A STUDY OF CERTAIN FACTORS INFLUENCING THE CULINARY QUALITY OF POTATOES, WITH SPECIAL REFERENCE TO THE COLOR OF BOILED POTATOES

THESIS FOR THE DEGREE OF M. S.

Arthur Ward Glidden

1932

THESIS

Potatoes

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THESIS

ACKNOWLEDGEMENT

The author wishes to express his appreciation to Professor H. C. Moore and Dr. E. J. Miller for their guidance and helpful criticism given this work; to the members of the Experiment Station Chemistry staff who assisted in the scoring of the potatoes; and to all others who from time to time have given the author their cooperation.

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A Thesis Prepared by
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in partial fulfillment of
the requirements for the
Degree of Master of Science
Department of Farm Crops

MICHIGAN STATE COLLEGE OF AGRICULTURE AND APPLIED SCIENCE
1932

INTRODUCTION

With the exception of the potatoes used for seed purposes, practically all of the potatoes produced in the United States are used for human consumption. Consequently quality is an important factor in potato production and marketing.

Quality in potatoes is dependent upon two component factors, namely, market quality and culinary quality. Market quality of potatoes is determined by the general appearance of the tubers, attention being given to the size, type and uniformity of the potatoes as well as freedom from surface diseases and mechanical injuries. Culinary quality refers to the quality of the potatoes when prepared for table use. Culinary quality is determined by the cohesion of flesh or sluffing of the cortical layer, the color, the texture and the flavor of the potatoes when cooked.

In recent years the culinary quality of Michigan potatoes has been severely criticized. This criticism is no doubt at least partially responsible for the range in price between Michigan potatoes and potatoes produced in some other states. The price of Michigan potatoes on the Detroit market during the first week of December 1931 was 49 cents per bushel, compared with $1.10 per bushel for Idaho potatoes and 67 cents per bushel for potatoes produced in Maine. It is impossible to determine accurately the exact percentage of this difference

which is due to poor quality, but it would be reasonable to conclude that the profitableness of the potato crop in Michigan could be greatly increased by improving the quality of the crop.

The experiments reported in this paper are all more or less of a preliminary nature. An attempt has been made to determine in what manner Michigan potatoes differ in culinary quality from potatoes grown in Idaho, Maine and Florida. A study of maturity and certain cultural practices was also made in an attempt to ascertain the practices which are inducive to good culinary quality. Since the darkening after cooking is often a serious factor in Michigan potatoes, a study was made to determine the cause of this condition.

REVIEW OF LITERATURE

FACTORS INFLUENCING THE GENERAL CULINARY QUALITY OF POTATOES

Gilmore (1905) working with the Doe's Pride variety found that tubers produced on clay loam were poor in quality, being firm and soggy after boiling, while tubers produced on sandy loam were excellent in quality. The same investigator also reported that immature tubers were less mealy and more soggy than mature tubers.

Ashby (1906) working in England, summarized his investigations as follows: "Indications seem to point to physical causes as exercising the greatest influence on quality, especially temperature and water supply. Loamy soils give uniform warmth and water supply and, therefore, produce the best quality."

East (1908) reported that to give good culinary quality the starch content of the tuber should be high enough to fill the cells of the cooked tuber to the bursting point. Potatoes with a starch content above a certain point, approximately 18%, would easily fall to pieces, or if the cell walls were strong enough to hold together under pressure they would necessarily be tough and woody.

Butler, Morrison and Boll (1913) concluded from their investigations that:

1. As the relative quality of the potatoes increased there was a decrease in the differentiation of the inner medulla.

2. The percentage of starch had no direct influence upon the mealiness of the potato.

3. Mealiness is modified by the water content, potatoes having a relatively high water content being less mealy than potatoes of low water content.

Headen (1927) reported that the results of 68 tests showed that the application of nitrates produced potatoes of poor quality.

Findlay (1928) made an investigation of the quality of potatoes in Scotland. A brief summary of his work is here given:

1. A better quality of potatoes was produced on sandy soil than was produced on clay or peat soils.

2. Dry conditions favored good quality, whereas, wet conditions were apt to cause poor quality.

3. Regardless of wet or dry seasons early plantings gave extremely dry, mealy potatoes, while late plantings gave wet, soapy potatoes.

4. Excessive use of nitrogen and poorly balanced fertilizers resulted in poor quality.

5. The quality of the potatoes was lowered by the omission of phosphorous from the fertilizer mixture.

6. The omission of potash caused many of the varieties to turn black after cooking.

7. Quality was impaired by lime and the continued use of manure.

8. Mosaic affected plants showed no difference in quality, but plants affected with leafroll tended to produce poor quality potatoes.

Child and Williman (1929) found that potatoes with a high percentage of dry matter tend to be accompanied by better texture and flavor than potatoes with a low percentage of dry matter.

The work of Neil and Whittimore (1930) on the relation of mealiness in potatoes and the amount of potash in the fertilizer shows that boiled, baked and mashed potatoes are more mealy when fertilized with a high rather than a low quantity of potash. No correlation between starch content and mealiness was found.

Peacock, Wright, Whiteman and Fuller (1930) made a study of the influence of storage temperatures upon the quality of potatoes. Their investigations showed that the cooking quality becomes better as the storage temperature increased from 32° F. to 60° F. The maximum culinary quality was found in the tubers stored at 60° F. The tubers stored at the lower temperatures were poorest in quality due to the sweet flavor caused by the accumulation of sugars.

