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POTATO FLAKES-

A New Form of Dehydrated Mashed Potatoes

IV. Effects of Cooling After Precooking

U. S. DEPARTMENT OF AGRICULTURE

AGRICULTURAL RESEARCH SERVICE

This is the fourth in a series of papers describing the manufacture of potato flakes (the three preceding papers are given under *Literature Cited*, Nos. 5,6, and 9). This one describes the benefits of cooling the potatoes after precooking and before the final steam cooking. Based on "blue value indexes" (indication of free soluble starch content) of potato flakes, and also on taste-panel tests, the cooling step makes it possible to produce excellent flakes from lower solids potatoes which would not otherwise be suitable. It also permits the flakes to be broken to smaller sizes without damaging the texture, so that a greater amount of flakes, by weight, can be put in a given size of package. A still further advantage is that flakes can be reconstituted at the temperature of boiling water without significant damage to texture. Blue value data are compared for flakes made with and without the cooling step from several varieties of potatoes of both high- and low-solids content.

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POTATO FLAKES

A New Form of Dehydrated Mashed Potatoes

IV. Effects of Cooling After Precooking

The development of the process for making the new form of dehydrated mashed potatoes, now well known as potato flakes, has been described in earlier papers (5,6,7,9)*. Potato flakes are now made commercially in Idaho, Maine, Michigan, New York, North Dakota and Oregon. Plants are operating in England and Germany; others are planned for Australia, Austria, Canada and Switzerland. As predicted by market acceptance tests (8,10), flakes are finding good acceptance in both retail and institutional markets when marketed by organizations with adequate sales and promotional facilities.

Much of the recent work at the Eastern Utilization Research and Development Division has been concerned with aiding manufacturers in setting up and initially operating their plants. Concurrent with this work, however, research has continued on the application of the flake process to potato varieties not yet studied, and on modifications of the process aimed at further processing economy and further improvement of the product. The object of this paper is to make available to processors the data forming the basis for the processing change we have already suggested to them, mainly, that of cooling the precooked potato slices before the final cooking. This cooling step greatly improves the texture

* FIGURES IN PARENTHESES REFER TO *Literature Cited* AT THE END OF THIS PUBLICATION.

of the flakes when rehydrated, and makes it possible to produce excellent flakes from lower-solids potatoes which would not otherwise be suitable. It also permits the flakes to be broken to smaller sizes without damaging the texture, so that a greater amount of flakes, by weight, can be put in a given size of package. A still further advantage is that the flakes can be reconstituted at the temperature of boiling water without significant damage to texture.

BACKGROUND

The factors associated with cooking quality of potatoes, with emphasis on the texture of the cooked potato, have been the subject of many investigations. That there is a high correlation between degree of meakiness of the cooked potato and the specific gravity and starch content of the raw tuber has been shown (3, 11, 13, 17, 21, 23, 26). Bettelheim and Sterling (2) found the specific gravity-texture correlation to be significant but concluded that it is meaningful only insofar as it reflects the starch texture correlation. They concluded (22) that the principal determining factor in potato texture is the starch content, and that its probable role in texture is to induce cell separation through distention of cells during gelatinization. These observations concur generally with those of Whittenberger (24) and Whittenberger and Nutting (25).

While much has been done to correlate the components of the potato with its texture when cooked, little has been published on attempts to alter texture by in-process treatment of the potato. Personius and Sharp (16) determined, by measurement of the tensile strength of cooked potato tissue, that within the temperature range 113° to 167° F. weakening of the cell-cementing material is carried to a definite point at each temperature and then stops, and that at 167° F. tensile strength is comparable to that of fully cooked potato. They noted no difference between soggy and mealy potatoes in the adhesion of cells.

Reeve's histological surveys (18,19,20) of conditions influencing texture in potatoes indicate that the properties of gelled starch in potato tissue are related to texture of potatoes, and that the influence of these properties can be modified by heat treatment and by other conditions.

