REDUCTION OF POSTHARVEST AVOCADO FRUIT DECAY BY OPTIMISED RAPID HOT WATER TREATMENT

Majola, T.F. and Laing, M.D.

Plant Pathology, University of KwaZulu-Natal, SOUTH AFRICA
major4tm@gmail.com

laing@ukzn.ac.za

ABSTRACT
Postharvest hot water treatment has been used intensively for disinfestation and disinfection of a wide variety of crops against a wide range of pests and diseases, offering a pesticide-free option to control postharvest diseases. The objective of this study is to optimise a hot water technology to offer fast and effective control of postharvest decay of avocado fruit. Initially, we exposed avocado fruit to hot water in a series of temperature and time combinations: 45, 50, 55, 60, 65, 70, 75 and 80 °C (± 0.1 °C) x 20, 30, 45, 60, 75, 90, 105, 120 and 180 seconds, to evaluate avocado skin sensitivity to heat treatments. Subsequent trials for disease control used temperatures of control (room temperature), 52, 54, 56 and 58 °C (± 0.1 °C) x control (0), 10, 15, 20 and 30 seconds. A third series of tests used control (room temperature), 50, 52, 54, 56, 58, 60, 62, 64, 66, 68 and 70 °C (± 0.1 °C) x control (0), 2, 4, 6, 8 and 10 seconds to determine optimum disease control in the shortest time. The best disease control of 60-100% was achieved by 70 °C x 6 seconds and 56 °C x 10 seconds. To counteract future infections of the host fruit, integration of rapid hot water treatment and biological control yeasts can be ideal for the preservation of fruit freshness until consumption.

Keywords: Hass, Physical treatment, Fungicides, Fruit rot, Shelf life.

INTRODUCTION

The shelf life of avocado fruit is often reduced by postharvest decay due to economically important fungal pathogens following latent infections (Irtwange, 2006; Palou, 2009). These infections have been primarily controlled with the application of synthetic fungicides (Palou, 2013). However, due to health concerns, importing countries have enforced rules and regulations limiting the application of chemical fungicides (Palou, 2013; Sivakumar and Fallik, 2013; Usall, 2016). Consequently, there is a pressing need to find chemical-free management strategies against postharvest avocado decay (Schirra, 2000; Palou, 2009; Schirra, 2011). In the first decades of the 20th century, postharvest disease control practices involved the application of heat treatment before transitioning to the application of chemical fungicides (Schirra, 2000; Ben-Yehoshua and Porat, 2005; Irtwange, 2006). Hence, this project has focused on this approach.

Heat treatment leaves no chemical residues and causes minimal environmental impact, whilst controlling diseases and extending the shelf life of fruits and vegetables (Palou, 2008; Lurie, 2016; Usall, 2016). Hot water treatment is fairly easy to use, cost-effective and, additionally, water is a more efficient medium in transferring heat than air or steam (Irtwange, 2006; Sivakumar and Fallik, 2013). Hot water treatment is a process of treating fresh produce at temperatures above 40 °C for a certain period to control postharvest infections (Barkal-Golan and Phlllips, 1991). Control of postharvest decay in fruit has been studied intensively (Sivakumar and Fallik, 2013) with success in controlling anthracnose of papaya and mango using hot water dips (HWD) of 48 °C for 20 minutes and 53 °C for 20 minutes, respectively, as well as stem-end rot of mango at 55 °C for 5 minutes (Usall, 2016).

The objective of the study was to optimise the technology of hot water treatment to provide control of postharvest avocado decay comparable to that of the fungicide Prochloraz. The effect of hot water treatments is brief, relative to the long period involved in postharvest handling, transport and sale. Consequently, the application of hot water treatment as a stand-alone treatment is usually avoided in commercial settings (Palou, 2013). The use of biocontrol yeasts to provide long-term protection of hot

water-treated fruit is an option that has been explored by some researchers (Abraha *et al.*, 2010).

MATERIALS AND METHODS

Trial 1: Avocado fruit skin sensitivity test towards hot water treatments

The initial screening was of healthy mature avocado 'Hass' fruits that were treated in a hot water bath in a series of temperature x time combinations, as follows: control (room temperature), 45, 50, 55, 60, 65, 70, 75 and 80 °C (± 0.1 °C) x control (room temperature), 20, 30, 45, 60, 75, 90, 105, 120 and 180 seconds. Each treatment combination was applied to 10 avocado fruits. The treated fruit were then air-dried, placed in cardboard boxes on a bench in a randomised complete block (RCB) design, and maintained at 25 °C until they were ripe. Once ripe, the fruit were classified according to the following skin colours: (1) green, (2) green-black, (3) brown-black and (4) black. The experiment was performed twice.

