PROCEDURES THAT REDUCE DARKENING OF COOKED POTATOES[1] [2]

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INTRODUCTION

Blackening of potatoes after cooking is unsightly and markedly affects their market value and consumer acceptance. Ultimately, any appraisal of a food must be based on the characteristics consumers prefer (*5*).[3] Several studies of American consumers' preferences tabulate the cooking qualities in potatoes considered most desirable. In 1,032 home interviews in the cities of Cleveland and Rochester (*8*), mealiness was the quality mentioned by more than three-fourths of the homemakers; whiteness was next in preference. The most common complaint of 880 retailers was the tendency of some potatoes to cook black. In a consumer study of 1,653 individuals in New Hampshire, Rinear (*16*) found that 71 percent stressed mealiness and 14.1 percent stressed white appearance as the cooking quality most desirable for potatoes. Spangler (*19*) reported that of 1,165 Chicago retailers, 25 percent listed a tendency to cook black as either the first or the second objectionable cooking defect of potatoes. In a survey of potato preferences among 1,203 household consumers by the Bureau of Agricultural Economics (*27*), 16 percent mentioned "cooked black" as a frequent defect.

Blackening after cooking is a common fault in potatoes grown in certain northern areas. This discoloration does not appear before and during cooking but develops gradually upon exposure of the potatoes to air after cooking, thus reducing their desirability for home and institutional use. The discoloration most often appears first at the stem-end as a gray or blue-gray color. The area may extend over much of the surface and through the vascular regions and even into the interior of the tuber or it may be quite localized. The color varies from a pale blue-gray to a very dark or even black discoloration. If discoloration takes place, it is more intense if the potatoes are steamed or if they are boiled before peeling.

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[3] Italic numbers in parentheses refer to Literature Cited, p. 635.

A number of investigators have successfully reduced the extent and intensity of discoloration in boiled potatoes by adding certain acids to the cooking water. Tinkler (*22*) found that if potatoes which were susceptible to blackening were steamed with ammonium carbonate vapor, darkening was intensified but that potatoes cooked in water containing a little acetic acid were usually better than those cooked in tap water. Gleason and Marlatt (*6*) used 1 part vinegar to 30 parts of water, which lessened darkening but prevented the potatoes from cooking tender. Hansen (*7*) cooked potatoes in acidified waters, and although the color improved, the tubers were not tender. Nutting and Pfund (*14*) boiled potatoes in waters to which either citric acid, lemon juice, or vinegar was added. If the acid was sufficient to give the water a pH value of 4.1 or less before cooking, and not more than 4.9 after cooking, the tendency to blacken decreased or was even prevented. Potatoes cooked in waters with such low pH levels were not palatable because tough layers formed on the outside. Darkening was unchanged or slightly intensified by the use of cooking waters pH 8.4 to 10.

Smith, Nash, and Dittman (*20*) found that the correlation between hydrogen-ion concentration in tuber tissues and the nature and extent of darkening after cooking was high. If potatoes were cooked in dilute solutions of hydrochloric acid and sodium dihydrogen phosphate, pH 4.5, they did not turn dark. Similar potatoes boiled in a disodium phosphate solution, pH 9.6, discolored extensively. Smith and Kelly (*21*) blanched potatoes prior to dehydration in various acid solutions to reduce greying. These workers tested acetic, citric, lactic, orthophosphoric, dihydrogen phosphate, and sulphurous acids and recommended orthophosphoric acid because it was easy to handle, harmless, and cheap.

Thus, there was ample evidence that adding acids to the water when boiling potatoes having a tendency to darken caused color improvement. However, none of the investigators recommended this procedure because potatoes thus prepared did not cook tender. In preliminary tests comparing recommended cooking methods (acid treatment, soaking in water, cooking in milk) acid was shown to be by far the most effective in improving the appearance of potatoes that discolored.

This study was undertaken (*1*) to observe the color, after boiling, of varieties of potatoes commonly grown in Wisconsin and of some newer varieties after various intervals of storage, and (*2*) to determine the effect of various acid treatments on color, flavor, and texture of cooked potatoes.

