HOT AIR--ALTERNATIVE QUARANTINE TREATMENT FOR METHYL BROMIDE FUMIGATION TO DISINFEST FRUITS

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Hot air is the application of recirculated air that has been heated and humidified and then forced over fruit surfaces to raise the temperature of the fruit pulp or surface to a temperature that is lethal to the target pest species. Condensation on fruit surfaces or in the treatment chamber is prevented by keeping the dew-point temperature 2 - 3 C below the dry-bulb temperature throughout the duration of the test. Fruit moisture loss is reduced. The relative humidity of the chamber increases during the treatment. The heating process and research equipment have been described by Gaffney and Armstrong (1990) and Sharp et al. (1991). The three hot air devices used in Miami at the Subtropical Horticulture Research Station are controlled by computer and cost $20,000 each to build in 1990. Similar devices are in use at Weslaco, Texas and Orlando, Florida. Commercial facilities are in place in Hawaii (Williamson and Winkelman 1989). The possibility that exposure to hot air could reduce the quality of commodities requires research to investigate the chances before a treatment is recommended. Some fruit such as mango could exhibit acceptable damage, whereas most commercial cultivars of avocado turn black when exposed to hot air.

Research is ongoing to develop new hot air quarantine treatments. In the literature at least ten different fruit types and eleven different pests have been treated using hot air. The treatment is not suited for all commodities, can damage some fruits and vegetables, and must be evaluated for its effect to commodity quality for each new commodity. Hot air treatments that have been developed to disinfest commodities are discussed.

PAPAYA. A four stage disinfestation treatment approved by the Animal and Plant Health Inspection Service (APHIS), Plant Pest and Quarantine (APHIS 1994) uses four temperature stages to disinfest Hawaiian-grown papaya of immature stages of Mediterranean fruit fly, Ceratitis capitata (Wiedemann), oriental fruit fly, Bactrocera dorsalis (Hendel), and melon fly, Bactrocera cucurbitae (Coquillett). The four stage treatment forces 43 ± 1, 45 ± 1, 46.5 ± 1, and 49 ± 0.05 C air over the papayas until the centers reach 41 ± 1.5, 44 ± 1, 46.5 ± 0.75, and 47.2 C, respectively (Armstrong et al. 1989). The purpose of the slow increase in temperatures was to help reduce damage by allowing the fruit to become conditioned to the heat. The treatment has been refined by J.W. Armstrong (unpublished data) who developed a single stage treatment that disinfested papaya after they were

heated to 47.2 C in the cavity. APHIS allows papaya from Hawaii to be shipped to the USA if the papaya have received the four stage treatment (APHIS 1994). Also, APHIS accepts the use of hot air as a quarantine treatment for papaya from Belize. A proposed rule published in the Federal Register will have to be published before hot air is approved for papaya from Belize. Armstrong et al. (1989) reported that papaya treated with hot air showed no evidence of external scalding, almost no internal hard spots that often are present following treatment with hot water, no aberrant ripening, and exhibited better quality than papaya treated with either hot water immersion or vapor heat.

CARAMBOLA. A single stage quarantine treatment forced 47 ± 0.2 C air over carambola surfaces until the center pulp was ≥45.5 C and provided security against stages of Caribbean fruit fly, Anastrepha suspensa (Loew) (Sharp and Hallman 1992). Miller et al. (1990) evaluated the quality and characteristics of Florida-grown carambola after the fruit had been treated with air at 47, 48, and 49 C for 90, 120, and 150 minutes, and following cold storage at 4.4 C for 1 - 2 weeks plus three days at 15.6 C. They reported that carambola treated at 47 C for 90 and 120 minutes and then refrigerated were generally more acceptable to consumers than fruits treated at higher temperatures. The most common adverse effect readily visible is slight browning of the ribs.

MANGO. Two studies have been published that describe methods to disinfest mangos using hot air. Mangan and Ingle (1992) discovered that immatures of West Indian fruit fly, Anastrepha obliqua (Macquart) in 'Tommy Atkins,' 'Keitt,' 'Haden,' and 'Kent' Mexican-grown mangos were killed when mangos were treated with 50 C until the seed surface was 48 C. Sharp (1992) discovered that immatures of Caribbean fruit fly in 'Tommy Atkins,' and 'Keitt' Florida-grown mangos were killed when fruits were treated with 48 ± 0.3 C air until the seed surface was ≥44 C. Miller et al. (1991) reported no adverse effects on fruit quality of 'Tommy Atkins' mangos treated with 51.5 C air for 125 minutes, then stored for 1, 2, or 3 weeks at 12 C before ripening at 21 C. McGuire (1991) reported that hot air was an acceptable treatment, it reduced anthracnose disease in treated mangos, but the treatment was not as effective as immersion in 46 C water. Mangan and Ingle (1992) reported no adverse effects to the fruit quality of mangos from Mexico treated with 50 C air until the seed surface was 48 C.

