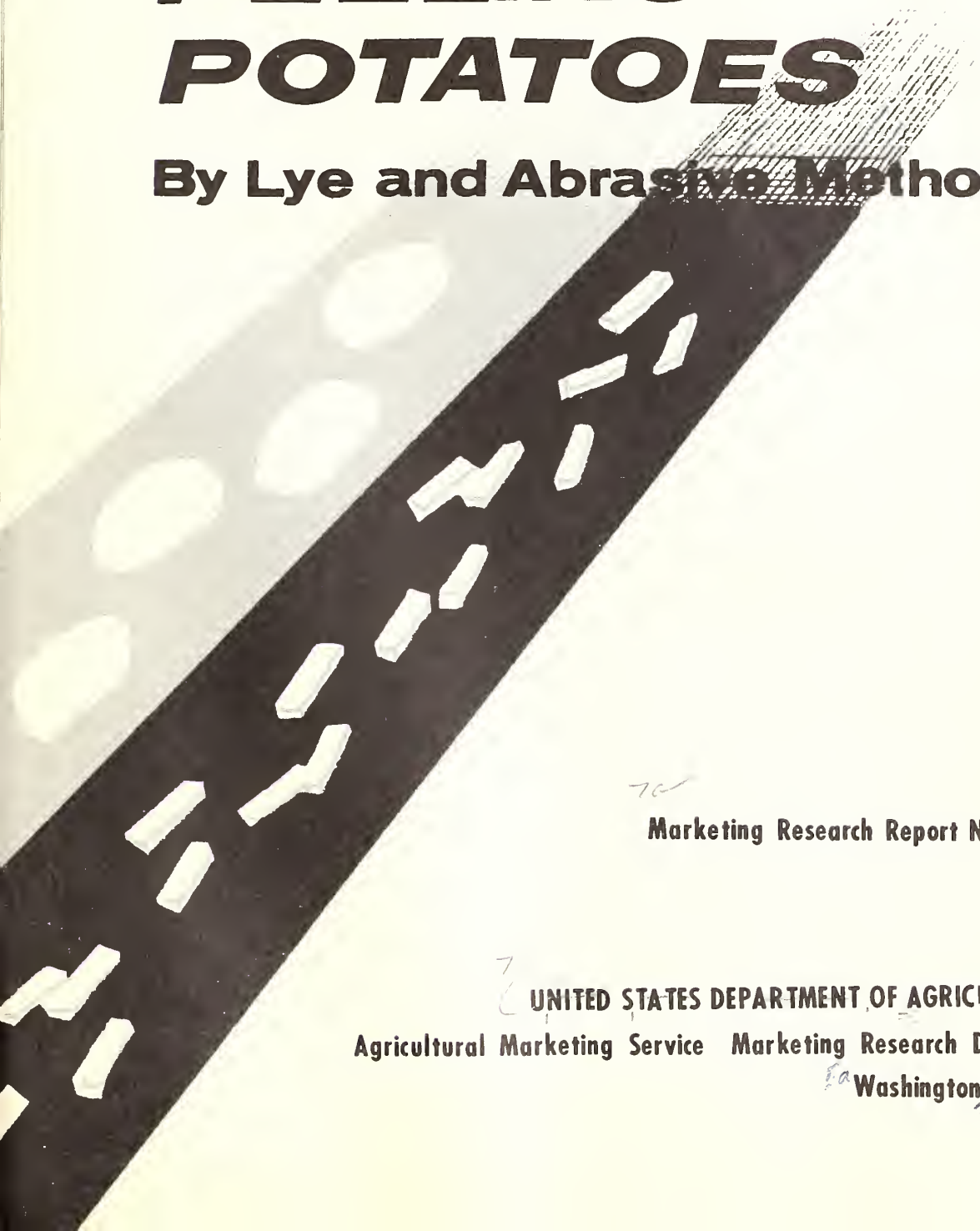
Costs of PEELING POTATOES

By Lye and Abrasive Methods



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PREFACE

This study of the comparative costs of peeling potatoes by different methods is part of a broad program of research to reduce the costs of marketing farm products. The purpose of the report is to help operators of commercial potato peeling plants to decide which type of equipment is more economical for their particular plants.

Marshall E. Keller, of the Fruit and Vegetable Division, conducted the inspection in the plants on the quality of the finished product and assisted in some phases of the cost study. John B. Wegener, also of the Fruit and Vegetable Division, graded samples of the finished product from each of the cooperating plants.

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COSTS OF PEELING POTATOES BY LYE AND ABRASIVE METHODS

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SUMMARY

Changes, 1953-55

Commercial peeling of potatoes expanded considerably from 1953 to 1955 and appears to be continuing to expand. From 1953 to 1955, the volume of potatoes used increased from 3.2 million bushels to approximately 5 million bushels. In spite of this growth, nearly 13 percent of the firms operating in 1953 were no longer operating by 1955.

The proportions of the various products also have changed appreciably since 1953. Only 15 percent of the 1953 production was whole peeled potatoes; 85 percent was french-fry slices. By 1955 the percentage of whole peeled potatoes had increased to 31 percent and french-fry slices made up the remaining 69 percent. Fifty-one percent of the production by steam peeling plants was whole peeled potatoes, while the percentage for lye plants was 32 and for abrasive plants 24.

The 30-pound bag continued as the most popular size of container and was used for 70 percent of the production of peeled potatoes. The packaging material most commonly used was the kraft paper bag with a polyethylene inner liner--over 58 percent of production--followed by a kraft bag with a wet-strength paper liner.

A trend from abrasive to lye or steam peeling has developed. In 1953, 39 percent of the volume was produced by lye peeling. In the plants reporting in 1955, nearly 54 percent of the potatoes processed were peeled with lye.

Late crop potatoes were processed during the major portion of the year. The Russet Burbank variety was most commonly used, followed by the Katahdin variety.

The U. S. No. 2, or Utility grade, size A, was the predominant grade and size used of the Russet Burbank variety, both for whole potatoes and for french-fry slices. Of the Katahdin variety, the U. S. No. 1 grade, 3- to 4-inch

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1/ Dr. Greig left the Department of Agriculture in December 1956 after completing the first draft of this manuscript. The final draft was prepared for publication by Dr. Manchester.

size, was most commonly used for french-fry slices, and the 2 1/4- to 4-inch size for whole peeled potatoes.

During summer months, California Long White was the most commonly used variety, with nearly national distribution, while most other varieties were used primarily near their production areas.

Costs

At levels of production which would efficiently utilize the facilities of a peeling plant with a capacity of 3,000 pounds per hour, the lye method of peeling would be more economical than abrasive at all except the lowest prices of raw potatoes.

Fairly wide differences in fixed, operating, and labor costs were found among the nine plants studied. Many of these differences were due to equipment utilization within the plants. Both the number of hours the equipment was used per week and the rates of production, in terms of equipment capacity, varied widely from plant to plant.

Differences in the cost of producing peeled potatoes by the lye and abrasive methods were primarily due to differences in (1) cost of equipment in the peeling line, (2) peeling waste, (3) the amount of hand trimming required, and (4) operating costs for the equipment in the peeling line.

Under the assumptions detailed in the study, at a production rate of 2,000 30-pound bags per month, it would be more economical to peel by the lye method if the cost of the raw product was 1.5 cents per pound or more. Similarly, with a production rate of 3,000 bags per month, it would be more economical to peel by the lye method, if prices of raw potatoes were more than 1.0 cent per pound.

Approximately one-third of the abrasive peeling plants surveyed have the necessary production to justify the use of the lye peeling method if the average cost for the raw potatoes was 1.0 cent per pound. If the cost for the raw potatoes was 2.0 cents per pound, then approximately three-fifths of the present abrasive peeling plants have the production necessary to justify using the lye peeling method.

The level of equipment utilization of the peeling industry as a whole is quite low, which not only increases costs but also intensifies competition for sales in some markets.

INTRODUCTION

Commercial peeling of potatoes for sale in fresh form became possible with the development of chemical treatments which control enzymatic discoloration and the finding that low temperatures will control spoilage. Hotels, restaurants, and institutions are the principal outlets for peeled potatoes, since

spoilage can be controlled more closely in selling to these types of buyers. Several commercial plants have experimented with selling peeled potatoes in 1- or 2-pound packages through retail outlets. Some of the problems in retailing are now being overcome, and at least one plant has been built to process peeled potatoes primarily for retail outlets.

CHANGES, 1953 TO 1955

In 1953, 120 commercial plants peeled an estimated 3.2 million bushels of potatoes. 2/ Two years later total volume had increased to an estimated 5 million bushels, about 7.5 percent of the estimated total use of potatoes by hotels, restaurants, and institutions. Sixteen firms went out of the potato peeling business and 55 to 60 new ones entered the industry during the 2 years. At least three-fourths of the plants now in existence have entered the industry since 1950. Only three started operations before 1946.

Kinds of Product

In 1953, about 85 percent of the production of peeling plants was french-fry, including crinkle-cut, slices and 15 percent whole potatoes. In 1955, 31 percent was whole potatoes and 69 percent was french-fry slices. Peeling plants using the steam or lye peeling method produced a greater proportion of whole potatoes than plants using the abrasive peeling method (table 1). The relatively small production of whole potatoes by the abrasive method is probably due to the higher production cost of completely peeled potatoes compared with french-fry slices which often are not completely peeled.

Table 1.--Kinds of finished products by peeling method, 80 plants, 1955

Peeling method	Number of plants reporting	Kind of product						Total
		Whole potatoes	French-fry slices				Other	
			1/2 inch	3/8 inch	1/4 inch	Crinkle-cut		
	Number	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Steam	4	51	23	20	5	1	--	100
Lye	28	32	25	35	2	4	2	100
Abrasive	48	24	21	35	9	7	4	100
Total	80	31	24	33	5	5	2	100

2/ Garrott, W. N. "The Commercial Potato Peeling Industry--A Survey." U. S. Dept. Agr. Mktg. Res. Rpt. 105, 13 pp., illus. April 1955.

