Decay and Acceptability of Mangos Treated with Combinations of Hot Water, Imazalil, and γ-Radiation

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ABSTRACT

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Combination treatments with radiation at 200 or 750 Gy and hot water (53 C) or hot 0.1% a.i. imazalil (53 C) for 3 min were more effective than single treatments for control of anthracnose and stem-end rot of Tommy Atkins mangos caused by *Colletotrichum gloeosporioides* and *Diplodia natalensis* or *Phomopsis citri*, respectively. Irradiation at 750 Gy inhibited development of ripe skin color and caused some browning and pitting of the skin. Effects of radiation on skin color and injury were partially offset when heat treatment preceded irradiation. Individual wrapping of mangos in shrink film resulted in increased decay and breakdown.

Anthracnose, caused by *Colletotrichum gloeosporioides* Penz., and stem-end rot, caused by *Diplodia natalensis* P. Evans or *Phomopsis citri* Fawc., are the major causes of loss in Florida mangos (*Mangifera indica* L.) during marketing. No postharvest fungicide treatment has been approved for use in the United States. The only postharvest treatment used commercially for decay control in Florida is immersion in, or drenching with, hot water (53 C) for 3 min. Time and temperature of hot water treatment must be adjusted to ensure that a given cultivar is not injured. The hot water treatment (55 C for 5 min) previously used in Florida (7,12) was effective for decay control but could injure Keitt mangos stored at 13 C (15). Addition of various fungicides has been reported to increase the effectiveness of the hot water treatment for disease control (10,15). γ-Irradiation of mangos at dosages of 1,050–2,100 Gy (105–210 Krad) reduced anthracnose incidence, but increased control of decay was obtained with irradiation combined with hot water treatment (1). A combination of hot water (55 C for 5 min) with radiation (750 Gy) is used commercially for treating mangos in South Africa and is reported (16) to act synergistically to control anthracnose and soft brown rot (*Hendersonia creberrima* Syd. & Butl.) of mangos in addition to providing quarantine control of the mango seed weevil (*Sternochetus mangiferae* Fab.). Low-dose irradiation (not to exceed 1,000 Gy) was approved in 1986 for treating fresh fruits and vegetables in the United States, but additional data on beneficial effects and cultivar tolerance, as with mangos for example, are needed to warrant such use.

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This paper reports the results of research to determine the effects of various combinations of hot water, imazalil fungicide, and γ-irradiation on decay and acceptability of Tommy Atkins mangos.

MATERIALS AND METHODS

Mature-green Tommy Atkins mangos were obtained from a local packinghouse and sorted into similar lots of 24 fruits per treatment according to size, appearance, and freedom from decay and injury. Three replicates were run during each of the 1984 and 1985 mango seasons, with each replicate representing a different picking from June through July in South Florida. Each lot was dipped in tap water for 3 min at 27 C (unheated control) or 53 C (heated control), with or without imazalil at 0.1% a.i. (w/v) and with or without irradiation at 200 (1984 test) or 750 Gy (1985 test). The imazalil was a 1.125% EC formulation of 1-[2,4-dichlorophenyl)-4-ethyl-1, 3-dioxolan-2-yl-methyl]-1H-1,2,4-triazole. Heat treatments were done using equipment and procedures described previously (11). Irradiation, within 2 hr of an aqueous immersion treatment, was accomplished with a laboratory-type irradiator (Gammacel 220), using a cobalt-60 source at a dosage rate of 250–299 Gy/min. Air was continuously blown through the irradiation chamber to prevent the accumulation of ozone, which would possibly cause fruit injury.

In the 1984 test, duplicate treatments were conducted to determine if the treatments could prevent decay when mangos were wrapped individually with a heat-shrinkable film after the aqueous immersion treatments and before irradiation and storage. Wrapping was done with Cryovac 955, a cross-linked polyolefin film 0.6-mil thick. The film was applied to each fruit with a Weldotron model 6001 hot-wire sealer, then shrunk by passage through a Weldotron model 7001 heat tunnel (9).

After treatment, all fruit (wrapped and nonwrapped) were stored for 16–21 days (1984 test) or 16–17 days (1985 test) at 13 C followed by ripening at 24 C. Each mango was examined for injury and decay as soon as it ripened to a stage soft enough to eat.

Skin injury, based on percentage of surface area affected, was rated on a scale of 1–9, where 1 = none, 2 = up to 10%, 3 = 11–20%, 4 = 21–30%, 5 = 31–40%, 6 = 41–50%, 7 = 51–60%, 8 = 61–70%, and 9 = 71% or more.

