the fact that the curing process lowered the gelatinization temperature in three separate varieties. It is generally thought that lowering the particle size of a starch will raise its gelatinization temperature. Since it is shown in another part of this study that the granule size was lowered by curing and it has been shown here that the gelatinization temperature was lowered by curing, it must be concluded that the curing process also alters the granules in some other manner, thus producing this apparent anomaly. The principal purpose in collecting this part of the data was for use in connection with another phase of the project which is being carried on at the present time. This phase is concerned with the study of gelatinization by viscosity methods, and at the present time, indications are that the gelatinization temperatures being obtained by that method will check very well with those of this study.

Effect of Growth Conditions on Granule Size

For this purpose use was made of the measurements of granule size through an analysis of variance. This was performed by Dr. H. C. Fryer of the Department of Mathematics. The involved statistical treatment will not be given here as standard methods were used. It must be emphasized very strongly that these data did not lend themselves readily to a treatment of this kind, as comparable data were not available for all the variations to be studied. As originally planned, the data would have been much more usable, but some of the samples had been used up when this investigation began and this fact greatly complicated the situation. Notwithstanding this, some trends and several definite conclusions came out of the analysis. The principal results of this analysis are given here.

White Potatoes.

Source. The only comparable data available are on the Irish Cobblers from Edwardsville and Newman, Kansas. Since the variation of the granules within the factors considered for this part outweighs the variation in source, nothing can be concluded about the effect of the source in this case. This may have been due to defective data or defects in the original sampling methods.

Time of Harvest. No general statement can be made about this as the average size of granules seems to be affected both by the variety chosen and the time of harvest. For white potatoes, as a group, it would seem to indicate that time of harvest makes no difference. However, this is not true for individual varieties. These differences are shown in Table 9.

Table 9. Effect of variety and harvest upon granule size of white potatoes

Variety	Time of harvest giving smallest granules
Irish Cobblers	Early
Bliss Triumph	No difference
Warba	Late

Variety. When the mean squares of the different varieties alone were compared, the indications were that the differences in varieties for a given harvest were highly significant in regard to granule size. In order of increasing granule size, the varieties of white potatoes studied were: (1) Bliss Triumph, (2) Irish Cobbler, (3) Warba.

Sweet Potatoes.

Source. The comparison in this case was limited to two varieties: Little Stem Jersey and Nancy Hall, because only on these two were there data for both sources. Here, again, the locality producing the smallest granules seemed to depend upon the variety in question. This is shown in Table 10.

Table 10. Effect of variety and source upon granule size of sweet potatoes

Variety	Source giving smallest granules
Little Stem Jersey	Arkansas Valley
Nancy Hall	Kaw Valley

Curing. Using the comparable data on three different varieties: Little Stem Jersey, Red Bermuda, and Improved Big Stem Jersey, statistical analysis showed that the cured samples unquestionably have a smaller granule size than the corresponding uncured samples.

Variety. The indications were that there are no real differences in granule size in sweet potatoes produced by variety alone. This was shown by the fact that the variations within varieties were greater than the variations between different varieties.

Number of Granules to be Counted.

White Potato Starch. The situation is confused by the fact that the differences within varieties were almost significantly greater than the differences between varieties. Hence, nothing was concluded as to the proper number of granules to measure to characterize white potato starch.

Sweet Potato Starch. The ratio of the granule-to-granule variability to the sample-to-sample variability seems to indicate that 500 granules was a sufficient number, and a smaller number would not have been advisable.

CONCLUSIONS

1. Blackhull Kafir starch is best stained with a Gentian violet-picric acid stain, as this brings out the character of the granules most clearly.

2. Blackhull Kafir starch has a range of gelatinization of 67.3° C - 70.1° C. Its mean gelatinization temperature is 68.7° C.

3. A size-frequency histogram of Blackhull Kafir starch shows extraordinary variability of the granule sizes.

4. The method of Francis and Smith for determining gelatinization temperatures works quite well, and the different varieties of Irish and sweet potatoes have appreciably different gelatinization temperatures.

5. Whether or not the time of harvest is a factor in the granule size of white potato starch depends upon the variety involved. With Irish Cobblers, early harvest would seem to give the smallest granules. With Warba, late harvest is indicated for minimum size, while there seems to be no difference between early and late harvests of Bliss Triumph.

6. Granule size in white potatoes, for a given harvest,

is definitely influenced by variety in the following order of increasing granule size: Bliss Triumph, Irish Cobbler, Warba.

7. There is some evidence that granule size of sweet potato starch is influenced by locality, but the variety factor enters in again. The trend is for Little Stem Jerseys to give smaller granules in the Arkansas Valley and Nancy Halls to give them in the Kaw Valley.

8. Cured sweet potato samples definitely have a smaller granule size than the corresponding uncured samples.

9. Variety alone does not appear to be a factor in the size of the sweet potato starch granules.

10. Five hundred granules seem to be a sufficient number to measure in order to characterize sweet potato starch, and a number smaller than this would seem inadvisable.

11. The curing process of sweet potatoes definitely has the effect of lowering the gelatinization temperature of the starch produced from them.

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APPENDIX

HISTORY OF SAMPLES

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, nonuniform 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-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 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.

Sweet Potatoes

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 size, but irregular in 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 Brothers, 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 - Before 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.