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Effect of postharvest treatments on quality and shelf life of mango fruit cv. 'Cat Chu' at suboptimal temperature

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ABSTRACT

This research aimed to determine an appropriate postharvest treatment that inhibited decay, maintained quality, and prolonged the storage life of the 'Cat Chu' mango. The mangoes were subjected to hot water dip treatment at 53°C for 5 mins combined with natamycin (1000 ppm), fludioxonil (200 ppm), sodium benzoate (2%), natamycin alone and untreated control. Mangoes were stored at 8°C for 35 days and ripened at 20°C for 5 days during the storage period. The results revealed that hot water treatment did not develop white-corky pulp in mango during storage at 8°C for 28 days. Hot water treatment in combination with dipping natamycin enhanced chilling tolerance and reduced decay of mango storage at 8°C for up to 28 days and ripening at 20°C. This combination treatment inhibited the rot of mango and was lower than fludioxonil fungicide during storage. Hence, hot water treatment in combination with natamycin stored at 8°C showed great potential to prolong the storage life of Cat Chu mango by up to 28 days as a safe alternative to chemical fungicides.

Key words: *Mangifera indica L.*, Chilling tolerance, Decay, Fludioxonil, Hot water. Sodium benzoate.

INTRODUCTION

The susceptibility of mango fruit to rot, low temperature, and fruit deterioration caused by fast ripening and softening restricts its potential postharvest management (Zheng *et al*., 21). Vietnam is the 13th largest mango producer in the world with a total mango-growing area of 114,200 hectares and a total production of 938,200 tons/year in 2021 (Vinafruit, 19). In Vietnam, 'Cat Chu' mangoes are most widely grown in Dong Thap province and consumed for domestic and export markets. 'Cat Chu' mango handled in hot water at 53°C for 5 minutes, packed in a perforated polyethylene, and kept at 13°C could maintain the quality for 20-25 days (Nguyen, 12). Fungicides are an effective way to control decay in mangoes, but the abuse of fungicides can impact human health and develop resistance to fungi. Many research results have recently attempted to replace fungicides with alternative and safe technologies. Fludioxonil fungicides inhibited postharvest decay in mangoes (Diskin *et al.*, 2). Hot water treatment effectively controlled decay in mangoes. Hot water treatment combination with carbendazim was more effective than heat treatment alone (Spirong *et al.*, 15). Natamycin is a naturally occurring antifungal agent produced by the fermentation of Streptomyces natalensis. Natamycin is a natural fungicide approved worldwide as a safe food additive. Natamycin can destroy the cell membrane, interfere with the physiological activity and influence metabolic actions on postharvest anthracnose of mango (Liu *et al.*, 7). Based on the above information, the objective of this research was to find the effectiveness of hot water treatment used separately or in combination with natamycin, sodium benzoate, and natamycin as alternatives to fungicides in inhibition of decay and keeping the quality of 'Cat Chu' mango fruit at sub-optimal temperature.

MATERIALS AND METHODS

'Cat Chu' mangoes at 90 days after fruit set were harvested from the orchard in Dong Thap province, Vietnam, during morning hours. The experiment was conducted at the Southern Horticultural Research Institute in 2021. The experiment was established in a completely randomized design comprising four replicates. Ten fruits were taken in each replication of each treatment. Treatments included hot water (53°C for 5 min) treatment (HWT); Fludioxonil @200ppm (FLU); sodium benzoate@2% (SB); Natamycin (1000 ppm) (Natasan) alone; HWT and combination natamycin dipping (HWT+Nata); and untreated (control). All fruits were treated for de-sapping with $CaCO_3$ (1%) for 10 minutes and dipped quickly in NaOCl (200 ppm). The mangoes were separated into six treatment groups. Upon drying the fruit surface moisture, fruits were packaged with a perforated polyethylene bags (with eight holes of 0.4 cm diameter each) and packed in 5kg corrugated fiber board boxes. Mangoes were assessed for quality after 7, 14, 21, 28 and 35 days of storage at

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8°C, 80-90% RH and ripened at 20°C for 5 days at each storage period.