Discovery of "precooking" as a step in the potato flake process (6,4) provided a means for improving and controlling the texture of cooked potatoes. It was found that potato slices precooked at 140° to 180° F., preferably at about 160° F., for about 20 minutes, and then finally cooked in steam at 212° F., had much mealier texture than slices cooked only in steam at 212° F. Potato flakes prepared from potatoes first precooked and then finally cooked in steam at 212° F., yield mashed potatoes of much mealier texture when rehydrated than flakes made from potatoes cooked only at 212° F. Through the discovery of the precooking step it became possible to make a mealier product--not only from high-solids content potatoes usually preferred for dehydration processes, but also from lower-solids content potatoes which have nonmealy texture when cooked by ordinary methods.

EXPERIMENTAL

In the course of pilot-plant experiments on potato flakes at the Eastern Utilization Research and Development Division early in 1955, it was observed that potato flakes made from precooked slices that had been held for a time and allowed to cool at room temperature before final cooking had even mealier texture when rehydrated than flakes from precooked slices cooked immediately. Experiments were therefore carried out in which the precooked slices were cooled in water before final cooking. Rehydrated potato flakes made from the precooked and cooled slices in these experiments were submitted to a taste panel for judgment of mealiness. When compared with rehydrated flakes made from slices precooked

but not cooled, the products from cooled slices were generally of better texture. When made from very low solids content potatoes, rehydrated flakes from cooled slices were always of better texture than those from slices precooked but not cooled.

The cooling procedure was then studied in more detail, using more precise measurements of product quality than the taste-panel tests.

Pilot-Plant Procedure

Experiments were made with pilot-plant equipment simulating the processing steps shown in the flowsheet, Figure 1, illustrating a commercial line. Potatoes were peeled by immersion in lye solution of 20% by weight NaOH at 150° F. for a time sufficient to loosen the skins (usually about 6 min.) followed by passage through

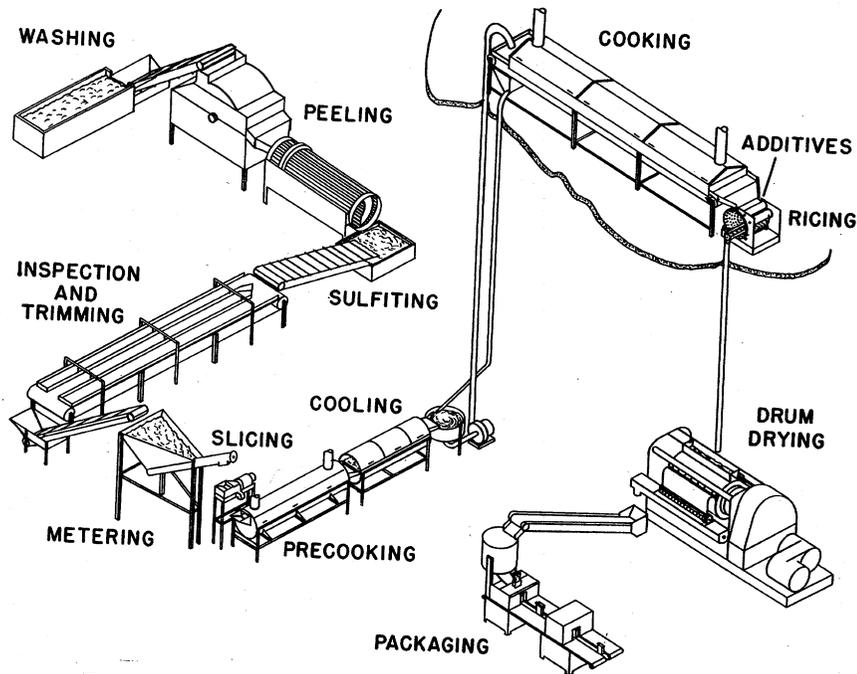


Fig. 1. Flowsheet of Potato-Flake Manufacture

a rod-reel type washer where the skins were removed by high-pressure (100 p.s.i.) water sprays. The peeled potatoes were handtrimmed to remove damaged tissue, and then were sliced into 5/8-in. thick slabs in an Urschel Laboratories Model B slicer.* Water was run into the slicer with the potatoes to wash away starch liberated during slicing.

