Working Paper Series

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Improving smallholder farmer incomes through strategic market development in mango supply chains in Southern Vietnam

Resource: A2.1 Fruit productivity and quality improvements through on farm innovations

Study focus – Hot water treatment

To control mango postharvest disease for longer distance supply chains

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Summary

Post-harvest disease is a significant issue for transporting mangoes from the Mekong River Delta to medium distance markets such as Hanoi and China as well as long distance sea export markets. Losses of up to 100% have been experienced especially during off season.

The study looks at identifying the causal agents of post-harvest disease in mango from the Mekong River Delta. In addition to this it looks at suitable treatments for delaying or suppressing post-harvest disease. These control methods were based on hot water treatment with the addition of Chitosan, a biopolymer that has film forming and antibacterial/fungal properties which can have the potential to control or suppress the development of pre and postharvest disease of many agricultural products

The results found that the dominant causal agent of the rots observed postharvest with Colletotrichum sp. being the most dominant for both Cat Chu and Cat Hoa Loc varieties. Hot water treatment (HWT) proved to be effective at reducing levels of post-harvest rots 53^{o}C - 5 minutes. Whilst the Chitosan coatings did not significantly enhance the levels of post-harvest disease control over longer duration of storage time. It did have effects on reducing moisture loss and reduce the levels of post-harvest disease over shorter storage durations.

Hot water treatment can significantly reduce the levels of disease which would certainly be advantageous for short to medium distance markets, although the reduction in disease levels is still not high enough for long distance shipping into modern retail markets, this would most likely require the inclusion of a fungicide into the hot water treatment. Whilst the overall results of the addition of Chitosan appear to be inconclusive there is an indication of having a disease suppressive attribute for medium storage durations. Chitosan could therefore be a useful treatment for short to medium distance markets where storage requirements do not exceed two weeks. Further commercial testing of HWT plus Chitosan for short to medium distance markets such as Hanoi and China with the addition of post-harvest fungicide would be helpful.

1 Introduction

Mango is one of the most important fruit crops in Vietnam, with two varieties, Cat Hoa Loc and Cat Chu, dominating domestic market and exports. However, the development of the full economic potential of these varieties is limited due to high losses associated with post-harvest diseases.

Post-harvest disease is a significant issue for exports to medium distance markets such as Hanoi and Hong Kong from the Mekong River Delta. In the rainy season, with these long-distance markets losses of up to 100% have been experienced. Hot water treatment (HWT) is used by many countries to control post-harvest diseases in mangoes (Crowe-White et al. 2012; Shin et al. 2012). Hot water has been shown to give a level of control with anthracnose and stem end rot (Muirhead and Grattidge 1986; Sepiah 1986; Johnson et al. 1989). Hot water treatment effectively kills pathogens directly or indirectly in fruit and vegetables (Lurie et al. 1996) without leaving any chemical residue

The regime of heat treatments, for control of rot diseases on mangoes, currently used by many countries is 52^{o}C for 5 to 10 minutes and its effectiveness depends on varieties, inoculum level, planting regions as well as climatic conditions.

In Vietnam, previous studies by Nguyen and Nguyen (2010) indicated a regime of 55^{o}C for 5 minutes was the most suitable for Hoa Loc variety and 53^{o}C for 7 minutes for Cat Chu variety. However, in recent years, a problem of heat-damage has been observed on the skin when HWT was applied using these regimes. This may have been influenced by the recently introduced practice of pre-harvest fruit bagging for the prevention of fruit fly. As a result, lower heat treatment settings have been applied by various packhouses, this has also coincided with an observed reduction in effective disease control after HWT.

Chitosan, is a biopolymer synthesized from nature, has film forming and antibacterial properties which can have the potential to control or suppress the development of pre and postharvest disease of many agricultural products (Bautista-Banos et al. 2006; No et al. 2007). In mango, researchers have reported that chitosan coating improved mango storage ability in terms of delaying rot disease development, ripening, water loss and prolonged storage (Slippers et al. 2005; Tran 2005).

Study aims

The aims of this study are to determine if HWT can be improved by combining its application with chitosan coating by:

- Isolation and identification of postharvest diseases causing rots on postharvest Cat Chu and Cat Hoa Loc
- Identify effective hot water treatment followed by chitosan coatings on rot diseases and quality of Cat Hoa Loc and Cat Chu during storage

2 Materials and methods

Experiments were conducted at Postharvest Technology Laboratory Department, Southern Horticultural Research Institute (SOFRI) in 2021. Fruit varieties Cat Hoa Loc and Cat Chu were harvested mature from orchards in Dong Thap province.

Preparation of chitosan coatings: A stock solution of chitosan 1% was prepared by weighing chitosan powder (85.0% deacetylated and MW = 1.15 MD) then dissolved in acetic acid solution 1% and stirred overnight. The stock solution was diluted into various concentrations such as 0.2, 0.4 and 0.6 for further experiments.

Equipment used: Chroma Meter (Minolta CR-400), pH Meter (Hanna), Alaska cold store (±0.5°C), water bath, autoclave.

Chemicals: Chlorine (NaClO- Sodium hypochlorite, 15%); Streptomycin sulfate salt; NaOH 0.1N; 2, 6 dichlorophenolindophenol, phenolphtalein 1%, PDA (potato dextrose agar), WA (water agar).

Statical analysis: Data was analysed by using SAS software (version 8.1). The significant difference of means was calculated using Duncan test. The critical difference value at 5% level of probability was used for comparison of the among treatment means.

2.1 Isolation and identification of postharvest diseases causing rots on Cat Chu and Cat Hoa Loc

Fruit was bought from orchards in Dong Thap province, during the wet season. The fruit selected had no mechanical damage or disease. The fruit was washed with water and dried in preparation for the experiment.