Anthracnose decay, based on the percentage of surface area showing symptoms, was rated on a scale of 1–9, where 1 = none, 2 = up to 1%, 3 = 1–2% (trace), 4 = 3–5%, 5 = 6–10% (slight), 6 = 11–15%, 7 = 16–20% (moderate), 8 = 21–50%, and 9 = 51% or more (severe). Stem-end rot, based on the greatest surface distance spread from the stem, was rated from 1–9, where 1 = none, 2 = up to 1.5 mm, 3 = 1.6–3.0 mm (trace), 4 = 3.1–6.5 mm, 5 = 6.6–12.5 mm (slight), 6 = 12.6–19.0 mm, 7 = 19.1–25.0 mm (moderate), 8 = 25.1–37.5 mm, and 9 = 37.6 mm or more (severe).

Mangos at the soft-ripe stage (edible stage in which flesh yields readily to finger pressure but is not mushy or overripe) with no more than slight skin injury and no more than slight (rating of 5) anthracnose or stem-end rot, or with less than slight amounts of a combination of both decays, were considered acceptable for sale and consumption. Mangos with more than these amounts of decay were included in the calculation of percent decayed fruit.

Data were analyzed statistically by analysis of variance. Percentages were converted to the arc sine of the square root of the percentage for analysis. Duncan's multiple range test was used to determine mean separation at $P = 0.05$.

RESULTS

Ripening and appearance. Immersion of mangos in hot imazalil solution followed by irradiation (200 Gy) retarded ripening in the 1984 test (Table 1). Ripe skin color developed to a lower percentage in mangos treated with unheated water plus radiation than in mangos treated with unheated water or unheated or hot imazalil. A blotchy appearance of the skin was noted in some of the mangos after treatment and storage. Blotchy, reddish patches developed in the area around the lenticels. The cause of the condition is not known, but less blotchiness was found in irradiated mangos with or without hot water treatment. The condition was rated as skin injury.

Hot water or hot imazalil plus radiation (750 Gy) treatment delayed ripening in the 1985 test (Table 1). Development of ripe skin color was significantly reduced in all irradiated mangos, especially in those given unheated water or unheated imazalil treatment plus radiation. The blotchy skin condition noted in 1984 did not develop on any mangos treated in 1985. Irradiated mangos did, however, develop a brown scaldlike skin injury, which was most serious in mangos treated with unheated water plus radiation or unheated imazalil plus radiation. Again, as with the development of ripe skin color, heat treatment appeared to modify the injurious effect of radiation. The percentages of mangos showing more than slight amounts of skin injury were 4.2 for hot imazalil plus radiation and 1.4 for hot water plus radiation versus 75.7 for unheated water plus radiation and 75.3 for unheated imazalil plus radiation.

Decay and acceptability. Unheated imazalil alone did not reduce anthracnose but did reduce stem-end rot and the percentage of decayed mangos, thereby increasing the percentage of acceptable fruit in the 1984 test (Table 1). Hot imazalil alone was not significantly better than unheated imazalil in reducing the incidence of decay and increasing the percentage of acceptable fruit. Unheated water plus radiation had no effect on decay or percentage of acceptable fruit. However, combination of hot water plus radiation or hot imazalil plus radiation substantially reduced decay and increased the percentage of acceptable fruit.

Unheated imazalil, compared with the unheated water control, did not significantly reduce the incidence of decay or the percentage of acceptable fruit in the 1985 test as it did in the 1984 test (Table 1). Hot water reduced decay, especially stem-end rot, and doubled the percentage of acceptable fruit. Hot imazalil alone again effectively reduced decay and increased the percentage of acceptable fruit. Hot imazalil alone was more than twice as effective as unheated imazalil based on percentage of acceptable fruit. Unheated water plus radiation (750 Gy) or unheated imazalil plus radiation reduced anthracnose decay but not stem-end rot. However, decay reduction was slight and the percentage of acceptable fruit was not lower than the unheated water control fruit. Again, as in 1984, the combination of hot water plus radiation or hot imazalil plus radiation gave the most effective decay control and the highest percentage of acceptable fruit.

Mangos individually wrapped in heat-shrinkable film for comparative purposes in the 1984 test developed excessive decay and failed to ripen properly and therefore were considered unacceptable.

DISCUSSION

Irradiation preceded by immersion in unheated water did not delay ripening of the Tommy Atkins mangos used in this study. Reports of radiation effects on the ripening of mangos have ranged from no delay in Haden mangos irradiated at 1,000 Gy (2) to a delay of 3 days in Sensation (100 or 250 Gy) and Irwin (500 Gy) mangos (6). Thus, low-dose irradiation of mangos can be beneficial through extension of normal shelf life for some cultivars, but this benefit was only noted in our study when irradiation of Tommy Atkins mangos was preceded by a heat treatment. Irradiation, as shown in this

Table 1. Ripening, appearance, decay, and acceptability of mature-green Tommy Atkins mangos given various postharvest treatments and stored for 16–21 days (1984 test) or 16–17 days (1985 test) at 13 C followed by ripening at 24 C[u]

