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In Search of the Best Hot Water Treatments for Sindhri and Chaunsa Variety of Mango

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Abstract.- Pakistan produces world's best quality mangoes and its growers and entrepreneurs would like to exploit new markets. Although hot water treatments of exportable mangoes effectively kill the fruit flies but can significantly deteriorate the fruit quality during post-storage period. In the present study, we tested the mango varieties Sindhri and Chaunsa on recommended *i.e.* 48°C for 60 minutes and two proposed hot water treatments *i.e.* 46°C for 60 minutes and 50°C for 60 minutes. All the three hot water treatments killed all the fruit fly eggs and larvae in both varieties of mango. Yet the fruit quality was affected during post-storage period of 9 days in terms of weight loss in Sindhri while stem end rot or brown rot and physical injury in Chaunsa. Based on the findings of current study, we recommend hot water treatment of Sindhri at 50°C for 60 minutes and Chaunsa at 48°C for 60 minutes.

Key words: Hot water treatment, mango, Sindhri, Chaunsa, post storage quality.

INTRODUCTION

Mango ranks second in cultivated area and production among the fruits of Pakistan which is the fifth largest mango producer in the world (FAO, 2006). The bulk production of good quality mangoes is usually undermined by certain pre-harvest factors, like insect pests and diseases (Ishaq *et al.*, 2004; Iqbal *et al.*, 2004). Among insect pests, fruit flies are of great economic importance since they bring about huge loss through direct fruit damage and fruit drop (Ghafoor *et al.*, 2010).

Two of the fruit fly species attacking mangoes in Pakistan are known as oriental fruit fly, *Bactrocera dorsalis* and peach fruit fly *B. zonota* (Stonehouse *et al.*, 2002). These two species are hindering the export of mangoes due to impaired quality and quantity (Stonehouse *et al.*, 1998). Annual losses of fruits and vegetables in Pakistan caused by fruit flies are reported to be more than 144.6 million US dollars (Stonehouse *et al.*, 2002).

The emanating idea of improved quality and increased quantity of exportable mango through on-farm integrated management of orchards is quite young in Pakistan. Additionally the postharvest technology lacks on commercial scale. Nevertheless, the importer countries necessitate some post harvest treatments like hot water, vapor heat and irradiation treatments, which ensure complete disinfestation of fruit flies (GuangQin *et al.*, 1999; Corcoran *et al.*, 2002; Collin *et al.*, 2007).

As a disinfestation treatment, hot water has earned fame and adoption at a large scale because of its high efficacy in reducing the post -harvest diseases (e.g. anthracnose and stem end rot) as well as its low cost (Jacobi *et al.*, 1995; Esguerra *et al.*, 2004; Sopee and Sangchote, 2005). For example, hot water immersion of mangoes at 45.9°C and 46.3°C for 39.7 and 68.5 minutes, respectively can induce 99.99 percent egg and larval mortality in South American fruit fly *Anastrepha fraterculus* (Nascimento, 1992).

In 2005, Pakistan signed a protocol with Iran and China regarding export of mangoes which necessitates hot water treatment *i.e.* Iran: 45°C for 75 minutes; China: 48°C for 60 minutes (Anonymous, 2005b), but the consequences of such treatments on different mango varieties regarding fruit fly disinfestations, post-harvest diseases, shelf life and quality traits (Anwar and Malik, 2007) are yet to be tested. Heat involves both insecticidal and fungicidal action, but the treatment conditions optimized for insect control may not be optimal for disease control and, in some cases may even be detrimental for fruit (Coates and Johson, 1993). So

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the disease control and fruit quality parameters must carefully be observed when developing the heat disinfestation treatments to export mango. Previously, the cultivar of Chaunsa was not entertained with information required while Anwar and Malik (2007) did some preliminary work on Sindhri at the recommended hot water treatments.

In this study, we investigated the effects of one recommended and two proposed hot water treatments on fruit fly disinfestation, disease control and quality of Sindhri and Chaunsa cultivars, keeping in view the standardized export and quarantine demands.

MATERIALS AND METHODS

Experimental material

Mature healthy mango fruits cultivars, Sindhri and Chaunsa were obtained from an orchard situated in Nawabpur, Multan, Pakistan (30°28" N, 71°46'40" E) and fetched to the fruit fly rearing laboratory at Multan, within 24 h. The fruits with yellowish markings or partial softening were suspected to be fruit fly infested and excluded from the experiment. The 24 mango fruits of each cultivar were sorted by an average weight of 211.68+56.96 gm and 210.76+52.08 gm *i.e.* Sindhri and Chaunsa, respectively.