The fruits were packed into cartons (10/box) and stored under two conditions: (i) 12°C - 21 to 28 days and followed by storing at 22°C for 5 days and (ii) 22°C for 7 to 14 days. During storage, all symptoms appearing on the fruit were numbered, isolated and identified following Koch's postulates. The pure cultures were morphologically identified and sent to Nam Khoa Bioteck to identify the ITS gene sequence, undertake analysis and blast search. Rot appearing on fruit was examined and categorised according to symptom characteristics. The different types of symptoms were described and photographed. Isolations of the causal organisms into pure culture were conducted, tissue was taken aseptically from beneath the epidermis at the lesion margin and grown on Potato Dextrose Agar (PDA) consisting of penicillin and streptomycin to inhibit bacterial growth.

2.2 Effect of hot water treatment combined with chitosan coating on disease and quality of Cat Hoa Loc.

Experimental design: The experiment was designed as a complete randomised design with nine treatments, each treatment with three replications and 10 fruits per replication.

Table 1. Treatments used in experiment 2.2

No.	Treatments	No.	Treatments
T1	Control	T6	53°C - 5 minutes + Chi A (0.4%)
T2	52°C - 5 minutes	T7	53°C - 5 minutes + Chi B (0.6%)
T3	53°C - 5 minutes	T8	Chi A (0.4%)
T4	52°C 5 minutes + Chit A (0.4%)	T9	Chi B (0.6%)
T5	52°C - 5 minutes + Chi B (0.6%)		

Source: Author's analysis

Note: T = treatment

Fruit was bought from orchards in Dong Thap province: The fruit was selected to have no mechanical damage or disease. Stems were cut short and de-sapped by dipping in a lime solution 0.6%. This was followed by a rinse wash and fan drying.

Fruit was divided into nine groups corresponding to treatments then T2 to T7 was subjected to HWT by dipping in hot water, this was followed by soaking in chitosan solution for T4 to T7. After treatment, fruits were fan dried and packed into ventilated cartons (nine fruit/carton box). Cartons were stored in a cool room at 22°C with fruit quality assessment conducted at day 7 to 12.

Measurements

Weight loss (%): was determined by the difference between the initial weight and final weight.

Disease incidence (%) = Sum of disease fruits * 100/Total number of observed fruits.

Disease severity (%): by the disease index (0-5) (Sharma et al. 1985).

Rating scale used 0 = no visual development of disease; 1= <10%; 2= 10 to 30%; 3= 31 to 70%; 2= 10-<25%; 3= 25-<50%; 4= 50-<75%; 5=>75% of the affected surface area of disease. Severity was calculated by the following formula

$$\text{Disease severity (\%)} = \frac{[(N1x1)+(N2x2)+(N3x3)+..(Nnxn)]}{Nxn} \times 100$$

Respiration rate (mg CO_2/kg/h): fruits was placed in airtight boxes (volume known), closed, measured the volume of air in the box after 1 to 2 hours.

Skin colour *(L*, a*, b*):* was evaluated by using Chroma meter CR-400 by the method of Piriyavinita et al. (2011). Firmness (kg/cm^2): by using Fruit Texture Analyzer. Titratable acid (TA) (% or g/100ml): determined by the method of TCVN 5483-1991. Total soluble solids (TSS): by using hand refractometer (ATAGO, Japan).

2.3 Effect of hot water treatment combined with chitosan coating on disease and quality of Cat Chu

Experimental design: The experiment was designed as a complete randomized design with five treatments, each treatment with four replications and nine fruits per replication.

Fruit was bought from orchards in Dong Thap province: The fruit was selected to have no mechanical damage or disease. Stems were cut short and de-sapped by dipping in a lime solution 0.6%. This was followed by a rinse wash and fan drying.

Table 2. Treatments used in experiment 2.3

No.	Treatments
NT1	Control
NT2	HWD (52°C - 5 minutes)
NT3	HWD (52°C - 5 minutes) + chitosan 0.2%
NT4	HWD (52°C - 5 minutes) + chitosan 0.4%
NT5	HWD (52°C - 5 minutes) + chitosan 0.6%

Source: Author's analysis

Note: NT = chitosan treatment

Fruit was divided into five groups corresponding to treatments then NT2 to NT5 was subjected to HWT by dipping in hot water 52°C for 5 minutes, this was followed by soaking in chitosan solution for NT3 to NT5 at the rates of 0.2, 0.4 and 0.6(%) respectively. After treatment, fruits were fan dried and packed into ventilated cartons (nine fruit/carton box). Cartons were stored in a cool room at 22°C with fruit quality assessment conducted at day 7 to 12. Cartons were then equally divided into two groups one stored at 12°C the other at 22°C.

Measurements

Fruits stored at 12^oC was held for 3 to 4 weeks followed by an additional 3 to 5 days at 22^oC to simulate retail sale conditions. Measurements of quality attributes and rots were taken at day 14, 21 and 28.

Fruits stored at 22^oC was held for 14 days with measurements of quality attributes and rots were taken at day seven and 12.

Respiration measurements were taken at day 6, 8, 10 and 12.

Weight loss (%): was determined by the difference between the initial weight and final weight.

Disease incidence (%) = Sum of disease fruits * 100/Total number of observed fruits.

Disease severity (%): by the disease index (0-5) (Sharma et al. 1985).

Rating scale used 0= no visual development of disease; 1= <10%; 2= 10 to 30%; 3= 31 to 70%; 2= 10-<25%; 3= 25-<50%; 4= 50-<75%; 5=>75% of the affected surface area of disease. Severity was calculated by the following formula:

$$\text{Disease severity (\%)} = \frac{[(N1x1) + (N2x2) + (N3x3) + ..(Nnxn)]}{Nxn} \times 100$$

Respiration rate (mg CO_2/kg/h): fruits was placed in airtight boxes (volume known), closed, measured the volume of air in the box after 1 to 2 hours.

Skin colour *(L*, a*, b*):* was evaluated by using Chroma meter CR-400 by the method of Piriyavinita et al. (2011). Firmness (kg/cm^2): by using Fruit Texture Analyzer. Titratable acid (TA) (% or g/100ml): determined by the method of TCVN 5483-1991. Total soluble solids (TSS): by using hand refractometer (ATAGO, Japan).