Peeling Methods

There has been some shift from abrasive to lye peeling during the last few years. Abrasive plants produced 45 percent of the volume in 1953 and 36 percent in 1955. The percentage of lye plants increased from 39 to 54 over the same period (table 2). The trend may well continue for reasons discussed later in this report.

Table 2.--Potato peeling plants: Number reporting, volume of raw and processed potatoes, and peeling losses, by peeling method, 1955

Peeling method	Number of plants reporting	Average volume raw potatoes used per plant	Total quantity		Weighted average peeling losses	Percentage distribution peeled product	
			Raw potatoes used	Finished product		1953 1/	1955
	Number	1,000 pounds	1,000 pounds	1,000 pounds	Percent	Percent	Percent
Abrasive	51	1,444	73,629	55,624	24.9	45	36
Lye	32	3,304	105,742	83,074	22.4	39	54
Steam	3	6,153	18,460	15,020	18.6	16	10
Total or average	86	2,300	197,831	153,718	23.0	100	100

1/ 100 plants peeling 191,853 thousand pounds of raw product.

In the abrasive method, potatoes are dumped into either a batch or a continuous-type abrasion peeler. If the batch peeler is used, the peelings are removed by the rotation of the bottom of the drum at high speed, which tumbles the potatoes against the silicon carbide finish on the bottom and sides of the drum. Water is sprayed over the potatoes to wash away the skin particles. Most batch-type peelers will handle about a bushel of potatoes at a time, and the skins are fairly well removed after about a minute of operation. The continuous abrasion peeler consists of several compartments, each of which contains a series of silicon carbide coated rollers that rotate at high speed, effectively removing the skins from the potatoes.

In the lye peeling method, potatoes are soaked in a solution varying in concentration from 15 to 25 percent lye and in temperature from 135° to 155° F. for 3 to 8 minutes to loosen the skin. The length of time varies according to the variety of potato and the concentration and temperature of the solution. The potatoes are then passed through a rotating drum where sprays of water at high pressure wash off the skin and partially wash away the solution. The potatoes are then dipped into an acid solution which neutralizes any remaining lye and preserves the color of the potatoes during trimming and inspection.

Containers

Marked changes in size and type of container took place between 1953 and 1955. To a considerable extent, the kraft paper bag with polyethylene liner replaced the kraft bag with wax liner and the 30-pound bag replaced the 35-pound bag (table 3).

Varieties and Grades Used

Selection of the variety and grade of potatoes used by peeling plants is affected by seasonal availability and the type of finished product. Late crop potatoes were available for 8 or 9 months of the year. During this period most of the plants used western Russet Burbank (chiefly U. S. No. 2's) for french-fry slices. Plants in the eastern part of the country generally used Katahdins for whole potatoes, while western plants used mostly Russet Burbanks (table 4).

During the 3- to 4-month period when early and intermediate crop potatoes dominated the market, California Long Whites (the White Rose variety) were used by most plants for both french-fries and whole potatoes, being utilized to a considerable extent in the South and East.

COMPARATIVE COSTS OF LYE AND ABRASIVE PEELING METHODS

Costs for the two methods were compared for differences in labor, equipment, and raw product costs. 3/

Trimming Labor and Peeling Losses

Differences in trimming labor and peeling losses due to variety, size, and grade of potato processed in 5 commercial lye peeling plants are shown in table 5. There were wide differences both in trimming time and in peeling losses with potatoes of different varieties and sizes. The trimming time ranged from 5.4 minutes to as high as 25.4 minutes per bag for potatoes of good to excellent quality. Peeling losses ranged from as low as 18.1 percent to as high as 40 percent.

There appears to be little difference either in trimming time or in peeling waste between U. S. No. 1 and Idaho Utility or Maine No. 2 Russet Burbanks. In the round varieties there was a big difference in trimming labor between the Katahdin and Kennebec varieties.

The amount of trimming labor and the average losses in peeling were usually higher in abrasive plants than in lye plants using similar varieties and sizes (table 6). Trimming time ranged from 9.7 minutes to 23.5 minutes for potatoes of good to excellent quality. Peeling losses ran from 22.8 percent to 40 percent.

3/ See appendix A for a detailed discussion of methodology.

Table 3.--Type and size of container used in commercial potato peeling plants, 1953 and 1955

Type of container	Size of container in pounds, 1955							Percentage of total	
	Less than 20	20	25	30	35	More than 35	Total	1953	1955
	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	Percent	Percent
Kraft paper bag with--									
Polyethylene liner	1,550	3,643	949	73,538	484	5,770	85,934	48.3	58.7
Kraft paper wet-strength liner	---	3,752	8,366	13,324	3,920	---	29,362	17.6	20.0
Wax liner	492	---	---	7,832	2,831	3,208	14,363	20.1	9.8
Polyethylene bag	1,778	1,724	1,298	4,577	---	2,708	12,085	7.9	8.3
Other	68	---	1,257	3,400	---	---	4,725	6.1	3.2
Total	3,888	9,119	11,870	102,671	7,235	11,686	146,469	100.0	100.0
Percentage of total:	Percent	Percent	Percent	Percent	Percent	Percent			
1953	0.2	9.3	9.9	56.4	17.2	7.0		100.0	
1955	2.7	6.2	8.1	70.2	4.9	7.9			100.0

Table 4.--Number of plants peeling specified varieties, grades, and sizes of potatoes, by season and kind of finished product, 1955 1/

Variety, grade, and size	Fall and winter		Spring and summer	
	French-fry slices	Whole potatoes	French-fry slices	Whole potatoes
	Number	Number	Number	Number
Russet Burbank:				
U. S. No. 1, 8- or 10-oz. minimum	19	5	5	6
U. S. No. 2, size A	52	24	4	1
Katahdin:				
U. S. No. 1, 3 to 4 in.	15	5	--	--
U. S. No. 1, 2¼ to 4 in.	9	23	--	4
Long White:				
U. S. No. 1, 4- or 6-oz. minimum	--	--	13	10
U. S. No. 1, 8- or 10-oz. minimum	--	3	27	17
U. S. No. 2, size A	10	5	20	12
Sebago, U. S. No. 1, 1 7/8-in. minimum, size A	1	4	15	22
Cobbler	--	3	2	3
Kennebec	2	2	--	2
Round Reds	--	4	--	2

1/ Some plants reported using more than one variety for each purpose, so the totals in each column may be more than the 81 plants reporting.

Table 5.--Lye peeling plants: Trimming labor and peeling losses per 30-pound bag of finished product, by variety, size, and grade of potatoes, 1956 1/

Product quality, variety, and size	U. S. No. 1		U. S. No. 2	
	Trimming labor	Peeling loss	Trimming labor	Peeling loss
	Minutes	Percent	Minutes	Percent
Good to excellent quality:				
Kennebec:				
2½-4 inch	6.9	21.2	---	---
Katahdin:				
3-4 inch	9.1	21.1	---	---
2¼-4 inch	10.2	22.6	---	---
Russet Burbank:				
Size A	8.4	25.2	2/12.2 3/9.0	2/31.6 3/26.3
Round White; Round Red:				
Size B	25.4	40.0	---	---
Long White:				
Size A	8.9	25.8	---	---
16-oz. minimum	5.4	18.1	---	---
Chippewa:				
Size A, 2-inch minimum	8.9	24.4	---	---
Fair quality:				
Katahdin:				
3-4 inch	4.2	17.1	---	---
Russet Burbank:				
Size A	---	---	6.1	22.7
Long White:				
Size A	---	---	3.1	16.2

1/ All observations made during April and May 1956, except those for Long Whites and Chippewas which were made during August 1956; direct observations made on 63 runs producing 8,924 30-pound bags. Peeling loss adjusted to equivalent losses in production of ½-inch french-fry cuts, excepting size B potatoes.

2/ 75 percent U. S. No. 2.

3/ Idaho Utility or Maine No. 2.

Table 6.--Abrasive peeling plants: Trimming labor and peeling losses per 30-pound bag of finished product, by variety, size, and grade of potatoes, 1956 1/

Product quality, variety, and size	U. S. No. 1		U. S. No. 2	
	Trimming labor	Peeling loss 2/	Trimming labor	Peeling loss 2/
	Minutes	Percent	Minutes	Percent
Good to excellent quality:				
Katahdin:				
2¼-4 inch, mostly 3-4 inch	14.6	30.3	---	---
Russet Burbank:				
Size A	---	---	3/11.4	3/40.5
Russet type:				
Mostly under 8 oz.	4/23.5	4/38.6	---	---
Long White:				
16 oz.	9.7	22.8	---	---
Chippewa:				
Size A, 2-inch minimum	12.1	27.4	---	---
Fair quality:				
Russet Burbank:				
Size A	---	---	3/6.2	3/35.8
Long White:				
Size A	---	---	2.9	19.8

1/ All observations made during April and May 1956, except those for Long Whites and Chippewas which were made during August 1956. Direct observations made on 45 runs totaling 3,301 30-pound bags.
2/ Adjusted to equivalent losses in production of ½-inch french-fry cuts.
3/ Utility grade.
4/ 60 percent U. S. No. 1.

Size is extremely important, both in the trimming labor required and in peeling waste. When the lye method is used on long varieties, there apparently is little difference in either trimming labor or in waste between grades of similar size.

The term "high quality," as used in this report, refers to the result of peeling only, not to the quality characteristics of the raw potatoes. It means

that practically all of the skin, including areas around the eyes and stem scars, was removed and all defects were trimmed out. The resulting product, including french-fry slices, should be of such a quality that it might be used for mashed or boiled potatoes with no further trimming. Factors such as a cooked surface layer and "leakage" of the product (loss of water due to ruptured cells) were not considered.