In all tests slices were precooked (6) in water at 160° for 20 min. They were placed in wire baskets and moved through the precooking tank at the required rate, as described and pictured in an earlier publication (7).

For the cooling tests, a cooling tank was installed between the precooker and the cooker. In control tests, this unit was bypassed, and the precooked slices were carried directly to the steam cooker. The treated slices were cooked in steam at 212° in a continuous steam cooker (Robins No. 20283 blancher). Cooking times were varied to suit the solids content of the potatoes, potatoes of low solids content requiring longer times than those of high solids content. Cooled, precooked slices required 10 to 15 min. longer cooking time than those precooked but not cooled.

The cooked slices were riced in a ricer designed at the Eastern Utilization Research and Development Division (Figure 2). This machine consists of a cylinder of perforated metal, with openings 17/64 in. in diameter, and 2 solid rolls for forcing the cooked potato slices through the perforations of the cylinder. Since the cylinder and the crushing rolls rotate at the same peripheral speed, shearing action, which ruptures potato cells, is avoided.

*MENTION OF SPECIFIC MANUFACTURERS OR PRODUCTS IN THIS PUBLICATION DOES NOT IMPLY ENDORSEMENT BY THE U.S. DEPARTMENT OF AGRICULTURE OVER OTHERS NOT MENTIONED.

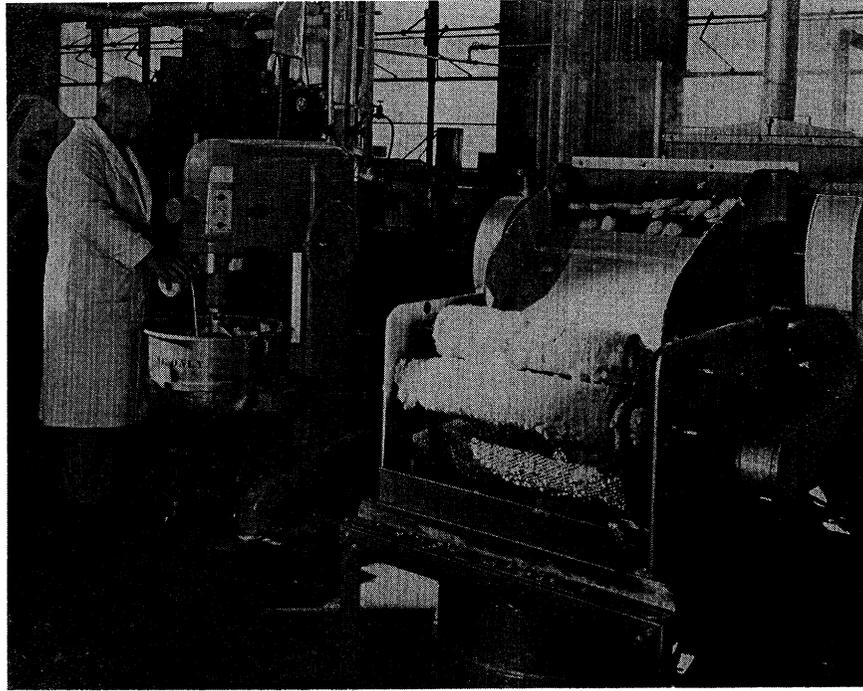


Fig. 2. Ricing the Potatoes

Antioxidant, emulsifier, milk solids, and sulfite solutions were incorporated into the riced potatoes by mixing for 2 minutes in a Hobart Model L-800 mixer.