Rearing of fruit fly culture

The fruit fly, *B. zonata* culture was raised in the Fruit Fly Rearing Laboratory at Multan under controlled conditions. One thousand mature pupae were kept in the rearing cage under 27±1°C temperature and 60±5% relative humidity with a light and dark ratio of 14:10 hours. The adult fruit flies were fed on artificial proteinecious diet (Anonymous, 2006).

Infestation of mango fruit

The mango fruits of both cultivars were exposed to gravid fruit flies in cage for 24 hours at 27±1°C. The infested fruits were removed from cage and placed in the lab at 27±1°C for 2 days until the eggs hatched.

Hot water treatment

The infested mango fruits with 1st or 2nd instar fruit fly larvae were transported by road from Multan to Postharvest Lab, Institute of Horticultural Sciences, University of Agriculture, Faisalabad for hot water treatment within 24 hours. The fruits of each tested cultivar were divided into four lots each containing six mangoes. Three lots were subjected to hot water treatments by dipping in hot water at 46°C, 48°C and 50°C for 60 minutes, respectively followed by cooling with ambient water for 20 minutes up to room temperature and then allowed to dry in the air. This experiment was performed in water bath with controlled temperature (Thermoline Scientific Inc.). The fourth lot was not treated and served as control. After treatment, all fruits were repacked into cartons and allowed to ripe at ambient temperature.

Fruit fly mortality

Fruits in each lot were observed on alternate days for any signs of larval emergence *i.e.* partial softening. Once partial softening in any of the mango had been observed (*ca.* 5 days after treatment), all the fruits were shifted to pots with 4 cm sand layer at bottom as pupation media and covered with muslin cloth on the top.

After ripening all the fruits were dissected and examined carefully for infestation and mortality of all developmental stages of fruit flies. The sand at the bottom of the pots was sifted out to screen the fruit fly pupae.

Fruit quality

After hot water treatment, fruits were observed at different fruit quality and disease parameters *i.e.* weight loss, peel colour, peel blackening, fruit softening, skin shriveling, physical injury/press, rot and marketability. For measuring weight loss, fruits were weighed before and after hot water treatments at two days interval until ripening. The change of peel colour was assessed by using colour index scale of 1 to 5 (where 1: 100% green, 2: 75% green, 3: 50% green, 4: 25% green and 5: 100% yellow; Miller and McDonald, 1991). Peel blackening was recorded using a scale of 1 to 5 (where 1: no blackening, 2: < 10 %, 3: 10-25%, 4: 25-50% and >50%; Mansour *et al.*, 2006). The fruit softness was determined by subjective assessment of whether the mango yielded to thumb pressure *i.e.* 1:

very hard, 2: sprung, 3: slightly soft, 4: eating soft/ ripe and 5: over ripe (Miller and McDonald, 1991).

Fruit skin shriveling and rots (stem end rot and brown rot) were assessed by using indices based on the proportion of fruit surface affected and ranked as 1: 0%, 2: <10%, 3: 10-25%, 4: 25-50% and 5: >50% (Lizada *et al.*, 1986). Physical injury/press of fruits were recorded using 5 rank scale *i.e.*, 1: no injury, 2: <5%, 3: 5-10%, 4: 10-25%, 5: >25% (Smith *et al.*, 1992).

The marketability of all fruits was classified with the use of visual quality rating (VQR) as follows: 1: inedible, 2: edible but not marketable, 3: poor, limit of marketability, 4-5: fair, moderate defects, 6-7: good, minor defects, and 8-9: excellent, field fresh (Lizada *et al.*, 1986).

Data analysis

All the data was analyzed using one-way ANOVA. The mean comparisons were made by Fisher LSD test at P=0.05 (Steel and Torrie, 1980). All statistical analyses were completed in XLSTAT 2009 (XLSTAT, 2009).

RESULTS

Sindhri

At the time of hot water treatment (5th July), the peel colour was 75% green in all the mangoes which started turning more yellow two days (7th July) after the treatment and fully turned yellow (rank 5) after two more days (9th July) (Fig. 1a). There was no significant difference among three hot water treatments and control at the end of observation dates (nine days after hot water treatments).

Peel blackening was non-significant and negligible (<10%) at the time of hot water treatment among all the three hot water treatments and control which stayed as such during second observation (7th July). The maximum blackening was observed in control where it attained rank 5 (75% blackening) on 13th July. The three hot water treatments stayed non-significant and ended in negligible blackening at the end of observation dates (Fig. 1b).