3 Results and discussion

3.1 Isolation and identification of postharvest diseases causing rot on Cat Chu and Cat Hoa Loc

Disease symptoms and causal agents were detected on Cat Chu mango. The result of the isolations and identification were based on morphological characteristics and internal transcribed spacer regions (ITS) sequences. This indicated that there were three major fungi species causing postharvest rot diseases on Cat Chu. These were identified as Lasiodiplodia pseudotheobromae, Colletotrichum gloeosporioides and Phomopsis longicolla. Lasiodiplodia pseudotheobromae caused stem end rot where the symptoms appeared at the stem part of fruit, with Colletotrichum gloeosporioides and Phomopsis longicolla, the symptoms could be appeared over the fruit body (Figure 1).

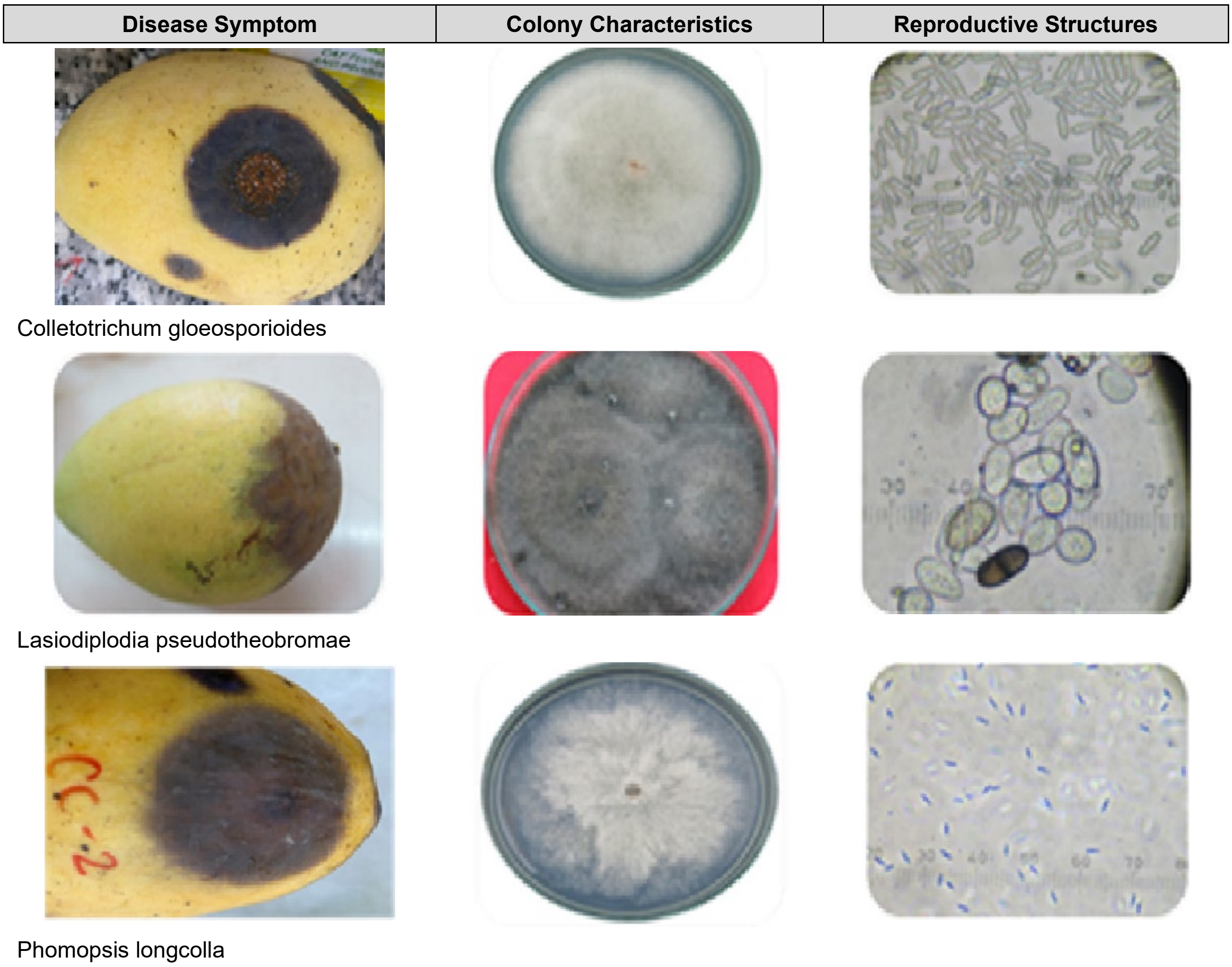

Figure 1. Postharvest pathogens detected on Cat Chu mango

Source: Author's images

For Cat Hoa Loc the isolations and subsequent identification based on morphological characteristics and internal transcribed spacer regions (ITS) sequences indicated that there were four major causal fungi species. These were identified as Diaphorthe sp., Colletotrichum acutatum, Colletotrichum gloeosporioides, Botryosphaeria dothidea. The result also indicated rot diseases caused rot symptoms at the stem part of Hoa Loc mangoes were because of Botryosphaeria dothidea (Figure 2).