PROCEDURE

SELECTION OF VARIETIES

The ten varieties chosen for preliminary comparisons included those which Rieman, Tottingham, and McFarlane (*15*) and Tottingham et al. (*24*) classified as having a considerable tendency to blacken as well as some of those that seldom darken. These workers reported that Chippewa, Triumph, or Sebago potatoes rarely cook black regardless of growing conditions, but that Rural New Yorkers and Irish Cobbler often do cook black. Of the samples examined these varieties in 1945 rated for color as follows:

Good	*Fair*	*Poor*
Chippewa	Irish Cobbler	Erie
Sebago	Red Warba	Katahdin
Triumph	Russet Rural	Menomonie
	White Rural	

ENVIRONMENTAL CONTROL

To reduce possible differences in the blackening reaction that might be the result of soil or weather conditions, all potatoes used in any comparative tests were grown in the same experiment station fields. Several investigators have observed that environmental factors influence blackening in potatoes. They are: Tottingham, Nagy, and Ross (*23*), Cowie (*4*), Nash (*11*), Nash and Smith (*12*), Robinson (*17*), Smith, Nash, and Dittman (*20*), Rieman, Tottingham, and McFarlane (*15*), Tottingham et al. (*24*), Wager (*25*) (*26*), Bandemer, Schaible, and Wheeler (*1*).

All potatoes were graded and stored in the cold room of the horticulture department at the Wisconsin station at 38°–42° F. Samples were removed from storage at regular intervals and held at room temperature 10 to 14 days before the cooking tests.

SAMPLING

Previous observations disclosed that darkening in a given variety varies considerably from tuber to tuber. To obtain potatoes that were representative of each variety and as nearly identical as possible, sampling was carefully controlled. For each cooking test, tubers were selected for their uniformity in size and freedom from defects and injuries. Six to 10 tubers were used in most of the observations. Potatoes were cut in equal segments (halves, quarters, or sixths, depending upon the number of tests in a series). For each series, potato segments were distributed in a regular sequence to secure samples that were comparable.

COOKING AND EVALUATING

In a single series all samples were boiled in identical saucepans for the same length of time. After draining, the potatoes were exposed to the air 1 hour at room temperature to permit maximum development of color before color ratings were made. The pH value of the cooking water was determined at the end of the cooking period using a Beckman pH meter with a glass electrode.

Each series of cooked potatoes was scored subjectively for color, texture, and flavor by two to five judges. In addition, a judging panel of about 20 faculty members and students in advanced foods courses evaluated boiled and mashed potatoes treated with cream of tartar. This was repeated three times in order to check the conclusions of the smaller group.

Since there was a decrease in graying of the potatoes when cream of tartar was used, it may have influenced the flavor scores. A consumer preference test (279 individuals) was conducted in an effort to evaluate flavor with a minimum bias. Potatoes that did not discolor were cooked, mashed, and seasoned and then divided into two portions. One served as the control; cream of tartar was added to the other portion in the proportion of one-fourth teaspoon per pound of

peeled potatoes. Color differences between samples thus treated were too slight to be perceptible. Consumers were served two samples and asked to check their flavor preference.

RESULTS

Influence of pH on Color Scores

The effects of different acid treatments on pH values of the cooking water and the corresponding color ratings for boiled potatoes are shown in table 1. Ascorbic, citric, and tartaric acids, calcium diphosphate $CaH_4(PO_4)_2$ and cream of tartar were effective in reducing blackening, if the quantity of acid was sufficient to lower the hydrogen-ion concentration of the cooking water to pH 5 or less. This confirms the findings of Nutting and Pfund (*14*). As pH values for the cooking water decreased, numerical scores for color of boiled potatoes usually increased. When potatoes were poor and darkened severely, as in the 1946 crop, smaller amounts of acid did not always produce good

