STORAGE OF POTATOES IN PALLET BOXES FOR CHIP MANUFACTURE

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PREFACE

This report is a part of a broad program of continued research aimed at improving efficiency and reducing costs in the marketing of farm products.

The author wishes to express his appreciation to R. S. Claycomb, formerly with the Agricultural Marketing Service, and E. C. Yaeger, AMS, for obtaining the data on weight loss in the 1-ton pallet boxes and regulating the storage temperature; to J. C. Hansen and T. T. McClure, both formerly with AMS, for assistance in carrying out the study; to the Red River Valley Potato Growers Association for furnishing the potatoes, and to the Naugatuck Chemical Division, U. S. Rubber Co., for supplying the potato sprout inhibitor.

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STORAGE OF POTATOES IN PALLET BOXES FOR CHIP MANUFACTURE

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SUMMARY AND CONCLUSIONS

Sprouting and consequent weight loss and shriveling of Irish Cobbler and Kennebec potatoes stored in 1-ton pallet boxes at an average temperature of 56° F. and 60-percent relative humidity were successfully controlled by foliar application of maleic hydrazide (MH), provided it was applied while the foliage was still green, and the potatoes were not skinned excessively prior to storage. When the potatoes were harvested before the advent of cold weather, they produced chips of satisfactory color at harvest, and continued to produce chips of about the same or better color throughout the storage season. Under these conditions MH had no marked effect on chip color nor was there any consistent difference between varieties. With few exceptions, Kennebec lost more weight in storage than did Irish Cobbler. The losses were undoubtedly higher than would have been encountered had it been possible to maintain a higher relative humidity in the storage.

With the exception of Irish Cobbler in 1956-57, total injuries increased during storage, in some cases doubling while in others increasing only slightly. The increase in most instances was in nongrade defects but in one instance there was marked increase in grade defects.

Decay after storage ranged from 1 percent or less in 1956-57 to as high as 16 percent in 1957-58 when late blight was present. MH had no apparent effect on decay.

Usually chip yields per 100 grams of peeled, sliced potatoes increased gradually during storage. Irish Cobbler potatoes yielded slightly more chips than did Kennebec. MH had little effect on chip yields.

INTRODUCTION

Potato chip companies now attempt to obtain potatoes that can be processed at once into light-colored chips, without reconditioning the potatoes at the chip plant. Storage temperatures much below 50° F. result in excessive accumulation of reducing-sugars in potatoes and consequent undesirable dark-colored chips. Although raising the temperature to 70° to 80° for 1 to 4 weeks following cool storage may restore the potatoes to the desired condition, this process is costly and uncertain. High real-estate values at many of the chip plant locations make extensive reconditioning facilities too costly there. Moreover, a certain amount of risk is involved in reconditioning potatoes. Sometimes this process cannot be accomplished at all or within a reasonable length of time. By the time the processor has determined this, the potatoes have become almost worthless for other uses because of sprouting, shriveling, and decay.

Potatoes stored at 50° F. or higher soon begin to sprout and unless used shortly after sprouting begins, excessive loss of weight results. Zukel (14)[1] was probably the first to demonstrate that the foliar application of maleic hydrazide (MH) would inhibit potato sprouting at moderate temperatures. Following this discovery many investigators

[1] Underscored numbers in parentheses refer to Literature Cited, page 14.

gave attention to this problem (2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13). Results of many studies show that application 4 to 6 weeks before harvest at the rate of 2 to 3 pounds of the active ingredient per acre was apparently best. Patterson and others (10) obtained beneficial effects on the specific gravity and color of potato chips from the use of maleic hydrazide, but in general other workers have not obtained these effects (2, 5, 9, 12).

This report deals with a study of pilot-plant size to test the commercial feasibility of storing potatoes in 1-ton pallet boxes that could be handled with forklift equipment, at temperatures high enough to insure good chip color and yield by using foliar applications of MH to prevent excessive sprouting during long storage.