Cost of Peeling the Katahdin Variety

The Katahdin and Russet Burbank varieties were selected for direct comparisons of the lye and abrasive peeling methods. Some comparisons of peeling methods for Chippewas and Long Whites were also made but not in as great detail. In these comparisons the grade and size of the raw product and the quality of the finished product were similar.

Data were obtained for the Katahdin variety in 4 plants using lye and in 3 using abrasive methods. Trimming labor with lye averaged 8.6 minutes and with abrasive 14.6 minutes per 30-pound bag of finished product. The average peeling loss was 21.5 percent for the lye method and 30.3 percent for the abrasive.

Total labor requirements in the direct operation of the peeling line for dumping, trimming, cutting, sorting, and bagging were 22.1 minutes per 30-pound bag for the abrasive method and 12.8 minutes for lye (table 7). No distinction was made between potatoes for french-fry slices and those for whole potatoes. The cost of labor other than trimming was associated more with scale or rate of operation than with the peeling method.

The average trimming cost for the lye method, with labor at $1 an hour, was 14.3 cents for 30 pounds of finished potatoes. With abrasive the trimming cost was 24.3 cents per bag. The approximate wholesale price of Katahdins during this study was $4 per hundred pounds. On this basis, the cost of the raw potatoes necessary to produce 30 pounds of peeled potatoes by the lye method was $1.53 and by abrasive, $1.72. The total cost for trimming labor and raw product was $1.67 for the lye method compared with $1.96 for the abrasive, an average difference of 29 cents per 30-pound bag of finished product.

Cost of Peeling the Russet Burbank Variety

Costs of both trimming labor and raw product were higher in abrasive than in lye plants for Utility grade Russet Burbanks--the most generally used grade in the nine plants studied in detail. Trimming labor requirements for a high-quality product averaged 9.0 minutes per bag in lye plants and 11.4 minutes in abrasive plants. Peeling losses were 26.3 percent, on the average, by the lye method and 40.5 percent by the abrasive (table 8).

For a finished product of fair to good quality, there was little difference in trimming labor between the two methods, but there was a considerable difference in peeling loss. From 10 to 15 percent of the skin was sometimes left on the potatoes.

Table 7.--Trimming labor, total labor, and peeling loss per 30-pound bag of finished product in peeling U. S. No. 1 Katahdin potatoes by lye and abrasive methods, April and May 1956 1/

Peeling method, size of potatoes, and plant number	Labor		Peeling loss
	Trimming	Total 2/	
	Minutes	Minutes	Percent
Lye (some lots $2\frac{1}{4}$-4 inches, others 3-4 inches):			
Plant no. 1	8.2	11.7	20.0
Plant no. 2	9.6	12.6	23.7
Plant no. 3	7.3	12.0	24.5
Plant no. 4	9.5	15.0	17.6
Average	8.6	12.8	21.5
Abrasive (all lots 3-4 inches):			
Plant no. 3	15.5	29.5	39.2
Plant no. 7	14.6	15.8	32.3
Plant no. 8	13.7	21.1	19.4
Average	14.6	22.1	30.3
Difference	6.0	9.3	8.8

1/ Only lots having similar characteristics both in raw and processed form were included in these comparisons. See tables 16 and 17 for figures for individual runs in each plant and table 18 for corresponding data on quality factors for each run in each of the plants.

2/ Total labor in the direct operation of the peeling line, including all labor from dumping the potatoes onto the line to sealing the bags of processed potatoes and placing them aside after sealing.

The total cost for trimming labor and raw product was 39 cents per bag higher by the abrasive method than by the lye method for a good to excellent finished product and 28 cents higher for a fair quality product, with raw potatoes at $3.50 per hundred pounds.

With either the round-type Katahdin or long-type Russet Burbank potatoes, there was generally less trimming labor necessary and less peeling loss with lye than with abrasive.

Table 8.--Trimming labor, total labor, and peeling loss per 30-pound bag of finished product in peeling U. S. No. 2 Russet Burbank potatoes by abrasive and lye peeling methods, April and May 1956 1/

Product quality and peeling method	Labor		Peeling loss
	Trimming	Total 2/	
	Minutes	Minutes	Percent
Excellent quality product:			
Lye	9.0	13.6	26.3
Abrasive	11.4	16.6	40.5
Fair to good quality product:			
Lye	6.1	8.9	22.7
Abrasive	6.2	9.6	35.8

1/ Only lots having similar characteristics both in raw and processed form were used in these comparisons. These are averages of the individual runs listed in table 18.

2/ Total labor in the direct operation of the peeling line, including all labor from dumping the potatoes onto the line to sealing the bags of processed potatoes and placing them aside after sealing.

Although not enough data were obtained for a detailed analysis of differences between lye and abrasive methods for the Long White and Chippewa varieties, the indications are that they would be similar to those for the Russet Burbank and Katahdin varieties. In general, freshly harvested potatoes are harder to peel with lye than potatoes from storage, but freshly harvested potatoes are more easily peeled than potatoes from storage by the abrasive method. In lye peeling, many freshly harvested varieties tend to peel unevenly and to have a pitted appearance. Although there was less loss and less trimming labor by lye than abrasive for the Long White and Chippewa potatoes, the differences in losses were not as large as for the late crop potatoes.

Adjusted Loss Differences

The differences in peeling loss between lye and abrasive methods found in the cost study were considerably higher than those in the mail survey of the industry as a whole (tables 18 and 19). Therefore, in the analysis the measured loss differences were adjusted to conform more nearly to the industry average. This adjustment was made because (1) in some runs observed in the abrasive peeling plants, particularly for the Russet Burbank variety, the amount of peel removed appeared to be greater than necessary for a reasonably effective hand trimming operation; (2) in peeling the Katahdin variety with

abrasive, there were considerable differences between peeling plants; and (3) a further analysis using an adjusted loss difference might reflect actual industry differences due to peeling method more accurately than an analysis based on direct measurement of losses in a few plants.

The analysis is based on the observed trimming times and one-half of the differences in peeling losses between the lye and abrasive methods (table 9).

Table 9.--Trimming labor and adjusted peeling losses per 30-pound bag of finished product for peeling Katahdin and Russet Burbank potatoes by abrasive and lye peeling methods, April and May 1956

Peeling method	Trimming labor		Raw product used	Peeling loss 1/
	Time	Cost		
	Minutes	Cents	Pounds	Percent
Lye:				
Katahdin	8.6	14.3	38.3	---
Russet Burbank	9.0	15.0	40.6	---
Average	8.8	14.7	39.4	23.9
Abrasive:				
Katahdin	14.6	24.3	40.7	---
Russet Burbank	11.4	19.1	45.6	---
Average	13.0	21.7	43.1	30.4
Difference	4.2	7.0	3.7	6.5

1/ Adjusted losses: Observed loss for lye peeling plus one-half the observed difference between the lye and abrasive peeling methods.

The average adjusted difference in peeling losses to be used in a further analysis is 3.7 pounds, a 6.5 percent difference in loss between the two peeling methods for each 30-pound bag of peeled potatoes. This is nearly identical with the average difference of 6.3 percent reported in the mail survey when these varieties were used for whole peeled potatoes.

Equipment Costs

The lye peeling method has a substantial cost advantage in both trimming labor and peeling loss. However, the equipment necessary for the lye method is substantially more expensive to buy and to operate than the equipment used in the abrasive method. The average costs for equipment per 30-pound bag of peeled potatoes varied markedly from one plant to another in the nine plants where observations were made (table 10). Most of this variation was due to

Table 10.--Fixed and operating equipment costs per 30-pound bag of finished product for lye and abrasive peeling lines, 9 commercial processing plants, April and May 1956

Peeling method and plant number	Fixed costs 1/			Operating costs 2/			Total fixed & operating costs
	Peeling equipment	Other equipment	Total	Peeling equipment	Other equipment	Total	
	Cents	Cents	Cents	Cents	Cents	Cents	Cents
Lye:							
Plant no. 1 ..	1.3	1.4	2.7	5.9	0.2	6.1	8.8
Plant no. 3 3/	4.3	11.0	15.3	11.3	.6	11.9	27.2
Plant no. 4 ..	2.8	1.8	4.6	4.8	.4	5.2	9.8
Plant no. 9 ..	4.8	5.0	9.8	8.7	.3	9.0	18.8
Plant no. 10 .	2.6	3.3	5.9	11.1	.5	11.6	17.5
Average	3.2	4.5	7.7	8.4	.4	8.8	16.4
Abrasive:							
Plant no. 3 3/	2.2	11.0	13.2	2.5	1.1	3.6	16.8
Plant no. 5 ..	1.1	1.1	2.2	1.0	.3	1.3	3.5
Plant no. 6A 4/	.6	1.5	2.1	1.1	.1	1.2	3.3
Plant no. 6B 4/	.6	1.5	2.1	3.8	.1	3.9	6.0
Plant no. 7 ..	.4	2.1	2.5	.5	.2	.7	3.2
Plant no. 8 ..	.8	1.5	2.3	1.3	.3	1.6	3.9
Average	1.0	3.1	4.1	1.7	.4	2.0	6.1

1/ Fixed costs of equipment were calculated at observed rates of production with a charge of 15 percent per year of current replacement costs for depreciation, insurance, repairs, etc. Replacement costs were obtained from operator estimates and from equipment manufacturers.

2/ Operating costs were calculated from plant records or operator estimates for water, gas, and lye. Electrical costs were calculated at a fixed rate of 3 cents per horsepower hour for all the motors in the peeling line. (See table 20.)