Table 1.—*Influence of pH upon color of boiled potatoes*

Year and series	Variety	Kind of cooking water or of solution	pH	Color score [1]
1945:				
1a	Erie	Distilled water	6.3	5.5
1a	Erie	Ascorbic acid solution (0.1 percent)	5.3	6.5
1945:				
1b	Erie	Distilled water	6.3	5.0
1b	Erie	Ascorbic acid solution (0.2 percent)	4.5	7.5
2a	Katahdin	Distilled water	6.6	5.5
2a	Katahdin	Ascorbic acid (0.08 percent) solution	5.4	6.5
2a	Katahdin	Ascorbic acid solution (0.16 percent)	4.9	7.5
2b	Katahdin	Distilled water	6.6	5.5
2b	Katahdin	Ascorbic acid solution (0.16 percent)	4.9	8.8
3a	Menomonie	Distilled water	6.3	5.5
3a	Menomonie	Ascorbic acid solution (0.16 percent)	4.8	8.0
3b	Menomonie	Distilled water	6.0	7.0
3b	Menomonie	Ascorbic acid solution (0.1 percent)	5.3	7.5
3b	Menomonie	Ascorbic acid solution (0.16 percent)	4.7	8.0
3c	Menomonie	Distilled water	6.1	5.0
3c	Menomonie	Ascorbic acid solution (0.2 percent)	4.7	8.0
4	Red Warba	Distilled water	6.0	7.0
4	Red Warba	Ascorbic acid solution (0.2 percent)	4.8	8.5
5a	Russet Rural	Distilled water	6.4	6.0
5a	Russet Rural	Ascorbic acid solution (0.2 percent)	4.4	9.0
2	Katahdin	Distilled water	6.6	5.5
2	Katahdin	Calcium biphosphate solution (0.16 percent) $CaH_4(PO_4)_2$.	4.5	7.5
5b	Russet Rural	Distilled water	6.4	6.5
5b	Russet Rural	Calcium biphosphate solution (0.16 percent) $CaH_4(PO_4)_2$.	5.3	7.5
5b	Russet Rural	Citric acid solution (0.2 percent)	4.2	9.0
1946:				
1	Cobblers	Tap water	8.6	5.0
1	Cobblers	Tap water plus 0.2 percent cream of tartar	4.9	6.0
1	Cobblers	Tap water plus 0.4 percent cream of tartar	4.4	6.0
2	Katahdin	Tap water	8.8	7.0
2	Katahdin	Tap water plus 0.2 percent cream of tartar	4.6	8.0
2	Katahdin	Tap water plus 0.4 percent cream of tartar	4.0	9.0
3	Menomonie	Tap water	9.0	5.0
3	Menomonie	Tap water plus 0.2 percent cream of tartar	4.6	8.0
3	Menomonie	Tap water plus 0.4 percent cream of tartar	4.4	6.0
4	Pontiac	Tap water	8.1	6.0
4	Pontiac	Tap water plus 0.2 percent cream of tartar	4.6	9.0
4	Pontiac	Tap water plus 0.4 percent cream of tartar	4.1	6.0
1947:				
1	Russet Rural	Distilled water	6.4	6.5
1	Russet Rural	Cream of tartar solution (M/20)	4.0	8.5
1	Russet Rural	Tartaric acid solution (M/20)	3.1	9.0
1	Russet Rural	Sodium potassium tartrate solution (M/20)	7.4	7.0

[1] Maximum score=10 for most desirable color.

color. When larger amounts of cream of tartar, 0.4 percent were added, a deeper yellow color developed which was considered undesirable by the judges.

The regression equation for color score (y) as a function of pH for all data, regardless of variety was found to be:

$$y=10.4-0.62\ \text{pH}$$

The regression was found to be statistically significant ($t=5.45$, 39 degrees of freedom). There is one chance in 100 that the value of t calculated from a set of data of this size would be greater than 2.71 if there were no true regression.

Effects of Cream of Tartar Treatment on Color and Texture of Boiled Potatoes

The quantity of cream of tartar and the time at which it was added markedly influenced the desirability of the potatoes, as shown in table 2. Texture scores were high if no cream of tartar was employed but color scores were low. If 1 gram cream of tartar was added at the beginning of the cooking period, as illustrated in table by the Katahdin variety of series 2, color ratings were good but textures were poor. If the same quantity of cream of tartar was added to the cooking water after potatoes had boiled 25 minutes, the acid was not detrimental to texture but this treatment was inadequate to improve color. If potatoes were boiled 20 minutes before the addition of cream of tartar, the ratings for texture were good, but color scores were fair. As the results using four different varieties show, potatoes boiled 15 minutes before the addition of cream of tartar had good texture and good color. Increasing the quantity of cream of tartar to 1½ grams or to 2 grams usually resulted in better color scores if