The mash was fed to a single-drum drier (Overton Machine Co.) with a drying drum 2 ft. in diameter and 3 ft. long, where it was dehydrated in the form of a continuous sheet about 8 thousandths of an inch thick with a final moisture content of about 5% (7). The sheet was cut into flakes about 1/2 in. square by passing it through a 3-roll cutter attached to the drier.

Evaluation of Products

Since the aims of the research reported in this paper were to increase flake density (to get more weight in the package), and to improve tolerance for reconstituting liquids at high temperature, the products were evaluated as described below.

To evaluate products for tolerance to further breaking, i.e., tolerance for size reduction without marked increase in pastiness of the reconstituted product, samples of the 1/2-in. cut flakes from the drier were broken in a Fitzpatrick Model D. comminuting machine using knives instead of hammers, and screens of various sizes. Products of the tests were evaluated by submitting them to a taste panel for judgment of texture, by determination of their "blue value indexes" at 160° F., and by comparing on a curve their blue value indexes over a range of temperatures between 150° and 212° (see Figure 4).

Blue value is a measure of the free soluble amylose. It is based on the difference in affinities of amylose and amylopectin for iodine, first demonstrated by Bates, French and Rundle (1) by potentiometric titration. The colorimetric determination of unretrograded (soluble) amylose and amylopectin (12,14) is based on the fact that the former, when diluted, turns a deep blue color with iodine, while the latter gives a less intense color. In these determinations, a measured amount of iodine solution is added to a weighed amount of starch in solution, and the intensity of color developed is therefore proportional to the relative quantities of unretrograded amylose and amylopectin present. Thus a high numerical optical density represents a high percentage of unretrograded amylose and a low percentage of amylopectin. "Blue value" is defined (12) as the optical density of a layer of solution 40 mm. thick, corrected for the optical density of the free iodine.

Mullins et al. (15) used the "blue value" method to determine the "blue value index" of potato granule samples. Blue value index is the color intensity in units of direct scale reading on the Klett Summerson photoelectric colorimeter with a No. 66 red filter having a transmission range of 640 to 700 m μ . Blue value index is an indication of the free soluble starch content of dehydrated mashed potatoes, and has been shown to be related to organoleptic evaluation of texture of reconstituted granules (15) provided no differences in process or raw materials exist.

Blue value index has been found useful and reliable when used in conjunction with taste-panel texture judgments, in relating texture of potato flakes to process variables. More important, it can be used to predict quality of potato flakes as regards their tolerance for abuse, i.e., breakage to smaller size. By a modification, as explained later, it can be used to show tolerance for reconstitution with liquids at high temperature. Since blue value index depends on the reaction of iodine with soluble starch only, it is related to cell breakage only insofar as the starch liberated from the cells is soluble. Since potato starch contains both amylose, which develops intense color, and amylopectin, which does not, the blue value index depends on the relative amounts of the two forms in the particular potatoes being tested, the cell breakage, and the degree to which the amylose is retrograded.

In the experiments described here, potatoes for each series of tests were of the same variety taken from the same lot; it is therefore assumed that the starch content and composition were the same for the tests within each series.

In determining blue value index, 2.5-g. samples of potato flakes are extracted, with stirring, in 500 ml. of distilled water at an initial temperature of 160° F. for 5 min. The slurry thus formed is settled and

filtered through a Whatman No. 1 filter paper. Repeated tests have shown that the use of a standard filter paper is critical; finer filters give lower blue values. A measured volume of 5 ml. of filtrate is combined with 1 ml. of 0.02 N iodine-potassium iodate solution and 44 ml. of distilled water. The intensity of the blue color which develops is measured on a colorimeter. A solution containing 1 ml. of the iodine solution and 49 ml. of distilled water is used to standardize the colorimeter before each determination.