Weight loss (WL) was recorded using electronic weighing balance (FZ-5000i, Korea) and expressed as percentage. The colour of mango pulp (L* and b*) was recorded at the near stem end, middle, and blossom end of the fruit by Chroma Meter (Minolta CR-400, Japan). Disease index (DI) was measured using the method of Shao *et al.* (2019) on mango fruit. Fruit decay was determined according to a 5-point scale, where 0=no decay, 1=very slight decay, covering <10% of the surface area of fruit, 2=slight decay, covering>10% but <25% of the surface area of fruit, 3=moderate decay, covering>25% but <40% of the surface area of fruit and 4=severe decay, covering>40% of the surface area of fruit. The decay index was calculated using the following formula:

$$DI\ (\%) = \frac{(1xN1 + 2xN2 + 3xN3 + 4xN4)}{4xN} \times 100$$

Where, N is the total number of fruit measured and N1, N2, N3 and N4 are the numbers of fruit showing the different severities of decay.

The pulp under the fruit peel was penetrated using an 8mm diameter probe at three places in the near equator with downward penetration up to 11 mm and measured at a speed of 5 mm s-1 using a fruit firmness tester (GUSS-15, Germany). The data on fruit firmness were expressed as kgf. Electrolyte leakage (%) was measured using the method described by Zhao *et al.* (20), taking 3 mm thick pulp from the equatorial region of the fruit. Respiration rate (mg CO_2 kg^{-1} h^{-1}) was measured as per the method described by Aindongo *et al.* (1), which had some modifications such as unit of measurement and coefficient of measured adjustment (Check Mate 3, Dansensor, Denmark). Total Soluble Solids (TSS) were recorded using a pocket refractometer (Japan 0-53°B). Titratable acidity (%) was measured and calculated based on a percentage of citric acid (SI ANALYSIS Titroline 7000, Germany). Ascorbic acid (100mg ml^{-1}) was recorded using Srivastava and Kumar's method (16). The studied data were analyzed for analysis of variance by software SAS 8.1. The means were compared using an LSD test at a significant level of 0.05.

RESULTS AND DISCUSSION

The fruits in hot water treatment (HWT) and HWT combined with natamycin had higher weight loss than other treatments on the 21st and 35th day of storage (Fig.1). The maximum loss (4.94%) occurred in fruits with HWT on the 35th day of the storage period. The minimum WL of fruit was recorded with fludioxonil treatment (3.83%), but all other treatments were at par. The decrease in weight of mango fruit was caused by respiration, water transpiration, and other biological changes taking place in the fruit. Mango fruit with heat treatment shows more weight loss than the untreated during storage (Lurie and Mitcham, 9).

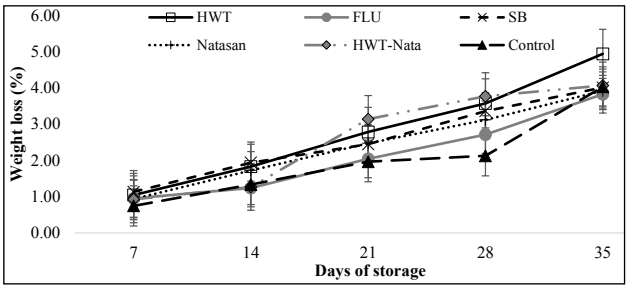

Fig. 1. Effect of postharvest treatments on weight loss of mango stored at 8°C.

Vertical bars represent ± SE of mean.

The respiratory rate (RR) of mangoes in all treatments increased slowly on the 7th and 14th day of storage at 8°C (Fig. 2). The respiratory peak of mangoes in control (38.81 mg CO_2 kg^{-1} h^{-1}) was observed at 21st days after storage. It was a significant difference compared with other treatments. The respiration peaks of mango in other treatments were delayed by up to 7 days when the peaks appeared on the 28th day of storage. On this date, mangoes in SB treatment had the highest RR (39.23 mg CO_2 kg^{-1} h^{-1}). At the end of storage, mangoes in SB and control treatments significantly decreased RR compared with other treatments (Fig.2). The application of postharvest treatments in 'Cat Chu' mango fruit delayed and decreased the rate of respiration compared with control storage at 8°C for 35 days. The reduction in respiration rate may be attributed to slowing the ripening process and inhibiting the susceptibility to sub-optimal temperature (Saftner *et al.*, 13). A similar result has been reported on inhibiting the respiration rate of mango cv. 'Keit' (Vege-Alvarez *et al.*, 18).

