Hot-Water Treatment of Mango Fruits to Reduce Anthracnose Decay

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INTRODUCTION

Anthracnose decay of ripening mango fruit is a most troublesome problem in the storage and shipment of this fruit. In Puerto Rico it is a fairly recent problem because most of the fruits shipped heretofore have been largely of the Mayagüezano variety which is highly resistant to this disease. Recently, however, it has increasingly become a most serious problem with the "Cubano", a high-priced variety of good quality grown near Salinas. The problem threatens to become of much greater consequence with the planting of other commercial varieties of high quality, such as Haden, Irwin, Kent, Zill, and Palmer.

As reported by Baker (*1*)[3] and subsequently by Ruehle (*2*) and other workers, much of the decay that develops on ripening fruit has its inception as latent infections occurring when the fruits are quite small. These latent infections become active as the fruit ripens and cause considerable loss in transit or storage. Refrigeration at about 50° F. apparently does not appreciably retard the increased activity of the infection, but does delay ripening of the fruit, thereby extending its period of greatest vulnerability. Moreover, when the fruits are removed from refrigeration and placed at room temperature the "sweating" which occurs as a consequence of condensed moisture on the cold surface of the fruit creates a highly favorable environment for the rapid increase of anthracnose rot. This is particularly true when the fruits are allowed to remain in the boxes thereby prolonging the time required for the surface of the fruit to dry out.

The shipment of mangos to the continental United States markets requires refrigerated storage, consequently the fruit must be meticulously inspected and all fruit having even the slightest indication of anthracnose infection should be rigorously culled. Despite the most rigid inspection and culling, however, appreciable losses caused by anthracnose have continued to take place whenever choice commercial varieties have been shipped. It, therefore, occurred to the writer to test the effect of hot-water treatment of mango fruits, since this has proven highly successful for papaya fruits (*3*).

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[3] Italic numbers in parentheses refer to Literature Cited, p. 283.

EXPERIMENTAL PROCEDURE

Fruit with obvious though slight anthracnose infection was picked at shipping maturity and grouped according to the severity of anthracnose injury so that lots of fruits which were as nearly as possible comparable would receive the different treatments. The fruits of each variety were treated independently and in every case a nontreated control was included, in addition to the different treatments, each of which consisted of immersion for a specified interval in hot water held at a specified temperature.

For treating the fruit we made use of equipment belonging to the Pathology Department of this Agricultural Experiment Station which was built for treating sugarcane planting material infected with chlorotic streak disease. Figure 1 shows this equipment which proved to be well suited for treating mangos. It consists of two oil drums with the tops removed which are connected by pipes and a circulating pump. Four heating elements which can be operated independently of each other are located in one of the drums. The fruits are immersed in the other in a wire basket which must have a lid to prevent the floating of some of the fruit. The important features of this apparatus are as follows:

1. A large volume of water (about 75 gallons) which keeps the temperature from fluctuating even when a large quantity of fairly cold fruit is suddenly immersed in it.

2. The input pipe on the circulating system in the treating drum is bent at an angle so that the water is thoroughly agitated at all times.

This apparatus keeps temperature easily within the range of 0.5° C.

After removal from the water the fruit was allowed to dry out and was then placed in refrigerated storage. Periodically the fruit was removed from refrigeration and data indicating the severity of infection of each fruit were taken, usually at several successive intervals. In the early tests the severity of infection was simply estimated on the basis of the percentage of the total fruit surface which had the typical black color of anthracnose lesions. In subsequent tests, however, a more accurate though indirect, method of measuring the area of the anthracnose lesions was devised. This was done by covering the lesions precisely and exclusively with mucilage and, thereafter, sprinkling this surface with florist's "glitter", a colored, metallic dust usually employed for lettering funeral-wreath inscriptions. Differential weighing of the supply of "glitter dust" before and after sprinkling over each fruit gave the weight which adhered to the mucilage and which constituted a reliable index of the extent of the lesioned surface of each fruit. By testing four times on graph paper it was determined that 500 mg. of "glitter" would cover 10 cm.^{2} of surface with a coefficient of

variability of only 6.9 percent. However, we have used the weight data directly without bothering to convert to area.