PROCEDURE

The experiment was conducted during a 3-year period, with both Irish Cobbler and Kennebec potatoes, each grown in 5-acre adjacent plots on Bearden silt loam typical of the better soils of the Red River Valley of North Dakota-Minnesota. Two hundred pounds per acre of 4-24-12 fertilizer (a normal application rate in this area) was applied at planting time in bands in the row slightly below and to each side of the seed piece. Cultural and harvesting operations performed on the plots represented those typical of good commercial practice for the area. One-half of each plot was sprayed with a commercial sprayer with MH-30 (diethanolamine salt) or MH-40 (sodium salt) at the rate of 3 pounds per acre of active ingredient in 30 gallons of water. The dates of planting, MH applications, and harvest for the 3 years were:

Year	Planted	MH applied	Harvested
1956	May 26	Aug. 21	Sept. 18
1957	May 10	Aug. 17	Sept. 23
1958	May 7	Aug. 13	Sept. 15

The potatoes were placed in 70 to 80 1-ton-capacity pallet boxes for convenience in handling, weighed, and stored at an average temperature of 56° F. and 60-percent relative humidity (RH). After the first 2 months' storage, commercial-size lots of each variety were weighed and removed from storage at monthly intervals and made into chips by a local chip manufacturer. Following what was considered good commercial practice, the untreated lots were removed first and the treated last. The storage period extended to mid-April each year.

Subsamples of potatoes weighing about 2,000 grams, each containing 10 tubers, were used for the chipping tests. Four or more random subsamples were obtained at harvest and each time a lot was removed from storage. A few additional samplings were made for the chipping tests.

Chips were prepared and their color and yield determined in a manner described in (4). In brief, following abrasion peeling, several transverse slices 3/64-inch thick were taken from near the center of each potato to make a composite sample weighing exactly 100 grams. The sample was rinsed in cool tap water, blotted between cotton towels, and fried in peanut oil at 340° F. Each sample was weighed to determine yield and was then scored for color using the scale: Very dark brown, 50 or less; dark brown, 55 to 60; medium brown (lowest salable grade), 70; light brown, 75 to 85; cream, 90.

Four to five 50-pound random samples of both treated and untreated potatoes of each variety were examined at harvest and after a period of storage for mechanical injury and decay. The injury was classified into nongrade defects (within the tolerance of U. S. No. 1 grade) and grade defects (outside the tolerance of U. S. No. 1 grade).

When sprouts were present, a 25-pound random sample was selected from each box at the time it was removed from storage and desprouted to obtain data on losses from sprout removal.

RESULTS

Storage Losses

Weight losses and sprouting. --During the first 60 days of the 1956-57 season the untreated potatoes of the two varieties lost weight at about the same rate (table 1). By January 20, however, the untreated Kennebecs had lost about 1 percentage point more weight and by February 20 over 3 percentage points more than the Irish Cobblers. Sprouts were first observed in the untreated lots on December 31 (after just over 3 months' storage). Although the loss from sprout removal by that time was minor, amounting to less than 0.4 percent, the presence of the sprouts noticeably increased other weight loss. Representative untreated and MH-treated Irish Cobbler and Kennebec potatoes are shown as they appeared on February 20 in figures 1 and 2. Even though good sprout inhibition was obtained in the Kennebecs treated with MH, weight loss and consequent sponginess became excessive by February 20 and the remainder of the Kennebecs were marketed at that time to preclude further monetary loss by the cooperator.

TABLE 1.--Weight losses due to sprout removal and other weight losses of untreated and MH-treated potatoes [1]

Date and treatment	Weight loss (percent of original fresh weight)					
	Irish Cobbler			Kennebec		
	Sprouts	Other	Total	Sprouts	Other	Total
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Nov. 20, 1956:						
Untreated.....	0	4.67	4.67	0	4.36	4.36
Dec. 20, 1956:						
Untreated.....	0	4.10	4.10	0	5.52	5.52
Jan. 23, 1957:						
Untreated.....	0.37	5.98	6.35	0.34	7.04	7.38
Feb. 20, 1957:						
Untreated.....	1.44	6.36	7.80	1.62	9.60	11.22
MH-treated.....	0.36	6.19	6.55	0.13	9.84	9.97
Mar. 21, 1957:						
Treated.....	1.04	6.98	8.02	---	---	---
Apr. 11, 1957:						
Treated.....	1.16	8.91	10.07	---	---	---

[1] Stored in 1-ton pallet boxes at about 56°F. and 60-percent RH from September 18, 1956 to April 11, 1957.

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Figure 1.--Sprout growth in untreated (top) and MH-treated (bottom) Irish Cobbler potatoes stored in pallet boxes at about 56°F. and 60-percent RH from Sept. 18, 1956, to Feb. 20, 1957.