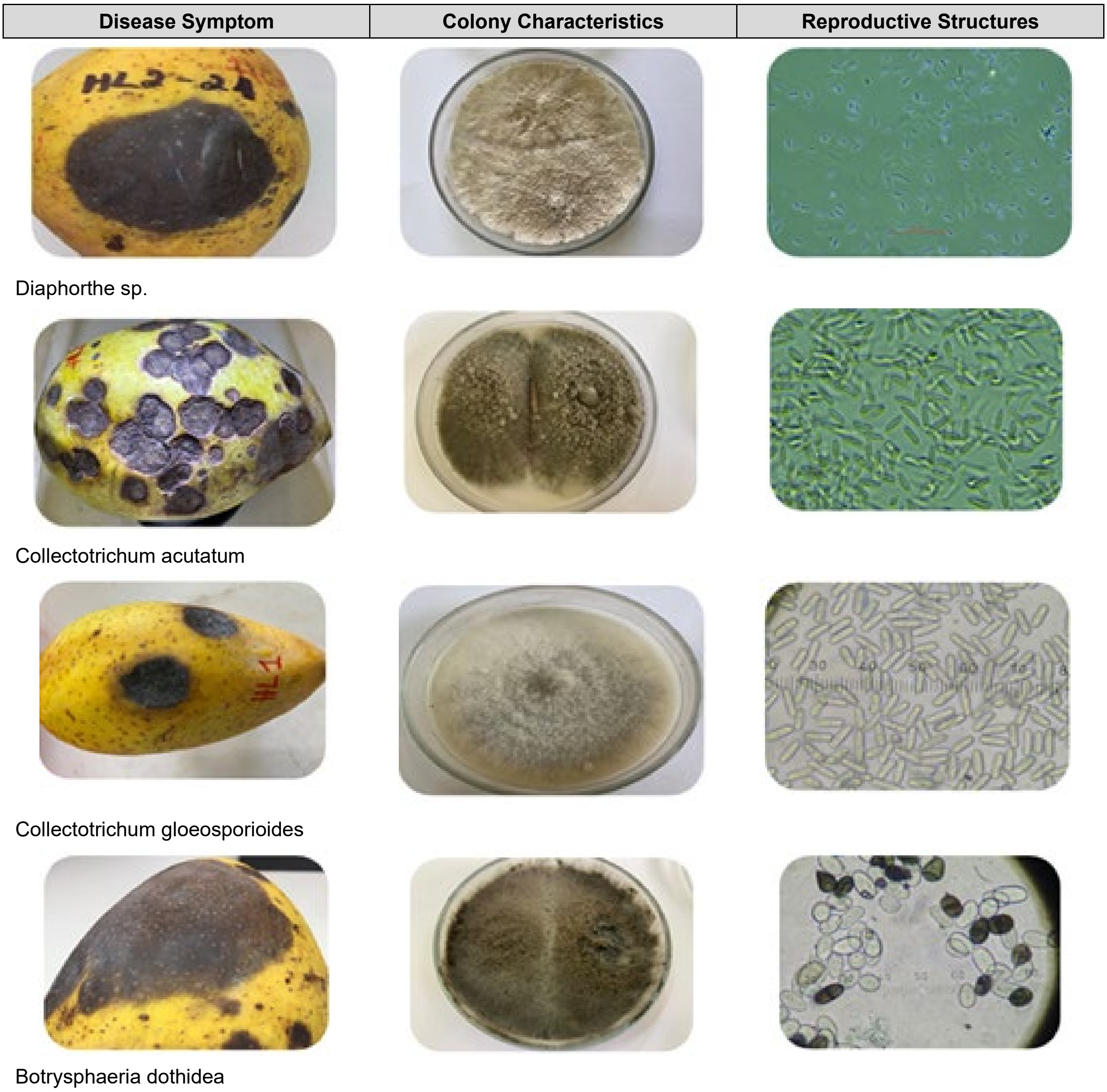

Figure 2. Postharvest pathogens most often detected on Hoa Loc mango

Source: Author's images

Discussion

Fungi sp were the causal agents of the rots observed postharvest with Colletotrichum sp. Being the most dominant for both Cat Chu and Hoa Loc varieties. This is not surprising as the time of the study coincided with off season fruit which has developed during the rainy season, it is plausible that the dominance may change with seasonal conditions. The study also found that the different varieties have a different profile of disease causal agents. However, most of the species identified in this study were similar to what has previously been reported by Dinh (2003); Slippers et al. (2005); Rivera-Vargas et al. (2006); Jayasinghe and Fernando (2009); De Oliveira Costa et al. (2010); Ni et al. (2012); Twumasi et al. (2014).

3.2 Effect of hot water treatment and chitosan coating on disease and quality of Cat Hoa Loc mango during storage

Effect of HWT and chitosan coating on rot diseases of Hoa Loc mangoes

Results in the Table 3 indicated that the hot water treatment significantly reduced the incidence of post-harvest rots the addition of a chitosan coating did not have a significant effect on improved disease control, indicating that the HWT was the contributing factor to the level of control achieved. efficiency over what the HWT treatment alone was achieved. Although the treatment with Chi A alone after 12 days did appear to have a significant reduction in disease severity, this was not observable at day nine or with the Chi B treatment.

Table 3. Disease incidence and disease severity of Hoa Loc storage at 22ºC

Treatment	9 days		12 days	
	DI (%)	DS (%)	PDI (%)	PDS (%)
Control	85.19[a]	49.63[a]	96.30[a]	63.70[a]
52ºC - 5 min	33.33[b]	8.89[b]	59.26[c]	22.96[bc]
53ºC - 5 min	37.04[b]	9.63[b]	62.96[c]	19.26[c]
52ºC - 5 min + Chi A	29.63[b]	13.33[b]	70.37[bc]	27.41[c]
52ºC - 5 min + Chi B	40.74[b]	11.11[b]	59.26[c]	22.22[c]
53ºC - 5 min + Chi A	29.63[b]	12.59[b]	66.67[c]	30.37[c]
53ºC - 5 min + Chi B	44.44[b]	11.85[b]	51.85[c]	29.63[c]
Chi A	85.19[a]	43.61[a]	92.59[ab]	39.44[bc]
Chi B	92.59[a]	40.93[a]	96.30[a]	60.28[ab]
CV%	20.47	19.90	14.21	15.67

Source: Author's analysis

Note: DI: Disease incidence; DS: disease severity

Effect of HWT and chitosan coating on weight loss and fruit firmness

At day nine storage at 22ºC (Table 4), the weight loss and the fruit firmness in various treatments and control were not significantly different. However, day 12, treatment 52ºC - 5 minutes + Chi B showed significantly reduced weight loss this was not observed in the other treatments that received the coatings.