Electrolyte leakage fruits in all the treatments increased up to 21 days of cold storage (Fig. 3). HWT recorded the highest EL value (65.62%). There

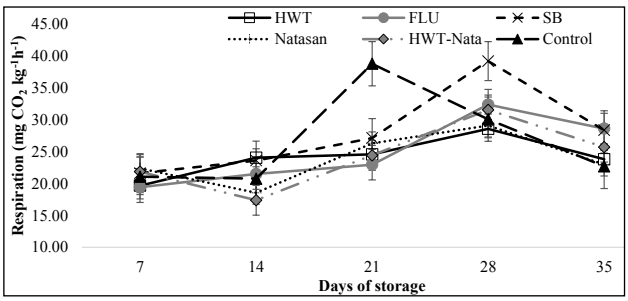

Fig. 2. Effect of postharvest treatments on respiration rate of mango stored at 8°C.

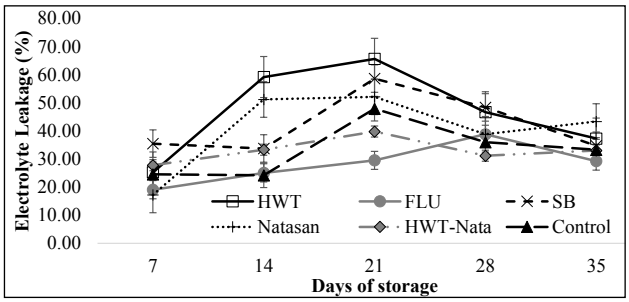

Fig. 3. Effect of postharvest treatments on electrolyte leakage of mango stored at 8°C.

was a significant difference among the treatments on the 21st day of storage at 8°C, whereas fruits in HWT combined with natamycin and fludioxonil recorded low EL values (39.79% and 29.53%). The decreased EL of mango fruits in all treatments was not significant on the 35th day of storage at 8°C. Meanwhile, HWT combined with natamycin showed low EL and maintained a constant value compared with other treatments in mango during storage at 8°C for 35 days. The rise in EL with increased storage duration could be due to the chilling injury and ripening (Suwapanich and Haewsungcharoen, 17). In all treatments, 'Cat Chu' mangoes ripened normally without chilling injury symptoms when removed from cold storage. A similar result has been reported for mango cv. 'Keitt' (Lopez-Lopez *et al.*, 8).

After 21 days of storage at 8°C, fludioxonil and HWT combined with natamycin treatments did not develop diseases and were found significantly superior to (P≤0.05) other treatments. The fruits treated HWT and SB recorded high disease index (DI) compared with the control fruit on 28th day at 8°C. The control fruit (48.00%) had the highest DI on the 35th day storage at 8°C (Table 1)

At the end of storage for ripening at 20°C, the DI of mangoes in HWT, natamycin, and SB treatments were not significantly different compared with the control treatment. Fludioxonil treatment had the lowest DI in mango fruit compared with other treatments in ripening at 20°C during the storage period. HWT combined with natamycin treatment also effectively controlled the DI. This result showed that HWT affected the rate of metabolism of fruit. The drawback of heat treatments is that the effects contributing to rot control may not remain for long-term (Escribano and Mitcham, 3).

The control and HWT fruits softened rapidly than the other treatments during ripening at 20°C on the 14th and 21st day of storage. The firmness of pulp was maintained in fludioxonil (0.58 Kgf) and HWT combination with natamycin (0.62 Kgf) treatments during storage and ripening (Fig. 4). Similar findings on the effect of HWT on firmness of mango fruits were reported by Spirong *et al.* (15) in cv. Chok-Anan and Vege-Alvarez *et al.*(18) on cv. Keitt.