3/ Plant no. 3 processed potatoes by both lye and abrasive methods. The figures in each case assume total operations by each of the two methods. In either case, the rate of production was low compared to equipment and operating costs.

4/ For some customers, plant no. 6 prepared an excellent quality finished product (6B); for others, a considerable amount of peel was left on product (6A). Costs were apportioned to the time spent in each of the two methods.

marked differences in the rate of equipment utilization, both in terms of the rate at which the equipment was operated in relation to capacity and in terms of the number of hours per month that it was operated. Some portion of the cost difference is also attributable to differences in size of operation.

In the lye peeling plants the total fixed and operating costs ranged from 8.8 cents to 27.2 cents per 30-pound bag of finished product with an overall average of 16.4 cents. In the abrasive peeling plants the total of the fixed and operating costs ranged from 3.2 cents to 16.8 cents per 30-pound bag with an average of 6.1 cents. On the average, this was 10.3 cents per 30-pound bag additional fixed and operating costs for the lye peeling method compared with the abrasive method. A further breakdown of operating costs for the lye method is given in table 20.

EFFECT OF EQUIPMENT UTILIZATION ON COSTS

The effect of variations in equipment utilization on costs of peeling potatoes by the lye and abrasive methods can be illustrated best by the use of two model peeling lines. This will allow us to standardize the many factors besides equipment utilization which affect costs, including peeling losses, trimming labor, prices of supplies and utilities, and rates of depreciation.

Both of these lines have a capacity of 3,000 pounds of raw potatoes per hour. Although equipment is available for capacities as low as 1,000 pounds per hour, plants of this size have not been considered in this analysis, since almost all of the plants surveyed have been built with an eye to future expansion. Many are currently producing at rates of 1,000 to 2,000 pounds per hour, but almost all have capacities of 3,000 pounds or more.

The production range used in the illustration of the two model lines--3,000 pounds of raw product per hour at 40 hours per week (6,240,000 pounds per year) to 1,000 pounds per hour at 20 hours per week (1,040,000 pounds per year)--covers the actual production of 50 out of 81 plants which reported peeling potatoes in 1955. Only 6 commercial plants which reported in the survey had a higher output, and 25 had a lower output than those shown in this illustration.

Model lye peeling line.--The line has a rated capacity of 3,000 pounds of raw product per hour and consists of the following equipment: (a) Dumper, prewasher, and elevator, (b) lye peeler, (c) barrel washer with 10-horsepower booster water pump, (d) stainless steel predip or neutralizing tank, (e) trimming table, (f) automatic french-fry cutter, (g) sliver remover, (h) stainless steel dip tank, (i) stainless steel bagging attachment, and (j) scale. The estimated installed cost of units (a) through (d), including motors, electrical wiring and plumbing, is $11,800.

The complete peeling line costs $28,800.

Model abrasive peeling line.--This line also has a rated capacity of 3,000 pounds of raw product per hour. The equipment is similar in all respects to the lye peeling line except for the peeling unit itself; a continuous abrasive peeler with a garbage disposal unit replaces the lye peeler and barrel washer in the lye method. The estimated installed cost of items (a) through (d) in this line is approximately $5,280 and of the complete line $22,280.

Effect of equipment utilization on fixed costs.--Unit fixed costs for equipment vary from one production rate to another because of (1) differences in the hours of usage over which fixed equipment charges are spread and (2) differences in the amount of peeling losses between the lye and abrasive methods. Fixed equipment costs for production rates of 1,000, 2,000, and 3,000 pounds per hour and for 20, 30, and 40 hours use per week are shown in figure 1 and table 21. For instance at a production rate of 1,000 pounds of raw product per hour and 20 hours use per week, 508 bags would be produced by the lye method with fixed equipment costs of 16.4 cents per bag; 464 bags would be produced by the abrasive method at a cost of 13.8 cents per bag. With a production rate of 3,000 pounds per hour and 40 hours use per week, fixed equipment costs would decline to 2.7 cents per bag with lye equipment and 2.3 cents with abrasive equipment. These ranges in costs were close to actual costs reported by plants studied (table 10).

Effect of equipment utilization on operating costs.--Equipment utilization affects not only fixed costs but also operating and labor costs. In the lye peeling plants particularly, the operating costs per bag increase considerably when the equipment is used at less than full capacity. Although the lye and fuel costs are more nearly proportional to the volume per hour, water and electricity are affected more by hours of use than by volume per hour. Both water and electricity costs remain fairly constant whether a peeling line is run at 3,000 pounds per hour or at 1,000 pounds per hour. Other electric motors are in more or less continuous use regardless of volume. The water and electricity costs are then more of a per-hour operation cost, whereas the fuel and lye costs are more nearly a per-bag cost and are not greatly affected by production rates.

The operating costs per bag at various rates of production are shown in table 11. The operating costs alone for the lye peeling line vary from 5.6 cents per bag of finished product to as high as 9.2 cents, depending upon the degree of equipment utilization while the line is in operation.

The operating costs for the abrasive peeling line vary from 0.9 cents per 30-pound bag of finished product to 2.6 cents per bag (table 12).

When the operating costs are added to the fixed costs for different levels of equipment utilization, the results are similar to the range in actual costs of the 9 plants studied (table 10 and figure 1). For the lye method, the fixed and operating costs ranged from a total of 8.3 cents per bag to as high as 25.6 cents per bag. The actual costs in the lye peeling plants in the study ranged from 8.8 to 27.2 cents per bag. Similarly, the

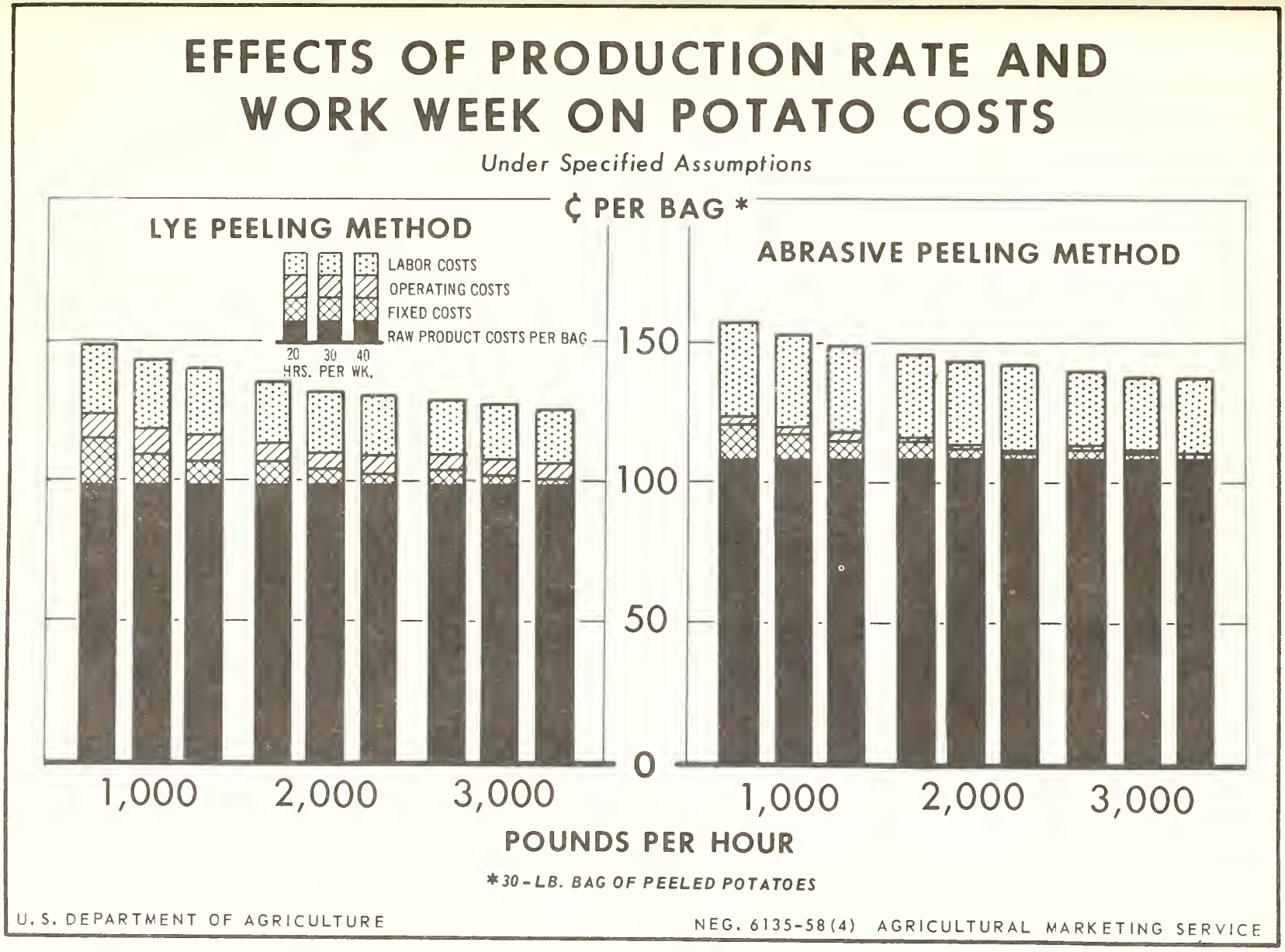
EFFECTS OF PRODUCTION RATE AND WORK WEEK ON POTATO COSTS
Under Specified Assumptions
¢ PER BAG *
LYE PEELING METHOD
ABRASIVE PEELING METHOD
LABOR COSTS
OPERATING COSTS
FIXED COSTS
RAW PRODUCT COSTS PER BAG
20 30 40 HRS. PER WK.
150
100
50
0
1,000
2,000
3,000
1,000
2,000
3,000
POUNDS PER HOUR
*30-LB. BAG OF PEELED POTATOES
U. S. DEPARTMENT OF AGRICULTURE
NEG. 6135-58(4) AGRICULTURAL MARKETING SERVICE

Figure 1

Table 11.--Operating costs of a lye peeling line per 30-pound bag of finished product, at specified rates of production

Cost item	Operating costs with production per hour of-- 1/		
	3,000 pounds	2,000 pounds	1,000 pounds
	Cents	Cents	Cents
Lye 2/	2.4	2.4	2.4
Gas 3/	1.4	1.4	1.4
Water 4/	1.0	1.5	3.0
Electricity 5/	.8	1.2	2.4
Total	5.6	6.5	9.2

1/ The production rates of 3,000, 2,000, and 1,000 pounds of raw product per hour are the equivalent of 76, 51, and 25 bags per hour respectively.
2/ Average of 5 lye peeling plants.
3/ Average of costs for gas in 4 plants.
4/ A per-hour cost of 76.1 cents (approximate actual costs of similar lines).
5/ A per-hour cost of 62.2 cents (motors total 20.75 horsepower at 3 cents per horsepower hour).