FACTORS RELATIVE TO THE COLOR OF COOKED POTATOES

Several investigations have been made to determine the cause of the blackening of raw potatoes. Since there may be a relationship between this type of blackening and the blackening of potatoes after cooking it seems advisable to review some of the outstanding and more recent works. Reference will first be made to the oxidation enzymes of the potato in order to make the resumè of these investigations more understandable.

Onslow (1931) classifies the potato as a plant giving oxygenase and tyrosinase reactions as well as peroxidase reactions. Associated with these enzymes are certain aromatic compounds with the ortho-dihydroxy grouping characteristic of catechol. Oxygenase (Onslow, 1931) catalyses the autoxidation of this group of aromatic substances. This reaction gives an organic peroxide, catechol peroxide, which is subsequently decomposed in the presence of water, giving hydrogen peroxide. The enzyme tyrosinase (Onslow, 1931) is closely associated with oxygenase, as no plant so far studied gives the tyrosinase reactions without also giving oxygenase reactions. Tyrosinase has the power to catalyze the oxidation of the amino acid, tyrosine, producing a pink coloration which gradually deepens to red and finally to black. The black compounds thus formed are known as melanins. Peroxidase (Onslow, 1931) in the presence of hydrogen peroxide will oxidize a number of phenolic substances of different composition such as pyrogallol, catechol,

quinol, benzidine, guaiacum, guaiacol, p-cresol and others. The nature of the actual oxidations associated with peroxidase in the plant is unknown. When normal respiration is taking place in the potato tuber the reactions of these three enzymes are held in a delicate balance and no bad effects are produced.

Under conditions of abnormal respiration certain of these enzymes catalyze reactions detrimental to the potato tuber. Evidence of this is the blackening of raw potato tissue which may be brought about by various causes.

When a raw potato tuber is injured mechanically blackening takes place. Onslow (1931) reports this blackening as being typical of all plants containing oxygenase and a catechol compound. The discoloration is the result of the oxidation of the aromatic substrate by oxygenase and in addition the probable secondary oxidation of other aromatic substances.

Bartholomew (1913), Stewart and Mix (1917), Bartholomew and Bennett (1924) and others have shown that black heart develops when potatoes are stored where the oxygen supply is not ample. According to Bartholomew (1913) an excess of oxygen accumulates in the tubers when they are again placed in an ample atmosphere of oxygen. As a result, the enzyme tyrosinase catalyzes the oxidation of the amino acid tyrosine which has accumulated in a free form. As a final result, the tissue ultimately becomes black.

While working with potato enzymes Onslow (1931) observed another type of abnormal behavior. This may also have

some bearing upon the blackening of potatoes after cooking. In making enzyme preparations from normal potatoes this investigator found that it was possible to wash away the aromatic compound, catechol, with alcohol leaving a colloidal surface bearing only traces of oxidized products of this substance. Such a preparation will give a negative test with guaiacum, since no peroxide will be formed by the action of the oxygenase present. As a result the enzyme peroxidase, which is also present and acts as a catalyst only in the presence of a peroxide, cannot catalyze the oxidation of the guaiacum. However, if the potato tissue is allowed to oxidize considerably before it is treated with alcohol it is impossible, even by the most careful methods, to wash the colloidal surface free from the oxidation products of catechol. The combination of oxygenase and the oxidation products of catechol present in such a preparation is called a laccase. A laccase will always give a positive test with guaiacum.

Tinkler (1931) states that the actual blackening of potatoes after cooking is probably due to oxidation. However, enzyme oxidation is out of the question as any enzymes present would be killed by the boiling process which is at least twenty minutes in duration.

Tinkler makes no mention of the possibility that oxidation products formed previous to the time of cooking may have an important bearing upon the extent of blackening of cooked potatoes. However, the findings of Onslow, Bartholomew

Stewart and Mix, Bartholomew and Bennett, and others, indicate that such a condition is probable.

EXPERIMENTAL

General Methods

The method of determining the culinary quality, the method of scoring and the method of cooking the potatoes was the same throughout all of the experiments. An explanation of these methods is given in the following general procedure.

Method of Determining Culinary Quality

The culinary quality of the potatoes cooked in the experiments reported in this paper was determined by the color, texture, cohesion of flesh, and flavor of the cooked tubers. Perhaps the most important of these factors is the color of flesh after cooking. The most desirable color for boiled, baked or mashed potatoes is a creamy white. A yellowish- white tinge is rather common, and although it is not preferred it is more desirable than a dark grayish or black color. Texture is a second factor which determines culinary quality. A tuber which is mealy or somewhat granular in structure is preferred to one which is soggy, waxy or tough. Sluffing of the cortical layer and cohesion of the flesh is a third factor influencing culinary quality. This applies chiefly to boiled potatoes. The general preference is in favor of a potato which is not firm after boiling and is still held together enough to prevent a sluffing and consequent loss of the cortical layer.

Flavor is the fourth factor used in determining the culinary quality of potatoes. Usually a potato is not seriously discriminated against unless it is either bitter or sweet to the taste.

Method of Scoring

The score card used in judging the culinary quality of the potatoes in these experiments was a simplified form of a score card submitted by Dr. C. F. Clark, Office of Horticultural Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture. The original score card su gested by Dr. Clark was rather complicated, as it involved many factors and even included the degree of intensity of these factors. The individual interpretation of this score card by members of the Experiment Station staff was so varied that it was believed the final results would be very inconsistent if such a scoring system were used. The following simplified score card was devised to overcome this discrepancy.