The results presented in Fig. 5 showed that the ripened mango fruits with HWT combined with natamycin had a more stable colour change than the control and other treatments when ripened for 5 days at 20°C. The ripened mangoes without HWT had white-corky pulp tissues near the peel on the 28th day of storage. This might be due to cell wall

Table 1. Effect of postharvest treatments on disease index of mango var. 'Cat Chu' stored at 8°C and ripen at 20°C.

Treatment	Disease Index-Storage (%)					Disease Index-Ripening (%)				
	7d	14d	21d	28d	35d	7d+5	14d+5	21d+5	28d+5	35d+5
HWT	0.00	23.67 (29.09)	26.00 (30.65)	30.67 (33.61)	42.00 (40.39)	41.00 (39.81)	55.00 (47.88)	64.33 (53.38)	80.33 (63.74)	91.33 (73.00)
FLU	0.00	0.00 (0.91)	0.00 (0.91)	9.67 (17.91)	15.67 (23.30)	0.00 (0.91)	16.00 (23.55)	18.33 (25.32)	42.00 (40.39)	70.33 (57.07)
SB	0.00	16.67 (24.09)	24.67 (29.74)	41.00 (39.81)	44.00 (41.55)	23.67 (29.09)	24.67 (29.74)	48.00 (43.85)	85.33 (67.70)	93.33 (75.15)
Natasan	0.00	4.33 (10.14)	7.33 (15.70)	16.33 (23.84)	41.00 (39.81)	17.00 (24.34)	17.67 (24.85)	30.67 (33.61)	76.67 (61.24)	92.67 (74.51)
HWT-Nata	0.00	0.00 (0.91)	0.00 (0.91)	16.00 (23.55)	30.67 (33.61)	7.00 (15.32)	16.33 (23.84)	23.67 (29.09)	55.00 (47.88)	87.33 (69.36)
Control	0.00	4.33 (10.14)	16.00 (23.55)	21.33 (27.46)	48.00 (43.85)	16.00 (23.55)	26.00 (30.65)	68.33 (55.90)	84.67 (67.06)	95.33 (77.64)
SEm (±)		(2.76)	(3.00)	(1.79)	(1.70)	(2.92)	(2.07)	(2.90)	(2.57)	(1.75)
LSD (0.05)		8.34	2.25	3.64	2.51	2.07	2.90	5.50	5.74	5.57

Means in parenthesis were arcsine transformed. 'd': day

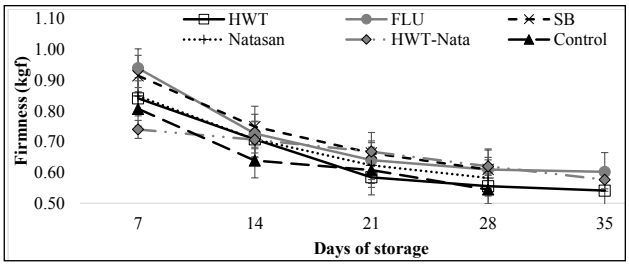

Fig. 4. Effect of postharvest treatments on the firmness of mango stored at 8°C and ripening at 20°C for 5 days.

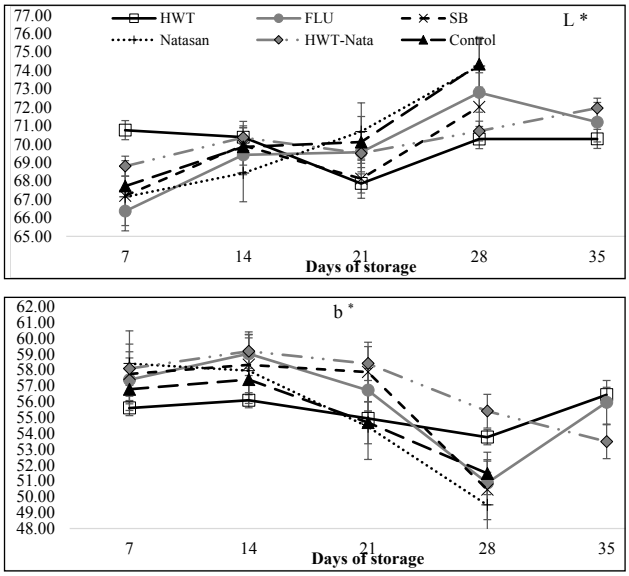

Fig. 5. Effect of postharvest treatments on pulp color of mango ripen at 20°C for 5 days at each storage period.

degradation (Kumpoun *et al.*, 6). Similar results were reported by Kantanet and Chompoorat (5) on mango cv. Mahachanok.

