International Journal of Horticulture, 2024, Vol.14, No.1, 38-43
http://hortherbpublisher.com/index.php/ijh

Research Report Open Access

Effect of Different Postharvest Treatments on Quality and Shelf Life of Mandarin (*Citrus reticulata* Blanco) in Gokuleshwor, Baitadi

Kiran Prasad Upadhayaya [1], Arati Chapai [2], Binay Maharjan [1], Raju Ranabhat [1], Rajesh Pant [1], Sanjeet Basnet [1]
1 Institute of Agriculture and Animal Science, Tribhuwan University, Kirtipur, P.O. Box 143, Nepal
2 Agriculture and Forestry University, Rampur, Chitwan, 44209, Nepal
Co-Corresponding email: wordsforkiran@gmail.com; chapaiarati100@gmail.com
International Journal of Horticulture, 2024, Vol.14, No.1 doi: 10.5376/ijh.2024.14.0005
Received: 21 Feb., 2024
Accepted: 18 Mar., 2024
Published: 03 Apr., 2024

Preferred citation for this article:
Upadhayaya K.P., Chapai A., Maharjan B., Ranabhat R., Pant R., and Basnet S., 2024, Effect of different postharvest treatments on quality and shelf life of mandarin (*Citrus reticulata* Blanco) in Gokuleshwor, Baitadi, International Journal of Horticulture, 14(1): 38-43 (doi: 10.5376/ijh.2024.14.0005)

Abstract The experiment was carried out from December 2018 to January 2019 with the objective of assessing the effect of different postharvest treatments on the quality and shelf life of mandarin (*Citrus reticulata* Blanco). The design of the experiment was a Completely Randomized Design (CRD) with five treatments (T1= Control, T2= Calcium chloride 1%, T3= Cinnamomum oil 2%, T4= Bavistin 0.1% and T5= Salt water 1%) and four replications. T3 was found to be the most effective in reducing the physiological loss in weight (18.10%) in comparison with T5 (23.28%) and T1 (22.79%), whereas T4 proved to have minimum decay loss (25%) up to four weeks of storage. The fruits treated with T2 retained maximum firmness (3.96 kg/cm^2). The maximum total soluble solid (12.36˚ Brix) was recorded in T5 and the maximum Titrable Acidity was recorded in T3. The present findings indicate that mandarin can be stored for up to four weeks when treated with Cinnamomum as well as with Bavistin in a condition with a temperature of 13 °C-18 °C and a relative humidity of 75%-90%.
Keywords Mandarin; Fruit quality; Postharvest treatments; Shelf life; Postharvest loss in weight

Introduction

The Mandarin, also known as Mandarine (*Citrus reticulata*), one of the most vital and commercially valuable fruit crops in Nepal, is a small citrus tree that produces fruits resembling oranges. The Mandarin tree belongs to the Rutaceae family. Mandarins thrive in tropical and subtropical regions but are delicate and vulnerable to cold temperatures.

World production of mandarin oranges was 33.4 million tons, led by China with 54% of the global total. Producing more than one million tons each in 2017 were Spain, Turkey, Morocco, Brazil, and Egypt (FAOSTAT, 2017). Top Producer of Mandarin in world is China. Top Exporter is Spain and Top Importer is Russia. Mandarin are thought to have evolved in a region including Vietnam, South China, and Japan.

The mandarin fruit plays a significant role in the national economy of Nepal, contributing to 0.97% of the Agricultural Gross Domestic Product (AGDP) and 0.33% of the GDP (PMD, 2012**)**. Nepal also produces a huge amount of mandarin in its hilly areas from east to west comprising 56 districts and occupies 20th position in the world's mandarin production (Rokaya et al., 2016). Mandarin cultivation occupies approximately 26,282 hectares of land in Nepal, with 16,248 hectares designated as productive. The country's total production amounts to about 146,690 metric tons, with an average productivity of 9.0 metric tons per hectare (MoALD, 2016). Mandarin are non-climacteric and perishable, and are prone to quality loss during storage. In Nepal, around 15% to 20% of citrus fruit is lost during the postharvest period (Bhattarai et al., 2013).

In Baitadi, mandarin production covers about 16 hectares, of which 13 hectares are productive. The total production is approximately 120 metric tons, with an average productivity of 9.2 metric tons per hectare (MoALD, 2016). The large volume of the losses starts right from harvesting and loss increases many folds during the postharvest steps. The process of growing, harvesting, and post-harvesting oranges leads to significant damages, resulting in losses for farmers, impacting the country's economy, and decreasing food availability (Kabas, 2010).

Postharvest treatments play a significant role in extending shelf life of the fruits (Deka et al., 2006). In Nepal, mandarin losses are substantial annually due to insufficient postharvest practices during harvesting, transportation, and storage. To minimize these postharvest losses, postharvest treatments with wax and other safe fungicides are urgent (Rokaya et al., 2016). Temperature also plays the important role during storagr and the safe minimum temperatures for mandarin postharvest storage are between 5 °C and 8 °C (Kader, 1985). Edible coating of fruits can result in the creation of a modified atmosphere due to ineffective blockage of the pores within the fruits, reducing respiration rate and improving postharvest quality (Kader, 1985). Checking the rate of transpiration, respiration, microbial infection and protecting membranes from disorganization are some ways to extend shelf life and minimize postharvest loss (Sahu and Vishwavidyalya, 2016).