Table 4. Weigh loss & fruit firmness of Hoa Loc storage at 22ºC

Treatment	9 days		12 days	
	Weight Loss (%)	Fruit firmness (kg/cm^2)	Weight Loss (%)	Fruit firmness (kg/cm^2)
Control	5.70	0.57	8.55[abc]	0.43
52ºC - 5min	6.23	0.60	9.58[a]	0.40
53ºC - 5min	5.82	0.49	8.94[ab]	0.41
52ºC - 5 min + Chi A	5.85	0.54	8.53[abc]	0.41
52ºC - 5 min + Chi B	4.72	0.45	6.44[c]	0.37
53ºC - 5 min + Chi A	5.80	0.62	8.34[abc]	0.39
53ºC - 5 min + Chi B	5.73	0.59	8.20[abc]	0.41
Chi A	5.56	0.51	8.18[abc]	0.41
Chi B	4.55	0.62	6.74[bc]	0.45
CV%	15.77	17.19	12.86	7.12

Source: Author's analysis

Effect of HWT and chitosan coating on respiration rate

Results indicate (Table 5) that HWT significantly increased the respiration rate of the fruit storage at 22°C and resulted a faster ripening rate as compared to the control. The combination with chitosan coating Chi b significantly reduced the respiration rate helping to delay ripening.

Table 5. Respiration rate of Hoa Loc mango during storage at 22°C

Treatments	2 days	4 days	7 days	10 days
Control	134.31	311.02	236.86^{cb}	-
52°C - 5 min	163.65	276.14	302.01^{a}	265.98
53°C - 5 min	191.19	293.23	301.69^{a}	265.93
52°C - 5 min + Chi A	182.8	289.33	283.19^{ab}	262.92
52°C - 5 min + Chi B	132.87	251.93	212.07^{c}	227.73
53°C - 5 min + Chi A	123.75	250.95	243.57^{bc}	253.95
53°C - 5 min + Chi B	96.35	241.6	206.21^{c}	216.84
Chi A	157.02	273.3	203.53^{c}	242.59
Chi B	123.26	242.1	122.79^{d}	122.95
CV%	30.77	14.59	9.79	-

Source: Author's analysis

Effect of HWT and chitosan coating on colour changes of skin and flesh of mango

Changes of mango during storage related to ripening measured using the colour system (L,C,H) with the difference of C value used as the measure of change. The results in Table 6 showed that treatment 52°C - 5 minutes + Chi B resulted in lower C values compared to the control and other treatments. Treatment 53°C - 5 minutes + Chi B also significantly delayed colour development compared to the HWT alone. Indicating the Chi b can delay skin colour development but did not appear to have a significant difference on internal flesh colour Table 7.

Table 6. Skin colour of Hoa Loc mango during storage at 22°C

Treatments	Skin colour					
	9 days			12 days		
	L	C	H	L	C	H
Control	66.02^{a}	50.53^{a}	95.90^{bc}	64.90	52.03^{ab}	91.45^{bc}
52°C - 5min	65.64^{a}	51.26^{a}	95.80^{bc}	63.77	51.98^{ab}	90.03^{c}
53°C - 5min	66.31^{a}	51.26^{a}	94.19^{c}	64.61	52.56^{a}	89.62^{c}
52°C - 5 min + Chi A	66.08^{a}	49.33^{ab}	96.98^{bc}	64.28	51.76^{ab}	91.73^{bc}
52°C - 5 min + Chi B	63.60^{a}	46.36^{c}	101.23^{ab}	62.58	48.26^{c}	96.74^{ab}
53°C - 5 min + Chi A	65.05^{a}	49.95^{ab}	95.24^{c}	64.24	51.57^{ab}	90.40^{bc}
53°C - 5 min + Chi B	64.97^{a}	46.80^{c}	97.01^{bc}	63.46	49.08^{bc}	93.44^{bc}
Chi A	63.42^{a}	47.59^{bc}	99.40^{abc}	62.07	50.76^{abc}	94.42^{bc}
Chi B	57.40^{b}	39.08^{d}	103.99^{a}	62.58	44.30^{d}	101.12^{a}
CV%	2.14	2.10	2.37	2.23	2.61	3.01

Source: Author's analysis

Table 7. Flesh colour of Hoa Loc mango during storage at 22°C

Treatments	Flesh colour					
	9 days			12 days		
	L	C	H	L	C	H
Control	59.70^{ab}	49.67^{ab}	81.92	65.13	57.78	78.83^{b}
52°C - 5 min	60.43^{ab}	52.41^{a}	81.19	65.47	56.55	77.97^{b}
53°C - 5 min	55.08^{bc}	47.61^{ab}	81.94	67.31	58..15	79.46^{b}
52°C - 5 min + Chi A	38.15^{d}	35.25^{c}	82.64	65.40	57.27	79.19^{b}
52°C - 5 min + Chi B	54.58^{bc}	46.29^{ab}	83.28	64.97	57.51	79.63^{b}
53°C - 5 min + Chi A	61.10^{ab}	51.97^{a}	81.80	66.08	56.87	80.60^{ab}
53°C - 5 min + Chi B	48.92^{c}	42.63^{b}	82.60	67.01	58.28	81.35^{ab}
Chi A	65.90^{a}	53.03^{a}	82.49	67.11	58.15	80.63^{ab}
Chi B	60.62^{ab}	50.11^{a}	84.28	67.47	56.61	83.89^{a}
CV%	7.51	6.40	1.93	2.27	2.17	2.09

Source: Author's analysis

Effect of HWT and chitosan coating on TSS & TA

Coating with chitosan in helped to maintain significantly higher total soluble solid content at day 12 compared HWT 53°C -5min with the exception of 53°C - 5 min + Chi B (Table 8).