Following immersion in hot water the fruits were allowed to dry out, were sprinkled with "glitter" to measure the initial extent of anthracnose

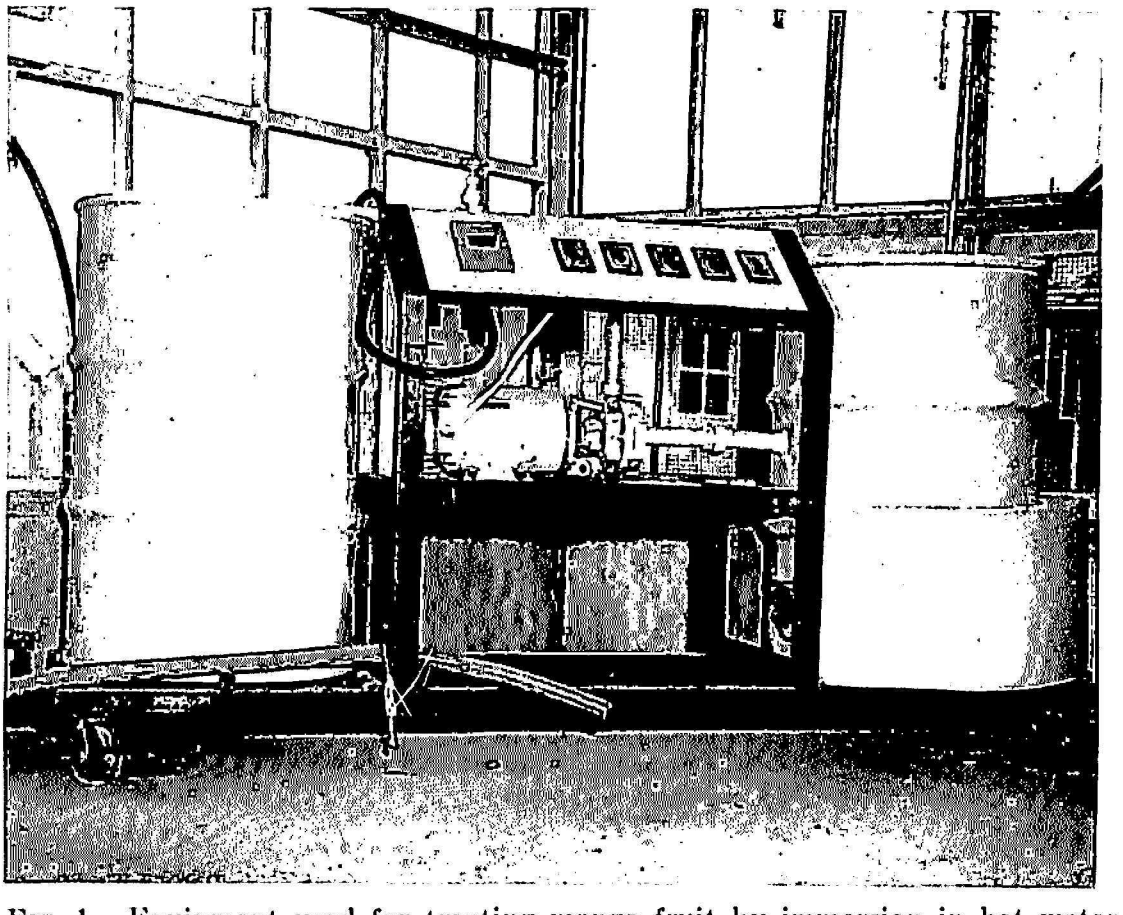

FIG. 1.—Equipment used for treating mango fruit by immersion in hot water. Drum on the right contains heating elements which are controlled individually by switches on the central panel. Fruits are immersed inside of a wire basket which is lowered into the drum on the left. The pump draws water from the right-hand drum and forces it into the top of the left-hand drum at an angle thereby keeping the contents of this drum thoroughly agitated at all times. The valve at the top reduces flow from pump to desired amount. Return flow is by gravity through a 2″ pipe which is partly hidden by lower member of dolly. The union of this pipe is visible just above the open end of hose. Temperatures are read directly from thermometers placed in the left drum. Heat is increased by electrical elements and can be lowered rapidly by adding cold water and draining hot water simultaneously. The large volume of water makes it unnecessary to use delicate thermal controls.

injury, and then were placed in cardboard boxes and subjected to refrigerated storage for 5 days at 47.5° F. Early on the sixth day the fruit was removed from storage but was kept in the boxes until the seventh day when it was again sprinkled with "glitter" to determine the increment in anthracnose injury during storage.