SCORE CARD FOR BOILED POTATOES

Cohesion of flesh	Slightly disinte-grated Score 5	Moderately disinte-grated Score 4	Firm Score 3	Much disinte-grated Score 2	Completely disinte-grated Score 1
Color of flesh	Creamy White Score 5	Yellowish White Score 4	Grayish Score 3	Yellow Score 2	Cortex or Basal end blackish Score 1
Texture	Mealy Coarse Grained Score 4	Mealy Fine Grained Score 3	Waxy Score 2	Soggy Score 1	
Flavor of flesh	Normal Pleasant Score 4	Flat Score 3	Earthy Score 2	Sweet Score 1	

Figures 1,2,3,4,5 illustrate the five degrees of cohesion of flesh given on the above score card.

Effectiveness of the Score Card Used

The score card used in determining the culinary quality of potatoes in these experiments was, in most cases, satisfactory. An occasional lot of potatoes was found, however, which was difficult to score. Such lots were always tough and hard after they had been cooked. Experience with these lots has suggested the advisability of adding to the score card a factor pertaining to the tenderness of the cooked potato.

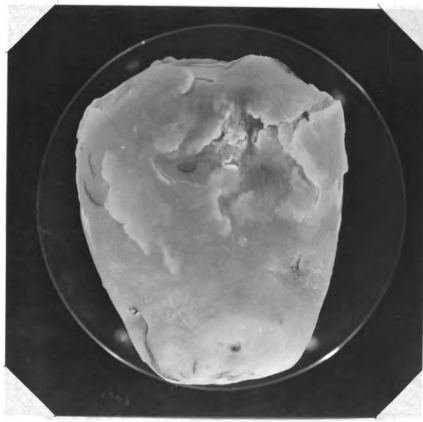

Figure 1. A Cooked Potato Tuber Slightly Disintegrated

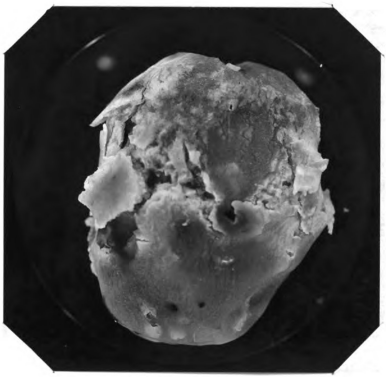

Figure 2. A Cooked Potato which is Moderately Disintegrated

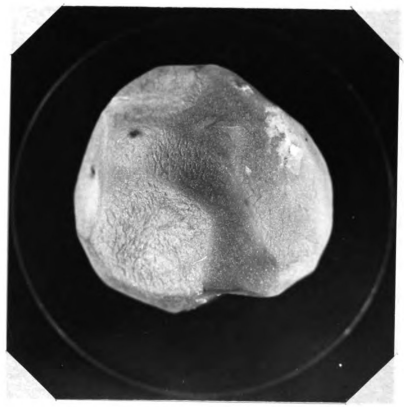

Figure 3. A Cooked Potato Tuber which is Firm

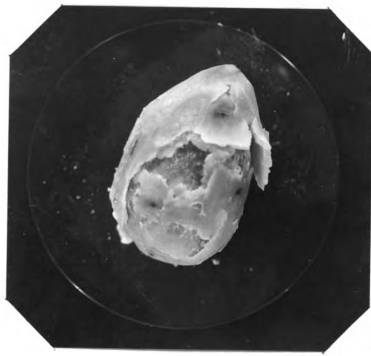

Figure 4. A Cooked Potato Tuber which is Much Disintegrated

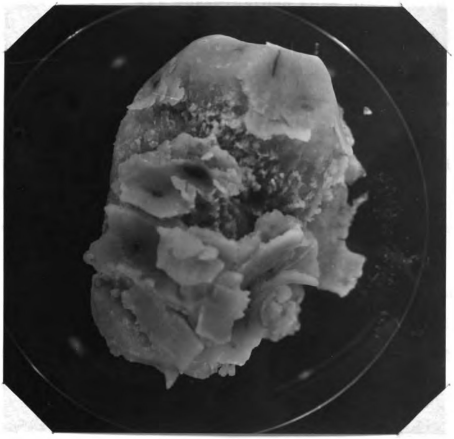

Figure 5. A Cooked Potato Tuber Completely Disintegrated

Method of Cooking

In the cooking tests the potatoes were boiled. Preliminary observations indicated that this method emphasized the factors which go to make up culinary quality better than baking or mashing. These observations were similar to the results obtained by Child and Williman (1929) who found that potatoes which show high quality for boiling will also show it for baking, providing the tendency to sluff is ignored. Boiling also has certain advantages over baking as a method of determining the culinary quality of potatoes. First, it requires less time to complete the test. Second, in boiling potatoes the sluffing of the cortical layer becomes an additional factor by which the culinary quality can be judged.

The potatoes were boiled in four-quart aluminum kettles. Each kettle was provided with a galvanized wire basket which was suspended in the kettle so that the bottom of the basket was one and one-half to two inches from the bottom of the kettle. The tubers were placed in the basket for boiling. This method facilitated the removal of the potatoes when cooked and prevented burning. A hole was made in the cover of each kettle so that a thermometer could be inserted in one of the tubers. This apparatus is shown in Figure 6.