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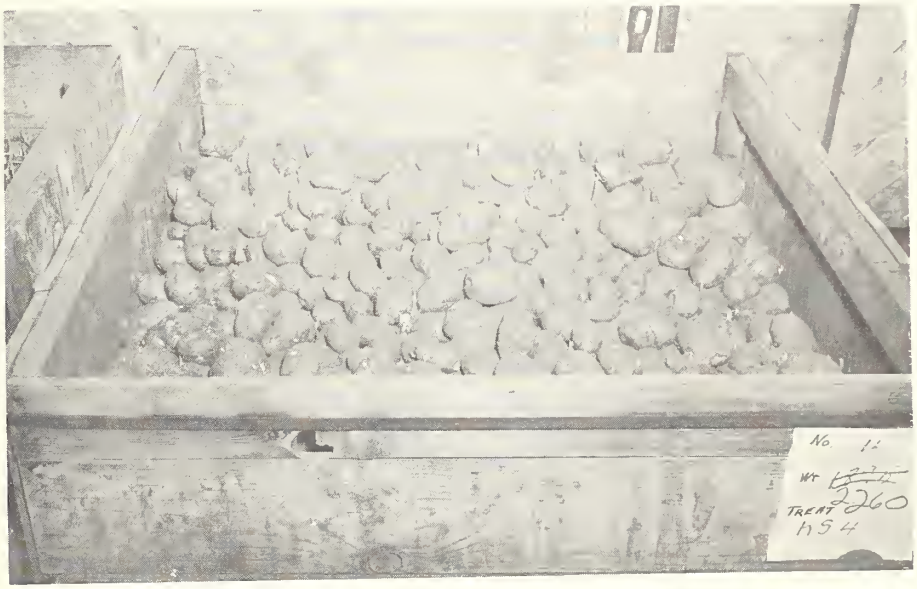

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Figure 2.--Sprout growth in untreated (top) and MH-treated (bottom) Kennebec potatoes stored in pallet boxes at about 56°F. and 60-percent RH from September 18, 1956, to February 20, 1957.

The larger weight loss of the Kennebecs was the result of about 35-percent skinning on the tubers of this variety whereas the Irish Cobblers had only 2 percent. Although MH retarded sprouting and consequent weight loss, it was not as effective as expected, as some sprouting did occur in the Irish Cobblers; there were two reasons: First, the Irish Cobbler potato vines were 20- to 30-percent defoliated by early blight before the MH could be applied, thus reducing its effectiveness. Second, even though the average relative humidity of the storage was 60 percent, it decreased gradually from an average of 78 percent during the first month of storage to only 48 percent during the last 3 months of storage. The reduction in relative humidity during the storage season was, in large part, due to a lack of an adequate moisture barrier between the warm storage and an adjacent cool storage. The difference in vapor pressure between the two rooms was so great that moisture migrated from the warm storage room to the cool one. Adequate moisture barriers, therefore, were used between adjacent bins in "multi atmosphere" storages (1) to maintain high humidity and thus reduce weight losses. In spite of these adverse circumstances, all except about 2 to 4 percent of the MH-treated Irish Cobblers were quite firm when the experiment was terminated April 11.

During the 1957-58 season, chips of satisfactory color could not be made from any of the treated potatoes, probably because of a combination of very heavy rainfall and low temperatures prior to harvest. In an effort to recondition these potatoes, the storage temperature was raised to 65° F. on about November 11, where it was held until February 11, when the remainder of the potatoes were marketed to preclude further monetary loss by the cooperator. At that time, 2,000-gram samples were removed from each of the 1-ton boxes, placed in 4-quart till baskets, transferred to a room held at 55° F. and 55-percent RH and held there until the experiment was terminated. Even with these changes in storage temperature, the average temperature for the season was 56°. MH effectively controlled sprouting and consequent excessive weight loss and shriveling (table 2 and figure 3). By April 15, when the experiment was terminated, the untreated

TABLE 2.--Weight losses due to sprout removal and other weight losses of untreated and MH-treated potatoes[1]

Date and treatment	Weight loss (percent of original fresh weight)					
	Irish Cobbler			Kennebec		
	Sprouts	Other	Total	Sprouts	Other	Total
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Dec. 18, 1957:						
Untreated[2]	0	5.88	5.88	0	6.38	6.38
Feb. 6, 1958:						
Untreated[3]	0.41	11.65	12.06	0.54	10.58	11.12
Treated[3]	0.02	9.44	9.46	([4])	11.26	11.26
Mar. 12, 1958:						
Untreated[5]	2.12	14.86	16.98	3.00	14.35	17.35
Treated[5]	0.06	11.24	11.30	([4])	13.13	13.13
Apr. 15, 1958:						
Untreated[5]	8.04	17.77	25.81	14.67	20.39	35.06
Treated[5]	0.53	13.85	14.38	([4])	14.26	14.26

[1] Stored at about 56° F. and 60-percent RH from September 23, 1957 to April 15, 1958.
[2] Data obtained from weighing several 1-ton-capacity boxes.
[3] Data obtained from weighing five 50-lb. samples.
[4] Less than 0.01 percent.
[5] Data obtained from 4 to 7 2,000-gm. samples.

