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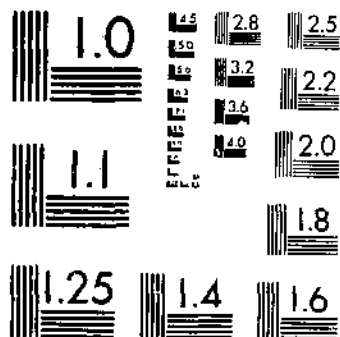
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REDUCING DECAY IN CITRUS FRUITS WITH BORAX

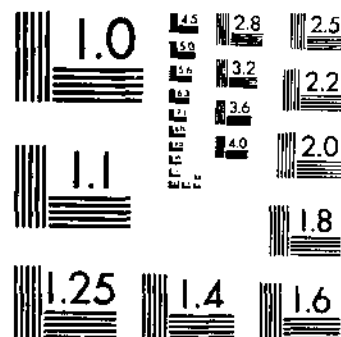
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UNITED STATES DEPARTMENT OF AGRICULTURE  
WASHINGTON, D. C.

DEPOSITORY

# REDUCING DECAY IN CITRUS FRUITS WITH BORAX

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## INTRODUCTION

Although the production of citrus fruits is confined to relatively small areas in a few States, the market for the crop is Nation-wide and there is a growing export trade as well. The losses from decay developing between the time the fruit is harvested and consumed are often serious and greatly complicate the marketing program.

## FUNGI CAUSING DECAY

Citrus fruits are subject to a number of types of rot during the marketing period. Some of these, the ones caused by species of *Penicillium* for example, occur wherever citrus fruits are grown, while others are less generally distributed. In the Gulf States two major classes of rots occur: (1) The green and blue molds caused by *P. digitatum* Sacc. and *P. italicum* Wehmer, the former being by far the more common; and (2) the stem-end rots caused by *Diplodia natalensis* Evans and the *Phomopsis* stage of *Diaporthe citri* Wolf. The latter fungus also is the cause of the rind blemish known as melanose. In the more arid citrus-growing districts of California and Arizona the stem-end rots are found only occasionally and so far have been reported only on lemons. Several other fungi, such as *Colletotrichum*, *Alternaria*, *Rhizopus*, *Aspergillus*, *Oospora*, *Fusa-*

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*rium*, etc., are isolated occasionally from decaying fruit from all producing districts.

For a long time the penicillium rots were the ones most commonly found and caused the greatest loss, but at the present time this form of decay represents only a relatively small part of the total. This improvement in conditions is largely because of an application of the fundamental principles of fruit handling developed by Powell and his associates.<sup>1</sup> Improvements in clippers have greatly reduced clipper cuts, and overfilling of field or lug boxes resulting in box bruises is usually avoided. The fruit, therefore, is now harvested and delivered to the packing houses in much better condition than formerly. Packing houses are now being improved as to cleanliness and sanitary conditions, thereby reducing the chances for contamination; fruit is being handled and packed more carefully; refrigeration is in more general use; and last, but not least, antiseptic fruit washes, such as borax and carbonate of soda, have come into general use and have played an important part in delaying or actually preventing penicillium rots.

The beneficial effects from the adoption of these improved practices are principally apparent in the reduction of penicillium rots, which have thus been relegated to comparatively minor importance in the handling of a citrus crop; consequently, in regions where stem-end rot fungi occur, these more slowly developing decays are now of primary importance. It seems probable that much of the fruit which formerly decayed with *Penicillium* was also actually infected with stem-end rot, but that the blue or green molds destroyed it before stem-end rot had time to develop.

The blue and green molds differ radically from the stem-end rots, not only in gross appearance but in pathological aspects as well. For the most part, penicillium rots result from infections established through mechanical injuries, such as clipper cuts, box bruises, etc., sustained during the harvesting (fig. 1) and packing operations, and, in addition, infection by *Penicillium italicum* also passes from a decaying fruit to an uninjured one by contact. Most of the injuries that afford entrance for the penicillium fungi occur before the fruit reaches the packing house.<sup>2</sup> One of the most important causes of such injuries is the use of a high bulge pack as demanded by the trade. This generally results in such severe bruising, especially of the top layer, that penicillium rots gain ready entrance. Susceptibility to stem-end rot varies from grove to grove. Fruit from young trees is less likely to be affected than that from old trees. Fruit produced where there is considerable open space between the trees (fig. 2) develops stem-end rot much less rapidly than that produced on thickly growing trees (fig. 3), other things being equal. While the exact mode and time of infection by the stem-end rot organisms is not definitely known, for all practical purposes they may be regarded as causing incipient infection while the fruit is on the tree, being in or on the stem or stem parts at time of harvest. However, they may not develop to the point of

<sup>1</sup> POWELL, G. H., STERNBERG, A. V., TENNY, L. S., EUSTACE, H. J., HOSFORD, G. W., and WHITE, H. M. THE DECAY OF ORANGES WHILE IN TRANSIT FROM CALIFORNIA. U. S. Dept. Agr., Bur. Plant Indus. Bull. 123, 79 pp., illus. 1908.



FIGURE 1.—Picking crew at work in a Florida orange grove. The boxes are overfilled so that bruising of the top fruit will result when they are stacked on the trucks and in the packing house. While such bruising should be avoided to reduce penicillium rot, a borax bath given immediately upon arrival at the packing house will greatly retard the decay.



FIGURE 2.—A young orange grove in Florida. Fruit produced on young trees which have considerable open space between them and which are generally free from much deadwood develops stem-end rot much less rapidly than that from old trees which have grown together and which have many sources of infection in deadwood.

becoming visible for several days after packing or until after the fruit has entered shipment or reached its market destination. The resulting losses react not only on the grower or shipper but also on the receiver, the retail merchant, and the ultimate consumer as well, thus developing a lack of confidence all along the line which is reflected in the price that the fruit will bring.

#### COMMON REMEDIAL PRACTICES

In the control of various kinds of citrus rots during the marketing process, various procedures are followed, depending upon the peculiarities of the causal organism. In general, these measures may be divided into five classes: (1) Prevention of infection in the grove through sanitation, including the removal of the sources of infec-



FIGURE 3.—Old orange trees with branches interlaced afford good conditions for the development of stem-end rot, there ordinarily being more deadwood in the trees and less air circulation to dry out moisture than in trees like those shown in figure 2.

tion; (2) careful mechanical handling at all stages of the harvesting and packing operation, in order to reduce the number of lesions which may afford ready entrance for decay organisms, particularly the penicillium rots; (3) the removal of stem "buttons" while the fruit is being packed, in order to check those decays that enter the fruit through the stem or stem parts; (4) inhibiting the development of decay organisms that may have found lodgment on the fruit or that possibly may have advanced slightly into the tissues of the fruit, by the use of heat and/or mild antiseptics such as borax, carbonate of soda, etc., applied at some stage in the packing operations; and (5) checking the development of the decay organisms by the use of refrigeration after the fruit is packed. There are definite limitations to the effectiveness of each of these treatments.

Grove sanitation, involving both pruning and spraying, has been shown by Fulton and Bowman,<sup>2</sup> Reichert and Hellinger,<sup>3</sup> Reichert,<sup>4</sup> and others, to be helpful in the reduction of stem-end rot. However, cost considered, it is not believed to be effective enough to be generally practicable as a means of stem-end rot control for commercial growers. It has little or no effect upon penicillium rots, but both pruning and spraying must be done as a part of every well-rounded program of grove operations.

Careful handling is the very foundation of decay prevention, especially in the case of penicillium rots. Other decay-control treatments are made more effective if the fruit has been carefully handled to prevent mechanical injuries. Careful handling is of the utmost importance in all commercial operations.

Disbuttoning the fruit during the packing operation is fairly effective in the reduction of stem-end rot, but it is not effective against blue mold or green mold; in fact, this practice may increase loss from penicillium rots when the rind tissues are torn or injured in the disbuttoning operation. This process usually requires a preparatory treatment to loosen the buttons, the greater portion of which at times may then be removed by passing the fruit through a brushing machine fitted with rather stiff bristles. A spoonlike instrument operated by hand is also used sometimes to remove the stems. While ethylene gas may be used to loosen the buttons, the treatment has not been found to be generally effective with different kinds of fruit during the principal part of the shipping season. When blue mold is prevalent, disbuttoned fruit may require subsequent treatment with a mild antiseptic, or it may need to be held at low temperatures to prevent excessive development of this type of decay which enters the fruit through wounds that may be made during the disbuttoning process. At best, disbuttoning is a laborious operation that is hardly compatible with mass production and high labor costs, although it may be commercially practicable in Florida during the forepart of the shipping season when ethylene is most effective in loosening stem buttons, causing a large percentage of them to fall out during the usual washing and polishing treatment, and when fruit movement to market is at its lowest ebb. At this season fruit prices are usually high, thereby justifying maximum financial investment in decay reduction. The treatment, however, is reported to be in successful commercial operation in Jamaica where labor is cheap and production is rather limited.

Exposure for a few minutes to a water bath heated to 110° to 120° F. is effective against certain rots (brown rot, botrytis rot, etc.), but the method as ordinarily employed is only partially successful in the control of blue mold and stem-end rot. Fulton and Bowman<sup>5</sup> showed that a heated borax solution is capable of reducing both blue-mold rot and stem-end rot of Florida citrus fruits, and

<sup>2</sup> FULTON, H. R., and BOWMAN, J. J. EFFECT OF SPRAYING WITH FUNGICIDES ON THE KEEPING QUALITY OF FLORIDA CITRUS FRUITS. U. S. Dept. Agr. Circ. 409, 14 pp., illus. 1927.

<sup>3</sup> REICHERT, I., and HELLINGER, E. FURTHER EXPERIMENTS ON THE CONTROL OF DIPLODIA STEM-END ROT OF CITRUS BY PRUNING AND SPRAYING. *Hadr* 5: 142-143. 1932.

<sup>4</sup> REICHERT, I. THE INVESTIGATION OF FRUIT ROTS SUPPORTED BY THE EMPIRE MARKETING BOARD. *Hadr* 5: 236-238. 1932.

<sup>5</sup> FULTON, H. R., and BOWMAN, J. J. PRELIMINARY RESULTS WITH THE BORAX TREATMENT OF CITRUS FRUITS FOR THE PREVENTION OF BLUE MOLD ROT. *Jour. Agr. Research* 28: 961-968, illus. 1924.



Barger and Hawkins<sup>6</sup> reported the same general results on penicillium decay in California oranges. Subsequently, other mild antiseptics such as boric acid and sodium carbonate have come into general use, being applied during the washing process immediately before packing. Of the various antiseptics now in use, none excels borax in general all-round effectiveness for commercial use, especially when the solution is applied at a temperature of 100° to 110°. During the past few years the use of borax in this manner has increased very markedly.