The rot was less than 10% and non-significant in three hot water treatments and control during first three post-treatment observation dates. While during 4th and 5th post-treatment observation dates (13th and 14th July), the mangoes in control embrace more than 50% rotting while the mangoes with three hot water treatments showed only 10-25% rotting and were statistically non-significant (Table I).

The visual quality rating was non-significant among the three hot water treatments and control within the individual dates. The VQR dropped gradually on the observation days and on the last observation date, the mangoes under all the four treatments turned unmarketable. The hot water treatments had physical injury unaffected when compared with the control across the observation dates. Fruit softening was non-significant and exceeded the level of eating softness up to 3rd post-treatment observations (Fig. 1f). On the last observation date, the mangoes under all the four treatments were over ripened (Table I)

Skin shriveling stayed less than 10% in all the observation dates (Fig 1g) and differed non-significantly among the three hot water treatments and control (Table I). The weight loss was non-significant among the three hot water treatments and control up to six days (11th July) after treatments. In the last observation date, maximum weight loss (30.11%) was observed in control followed by the mangoes treated at 46°C (22.37% weight loss), 48°C (19.63% weight loss) and 50°C (17.23% weight loss) (Table I).

Chaunsa

At the time of hot water treatment (5th July), the peel colour was 75% green (rank 2) in all the mangoes which started turning yellow two days (7th July) after treatment and fully turned yellow after four more days (11th July) (Fig. 2a). No significant difference between three hot water treatments appeared during the last observation date (Table I).

Peel blackening was non-significant and negligible (<10%) at the time and eight days after hot water treatment (up to 13th July) among all the three hot water treatments and control (Fig. 2b). After one more day (14th July), the mangoes under all the treatments non-significantly turned 10-25% black (rank 3) (Table I).

The rot was less than 10% (rank 2) and non-significant among three hot water treatments and control during first three post-treatment observation

