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A STUDY OF THE MANAGEMENT FACTORS
ASSOCIATED WITH THE WASHING OF POTATOES

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY

Gary Thomas Grigg

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ABSTRACT

A STUDY OF THE MANAGEMENT FACTORS ASSOCIATED WITH THE WASHING OF POTATOES

Gary Thomas Grigg

Washing potatoes before shipping to market is a widely accepted practice in most potato producing areas. In more recent years, the use of disinfecting agents in the wash water has received limited attention. A study was initiated to determine the effects of chlorine, Hyamine and Dowco-184 solutions on the appearance, storage quality, sprouting and seed quality of selected varieties. The effect of chlorine on suberization was also studied. Rates up to 10,000 ppm of each chemical were studied and it was found that chlorine in excess of 1,000 ppm, Dowco-184 in excess of 1,000 ppm and Hyamine in excess of 100 ppm could have an adverse effect on potato market quality. The healing of cut surfaces was found to be enhanced by the use of chlorine wash solutions when compared with tubers washed in water or with unwashed tubers.

A study was also initiated to determine the feasibility of pre-storage washing. Russet Burbank, Arenac and Sebago potatoes were washed with water and several solutions of chlorine, Dowco-184 and Hyamine. Samples were stored at temperatures of 40 F and 52 F and observations on weight loss, general appearance, keeping quality, sprouting and seed quality were noted and compared. Potatoes washed after seven months of storage with the same solutions were used as a

comparison for appearance and seed quality. It was found that none of the selected concentrations had any adverse affect on the tubers at either temperature during the storage duration, and that potential consumers preferred the pre-storage washed potatoes 10 to 1 over those washed after seven months of similar storage.

A STUDY OF THE MANAGEMENT FACTORS ASSOCIATED WITH
THE WASHING OF POTATOES

By
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INTRODUCTION

Consumers are demanding fresh fruits and vegetables and in most market outlets today, it is a recommended practice to wash potatoes prior to packaging. Tuber defects are more prominent on washed potatoes which aid the packer in his grading operation resulting in a more appealing consumer pack, and increased capacity of grading equipment.

The most common method of washing potatoes is to store them and then wash them just prior to packaging. However, washing of potatoes after storage fails to restore the original brightness of the tubers. During storage the pressure upon the tubers in the pile may force soil particles into the surface of the skin. Subsequent early storage sweat heals this dirt into the skin and the tubers cannot be easily cleaned to their original brightness when removed from storage in the winter.

A management practice which may offer additional merit is that of washing and drying potatoes before storage. Such a procedure would improve tuber appearance and market quality, improve ventilation efficiency, reduce storage breakdown, eliminate culls before storage and assure the storage of dry tubers. The major disadvantage is the requirement that the washer-dryer operation must have a capacity equal to the rate of harvest for economic labor utilization.

The cost of washing potatoes includes: 1) the investment and installation of the washing and drying equipment;

2.

2) an adequate source of clean water and a system for the disposal of used water; 3) electric power; and 4) fuel for dryers if they are used.

The objective of this study was to determine the management principles, materials and techniques involved in the washing of potatoes to be used for tablestock, processing and seed, and to study the feasibility of pre-storage washing.

REVIEW OF LITERATURE

In 1932 (3) Jackman foresaw the coming of improved potato appearance. He stated that clean potatoes could return to the packers up to 5¢ per bushel more than soiled potatoes.

Tucker (17) in 1942 noted that more warehouses were equipped with washers, and that the premium for washed potatoes was increasing. The loss from breakdown due to rots resulting from washing and drying was remarkably small, but he stated that washed potatoes should always be marketed and consumed promptly and not held for storage.