Table 12.--Operating costs of an abrasive peeling line per 30-pound bag of finished product, at specified rates of production

Cost item	Operating costs with production per hour of-- 1/		
	3,000 pounds	2,000 pounds	1,000 pounds
	Cents	Cents	Cents
Electricity 2/	0.5	0.7	1.5
Water 3/	.4	.5	1.1
Total	.9	1.2	2.6

1/ The production rates of 3,000, 2,000, and 1,000 pounds per hour are the equivalent of 70, 46, and 23 bags per hour, respectively.
2/ A per-hour cost of 34.5 cents. (Motors totaled 11.5 horsepower at 3 cents per horsepower hour.)
3/ A per-hour cost of 25 cents (approximates actual costs in similar lines).

costs in the model abrasive plant were from 3.2 to 16.4 cents per bag, whereas the costs of the actual plants in the study varied from 3.2 to 16.8 cents per 30-pound bag of finished product.

At each level of equipment usage, the fixed and operating costs for lye equipment were higher than for abrasive. The difference ranged from a little over 5 cents per bag at high rates of equipment utilization to over 9 cents per bag at the lowest level.

Effect of equipment utilization on labor costs.--The amount of labor per bag of finished product necessary in the direct operation of the peeling line decreases as the rate of production per hour is increased. This is true both for the lye and abrasive peeling lines within the range of equipment utilization in the model plants. For example, in most plants at least one man was employed to dump the raw product into the peeler whether the rate was less than 1,000 pounds or up to 8,000 pounds per hour. Similarly, one man was required to bag the finished product from rates of 15 bags up to 40 bags per hour. If production was between 40 and 90 bags per hour, at least two men were used. Trimming labor per bag appeared to be the same whether a plant was running at 15 bags per hour or 150 bags per hour.

The range in labor costs due to equipment utilization was from 19.6 to 24.7 cents per bag for the lye method and 27.1 to 32.5 cents per bag for the abrasive method (table 13). This difference between methods is quite large and offsets the differences between methods in fixed and operating costs at most levels of production. When fixed, operating, and labor costs are combined, the lye peeling method is most economical at production rates of 3,000 pounds and 2,000 pounds per hour, but the abrasive method is more economical when the production rate is 1,000 pounds per hour (fig. 1).

Although the difference in costs between the lye and abrasive methods is decreased when labor costs are added to the fixed and operating costs, the difference due to equipment utilization becomes increasingly wide. Costs range from 27.9 cents per bag at 3,000 pounds per hour to 50.3 cents per bag at 1,000 pounds per hour for the lye method. For the abrasive method, the range in costs is from 30.3 cents to 48.9 cents per bag, with production rates from 3,000 to 1,000 pounds per hour.

Peeling losses added to fixed, operating, and labor costs.--Although neither the hourly rate of production nor the equipment use per week has any measurable effect on peeling losses, the losses differ considerably between methods. Therefore, in a comparison of lye and abrasive lines, this factor must be taken into consideration. For every 30 pounds of finished product, 39.4 pounds of raw potatoes are needed for the lye peeling method and 43.1 pounds for the abrasive method. In this section, a price of $2.50 per hundred pounds of raw potatoes will be assumed. In a later section, some of the effects of varying prices for raw potatoes will be considered.

Totaling the fixed equipment, operating, labor, and raw product costs for the two model lines, we find that the lye peeling line is more economical than the abrasive line at any level of equipment utilization considered.

Table 13.--Labor costs of lye and abrasive peeling lines per 30-pound bag of finished product, at specified rates of production

Method of peeling and labor operation	Labor costs with production rate per hour of-- 1/		
	3,000 pounds	2,000 pounds	1,000 pounds
	Cents	Cents	Cents
Lye:			
Trimming 2/	14.7	14.7	14.7
Dumping 3/	1.6	2.4	5.0
Bagging 4/	3.3	4.9	5.0
Total	19.6	22.0	24.7
Abrasive:			
Trimming 2/	21.7	21.7	21.7
Dumping 3/	1.8	2.7	5.4
Bagging 4/	3.6	5.4	5.4
Total	27.1	29.8	32.5

1/ For lye peeling the production rates would be 76, 51, and 25 bags per hour with a raw product use rate of 3,000, 2,000, and 1,000 pounds per hour, respectively. For abrasive peeling the production rates would be 70, 46, and 23 bags, at the same rates.

2/ Average for Katahdin and Russet Burbank potatoes.

3/ One laborer, at $1.25 per hour, for all rates of production.

4/ One laborer, at $1.25 per hour, for rates up to 40 bags per hour; 2 laborers, at $1.25 per hour each, for rates of from 40 to 90 bags per hour.

The cost difference between the two methods varies from 8.0 to 11.5 cents per bag in favor of the lye method (fig. 1).

The range in cost for the lye method was from $1.26 per bag, at 3,000 pounds per hour and 40 hours of operation per week, to $1.49 per bag, at 1,000 pounds per hour and 20 hours of operation per week, a difference of 22.3 cents per bag.

The range in cost for the abrasive method was from $1.38 per bag, at 3,000 pounds per hour and 40 hours per week, to $1.57, at 1,000 pounds per hour and 20 hours per week, a difference of 18.8 cents per 30-pound bag.

With the given figures, the abrasive method would be more economical than the lye only when the abrasive equipment is operating at maximum utilization compared to the lye at one-third capacity. However, it should not be concluded that lye peeling is always the more economical method. This example was based on two model peeling lines of equal productive capacity. Many plants have

lines of smaller capacity with considerably lower equipment cost. The primary purpose of this example is to explain the wide variation in fixed and operating costs among the 9 plants in the cost study (table 10) and also to explain the wide variation in total labor requirements per 30-pound bag of finished product (tables 7 and 9).

Low Equipment Utilization in Peeling Industry

The 81 plants surveyed used an average of 2,300,000 pounds of raw potatoes per year. This average volume of use could be obtained with a single batch-type abrasive peeling unit with a 60-pound capacity. By carefully selecting raw stock it is possible to peel up to 1,500 pounds of potatoes per hour in such a unit. Some abrasive plants in the cost study peeled in excess of 10,000 pounds of potatoes per day with one of these units, over 2,600,000 pounds per year. Thus, present plant capacity is not a limiting factor in the volume of peeled potatoes produced by the industry. Distribution and sales, rather than capacity, govern the production of most plants. Many firms process potatoes only a few hours per day, and in some cases only 3 or 4 days a week. Even when the plant is operating, it may do so at only a fraction of capacity. With maximum usage of present equipment and a 40-hour week, the peeling industry could easily increase production from 50 to 100 percent over current volume. Distribution is normally in a fairly limited area, partially because of possible spoilage losses. The unused equipment capacity, plus limited distribution areas for the product, increases cost per bag and results in severe competition between peeling plants in some locations.

Minimum Production Level for Lye Peeling

The comparisons of lye and abrasive methods presented to this point have shown (a) general differences in peeling loss and trimming labor for different grades and varieties of potatoes, (b) direct comparisons of trimming labor and peeling loss for the two principal varieties, (c) differences in actual fixed and operating costs among 9 commercial plants, and (d) the effects of equipment utilization on costs of producing peeled potatoes on two hypothetical lines.

By combining some of the above differences in the lye and abrasive peeling methods, it is possible to estimate the minimum production level at which lye peeling would be more economical than abrasive, if both lines had a capacity of 3,000 pounds per hour.

The principal differences in cost between the two methods of peeling are (1) fixed cost of equipment, (2) peeling losses or waste in processing, (3) dumping, bagging, and trimming labor, and (4) variable operating costs.

Many factors other than the costs considered in this report may influence an operator's choice of peeling method. Among these are product quality in terms of leakage and the possibility of a cooked layer if potatoes are peeled by methods requiring chemicals or heat. Others are technical training of plant personnel, whether present plant size will permit the

installation of a lye peeler, availability and cost of fuel and water, and availability of labor.

The data which have been presented are for completely peeled potatoes. In many cases, particularly for french-fry slices, not all of the skin is removed. In this situation there would appear to be little saving in trimming labor but some definite saving in peeling losses and an appreciable upgrading of product quality by the use of the lye peeling method compared with abrasive.

The comparative costs of peeling by lye and abrasive methods are based on the costs of operating the two model lines developed in the preceding section. In general, most plants must operate at least 3 days a week in order to produce freshly peeled potatoes often enough to maintain quality for the buyers. Since generally it is extremely difficult to assemble and maintain a labor force for less than about 6 to 7 hours of work per day, it is necessary to operate about 20 hours per week. Thus, in a plant producing 500 bags per week, it would be possible to produce this quantity in about 10 hours at a production rate of 2,000 pounds per hour, but in order to maintain the labor force by offering sufficient employment, a plant would need to operate at the 1,000-pound rate for about 20 hours. In order to show figures for a production rate as low as 250 bags per week using this type of equipment, it was necessary to provide for a work week of only about 10 hours in this one case.