Peacock, Wright, Whiteman and Fuller (1930) found that potatoes were thoroughly cooked when the temperature inside the tubers reached 95° C. Preliminary tests showed this

temperature to be very satisfactory for these experiments. When this temperature was reached the potatoes were removed and placed on porous plates. After allowing four minutes to cool the potatoes were scored.

Figure 6. The Apparatus used in the Cooking Experiments

Two phases of experimental work are here presented. Part I deals with factors influencing the general culinary quality of potatoes. Part II deals with factors influencing the color of boiled potatoes.

PART I

FACTORS INFLUENCING THE GENERAL CULINARY QUALITY OF POTATOES

Procedure and Results

Comparison of the Culinary Quality of Certain Varieties of Potatoes from Various Sources

In this experiment comparisons were made between the culinary quality of the 1931 crop of Idaho Russet Burbanks, Maine Green Mountains, Michigan U. S. #1 Russet Rurals, Michigan New Standard Potato Club Russet Rurals and the 1932 crop of winter potatoes of the Spaulding Rose and Bliss Triumph varieties from Florida.

The New Standard Potato Club is an organization of Michigan potato growers under the direct supervision of the Michigan Crop Improvement Association. Potatoes marketed as New Standard Club stock have been grown under soil and cultural conditions which tend to produce a product of good culinary quality. The rules regulating the grading and sorting of this

stock are very strict. The potatoes must be graded to a 2½ inch minimum. All mechanically injured, scabby and off-type tubers must be removed to eliminate waste in paring. All potatoes marketed as New Standard Club potatoes bear the tag of the Michigan Crop Improvement Association stating that the above conditions have been fulfilled.

Ten lots of Idaho Russet Burbanks and the U. S. #1 Michigan Russet Rurals were purchased from time to time from grocery stores in Lansing and East Lansing. Ten lots of the 1932 winter crop of the Spaulding Rose and Bliss Triumph varieties from Florida were obtained from produce terminals in Detroit through the Michigan State Department of Agriculture. Only seven lots of Maine Green Mountains could conveniently be obtained. Two of these lots were purchased from grocery stores in Lansing. The remaining five lots were obtained from produce terminals and grocery stores in Detroit. Twenty-five lots of Michigan New Standard Potato Club Russet Rurals were used in this experiment. Two of these lots were purchased in March 1932 from grocery stores in Lansing. The remaining twenty-three lots were obtained directly from the growers during November 1931.

The general method of sampling for the boiling tests was as follows. Three samples of five tubers of uniform size were taken from each lot and boiled in separate kettles. Each sample was scored by three judges. The same individuals acted as judges throughout the entire experiment. The data presented are the average score of all judges for all three

samples. Two exceptions were made in this procedure. Only one sample was taken from the twenty-three lots of New Standard Potato Club Russet Burals obtained from the growers. It is felt that the relatively large number of lots helps to offset this discrepancy. The second exception was made with the Spaulding Rose and Bliss Triumph potatoes from Florida. These lots were so small that only two samples could be used for the cooking tests. However, little variation was observed in the tubers from any one of these lots and it is believed that the culinary quality of each lot was accurately determined by the two samples.

Calculations

In making the comparisons between the varieties the mean total score was used. The probable error was calculated by multiplying the standard deviation by 0.6745 and dividing by the square root of the number of lots. Expressed by formula this method is

$$P.E._{mean} = \frac{S.D. \times 0.6745}{\sqrt{N}}$$

When comparisons were made between varieties which were represented by an unequal number of lots the smaller number of lots was taken as the value of N.

The mean scores of the varieties and their differences with their respective probable errors are given in Table I.

An additional comparison was made to show the manner in which the varieties differed from each other. These data are given in Table II. Each factor upon which the culinary quality was determined is listed in column 1 opposite the varieties in column 2. The number of times each variety received a certain score for each factor on the score card is given in column 3. In order to make the comparisons more apparent, the figures given are all on the basis of 100 times scored. The actual number of times scored is given in column 4. The weighted average score for each variety for each factor is given in column 5. As calculated, the weighted average score for any factor is the sum of the products of the number of times each score was given, multiplied by the number corresponding to that score, divided by 100. For example, on the basis of 100 times scored the cohesion of flesh for the Idaho Russet Burbanks was scored 20 times as 5, 23 times as 4, 19 times as 3, 28 times as 2, and 10 times as 1. The weighted average score for cohesion of flesh for this variety consequently is,

$$\frac{(20 \times 5)+(23 \times 4)+(19 \times 3)+(28 \times 2)+(10 \times 1)}{100} = 3.15$$

Table I. Mean Scores for each variety tested, and the differences between the Means with their respective Probable Errors.