In 1951 Perry and Merchant (10) reported the results of a study showing the consumers preference for washed potatoes. Washed and unwashed potatoes of similar quality were packaged in regular 10 pound paper bags. The potatoes were then trucked to Portland and Boston and sold in chain stores over a five week period. In four sales trials, the packs of washed potatoes were sold at a 2¢, 4¢, and 6¢ premium and at the same price as the unwashed potatoes. Of the total sales, the percents represented by the washed potatoes were as follows:

Trial 1	64.2% when sold at the same price
Trial 2	58.8% when sold at a 2¢ premium
Trial 3	53.3% when sold at a 4¢ premium
Trial 4	38.2% when sold at a 6¢ premium

Even at the 6¢ premium for 10 pounds more than one third of the consumers showed a preference for the washed potatoes. When tubers were washed, dried, packaged and stored at three

temperatures of 40, 60 and 70 degrees F during a four week period there was no apparent difference between washed and unwashed potatoes either in development of defects or enlargement of defects.

Waggoner (18) experimented with Katahdin tubers taken from storage that were rotted to determine if washing 1) increased the decay of tubers already infected with soft rot or 2) caused infection of sound tubers artificially wounded during the operation. Washing did not increase the decay of infected tubers nor did it spread the infection to sound tubers wounded during the operation, if the tubers were well dried after washing. Washing and drying actually decreased the spread of soft rot on tubers which were already infected.

Lutz, Findlen and Hansen (9) found that presoaking was the most effective means of soil removal. Potatoes susceptible to injury were damaged by the washer and that drum type washers caused more damage than did brush type.

Swan (13) reported that he had been washing potatoes prior to storage for fifteen years, and that to be successful, the tubers must be: 1) mature; 2) relatively free from disease, bruises and damage; 3) free of surface water at the time of storage; and 4) well ventilated in storage. Even after prolonged storage, pre-storage washed potatoes tended to pack-out as bright as fresh dug and washed potatoes.

The protection afforded cut tuber surfaces by natural suberization and healing over has long been recognized.

Studies by Priestly and Woofenden (11), and Artschwager (1) established the sequences of changes which are involved in the process of healing. The first step is a blocking action in which suberin is deposited following its formation by oxidation and condensation of fatty acids. Oxygen is essential to this reaction and a moist storage atmosphere was also shown to be important in promoting a good layer of aggregated molecules. The second step is the initiation of a phellogen which produces a new cork layer below the suberin deposit.

Artschwager emphasized the importance of temperature and humidity in suberization and periderm formation. He showed that rapid healing occurred at 21 C and above and at a relative humidity of 85 to 100 percent.

The resistance to infection of microorganisms afforded by the healing of the wound surface of cut seed was studied by Shapavalov and Edson (15) and also by Sanford (14). Sanford concluded that any physical, chemical or biological agent which speeds up the formation of a continuous outside layer may become very important in the exclusion of fungal parasites as well as the subsequent development of wound periderm layers below.

Lane (4), (5), found that a concentration of Chlorine of 5,000 ppm is an effective disinfectant for the ring rot organism on machinery such as the seed cutter.

EXPERIMENTAL PROCEDURE

Materials Studied

A. Chlorine - A relatively inexpensive disinfectant currently being used in the wash water by many growers. Formulations used were per-clor-on, a granular 70% calcium hyperchlorite produced by the Pennsalt Chemical Company and XY-12, a 10% solution of sodium hyperchlorite formulated by the Klenzade Chemical Company.

B. Hyamine - A quarternary ammonium compound produced by Rohm & Haas Company and used as a storage and equipment disinfectant. The formulation used was Aqua-Hyme, a 10% Hyamine solution distributed by the E-Z Flo Chemical Company.

C. Dowco-184 - A new chemical in the experimental stage produced by the Dow Chemical Company and formulated as a 20% powder.

These compounds were evaluated to determine their effects at different concentrations on the appearance of tubers of several varieties before and after storage and on seed quality when used before and after storage.

Washing Procedure

All small lots of potatoes were washed in a modified system consisting of a wire basket rotated inside a thirty gallon plastic drum which contained the various washing solutions. The large lots were washed in a commercial brush washer with six absorbent rollers to remove the excess water (Fig. 1).



FIGURE 1. The absorbent rollers of a commercial washer which remove excess surface moisture before grading and packaging.