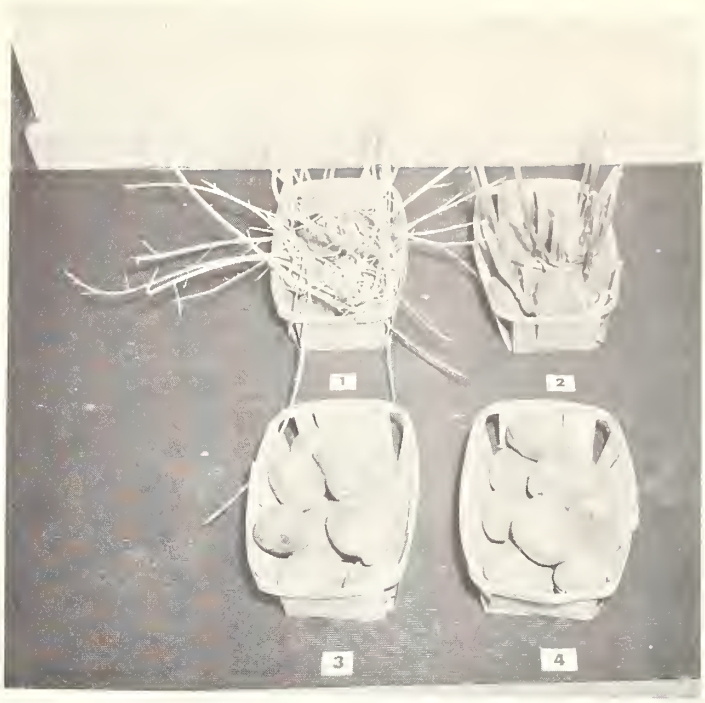

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Figure 3. --Sprout growth in untreated and MH-treated potatoes stored at about 56°F. and 60-percent RH from Sept. 23, 1957, to Apr. 15, 1958. 1, untreated Kennebec; 2, untreated Irish Cobbler; 3, MH-treated Kennebec; 4, MH-treated Irish Cobbler.

Irish Cobblers had lost almost twice as much weight, and the untreated Kennebecs more than twice as much weight, as the MH-treated lots. Both untreated varieties were so badly shriveled at this time that they were difficult to peel and to slice. Weight loss in this season was unusually high, because of the high storage temperatures and the large amount of decay.

The results for the 1958-59 season were somewhat similar to those obtained for 1956-57, except that sprouting of the potatoes in the untreated lots occurred a little earlier in the 1958-59 season, and consequently the potatoes lost weight more rapidly during the latter part of the storage period (table 3). Again, sprouting and consequent excessive weight loss and shriveling were controlled by the MH treatment.

Losses from mechanical injuries and decay. --Total injuries increased during storage, except with Irish Cobblers in 1956-57 (table 4). In some cases they more than doubled, while in other cases they increased only slightly. The greatest increase occurred with Kennebecs in 1956-57. Injuries that reduced grade in some instances decreased slightly or remained essentially unchanged, although in one instance there was a sevenfold increase. Nongrade injuries, with one exception, increased during storage. These changes were due in part to the development of decay in some of the tubers during storage and in part to the fact that small bruises unnoticed at harvesttime developed to some extent in storage so that they became distinguishable. Moreover, some of the injuries that were not considered grade injuries at harvesttime developed into grade injuries during storage as shown by the sevenfold increase in grade injuries of Kennebec variety in 1956-57. The decrease in injuries of Irish Cobbler in 1956-57 was surprising and the reason for these results remains obscured. MH had no discernible effect on injury.