Unit fixed costs for equipment are determined by the cost of the equipment, the rate charged for depreciation, repairs, etc., and the volume produced. In this illustration, lye peeling equipment for a 3,000-pound-per-hour line costs $6,500 more than for an abrasive line of the same capacity. A charge of 15 percent per year is made for depreciation, repairs, etc. Thus, it costs $975 per year more to own the lye equipment than the abrasive. Unit costs are determined by dividing the annual charge of $975 by the total annual production.

Equipment operating costs are related to the rate of production (tables 11 and 12). Labor costs by the two methods are the same except for trimming, dumping, and bagging. Trimming costs are higher for the abrasive method because more peel is left on the potatoes by the machinery. Dumping and bagging costs are higher for the abrasive method because of the somewhat lower output (due to higher peeling losses) with a fixed work crew for these operations (table 13).

The costs of 6.5 percent additional peeling losses by the abrasive method are determined by the price of the raw product. The additional 3.7 pounds of raw product required to produce a 30-pound bag of peeled potatoes by the abrasive method would cost 3.7 cents if potatoes were $1 per hundred pounds and 11.1 cents if they cost $3.

The most economical method of peeling potatoes with lye and abrasive lines of 3,000 pounds per hour capacity at production rates from 250 to 1,500 bags per week and raw product prices ranging from $1 to $5 per hundredweight

is indicated in figure 2 and tables 14 and 15. Thus, if raw potatoes cost $1 per hundred pounds, the costs of peeling by the lye method will be lower than by the abrasive method at all production rates above approximately 425 bags per week. Similarly, if potatoes are $5 per hundred pounds, the lye method will be more economical at any production level which would be feasible.

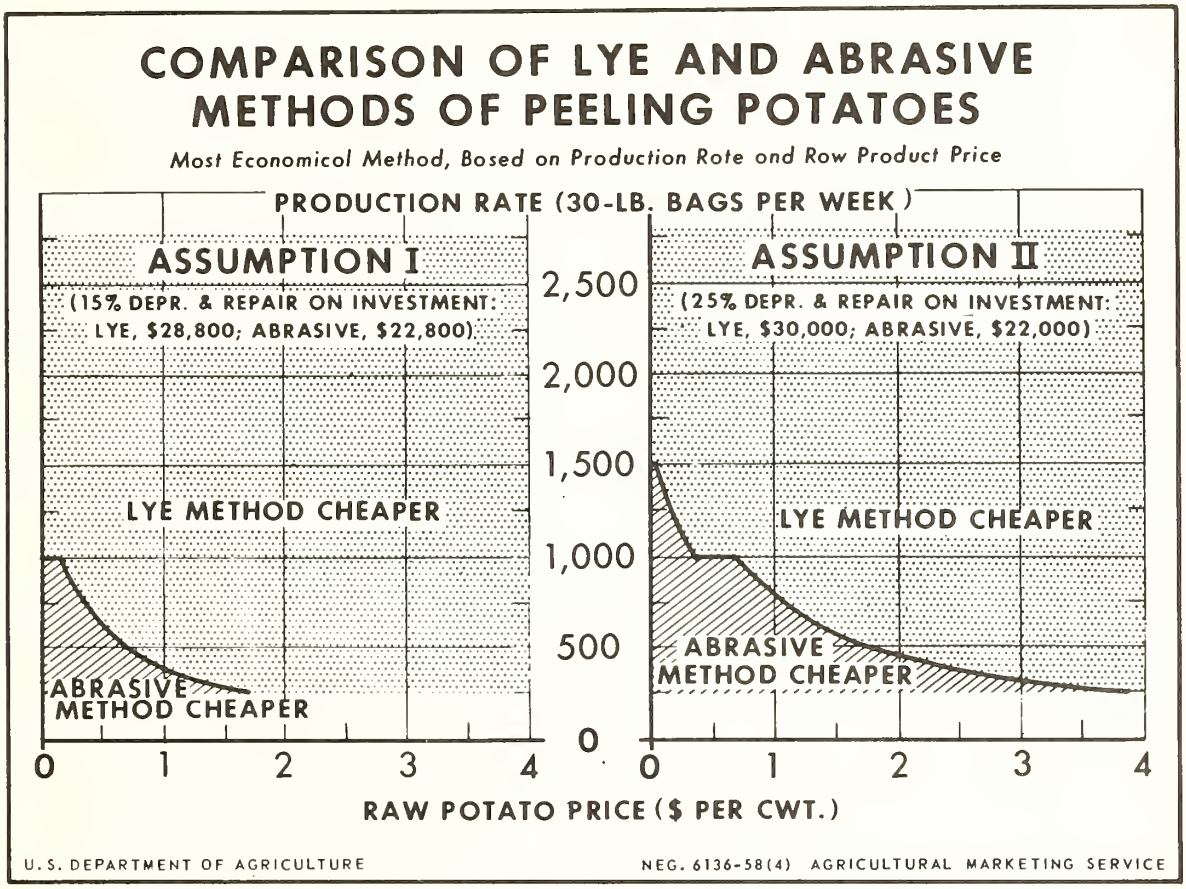

Figure 2

A plant manager can use these figures in deciding which type of equipment to install. For example, if he anticipates that his production will average 250 bags per week and that raw potatoes of the size and grade which he wishes to use will average $1 per hundred pounds during his period of production, he will install abrasive equipment, since his costs would be lower than with lye equipment. However, if he anticipates higher potato prices--say, $2 per hundred pounds--and production averaging 250 bags per week, he will install lye equipment.

Of course, if he wishes to make his plans in terms of producing at the capacity rate of the equipment, he will install lye. At 3,000 pounds per hour in a 40-hour week, he could produce over 3,000 bags per week at lower cost for any price of raw potatoes.

Table 14.--Comparative costs of peeling potatoes by lye and abrasive methods at different production rates under two sets of assumptions as to equipment costs 1/

Peeling method and weekly production rate	Operating hours per week	Production per hour	Costs per 30-pound bag					
			Dump, trim, and bag labor	Equipment operating	Fixed equipment		Total	
					Assumption I	Assumption II	Assumption I	Assumption II
	Hours	Pounds	Cents	Cents	Cents	Cents	Cents	Cents
Lye peeling method:								
250 bags...	9.85	1,000	9.2	24.7	33.2	57.7	67.1	91.6
500 bags...	19.70	1,000	9.2	24.7	16.6	28.8	50.5	62.7
750 bags...	29.55	1,000	9.2	24.7	11.8	21.6	45.7	55.5
1,000 bags.	19.70	2,000	6.5	22.0	8.3	14.4	36.8	42.9
1,500 bags.	19.70	3,000	5.6	19.6	5.5	9.6	30.7	34.8
Abrasive peeling method:								
250 bags...	10.78	1,000	2.6	32.5	25.7	42.3	60.8	77.4
500 bags...	21.56	1,000	2.6	32.5	12.9	21.2	48.0	56.3
750 bags...	32.34	1,000	2.6	32.5	8.6	15.9	43.7	51.0
1,000 bags.	21.56	2,000	1.2	29.8	6.4	10.6	37.4	41.6
1,500 bags.	21.56	3,000	.9	27.1	4.3	7.1	32.3	35.1

1/ Costs only for items indicated; costs for other items the same by either method.

Assumption I: Equipment investment: Lye method, $28,000; abrasive method, $22,280. Depreciation and repairs, 15 percent of investment per year: Lye method, $83.08 per week; abrasive method, $64.27 per week.

Assumption II: Equipment investment: Lye method, $30,000; abrasive method, $22,000. Depreciation and repairs, 25 percent of investment per year: Lye method, $144.23 per week; abrasive method, $105.77 per week.

Table 15.--Difference in costs of peeling potatoes by lye and abrasive methods at different production rates and raw product price which equates costs by two methods under two sets of assumptions as to equipment costs and depreciation rates 1/

Weekly production rate	Operating hours per week	Production per hour	Assumption I		Assumption II	
			Cost difference: Lye minus abrasive	Price per pound of raw product which equates costs by the two methods	Cost difference: Lye minus abrasive	Price per pound of raw product which equates costs by the two methods
	Hours	Pounds	Cents	Cents	Cents	Cents
250 bags	9.85	1,000	6.3	1.7	14.2	3.8
500 bags	19.70	1,000	2.5	.7	6.4	1.8
750 bags	29.55	1,000	1.3	.4	4.5	1.1
1,000 bags	19.70	2,000	-.6	2/	1.3	.4
1,500 bags	19.70	3,000	-1.6	2/	-.3	2/

1/ Assumption I: Equipment investment: Lye method, $28,800; abrasive method, $22,280. Depreciation and repairs, 15 percent of investment per year: Lye method, $83.08 per week; abrasive method, $64.27 per week.

Assumption II: Equipment investment: Lye method, $30,000; abrasive method, $22,000. Depreciation and repairs, 25 percent of investment per year: Lye method, $144.23 per week; abrasive method, $105.77 per week.

2/ Lye method cheaper at any price of raw potatoes.

On the other hand, if a manager wishes to plan solely in terms of lower production levels--say, 500 bags per week--without the possibility of expanding output or changing equipment, he should consider the installation of a batch-type abrasive unit or a smaller lye unit with a capacity of about 1,000 pounds per hour.