Trial 2: Temperature and time combinations of hot water treatment to control postharvest avocado rot

Healthy mature avocado 'Hass' fruit were submitted to the following temperatures: 25 (control), 54, 56 and 58 °C (± 0.1 °C). For each temperature, the avocado fruit were exposed for the following period: 0 (control), 10, 15, 20 and 30 seconds.

Trial 3: Comparing Prochloraz versus the best of the rHWT combinations from Trial 2

The efficacy of the best of the rHWT combinations 56 °C for 10 seconds (T56 x t10) from Trial 2 was compared with the fungicide Prochloraz at full strength (Prochloraz at 1100 mL per 100 L water) and half-strength (Prochloraz at 550 mL per 100 L water).

Trial 4: Temperature and time combinations of hot water treatment to control postharvest avocado rot to identify very rapid treatments

Further tests were conducted to determine optimum control at the shortest time, using the temperature and time combinations of 25 (control), 50, 52, 54, 56, 58, 60, 62, 64, 66, 68 and 70 °C (± 0.1 °C) for 0 (control), 2, 4, 6, 8 and 10 seconds. The efficacy of hot water treatment was compared against the fungicide Prochloraz at full strength (Prochloraz 1100 mL per 100 L water) and half strength (Prochloraz 550 mL per 100 L water).

Each treatment was applied to 25 avocado fruit and repeated four times. The treated fruit were then air-dried, placed in cardboard boxes on a bench in a RCB design at 25 °C until they were ripe. After storage to ripeness, the fruit were classified as follows: A = healthy avocado fruit (0% infection); B = the fruit is rotten, smells and is not edible (90% infection). The experiment was conducted twice.

Statistical analysis

The data were subjected to analyses of variance (ANOVA) using the Agricolae package in the R Statistical Analysis Software (version 3.6.1) (De Mendiburu and De Mendiburu, 2020; R Core Team, 2013) to determine differences between treatments. Fisher's Least Significant Difference Test was used for treatment means separations ($P < 0.05$).

RESULTS AND DISCUSSION

Trial 1: Hot water treatments for a safe temperature and exposure time for fresh avocado 'Hass' fruits

Avocado fruit skins are highly sensitive to stressful conditions and, to account for this, in our study avocado fruit were subjected to different hot water temperatures for different periods to determine safe temperature and time combinations to control postharvest avocado decay (Palou, 2008). Table 1 presents the effects of combinations of temperatures of 45 °C to 55 °C applied for 20 s to 180 s; and 60 °C with the time combination of 20 s to 30 s, where fruit had no skin damage from heat. At 60 °C with time combinations of 45 s to 105 s the fruit had green-black fruit skin colour, indicating moderate skin damage. At temperatures of 65 °C to 80 °C x 20 s to 180 s and 60 °C x 120 s to 180 s, the fruit went black, indicating severe skin damage.

Table 1: Skin sensitivity test results for the HWT at different temperature and time combinations of avocado 'Hass'

	20s	30s	45s	60s	75s	90s	105s	120s	180s
45c	Green	Green	Green	Green	Green	Green	Green	Green	Green
50c	Green	Green	Green	Green	Green	Green	Green	Green	Green
55c	Green	Green	Green	Green	Green	Green	Green	Green	Green
60c	Green	Green	Green-Black	Green-Black	Green-Black	Green-Black	Green-Black	Black	Black
65c	Black	Black	Black	Black	Black	Black	Black	Black	Black
70c	Black	Black	Black	Black	Black	Black	Black	Black	Black
75c	Black	Black	Black	Black	Black	Black	Black	Black	Black
80c	Black	Black	Black	Black	Black	Black	Black	Black	Black
Control	Green	Green	Green	Green	Green	Green	Green	Green	Green

Trial 2: Hot water treatment for the control of postharvest avocado rot

Temperature and time combinations that caused no skin damage and which were efficient in time were selected to determine the optimal time and temperature combination for the control of avocado rot. Table 2 depicts the best treatments which were 58 °C for 10 seconds; 52 °C for 20 seconds; and 56 °C for 10 seconds.