TABLE 3.--Weight losses due to sprout removal and other weight losses of untreated and MH-treated potatoes[1]

Date and treatment	Weight loss (percent of original fresh weight)					
	Irish Cobbler			Kennebec		
	Sprouts	Other	Total	Sprouts	Other	Total
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Nov. 14, 1958:						
Untreated[2].....	0	3.14	3.14	0	4.52	4.52
Dec. 15, 1958:						
Untreated[2].....	0	3.79	3.79	0	5.54	5.54
Jan. 14, 1959:						
Untreated[2].....	0.58	5.18	5.76	0.40	7.02	7.42
Feb. 16, 1959:						
Untreated[2].....	2.84	6.83	9.67	2.93	10.53	13.46
MH treated[2].....	0.25	7.45	7.70	0.48	7.49	7.97
Mar. 18, 1959:						
MH treated[2].....	1.02	7.77	8.79	0.54	7.88	8.42
Apr. 14, 1959:						
Untreated[3].....	9.70	14.31	24.01	5.55	14.56	20.11
MH treated[2].....	1.72	9.82	11.54	0.23	10.43	10.66

[1] Stored in 1-ton pallet boxes at about 56° F. and 60-percent RH from September 15, 1958 to April 14, 1959.
[2] Data obtained from weighing several 1-ton-capacity pallet boxes.
[3] Data obtained from weighing five 50-lb. samples.

TABLE 4.--Injury and decay of potatoes at harvest time and after several months' storage at about 56° F. and 60-percent RH 1956-1959

Year and date of examination	Variety and type of injury							
	Irish Cobbler				Kennebec			
	Non-grade	Grade	Total	Decay	Non-grade	Grade	Total	Decay
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
1956-57:								
At harvest.....	28.5	12.1	40.6	0	17.1	7.0	24.1	0
After storage.....	15.1	10.8	25.9	1.2	24.5	36.7	61.2	0.1
1957-58:								
At harvest.....	6.7	7.1	13.8	4.1	5.1	3.8	8.9	1.0
After storage.....	13.7	5.7	19.4	8.2	8.8	2.8	11.6	15.9
1958-59:								
At harvest.....	20.0	5.9	25.9	1.2	14.7	4.0	18.7	1.3
After storage.....	39.9	5.2	45.1	3.3	37.6	3.7	41.3	3.5

Decay increased in storage, ranging from 0 to 4.1 percent or less at harvesttime in 1956-57, to as high as 16 percent after storage in 1957-58 with Kennebecs. During this season, late blight was present on the foliage during the latter part of the growing season, and heavy rains washed spores down onto the tubers, causing considerable infection. Although some of the infection was detected at harvest, the majority was detected only after a period of storage which allowed the infection time to develop.

Chipping Quality

Chip color. --During the 1956-57 season, color of the chips prepared from the untreated Irish Cobbler potatoes remained essentially unchanged from harvest until the last of this lot was chipped February 20 (table 5). In general, color of chips from MH-treated Irish Cobbler, and both untreated and MH-treated Kennebec potatoes, improved gradually through the storage period. MH-treated Kennebecs at harvesttime produced chips which were hardly salable but on February 20 produced attractive light-golden-brown chips. Both the untreated and MH-treated Irish Cobblers processed into chips of slightly lighter color than the Kennebecs at harvest but by February 20, the color of chips from the Kennebecs was superior.

TABLE 5.--Color ratings and yield of chips made from untreated and MH-treated potatoes[1]

Date and treatment	Irish Cobbler		Kennebec	
	Color[2]	Yield[3]	Color[2]	Yield[3]
		Pct.		Pct.
Sept. 18, 1956:				
Untreated	75	32.9	72	32.0
MH-treated	70	33.3	67	32.6
Nov. 2, 1956:				
Untreated	76	33.6	66	32.0
Nov. 20, 1956:				
Untreated	75	34.4	72	32.5
Dec. 20, 1956:				
Untreated	73	35.0	73	33.0
Jan. 23, 1957:				
Untreated	76	36.6	76	34.6
Feb. 20, 1957:				
Untreated	75	36.8	79	34.3
MH-treated	78	35.3	84	33.4
Mar. 21, 1957:				
MH-treated	81	35.6	---	---
Apr. 11, 1957:				
MH-treated	79	36.4	---	---

[1] Stored at about 56° F. and 60-percent RH from September 18, 1956 to April 11, 1957.
[2] Scale of color ratings: Very dark brown, 50 or less; dark brown, 55 to 60; medium brown (lowest salable grade), 70; light brown, 75 to 85; cream, 90.
[3] Chip yields are expressed as percentage of peeled, raw, sliced potato weight.