The blue value index, at any temperature of extraction, is an indication of the amount of free soluble starch, the amount of cell damage that occurred during extraction, and the condition of the starch in the cells themselves. If it were an estimation only of the free starch in a condition for rapid solubilization, the blue value index of a given sample would not be expected to increase with an increase in the extraction temperature. It would also be expected that retrogradation of the starch within the undamaged cells would decrease the amount of soluble starch released by cell-wall rupture at higher temperatures of extraction or by grinding, and so produce lower relative blue value indexes and less pastiness in the reconstituted flakes. Therefore, it should be possible to predict, from blue value index at any given temperature, the texture of the sample when it is reconstituted at the temperature of the extracting liquid. The slope of a curve produced by plotting blue value index versus the temperature of extraction could predict the texture behavior of a given sample as the temperature of reconstitution is increased, especially if related to taste-panel results. Samples were therefore evaluated by determining blue value index at different temperatures, plotting temperature of extracting liquid against blue value index, and comparing the curves. Temperature of the extracting liquid was held constant for the 5.min. period of extraction.

RESULTS AND DISCUSSION

Effect of Cooling on Blue Value Index

In Table I are shown blue value index measurements on flakes made from potatoes precooked only, compared with those of flakes made from potatoes precooked and then cooled in water for 20 minutes. In these tests the precooked slices were placed in a tank of water to which enough water was continuously added to maintain the temperature below 75° F. Little if any washing action occurred, since neither circulation of the water nor agitation of the potato slices was done.

The effects on blue value index are therefore attributable to cooling alone. For the 7 lots tested, blue value index of the flakes was reduced by 33% to about 60% by cooling.

There is no apparent correlation between the percent reduction in blue value index and the specific gravity of the raw potatoes. Taste tests on the products indicated acceptable texture for those having blue value index 125 or lower. Reconstitution was done in the customary way i. e., with a mixture of 3 parts of boiling water and 1 part of cold milk. The sample with blue value index of 200 was considered unacceptable.

Table II shows the effect of cooling time on blue value index of flakes made from potatoes of different varieties and different specific gravities. From these data it appears that for the 2 lots of Idaho Russet tested, the full effect of cooling had been achieved in 20 minutes. The lot of 1.095 specific gravity showed no reduction between 15 and 20 minutes cooling and the other lot showed only 18% decrease in blue value index between 20 and 60 minutes. For the Washington Russet Burbank lot, a small decrease (as compared with the lower solids lot of Pennsylvania Katahdins) in blue value index is observed between the 15-min. cool and

TABLE I
 Effect of Cooling
 on the Blue Value Index* of Potato Flakes
 (Cooling Time: 20 Min.)

Variety	Specific Gravity	Blue Value Index		Decrease in Blue Value Index (%)
		Precooked	Precooked & Cooled	
Washington Russet Burbank	1.089	122	49	59.8
Oregon Russet Burbank	1.089	107	65	39.3
Idaho Russet Burbank	1.088	105	49	53.4
Maine Russet Burbank	1.075	125	74	40.8
California White Rose	1.069	100	67	33.0
N. Carolina Cobbler	1.069	135	77	43.0
Pennsylvania Katahdin	1.066	200	92	54.0

TABLE II

Effect of Cooling Time on
Potato Flake Blue Value Index

Variety	Spec. Grav.	Blue Value Index						
		Precooked Slices Cooled for:						
		5 Min.	7 Min.	10 Min.	15 Min.	20 Min.	40 Min.	60 Min.
Washington Russet Burbank	1.089	88	--	82	64	49	--	--
Maine Russet Burbank	1.072	--	--	--	--	114	84	--
Penna. Katahdin	1.066	--	188	--	171	92	--	--
Idaho Russet Burbank	1.086	--	--	--	--	77	--	63
Idaho Russet Burbank	1.095	--	113	--	98	100	--	--
Maine Katahdin Size B	1.080	--	--	--	--	124	73	--

the 20-min. cool. On this basis a 20-min. cooling period for this lot seems adequate. For the lots of other varieties shown in Table II, significant numerical blue value index decreases occur after 20 min., and would suggest the use of longer cooling times, where practical, in processing lines dehydrating low-solids potatoes.