Figure 2 shows such "gilded" fruit in which the initial and subsequent anthracnose injury is covered with "glitter dust". The initial areas were covered with silver glitter and subsequent increase was covered with gold to give contrast for photographic purposes. The variety shown is Sandersha which is unusually susceptible to anthracnose while still green.

FIG. 2.—Mangos of the Sandersha variety which have been sprinkled with metallic "glitter" dust to measure the surface area of anthracnose lesions. Mucilage which was previously painted precisely and exclusively over the injury holds the dust fast. Two different colors of dust were used to distinguish initial injury from that occurring after treatment. The central areas with higher shine are silver in color and were covered immediately after treatment. The peripheral duller areas are in gold and were covered 7 days later. Differential weighing of the supply of "glitter" dust (after sprinkling and quantitative return of surplus) gives a weight index of the extent of the injured surface.

EXPERIMENTAL RESULTS

The early tests were largely exploratory but were useful in determining the ranges in temperature and intervals of immersion which should be included in later experimentation with the intent of reducing anthracnose injury. One of these experiments, however, investigated the possibility that the hot-water treatments might serve the added purpose of killing Anastrepha fly larvae in the fruit. We found dead larvae in a number of the

treated fruit, but live larvae also appeared in some of the fruits that were scalded by excessively severe treatments. Further work with Anastrepha larvae, therefore, was discontinued on the assumption that noninjurious hot-water treatments would not kill some of the deeply imbedded larvae and would, therefore, be unreliable for this purpose.

In table 1 are shown the data obtained in an experiment which was carried out in August and September, 1960, with fruits of the Larrauri mango variety. In this experiment the "glitter-dust" technique was used to obtain a weight index of the extent of the initial anthracnose infection as well as of the subsequent increase in damage during the period of storage and ripening following the treatments with hot water. The 10 treatments used consisted of the untreated control and of immersion in hot water for 5, 15, and 25 minutes at each of three temperatures, namely 45° C., 49° C., and 53° C.

As may be appreciated from a rapid inspection of the treatment means, immersion in hot water held at 45° C. was ineffective at all three immersion intervals. In these three treatments, as well as in the untreated control, the additional damage from anthracnose on the seventh day after treatment was about four to five times as great as the initial damage recorded at the start of the storage period. On the other hand, all the other treatments were effective in markedly reducing anthracnose injury and, when the immersion time exceeded 5 minutes, the increased damage during storage was less than the initial infection.

These data were subjected to analysis of multiple regression which gave the following equation:

$$Y = 5{,}848.5 + 0.6438X_1 - 24.1X_2 + 499X_3 - 7.4X_4$$

In this equation Y, the dependent value, is the anthracnose injury occuring during the storage period after treatment: X_1 denotes the extent of initial infection as indicated by milligrams of "glitter dust" adhering to the surface of the lesions; X_2 is the length in minutes of the immersion period; X_3 is the water temperature in Centigrade; and X_4 is the square of this temperature.

The coefficient for length of the immersion period gave a value which was short of the 5-percent level of significance. On the other hand, the coefficients for regression on initial infection, on temperature and temperature squared were all highly significant.[4]

DISCUSSION

The above equation enables us to determine the optimum treatment for commercial use. In view of the three variables involved, we could con-

[4] The statistical analysis was performed by the Statistical Section of this Agricultural Experiment Station.

ceivably suppress further anthracnose injury by bringing any one of the three factors to optimum value while maintaining the other two at mere adequate levels. However, in practice, we can exercise but very limited control on the factor of initial injury. In figure 3 is shown a graphic representation of the effect of this factor on subsequent anthracnose injury during storage and ripening. The graph is specific for a water temperature of 50° C. and an immersion time of 15 minutes followed by storage up to the seventh day as previously described. As may be seen this is a straight-