In 1957 unseasonably heavy rains forced postponement of harvest until after the onset of cold weather and as a result only the untreated Kennebec potatoes produced chips of light enough color at harvesttime to be salable and these barely exceeded the level of acceptability (table 6). The MH-treated Irish Cobbler and Kennebec potatoes made chips of lighter color as the storage season progressed whereas the untreated lots made darker chips. Chips prepared from MH-treated Kennebecs at harvesttime were much too dark to be salable but fairly attractive light-brown chips were prepared from these potatoes April 15. The untreated Kennebecs, on the other hand, were too dark to be salable when prepared December 17, and continued to be too dark throughout the remainder of the storage period. Little change in storage was observed with Cobblers.

During the 1958-59 season, the color of chips prepared from both the untreated and MH-treated Irish Cobbler and the MH-treated Kennebec potatoes remained essentially unchanged throughout the storage period. The untreated Kennebec potatoes, on the other hand, made moderately darker chips during the first 3 months of storage; the color improved somewhat during the subsequent 2 months. This same effect was observed to a greater or lesser degree in all three seasons and has been reported by many storage operators. It may be a result of physiological immaturity.

TABLE 6.--Color ratings and yields of chips made from untreated and MH-treated potatoes[1]

Date and treatment	Irish Cobbler		Kennebec	
	Color[2]	Yield[3]	Color[2]	Yield[3]
		Pct.		Pct.
Sept. 23, 1957:				
Untreated	67	32.6	71	30.7
MH-treated	62	33.4	56	30.7
Dec. 17, 1957:				
Untreated	63	31.8	59	29.9
Feb. 6, 1958:				
Untreated	66	33.6	66	32.3
MH-treated	68	33.7	73	30.3
Mar. 12, 1958:				
Untreated	62	33.8	60	33.1
MH-treated	67	35.6	73	33.6
Apr. 15, 1958:				
Untreated	62	35.0	64	35.8
MH-treated	64	33.6	75	32.0

[1] Stored at about 56° F. and 60-percent RH from September 23, 1957 to April 15, 1958.

[2] Scale of color ratings: Very dark brown, 50 or less; dark brown, 55 to 60; medium brown (lowest salable grade), 70; light brown, 75 to 85; cream, 90.

[3] Chip yields are expressed as percentage of peeled, raw, sliced potato weight.

Chip yield. --The chip yields were calculated as a percentage of peeled, raw, sliced potato weight and are therefore not comparable to commercial yield figures, which are based on unpeeled potatoes. Percentage of chip yields gradually increased during the 1956-57 storage season, the untreated at a faster rate than the MH-treated lots (table 5), probably as a result of the greater weight (largely water) loss in the untreated potatoes after sprouting occurred. Irish Cobbler potatoes gave higher yields than Kennebecs, the difference becoming progressively greater as the storage season progressed.

Somewhat similar results were obtained during the following two storage seasons (table 6 and 7), except that the yield of both Irish Cobblers and Kennebecs decreased slowly during the first 3 months of the 1958-59 storage season, and then increased sharply during the next month. The cause of this effect is unexplained at present.

TABLE 7.--Color ratings and yields of chips made from untreated and MH-treated potatoes[1]

Date and treatment	Irish Cobbler		Kennebec	
	Color[2]	Yield[3]	Color[2]	Yield[3]
		Pct.		Pct.
Sept. 15, 1958:				
Untreated	75	35.8	84	35.6
MH-treated	74	35.5	80	35.0
Nov. 14, 1958:				
Untreated	73	34.0	73	32.9
Dec. 17, 1958:				
Untreated	76	32.7	72	32.2
Jan. 14, 1959:				
Untreated	76	37.2	76	35.2
Feb. 16, 1959:				
Untreated	74	36.3	78	35.8
MH-treated	78	36.7	77	35.9
Mar. 18, 1959:				
MH-treated	75	37.4	81	36.6
Apr. 15, 1959:				
MH-treated	72	37.5	83	36.4

[1] Stored in 1-ton pallet boxes at about 56° F. and 60-percent RH from September 15, 1958 to April 14, 1959.

[2] Scale of color ratings: Very dark brown, 50 or less; dark brown, 55 to 60; medium brown (lowest salable grade), 70; light brown, 75 to 85; cream, 90.

[3] Chip yields are expressed as percentage of peeled, raw, sliced potato weight.

It should not be inferred from this that storing a given quantity of potatoes will increase the amount of chips which could be produced from them, but rather that moisture was lost more rapidly during storage than was dry matter.

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