HAWAII AGRICULTURAL EXPERIMENT STATION
of the
UNIVERSITY OF HAWAII
CIRCULAR NO. 17

METHYL-BROMIDE FUMIGATION OF PAPAYA AND TOMATO

by

WINSTON W. JONES, Assistant Horticulturist

HONOLULU, T. H.
August 1940

HAWAII AGRICULTURAL EXPERIMENT STATION

of the

UNIVERSITY OF HAWAII

D. L. CRAWFORD, President
University of Hawaii

J. H. BEAUMONT, Director
Hawaii Agricultural Experiment Station

CONTENTS

Acknowledgment

The author and the director wish to express their appreciation to Mr. O. C. McBride, of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, for his cooperation in supplying the methyl bromide and furnishing the equipment for the experimental work discussed herein.

Earlier work (not here reported) was done in cooperation with Mr. L. A. Whitney, of the Territorial Plant Inspection Office.

INTRODUCTION

Since November 1, 1938, Hawaiian-grown fruits and vegetables have had the right of entry to mainland United States, provided they had undergone one of two treatments, designed to destroy the Mediterranean fruitfly and the melonfly and approved by the U. S. Bureau of Entomology and Plant Quarantine.

One, a cold treatment, has been found to produce a "chilling" effect on most tropical fruits; it is, therefore, not considered practical in Hawaii.

The second, known as the vapor-heat treatment, has been tested experimentally and applied to all commercial shipments of Hawaiian fruits and vegetables previously barred from the mainland. Vapor-heat sterilization has been discussed more fully in Circulars 14 and 16, issued by this station (*2, 3*).[1]

Effective as of August 1, 1940, a third method of sterilization has been approved for specific Hawaiian agricultural crops, namely: papaya, guava, bell pepper, bitter melon, cucumber, summer squash, string bean, and tomato. The method consists of fumigation, with methyl bromide, 2 pounds per 1,000 cubic feet, for 3½ hours at atmospheric pressure and at a temperature not less than 80° F.

The experiment station has been studying methyl-bromide fumigation for several years, and it is the purpose of this circular to present the available information which may be of value to prospective shippers. It must be remembered, however, that only laboratory experimentation has been possible heretofore. Experimental shipments, which are planned for the near future, may bring to light new factors and lead to changes in recommendations.

Nature of Methyl Bromide

Methyl bromide is a poisonous gas and should be handled as such. It is colorless and practically odorless in concentrations used for fumigation. Any operator working with the gas should use an approved gas mask.

This is a relatively new gas in the field of fumigation. Although the efficiency of methyl bromide as a fumigant has been tested, there

[1] Reference is made by number (*italic*) to Literature Cited, p. 14.

has been relatively little study of the physiological effects of the gas on plants. In general, plants are more tolerant to methyl bromide than to certain other fumigants—hydrocyanic acid or carbon tetrachloride. Mackie (*4*) found that green beans, bell peppers, tomatoes, and other fruits were uninjured by treatment at the rate of 2½ pounds of methyl bromide per 1,000 cubic feet for 1½ hours, under a 20- to 27-inch vacuum. Coloring was slightly delayed in tomatoes.

EXPERIMENTAL RESULTS

Of the crops included in the authorization for methyl-bromide fumigation, papayas and tomatoes are of chief commercial importance locally at present, and physiological studies have been made on the effect of fumigation on these two fruits at various stages of maturity. Data were obtained on color development, absorption of methyl bromide, and holding qualities after treatment. Unless otherwise specified, all experimental fruits were treated for 3½ hours with methyl bromide at the rate of 2 pounds per 1,000 cubic feet.

Papaya

Color Development. The most obvious effect of methyl bromide on the papaya is a retardation in coloring. This effect varies with the maturity of the fruit at the time of treatment and with the dosage and length of treatment. Mature-green fruits are affected more than firm-ripe fruits. The color of the ripe fruits is fully established before treatment and does not change.