Table 8. TSS & TA of Hoa Loc mango during storage at 22°C

Treatment	9 days		12 days	
	°Brix	Acid (%)	°Brix	Acid (%)
Control	17.87^{c}	0.54^{a}	15.97^{bc}	0.21
52°C - 5 min	18.7^{abc}	0.37^{b}	15.85^{bc}	0.22
53°C - 5 min	19.2^{ab}	0.40^{ab}	14.80^{c}	0.27
52°C - 5 min + Chi A	19.4^{ab}	0.38^{ab}	17.10^{ab}	0.18
52°C - 5 min + Chi B	18.77^{abc}	0.33^{b}	16.82^{ab}	0.21
53°C - 5 min + Chi A	18.60^{bc}	0.32^{b}	17.57^{a}	0.17
53°C - 5 min + Chi B	19.47^{ab}	0.33^{b}	16.02^{bc}	0.22
Chi A	19.77^{a}	0.43^{ab}	16.65^{ab}	0.17
Chi B	19.50^{ab}	0.36^{b}	17.30^{ab}	0.18
CV%	**2.61**	**19.10**	**3.82**	**29.57**

Source: Author's analysis

Conclusion

Chitosan coatings can reduce fruit respiration rates, this can lead to delayed skin colour development, and reduced weight loss. HWT can significantly reduce the levels of post-harvest disease, under the conditions within this trial this was not significantly enhanced by the addition of Chitosan coating.

3.3 Effect of hot water treatment and chitosan coating on disease and quality of Cat Chu mango during storage

Effect of HWT and chitosan on rot disease and quality of Cat Chu mango during storage at cool room (22°C)

The results (Table 9) indicate that all treatments HWD at day nine significantly reduced disease incidence and severity, however at day 12 treatment HWD + Chi 0.6% was not significantly deferent from the control in severity or incidence the other treatments were significantly different in incidence but not severity with the exception of HWD + 0.2% there was a significant reduction in both incidence and severity.

Table 9. Disease incidence (DI) and disease severity (DS) of Cat Chu at 22°C

Treatments	7 days		12 days	
	DI%	DS%	DI%	DS%
Control	20,00^{a}	4,00^{a}	76,67^{a}	36,67^{a}
HWD (52°C - 5 min)	3,33^{bc}	0,67^{b}	36,67^{b}	16,00^{ab}
HWD + Chi 0.2%	0,00^{c}	0,00^{b}	36,67^{b}	11,33^{b}
HWD + Chi 0.4%	0,00^{c}	0,00^{b}	46,67^{b}	19,33^{ab}
HWD + Chi 0.6%	6,67^{b}	0,67^{b}	63,33^{ab}	21,33^{ab}
CV%	**53,97**	**53,09**	**16,86**	**27,26**

Source: Author's analysis

Effect of HWT and chitosan coating on weight loss and fruit firmness

Table 10. Weight loss and fruit firmness of Cat Chu at 22°C

Treatments	7 days		12 days	
	Weight loss (%)	Fruit firmness (kg/cm^2)	Weight loss (%)	Fruit firmness (kg/cm^2)
Control	6.74^{b}	0.95	13.78	0.53
HWD (52°C - 5 min)	7.63^{ab}	0.75	14.55	0.52
HWD + Chi 0.2%	7.98^{a}	0.74	14.70	0.55
HWD + Chi 0.4%	7.70^{ab}	0.96	14.26	0.55
HWD + Chi 0.6%	7.76^{ab}	0.90	13.66	0.51
CV%	7.04	24.58	8.27	4.06

Source: Author's analysis

Effect of HWT and chitosan coating on respiration rate

Table 11. Respiration rate of Cat Chu mango during storage at 22°C

Treatments	0 days	6 days	8 days	10 days	12 days
Control	60.1	172.09^{c}	154.18	150.68	135.71^{b}
HWD (52°C - 5 min)	65.66	229.92^{a}	167.42	175.35	164.14^{a}
HWD + Chi 0.2%	68.28	234.74^{a}	160.68	158.33	157.77^{a}
HWD + Chi 0.4%	69.91	195.70^{bc}	156.87	165.3	155.92^{a}
HWD + Chi 0.6%	75.3	201.84^{c}	174.04	150.77	154.78^{a}
CV%	15.12	5.89	7.08	10.01	5.88

Source: Author's analysis

Effect of HWT and chitosan coating on colour changes of skin & flesh

Table 12. Skin color of Cat Chu mango during storage at 22°C

Treatments	7 days			12 days		
	L	C	H	L	C	H
Control	70.11[bc]	42.98[ab]	100.11[a]	67.99[a]	44.61	85.90
HWD (52°C - 5 min)	72.07[a]	44.15[a]	94.68[bc]	66.86[ab]	46.49	83.35
HWD + Chi 0.2%	71.70[ab]	44.46[a]	92.92[c]	65.11[ab]	45.04	84.45
HWD + Chi 0.4%	70.71[abc]	43.53[a]	98.04[ab]	64.44[b]	44.49	84.23
HWD + Chi 0.6%	69.62[c]	41.59[b]	97.60[ab]	65.81[ab]	45.30	84.81
CV (%)	1.31	2.09	2.25	2.23	3.01	1.94

Source: Author's analysis

Table 13. Flesh color of Cat Chu mango during storage at 22°C

Treatments	7 days			12 days		
	L	C	H	L	C	H
Control	72.77	54.66	85.46	73.75[a]	57.8	76.41
HWD (52°C - 5 min)	71.96	56.54	83.93	72.45[ab]	59.19	75.97
HWD + Chi 0.2%	71.74	53.36	85.98	71.77[ab]	58.21	75.48
HWD + Chi 0.4%	72.84	52.88	87.15	70.97[b]	58.63	75.56
HWD + Chi 0.6%	72.19	54.64	85.75	71.27[b]	59.97	77.18
CV (%)	2.65	4.08	2.03	1.55	2.18	1.20

Source: Author's analysis

Effect of HWT and chitosan coating on TSS & TA

Table 14. Total soluble solid content (TSS) & Total acidity A (%) of Cat Chu mango during storage at 22°C

Treatments	7 days		12 days	
	TSS (%)	TA (%)	TSS (%)	TA (%)
Control	16.27[b]	0.68[a]	15.59	0.32[a]
HWD (52°C - 5 min)	17.30[a]	0.51[ab]	15.70	0.29[ab]
HWD + Chi 0.2%	16.69[ab]	0.53[ab]	15.05	0.28[ab]
HWD + Chi 0.4%	17.09[ab]	0.45[b]	15.31	0.20[b]
HWD + Chi 0.6%	17.34[a]	0.47[b]	15.55	0.22[ab]
CV%	**2.68**	**18.69**	**4.84**	**21.45**

Source: Author's analysis

Effect of HWT and chitosan coating of rot diseases and quality of Cat Chu stored at 12°C

Incidence of disease increased over the time with initially no development in the first 2-week period Table 15. At day 28 the HWT at 5 minutes had significantly less incidence of disease compared to the control, but not significant in disease severity. The remaining treatments were not significantly different from the control. HWD + Chi 0.4% treatment appeared to delay disease development by day 21 but this was not carried through to day 28.