The frequently serious prevalence of stem-end rot in fruit arriving on the market seems to indicate that the application of antiseptics is sometimes delayed until after the causal organism has advanced too deeply into the fruit to be reached by the chemical. This is especially the case with fruit that has been harvested several days and also with that undergoing the usual coloring process which affords an environment especially favorable to the development of these decay organisms before treatment with borax.

Refrigeration, aside from keeping fruit in a fresh condition, does little more than delay the development of decay. It does not permanently prevent decay, since slow growth of decay organisms occurs within the tissues, particularly with the *Penicillium* species, at ordinary refrigeration temperatures. Prolonged refrigeration may even weaken the fruit, thereby permitting a somewhat more rapid spoilage after the removal from low temperatures. Upon removal from cold storage the fruit frequently sweats because of the difference between the fruit temperature and that of the air, which causes a condensation of moisture on the surface. This is very undesirable because it provides conditions favorable for immediate infection and the rapid development of decay.

#### EXPERIMENTAL WORK

In the fall of 1931 experimental work was begun at Orlando, Fla., to determine whether a more effective control of stem-end rot could be obtained by the use of borax or some other cheap antiseptic applied in the packing house during the handling operations. Insofar as stem-end rot is concerned, the available evidence from commercial experience indicated that the fungi principally concerned in this decay are in a somewhat dormant state in or on the stem or stem parts when the fruit is harvested, and that under conditions of comparatively high temperatures and humidity these organisms are capable of rapidly advancing into the fruit. They advance even more rapidly if the fruit is held in an atmosphere of rather concentrated coloring gases. Working upon this hypothesis, experiments were conducted with antiseptics applied as soon as commercially practicable after harvesting, that is, immediately after the fruit reached the packing house in comparison with delayed application, as in the case of the usual commercial practice in which the coloring treatment was given before application of the antiseptic. In the coloring treatment the fruit is not only exposed to coloring gases from 24 to 60 hours or longer but is held under conditions of

<sup>6</sup> BARGER, W. R., and HAWKINS, L. A. BORAX AS A DISINFECTANT FOR CITRUS FRUITS. *Jour. Agr. Research* 30: 189-192. 1925.

high atmospheric temperature and humidity as well—ideal conditions for the development of stem-end rot organisms. The studies reported herein were directed particularly to the solution of the decay problem presented by these conditions.

#### METHODS

All of the fruit used in these experiments was harvested, hauled, and otherwise handled in accordance with the practice at the better commercial packing houses. Upon its arrival at the laboratory the fruit was divided into lots of about 50 pounds each for oranges and grapefruit and about 25 pounds for tangerines. The number of fruits per lot varied, depending on the size. Early in the season the number of fruits per lot was greater than later when the fruits were larger. No attempts were made to grade the fruit or sort for defects, except to discard those badly damaged during the handling operation. A 5-percent borax solution was used as the standard unless otherwise noted. The method of application was by dipping or immersing the fruit for the specified length of time in the antiseptic, and unless otherwise noted the fruit was allowed to dry in the open air for a few minutes to an hour or more, depending on atmospheric conditions. Unless otherwise noted, also, the residue from the antiseptic solutions was left on the fruit several days and was then removed by rinsing in water, after which the fruit was allowed to dry. Thus, sometimes several hours elapsed before the fruit could be placed in the holding room. This room was maintained at a temperature of about 70° F. and 82 to 88 percent relative humidity. In all cases, the fruit was dried before being transferred to the holding room. Periodically all lots of fruits were carefully examined for decay, in accordance with a prearranged schedule, and all rotting fruits were removed. A record of the type and number of fruits affected was first made on the sixth day from the tree and twice weekly during the 30-day holding period.

In these experiments fruit from a large number of groves was used to determine any difference in response that might reasonably be attributed to cultural practices or to varietal characteristics. For the most part, the fruit was produced in the Orlando district, although some of it was produced on the Government reservation near Brooksville, Fla., requiring a haul of about 80 miles. In the latter case, most of the fruit was not given the borax bath until the day after it was picked. Since stem-end rot is not generally serious on fruit from well-kept young groves, but is often severe in the older groves because of the greater prevalence of sources of infection in deadwood, the fruit used in these experiments was taken from old trees, unless otherwise noted.

#### COMPARISON OF ANTISEPTICS

Experiments were planned to obtain information as to the effect of the concentration of the solution and also as to the comparative effects of the component ions. The following tests were included:

- (1) A 5-percent solution of borax,  $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$ , which was taken as the standard of comparison, since it has been in common use in commercial procedure.
- (2) A 5-percent solution of boric acid,  $\text{H}_3\text{BO}_3$ .

- (3) A 3.2-percent solution of boric acid, which contains a concentration of boron ions equivalent to that in a 5-percent solution of borax.
- (4) A 5-percent solution of a mixture of 8 parts borax and 1 part boric acid, producing an approximately neutral solution.
- (5) A 3.5-percent solution of sodium carbonate,  $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$  which contains the same concentration of sodium ions as found in a 5-percent solution of borax.

The experiments were conducted in October, November, and December 1932, using oranges, grapefruit, and tangerines harvested on four different dates from the Government reservation near Brooksville. The standard procedure in all cases was to dip the fruit into the antiseptic solution for the time indicated and then allow it to dry before subjecting it for 72 hours to the coloring treatment. After coloring, the fruit was washed in clean running water to remove the adhering residue of the antiseptic and was then dried and transferred to a room held at 70° F. for subsequent observation of the rate of decay. The results with oranges, presented in figure 4, are typical of those obtained with grapefruit and tangerines except for the rate of decay, which is usually faster with oranges. The decay during the first 3 weeks was almost exclusively stem-end rot.

It was found that boric acid, alone or in combination with borax, injured the rinds of oranges, grapefruit, and tangerines. This injury was characterized by the development of a brown, discolored, slightly sunken area, usually around the stem and becoming evident after about 16 days' holding. Usually these discolored areas increased in size after prolonged holding. In many instances the fruits thus affected were otherwise sound at the end of the holding period, but in some cases typical stem-end rot or a colletotrichum rot developed. Sodium carbonate produced a brownish rind scald that became noticeable after a few days and increased rapidly as the storage period advanced. Fruit thus affected decayed rapidly with stem-end rot. On the other hand, the use of borax resulted in practically no injury to the fruit and stem-end rot was fairly well controlled, but treatment after coloring was not nearly so effective as when it was applied before coloring. Practically as good results were obtained from only a momentary dip as from the 5-minute bath in the 5-percent borax solution or the neutral borax solution. Similar results were obtained on tangerines, Satsuma oranges, and grapefruit. However, in tests on very ripe oranges in February, stem-end rot was not reduced, and the rind injury noted earlier did not develop. From the results in general it appears that the boron ion in borax or boric acid exerts the principal fungicidal effect.

Further tests were made comparing borax with some of the preparations commonly used as an aid in washing. These consisted principally of sodium metasilicate, soda ash, or trisodium phosphate, etc., in various combinations, as well as sodium polysulphide with and without the aid of soap; sodium hypochlorite and such gases as anhydrous ammonia, nitrogen trichloride, chlorpicrin, and sulphur dioxide applied before or during the coloring process, but none of these seemed to possess decay-retarding properties approaching those of borax, nor was the efficiency of borax increased by the addition of soap. A series of 17 tests was made in the spring of

1934 with oranges that ripened in midseason or later, using borax in comparison with sodium metaborate, potassium metaborate, and potassium tetraborate using a solution in each case with a boron ion concentration equivalent to that in an 8-percent borax solution. The

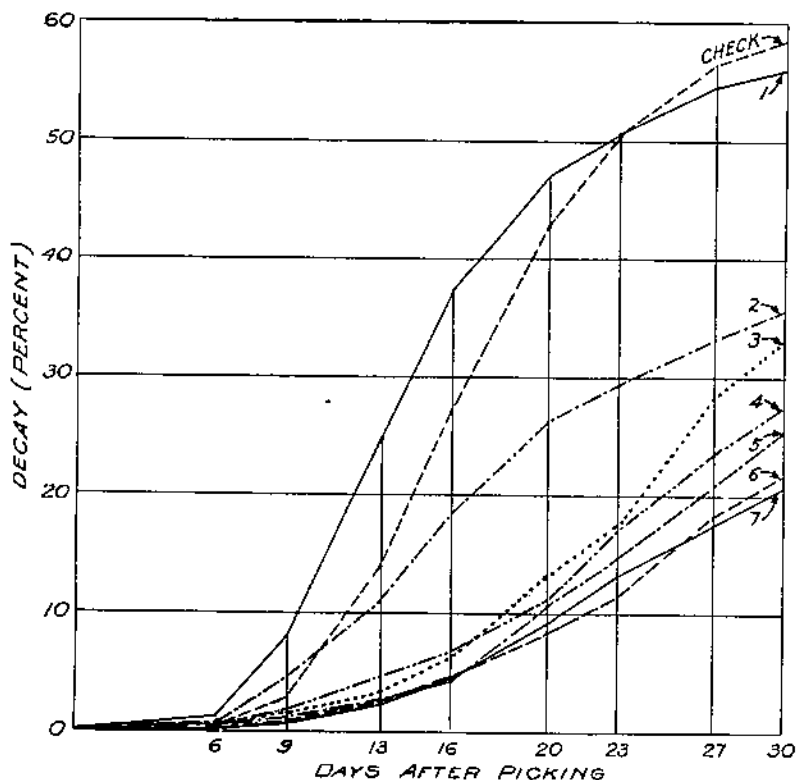


FIGURE 4.—Decay of oranges as influenced by various chemical treatments.

Curve no.	Solution				Treatment before or after coloring
	Solute	Concentration	Temperature	Time of exposure	
1	Sodium carbonate.....	Percent 3.5	° F. 80	Dip	Before.
2	Borax.....	5	110	5 minutes	After.
3	Boric acid.....	5	80	Dip	Before.
4	do.....	3.2	80	do	Do.
5	Borax.....	5	110	5 minutes	Do.
6	Borax and boric acid.....	5	80	Dip	Do.
7	Borax.....	5	80	do	Do.
Check	No chemical treatment.				

decay control in all cases was comparable, which is further evidence that it is the boron ion that exerts the principal fungicidal effect. While sodium metaborate caused a slight discoloration of the rind around the stem in some cases, it was not serious enough to be ob-

jectionable and this chemical may prove to be more satisfactory than borax for use in cool weather, especially where facilities are lacking for keeping the antiseptic solution warm.