TABLE 1.—*Initial and subsequent increase between Aug. 28 and Sept. 3 in anthracnose injury of individual mango fruits as shown by weight in milligrams of "glitter dust" adhering to surface of injured spots*

Milligrams representing extent of injury under treatments indicated							
Immersed control		Immersed 5 minutes		Immersed 15 minutes		Immersed 25 minutes	
Water held at 45° C.							
140	1,610	40	2,450	40	780	180	1,740
120	960	60	2,450	320	2,565	20	410
220	4,550	120	235	30	360	30	2,250
50	1,980	50	420	20	0	60	220
100	585	(1)	(1)	40	500	110	750
30	655	100	725	110	1,065	130	1,315
390	1,830	500	2,320	1,030	2,640	470	875
910	2,180	1,040	4,470	1,340	3,180	1,900	2,240
3,499	4,630	2,140	5,120	320	7,030	60	4,830
3,320	4,710	40	1,190	80	2,010	370	5,670
Total 8,779	23,690	4,090	19,380	3,330	20,130	3,330	20,300
Mean 878	2,369	454	2,153	333	2,013	333	2,030
Water held at 49° C.							
		10	0	260	70	910	0
		60	0	60	65	240	0
		10	0	90	0	10	420
		(1)	(1)	(1)	(1)	70	200
		120	330	30	150	170	570
		10	255	20	0	130	0
		26	170	1,290	200	180	280
		1,050	460	3,510	265	870	15
		670	860	190	0	930	0
		210	330	1,740	35	270	115
Total		2,166	3,405	7,190	785	3,780	1,600
Mean		241	378	799	87	378	160

TABLE 1.—*Continued*

Milligrams representing extent of injury under treatments indicated

Immersed control		Immersed 5 minutes		Immersed 15 minutes		Immersed 25 minutes	
Water held at 53° C.							
		15	0	(2)		(3)	
		195	0	30	0		
		140	275	(2)			
		180	1,010	(2)			
		80	0	320	80		
		30	0	(2)			
		1,040	770	(2)			
		340	1,640	70	130		
		30	100	(2)			
		915	560	2,140	1,190		
Total		2,965	4,355	2,560	1,400		
Mean		297	436	640	350		

[1] Indicates soft rot not caused by anthracnose but which impeded taking data. This rot was associated with Anastrepha larvae infestation.

[2] Scalded.

[3] Scalded and all data in the column therefore discarded.

line relationship. Changes in water temperature or duration of immersion would be expected to shift the line up or down without affecting its slope. Even at the effective levels of temperature and immersion time selected for illustration, however, complete absence of initial injury did not suppress subsequent damage completely. We can only hope to keep initial injury as low as possible. For export we can doubtless keep the initial fruit injury well below an index of 100 mg. On the other hand, however, we may wish to treat cull fruit since it can doubtless be sold locally if further damage can be limited. If possible, therefore, we should select a treatment capable of suppressing damage in fruit having an index of 100 mg. which would roughly coincide with 2 cm.^{2} of lesioned surface.

It would seem logical to assume that the mechanism of hot-water treatment would require some minimum period of immersion for effective heat to penetrate to the full depth of the tissue invaded by the fungus. Moreover, in conformance with elementary thermodynamics, the speed of this penetration should increase as the temperature of the water was increased. In the analysis of multiple regression we have simply tried to find the best fitting straight line commensurate with the data. This may, in fact, be

partly responsible for the lack of significance of this coefficient. Figure 4 shows this linear relationship derived from the equation. As shown by the above discussion we would expect a much better fit from a curve in which the slope would increase with the increase in temperature. Such a curve