Table 15. Disease incidence and severity of Cat Chu during storage at 12°C

Treatments	14 days		21 days		28 days	
	DI%	DS%	DI%	DS%	DI%	DS
Control	0,00	0,00	66,67[a]	19,33[a]	83,33[a]	23,33[ab]
HWD (52°C - 5 min)	0,00	0,00	23,33[b]	6,00[b]	43,33[b]	10,67[b]
HWD + Chi 0.2%	0,00	0,00	46,67[ab]	13,33[ab]	73,33[a]	24,67[a]
HWD + Chi 0.4%	0,00	0,00	16,67[b]	5,33[b]	76,67[a]	29,33a
HWD + Chi 0.6%	0,00	0,00	30,00[ab]	10,67[ab]	76,67[a]	18,67[ab]
CV%	-	-	37,24	33,17	14,87	18,10

Source: Author's analysis

Table 16 shows fruit stored at 12°C then held at an additional 5 days at 22°C had a significant impact on the development of disease. The HWD (52°C - 5 minutes) was the only treatment that significantly lowered disease severity than the control. The disease incidence however was not significant.

Table 16. Disease incidence and severity of Cat Chu storage at 12°C followed by 5 days at 22°C

Treatments	14 days +5D		21 days +5D		28 days +5D	
	PDI%	PDS%	PDI%	PDS%	PDI%	PDS
Control	86,67	31,33	96,67[a]	58,67	100,00	72,00[a]
HWD (52°C - 5 min)	80,00	25,33	83,33[b]	45,33	100,00	55,33[b]
HWD + Chi 0.2%	63,33	29,33	96,67[a]	49,33	96,67	70,00[ab]
HWD + Chi 0.4%	76,67	29,33	96,67[a]	43,33	100,00	67,33[ab]
HWD + Chi 0.6%	70,00	22,00	96,67[a]	53,33	100,00	60,00[ab]
CV%	15,51	17,07	9,83	10,23	4,32	8,23

Source: Author's analysis

Effect of HWT and chitosan coating on respiration rate

Respiratory intensity is one of the important factors affecting physiological and biochemical activity and the duration of use of post-harvest vegetables. Controlled respiratory intensity will help slow down the physiological and biochemical changes of vegetables. Table 17 shows that the respiratory intensity of Cat Chu mangoes in the tests tends to increase over the storage time, overall, there was no statistically significant difference from the test. Thus, the problem of physiological transformation (respiration) of Cat Chu mango after harvest has not been controlled from the hot water treatment method combined with chitosan membranes.

Table 17. Respiration rate of Cat Chu mango during storage at 12°C

Treatments	2 days	16 days	19 days	21 days	24 days	28 days
Control	22.76	42.34	52.38	60.19	65.54a	72.11
HWD (52°C - 5 min)	25.79	46.77	53.31	56.05	51.13[b]	68.62
HWD + Chi 0.2%	25.05	41.68	50.48	47.63	45.28[b]	68.92
HWD + Chi 0.4%	27.75	46.95	57.59	53.76	50.31[b]	67.77
HWD + Chi 0.6%	34.44	47.88	56.57	52.64	66.07[a]	77.1
CV%	28.04	11	6.67	11.7	6.35	9.4

Source: Author's analysis

Effect of HWT and chitosan coating on weight loss

The weight of Cat Chu mangoes in the treatments decreased with storage time. Mangoes after harvesting continue to respire and therefore are prone to moisture loss. Respiration reduces the content of dry matter and causes mass loss. Chitosan coatings with concentrations of 0.4 to 0.6% at day 21 significantly reduced moisture loss compared to HWD (52ºC - 5 minutes) this was also evident at day 28 across all for the chitosan concentrations compared to HWD (52ºC - 5 min) but not significant from the control treatment Table 18. With fruit stored at 12ºC followed by 5 days at 22ºC Table 19, treatment significant reduction in weight loss was observed at day 14 on concentrations of 0.4 to 0.6% from HWD (52ºC - 5 min), this was reduced to 0.6% having a significant reduction at day 28 compared to HWD (52ºC - 5 min) and was comparable with the control.

Table 18. Weight Loss (%) of Cat Chu stored at 12ºC

Treatments	14 days	21 days	28 days
Control	5.65	7.74^{c}	10.28^{b}
HWD (52ºC - 5 min)	6.86	10.04^{a}	13.04^{c}
HWD + Chi 0.2%	6.45	9.5^{ab}	12.30^{ab}
HWD + Chi 0.4%	5.38	7.75^{c}	12.12^{ab}
HWD + Chi 0.6%	5.53	8.82^{b}	10.77^{ab}
CV%	**14.39**	**5.08**	**9.63**

Source: Author's analysis

Note: Values on the same horizontal row or a column with letters behind not the same characters are statistically significant differences (P ≤ 0,01).

Table 19. Weight Loss (%) of Cat Chu stored at 12ºC followed by 5 days at 22ºC

Treatments	14 days + 5 days	21 days + 5 days	28 days + 5 days
	HHKL	HHKL	HHKL
Control	10.45^{b}	13.91^{ab}	14.45^{c}
HWD (52ºC - 5 min)	14.12^{a}	16.80^{a}	17.72^{a}
HWD + Chi 0.2%	13.78^{a}	16.34^{ab}	17.00^{abc}
HWD + Chi 0.4%	11.24^{b}	13.73^{b}	17.19^{ab}
HWD + Chi 0.6%	11.93^{b}	14.80^{ab}	14.66^{bc}
CV%	7.13	9.45	7.99

Source: Author's analysis

Note: Values on the same horizontal row or a column with letters behind not the same characters are statistically significant differences (P ≤ 0,01).