Papayas treated with 2 pounds of methyl bromide and held at room temperature ripened 3 to 4 days later than untreated fruits. When held in cold storage (50° F.) for 6 days, check and treated fruits varied by only 2 to 3 days in ripening. Greater loss from decay occurred in the treated fruit, a factor which will be discussed more fully later.

Coloring, as well as catalase activity in the papaya, is an index of ripening. That methyl bromide retards coloring has been pointed out. As a further indication that retardation of the ripening process does occur, table 1 shows the effect of methyl bromide on catalase activity.

Table 1.—Effect of methyl bromide on catalase activity in papayas treated firm ripe and held until ripe (each figure average of 3 fruits)

Lot	Catalase activity					
	Immediately before treatment	Immediately after treatment	24 hours after treatment	48 hours after treatment	5 days after treatment	7 days after treatment
Check lot, held at room temperature	16.7	.....	15.4	11.7	.....	.....
Methyl-bromide-treated fruits, held at room temperature	14.4	4.4	1.6	1.6	.....	.....
Check lot, held at 50° F. for 5 days, then at room temperature for 2 days	12.5	.....	.....	.....	8.4	5.8
Methyl-bromide-treated fruits, held at 50° F. for 5 days, then at room temperature for 2 days	12.8	.....	.....	.....	3.1	2.5

Absorption of Methyl Bromide. If fumigation is to be effective against the Mediterranean fruitfly and the melonfly, it is necessary for the bromide to penetrate the fruit. This it does, as shown in table 2.

Table 2.—Absorption and retention of methyl bromide by papayas treated firm-ripe and held until ripe (composite sample of 3 fruits from lot of 24)

Time of analysis	Methyl bromide[1] per kilogram of fruit	Loss in methyl bromide
	Milligrams	*Percent*
Immediately after treatment	27.2	
After 3 days at room temperature	27.0	*0.7*
After 5 days at 50° F. plus 3 days at room temperature	14.2	*47.8*

[1] Bromide determined, then expressed as methyl bromide.

Holding Qualities. The chief causes of loss in papayas between time of harvesting and marketing are decay organisms. Normally such organisms do not develop until the fruit is slightly overripe, due to a natural resistance of papaya, but treatment with methyl bromide causes a premature loss of resistance with a consequent reduction in holding qualities. This premature loss of resistance to infections by tropical fruits, due to chill in cold storage and certain chemical treatments, has been pointed out by Wardlaw et al. (*5*).

Among the organisms which reduce the storage period for papayas are included wound parasites, such as *Rhizopus* and *Penicillium* species, which enter the fruit through breaks in the skin.

More serious because less avoidable are such organisms as *Colletotrichum* and *Phytophthora,* which cause latent infections in uninjured fruits. Infection may occur at any time during development, remaining dormant until the fruit has ripened or until environmental conditions within the fruit are favorable.

That decay losses are more serious in methyl-bromide-treated fruits may be seen from table 3.

Table 3.—Relation of methyl bromide to decay in papayas treated firm-ripe and held until ripe

Lot	Number of fruits treated	Number of fruits showing decay	Percentage of fruits showing decay
Check lot, held at room temperature for 4 days	19	3	*16*
Methyl-bromide-treated fruits, held at room temperature for 4 days (fruits treated for only 2 hours)	17	7	*41*
Check lot, held for 6 days at 50° F., plus 2½ days at room temperature	12	1	*8*
Methyl-bromide-treated fruits, held for 6 days at 50° F., plus 2½ days at room temperature	12	8	*67*

Anthracnose [*Colletotrichum* sp. (*gloeosporioides*?)] is the chief cause of loss in papayas treated with methyl bromide (see fig. 1). Cold storage retards the development of the organisms, but mature-green or firm-ripe fruits must be held at room temperature for several

days after cold storage in order to ripen. It is during this ripening period that anthracnose develops most rapidly on treated fruits.

Figure 1.—Papayas harvested firm-ripe, held in storage at 50° F. for 6 days, then allowed to ripen for 2 days at room temperature: Fruit at left from check lot; fruit at right treated with methyl bromide. Note spots on treated fruit indicating decay due to anthracnose.