Appearance

Studies were conducted to determine if any harmful or beneficial effects on external appearance resulted from washing potatoes with several different concentrations of the three solutions. Freshly dug Onaway tubers were washed with chlorine, Dowco-184 and Hyamine at 50, 100, 500, 1,000, 5,000 and 10,000 ppm and placed in storage at 60 F and 90% relative humidity.

In a separate test, time of wash was also varied. Tubers were washed for 15 seconds, 30 seconds, 1 minute and 2 minutes.

A study was made to determine if the wash agents had any effect on greening of the tubers. Potatoes of the Onaway variety were washed for 45 seconds with water, 100, 500, and 1,000 ppm of chlorine and Dowco-184, and Hyamine at 100 ppm. Unwashed potatoes were used as the control. Tubers were placed at 60 F and 90% relative humidity, under 475 foot candles of light for 96 hours.

In cooperation with the Department of Agriculture Economics, a test was made to determine the consumer acceptance of potatoes which were washed before storage and held for seven months at 40 F. Tubers were washed with 100, 500 and 1,000 ppm of chlorine. Comparisons were made with potatoes which were held for seven months under the same conditions and then washed with the same concentrations after storage. The three varieties used were Russet Burbank, Arenac and Sebago. The objective of this experiment was to determine the acceptance of the potatoes by a group of 35 unbiased

persons. The group was also asked to rank, in order of preference, 4 lots of Sebago and Russet Burbanks washed in water and chlorine at 500 ppm before and after 7 months of storage.

Pre-Storage Washing

Russet Burbank, Sebago and Arenac potatoes were washed with 100, 500 and 1,000 ppm of chlorine and Dowco-184, and with Hyamine at 25, 50, and 100 ppm.

The potatoes were washed in a brush type washer and excess surface moisture was removed by absorbent rollers. After grading, twenty pounds of potatoes were placed in special boxes and placed in storage at 40 F and 52 F. (Fig. 2). Each treatment was replicated four times at each storage temperature. Observations were made at one, five, six and seven months to evaluate the weight loss, sprouting, rot, appearance and keeping quality of the tubers.

Seed Quality

Tests were run to determine the concentrations which can be safely used without detrimental effects to seed quality. As a preliminary investigation, rates up to 10,000 ppm of chlorine, Dowco-184 and Hyamine were compared in tests on several varieties planted in the field and in the greenhouse.

Samples of two varieties, R. Burbank and Arenac, used in the pre-storage washing tests were removed from the 40 F storage in May of 1966 after seven months. These samples were planted in the field along with samples which were washed at the time of planting. These potatoes were stored under



FIGURE 2. Special boxes were used to store the washed samples. The sides were cut down for easy viewing of the samples during the storage period.

conditions similar to those washed before storage. Therefore, the affect on seed quality of the pre-storage washing could be compared with those washed after storage.

Effects of Chlorine on Suberization

One hundred-eighty freshly dug tubers 1 7/8 to 3 inches in diameter of the Onaway variety were selected for this study. The tubers were carefully halved longitudinally with a sharp knife. Thirty pieces were subjected to a 45 second wash in 100, 500, 1,000 and 5,000 ppm of chlorine solution and compared with a sample washed in water and an unwashed check.

At 2, 4 and 6 days, 10 of the pieces from each treatment were sampled. Samples were taken with a #5 cork borer from a stolon end near the vascular ring equidistant from the outside edge.

The tissue plugs were killed in a solution of 60 parts 95% ethyl alcohol, 40 parts distilled water and 4 parts of formalin. They were preserved for two months at which time they were dehydrated with chloroform by the following method: one-half day each in 70, 85, 95, and 100 percent ethyl alcohol solution, two-thirds alcohol and one-third chloroform, one-third alcohol and two-thirds chloroform and 100% chloroform.

The plugs were then infiltrated and imbedded in Fishers Tissue Mat for sectioning. Sections were 15 microns thick. Three glass slides were prepared from each tissue plug and the best of the three was stained in safranin and mounted in Canada balsam by the following method:

xylol I	10 min.
xylol II	2 min.
xylol & Ethyl Alcohol 1:1	2 min.
100% Ethyl Alcohol	2 min.
95% Ethyl Alcohol	2 min.
85% Ethyl Alcohol	2 min.
70% Ethyl Alcohol	2 min.
70% Ethyl Alcohol + Safranin	1 hour
85% Ethyl Alcohol	2 min.
95% Ethyl Alcohol	2 min.
xylol	2 min.

mount in Canada balsam and prepare for viewing.