#### CONCENTRATION OF BORAX

Tests were made in November and December 1932 with 32 lots (8 treatments in quadruplicate) of midseason oranges, 32 lots (8 treatments in quadruplicate) of tangerines, and 16 lots (8 treatments in duplicate) of grapefruit, averaging 94, 126, and 35 fruits, respectively, per lot, to determine the best concentration of borax ranging from 2 percent to 12 percent in steps of 2 percent, all being used at 110° F. Both a momentary dip and a 5-minute ex-

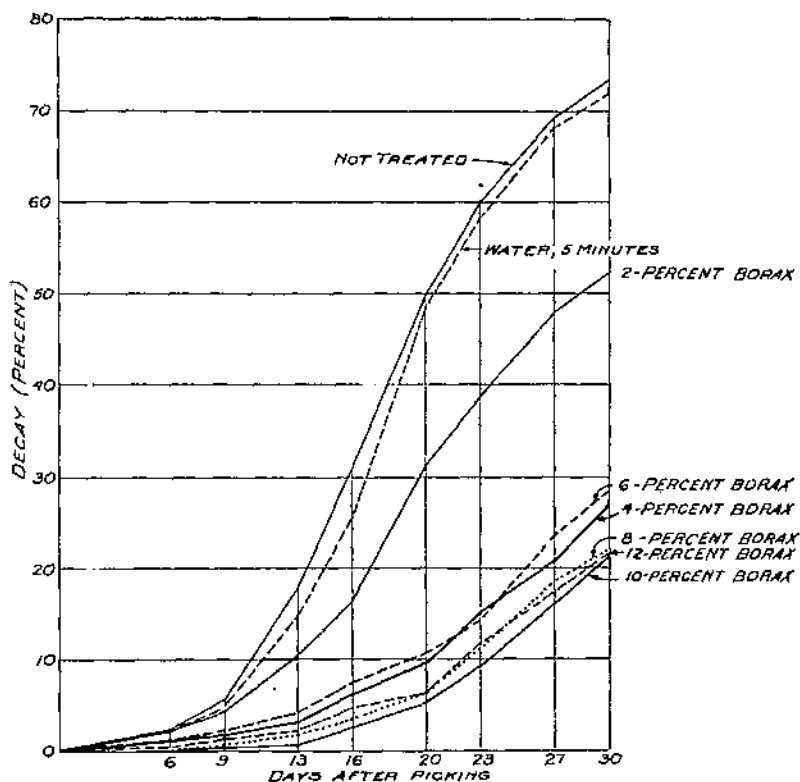


FIGURE 5.—Effect of various concentrations of borax at 110° F. on decay of midseason oranges. Composite results of dip and 5-minute treatments applied before coloring.

posure were tested and compared with similar treatment in water only, at the same temperature. Untreated check fruit was also used for comparison. All of the fruit was then colored in the usual manner and held under comparable conditions at 70° as already described. The comparative effect of the different treatments on decay control in oranges is illustrated in figure 5. Since the results with the momentary dip and the 5-minute bath in the borax solution were practically the same, they have been combined in the preparation of figure 5.

It will be noted that a bath in water at 110° F. for 5 minutes had no appreciable effect in reducing the decay in oranges, indicating that the results in decay control must be due to the borax in solution rather than to the temperature factor in the treatment. It is also apparent that the efficacy of the borax solution increased until the concentration reached about 8 or 10 percent; above that there appeared to be no marked increase in effectiveness in decay control. With tangerines and grapefruit, which normally keep better than oranges, similar results were secured, but the rate of decay was considerably slower. In connection with these results, it should be noted that the fruit was hauled about 80 miles in field boxes in a truck before it was treated. This long haul doubtless

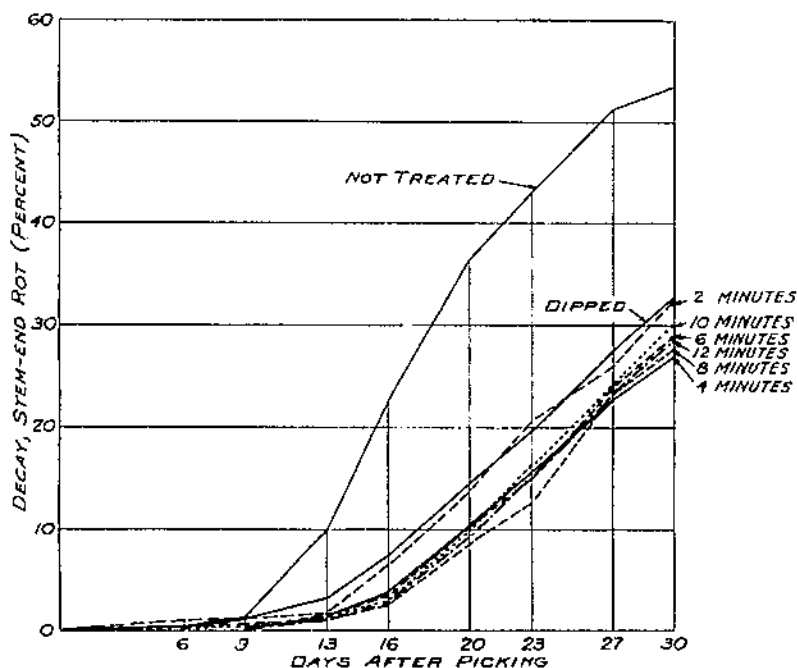


FIGURE 3.—Effect on stem-end rot of exposing citrus fruit for various lengths of time to a 5-percent borax solution at 110° F.; composite of results obtained with oranges, tangerines, and grapefruit. Treatment applied before coloring.

bruised it to a greater or less extent and thereby increased its susceptibility to decay. Under ordinary commercial procedure considerably better results should be expected.

#### LENGTH OF TREATMENT

During November and December 1932, 18 tests (9 treatments in duplicate) were made with oranges, 18 with tangerines, and 9 with grapefruit, including in all 1,600, 2,180, and 330 fruits, respectively, comparing momentary dips in 5-percent borax with 2-, 4-, 6-, 8-, 10-, and 12-minutes' exposure at 110° F. Similar tests were also made with water at the same temperature (fig. 6).

With the 5-percent borax solution there was a somewhat better control of stem-end rot from exposures of more than 2 minutes than from the momentary dip or the 2-minute exposure; however, the difference was not sufficiently great to be of practical significance.

Owing to the naturally better keeping quality of tangerines and grapefruit, the difference between the rates of decay in the treated fruit and the checks was not as great as in oranges.

Where water at the same temperature was substituted for the borax solution there was little or no reduction in stem-end rot or blue mold in either oranges or tangerines except from prolonged exposures to 110° F., but even then the reduction was not great enough to be significant. This indicated that the principal factor in suppressing stem-end rot decay was the borax and not the temperature used in the treatment.

#### TEMPERATURE

The temperature for the borax bath is important principally from the standpoint of the low solubility of borax in cold water. This necessitates the installation of heating equipment in the treating tanks to maintain an effective concentration of borax in solution and to prevent its crystallizing out at night or while cold fruit is being treated.

In order to prove whether the effectiveness of borax is affected by higher temperatures, a series of tests was made. Oranges during 3 seasons and grapefruit and tangerines during 1 season were given 5-minute exposure to the usual 5-percent borax solution at temperatures ranging upward from 80° to 120° F. in steps of 10°, and the results were compared with those from only momentarily dipping the fruit in the borax solutions at the same temperature. The momentary dip was found to be approximately as effective as the longer exposure.

The composite results of 13 tests with an average of 105 fruits each, made at each temperature during three seasons, are shown in figures 7 and 8, the former giving total decay, the latter stem-end rot, in both colored and uncolored oranges. The difference between total decay and stem-end rot consists almost entirely of blue mold, which was generally found to increase during the latter part of the holding period, doubtless due to the extra handling of the fruit in the periodical inspections.

From these results it appears that increasing the temperature of the borax bath was not ordinarily accompanied by a corresponding reduction in decay except at 110° F. In the latter case, the difference was due to reduction in blue-mold rot. Similar results were obtained with tangerines and grapefruit.

Figure 9 shows the composite results of momentarily dipping fruit in 5-percent borax at several temperatures, compared with 5-minute exposures in a 5-percent borax solution at the same temperature. The momentary dip proved to be almost as effective as the 5-minute exposure in reducing stem-end rot, indicating that it is the borax in solution adhering to the fruit as it leaves the bath rather than the action while in the bath that is effective in controlling decay. From this and subsequently presented data it is evident that the fungicidal action is not instantaneous.

Results from using water at corresponding temperatures showed little effect on decay in either oranges or tangerines except at 110° F. or above. At this and higher temperatures a 5-minute exposure was more effective than the momentary dip, particularly in the case of *Penicillium*, indicating that prolonged heat tends to reduce this type of decay.

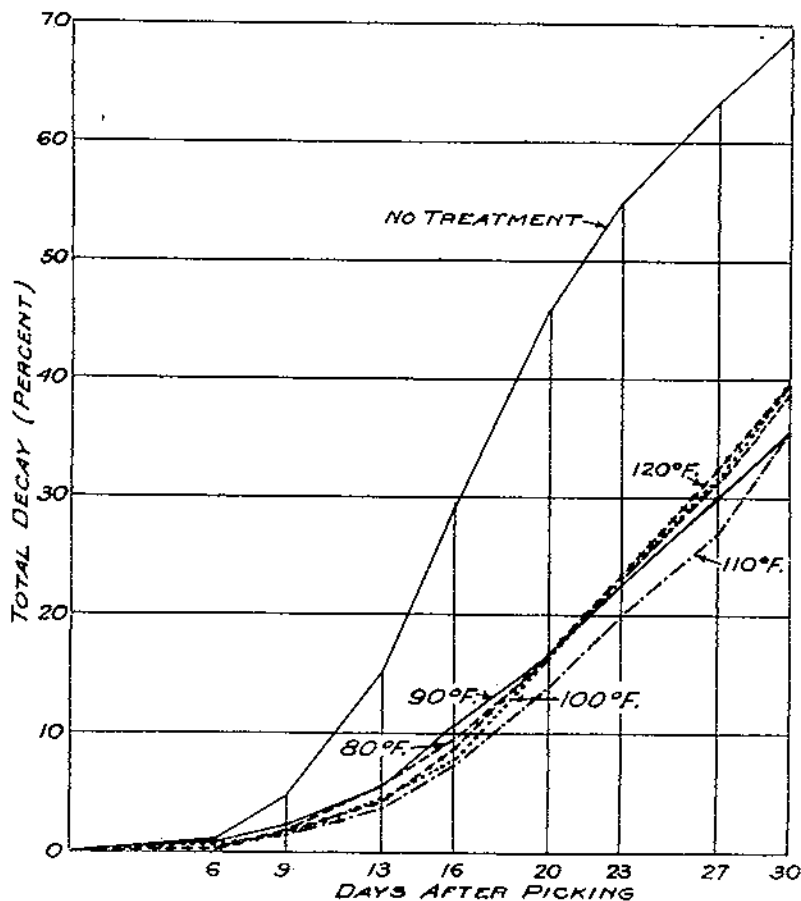


FIGURE 7.—Effect on decay (total) of exposing midseason oranges, colored and uncolored, to a 5-percent borax solution at various temperatures. Composite of results obtained from 5-minutes' exposure and dipping.