Variety and Origin	Mean Score	Michigan New Standard Potato Club Russet Rurals	Idaho Russet Burbanks	Florida Winter Crop 1932	Maine Green Mountains	Michigan U.S. #1 Russet Rurals
Michigan New Standard Potato Club Russet Rurals	15.16		0.46±.28	1.14 ± .50	*2.41 ± .47	*2.72±.65
Idaho Russet Burbanks	14.70	0.46 ± .28		0.68 ± .46	*1.95 ± .41	*2.26±.62
Florida Winter Crop 1932	14.02	1.14 ± .50	0.68±.46		1.27 ± .60	1.58±.72
Maine Green Mountains	12.75	*2.41 ± .47	*1.95±.41	1.27 ± .60		0.31±.78
Michigan U.S.#1 Russet Rurals	12.44	*2.72 ± .65	*2.26±.62	1.58 ± .72	0.31 ± .78	

Differences marked with asterisk are greater than 3.2 times their respective Probable Errors

Table II. Comparison of the scores given each variety for each Factor used on the Score Card. Comparisons are made on the basis of 100 times scored

Factor (Column 1)	Variety and Source (Column 2)	Number of times scored (Column 3)					Number of times actually scored (Column 4)	Weighted average score (Column 5)
		5	4	3	2	1		
Cohesion of Flesh	Michigan U.S.#1 Russet Rural	54	18	28	0	0	90	4.26
	Michigan New Standard R. Rural	31	48	0	21	0	75	3.89
	Fla. Winter crop of 1932-B.T.;Sp.R.	25	22	53	0	0	60	3.72
	Maine Green Mountains	35	5	55	5	0	63	3.70
	Idaho Russet Burbank	20	23	19	28	10	90	3.15
Color	Idaho Russet Burbank	60	31	9	0	0	90	4.51
	Fla. Winter crop of 1932	53	37	3	0	7	60	4.29
	Michigan New Standard R. Rural	36	28	36	0	0	75	4.00
	Maine Green Mountain	11	22	54	0	13	63	3.18
	Michigan U.S. #1 Russet Rural	15	21	37	0	27	90	2.97
Texture	Idaho Russet Burbank		71	29	0	0	90	3.71
	Michigan New Standard R. Rural		51	41	8	0	75	3.43
	Maine Green Mountain		6	57	35	2	63	2.69
	Fla. Winter crop of 1932		10	50	27	13	60	2.57
	Michigan U.S. #1 Russet Rural		9	42	28	21	90	2.39
Flavor	Michigan New Standard R. Rural		85	15	0	0	75	3.85
	Fla. Winter crop of 1932		58	32	10	0	60	3.48
	Idaho Russet Burbank		49	37	14	0	90	3.35
	Maine Green Mountain		36	46	16	2	63	3.16
	Michigan U.S. #1 Russet Rural		22	50	22	6	90	2.89

The Influence of Maturity Upon Culinary Quality

In recent years early planting of potatoes has been strongly recommended in Michigan. An experiment was conducted to determine whether or not the increased maturity obtained by early planting had any influence upon culinary quality. The potatoes used for this study were Russet Rurals obtained from the 1931 Date of Planting Demonstration Plots and from greenhouse plots.

Tests with Russet Rurals from 1931 Date of Planting Demonstration Plots

The Date of Planting Demonstration Plots were grown under the supervision of Mr. J. J. Bird, Extension Specialist in Farm Crops. These plots were planted on three dates, the first planting being on May 15, the second on June 1, and the final planting on June 15. At the time of harvesting in the latter part of September and the first part of October, a sample was taken from each date of planting.

Material was collected from one plot in each of the following counties, Emmet, Otsego, Tuscola, Oakland and Lenawee. The June 15 planting was not harvested in Tuscola county due to a very poor stand.

Previous to the time the cooking tests were made, which was during the first week in December, the samples were

stored in a cold storage plant at 40° F.

Five tubers were selected from each sample and cooked to determine the culinary quality. Each sample was scored by three judges. The data given in Table III are averages of the scores of all judges.

Table III. Average score for culinary quality of potatoes planted on three dates

Date of Planting	Average Score Given				
	Cohesion of flesh	Color	Texture	Flavor	Total Score
May 15	4.46	3.94	2.80	3.40	14.60
June 1	4.40	3.40	2.80	3.13	13.73
June 15	4.60	2.60	2.60	2.80	12.60

Tests with Russet Rurals from Greenhouse Plots

Eighty hills of Russet Rural potatoes were planted in the greenhouse on January 1, 1932. The plots were planted with certified seed which had been treated with ethylene chlorhydrin to break the rest period.

The entire planting was divided into three blocks for harvesting. Block I was harvested on March 28, 88 days after planting, block II was harvested on April 7, 98 days after planting, and block III was harvested on April 18, 109 days after planting. Figure 7 shows the greenhouse plots at the time

block II was dug. Blocks I and II were given the same treatment. Six hills in block III were given an excess of water daily for six days previous to digging. An attempt was made to hasten the maturity of the remainder of block III by not watering it for seven days previous to digging. However, the potatoes harvested from this block were still immature at time of harvesting.

In general the tubers produced in all blocks were of good type. An exception was found, however, in the six hills in block III which were excessively watered for six days previous to digging. A few of the tubers from these hills had developed considerable second growth. Figure 8 shows some of the off-type tubers from these hills in comparison with typical Russet Rural tubers from the portion of block III which had not been watered for seven days previous to digging.

The cooking tests were made the same day the potatoes were harvested. Five tubers were selected from each block for the cooking tests. There was a marked uniformity in the culinary quality of the individual tubers from all the greenhouse plots. In every case the three judges, working independently, scored the tubers from each block exactly the same. For this reason it is believed that the five tubers cooked gave an accurate criterion of the culinary quality of the block which they represented.