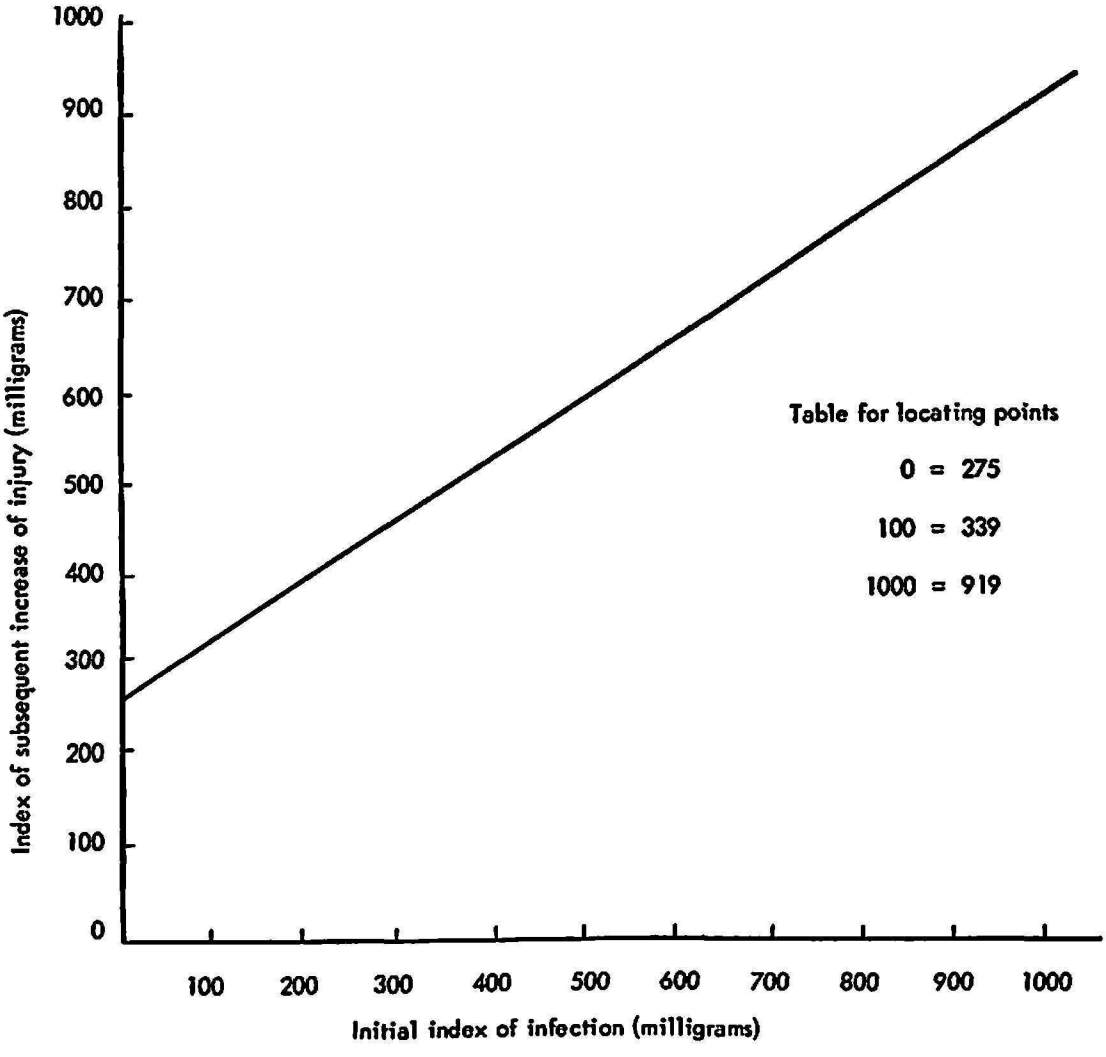

FIG. 3.—Effect of initial extent of infection on subsequent increase of anthracnose injury of mangos during storage. The graph shown is specific for a water temperature of 50° C. and an immersion period of 15 minutes.

would allow for little or no difference between immersion periods at 45°C. when the water was too cold to be effective.

Doubtless we could get some corroboration for the curve postulated above by including the interaction of immersion time and temperature as an additional independent value in a further analysis of multiple regression. This would be laborious, however, and possibly involve excessive manipulation of rather limited data. Its purpose would be to enable us to pinpoint

with considerable theoretical precision the minimum immersion period which would completely suppress further anthracnose damage after treatment with each different, effective temperature. Such precision is, however, subject to the limitations of the data. We have elected instead to recommend the use of the 15-minute immersion period which is convenient and adequate over a considerable range of temperatures.