EXPERIMENTAL RESULTS

Appearance

Chlorine at rates of over 1,000 ppm resulted in off-colored tubers after one day in storage. The skin was bleached white and the areas where the skin had flaked off were dark brown giving the tubers an undesirable mottled appearance (Fig. 3). Hyamine at rates of over 100 ppm resulted in off-colored tubers one day after and after three days, they turned black and started to deteriorate. Rates of over 3,000 ppm Dowco-184 were also found to produce an off-colored product after three days in storage. No differences in time of wash from 15 seconds to 2 minutes could be visually detected.

It was found that none of the treatments had any beneficial or detrimental effects on the greening during the 96 hour period, at which time all the tubers were very green.

The results of the evaluation study by potential consumers were expressed by the percent of the group willing to buy the pre-storage washed potatoes (table 1). They were also asked to rank in order of preference selected treatments. The ranking numbers for each treatment were added up and averaged (table 2). Of all varieties considered, 91.7 percent preferred those washed before storage and only 8.3 percent preferred those washed after storage. Differences between pre- and post-storage washing were more evident on the two white varieties than on the russet variety. The group preferred those washed in 500 ppm chlorine over those washed in water only.

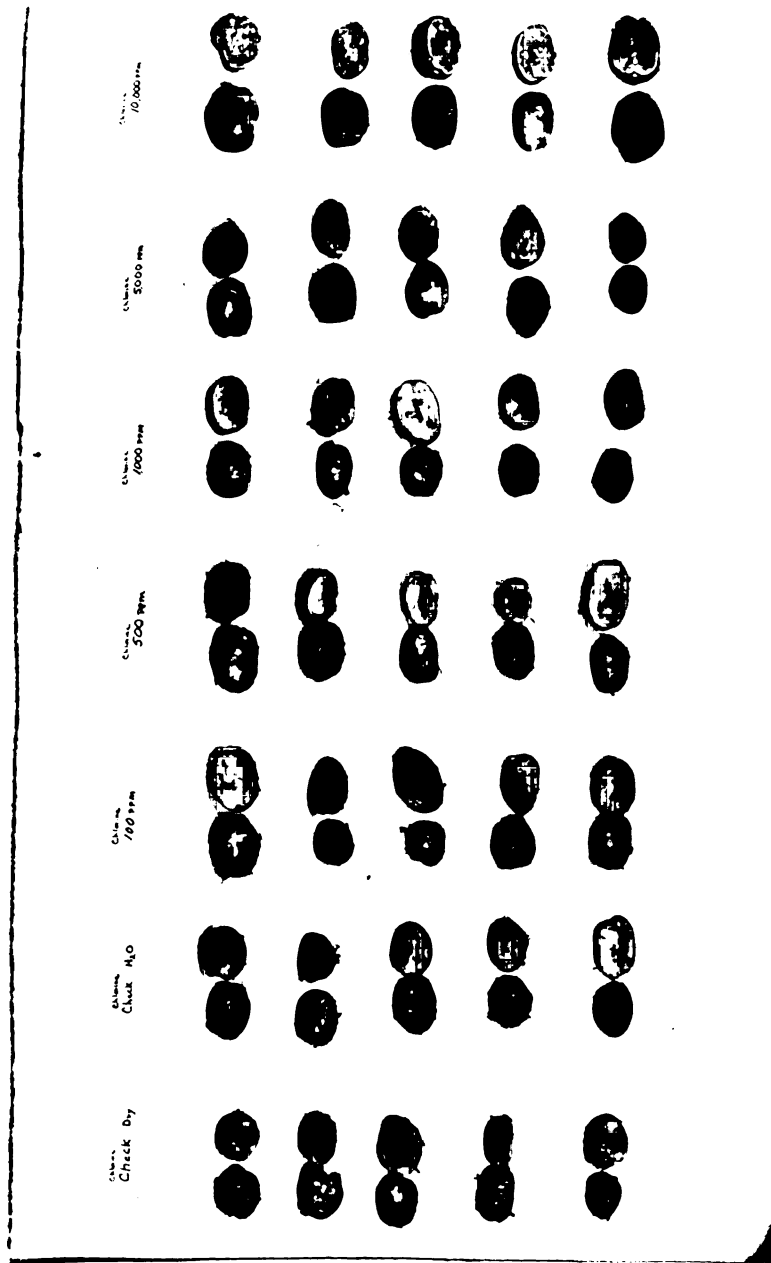


FIGURE 3. Note the discoloration at the 5,000 and 10,000 ppm rates of chlorine. The skin is bleached white and the areas where the skin has flaked off is dark brown. Also note the discoloration of the cut internal tissues at those same rates.

Table 1. The percent of the evaluation group preferring pre-storage and post-storage washed potatoes of three varieties.

<u>Wash Treatment</u>	<u>Percent of Group Preferring*</u>		
	<u>Sebago</u>	<u>Arenac</u>	<u>Russet Burbank</u>
Pre-storage H ₂ O	87.8	93.9	75.7
Post-storage H ₂ O	12.2	6.1	24.3
Pre-storage 100 ppm chlorine	100.0	97.0	81.8
Post-storage 100 ppm chlorine	0.0	3.0	18.2
Pre-storage 500 ppm chlorine	93.9	97.0	87.8
Post-storage 500 ppm chlorine	6.1	3.0	12.2
Pre-storage 1,000 ppm chlorine	100.0	90.0	93.9