Figure 7. Greenhouse plots at the time of harvest of Block II, April 7, 1932, 98 days after planting

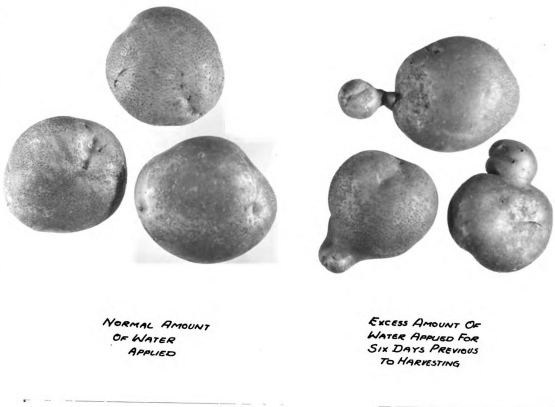

Figure 8. The three tubers at the left were produced in Block III and were not watered for seven days previous to digging. The tubers at the right were also produced in Block III, but were given an excess of water daily for 6 days previous to digging.

The results of the cooking tests made on the potatoes from the greenhouse plots are given in Table IV.

Table IV. Score for Culinary Quality of Potatoes from Greenhouse Plots

	Days Growing Period	Average score given				
		Cohesion of flesh	Color	Texture	Flavor	Total score
Block I	88	4	5	3	4	16
Block II	98	2	5	1	4	12
Block III dry	109	2	5	3	3	13
Block III wet	109	2	5	1	3	11

Influence of Fertilizer Analysis and Rate of Application upon Culinary Quality of Irrigated and non-Irrigated Plots

The material used for this experiment was obtained from the 1931 fertilizer and irrigation plots at East Lansing. Fertilizers of the following analyses were used, 4-16-8; 0-16-8; 0-8-16 and 0-16-0. Applications were made at the rate of 1,000 and 2,000 pounds per acre. Each plot was divided into three blocks for irrigation. The first block was not irrigated, the second block was irrigated from July 16 to September 3 at the rate of 2.08 inches of water per week, and the third block was irrigated at the rate of 1.28 inches of water per week from August 27 to

September 3. A check plot was also included under the irrigation. The overhead sprinkling type of irrigation was used. These plots were not replicated.

One sample was taken from each plot for cooking purposes. Five tubers were cooked from each sample and scored by three judges.

It is believed that the results obtained in this experiment are not worthy of detailed study, as the data do not show any outstanding differences between any of the treatments. Furthermore, since the plots were not replicated comparisons made between them would not be reliable.

DISCUSSION

The Influence of Varieties and Their Source upon Culinary Quality

The data obtained in the comparison of the culinary quality of Michigan New Standard Potato Club Russet Rurals, Idaho Russet Burbanks, Florida Spaulding Rose and Bliss Triumph potatoes, Maine Green Mountains and Michigan U. S. #1 Russet Rurals are given in Tables I and II.

Table I gives a comparison of the average total score of each variety. The differences between the Michigan New Standard Russet Rurals and the two lowest scoring varieties, the Maine Green Mountains and the Michigan U.S. #1 Russet Rurals, are great enough to indicate that the variation in culinary quality is due to factors other than chance. The same is also true regarding the Idaho Russet Burbanks and the two lowest scoring varieties.

The average score of each variety for each factor on the score card is given in Table II. The Michigan New Standard Russet Rurals scored relatively high for all factors, and were considered outstanding from the standpoint of flavor.

The Idaho Russet Burbanks were exceptionally good in color and texture. The flavor of this variety was frequently flat and a few lots were distinctly bitter. The Idaho potatoes showed a decided tendency to sluff when boiled. If sluffing and the cohesion of flesh were not a factor, as is the case when potatoes are baked, the Idaho Russet Burbanks would have been of excellent culinary quality. The potatoes from Florida were poor in texture in comparison to the Idaho Russet Burbanks and the Michigan New Standard Russet Rurals. Otherwise, the Florida varieties tested were of good culinary quality. The Maine Green Mountains and the Michigan U.S. #1 Russet Rurals very frequently turned grayish or black after boiling. These varieties were also inferior in texture and flavor.

The Influence of Maturity upon Culinary Quality

The Influence of Date of Planting upon Culinary Quality

Potatoes were collected from five Date of Planting Plots to determine the influence of early planting upon culinary quality. Although probable errors are not given in Table III a comparison of the differences of the average total scores in respect to their probable errors was made. No significant differences were found between any of the average

total scores. The number of plots represented is not large enough to warrant definite conclusions. However, the data presented in Table III indicate that culinary quality may be improved by early planting.

Influence of Time of Harvesting upon Culinary Quality of Potatoes from Greenhouse Plots

Table IV gives the culinary quality scores of potatoes grown in the greenhouse and harvested at regular intervals. The average total scores were nearly the same for the lots harvested 98 and 109 days after planting. The total score for the lot harvested 88 days after planting is considerably higher than the other scores. No satisfactory explanation can be made for this result. The texture was apparently improved when the potatoes were given the longest growing period and no water was applied for seven days previous to harvesting. An excessive application of water for six days previous to digging caused potatoes given the longest growing period to be soggy.

PART II

FACTORS INFLUENCING THE COLOR OF BOILED POTATOES

While making the cooking tests previously described it was noted that certain lots of potatoes showed a tendency to

turn gray or black after cooking. This blackening usually occured in the cortical area at or near the stem end of the tuber. The tendency to blacken after cooking was more pronounced in the lots of Michigan U. S. #1 Russet Rurals and the Maine Green Mountains than in the other samples cooked. For this reason studies were made in an attempt to determine the cause of the blackening of potatoes after cooking.