Tomato

Color Development. In tomatoes as well as papayas, fumigation with methyl bromide causes a marked retardation in coloring. This delay amounts to 3 to 4 days for "pinks" and 4 to 6 days for mature-green fruits held at room temperature.

When tomatoes were placed in cold storage (50° F.) immediately after treatment and held for 6 days, 6 additional days at room temperature were required for the pink fruits to ripen, while some of the mature-green fruits decayed without ripening.

Absorption of Methyl Bromide. A small quantity of methyl bromide is absorbed and retained by tomatoes, as may be seen from table 4. This residue could not be detected by taste, since the flavor of tomatoes is less delicate than that of papayas.

Table 4.—Absorption and retention of methyl bromide by tomatoes treated pink and held until ripe (composite sample of 6 fruits from lot of 42)

Time of analysis	Methyl bromide[1] per kilogram of fruit	Loss in methyl bromide
	Milligrams	*Percent*
Immediately after treatment	32.8	
After 4 days at room temperature	26.1	*20*
After 7 days at 50° F., plus 4 days at room temperature	22.8	*30*

[1] Bromide determined, then calculated as methyl bromide.

Holding Qualities. Tomatoes are far less subject than the papaya to latent infections, and the period of 3 to 6 days at room temperature required for ripening is not a serious handicap.

With this fruit, according to Baker (*1*), most serious loss is due to wound parasites. To date experimental results have not indicated that methyl-bromide fumigation seriously increases this loss. It is, however, of utmost importance to the shipper that only fruits free from mechanical damage, growth cracks, blossom end rot, and insect injuries be treated.

Since cold storage delays the ripening time of tomatoes, mature-green fruits should be held at room temperature after treatment, until pink, and then placed in cold storage at a temperature of 50° to 60° F.

DISCUSSION

Application of Methyl Bromide

Methods of applying methyl bromide (bromomethane) are under the supervision of the U. S. Bureau of Entomology and Plant Quarantine and must meet the approval of the Federal inspector. However, certain general requirements justify discussion.

First, the operator must provide a suitable fumigation chamber. It should be metal-lined, and all openings for ventilation and entrance must be so constructed that the chamber, when closed, will be gas-tight at atmospheric pressure. If the same chamber is to be used for methyl-bromide fumigation as for vapor-heat sterilization, provisions should be made for sealing the vapor-heat mixing chamber.

The room must be equipped with a fan capable of circulating the air at least once every 3 minutes; otherwise the methyl bromide, being about 3½ times as heavy as air, would tend to stratify.

Heat must be provided to attain the specified temperature of 80° F. after the room is loaded (not more than 4 hours should be necessary). In a closed room of this type one or more electric light bulbs should supply sufficient heat. The bulbs should be connected to a thermostat, to maintain the proper temperature. An exposed-wire electric heater cannot be used.

In estimating the dosage of methyl bromide (2 pounds per 1,000 cubic feet), the space occupied by the material to be fumigated must be included. The gas should be discharged into the room immediately in front of the fan, to be diluted with air instantly. Severe injury occurs when liquid methyl bromide comes in contact with the fruit.

The methyl bromide is usually injected by an applicator especially designed for this purpose, or it can be injected from the original cylinder by means of copper tubing. The cylinder is placed on a scale and the proper dosage is weighed out and forced through the copper tubing by the vapor pressure of the liquid.

After fumigation the room should be thoroughly aired before entrance without a gas mask.

The fruits, not yet wrapped, are packed loosely in the fumigation chamber. The room should have a false floor to provide for complete circulation. After treatment the product is wrapped and packed in an approved screened packing room and transferred, under canvas, to a refrigerated space on the boat.

Methyl-Bromide Versus Vapor-Heat Sterilization

Two factors must be considered in determining whether the methyl-bromide fumigation should replace the previously authorized vapor-heat treatment—cost of operation and probable loss ratio.