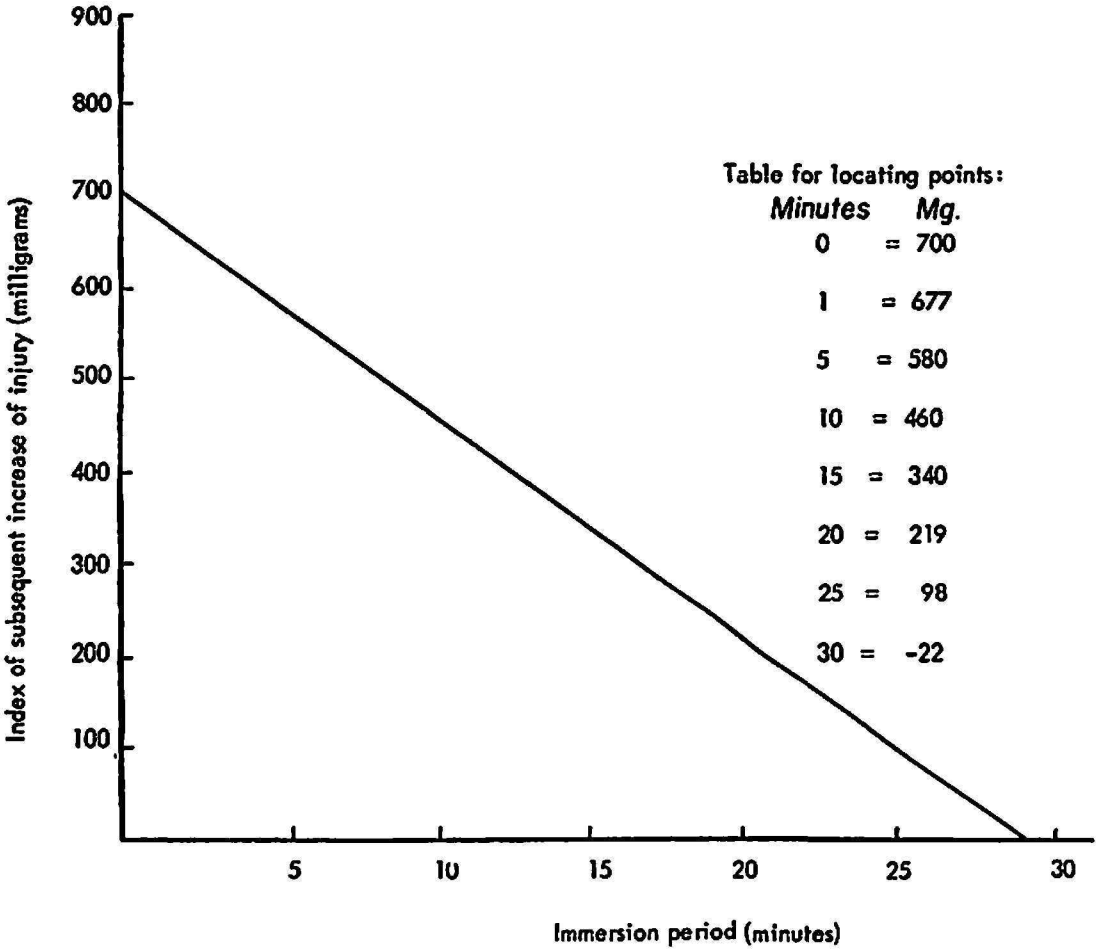

FIG. 4.—Effect of time of immersion on subsequent increase of anthracnose injury of mangos during storage. This graph is specific for a water temperature of 50° C. and fruit having a 100-mg. index of initial infection.

Figure 5 is a graphic representation of the effect of water temperature on further anthracnose damage after treatment. This second-order parabola applies specifically to conditions of the fruit having an initial infection index of 100 mg. and being immersed for 15 minutes. This curve would also be expected to retain its shape and would simply be shifted up or down by changes in either initial infection or time of immersion. We have also calculated additional curves under other conditions to enable us to determine optimum temperatures under various conditions. These temperatures which would suppress completely further anthracnose damage are shown in table 2.