Another possibility in deciding which type of equipment to install is that an individual manager may wish to estimate the additional costs of lye equipment on a more conservative basis. He may find, for example, that in his particular location and circumstances, transportation and installation costs for the lye equipment would be substantially higher than the average levels used in this analysis. He might also wish to plan on the basis of a more rapid depreciation rate, being more concerned with possible obsolescence of the equipment than the average manager considered here. Such a manager might wish to estimate an $8,000 difference in the cost of equipment between lye and abrasive methods and use a 25 percent rate for depreciation, repairs, etc., rather than the 15 percent rate used here. On this basis, the fixed equipment cost would be $2,000 per year rather than $975. The production level at which lye peeling would be more economical than abrasive would be substantially higher than that shown in figure 2 for average assumptions of equipment cost and depreciation rates (table 15). For instance, with raw potato prices at $1 per hundred pounds, abrasive would be more economical than lye at production levels up to approximately 800 bags per week. If potato prices went to $3, costs by the lye method would be lower at levels above 300 bags per week.

Thus, we find that in most situations the lye peeling method has lower costs than the abrasive method. However, each plant operator will need to consider his own situation and make his decision in the light of the facts which are relevant to it, especially the rate of production and the average price level for raw potatoes which he anticipates. The abrasive peeling method was used by 51 of the plants surveyed, 31 of which produced 2,000 bags per month or more, and 19 of which produced more than 3,000 bags per month. Therefore, it appears, on the basis of the foregoing analysis, that more than one-third of the present abrasive peeling plants might economically shift to lye, if the average cost for raw potatoes is 60 cents per hundred pounds or more. Approximately three-fourths of the present abrasive plants probably could shift to lye, if the average cost for raw potatoes is over $1 per hundred pounds.

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APPENDIX A--METHODS USED IN STUDY

Determining Grade and Size of Raw Product and Quality of Finished Product

In a commercial peeling plant from 1 to as many as 9 or 10 different lots of raw product may be used in a day. In order that comparisons would be made between lye and abrasive peeling only on lots possessing similar characteristics both in raw and processed form, each lot was inspected by a Federal-State fruit and vegetable inspector. This inspection consisted of the following:

(1) Determining through a sampling procedure the amount of defects in excess of peel which would have to be removed in peeling and trimming, in percentage of total weight of the raw product.

(2) Determining the size of potatoes in each lot. For round varieties, size was determined by individually sizing each potato in a sample into the following size groups: Under 1-3/4 inches, from 1-3/4 inches to 2-1/4 inches, from 2-1/4 inches to 3 inches, and from 3 inches to 4 inches. For the long varieties, the potatoes were divided into the following classes: Under 8 ounces, from 8 to 12 ounces, 12 to 16 ounces, 16 to 20 ounces, and over 20 ounces.

(3) Determining the amount of peel left on the potatoes after they had passed through the peeling unit but before they had been handtrimmed, in percentage of the surface area unpeeled.

(4) Determining by a sampling procedure the amount of peel left on the finished product after hand trimming, in untrimmed spots per pound for "good-to-excellent quality finished product."

Spots per pound of finished product were used when there was so little to be measured that it would be inaccurate to try

to express the amount in terms of percentage of unpeeled surface and too little to weigh with field apparatus after trimming. For the fair quality product, the finished quality was expressed as percentage of surface area unpeeled. The product quality was determined before the potatoes were sliced into french-fry slices.

(5) Sample lots of each run were shipped under refrigeration to the U. S. Department of Agriculture Processed Foods Inspection Laboratory in Washington, D. C., where they were graded in terms of U. S. Standards for Grade of Peeled Potatoes. For an example of quality measurements see table 18.

Determining Peeling Losses

Inventories were made before and after each run in a plant. Samples of the bags of unpeeled potatoes were weighed. Additional losses due to the style of product were determined by two methods: (1) By comparing differences in yield within a plant among different kinds of finished products from the same raw stock, and (2) by weighing losses from the sliver remover and from cutting machines. The losses were adjusted to equivalent losses in the production of 1/2-inch french-fry slices where a sliver remover with 5/16-inch openings was used.

Determining Time for Trimming and Other Operations

A work sampling procedure was used to determine the average working time necessary to perform any specific operation. 4/ With this method, nearly continuous observations were made of all the workers in a peeling line and the proportion of the total time spent by the various workers on each operation was determined. Nonproductive time due to idleness or delays was subtracted from the total time requirements to give productive time requirements. The total productive time spent by all workers on a specific operation, such as trimming, was divided by the number of 30-pound bags produced during this time to give the average man-minutes per bag for a specific operation.

4/ For a more detailed discussion of work sampling methods, see: Sammet, L. L., and Hassler, J. B. Use of the Ratio-Delay Method in Processing Plant Operations. Agr. Econ. Res. 3(4): 124-134. October 1951. Or: Barnes, Ralph M. Work Sampling. W. C. Brown Company, Dubuque, Iowa. 1956.

APPENDIX B--TABLES

Table 16.--Trimming labor, total labor, and peeling loss, per 30-pound bag of finished product, in peeling U. S. No. 1 grade Katahdin potatoes by abrasive and lye peeling methods, April and May 1956 1/

Peeling method, size of potatoes, plant number and run	Labor		Peeling loss	Raw product used
	Trimming	Total 2/		
	Minutes	Minutes	Percent	Pounds
Lye (some lots $2\frac{1}{4}$-4 in.; others 3-4 in.):				
Plant No. 1:				
Run 1	8.8	12.4	20.4	37.7
Run 2	7.6	11.5	21.4	38.2
Run 3	8.1	11.2	18.2	36.7
Average	8.2	11.7	20.0	37.5
Plant No. 2:				
Run 1	6.5	9.8	25.0	40.0
Run 2	5.4	8.5	--	--
Run 3	11.6	14.4	21.6	38.3
Run 4	14.8	17.8	24.5	39.7
Average	9.6	12.6	23.7	39.3
Plant No. 3:				
Run 1	8.0	12.6	24.8	39.9
Run 2	7.2	11.3	--	--
Run 3	7.2	11.6	--	--
Run 4	6.8	12.3	24.2	39.6
Average	7.3	12.0	24.5	39.8
Plant No. 4:				
Run 1	10.8	14.3	16.0	35.7
Run 2	8.1	15.3	19.1	37.1
Run 3	9.6	15.4	--	--
Average	9.5	15.0	17.6	36.4
Overall average of lye peeling 3/	8.6	12.8	21.5	38.3

Continued

Table 16.--Trimming labor, total labor, and peeling loss, per 30-pound bag of finished product, in peeling U. S. No. 1 grade Katahdin potatoes by abrasive and lye peeling methods, April and May 1956 1/--Continued

Peeling method, size of potatoes, plant number and run	Labor		Peeling loss	Raw product used
	Trimming	Total 2/		
	Minutes	Minutes	Percent	Pounds
Abrasive (all lots 3-4 in.):				
Plant No. 3:				
Run 1	16.0	30.1	40.0	50.0
Run 2	14.6	29.7	38.4	48.7
Run 3	14.1	27.8	--	--
Run 4	17.2	30.5	--	--
Average	15.5	29.5	39.2	49.3
Plant No. 7:				
Run 1	16.2	24.7	20.7	37.8
Run 2	16.7	25.2	--	--
Run 3	15.8	23.5	--	--
Run 4	16.3	24.2	--	--
Run 5	15.5	23.8	--	--
Run 6	12.8	19.1	18.1	36.6
Run 7	10.6	16.9	--	--
Run 8	12.2	19.5	--	--
Run 9	9.9	17.3	--	--
Run 10	10.7	16.5	--	--
Average	13.7	21.1	19.4	37.2
Plant No. 8	14.6	15.8	32.3	42.4
Overall average for abrasive peeling 3/	14.6	22.1	30.3	43.0

1/ Only lots with similar characteristics both in the raw and processed form were included in these comparisons. See table 18 for corresponding data on quality factors for each of the runs listed in this table.

2/ Total labor, including trimming labor, per 30-pound bag of processed potatoes in the direct operation of the peeling line. This includes all labor from dumping the raw potatoes to sealing the bags of processed potatoes and placing the bags aside after sealing.

3/ Simple average of individual plant averages.

Table 17.--Trimming labor, total labor, and peeling loss per 30-pound bag of finished product, in peeling U. S. No. 2 grade Russet Burbank potatoes by abrasive and lye peeling methods, April and May 1956 1/

Product quality, peeling method, plant number, and run 2/	Labor		Peeling loss	Raw product used
	Trimming	Total 3/		
	Minutes	Minutes	Percent	Pounds
Excellent quality finished product:				
Lye method:				
Plant No. 1:				
Run 1	8.6	13.6	28.5	41.6
Run 2	6.4	11.2	25.1	40.1
Plant No. 9	12.0	16.0	25.2	40.1
Average	9.0	13.6	26.3	40.6
Abrasive method:				
Plant No. 6:				
Run 1	9.9	14.3	34.3	45.7
Run 2	11.3	16.9	41.9	51.6
Run 3	12.3	17.9	--	--
Run 4	13.6	18.2	36.9	47.5
Run 5	10.7	15.2	44.3	53.9
Run 6	11.0	16.9	45.0	54.5
Average	11.4	16.6	40.5	50.6
Fair to good quality product:				
Lye method:				
Plant No. 2:				
Run 1	4.3	7.4	--	--
Run 2	3.1	5.1	28.6	42.0
Plant No. 9:				
Run 1	5.4	8.4	25.6	40.3
Run 2	4.9	7.6	--	--
Run 3	4.9	7.1	--	--
Run 4	5.4	7.8	29.6	42.6
Run 5	5.8	8.9	--	--
Plant No. 4:				
Run 1	7.4	10.4	17.0	36.1
Run 2	8.3	11.8	20.5	37.7
Run 3	9.2	12.6	20.9	37.9
Run 4	8.1	10.8	16.5	35.9
Average	6.1	8.9	22.7	38.9

Continued

Table 17.--Trimming labor, total labor, and peeling loss per 30-pound bag of finished product, in peeling U. S. No. 2 grade Russet Burbank potatoes by abrasive and lye peeling methods, April and May 1956 1/--Continued

Product quality, peeling method, plant number, and run 2/	Labor		Peeling loss	Raw product used
	Trimming	Total 3/		
	Minutes	Minutes	Percent	Pounds
Fair to good quality product:--Continued				
Abrasive method:				
Plant No. 5:				
Run 1	7.9	13.2	39.4	49.5
Run 2	7.4	11.4	--	--
Run 3	6.4	9.6	--	--
Run 4	7.8	11.4	--	--
Run 5	6.9	10.9	--	--
Run 6	4.9	7.5	32.3	44.3
Run 7	5.0	7.7	--	--
Run 8	4.7	7.3	--	--
Run 9	4.7	7.5	--	--
Average	6.2	9.6	35.8	46.9

1/ Only lots having similar characteristics both in raw and processed form were included in these comparisons. The raw product was graded and sized by a Fresh Fruit and Vegetable Inspector, the finished product by Processed Products Inspection Service of the U. S. Department of Agriculture.