Post-storage 1,000 ppm chlorine	0.0	9.1	6.1
Overall percent preferring pre-storage wash	95.5	94.7	84.8
Overall percent preferring post-storage wash	4.5	5.3	15.2

* 35 total participants

Table 2. The average ranking number assigned to each of four selected washing treatments.

Sebago

Wash Treatment	Average No.
1. Pre-storage washed with 500 ppm chlorine	1.32
2. Post-storage washed with 500 ppm chlorine	2.45
3. Pre-storage washed with water	2.48
4. Post-storage washed with water	3.74

Russet Burbank

Wash Treatment	Average No.
1. Pre-storage washed with 500 ppm chlorine	1.58
2. Pre-storage washed with water	2.48
3. Post-storage washed with water	2.55
4. Post-storage washed with 500 ppm chlorine	3.39

Wound Healing Results

The effects of chlorine on the wound healing process were observed (Fig. 4 and 5). The controls washed in water and unwashed both lacked uniformity in protective layer thickness. Treatment of cut potatoes with chlorine resulted in a generally thicker protective layer, with good uniformity. Differences could be noted between treatments after two days, however, it became more pronounced after six days. At the end of six days, the unwashed check had a protective layer with an average thickness of 76 microns, water resulted in a layer with an average thickness of 75 microns, while chlorine at 10, 500, 1,000 and 5,000 ppm resulted in layers 81, 95, 127 and 196 microns thick respectively.

Phytotoxicity Results

Under field conditions during the preliminary investigations, chlorine showed no harmful effects on the seed quality of Arenac at rates up to 10,000 ppm. Dowco-184 severely reduced germination at rates over 3,000 ppm, and Hyamine severely reduced germination at all rates over 100 ppm. Under greenhouse conditions, chlorine resulted in 100% germination up to 5,000 ppm on the seed of Russet Burbank and Onaway. Dowco-184 showed 100% germination at rates up to 3,000 ppm. Hyamine, however, severely reduced germination at rates over 50 ppm.

Russet Burbank and Arenac potatoes washed before and after seven months of storage with chlorine at 100 and 1,000 ppm, Dowco-184 at 100 and 1,000 ppm and Hyamine at 25 and 100 ppm showed no reduction in stand when compared with those left unwashed or those washed in water only (table 3).