Trial 3: Comparing Prochloraz versus the best of the rHWT from trial 2

A rHWT of 56 ºC for 10 seconds provided control comparable to that of the fungicide (Table 3). These findings are similar to studies on hot water rinsing and brushing (HWRB) of citrus fruit that was developed in Israel around 1990 to 1996 (Pavoncello, 2001; Palou, 2009; Palou, 2013; Lurie, 2016). Similarly, Sivakumar and Fallik (2013) noted that hot water treatments at temperatures between 48 ºC to 63 °C for 10 to 25 seconds extend the shelf life of a wide range of fresh and fresh-cut produce while maintaining the overall product quality. They found that mango decay could be controlled by rHWT of 48 ºC to 65 °C applied for 10 to 25 seconds.

Trial 4: Very rapid hot water treatments

In the subsequent studies to determine optimum control in less than 10 seconds, one treatment provided 100% disease control at 70 °C for 6 seconds (Table 4). The best rHWT treatments were substantially better than the two Prochloraz treatments. In a parallel study on tomato fruit, Ziena (2019) found that 62 °C for 8 seconds provided the best control of *C. gloeosporioides* and *G. candidum*, which cause postharvest rot of tomato fruit, confirming that rHWT less than 10 seconds can provide excellent disease control for fresh produce. The mechanism by which rHWT protects the host against the pathogen is due to heat shock-induced production of the phytoalexins scoparone and scopoletin, and the production of pathogen-related (PR) proteins (Ben-Yehoshua and Porat, 2005; Palou, 2009).

Results obtained may be inconsistent because all fruit may not react similar to rapid hot water treatment (Irtwange, 2006). To address any biases from our findings, further studies will involve applying rapid hot water treatment to most of the commercially produced avocado cultivars across Southern Africa, as well as screening for the heat shock proteins and phytoalexins responsible for pathogen control. We are working with an agricultural engineer to create and test rHWT equipment that can be integrated into existing commercial packhouses.

Table 2: Percentage of healthy 'Hass' fruits, free from avocado rot, after rapid hot water treatment

Temperature (degrees Celcius)	Time (seconds)	Mean percentage of healthy fruits
56	10	67 a
52	20	66 a
58	10	63 a
54	15	54 ab
56	15	50 abc
54	20	48 abc
52	30	38 bc
Control (25)	Control (0)	34 c

Values with the same letters were not significantly different
P-value - 0.01174
F-value - 3.3849
LSD-value - 19.74235
CV%- value - 25.76714

Table 3: Efficacy of best temperature and time combination compared to Prochloraz treatments for the 'Hass' cultivar

Treatments (Temp x time)	Percentage of healthy fruits
Full strength Prochloraz	91 a
T56 x t10	89 a
Half strength Prochloraz	75 b
Control	71b
P-value	4.303e-06
F-value	33.222
LSD-value	5.33698
CV%-value	4.250431

Mean values with the same letters are not significantly different
T = (temperature °C)
t = time (seconds)
Full strength Prochloraz at 1100 mL per 100 L water
Half strength Prochloraz at 550 mL per 100 L water

Table 4: Mean percentage of healthy 'Hass' avocado fruits heat-treated for 10 seconds or less

	2 sec	4 sec	6 sec	8 sec	10 sec
50°C	77.5	87.5	75	55	72.5
52°C	75	60	70	77.5	67.5
54°C	67.5	77.5	75	80	62.5
56°C	60	57.5	67.5	57.5	62.5
58°C	67.5	87.5	60	60	77.5
60°C	70	87.5	87.5	72.5	72.5
62°C	75	77.5	82.5	82.5	80
64°C	67.5	62.5	75	65	57.5
66°C	60	57.5	55	42.5	42.5
68°C	45	40	65	62	80
70°C	90	72.5	100	85	87.5

Mean values with the same letters are not significantly different
Control = 52.5
Half fungicide = 57.5
Full fungicide = 55
P-value = 2.612e-12
F-value = 3.9123
CV%- value = 25.76714

CORRUGATED

FSC
www.fsc.org
FSC® C133590
The mark of responsible forestry

“Quality packaging worth the price”

mpact
smarter, sustainable solutions

Mpact Corrugated has eleven corrugated plants, producing corrugated board and boxes. Eight plants are located in South Africa in Gauteng, KwaZulu-Natal, Western Cape, Eastern Cape and Mpumalanga, two in Namibia and one in Mozambique. All sites are fully equipped to produce corrugated packaging from regular slotted cartons to die-cut, self-locking trays for the local and export market. Our promise: smarter, sustainable solutions.