#### TIME OF APPLICATION

Heretofore, in commercial practice, application of the antiseptic has been delayed until after the fruit receives the coloring treatment, which is commonly from 1½ to 3 days, or longer, after harvest. During this time the fruit is held under conditions of high temperature, high humidity, and under the influence of ethylene gas, providing ideal conditions for the growth of stem-end rot fungi and the development of decay. This suggested the desirability of determining whether application of the borax treatment before coloring



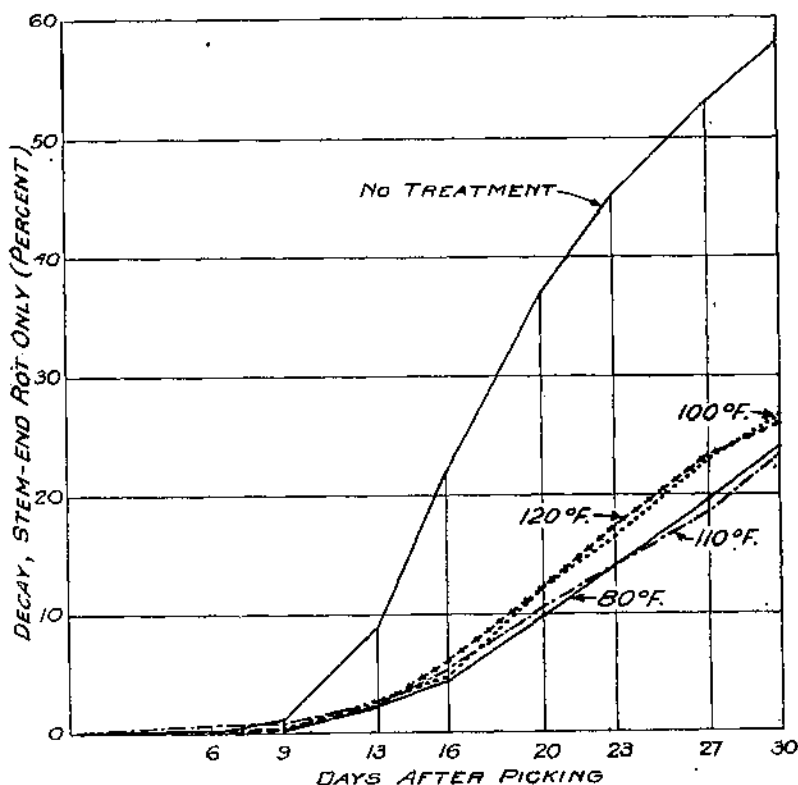


FIGURE 8.—Effect on stem-end rot of exposing midseason oranges, colored and uncolored, to a 5-percent borax solution at various temperatures. Composite of results obtained from 5-minutes' exposure and dipping.

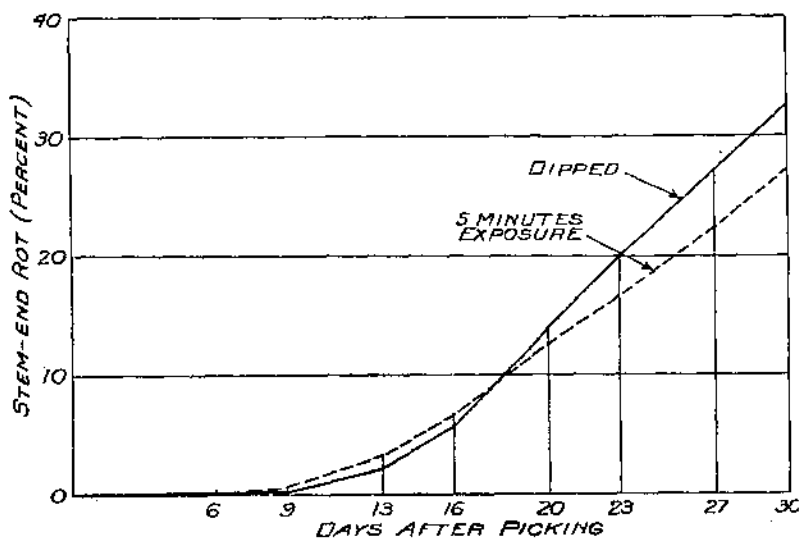


FIGURE 9.—Effect on stem-end rot of exposing midseason oranges, previous to coloring, to a 5-percent borax solution for 5 minutes or momentary dipping. Average results from solutions at temperatures of 80°, 90°, 100°, 110°, and 120° F.

might not be more effective than the usual commercial treatment after coloring.

Accordingly, a rather extensive series of tests was made in the fall and winter of 1931 in which 12 lots of oranges were divided into four parts: (1) Check—no borax treatment, (2) borax treatment given before coloring, (3) borax treatment given after coloring, and (4) borax treatment given both before and after coloring. A total of from 1,400 to 1,600 fruits were used in each treatment. Fruits used in these tests were obtained from 12 or more representative groves which differed in age, variety, and other characteristics and included fruit of advanced maturity. It was found that fruit from young groves kept better than that from old ones, but approximately the same difference in control was noted between the treated and the

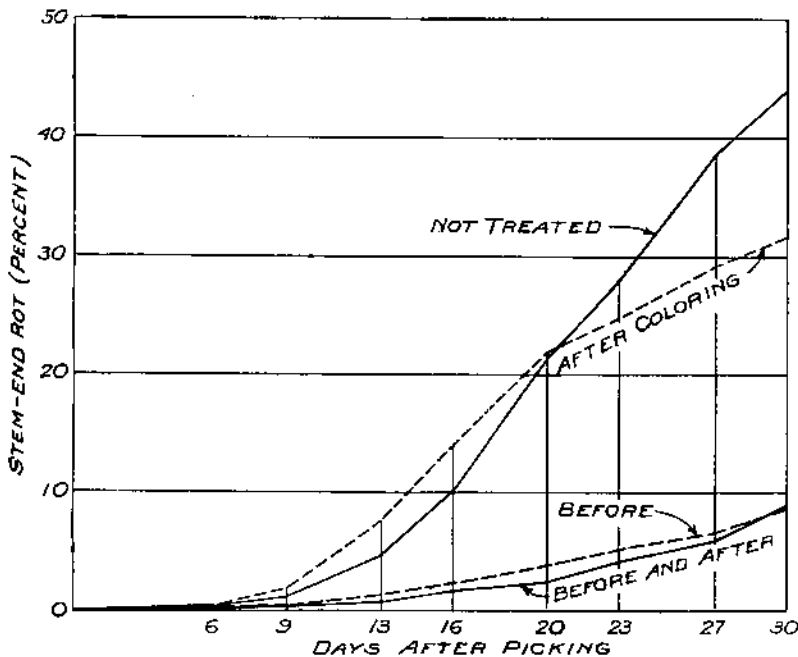


FIGURE 10.—Stem-end rot on midseason oranges treated in a 5-percent borax solution before, after, and both before and after coloring.

checks in fruit from both young and old groves. The results are summarized graphically in figure 10.

Three important points are brought out in figure 10: (1) Stem-end rot was not greatly retarded by an application of borax after coloring, (2) borax applied before coloring retarded stem-end rot to a marked degree, and (3) the double treatment (before and after coloring) was not significantly more effective on this rather mature fruit than a single application before coloring. However, under average commercial conditions where there is considerable variation in the keeping quality of fruit, it is advisable to treat all fruit with borax during the washing operation, regardless of whether an application is made before coloring, because bruises and scratches

opening the way for decay are likely to occur in the handling and washing operations in even the most carefully operated houses.

#### DELAYED BORAX APPLICATION

Fulton and Bowman<sup>7</sup> have shown that the decay-inhibiting effects of borax are impaired if the application is delayed until several hours after blue mold spores are planted in injured tissues. This, doubtless, accounts for the abnormal development of blue mold rot in fruit that is hauled long distances before treatment with borax, particularly that which is picked while wet or has been rained on after picking.

In winter or in cool foggy weather blue mold is often a problem because of favorable temperature and humidity conditions. During the experimental work, showers, heavy dews, and various other difficulties sometimes caused a delay in the application of borax to experimental lots of fruit until the day after picking. When, in addition, the fruit had to be hauled long distances to the packing house, conditions very favorable for blue mold development resulted and considerable loss from penicillium rots occurred despite the borax treatment which was subsequently given. Doubtless this increase in blue mold rot was due to the delay in the application of borax.

Ordinarily, blue mold is most serious during December and January when the weather is comparatively cool. At this time, during the 1932-33 shipping season, experiments were conducted to determine the comparative effects of immediate treatment with borax and an overnight delay before application. Oranges and grapefruit that had been severely scratched or bruised were dipped into a suspension of blue mold spores and were then given the borax treatment; one portion immediately, and the other following an overnight delay. The conditions thus provided were very comparable to those frequently arising in commercial practice during unfavorable weather, especially when field boxes are overfilled. These injuries were of the kind that could be detected easily on the grading belt. Several hundred fruits were used in these tests. Delayed application of borax reduced blue mold decay to some extent but was not as effective as immediate treatment, and the momentary dip into the antiseptic solution was not so effective as a 5-minute exposure at 110° F. However, in no case was the suppression of decay sufficiently great to be commercially satisfactory, but it is possible that the character of the lesions that became infected may have been responsible in some measure for the ineffectiveness of the antiseptic. These results, therefore, emphasize the importance of relying on careful handling as the most effective means of preventing blue mold rot. They indicate also that if fruit must be harvested or hauled in rainy or foggy weather an application of borax should be given as soon as possible after the fruit is picked or otherwise handled. This antiseptic treatment of carefully handled or even slightly bruised fruit should result in much less decay by blue mold.

In order to determine whether a delay in applying borax is similarly reflected in an increase in stem-end rot decay, tests were

<sup>7</sup> FULTON, H. R., and BOWMAN, J. J. See footnote 5.

made with oranges on three different occasions and with grapefruit twice in the spring of 1933 after warm weather had reduced the hazard of blue mold. The experimental fruit was divided into 4 lots of 230 oranges and 50 grapefruits each. One lot was given a borax bath immediately after picking and was then subjected to the usual coloring treatment; the remaining three lots were placed in a 70° F. holding room. On the following day a second lot was withdrawn from the holding room, treated with borax, and placed in the coloring room. This procedure was repeated on the third and fourth days so that comparisons could be made between immediate treatment and delays of 1, 2, and 3 days before application of the antiseptic. Each lot of fruit was given the same coloring treatment, at the conclusion of which the borax residue was washed off and the fruit was returned to the 70° F. holding room for extended observation. The results of these experiments were not entirely conclusive. However, during such delays as will be shown later, rapid development of stem-end rot usually occurs when the fruit is subjected to the usual coloring treatment. Delaying application of the borax treatment, therefore, cannot be regarded as good practice and should be avoided as much as possible.