Table 2.—*Effect of cream of tartar treatment on color and texture of boiled potatoes*

Series No.	Variety	Cream of tartar added	Cooking time[1] before adding cream of tartar	Color score[2]	Texture score[2]
		Grams	*Minutes*		
1	Erie	None		6.5	9.5
2	Katahdin	None		4.5	9.0
3	Menomonie	None		6.5	8.5
4	do	None		6.5	9.0
5	do	None		6.0	6.0
6	Pawnee	None		6.0	8.5
2	Katahdin	[3] 1.0	0	8.0	6.5
2	do	1.0	25	6.5	9.0
1	Erie	1.0	20	8.0	9.5
7	do	1.0	20	8.0	9.0
5	Menomonie	1.0	20	7.0	8.0
1	Erie	1.0	15	9.5	8.5
2	Katahdin	1.0	15	7.5	8.5
3	Menomonie	1.0	15	9.0	8.0
4	do	1.0	15	8.5	8.0
5	Pawnee	1.0	15	8.0	8.0
3	Menomonie	1.5	15	9.5	8.5
4	do	1.5	15	9.5	8.5
3	do	2.0	15	10.0	7.0
4	do	2.0	15	10.0	7.0
5	do	2.0	25	8.0	8.0

[1] Total cooking time, 30 minutes.
[2] Maximum score for most desirable color or texture is 10.
[3] 1 gram of cream of tartar to 500 ml. of water equals 0.2 percent.

the potatoes had a marked tendency to darken, but the detrimental influence of acid upon texture was greater.

Photographs of Pontiac potatoes (plate 1) show the regions most affected by blackening as well as the contrast between treated and untreated sections, comparable in every detail.

Effects of Cream of Tartar on Flavor

Both the ratings by a small group of judges of flavor and scorings for color by a panel of 20 make it clear that adding cream of tartar to the cooking water reduced discoloration of potatoes, and increased the color score. Flavor is the next question that must be considered. The distribution bars (fig. 1) show the range for color and flavor scores of boiled potatoes both with and without cream of tartar treatment. Mean values were:

	Color	*Flavor*
Controls	5.2	7.9
Treated	6.9	7.6

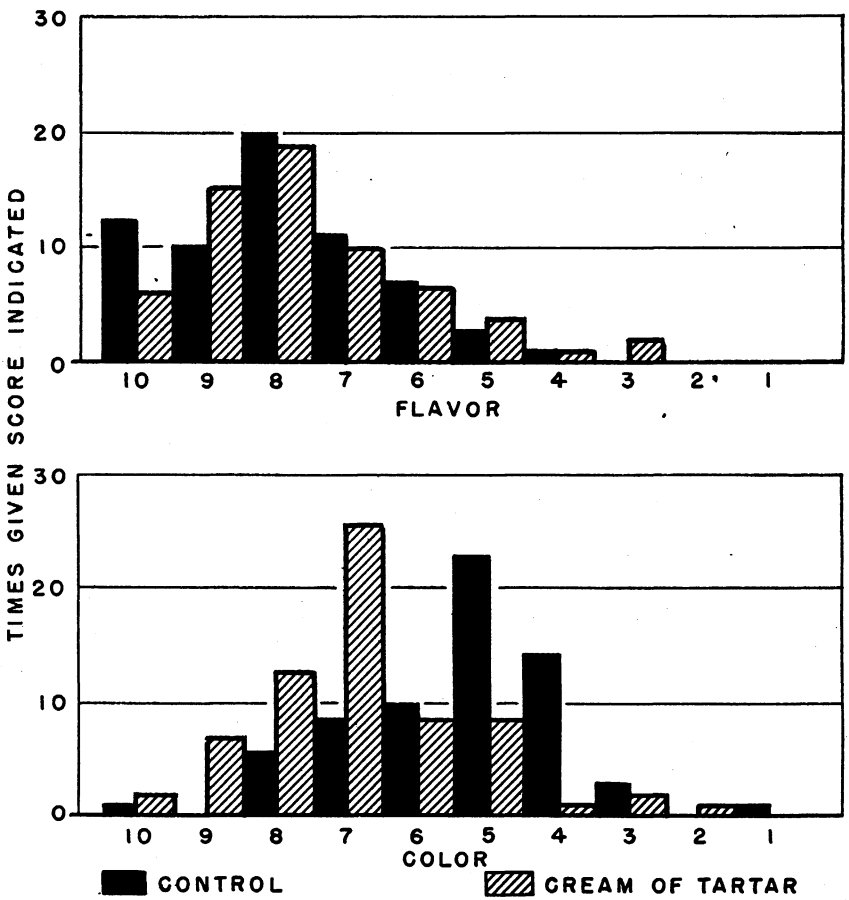
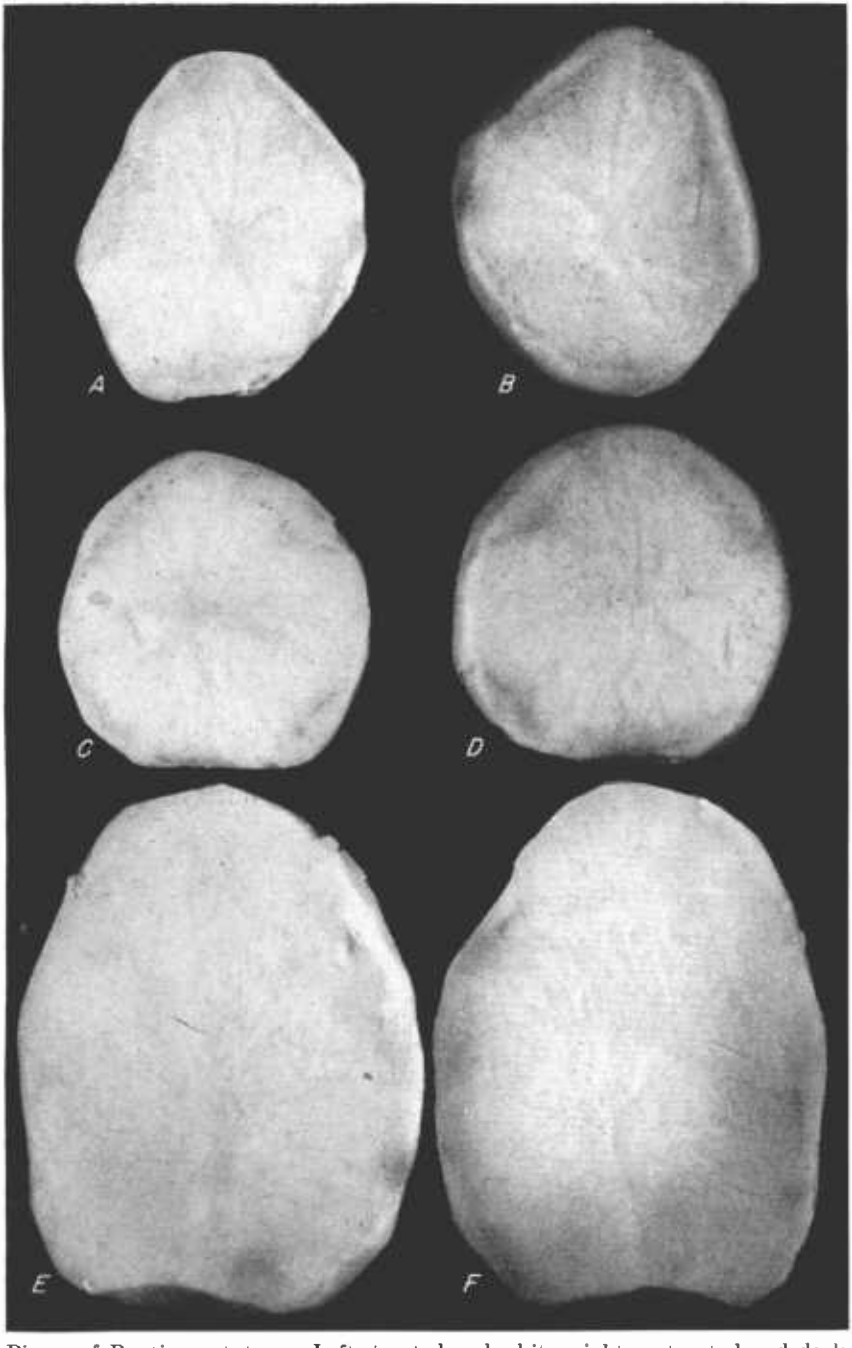