Table 2. Effect of postharvest treatments on total soluble solids and total sugar of mango var. 'Cat Chu' ripen at 20°C for 5 days at each storage period.

Treatment	Total soluble solids (°B)				
	7d+5	14d+5	21d+5	28d+5	35d+5
HWT	15.30	14.50	15.35	16.05	13.45
FLU	16.45	14.80	15.10	14.10	12.15
SB	14.35	14.85	14.05	16.50	-
Natasan	15.15	13.70	13.90	12.95	-
HWT-Nata	13.65	16.25	16.20	15.25	13.55
Control	14.00	15.65	14.70	12.90	-
SEm (±)	0.29	0.24	0.22	0.38	0.44
L.S.D(0.05)	1.63	1.15	1.02	1.49	NS

SE(m) stands for standard error; NS non-significant

Ripened mangoes in HWT, sodium benzoate, and HWT combined with natamycin trended to increase and maintain a stable Total soluble solid (TSS) during 28 days of storage (Table 2). On the contrary, mangoes in natamycin and control recorded the lowest TSS (12.95°B and 12.90°B). The rise and reduction in TSS in mango fruits were relevant to the conversion of starch to sugar during storage (Nair and Singh, 11). Similar results were obtained on mango 'Mahachanok' by Kantanet and Chompoorat (5).

An increasing trend in Titratable acidity (TA) of ripened mango may be due to the concentration effect on moisture loss from the pulp. However, the effect of different treatments on the acidity could not be established (Table 3). Nair and Singh also reported an increase in TA in mango during ripening after prolonged low-temperature storage (11).

A significant reduction in ascorbic acid (AA) content of ripe mango was observed in all treatments (Table 3). During storage, the AA showed a gradual

Table 3. Effect of postharvest treatments on titratable acidity and ascorbic acid of mango var. 'Cat Chu' ripen at 20°C for 5 days at each storage period.

Treatment	Titratable acidity (%)					Ascorbic acid (mg 100 ml^{-1})				
	7d+5	14d+5	21d+5	28d+5	35d+5	7d+5	14d+5	21d+5	28d+5	35d+5
HWT	0.17	0.27	0.23	0.19	0.27	72.64	63.85	57.43	46.67	18.58
FLU	0.13	0.18	0.32	0.34	0.17	96.28	69.26	49.33	47.00	25.34
SB	0.21	0.26	0.20	0.32	-	60.81	50.67	38.85	23.65	-
Natasan	0.20	0.23	0.21	0.36	-	54.05	49.67	48.67	38.51	-
HWT-Nata	0.13	0.19	0.28	0.38	0.30	75.68	62.00	52.03	44.59	21.96
Control	0.22	0.13	0.38	0.33	-	92.00	52.70	40.20	20.24	-
SEm (±)	0.01	0.01	0.02	0.02	0.03	4.67	2.20	2.47	3.05	0.32
L.S.D(0.05)	0.06	0.07	0.05	0.08	NS	25.72	11.44	17.18	13.60	NS

decrease in ripened mango in HWT combined with natamycin. Islam *et al.* (4) also reported a progressive decline in AA on ripening with increased storage duration. Chilling injured induced reduction in AA was reported by Maul *et al.* 10.

The application of HWT (53°C for 5 mins) combination with natamycin (1000 ppm) dipping for three minutes reduced the decay index, enhanced chilling tolerance, and maintained the quality of Cat Chu mango during ripening at 20°C after storage at 8°C up to 28 days. The combination treatment was more effective than the single treatment in keeping quality and prolonging the storage life of Cat Chu mango.

AUTHORS' CONTRIBUTION

Assessment of work, execution, and laboratory tasks (TTN), Data collection and statistical analysis (BK), Work planning and final correction (SM).

DECLARATION

The authors have no conflicts of interest.

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