#### BORAX ON UNCOLORED ORANGES

During the course of these experiments with borax on fruit that was subsequently subjected to the coloring treatment, similar fruit was held in the open air for comparison. These check lots were treated with borax in the usual way, but instead of being placed in warm coloring rooms they were stored in an open shed while other lots were receiving the coloring treatment. At the end of the coloring period, the borax residue was washed off from both lots and the fruit was then transferred to a holding room maintained at a temperature of 70° F. In both of the years during which these experiments were conducted the results were consistent in proving the effectiveness of the borax treatment. Figure 11 shows the differences in stem-end rot obtained in 13 lots of untreated and 12 lots of treated early and midseason oranges, and in 9 lots of untreated and 9 of treated Valencia oranges, averaging somewhat more than 100 fruits per lot.

The reduction in decay in the early and midseason oranges was greater than in the Valencia oranges, probably because the early oranges were from younger trees and were somewhat less mature at the time of treatment, hence, less subject to rapid decay. No evidence has been obtained that one variety of orange is more susceptible to stem-end rot than another. A comparison of the results shown in figure 11 with those presented in figure 10 shows that stem-end rot was very markedly increased by the coloring treatment, the maturity of the fruit, and possibly other factors, but that by use of the 5-percent borax solution the loss from stem-end rot even on this fruit was less than on fruit that received neither the borax nor the coloring treatment.

#### REMOVAL OF BORAX DEPOSITS

The length of time that borax should be allowed to remain on the fruit in order to effect maximum control of decay has an important

bearing on the commercial usefulness of this antiseptic. A deposit of borax on market fruit is objectionable, therefore it should be washed off before the fruit is packed. To determine the extent to which this removal of borax affects the control of decay, a series of experiments was conducted in 1932, using firm, fully matured mid-season oranges. Four tests were made on uncolored fruit of the Pineapple and Ruby Blood varieties of oranges from three different groves, employing more than 400 fruits per treatment. The results indicated that when the borax solution was rinsed off immediately after being applied, as in the ordinary commercial practice, stem-end rot was reduced only slightly below the untreated checks; however, when the borax deposit was left on for 48 hours there was a further

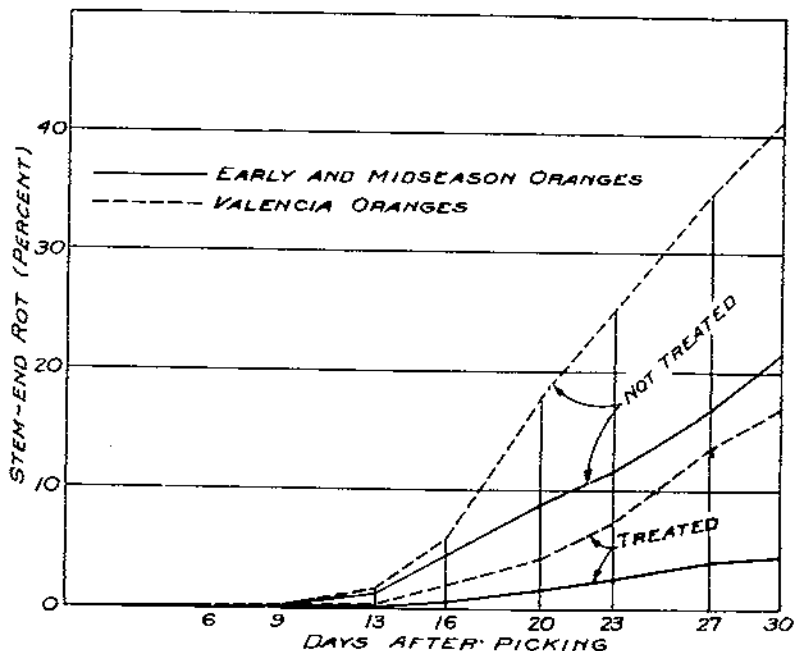


FIGURE 11.—Stem-end rot on uncolored early and midseason and on uncolored Valencia oranges treated with a 5-percent borax solution. Borax residue removed after 72 hours.

reduction, and a still greater reduction when the borax deposit was left on the fruit throughout the holding period, the maximum reduction occurring during the latter half of the holding period (fig. 12). Had this fruit been less mature, there undoubtedly would have been a greater difference in decay between the treated and the untreated lots. (See fig. 11 for comparison.)

Another test was conducted subsequently in which similar sized samples were gathered from seedling orange groves when the fruit was almost dead ripe and hence much weaker and more subject to rapid spoilage. It was again found that when the borax was rinsed off immediately after being applied it had little or no effect on stem-end rot, whereas that left on throughout the holding period was fairly effective, although not to the same extent as in the experiments

illustrated in figure 12, which included less senile fruit. Blue mold was quite effectively controlled in both tests.

The experiments were continued on Valencia oranges and grapefruit during March and April 1933, and on budded oranges in November 1933. In these tests the fruit was treated with an 8-percent borax solution and washed in clean water after intervals of 5 minutes, 1, 2, 4, 6, and 8 hours. Quadruplicate lots consisting of approximately 300 fruits each were used. The results, while not as clear-cut as in the earlier tests on more susceptible fruit, again indicated that to be most effective in rot control the borax should not be washed from the fruit until after 6 or 8 hours.

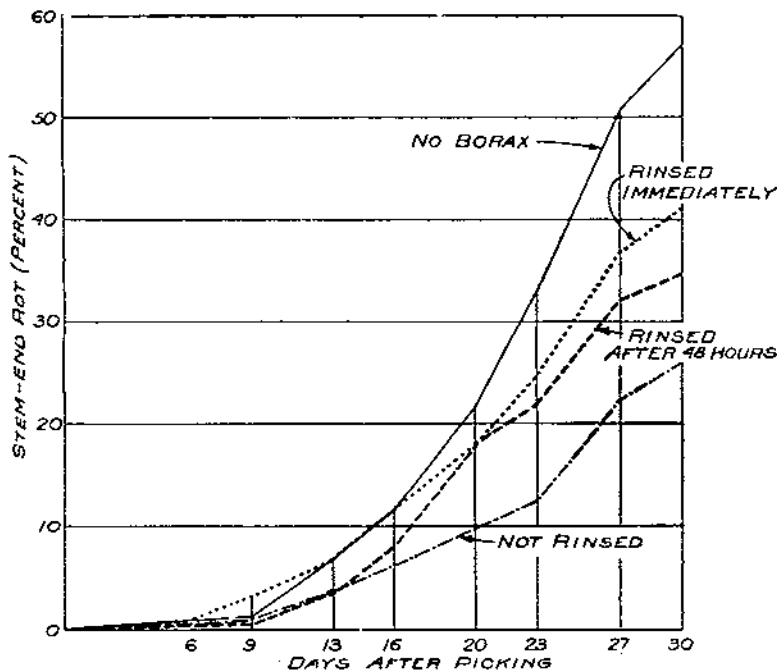


FIGURE 12.—Effect on stem-end rot of allowing borax residue to remain on navel oranges for various lengths of time.

No definite experimental evidence was obtained as to whether the antiseptic action of the borax continued after the treating solution had dried on the fruit; however, it is believed that the effects were obtained chiefly while the fruit was still wet with the antiseptic solution.

#### INFLUENCE OF MATURITY ON EFFICACY OF BORAX

It is well known that citrus fruit can be stored on the tree for several weeks after it reaches maturity and that this practice is followed in all producing districts, harvesting operations being determined to a large extent by the market demand.

When oranges first reach maturity ordinarily they are not especially subject to rapid spoilage from either stem-end rot, blue mold, or green mold, but as they become more mature the rate of decay

subsequent to packing increases rapidly. Dead-ripe fruit is especially susceptible to stem-end rot and can be marketed in a sound condition only with extreme difficulty. Experiments were therefore undertaken to determine the effect of the borax treatment on the keeping quality of such fruit. These tests were made in the spring of 1932 and again in 1933, using fruit so ripe that the slightest pressure would pull it from its stem. The first season's records were not made with respect to the retention of stems, but in 1933 the fruit was divided into two classes: (1) With stems adhering, and (2) without stems.

In both seasons the fruit was given the customary 5-percent borax treatment, but the 1933 fruit was also subjected to the ethylene coloring treatment for 50 hours and then stored. Very little difference was noted in the rate of decay between the treated and the untreated fruits, or between those without stems as compared with those with stems attached. These results indicated that the causal organisms had penetrated too deeply into the tissues to be reached by the anti-septic at the time of treatment.

#### INFLUENCE OF BORAX ON COLOR DEVELOPMENT AND LOSS OF WEIGHT

Throughout these experiments close observations were made on differences in the rate of coloring in fruit treated with borax as compared with the untreated lots in both the noncolored (not gassed) checks as well as in fruit subjected to ethylene to accelerate the disappearance of the green pigment.

With oranges, grapefruit, tangerines, Satsumas, and other common citrus species, no evidence was found to indicate that a deposit of borax tends to retard color development, either when forced with ethylene or allowed to proceed at the normal rate under atmospheric conditions. Similar observations have been made on fruit handled in commercial operations. It is evident that the rate of coloring is affected chiefly by such factors as temperature, humidity, and chemical constituents of the atmosphere rather than by the presence of borax on the fruit.

Several hundred carloads of citrus fruits, mostly oranges, were commercially treated with borax before coloring during the season of 1932-33, and a much larger number during the season of 1933-34. The results in general indicated that the borax deposit did not retard the rate of coloring nor did it in any manner make the fruit more difficult to clean.

Records were secured on the loss of weight of Valencia oranges treated with borax and colored, as compared with corresponding lots treated with plain water and colored. The results showed that the fruit treated with borax lost weight at essentially the same rate as did the untreated checks, proving that the rate of wilting is not affected by the treatment.

Quantitative chemical determinations were made for borax residue on fruit treated with solutions of different concentrations of borax in a 110° F. bath, both as a momentary dip and as a 5-minute immersion, using fruit at 50°, 72°, and 83° and dried in still air at these temperatures. These tests showed a general relationship between the concentration of the bath and borax deposited, also that there was a slightly less deposit from a momentary dip than

from a 5-minute immersion (table 1). Fruit russeted by rust mites retained practically no more borax than bright fruit.

Similar tests made earlier in the season with dirtier fruit indicated the same general trend, but such fruit retained a greater amount of borax.

## COMMERCIAL OPERATION

Because of the results of the experimental work reported above, during the 1932-33 season several packing houses installed equipment for applying borax to fruit before placing it in the coloring rooms. A number of others utilized the regular washing equipment to apply the borax treatment before coloring by shunting the fruit into field boxes from the second or "borax" tank of the usual packing-house equipment and then placing it in the coloring rooms.