Figure 3 shows that for both low- and high-solids content potatoes, lower cooling temperatures result in lower blue value indexes.

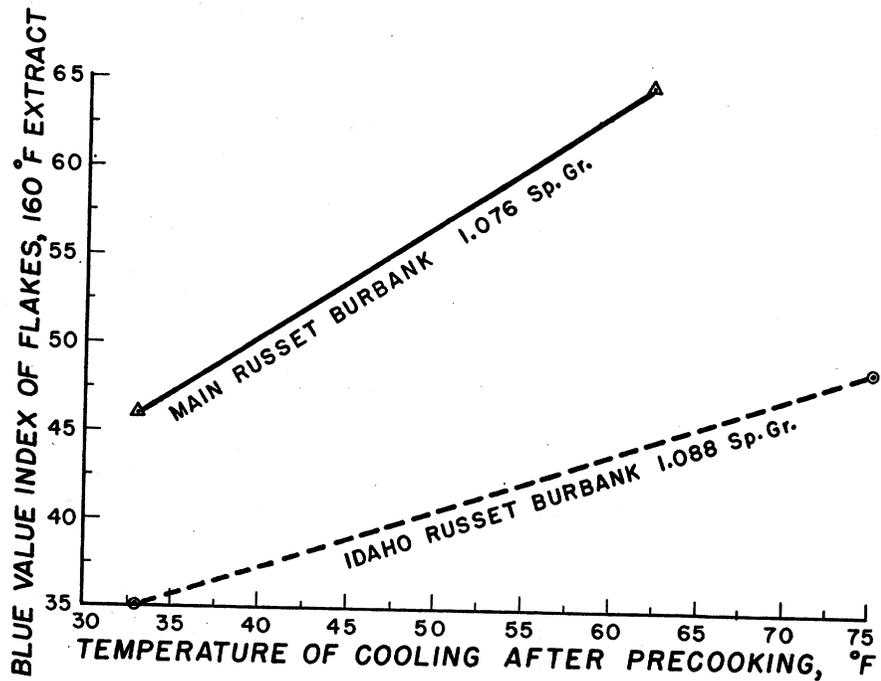


Fig. 3. Effect of Cooling Temperature on Blue Value Index of Potato Flakes

Effect of Cooling on Breakage Tolerance

When the sheet from the drum drier is cut or broken to small size for packaging, some cell rupture occurs along the lines of cleavage. As flake size is reduced, the number of broken peripheral cells compared with those enclosed in the piece increases and a higher blue value index (indicating more pastiness) results. Through retrogradation of the amylose within the cells to make it less soluble, a dried sheet can be made which tolerates breaking to very small size without excessive texture damage.

TABLE III
 Effect of Cooling After Precooking on Change of
 Blue Value Index with Flake-Size Reduction
 High-Solids Potato (Idaho Russet Burbank)

	Screen Size (in.)	Method of Preparation	Experiment 1		Experiment 2	
			Blue Value Index	Density*	Blue Value Index	Density*
Standard 1/2-Inch Flakes	--	Precooked	93	15.7	105	15.7
		Precooked & Cooled	47	15.7	49	15.7
Flakes Ground in Fitz- patrick Mill	1/2	Precooked	98	20.3		
		Precooked & Cooled	62	18.4		
	1/4	Precooked	122	24.8		
		Precooked & Cooled	84	22.9		
3/16	Precooked			216	27.5	
	Precooked & Cooled	87	24.2	75	27.5	

* Pounds per cubic foot, tapped.