The Influence of Poor Aeration in Storage upon the Color of Boiled potatoes

A series of experiments were conducted in an attempt to produce the blackening of potatoes after cooking by interfering with the normal respiration of the potato tubers. In these experiments six to eight tubers were sealed in air tight glass jars and kept in a room where the temperature was approximately 70° F. Figure 9 shows tubers sealed in one of the jars used in these experiments. The tubers were kept in the sealed jars for varying lengths of time. When the jars were opened half of the tubers were cooked immediately. The remaining tubers were placed in thin white muslin sacks and stored in a room at 70° F. for several days before being cooked. Mature and immature Russet Rurals and Florida Spaulding Rose and Bliss Triumph potatoes were used in these experiments.

Figure 9. This photograph shows the type of jar used to produce conditions of poor aeration.

Experiment with Mature Russet Rural Potatoes

The potatoes used in this experiment were Russet Rurals grown in Emmet county. The tubers were all of good type and varied from 7 to 10 ounces in weight. This lot of potatoes was selected for the experiment because cooking tests showed them to be free from blackening after cooking. Previous to the beginning of the experiment on March 7, 1932 the tubers were stored at 40° F.

Ten jars were used in this experiment. The first jar was opened four days after it had been sealed. One of the remaining jars was opened each day thereafter until the tenth jar had been opened. As previously stated, half of the tubers were cooked immediately after the jars were opened. With the exception of the tubers from jars 9 and 10, which were sealed 12 and 13 days respectively, the portion of the sample which was stored at 70° F. was not cooked until 7 days after removal from the jars. This exception was made because the tubers stored in jars 9 and 10 were so badly decayed when the jars were opened that it was believed they would not keep longer than one or two days. The results of this experiment are given in Table V.

Experiment with Immature Russet Rural Potatoes

An experiment similar to the one just described was conducted with some of the potatoes which were grown in the

Table V. The Effect of Deficient Oxygen Supply upon the Color of Russet Rural Potatoes

Jar Number	Days sealed in jar	Days stored in sacks	Color of cooked tubers	Condition of tubers at time of cooking
Check	0	0	White	Normal
1	4	0	Black	Normal
1	4	7	Black	Normal
2	5	0	White	Normal
2	5	7	Black	Button rot and slight black heart
3	6	0	White	Normal
3	6	7	Black	Black heart
4	7	0	Black	Normal
4	7	7	Black	Black heart
5	8	0	White	Normal
5	8	7	Black	Black heart
6	9	0	White	Normal
6	9	7	Black	Black heart
7	10	0	White	Normal
7	10	7	Black	Black heart
8	11	0	White	Normal
8	11	7	Black	Black heart and Button rot
9	12	0	White	Wet curdy rot
9	12	2	Black	serious Black heart and Button rot
10	13	0	White	Wet curdy rot
10	13	1	Black	Serious Black heart and Button rot

greenhouse for the maturity studies. The potatoes used in this experiment were obtained from block I which was dug on March 28, 88 days after planting. As would be expected these potatoes were very immature. The tubers were sealed in five jars. The first jar was opened three days after sealing. One of the remaining four jars was opened every other day thereafter. Two check lots were used in this experiment. The first check was cooked at the time the jars were sealed. The second lot of check tubers was stored in thin white muslin sacks at 70° F. This lot was cooked when the experiment was completed. The results of this experiment are given in Table VI.

Experiment with 1932 Winter Crop of Florida Potatoes

Six lots of the 1932 winter crop of Florida potatoes were used in a third experiment to determine the effect of poor aeration upon the color of boiled potatoes. The lots used in this experiment were selected from the lots used in the variety comparison. Five of the six lots were Spaulding Rose, the remaining lot was Bliss Triumph. With the exception of one lot there was a sufficient number of tubers in the lots to place in two jars. One jar was opened seven days after sealing, the other eleven days after sealing. The single lot which was placed in one jar was opened eleven days after it was sealed. In all cases two sets of check tubers were used. One set was cooked

the day the jars were sealed and the other when the experiment was completed. The results of this experiment are given in Table VII.

Table VI. The Effect of a Deficient Oxygen Supply upon the Color of Immature Russet Rural potatoes. The potatoes used were grown in the Greenhouse and dug 88 days after planting

Jar Number	Days sealed in jar	Days stored in sacks	Color of cooked tubers	Condition of tubers at time of cooking
Check #1	0	0	White	Normal
" #2	0	17	White	Slightly wilted
1	3	0	White	Normal
1	3	8	White	Wilted
2	5	0	White	Normal
2	5	9	White	Wilted
3	7	0	White	Normal
3	7	9	White	Wilted
4	9	0	White	Slight curdy rot
4	9	9	Gray	Soft and flabby
5	11	0	White	Pronounced curdy rot
5	11	3	Gray	Button rot, no Black heart

Table VII. The Effect of a Deficient Oxygen Supply upon the Color of the 1932 Winter Crop of Florida Potatoes