TABLE 1.—*Borax residue on Valencia oranges after momentary and 5-minute treatments and drying in still air at different temperatures with borax solution at different concentrations, 1934*

## GRAMS OF BORAX PER 100 POUNDS OF FRUIT

Date	Borax	50° F.		72° F.		83° F.	
		Momen- tary	5 min- utes	Momen- tary	5 min- utes	Momen- tary	5 min- utes
	<i>Percent</i>						
May 22.....	3.15	2.776	2.761	2.301	2.340	1.974	2.445
May 25.....	3.15	2.933	3.913	2.600	3.077	2.072	3.059
Average.....		2.854	3.337	2.450	2.711	1.908	2.752
May 22.....	6.59	3.260	5.046	4.385	4.489	4.404	5.309
May 25.....	6.59	4.441	6.116	4.280	5.565	5.047	6.151
Average.....		3.850	5.581	4.332	5.027	4.770	5.730
May 22.....	13.21	0.172	11.584	9.581	10.394	10.764	10.360
May 25.....	13.21	13.950	12.900	9.990	12.890	13.290	14.440
Average.....		11.561	12.242	9.770	11.042	12.027	12.400

GRAMS OF BORAX PER 1,000 CM<sup>2</sup> SURFACE

May 22.....	3.15	0.089	0.087	0.072	0.074	0.062	0.076
May 25.....	3.15	.082	.126	.082	.094	.087	.098
Average.....		.0905	.1065	.0770	.08400	.07450	.0870
May 22.....	6.59	.109	.161	.148	.142	.138	.163
May 25.....	6.59	.145	.181	.134	.177	.160	.192
Average.....		.1225	.1710	.1410	.1595	.1480	.1775
May 22.....	13.21	.291	.365	.292	.361	.347	.345
May 25.....	13.21	.467	.418	.325	.408	.408	.433
Average.....		.3700	.3905	.3085	.3685	.3775	.3890

In the first commercial attempts to use the borax treatment before coloring, ordinary citrus lug boxes filled with fruit were dipped into the antiseptic solution just as they were received at the packing house (fig. 13). Although this was a somewhat laborious method of applying borax, it was effective. Another procedure, developed shortly afterward, was to use a small vat, movable on casters and



having heating facilities. This was equipped with a hand-operated carriage that submerged the fruit and the container and then elevated them to a roller conveyer on which the treated boxes were moved away (fig. 14). Use of the roller conveyer allowed the greater part of the excess borax solution to drip back into the tank.

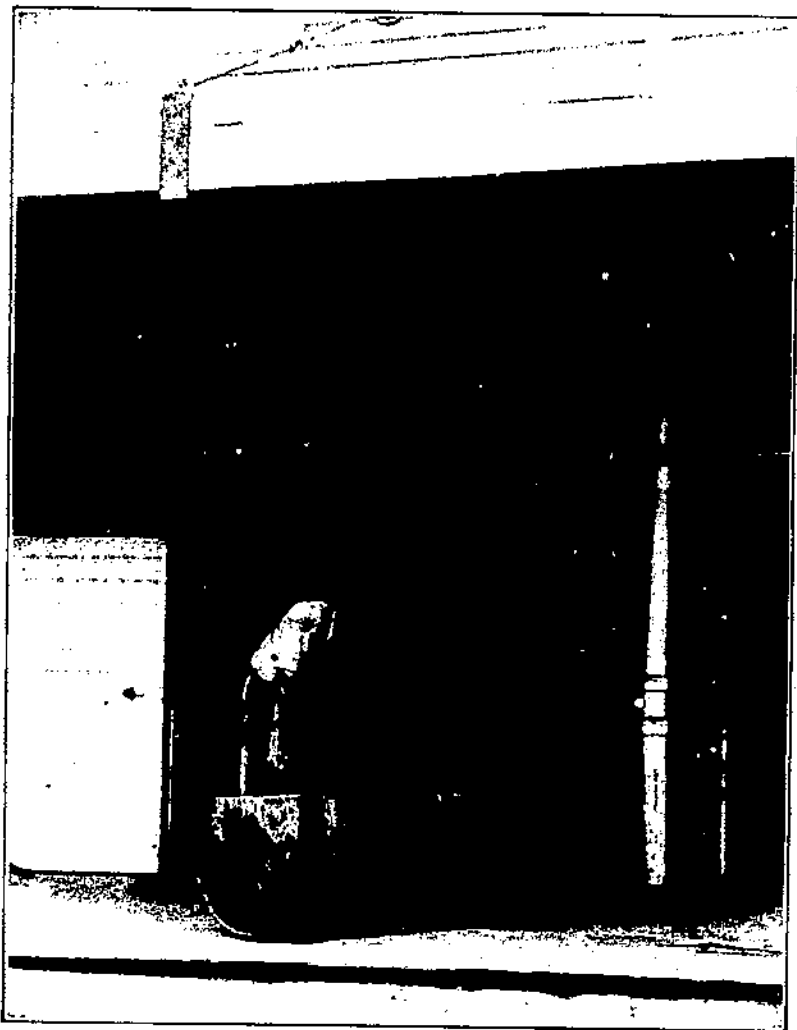


FIGURE 13.—Dipping oranges in ordinary citrus lug boxes into borax solution.

This proved to be a rapid and inexpensive method of applying borax, but it was rather sloppy and required much hand labor.

This method was also open to the criticism that the field boxes or lugs became wet. This is objectionable, particularly when the coloring rooms have inadequate provision for evaporating excess moisture. However, there is an offsetting advantage in not having to empty the crates and refill them, thereby reducing the chances

of bruising and injuring the fruit, which is of special importance early in the season when the oil cells are easily ruptured.

A more recent development in the treating method consists of the use of a few transverse scrubbing brushes or roller conveyers, a small soaking tank with heating equipment and with a conveyer belt on which fruit can be graded, as shown in figure 15. After the fruit is dumped, the empty field boxes are carried by gravity conveyers to the far end of the loading belt where they are filled with treated fruit and trucked to the coloring rooms. This method

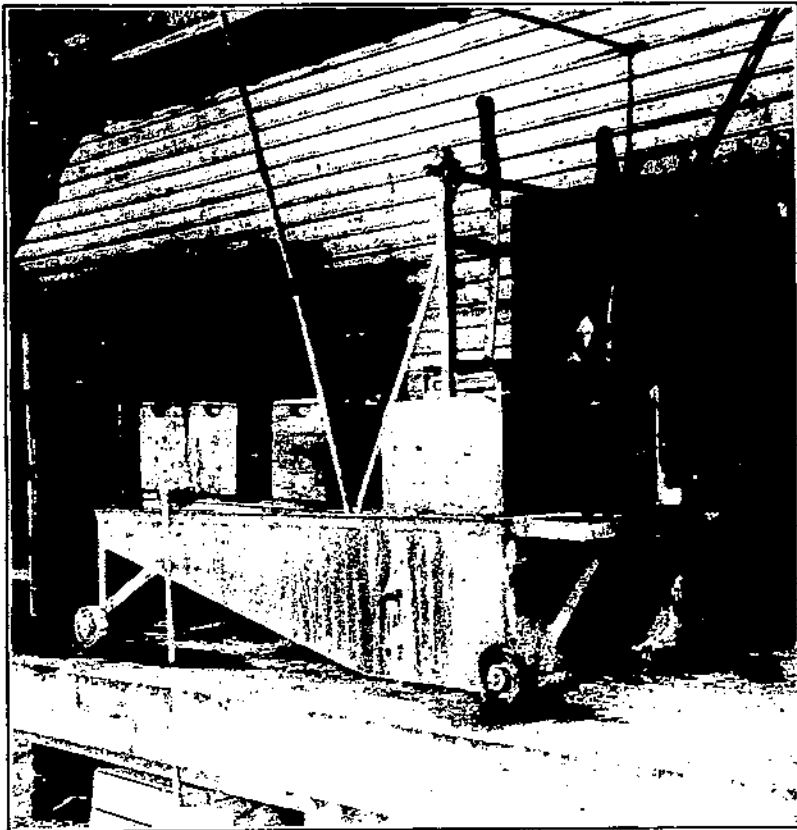


FIGURE 14.—A movable borax dipping tank with hand-operated carriage. The fruit in ordinary lug boxes is first submerged and then elevated to a roller conveyer.

of applying borax has a number of advantages, chief among which is the fact that since the boxes are not wetted the fruit can be dried more quickly. This method is favored by many commercial packers. It is also more economical in the consumption of borax, but, because of emptying and refilling each box, mechanical injury of the fruit is more likely to occur, although in the usual commercial operations very little injury is actually experienced. The treating equipment is often placed on small wheels enabling it to be moved wherever it may be needed, and it is used with a specially padded hopper for catching the treated fruit with the least risk of bruising (fig. 16).



FIGURE 15.—Improved borax-treating apparatus comprising a small soaking tank with heating equipment, some transverse scrubbing brushes or roller conveyors, and a belt upon which the fruit can be graded.

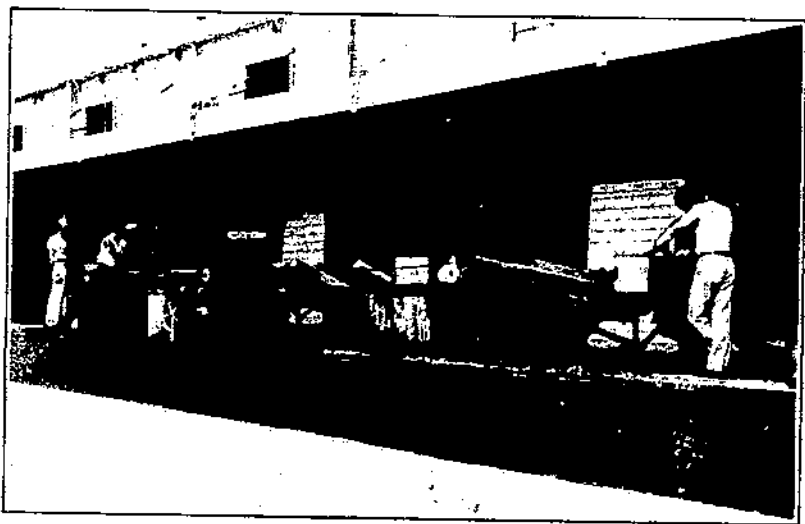


FIGURE 16.—Borax-treating apparatus mounted on wheels to permit moving wherever desired along receiving platform. This illustration also shows the use of a specially constructed hopper to receive the treated fruit with the least risk of bruising.