TABLE III (Cont.)
 Effect of Cooling After Precooking on Change of
 Blue Value Index with Flake-Size Reduction

Low-Solids Potato (Maine Russet Burbank)						
Screen Size (in.)	Method of Preparation	Experiment 1		Experiment 2		
		Blue Value Index	Density*	Blue Value Index	Density*	
Standard 1/2-Inch Flakes	Precooked	125	15.7	121	15.7	
	Precooked & Cooled	74	15.7	65	15.7	
Flakes Ground in Fitzpatrick Mill	Precooked	153	21.8			
	Precooked & Cooled	108	21.8			
1/4	Precooked	184	24.2			
	Precooked & Cooled	136	25.0			
3/16	Precooked					
	Precooked & Cooled			100		

Pounds per cubic foot, tapped.

Table III shows blue value indexes and densities for flakes of different sizes made by either precooking alone or by precooking and cooling potato slices before cooking. In all tests flakes were made by cutting the dried sheet coming from the drum into 1/2-in. square pieces and then further reducing their size by cutting in a Fitzpatrick comminuting mill to the size shown. For the 4 tests shown, the 1/2-in. standard flakes made by precooking alone were of satisfactory texture when reconstituted in the customary way, as would be expected by their blue value indexes ranging from 93 to 125. These flakes, when made from Idaho Russet Burbank potatoes, could not be cut smaller than 1/4 in. in the mill without excessive texture damage, as evidenced by their high blue value index (216) when cut to 3/16-in. Flakes from the Maine Russet Burbank potatoes could not be cut smaller than 1/2 in. without excessive texture damage.

On the other hand, flakes made by precooking followed by cooling withstood cutting through a 3/16-in. screen in the mill as shown by the blue value indexes of 100 or less for both potato varieties. Cutting to 3/16-in. size increases the density from 15.7 lb. per cu. ft., obtained by compression of 1/2-in. flakes into a No. 10 can, to more than 24 lb. per cu. ft. obtained by tapping while filling a No. 10 can.

Effect of Cooling on Resistance to High-Temperature Reconstitution

Figure 4 is a comparison of blue value indexes of flakes made from precooked versus precooked and cooled slices. These comparisons were made by extracting the flake samples with liquid at temperatures in the range from 150° to 212° F., and determining the blue value indexes of the extracts, as explained under *Evaluation of Products*.