Treatments[v]	Ripening time (days)	Ripe skin color[w] (%)	Skin injury rating[x]	Anthracnose rating[x]	Stem-end rot rating[x]	Decayed fruit[y] (%)	Acceptable fruit[z] (%)
1984 Test							
Unheated water control	8.8 b	88 a	2.2 a	4.4 a	4.7 a	66.7 a	33.3 c
Unheated imazalil alone	10.0 ab	92 a	1.8 ab	3.5 abc	3.7 b	46.7 b	53.3 b
Hot imazalil alone	9.7 ab	95 a	2.0 ab	3.0 bcd	2.8 bc	36.7 bc	63.3 ab
Unheated water plus radiation (200 Gy)	9.9 ab	71 b	1.3 b	4.1 ab	5.3 a	76.7 a	23.3 c
Hot water plus radiation (200 Gy)	10.4 ab	84 ab	1.3 b	2.6 cd	2.9 bc	33.3 bc	66.7 ab
Hot imazalil plus radiation (200 Gy)	10.7 a	82 ab	1.5 ab	1.8 d	2.3 c	21.7 c	78.3 a
1985 Test							
Unheated water control	6.6 c	86 a	1.0 c	5.0 a	4.6 a	77.8 a	22.2 cd
Hot water alone	6.7 bc	90 a	1.0 c	4.5 a	3.4 bc	56.9 bc	43.1 b
Unheated imazalil alone	7.2 bc	78 a	1.0 c	4.4 a	3.9 ab	68.1 ab	31.9 bc
Hot imazalil alone	7.2 bc	88 a	1.2 bc	3.0 b	2.7 cd	29.2 d	70.8 a
Unheated water plus radiation (750 Gy)	6.5 c	28 c	7.0 a	3.1 b	4.6 a	63.9 bc	11.1 d
Hot water plus radiation (750 Gy)	7.5 ab	55 b	1.8 bc	1.9 c	1.6 d	12.5 e	87.5 a
Unheated imazalil plus radiation (750 Gy)	6.7 bc	27 c	7.3 a	2.7 b	4.4 ab	55.6 c	12.5 d
Hot imazalil plus radiation (750 Gy)	8.0 a	55 b	2.3 b	1.7 c	2.2 d	19.4 de	76.4 a

[u] Each number is based on three replicates of 24 nonwrapped fruits each for a total of 72 fruits per treatment. Each replicate represents a different picking date. For each season, means within a column followed by a common letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).

[v] Aqueous treatments, with or without imazalil (0.1% a.i.), were for 3 min in unheated (27 C) or hot (53 C) water.

[w] Percentage of skin surface area showing red or yellow ground color.

[x] Skin injury, anthracnose, and stem-end rot were rated on a scale of 1–9, where 1 = none and 9 = severe.

[y] Decayed fruit were those with more than slight anthracnose or stem-end rot or a combination of slight anthracnose and slight stem-end rot.

[z] Acceptable fruit were those with no more than slight injury, no more than slight anthracnose or stem-end rot, or less than slight amounts of a combination of both decays.

and other reports (5), can inhibit development of ripe skin color, which if sufficient, reduces eye appeal and salability. Inhibition of color development in Tommy Atkins mangos was very noticeable when irradiation was not preceded by a heat treatment. Researchers (16) working with Kent mangos in South Africa found that irradiation (750 Gy) after the hot water treatment (55 C for 5 min) appeared to nullify the accelerating effect of the hot water treatment on the ripening process. Later work (3) suggested that color development was still a problem in mangos treated with hot water plus radiation and then placed in cold storage at 10–12 C for 3 wk before ripening. In this case, gassing the mangos with ethylene before placing them in cold storage stimulated yellow color development. Even so, the percentage of yellow color was only 50 vs. 88 in the control. These researchers (3) recommended picking mangos at colorbreak rather than at an earlier stage to ensure proper ripening. Inhibition of color development may also vary with cultivar as well as maturity and conditions of treatment, such as temperature, duration of hot water treatment, and dosage of radiation. In our study, the slight inhibition of color development noted in mangos irradiated at 200 Gy was eliminated when irradiation was preceded by the hot water treatment. Thus, the lowest dose possible for insect and decay control should be selected.

Our results confirm that treatment with hot imazalil controls decay more effectively than treatment with unheated imazalil or hot water (14). In both the 1984 and 1985 tests, the combination of hot imazalil with radiation was no better than hot imazalil alone or the combination of hot water with radiation. A radiation-heat synergism has been reported for the inactivation of market disease fungi of stone fruits (13). Heat treatment apparently sensitizes bacteria to radiation (8). In our studies, we irradiated the mangos within 2 hr of heat treatment. Irradiation should be done within 24 hr of the hot water treatment to be effective; disease control falls off rapidly with longer delays (3,17).

The choice for treatment of mangos would depend on which treatment was the most economical and convenient to use. The combination of hot water with radiation has the advantage of leaving no chemical residues within the mangos and of also providing fruit fly (4) and seed weevil (17) control in addition to decay control. Additional work is needed to determine the optimum condition for decay control and quality maintenance of the major cultivars.

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