2/ Each of the commercial processing plants in the study was assigned a number for identification purposes.

3/ Total labor, including trimming labor, per bag of processed potatoes in the direct operation of the peeling line. This includes all labor from dumping the unpeeled potatoes to sealing of the bags of processed potatoes and placing the bags aside after sealing.

Table 18.--Comparisons of the amount of defects before peeling, surface peel before trimming, peeling loss, and product quality of U. S. No. 1 grade Katahdin potatoes peeled by abrasive and lye peeling methods, April and May 1956

Peeling method, size of potato, plant number, and run	Defects before peeling 1/	Unpeeled surface area before trimming 2/	Peeling loss	Spots per pound of product 3/
	Percent	Percent	Percent	Number
Lye (some lots 2¼-4 in.; others 3-4 in.):				
Plant No. 1:				
Run 1	1.9	9.0	20.4	3.5
Run 2	1.3	7.0	21.4	6.0
Run 3	1.3	12.0	18.2	1.7
Average	1.5	9.3	20.0	3.7
Plant No. 2:				
Run 1	1.7	1.5	25.0	5.1
Run 2	--	--	--	--
Run 3	1.1	1.4	21.6	.0
Run 4	2.7	4.8	24.5	.1
Average	1.8	2.6	23.7	1.7
Plant No. 3:				
Run 1	1.3	10.	24.8	5.7
Run 2	--	--	--	--
Run 3	--	--	--	--
Run 4	1.7	8.0	24.2	5.9
Average	1.5	9.0	24.5	5.8
Plant No. 4:				
Run 1	2.7	8.0	16.0	4.9
Run 2	2.7	7.8	19.1	3.8
Run 3	--	--	--	--
Run 4	--	--	--	--
Average	2.7	7.9	17.6	4.3
Overall average of lye peeling	1.8	7.2	21.5	3.9

Continued

Table 18.--Comparisons of the amount of defects before peeling, surface peel before trimming, peeling loss, and product quality of U. S. No. 1 grade Katahdin potatoes peeled by abrasive and lye peeling methods, April and May 1956--Continued

Peeling method, size of potato, plant number, and run	Defects before peeling 1/	Unpeeled surface area before trimming 2/	Peeling loss	Spots per pound of product 3/
	Percent	Percent	Percent	Number
Abrasive (all lots 3-4 in.):				
Plant No. 3:				
Run 1	0.9	8.0	40.0	0.1
Run 2	1.8	7.6	38.4	.1
Run 3	--	--	--	--
Run 4	--	--	--	--
Average	1.4	7.8	39.2	.1
Plant No. 7:				
Run 1	4.2	16.0	20.7	4.1
Run 2	--	--	--	--
Run 3	--	--	--	--
Run 4	1.7	12.0	--	5.8
Run 5	3.8	16.0	--	8.0
Run 6	2.0	15.0	18.1	3.1
Run 7	1.8	11.0	--	1.7
Run 8	--	--	--	--
Run 9	1.1	9.5	--	4.2
Run 10	1.2	11.0	--	5.0
Average	2.3	12.9	19.4	4.4
Plant No. 8	6.7	10.0	34.4	6.5
Overall average of abrasive peeling	2.5	11.6	30.3	3.8

1/ Amount of defects in raw unpeeled potatoes. Percentage of total weight, in excess of that normally removed in hand peeling, which will have to be trimmed due to defects.

2/ Amount of peel or skin left on the potatoes after they have gone through the mechanical peeling units but before they have been trimmed by hand. Expressed in the percentage of the surface area which is unpeeled.

3/ The number of untrimmed spots per pound on whole peeled potatoes. In all cases these spots were less than one percent of total surface area.

Table 19.--Mail survey of peeling loss by variety and grade of potatoes, by season and kind of product, for the lye and abrasive methods, 1955

Raw and finished product 1/	Plants reporting 2/		Peeling loss by peeling method		
	Lye	Abrasive	Lye	Abrasive	Difference
	Number	Number	Percent	Percent	Percent
Late crop potatoes (used approximately 9 months):					
French-fry slices:					
U. S. No. 2, Russet Burbank, size A.....	21	28	21.3	25.2	3.9
U. S. No. 1, Katahdins, 3-4 inch.....	7	8	21.3	26.1	4.8
U. S. No. 1, Katahdins, 2¼-4 inch.....	2	7	23.0	27.2	4.2
Average or total....	30	43	21.9	26.2	4.3
Whole potatoes:					
U. S. No. 2, Russet Burbank, size A.....	5	19	20.8	27.7	6.9
U. S. No. 1, Katahdins, 2¼-4 inch.....	7	16	20.7	26.4	5.7
Average or total....	12	35	20.8	27.1	6.3
Early and intermediate crop potatoes (used approximately 3 months):					
French-fry slices:					
U. S. No. 2, Long White, size A.....	9	9	22.0	19.0	-3.0
U. S. No. 1, Long White, 8- or 10-oz. minimum...	9	17	21.0	22.0	1.0
U. S. No. 1, Sebago, 1-7/8 in. minimum, size A.	7	7	21.0	22.0	1.0
Average or total....	25	33	21.3	21.0	-0.3
Whole potatoes:					
U. S. No. 2, Long White, size A.....	3	8	22.0	25.0	3.0
U. S. No. 1, Long White, 8- or 10-oz. minimum...	5	11	23.0	27.0	4.0
U. S. No. 1, Sebago, 1-7/8-in. minimum, size A	13	7	22.0	24.0	2.0
Average or total....	21	26	22.3	25.3	3.0

1/ Only the principal varieties and grades of potatoes, of those reported in the survey, are listed here.

2/ The number of plants using a particular variety, grade, and size of potato varied widely. In each instance, the peeling losses are the average of those plants which reported its use.

Table 20.--Operating costs per 30-pound bag of finished product for equipment to peel potatoes in lye peeling plants, April and May 1956 1/

Plant	Operating costs 2/				
	Lye	Water	Fuel for heat	Electricity	Total
	Cents	Cents	Cents	Cents	Cents
1	2.9	1.1	1.2	0.7	5.9
4 3/	1.7	1.5	.6	1.0	4.8
9	2.9	3.0	1.8	1.0	8.7
10 4/	2.3	4.1	1.9	2.8	11.1
3 5/	2.5	2.3	4.5	2.0	11.3
Average	2.5	2.4	2.0	1.5	8.4

1/ The peeling operation includes washing after the lye bath to remove the skin and traces of lye from the tubers.

2/ Lye, water, and fuel costs were from operator estimates and/or plant records. Electrical costs were calculated on production rates in individual plants at a standard rate of 3 cents per horsepower hour of motor usage. Some differences in water and fuel costs were probably due to rate differences among areas.

3/ Plant 4 used low temperature peeling (under 130° F.) for a relatively long immersive time (10-12 minutes).

4/ Plant 10 used an unusually large quantity of water for washing the potatoes after the lye bath. A 50-horsepower water pump was employed. Other plants having more capacity per hour used only a 10-horsepower water pump. At this plant's rate of production, this appreciably increased the water and electrical costs per bag.

5/ Plant 3 used an electrically heated lye peeler. The production rate was slow for the equipment involved. Water costs were estimated in this plant as they were a part of rent and no figures were available.

Table 21.--Fixed costs per 30-pound bag of finished potatoes and production per week with different levels of equipment utilization, lye and abrasive peeling methods 1/

Peeling method and hours' use per week	Production and equipment costs per 30-pound bag of finished product at rate of production per hour of--					
	3,000 pounds		2,000 pounds		1,000 pounds	
	Production per week 2/	Fixed costs 3/	Production per week 2/	Fixed costs 3/	Production per week 2/	Fixed costs 3/
	30-lb. bags	Cents	30-lb. bags	Cents	30-lb. bags	Cents
Lye:						
10	761	10.8	508	16.4	254	32.7
20	1,523	5.5	1,015	8.2	508	16.4
30	2,284	3.6	1,523	5.5	761	10.9
40	3,046	2.7	2,030	4.1	1,015	8.2
Abrasive:						
10	696	9.2	464	13.9	232	27.7
20	1,392	4.6	928	6.9	464	13.9
30	2,088	3.1	1,392	4.6	696	9.2
40	2,784	2.3	1,856	3.5	928	6.9

1/ The production rates used in this illustration--from 1,040,000 pounds to 6,240,000 pounds of raw product per year--include the rates of 46 of the 80 plants in the survey of 1955 operations.

2/ Peeling losses were 23.9 percent for lye and 30.4 percent for the abrasive method.

3/ Estimated purchase costs of the peeling lines are $28,800 for lye and $22,280 for abrasive, with a 15-percent annual charge for depreciation, insurance, repairs, etc.

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