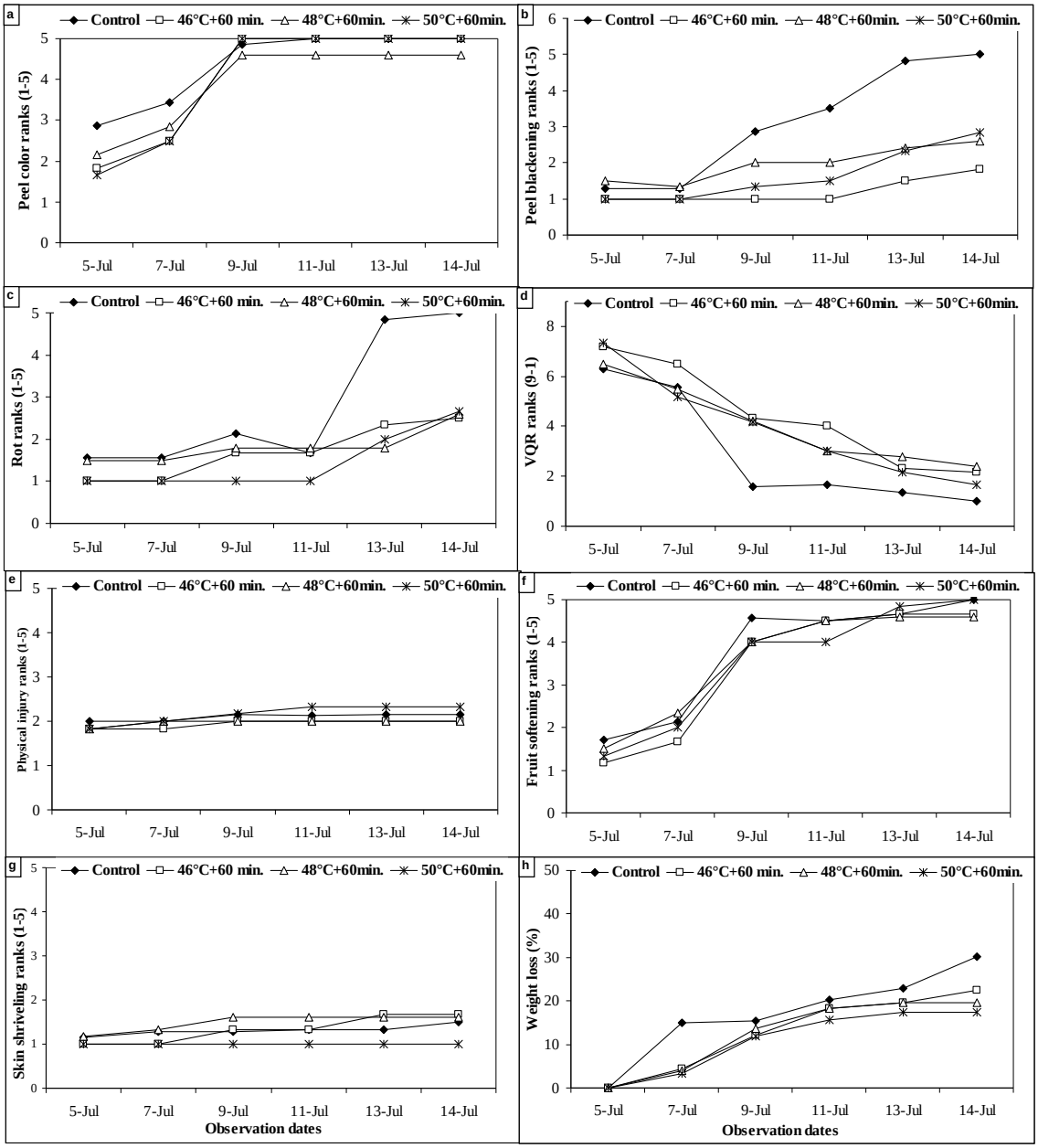

Fig. 1. Variation in post-storage quality of Sindhri within different observation dates. a, peel colour; b, peel blackening; c, rot; d, VQR; e, physical injury; f, fruit softening; g, skin shriveling; h, weight loss.

dates (7th, 9th and 11th July) (Fig. 2c). While during 4th and 5th post-treatment observation dates, the mangoes which were treated at 50°C attained 20-25% rotting (rank 4) while minimum rotting was noticed among the mangoes treated at 48°C. The mangoes in control and 46 °C were statistically non-significant. The visual quality rating was non-significant among the three hot water treatments and control within the individual dates. The VQR dropped gradually among the dates and on last observation day, the mangoes in all the four treatments appeared to be inedible or edible but not marketable (Fig. 2d).

The physical injury increased from rank 1 to rank 2 only in 1st post treatment observation date and remained almost constant up to 2nd post

Table I.- Post-storage effect of hot water treatments on quality components of Sindhri and Chaunsa variety of mango.

Treatment	Peel colour index	Peel blackening index	Rot (SER/BR) index	VQR index	Physical injury/ press index	Fruit softening index	Skin shriveling index	Weight loss %
Sindhri								
46°C for 60 min	5.00a	1.83b	2.50b	2.17a	2.00a	4.67a	1.67a	22.36b
48°C for 60 min	4.60a	2.60b	2.60b	2.40a	2.00a	4.60a	1.60a	19.62bc
50°C for 60 min	5.00a	2.83b	2.67b	1.67a	2.33a	5.00a	1.00a	17.29c
Control	5.00a	5.00a	5.00a	1.00a	2.00a	5.00a	1.50a	30.12a
ANOVA Result								
d.f; p; f	3; 0.32; 1.2	3; 0.01; 4.65	3; 0.02; 3.89	3; 0.21; 1.63	3; 0.84; 0.27	3; 0.15; 1.92	3; 0.40; 1.02	3; 0.00; 14.05
Chaunsa								
46°C for 60 min	4.33a	2.33a	3.50ab	1.67a	2.00b	4.66a	1.83a	18.27a
48°C for 60 min	4.33a	2.00a	2.33b	2.17a	2.00b	4.83a	2.16a	16.28a
50°C for 60 min	4.83a	2.83a	4.00a	1.16a	2.66a	5.00a	2.33a	22.63a
Control	4.57a	2.43a	3.57ab	1.57a	2.43ab	4.57a	2.14a	20.00a
ANOVA Result								
d.f; p; f	3; 0.70; 0.47	3; 0.38; 1.06	3; 0.11; 2.25	3; 0.25; 1.44	3; 0.06; 2.76	3; 0.50; 0.80	3;0.56; 0.69	3;0.58; 0.66

observation date. In the end of the observations (14th July), the maximum rot was observed in the mangoes treated at 50°C (5-10%) followed by control. The two other hot water treatments (46°C and 48°C) were statistically non-significant.