Discover more at **www.mpact.co.za**
Nelspruit **031 752 4111**

An ISO 9000, 14000, 18000 and 22000 Certified Company

CONCLUSION

The study demonstrates that rHWT can provide excellent control of avocado fruit decay, comparable with that provided by the fungicide Prochloraz. Further studies on the effects of rHWT on the physiology, pathology, biochemistry and molecular biology of avocado are called for (Lurie, 1998; Fallik, 2004; Sivakumar and Fallik, 2013). Additionally, rHWT typically controls existing or latent infections but does not protect the fruit subsequently in the period between packing and consumption. Therefore, integrated disease management combining the use of rHWT with a yeast biocontrol agent to prevent future infections may be ideal in providing long-term disease control for avocado fruit (Palou, 2009).

Acknowledgements

Thanks to the South African Avocado Growers' Association (SAAGA) and Post-Harvest Innovation (PHI) for funding the project. Thanks to Westfalia, Waterford and Avolands for supplying avocado fruit for the trials.

REFERENCES

ABRAHAM, O.A., LAING, M.D. & BOWER, J.P. 2010. Isolation and in vivo screening of yeast and *Bacillus* antagonists for the control of *Penicillium digitatum* of citrus fruit. *Biol. Control* 53: 32-38.

BARKAL-GOLAN, R. & PHILLIPS, D.J. 1991. Postharvest heat treatment of fresh fruits and vegetables for decay control. *Plant Dis.* 75: 1085-1089.

BEN-YEHISHUA, S. & PORAT, R. 2005. Heat Treatments to Reduce Decay. In: S.B. Yeoshua (ed). *Environmentally friendly technologies for agricultural produce quality,* CRC Press. pp. 11-42.

DE MENDIBURU, F. & DE MENDIBURU, M.F. 2020. Package 'Agricolae'. R package version 1-2.

FALLIK, E. 2004. Pre-storage hot water treatments (immersion, rinsing, and brushing). *Postharv. Biol. Technol.* 32: 125-134.

IRTWANGE, S.V. 2006. Hot water treatment: a non-chemical alternative in keeping quality during postharvest handling of citrus fruits. *Agric. Eng. Int.: CIGR J.* 8 : 1-10.

LURIE, S. 1998. Postharvest heat treatments. *Postharv. Biol. Technol.* 14: 257-269.

LURIE, S. 2016. Pre-storage heat stress to improve storability of fresh produce: a review. *Israel J. Plant Sci.* 63: 17-21.

PALOU, L. 2009. Control of citrus postharvest diseases by physical means. *Tree Forest. Sci. Biotechnol.* 3: 127-142.

PALOU, L. 2013. Mini-review: Heat treatments for the control of citrus postharvest green mold caused by *Penicillium digitatum*. In: A. Méndez-Vilas (ed), *Microbial pathogens and strategies for combating them: science, technology and education,* Formatex Res. Center, Badajoz. pp. 508-514.

PALOU, L., JOSEPH, L.S. & SAMIR, D. 2008. Alternatives to conventional fungicides for the control of citrus postharvest green and blue moulds. *Stewart Postharv. Rev.* 4: 1-16.

PAVONCELLO, D., LURIE, S., DROBY, S. & PORAT, R. 2001. A hot water treatment induces resistance to *Penicillium digitatum* and promotes the accumulation of heat shock and pathogenesis-related proteins in grapefruit flavedo. *Physiol. Plantarum* 111: 17-22.

SCHIRRA, M., D'AQUINO, S., CABRAS, P. & ANGIONI, A. 2011. Control of postharvest diseases of fruit by heat and fungicides: efficacy, residue levels, and residue persistence. A review. *J. Agric. Food Chem.* 59: 8531-8542.

SCHIRRA, M., D'HALLEWIN, G., BEN-YEHOSHUA, S. & FALLIK, E. 2000. Host-pathogen interactions modulated by heat treatment. *Postharv. Biol. Technol.* 21: 71-85.

SIVAKUMAR, D. & FALLIK, E. 2013. Influence of heat treatments on quality retention of fresh and fresh-cut produce. *Food Rev. Int.* 29: 294-320.

USALL, J., IPPOLITO, A., SISQUELLA, M. & NERI, F. 2016. Physical treatments to control postharvest diseases of fresh fruits and vegetables. *Postharv. Biol. Technol.* 122: 30-40.

ZIENA, L.W. 2019. Integration of Rapid Hot Water Treatments and Biocontrol Agents to Control Postharvest Pathogens of Tomato. MSc Thesis, UKZN.