The most recent commercial developments or adaptations of the method are modifications of those illustrated in figures 15 and 16, the essential difference being in the use of longer borax tanks to prolong the time of treatment. Some of the newer tanks are large enough to permit a normal flow of fruit to remain in the bath 10 or more minutes, which is considered especially desirable in cold weather not only because it permits more borax to remain in solution longer on the fruit, but the preheating also shortens the time necessary to raise the fruit to the temperature subsequently required for coloring.

While the methods of applying borax, as described, have certain advantages, it is believed that a regular washing procedure, including the use of a soaking tank, scrubbers, and a borax tank, might be desirable in small packing houses when the fruit is received from the orchard, especially during cool weather. It would be necessary, however, to have both tanks equipped with steam pipes so that cold fruit could be warmed up sufficiently to retain an effective amount of borax in solution. It is necessary to heat the borax solution during the greater part of the shipping season in order to prevent the temperature of the bath from falling below the saturation temperature of the desired concentration. In warm weather, however, heat may be needed only during the early morning.

It has been found that in cool weather the fruit often needs to be warmed before treatment to insure the maximum effect from the borax solution. The most economical and effective method of warming the fruit is a problem that varies from one packing house to another and requires individual solution. In some houses it has been found practical to utilize the coloring rooms with their steam-heating and air-circulating equipment. This, however, involves extra handling and added costs. In many packing houses it is found to be most practical to rely on the use of the long borax tanks to heat the fruit effectively for the treatment. It is possible also that sodium metaborate may be used as a substitute for borax during cold weather on account of its greater solubility.

#### TESTS UNDER COMMERCIAL CONDITIONS

Much of the experimental work conducted at the laboratory was repeated under commercial conditions. In midwinter fully mature oranges in need of the coloring treatment were selected from four groves that were notorious for producing fruit of unusually poor keeping quality. These lots were divided into two groups—one was dipped with the container into a warm 5-percent borax solution and the other was untreated. Both lots were then colored for 40 hours in the commercial way, together with a room full of other fruit. At the end of the coloring period composite samples from each lot totaling more than 400 fruits for each group were transferred to the holding room for observation. The decay record of these lots is presented in figure 17.

From these results it is apparent that the borax treatment controlled decay effectively for about 3 weeks even at a temperature of 70° F., whereas the loss in untreated fruit was very severe, being as great at the end of about 10 days as it was in the treated lots after 21 days.

In connection with observations on commercial operations, it has been noted repeatedly that on weak fruit treated with borax a brownish discoloration often develops on a small percentage of the fruit in the stem area after holding for about 2 or 3 weeks. Occasionally a rot caused by *Colletotrichum* sp. developed in these areas, but it was readily distinguishable from that caused by *Phomopsis* and *Diplodia*. Susceptibility to such injury from the borax treatment appears to vary considerably with the particular crop involved and

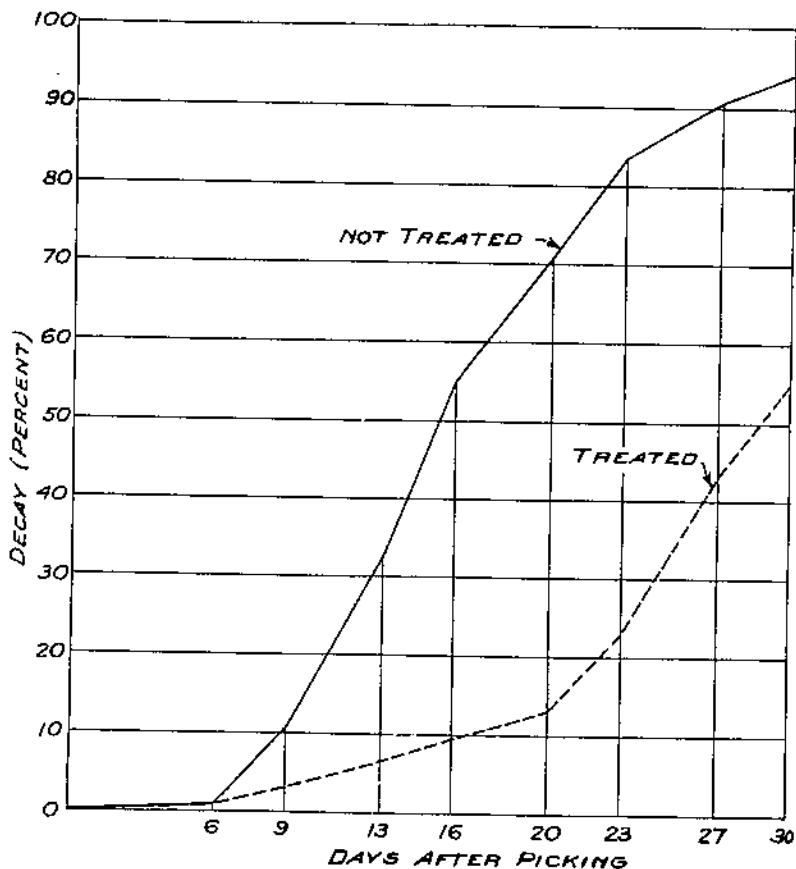


FIGURE 17.—Decay of midseason oranges, of poor keeping quality, as affected by dipping in a warm 5-percent borax solution before coloring under commercial conditions.

to increase when the time required for the fruit to dry is excessively long. Ordinarily, it has been of little or no commercial consequence.

The cost of the borax treatment varies with the facilities available in the different packing houses, but ordinarily it is from one-half to two-thirds of a cent per 100 pounds of fruit.

#### THE COLD WEATHER FACTOR

During 1 or 2 cold spells the 5-percent borax treatment, as used commercially, before coloring, failed to give protection against decay. An investigation into the trouble indicated two possible con-

tributing factors: The use of too much live steam in the coloring treatment, and the low temperature of the fruit at the time of the borax treatment. A too liberal use of steam at the beginning of the coloring period tends to wash off the borax from fruit in the lower and cooler boxes. When the fruit temperature is below the saturation point of the weakest effective concentration of the borax solution the fruit does not retain in solution a sufficient amount of borax to be properly protected against rot fungi. Unless the borax tank is equipped with adequate heating facilities, the solution may be-

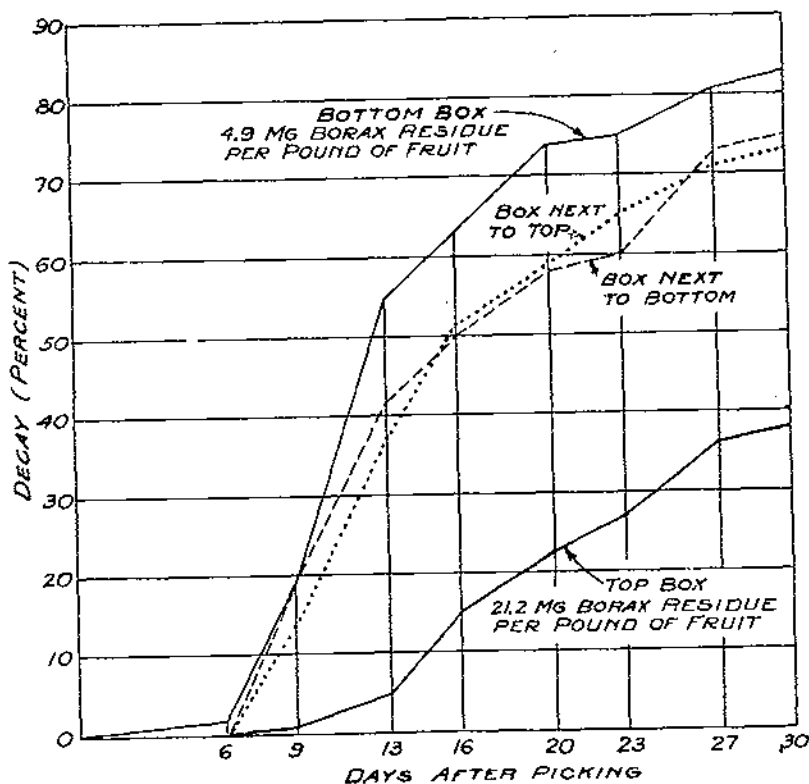


FIGURE 18.- Decay in different layers of midseason oranges as related to removal of borax by excessive steam in the coloring room.

come chilled by the passage of cold fruit, thereby resulting in lowering the concentration of borax in solution.

Special tests were conducted to prove these points and it was found that the liberal use of steam during the warming up portion of the coloring period resulted in the washing off of the borax from the cooler fruit in the lower part of the stacks. Samples of fruit to be held for extended observation and for chemical analyses were taken and the results are summarized in figure 18.

It will be noted that from two to four times as much borax was found on the fruit from the top boxes as on that from the bottom boxes. This doubtless had an important influence on the keeping

quality of the fruit in the lower boxes. In all of these instances the fruit was wet from the borax treatment and was in wet boxes when placed in the coloring rooms. Complications immediately arose in the condensation of water on the fruit in the lower boxes. Samples for a storage test were taken from the dumping belt during the regular packing operation subsequent to the coloring treatment. The results showed that the fruit in the lower boxes received less protection than that in the top boxes, because of the washing off of the borax as noted above. The protection noted was, in general, proportional to the borax residue recovered.

When the commercial use of borax before coloring was first attempted the dipping vats were not equipped with facilities for keeping the bath warm. Satisfactory results were secured until the onset of cold weather when almost without exception shippers experienced increased losses from decay, indicating that cold weather had introduced a new factor in the problem.

A special series of tests were then made under commercial conditions to determine the influence of the fruit temperature at the time of treatment in the effectiveness of borax as an antiseptic. At the same time, and with samples of fruit from the same grove, tests were made to determine the influence of wet boxes on the subsequent keeping quality of borax-treated fruit. The fruit used was taken from four groves that had consistently produced fruit of poor carrying quality. The lots used averaged 275 fruits for each treatment. All of the experimental lots were colored in rooms filled with commercial fruit treated with borax by dipping the fruit and boxes. Figure 19 gives the summarized results of these tests made in December 1932 with midseason oranges.

It will be noted that cold fruit was not adequately protected by the borax treatment, even prolonged exposure in the warm, non-agitated borax bath being only partially effective. In the experiments on the influence of wet boxes it was found that the fruit colored in dry boxes kept better than that held in wet boxes during the coloring period. Without exception, each lot transferred to dry boxes after being treated with borax decayed less rapidly than the corresponding lot left in wet boxes.

Unless the borax solution is heated it soon reaches the average temperature of the fruit being dipped. Thus, in cool weather, difficulty is encountered in maintaining the proper concentration of borax unless special steps are taken to keep the borax bath warm, because of the low solubility of borax in cold water. Likewise, when cold fruit was dipped it is probable that the film of borax solution adhering to the fruit lost a large part of its borax through crystallization and subsequent washing off of a portion of these crystals while the fruit was dripping. This may be of special importance whenever the borax solution is used at less than maximum effective concentration.