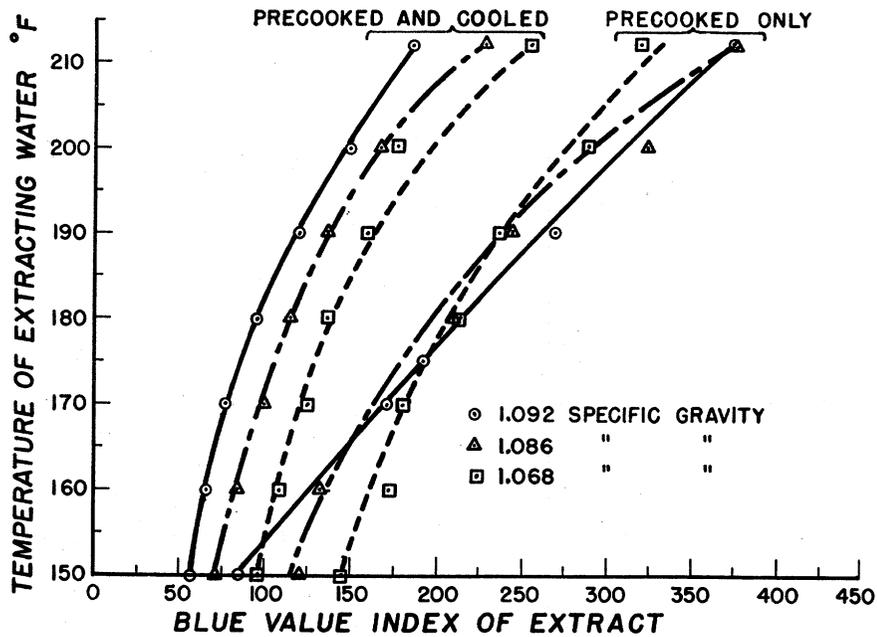


Fig. 4. Effect of Temperature of Extraction on Blue Value Index of Potato Flakes

Three lots of potatoes, of different solids content, were tested. Each lot was divided in half after peeling, trimming, slicing, and precooking for 20 min. at 160° F. One-half was cooked in steam until soft enough to mash. The other half was cooled in water for 20 min. at 50° to 68°, and then cooked in steam. Each half was riced separately, additives were incorporated, and the mash was dried separately on a single-drum drier. Flake samples were then evaluated for blue value index.

Blue value indexes from extractions of flakes at 150° F. from the three samples precooked only are in the order normally encountered, i.e., the high-solids flakes have the lowest blue value index and the low-solids flakes the highest blue value index. The curves of Figure 4 show, however, that as the temperature of the extracting liquid is increased, the blue value index of the high-solids flakes increases more rapidly than that of the medium-solids flakes, and that of the medium-

solids flakes more rapidly than that of the low-solids flakes. This must mean that, as the extracting temperature is increased, more cell rupture occurs with the higher-solids content potatoes. It has been observed (6) that precooking increases the amount of liquid required for reconstitution of flakes, presumably owing to modification of the starch within the cells. Since flakes from low-solids-content potatoes contain less starch per cell, the swelling capacity of the starch can be increased more before the cell becomes distended enough to break. This may explain why the flakes from low-solids-content potatoes have lower blue value indexes at higher temperatures (above about 190° F.).

For flakes from slices precooked and then cooled, blue value indexes of those from high-solids content potatoes are lowest over the entire range of temperatures of the extracting liquid, compared with blue value indexes of flakes from medium- and low-solids content potatoes.

For flakes made from potatoes of all solids contents tested, blue value indexes are lower at all extracting temperatures for the precooked and cooled samples. This apparently results from the retrogradation of the amylose fraction of the starch within the cells during cooling of the slices after precooking.

Blue value index determined at 160° F. is a measure of the behavior of the flakes when rehydrated with a mixture of 3 parts of boiling water and 1 part of cold milk in the customary way. Flakes with blue value index above 150 (determined at 160°) rarely have good texture. The relationship between blue value index (determined at 212°) and texture of the mash reconstituted with liquid at 212° is different. All of the precooked and cooled samples shown in Figure 4 had very good texture when reconstituted with boiling liquid, even though their blue values (determined at 212°) are high (180 to 260) as compared with the values conventionally determined at 160°.

CONCLUSIONS

The texture of mashed potatoes reconstituted from potato flakes is improved by cooling the precooked potato slices before final cooking.

Based on tests with seven lots of potatoes of specific gravity ranging from 1.066 to 1.089, blue value indexes of the flakes were significantly reduced by cooling the precooked slices.

For high-solids content potatoes (above 1.086 specific gravity) a cooling time of 20 min. appears adequate. For potatoes of lower solids content cooling times longer than 20 min. show continued reduction of blue value index and a cooling time of 30 min. should reduce the value to below 100. A cooling temperature of 75° F. or lower, for a time of 30 min., appears adequate.

Through introduction of a cooling step following precooking, flakes can be manufactured to withstand reconstitution with liquids at high temperature. This attribute can be predicted by extracting flakes with water at the temperature of the reconstituting liquid, and determining the blue value index of the extract.

The cooling step also allows flakes to be broken to much smaller sizes without significantly impairing texture, as shown by the low blue value indexes of ground flakes.

The use of cooling following precooking is of value to the producer of potato flakes in that:

1. It provides a means for texture improvement for potatoes of all specific gravities.
2. It minimizes texture variations due to specific-gravity changes.

3. It improves tolerance of flakes for reconstituting liquids at high temperature.
4. It permits reducing the size of flakes, thus increasing their density, which is reflected in lower packaging costs.

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