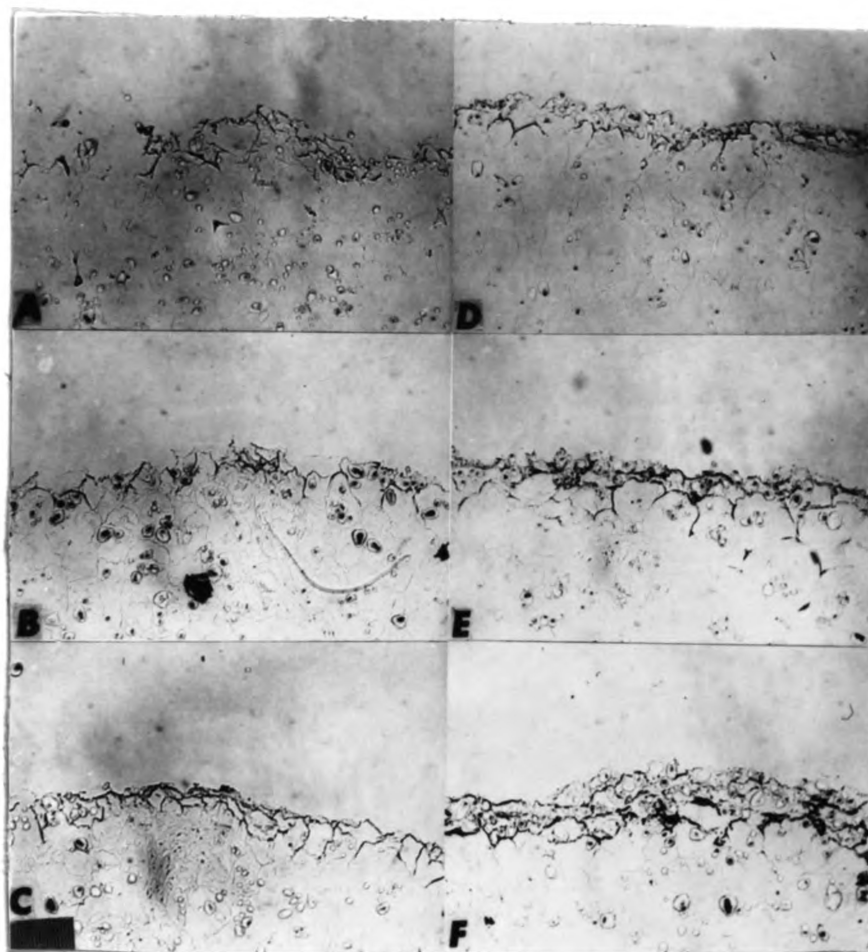


FIGURE 4. Tissue sections of potato tubers 2 days after treatment. A. unwashed, B. water, C. 100 ppm chlorine, D. 500 ppm chlorine, E. 1,000 ppm chlorine, F. 5,000 ppm chlorine.