Fruit softening was non-significant and crossed the level of eating softness up to 3rd post treatment observation date (Fig. 2f). On the last observation date the mangoes under all the four treatments were over ripened. Skin shriveling stayed less than 10% (rank 2) in all the observation dates (Fig. 2g) and these varied non-significantly among the three hot water treatments and control in the 6th observation day (Table I). The weight loss gradually increased among all the treatments and in the end of the experiment (Fig. 2h), the weight loss was noticed to be 16 to 20% but non-significant.

Impact on fruit fly eggs and larvae

All the eggs were found dead in all the three hot water treatments while no egg was found dead in the control. The number of live eggs (5.71) found in control was far less than the number of dead eggs found in the hot water treatments *i.e.* 15.83, 17.83 and 20.50 eggs in 46°C, 48°C and 50°C. No larva was found alive in the hot water treatments while 4.51 and 3.0 larvae were recorded in control mangoes of Sindhri and Chaunsa, respectively.

DISCUSSION

Hot water treatment is relatively inexpensive compared with other post-harvest treatments, such as irradiation and vapor heat treatment. Contrary to the most prevailing vapor heat and forced hot-air treatments, the hot-water treatment has many pros. It is quicker and easier to implement, kills surface parasitic organisms, cleans the fruit surface and costs only 10% of the vapor heat treatment (Collin *et al.*, 2007). Therefore its utility in commercial varieties of Pakistan is manifold.

The two commercial varieties “Sindhri” and “Chaunsa” responded in a similar way towards peel color, VQR, fruit softening and skin shriveling; there was no significant difference between treatments and control in both varieties. Similar findings have also been reported by Anwar and Malik (2007), who tested the quality and storage life of “Sindhri” after two hot water treatments *i.e.* 45°C for 75 minutes and 48°C for 60 minutes. They did not find any significant difference for fruit softness and pulp color; the peel color was less yellow in the mangoes treated on 45°C for 75 minutes as compared with those treated on 48°C for 60 minutes but both turned nearly more than 75% yellow. This is contradictory to the findings of Jacobi *et al.* (1995) who found that hot water