CITRUS. Sharp (1989) first showed that grapefruit could be treated with hot air and reported that 'Marsh' white grapefruit from Florida treated with hot air at 46 C for three hours was not damaged. The results provided impetus to develop hot air as a quarantine treatment for citrus. R.L. Mangan and S.J. Ingle (unpublished data) developed a

hot air treatment against Mexican fruit fly, Anastrepha ludens (Loew), immatures in 'Marsh' white and 'Marsh' pink grapefruits from California. Grapefruit was heated with 50 C air until the center pulp was 48 C. APHIS incorporated a treatment schedule into the Plant Protection Manual based on their results (APHIS 1994). Grapefruit are allowed into the USA from Mexico if disinfested of Mexican fruit fly. Grapefruit must have a diameter from 9 to 9.5 cm, weigh from 262 to 402 grams, have an internal pulp at 25 C or above and then be exposed to heated air at 40 C for 120 minutes, heated air at 50 C for 90 minutes, and heated air at 52.2 C until the fruit center reaches 47.77 C. Sharp (1993) developed a hot air treatment against Caribbean fruit fly immatures in Marsh' white Florida-grown grapefruit. Infested grapefruit was heated with 48 ± 0.3 C air until the center pulp was ≥44 C. Grapefruit heated with hot air can be hydrocooled immediately after disinfestation to reduce the possibility of latent heat damage (Sharp and Gould 1994). Japan encourages the shipment to their consumers of Florida grapefruit that has been harvested from fly-free zones instead of fruit that has been fumigated with methyl bromide, exposed to low temperatures, or heat treated. It seems doubtful that industry will use the hot air technology. J.L. Sharp is currently developing a hot air treatment against Caribbean fruit fly in naval oranges from Florida. Efficacy studies showed that 48 ± 0.3 C air forced over the fruit surfaces kills all immatures if the pulp center is ≥44 C. A confirmatory test is underway. McGuire (1991) and McGuire and Reeder (1992) reported that 48 C air for three hours did not affect juice characteristics or reduce the quality of treated grapefruit although early-season and late-season grapefruits were more easily damaged by the treatment compared with mid-season fruit. R.L. Mangan and S.J. Ingle (upublished data) found no adverse effects to the quality of 'Marsh' white and 'Marsh' pink grapefruits from California exposed to air at 50 C until the pulp was 48 C. Shellie et al. (1993) treated early-season degreened 'Dancy' tangerines at either 45, 46, or 48 C for 0, 1, 2, 3, or 4 hours and then stored them for 1, 2, and 3 weeks at 4 C. They reported inferior flavor and darkened flavedo tissue when fruit was treated at 46 or 48 C. Fruit treated with 45 C air had color changes in the flavedo but percent juice yield, soluble solids concentration and flavor ratings were similar to the ratings for untreated fruit.

PERSIMMON. Cowley et al. (1992) discovered that a fruit surface temperature of 47 C at 55 - 60% RH for 15 minutes killed adult thrips, Heliothrips haemorrhoidalis (Bouche), fifth instar leafrollers, Epiphyas postvittana (Walker), and mealybugs, Pseudococcus longispinus (Targioni-Tozzetti) present on the fruit surface. 'Fuyu' persimmons treated with 47 C air at 55 - 60% RH for 15 minutes were not damaged and retained fruit firmness, soluble solids concentration,

appearance, and shelf life (Cowley et al. 1992).

STONEFRUIT (summerfruit). McLaren et al. 1991 discovered that Thrips obscuratus (Crawford), on New Zealand nectarines, was controlled by 38 - 40 C applied for 12 hours. Waddell et al. (1990) and Waddell and Birtles (1992) found that twospotted spider mite, Tetranychus urticae Koch, preconditioned for 28 - 30 days at 15 C were killed on nectarines by exposure to air at 46.7 C for 15.5 hours or 43.9 C for 34 hours. Total mortality was observed when mites were preconditioned at 4 C for 5 - 15 days after exposure to 48.2 C for 28 hours. Total mortality of nondiapausing mites was reached after the mites were exposed to temperatures betweeen 43.2 and 46 C for 24 hours. McLaren et al. (1990) reported no damage to summerfruit exposed to 38 - 40 C for 12 hours at Clyde, New Zealand although similar trials done at Auckland produced flesh breakdown and greater incidence of postharvest rots. Lay-Yee et al. (1991) reported that the quality of 'Fantasia' nectarines was unaffected by exposure to 40 C at 95% RH for 12 hours.

LYCHEE. No information is available using hot air to disinfest lychee. Florida-grown lychee exposed to 46 - 47 C exhibited peel color changes from a normal deep red to an unacceptable light brown color within one hour of exposure (JLS unplublished data).

AVOCADO. No information is available using hot air to disinfest avocado. Kerbel et al. (1987) reported that 43 C air applied from 3.5 to 12 hours to California-grown 'Fuerte' avocados was too damaging and not recommended. The RH was not controlled or reported. Avocados were not infested and internal pulp temperatures were not reported.

The Animal and Plant Health Inspection Service has approved three hot air quarantine treatments (APHIS 1994). Grapefruit and mango from Mexico and papaya from Hawaii may be imported into the USA if the fruits have been properly treated at a certified facility. Fruit flies of concern are Mexican fruit fly in grapefruit from Mexico; Mediterranean fruit fly, oriental fruit fly, and melon fly in papaya from Hawaii; and Mexican fruit fly, West Indian fruit fly, and black fruit fly in mango from Mexico. Other quarantine pests of concern that are reported to be killed with hot air are light brown apple moth, longtailed mealybug, greenhouse thrips, and Thrips obscuratus. Hot air treatment did not kill twospotted spider mite. Seven fruits shown to tolerate treatment with hot air are mango, grapefruit, tangerine, orange, carambola persimmon, and papaya. Hot air is not recommended for avocado, lychee, and nectarine at temperatures needed to disinfest them of quarantine pests.

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