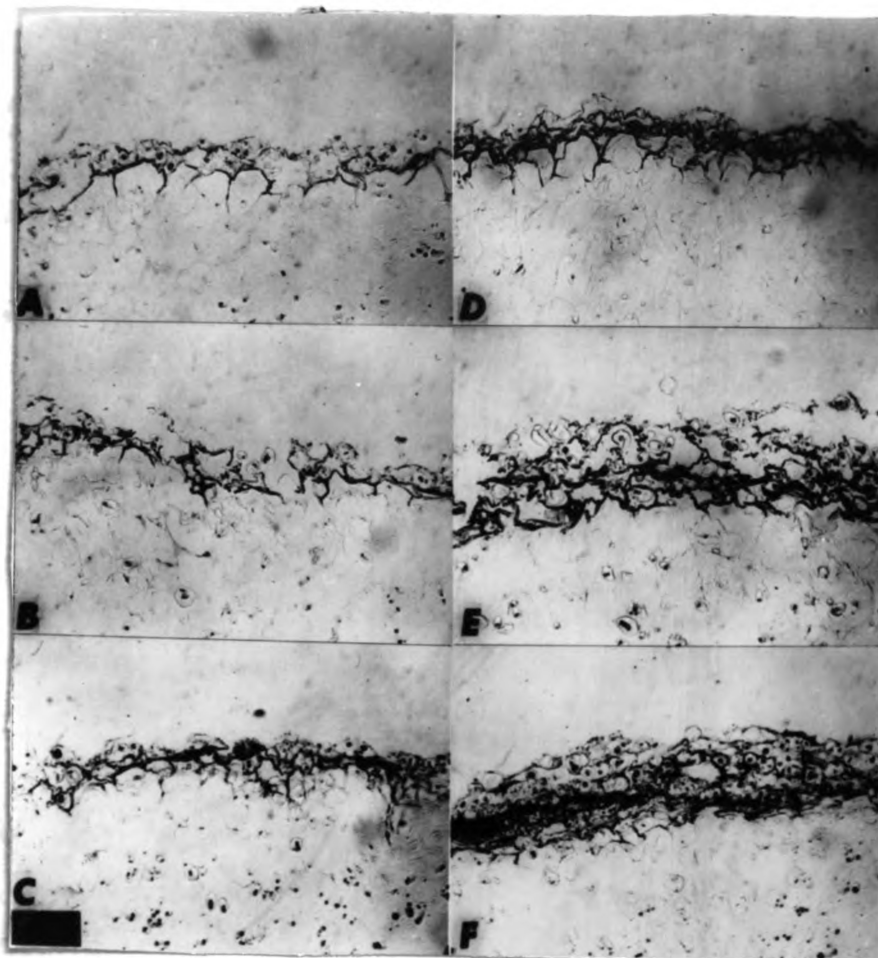


FIGURE 5. Tissue sections of potato tubers 6 days after treatment. A. unwashed, B. water, C. 100 ppm chlorine, D. 500 ppm chlorine, E. 1,000 ppm chlorine, F. 5,000 ppm chlorine.

Table 3.

PERCENT STAND PRE- AND POST-STORAGE WASHED
R. BURBANK AND ARENAC POTATOES

<u>TREATMENT</u>	<u>% UNWASHED CHECK</u>	
	<u>PRE</u>	<u>POST</u>
1. UNWASHED CHECK	100	100
2. WATER	112	114
3. CHLORINE 100 PPM	118	116
4. CHLORINE 1000 PPM	114	118
5. DOWCO 100 PPM	135	101
6. DOWCO 1000 PPM	145	108
7. QUARternary 25 PPM	97	108
8. QUARternary 100 PPM	<u>105</u>	<u>106</u>
AVERAGE	117.2	110.5

Pre-Storage Washing Results

The results of this study are discussed according to variety and storage at 52 F. (Table 4). At 40 F none of the treatments resulted in any significant differences in weight loss during the seven month storage (Table 5). No data was taken on sprouting at 40 F since these were used for seed. Sebagos at 52 F were heavily sprouted at 4 months so data was taken then instead of at 5 months.

Sebago

52 F: None of the treatments showed any significant difference in sprouting after 4 months (Table 4). Although Dowco-184 at 1,000 ppm showed a noticeable increase in sprouting, it was not significant. This increase in sprouting did cause an increase in weight loss which was significant. No other treatment showed any significant difference in weight loss.

Arenac

52 F: No treatments showed any significant difference in weight loss from the unwashed check during the five month storage. Chlorine at 100 and 500 ppm and Hyamine at 50 and 100 ppm showed an increase in sprouting which was significant but slight.

Russet Burbank

52 F: The weight loss of the unwashed check was greater than any of the treatments, but, there were no differences among the washed samples. This loss in weight

of the unwashed check may be explained by the fact that the potatoes were harvested under wet conditions and were muddy when washed. It was impossible to grade the unwashed check well enough on the commercial grader used, to pick out all the undesirable tubers. The unwashed check, therefore, contained several tubers which broke down during the storage period and may have accounted for the excessive weight loss.

Table 4. The percent of weight loss and sprouts of Arenac, Russet Burbank and Sebago potatoes stored at 52 F for five months.