Effect of HWT and chitosan coating on colour changes of skin

The colour of the fruit peel is an important quality attribute and can greatly affect the demand of the consumer market. Colour was evaluated after treatment and at 12ºC for 2 to 4 weeks.

As a result, the L*, a*, b* Table 20 values increased over storage duration with a significant difference between the chitosan treatment by 0.4% and the control at day 28. Table 20. The degree of colour change of mangoes treats hot water with chitosan 0.4% was slowed compared to the other treatments. This was also evident with the 0.2% on day 28 with fruit.

Table 20. Skin colour changes of Cat Chu stored at 12°C

Treatments	14 days			21 days			28 days		
	L	C	H	L	C	H	L	C	H
Control	65.31	38.81^{ab}	106.25^{a}	70.27	40.72^{bc}	98.71^{a}	71.68^{a}	42.33^{bc}	95.71^{ab}
HWD (52°C - 5 min)	67.13	39.97^{a}	102.73^{b}	71.47	42.78^{a}	96.23^{b}	71.05^{ab}	44.19^{a}	93.94^{bc}
HWD + Chi 0.2%	65.98	39.41^{ab}	105.16^{ab}	70.7	41.95^{ab}	95.92^{b}	71.16^{ab}	42.78^{abc}	93.39^{c}
HWD + Chi 0.4%	67.48	38.97^{ab}	103.95^{ab}	70.59	41.45^{ab}	97.40^{ab}	70.31^{b}	43.22^{ab}	95.31^{ab}
HWD + Chi 0.6%	65.76	38.11^{b}	104.66^{ab}	69.79	39.65^{c}	98.45^{a}	70.42^{ab}	41.54^{c}	95.91^{a}
CV%	2.37	2.04	1.36	1.17	2.03	0.98	0.91	1.63	0.97

Source: Author's analysis

Note: Values on the same horizontal row or a column with letters behind not the same characters are statistically significant differences (P ≤ 0,01).

Table 21. Skin colour changes of Cat Chu stored at 12°C followed by 5 days at 22°C

Treatments	14 days + 5 days			21 days + 5 days			28 days + 5 days		
	L	C	H	L	C	H	L	C	H
Control	68.72	52.49^{a}	80.59^{c}	65.01	48.10	83.85^{bc}	67.15^{a}	45.82^{a}	87.26
HWD (52°C - 5 min)	69.65	50.70^{b}	82.68^{ab}	67.70	47.09	85.86^{a}	64.66^{ab}	41.82^{b}	88.49
HWD + Chi 0.2%	69.31	49.34^{c}	82.56^{ab}	67.81	46.43	85.34^{ab}	62.43^{b}	41.16^{b}	88.16
HWD + Chi 0.4%	69.30	51.10^{ab}	81.72^{bc}	67.51	49.53	83.41^{c}	63.42^{ab}	43.40^{ab}	87.94
HWD + Chi 0.6%	69.81	49.00^{c}	83.92^{a}	69.06	48.17	85.56^{ab}	64.76^{ab}	42.48^{ab}	88.40
CV (%)	1.41	1.34	0.84	3.14	3.08	0.96	3.20	3.93	0.66

Source: Author's analysis

Note: Values on the same horizontal row or a column with letters behind not the same characters are statistically significant differences (P ≤ 0,01).

Effect of HWT and chitosan coating on total soluble sold content (TSS), total acidity (TA) and fruit firmness (kg/cm²)

The total dissolved solid content, total acid content and flesh firmness of Cat Chu mango generally made no statistical difference from the post-storage process at 12°C.

Flesh firmness decreases over time, due to the solubility of pectin in the cell walls over time. The results of the experiment showed that treating HWD + Chi 0.2% can maintain flesh firmness for up to 4 weeks at a storage temperature of 12°C Table 22.

Table 22. Fruit quality of Cat Chu in terms of (TSS), TA and fruit firmness (FF)

Treatments	14 days + 5 days			21 days + 5 days			28 days + 5 days		
	TSS	TA	FF	TSS	TA	FF	TSS	TA	FF
Control	16.55	0.26	0.55	16.98^{a}	0.26	0.52	16.31	0.27^{ab}	0.49$_{ab}$
HWD (52°C - 5 min)	16.36	0.24	0.58	16.53^{ab}	0.27	0.57	17.54	0.26^{b}	0.51^{ab}
HWD + Chi 0.2%	16.63	0.26	0.58	16.15^{ab}	0.28	0.53	15.98	0.36^{a}	0.44^{b}
HWD + Chi 0.4%	15.37	0.23	0.59	16.03^{bc}	0.26	0.54	16.36	0.30^{ab}	0.54a
HWD + Chi 0.6%	16.15	0.27	0.55	15.06^{c}	0.30	0.56	16.18	0.30^{ab}	0.50^{ab}
CV%	**4.20**	**18.13**	**4.56**	**2.96**	**14.27**	**6.84**	**6.59**	**13.96**	**7.28**

Source: Author's analysis

Note: Values on the same horizontal row or a column with letters behind not the same characters are statistically significant differences (P ≤ 0,01).

4 Conclusion and recommendations

Conclusion

Hot water treatment can significantly reduce the levels of disease which would certainly be advantageous for short to medium distance markets, although the reduction in disease levels is still not high enough for long distance shipping into modern retail markets, this would most likely require the inclusion of a fungicide into the hot water treatment.

Whilst the overall results of the addition of chitosan appear to be inconclusive there is an indication of having a disease suppressive attribute for medium storage durations. Chitosan could therefore be a useful treatment for short to medium distance markets where storage requirements do not exceed 2 weeks.

Recommendations

Further commercial testing of HWT plus Chitosan for short to medium distance markets such as Hanoi and China with the addition of post-harvest fungicide would be helpful.

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