As may be seen, the lowest completely effective temperature tabulated is 49.6° C., but this is contingent on using apparently uninfected fruit and submitting it to immersion for 30 minutes. We have serious doubts, for reasons previously discussed, that the 30-minute period would actually give an appreciably improved performance over a 15-minute period at this

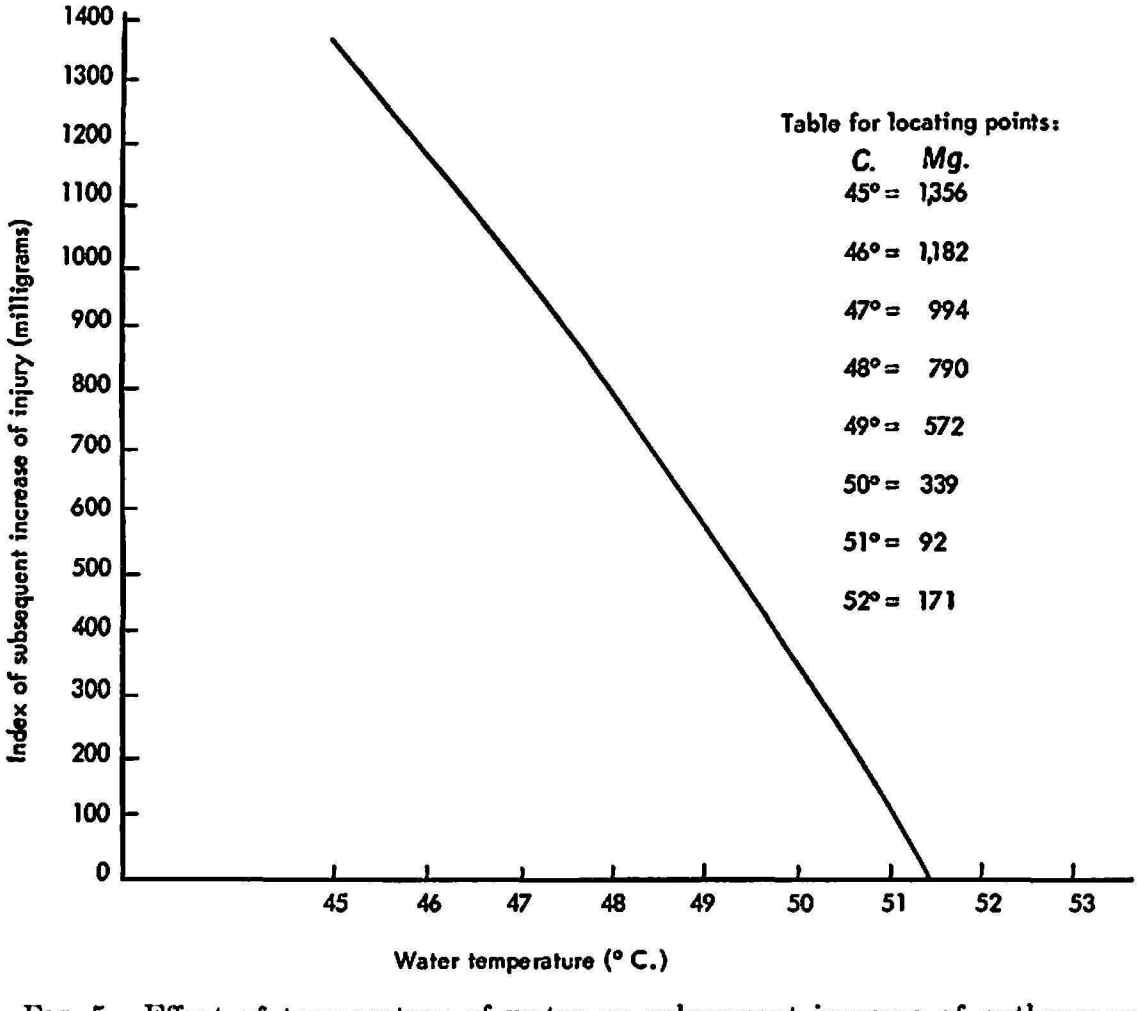

FIG. 5.—Effect of temperature of water on subsequent increase of anthracnose injury of mangos during storage. This graph is specific for fruit having a 100-mg. index of initial infection and for an immersion period of 15 minutes.

same temperature. We are, therefore, inclined to use a higher temperature. Moreover, our equipment for hot-water treatment of mangos would have much greater capacity if the 15-minute immersion period is used. On the other hand, a definite ceiling is imposed on water temperature by the danger of scalding the fruit.