Figure 1.—Distributions of 64 flavor and 70 color scores of boiled potatoes, with and without cream of tartar.



Pieces of Pontiac potatoes. Left, treated and white; right, untreated and darkened. *A–D*, matching faces of transverse and adjacent stem-end slices. *A* and *C*, cooked in water plus cream of tartar, pH 4.2; *B* and *D*, cooked in water of pH 8.5. *E* and *F*, matching halves cut longitudinally. *E*, boiled in water plus cream of tartar, pH 4.6; *F*, boiled in water of pH 8.6.

Figure 1 shows that the distributions for scores on flavor of boiled potatoes were similar except for the greater frequency of 8 for both the control and the treated samples. The distributions for color scores reached a maximum of 5 for the control and 7 for the treated samples.

The results for color and flavor judging for mashed potatoes are given in figure 2. The distribution shows that color scores were definitely higher in potatoes which had cream of tartar added when mashing. Flavor evaluations varied widely, but the mean value for mashed potatoes to which cream of tartar was added was low. The means were:

	Color	*Flavor*
Controls	7. 1	8. 2
Treated	9. 4	6. 2

These results indicated that cream of tartar improved the color of mashed potatoes but for a number of the judges flavor was impaired.

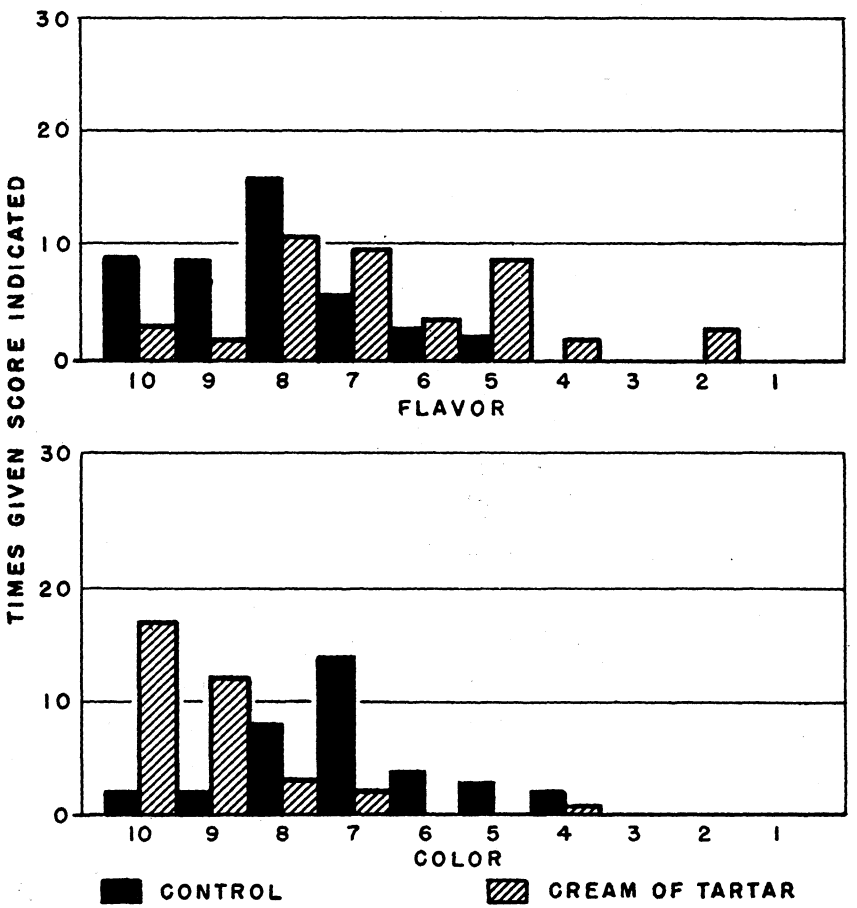


FIGURE 2.—Distribution of 35 flavor and color scores of mashed potatoes, with and without cream of tartar.