Variety and Lot Number	Jar Number	Days sealed in jar	Days stored in sacks	Color after cooking	Condition at time of cooking
No. 1 Spaulding Rose					
Check #1		0	0	White	Normal
" #2		0	18	White	Normal
	1	7	0	Yellowish white	Normal
	1	7	7	Yellowish white	Slight Black heart
	2	11	0	White	Normal
	2	11	7	Gray	Black heart
No. 2 Spaulding Rose					
Check #1		0	0	White	Normal
" #2		0	18	White	Normal
	1	11	0	White	Normal
	1	11	7	Yellowish white	Normal
No. 3 Spaulding Rose					
Check #1		0	0	White	Normal
		0	18	White	Normal
	1	7	0	White	Normal
	1	7	7	Gray	Normal
	2	11	0	White	Normal
	2	11	7	Black	Normal

Table VII. (continued)

Variety and Lot Number	Jar Number	Days sealed in jar	Days stored in sacks	Color after cooking	Condition at time of cooking
No. 4 Spaulding Rose					
Check #1		0	0	White	Normal
" #2		0	18	2 tubers white; 3 gray	Normal
	1	7	0	Yellowish white	Normal
	1	7	7	Black	Normal
	2	11	0	White	Normal
	2	11	7	Black	Normal
No. 5 Bliss Triumph					
Check #1		0	0	Yellowish white	Normal
" #2		0	18	Yellowish white	Normal
	1	7	0	Yellowish white	Normal
	1	7	7	Yellowish white	Slight to considerable Black heart
	2	11	0	White	Normal
	2	11	7	Yellowish white	Severe Black heart
No. 6 Spaulding Rose					
Check #1		0	0	Yellowish white	Normal
" #2		0	18	Yellowish white	Normal
	1	7	0	Yellow	Normal
	1	7	0	Gray	Slight Black heart
	2	11	0	Black	Normal
	2	11	7	Gray	Considerable Black heart

DISCUSSION

The data presented in Tables V, VI and VII were obtained in three experiments which were conducted to determine the influence of poor aeration in storage upon the color of boiled potatoes.

The results of these experiments show that the blackening after cooking was more frequent in the tubers which had been sealed in jars and later stored in cloth sacks. The length of the storage period in the sealed jars that was necessary to produce this condition varied with the different lots of potatoes used. No relationship was apparent between the blackening of cooked potatoes and black heart.

The changes within the potato tuber which are responsible for the blackening after cooking are not definitely known. However, it is possible that these changes are in some manner associated with the reactions studied by Onslow, Bartholomew, etc., to which reference has previously been made. The results of the investigations of these experimentors help to form a basis for the following discussion of the blackening of potatoes after cooking.

The normal respiration of the potato tuber is interfered with by poor aeration in storage. Under these conditions the amount of oxygen decreases very rapidly until it is either very small or entirely consumed. As the oxygen concentration decreases the carbon dioxide concentration increases. When the tubers are subsequently stored in a well ventilated place they

absorb oxygen rapidly. It is believed that associated with this oxygen absorption there is an oxidation of some of the aromatic compounds present in the potato tuber. The fact that potatoes which blacken after cooking appear normal before cooking is taken as evidence to indicate that this oxidation is inhibited before it is complete and that only intermediate products are formed. Upon exposure to air after cooking these intermediate products are auto-oxidized and the resultant black color is formed.

It will be noted by a study of Tables V, VI and VII that the procedure followed did not produce blackening in certain lots after cooking. Moreover, certain inconsistencies occur in the lots which did blacken after cooking. These differences may be due to inhibiting factors, or perhaps factors other than poor aeration have an influence upon the blackening of potatoes after cooking. The data suggest that maturity or the stage of the rest period or both may be such factors. Furthermore, the increase of carbon dioxide under conditions of poor aeration cannot be ignored, for it may also play a role in the blackening of potatoes.

The data given in this paper are of a preliminary nature. A more complete and thorough investigation is necessary before definite conclusions can be made concerning the cause of the blackening of cooked potatoes.

SUMMARY AND CONCLUSIONS

1. A comparison of the culinary quality of Michigan New Standard Potato Club Russet Rurals, Michigan U. S. #1 Russet Rurals, Idaho Russet Burbanks, Maine Green Mountains, and the 1932 winter crop of Florida Spaulding Rose and Bliss Triumph potatoes has been made.

2. The results of this comparison indicate that the Michigan New Standard Potato Club Russet Rurals and the Idaho Russet Burbanks were superior in culinary quality to the Maine Green Mountains and the Michigan U.S. #1 Russet Rurals. The Spaulding Rose and Bliss Triumph potatoes from Florida were intermediate in culinary quality, being superior to the Maine Green Mountains and the Michigan U. S. #1 Russet Rurals, but inferior to Michigan New Standard Russet Rurals and the Idaho Russet Burbanks.

3. The results of an experiment to determine the influence of the date of planting of Russet Rural potatoes upon culinary quality indicate that early planting may improve the culinary quality.

4. Cooking tests made on potatoes grown in the greenhouse indicate that a heavy application of water for a few days previous to harvesting causes the potatoes to be soggy in texture when cooked.

5. Experimental evidence was obtained which indicates that poor aeration in potato storage may be one factor which causes potatoes to turn black when cooked. Bartholomew and other investigators produced black heart in similar experiments, but made no reference to the effect of poor aeration upon the color of the cooked potatoes.

6. Black heart was produced in the potatoes in the experiments which were stored under conditions of poor aeration. No relationship was found, however, between black heart and the blackening of cooked potatoes.

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