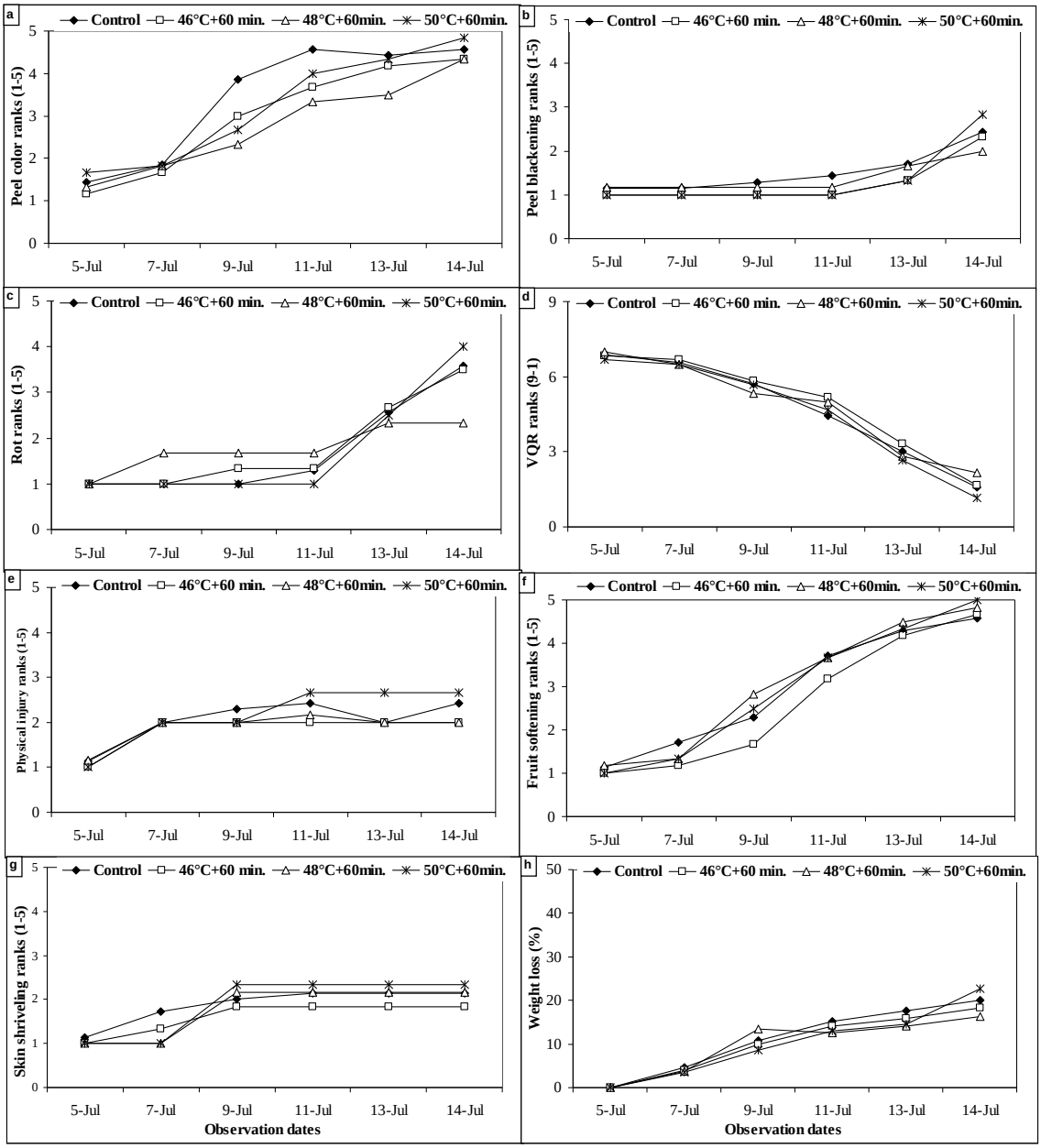

Fig. 2. Variation in post-storage quality of Chaunsa within different observation dates. a, peel colour; b, peel blackening; c, rot; d, VQR; e, physical injury; f, fruit softening; g, skin shriveling; h, weight loss.

treatment (47°C for 30 minutes) induced fruit softening, skin discoloration and disease incidence in Kensington mangoes seven days after hot water treatment at 22°C. The phenomenon of fruit softening, peel colour and disease incidence varied with variety, post-harvest period and storage temperature (Jacobi *et al.*, 1995; Uthairatanakij *et al.*, 2006).

Hot water treatment temperature and time may vary the results. A series of temperatures are usually tested against a series of time intervals pertaining to find the best recommended hot water treatments for any particular fruit. The species of fruit flies can also lead to the variation in results. For example, Sharp *et al.* (1989) recommended a hot water treatment of Mexican mangoes at 46.1°C for 90

minutes for Mexican fruit fly, *Anastrepha ludens* (Loew) which could be acceptable for 12 days at 24°C. Similarly, Smith and Chin (1989) established the best hot water treatment of Australian mango varieties against *Dacus aquilonis* (May) (Diptera: Tephritidae), at 48°C for 20 minutes in order to achieve the international quarantine standards.

The hot water treatment not only controls the diseases like anthracnose (Lonsdale, 1992) but also kills the eggs and larvae of fruit flies and many other insect pests (Collin *et al.*, 2007). Lonsdale *et al.* (1991) tried to control the post harvest decay of mangoes by combining mild (0.75 kGy) irradiation with hot water treatment. It presented excellent control of both anthracnose (*Glomerella cingulata*) and soft brown rot (*Hendersonia creberrima*) of mangoes cultivars "Ensation" and "Kent" but was found to be phytotoxic causing lenticel damage.

The rotting (stem end and brown rot) pattern was different in both varieties. In Sindhri, hot water treatments reduced the incidence of rot while in Chaunsa, the rotting process increased with the rise in hot water treatment temperature. Lizada *et al.* (1986) found that the rotting process in Philippians mango variety "Carabao" decreased with the increase in temperature of hot water treatment. This might be the reason that Sindhri has better demand in export market (Anonymous, 2005a). This also suggests that the phenomenon of fruit rotting also varies with the varieties. Although hot water treatments give satisfactory control of insects (Coates and Johson, 1993) but pathogens may be more heat invulnerable than the targeted pests. Therefore the incidence of rots and diseases to a variable extent are common phenomenon in pos-harvest stored mangoes.

The present study has reached the conclusion that all the three hot water treatments *i.e.* 46, 48 and 50°C for 60 minutes each, equally killed the fruit fly eggs and larvae in both of the mango varieties (Sindhri and Chaunsa). Yet the fruit quality was affected during post-harvest period of 9 days in terms of weight loss in Sindhri while rot and physical injury in Chaunsa. Based on these findings, we recommend hot water treatment at 50°C for 60 minutes for Sindhri and 48°C for 60 minutes for Chaunsa for the best post-harvest quality upto 9 days.

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