No salt or seasonings had been used in either case. Because there was such a wide range in the flavor scores and the color gave a clue to treatment, the question of flavor was investigated further.

In the consumer preference study on seasoned mashed potatoes additional information was secured concerning the effects of cream of tartar on flavor. The results and the statistical analysis follow:

Total number of individuals:	*Number preferring cream of tartar sample:*	*Number preferring sample without cream of tartar:*
279	161	118

$\chi = 6.627$

χ^2 at 5 percent level for 1 d. f. = 3,841; at 1-percent level = 6.635.

These data show that the preferences differ significantly from an expected ratio of 50:50 and approach the value at the 1-percent level.

Figure 2 shows that the greatest frequency of the distributions for scores on flavor of mashed potatoes were, for the controls, at 10, 9, and 8, and for the treated samples, at 8, 7, and 5. Similarly for color scores it was at 8 and 7 for the controls and 10 and 9 for the treated samples.

DISCUSSION

The favorable effect of acetic, ascorbic, citric, hydrochloric, and tartaric acids, as well as lemon juice, calcium diphosphate, and potassium tartrate was exerted on the pH only. This was demonstrated by the fact that when each acid medium was rendered alkaline, darkening developed. The factor or factors responsible for discoloration thus behaved reversibly with change in hydrogen-ion concentration.

That darkening has some relationship to tyrosinase or some labile substance activated by tyrosinase was indicated by Clagett and Tottingham (*3*), Hansen (*7*), Nagy and Tottingham (*10*), and Tottingham, Nagy, and Ross (*23*). It has been reported that certain compounds, among them boric acid and benzoic acid, combine with catechol or other phenolic compounds to interrupt the catalytic activity of pure tyrosinase (Behm and Nelson (*2*), Ludwig and Nelson (*9*) and Nelson and Dawson (*13*)). In this connection the results at the Wisconsin station with these two acids in native potato tissue are interesting. Boric acid or benzoic acid in the cooking water had a marked inhibitory effect on the development of blackening of boiled potatoes. In contrast to the other acids tested, this effect was not reversible with changes in hydrogen-ion concentration.

Although treatments with several acids reduced the extent of discoloration in cooked potatoes with a tendency to darken, few of the treatments were suitable for culinary purposes. Cream of tartar has certain distinct advantages in this respect. It is available, harmless, inexpensive, and reasonably effective. Not only does the action of cream of tartar compare favorably with other acids, but it is easy to measure. For boiled potatoes, the proportion of one-fourth teaspoonful of cream of tartar for each pint of water added when potatoes are half cooked, is best when all palatability factors, such as color, flavor, and texture are considered. For mashed potatoes, one-fourth teaspoonsful of cream of tartar per pound of peeled potatoes may be added at the time of mashing with such other seasonings as salt,

milk, and butter. The favorable effect upon color is thus obtained without any detrimental influence of acid upon texture and ease in mashing.

SUMMARY AND CONCLUSIONS

This study of the effect of acids upon color of potatoes susceptible to darkening confirms the work of others that there is a direct and reversible relationship between hydrogen-ion concentration and degree of darkening.

For two acids, boric and benzoic, some additional factor is probably involved since their effect could not be reversed by simply changing hydrogen-ion concentration.

Food tasting panels were employed to determine the practical application and consumer acceptability of potatoes treated with cream of tartar. Color scores for potatoes that normally cooked dark were significantly higher when the cream of tartar treatment was used than it was in untreated samples. The undesirable effect of acid upon texture of potatoes was reduced if the cream of tartar was added at the mid-point of cooking for boiled potatoes, or at the time of mashing. Flavor acceptability tests in which 279 individuals participated showed that a statistically significant number preferred the flavor of mashed potatoes to which cream of tartar had been added with the other seasonings such as salt, butter, and milk.

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