The possible danger of fruit scalding is undoubtedly a consideration of major importance. It will be seen in table 1 that, at 53° C., no scalding occurred during a 5-minute immersion but some of the fruits were scalded when immersed for 15 minutes and all were scalded when immersed for 25

minutes. Apparently, then, the immersion period of 15 minutes is just critical for this temperature. We can also infer that for a 15-minute immersion period a temperature which will scald some fruits and not others must itself be pretty close to the critical temperature for that period. Since

TABLE 2.—*Minimum water temperature required to arrest subsequent anthracnose damage completely under various conditions of initial infection and time of immersion*

Minimum required temperature (°C.)	Immersion time	Index of initial infection
	Minutes	*Milligrams*
49.6	30	0
51.1	15	0
51.3	15	100
51.7	10	100

TABLE 3.—*Observations on mango scalding or nonscalding made with fruit of different varieties on different occasions*

Date of Observation	Variety	Fruits observed	Water temperature °C.	Immersion period	Fruits scalded
		Number	*Degrees*	*Minutes*	
June 10, 1959	Pahiri	9	54.4	20	All
	Alphonse	9	54.4	20	Do.
	Pahiri	9	51.7	20	None
	Alphonse	9	51.7	20	Do.
June 28, 1959	Haden	10	53.9	15	All
	Zill	13	53.9	15	Do.
	Davis Haden	3	53.9	15	Do.
	Haden	10	52.2	15	None
	Davis Haden	3	52.2	15	Do.
June 8, 1960	Huevo de Toro	7	54.4	30	All
		7	51.7	30	None
June 23, 1960	Haden	8	52.0	20	Do.
	Davis Haden	3	52.0	20	Do.
	Zill	2	52.0	20	Do.

our data with respect to scalding are rather scarce, we feel obliged to annotate some of the observations made previously during the course of earlier experiments. These are shown in table 3.

As may be observed, all of the above observations confirm that temperatures of 52° C. or lower do not cause scalding of mango fruits of the

varieties used at the immersion periods indicated. Temperatures above 53° C. did cause scalding in immersion periods as short as 15 minutes.

We, therefore, recommend immersion of mangos for 15 minutes in hot water to be held at 51° to 51.5° C. We have allowed a safety margin of 0.5° C. and emphatically caution that under no circumstances should the heat of the water be allowed to exceed 52° C. Immersion periods as low as 10 minutes may give good results but we prefer not to recommend this practice at this time.

SUMMARY

1. Anthracnose damage was greatly reduced in mango fruit picked at shipping maturity and immersed in hot water before storage and subsequent ripening.

2. The equipment and method of treating the fruits are described and discussed.

3. A precise technique which was devised for measuring anthracnose damage before and after storage is also described.

4. Immersion of the fruit for 15 minutes in water held at temperatures between 51° C. and 51.5° C., with a safety margin of 0.5° C., is recommended for commercial practice before packing and shipment. Water temperature must be kept below 52° C. to prevent possible scalding of the fruit.

RESUMEN

1. El daño causado por la antracnosis durante almacenamiento y maduración de frutas de mango fue marcadamente reducido mediante su tratamiento con agua caliente.

2. Aquí se describe detalladamente el equipo empleado y la forma de tratar la fruta.

3. Se describe también un nuevo método muy preciso empleado para medir el alcance del daño causado por la antracnosis, tanto antes como después del almacenamiento y maduración de la fruta.

4. Se recomienda como práctica comercial sumergir la fruta durante 15 minutos en agua caliente antes de embalarla para embarque. El agua debe mantenerse entre 51° C. y 51.5° C. manteniendo así un margen de seguridad de 0.5° C. ya que de subir a 52° C. puede salcochar la fruta.

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