<u>Treatment</u>	<u>% Weight Loss</u>			<u>% Sprouts</u>		
	<u>Arenac</u>	<u>R. Burbank</u>	<u>Sebago*</u>	<u>Arenac</u>	<u>R. Burbank</u>	<u>Sebago</u>
Check	18.5	16.6	12.8	4.72	1.41	1.58
H ₂ O	18.8	12.1++	13.5	5.34	.85++	1.66
100 ppm chlorine	19.5	12.5++	13.8	5.61++	1.40	1.54
500 ppm chlorine	19.3	15.0	12.8	5.46++	1.28	1.50
1,000 ppm chlorine	16.9	15.0	10.4	4.41	1.05++	1.61
100 ppm Dowco-184	17.9	13.8	13.9	4.45	1.16	1.57
500 ppm Dowco-184	17.6	12.4++	11.9	4.12	1.01++	1.39
1,000 ppm Dowco-184	16.0	12.4++	16.3++	4.58	1.18++	2.49
25 ppm Hyamine	17.5	11.6++	13.8	4.37	1.12++	1.38
50 ppm Hyamine	18.5	11.6++	13.6	5.51++	1.28	1.52
100 ppm Hyamine	17.9	12.4++	12.5	6.25++	1.48	1.26

* Sebagoes were stored only 4 months

++ Significantly different than the check at .05 level

Table 5. The percent of weight loss of Arenac, Russet Burbank and Sebago potatoes stored 7 months at 40 F.

<u>Treatment</u>	<u>% Weight Loss</u>		
	<u>Arenac</u>	<u>Russet Burbank</u>	<u>Sebago</u>
Check	12.5	9.4	11.2
H ₂ O	10.9	11.0	14.3
100 ppm chlorine	13.5	10.8	14.3
500 ppm chlorine	11.9	9.0	12.4
1,000 ppm chlorine	12.5	10.6	11.5
100 ppm Dowco-184	12.5	11.6	13.0
500 ppm Dowco-184	12.0	12.9	13.6
1,000 ppm Dowco-184	10.0	10.9	15.5
25 ppm Hyamine	12.5	12.5	12.4
50 ppm Hyamine	12.5	10.6	13.1
100 ppm Hyamine	12.5	10.0	12.0

Water, chlorine at 1,000 ppm, Dowco-184 at 500 and 1,000 ppm and Hyamine at 25 ppm resulted in a significant decrease in sprout growth.

There was no consistency to the observations on sprouting. On the Sebago variety Dowco-184 at 1,000 ppm showed an increase in sprouting, however, on the Russet Burbank it showed a decrease. Chlorine at 100 and 500 ppm showed an increase of sprouting on the Arenac variety, however, it did not show an increase at 1,000 ppm. On the Russet Burbank chlorine at 1,000 ppm showed a decrease in sprout growth. Hyamine showed an increase in sprout growth on Arenac but a decrease on the Russet Burbank. Similarly, water showed a decrease of sprouting on the Russet Burbank but not on the Sebago or the Arenac.

SUMMARY AND CONCLUSIONS

The emphasis of this work has been on the use of chlorine, since it is relatively cheap, easy and safe to use. Chlorine meets the requirements of the U. S. Food, Drug and Cosmetic Act, and labeling of packed potatoes washed with chlorine is not required.

Dowco-184 and Hyamine are used commercially as disinfectants for machinery, seed cutting facilities and in dairy barns. The chemicals as far as can be ascertained at this writing have not been cleared for use on food for human consumption by the U. S. Food and Drug Administration.

Under the conditions of this study chlorine (1) enhanced the healing of cut surfaces, (2) improved marketability, (3) was safe on seed quality even at high concentrations and (4) improved storability.

It was found that Dowco-184 up to 1,000 ppm and Hyamine at rates up to 100 ppm had no detrimental effects on seed quality or storability of potatoes.

The increasing use of field harvesters coupled with the frequent periods of undesirable weather conditions at harvest-time has demonstrated the need for new techniques to improve storability of fall harvested potatoes. Pre-storage washing and drying of these potatoes may be an answer since it may improve appearance and market quality, improve ventilation efficiency, reduce storage breakdown and assure the storage of dry potatoes. Potatoes washed prior to storage were found to make a more desirable product on the market than those washed after storage and just prior to packaging.

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