The accompanying chart (fig. 20) can be used as a convenient guide in maintaining any desired concentration of borax. To use this chart, all the equipment that is needed is a thermometer and a Brix hydrometer, such as is used in making the customary maturity tests on citrus fruit.

In this chart, temperature is indicated by oblique lines, gravity (Brix) by perpendicular lines, and percent of borax by horizontal lines. Its use may be illustrated by the following example:

If the temperature of the bath (indicated by the oblique lines) is 90° F. and the Brix reading (shown as perpendicular lines) is 6.5 the concentration can be determined by following the oblique temperature line down until it cuts the perpendicular line, representing the Brix reading, then extending that point in a horizontal direction to the left of the chart, the amount of borax in solution is found to be approximately 6 percent. Usually, a borax solution of the desired concentration should be prepared in a special container such as a barrel or a large garbage can and then added to the dipping tank as needed. It will be noted that a Brix reading of 5 for a tank temperature of 70° indicates approximately a 4-percent borax solution, and the same Brix reading for a temperature of 100° indicates a 5-percent solution.

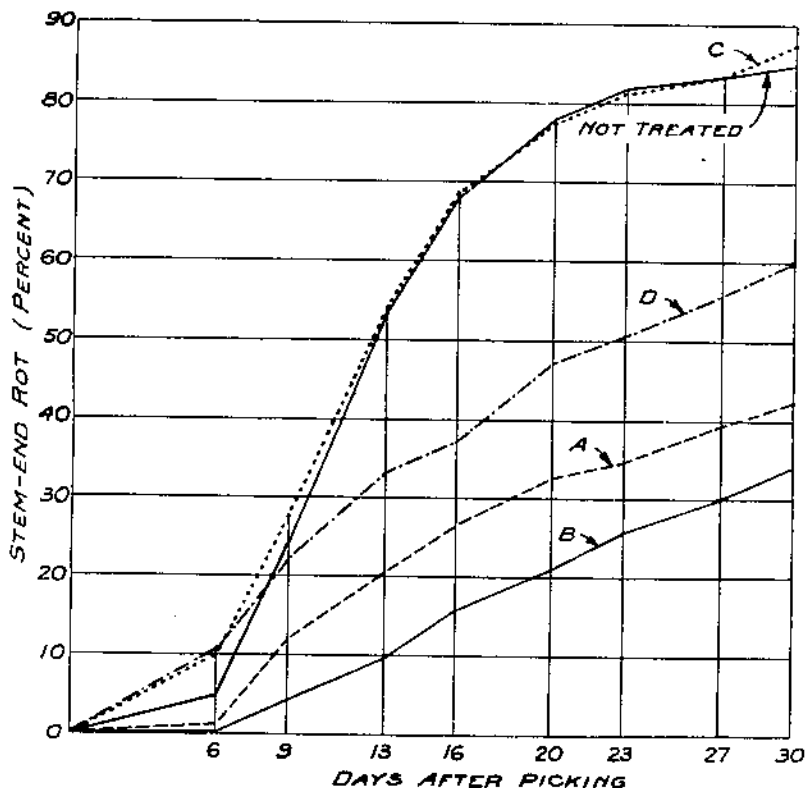


FIGURE 19.—Stem-end rot on midseason oranges as affected by temperature of fruit when exposed to a warm 5-percent borax solution before coloring and by various methods of handling: A, Fruit 70° F., dipped, left in wet boxes; B, fruit 70° F., dipped, transferred to dry boxes; C, fruit 50°–60° F., dipped, left in wet boxes; D, fruit 50°–60° F., 5-minute exposure, left in wet boxes.

Because of low solubility of borax it is not feasible to attempt to make a concentrated solution for subsequent dilution. However, concentrations up to 10 or 12 percent can be prepared with little difficulty by introducing live steam into the dissolving vessel, or by applying bottom heat. In the latter case, the solution should be stirred while heating.

For the solution of the problem of successfully treating citrus fruit with borax in cold weather, the following suggestions are



offered: (1) Use a longer tank in order that the outer rind of the fruit may have an opportunity to warm a little while passing through the borax solution. (2) Pass the fruit through the soaking tank and the borax tank as is the usual practice in washing fruit, and thence direct to dry field boxes. In such cases both tanks should be equipped with heating units. During the 1933-34 season commercial experience indicated that such equipment (fig. 15) was adequate during ordinary winter weather without the necessity of preheating the fruit. (3) Momentary dipping of the cold fruit in a 10- or 12-percent hot borax solution has given satisfactory results in some instances in commercial houses. Undoubtedly adequate amount of borax adhered to the fruit despite the immediate

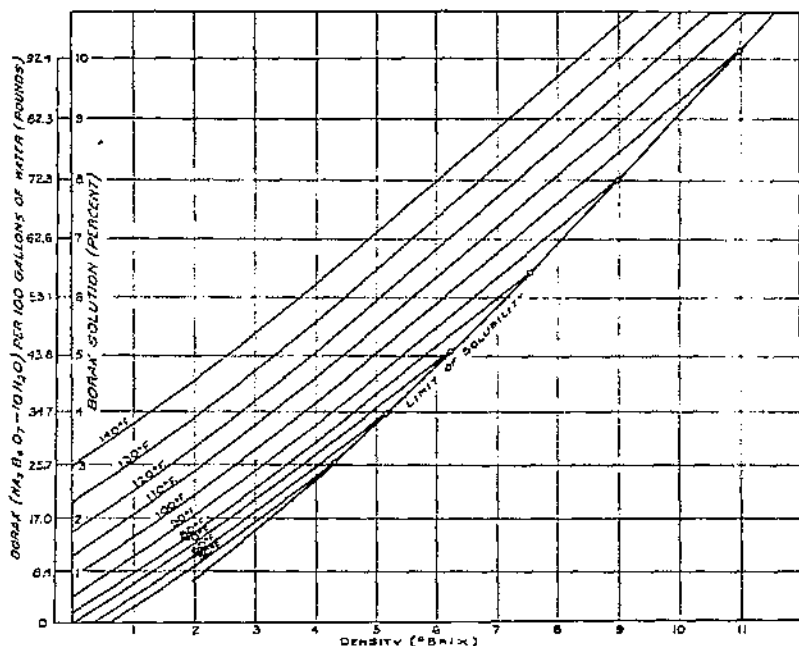


FIGURE 20. Density of borax solution at different temperatures. One hundred gallons of water at 80° F. = 832 pounds. One cubic foot of water = 7.48 gallons.

crystallization which occurred on its surface, provided the fruit was subsequently warmed in an atmosphere almost saturated with moisture. This method has been used to only a limited extent and its effectiveness has not been fully established. (4) Warm the fruit for a few hours in one of the coloring rooms where the temperature can be raised quickly and can be controlled through provision of adequate means for circulating the air. This prewarming would also serve to shorten considerably the time necessary to bring the fruit to coloring temperatures, and would thereby shorten the time required for coloring. Rind temperatures need not be raised much above the saturation temperature of the borax solution used. (See fig. 20.)

The rate at which fruit can be warmed up in this manner by use of live steam and adequate equipment for air circulation is shown

in figure 21, presenting the results of experiments conducted at Winter Haven, Fla.

From these results it is apparent that the temperature at or near the center of the fruit was raised about 30° in 5 hours in a car lot of fruit using equipment now generally used in coloring operations.

#### DRYING AFTER BORAX TREATMENT

When the wet borax-treated fruit was handled in dry boxes, little or no difficulty was encountered in drying the fruit in a reasonable time, that is 6 to 8 hours, but when both the fruit and the boxes were wet, especially in damp weather, and the coloring rooms were only partially filled, thereby reducing the amount of air that passed through the filled boxes, the rate of drying was considerably retarded. At such times, as much as 40 hours was required to dry the fruit in the lower part of the stacks. Under commercial conditions this usually resulted in a retarded rate of coloring in these lower boxes. At times, also, the fruit took up so much moisture that some splitting occurred in weak fruit and there was an additional loss in the impaired efficiency in decay control. In warm dry weather and with rooms equipped with large blowers, no trouble is ordinarily experienced in drying fruit, even when it is handled in wet boxes.

If coloring rooms are not equipped with blowers of sufficient capacity or if from any cause the air circulation is deficient, it is better to allow the borax-treated fruit and wet boxes to stand for a few hours where natural air currents can remove as much of the excess moisture as possible before transferring to the coloring rooms. If the boxes are not wet, the fruit usually dries quickly enough even in rooms with poor circulation. Under the former conditions it is advisable wherever possible to use dry heat or heat from a steam radiator instead of live steam in heating the fruit for coloring.

#### SUMMARY

A borax bath given to citrus fruit immediately upon arrival at the packing house was found to retard decay caused by the common stem-end rot and blue mold organisms. Delayed treatments were not as effective.

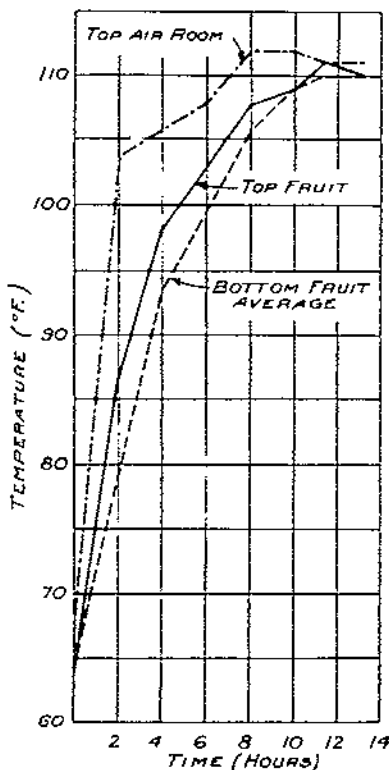


FIGURE 21.—Rate of heating carload lots of grapefruit with live steam previous to coloring.

The borax treatment was found to be effective on fruit needing the coloring treatment as well as on that which was fully colored when harvested.

The antiseptic treatment was much more effective on firm fruit than on over-ripe fruit ready to drop from the tree.

For best results it was found that the concentration of borax should not be less than 8 percent. Whenever possible the wet fruit should be dried slowly and the borax residue should be left on the fruit for several hours.

In cold weather it is desirable to raise the temperature of the rind of the fruit to about 90° F. before giving the borax treatment, in order to retain the maximum effective amount of borax in solution. This may be accomplished by warming the fruit in coloring rooms or by passing it slowly through long tanks with heated borax solution.

In well-organized packing houses the cost of this treatment has not exceeded one-half to two-thirds of a cent per 100 pounds of fruit.

The value of the treatment is reflected in a reduction of decay while the fruit is in transit and in improved keeping quality after the fruit arrives at the market and enters the hands of the retailer and the consumer. Its value is especially apparent when fruit is held on the market for several days, particularly in warm weather.

**END**