While no exact figures are available, the vapor-heat treatment would appear to be the more costly. The expense of constructing a vapor-heat chamber would be greater, since better heat insulation and machinery for supplying the vapor heat are necessary. Cost of operation would probably favor the methyl-bromide treatment, also, since the 2 pounds of gas required for 1,000 cubic feet cost only $1.70, and the time of operation is about one-half of that required for heat sterilization.

Percentage of loss of the treated product is less readily established than expense. It depends on such factors as type of fruit, degree of maturity, and presence of decay organisms, and will be determined by varietal selection, clean cultivation, adequate spraying, and careful handling.

Very little loss should occur when tomatoes are fumigated with methyl bromide, provided that the general recommendations are followed. Tomatoes also tolerate the vapor-heat treatment well, so that the aspect of cost would determine the preferred treatment.

Papayas, on the other hand, have so far been subject to greater loss when treated with methyl bromide. Unless fruits free of anthracnose can be obtained, vapor-heat sterilization may be the more economical treatment. The experiment station will continue to study this point.

SUMMARY

Papaya

1. Fumigation with methyl bromide (2 pounds per 1,000 cubic feet for 3½ hours) reduces the catalase activity of the papaya and causes a delay of 3 to 4 days in the ripening of firm-ripe fruits.

2. Papayas absorb and retain small quantities of methyl bromide. This residue imparts a slight taste to the fruits.

3. Anthracnose [*Colletotrichum* sp. (*gloeosporioides*?)] is the chief cause of loss of methyl-bromide-treated papayas.

Tomato

1. Fumigation with methyl bromide delays ripening of the tomato from 3 to 6 days, depending on the maturity of the fruits.

2. The small amounts of bromide retained do not affect the quality of tomatoes.

3. Decay is not increased in tomatoes, in most cases, by the methyl-bromide treatment. It is of utmost importance, however, that only sound fruit be fumigated.

RECOMMENDATIONS

Based on the experimental work to date, the following recommendations may be made for the treatment of papayas and tomatoes with methyl bromide. These recommendations are subject to change as more experimental data accumulate.

Papaya

1. Clean fruits are essential. Papayas to be treated with methyl bromide should be free from latent infections of *Colletotrichum* sp. (*gloeosporioides*?). It may be necessary to employ a spray program.

2. Papayas should be as ripe as can be handled without bruising—at least firm-ripe. Care in handling is always of the utmost importance. A bruise or skin break on a fruit reduces its holding qualities and increases the percentage of loss.

3. Methyl-bromide-treated papayas should be placed in cold storage, at a temperature of 50° to 60° F., immediately after treatment.

Tomato

1. Tomatoes to be treated with methyl bromide should be free of all skin breaks and bruises.

2. "Pinks" should be placed in cold storage, at a temperature of 55° to 60° F. immediately after treatment with methyl bromide. Mature-green fruits should be held at room temperature until they become pink before they are placed in cold storage.

Note: All treatments are under the direction and supervision of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture. For details of treatment see this Bureau.

LITERATURE CITED

1. BAKER, R. E. D.
1939. *Notes on the diseases and fruit rots of tomatoes in the British West Indies.* Trop. Agr. (Trinidad) 16:252-257.

2. JONES, W. W.
1940. *Vapor-heat treatment for fruits and vegetables grown in Hawaii.* Hawaii Agr. Expt. Sta. Cir. 16, 8 pp.

3. ————, HOLZMAN, J. J., and GALLOWAY, A. G.
1939. *The effect of high-temperature sterilization on the Solo papaya.* Hawaii Agr. Expt. Sta. Cir. 14, 8 pp.

4. MACKIE, D. B.
1938. *Methyl bromide—Its expectancy as a fumigant.* Jour. Econ. Ent. 31:70-79.

5. WARDLAW, C. W., BAKER, R. E. D., and CROWDY, S. H.
1939. *Latent infections in tropical fruits.* Trop. Agr. (Trinidad) 16:275-276.