Currently, there is lack of information on postharvest losses during storage of mandarins cultivated in Baitadi. The main objective of the present study is to explore methods to enhance the postharvest shelf life and quality of mandarins.

1 Materials and Method

The study was conducted at Horticulture Laboratory of Gokuleshwor Agriculture and Animal Science College, Gokuleshwor, Baitadi. It lies in the Longitude 80°50' East and Latitude 24°75' North and elevation of 700 masl.

Freshly harvested defect free light-yellow stage of Mandarin of local variety were brought from local community of Gokuleshwor, Baitadi. The collected fruits were washed with normal tap water to remove the adherent dirt materials and kept in the shade for air-dry. Each treatment per replication consisted twenty mandarin of uniform sizes packed and tooked non-destructive sample and kept in open plastic tray for control treatment. The experimental set up was done in Completely Randomised Design (CRD) with five treatments (T1 = Distilled water (Control), T2 = Calcium chloride ($CaCl_2$), T3 = Cinnamomum oil, T4 = Bavistin and T5 = Salt solution), each replicated four times. Total Soluble Solid (TSS), Tritable Acidity (TA) and Firmness Readings were taken in every five days interval from the non-tagging sample. Physiological loss in weight (PLW) was taken from the non-destructive samples in 2 days interval from the tagged sample. Fruit firmness was taken with the help of penetrometer and TSS was taken with the help of refractometer.

Data entry and analysis was done by using computer software package, Microsoft Excel (2019) and R-Stat.

2 Results and Discussion

2.1 Physiological loss in weight (PLW)

As the storage period progressed, the physiological loss in weight (PLW) was markedly increased in all the treatments (Table 1). The weight loss percentage exhibited maximum increasing trends in the untreated fruits serving as controls during storage period. The fruits treated with Cinnamomum oil and Bavistin consistently showed the lowest percentage of PLW throughout the storage weeks, while the fruits exposed to a salt solution experienced the maximum weight loss during storage.

Table 1 Effect of postharvest treatments on PLW

TREATMENT	PLW D1	PLW D5	PLW D10	PLW D15	PLW D20	PLW D25
CONTROL	1.20^{b}	3.14^{a}	5.69^{a}	9.91^{a}	16.91^{a}	22.79^{ab}
CALCIUMCHLORID	1.42^{a}	3.21^{a}	6.24^{a}	9.32^{a}	15.21^{b}	20.49^{bc}
CINNAMOMUM OIL	1.30^{ab}	1.92^{b}	4.40^{b}	7.12^{b}	13.65^{c}	18.10^{c}
BAVISTIN	1.15^{b}	2.25^{b}	4.77^{b}	7.81^{b}	13.67^{c}	19.04^{c}
SALT SOLUTION	1.35^{ab}	3.00^{a}	6.00^{a}	10.02^{a}	17.58^{a}	23.28^{a}
CV	9.77	10.57	7.67	9.21	6.45	7.69
F-VALUE	2.97	16.74	14.74	10.22	13.30	8.09
LSD	0.19	0.44	0.64	1.25	1.53	2.46
SE	0.05	0.26	0.36	0.58	0.81	1.01

Note: Means with the same letter within a column do not differ significantly at p= 0.05, CV = Coefficient of variation, LSD = Least Significant Difference, and SE = Standard Error

The decrease in weight loss seen in fruits treated with Cinnamomum oil could be due to the oil's ability to restrict transpiration and respiration processes by closing the lenticels and stomata on the fruit cell walls. Loss of weight and moisture in the peel mostly occurred through fruit transpiration, resulting in a wilted rind and shriveled appearance (Wills et al., 2007).

These findings were in consonance with the report of the Ahmad et al. (2005) in kinnow mandarin, Deka et al. (2006) in Khasi mandarin and Rokaya et al. (2016) who found minimum weight loss in the fruits coated with waxy substances.

2.2 Decay loss

At the end of the storage period (25th day) minimum decay loss was recorded in the fruits with Bavistin (25%) followed by Cinnamomum (30%) and calcium chloride (35%). Maximum decay loss was recorded on control (45%) and salt solution (60%). The fruits which were not treated with fungicide during storage suffered substantial losses (Reuther, 1967). As time passed during storage, decay in the fruits became more pronounced across all treatments.

The minimal decay loss in fruits treated with Bavistin and Cinnamomum oil is due to their ability to inhibit moisture and microbial agents, including fungi and bacteria. Bavistin acts as a fungicide, inhibiting fungal growth by disrupting cell wall synthesis, while Cinnamomum oil's antimicrobial properties prevent microbial proliferation by disrupting cell membranes and metabolic processes. Additionally, both treatments act as moisture barriers, further limiting microbial contamination and decay. The minimal decay loss could be because the coating substances serves as a protective barrier against microbial growth and helps prevent moisture penetration (Yadav et al., 2010).

Similar findings regarding minimal decay loss were reported by Rokaya et al. (2016) in mandarin and Ahmad et al. (2005) in kinnow mandarin. They found that using wax or wax-like safe fungicides during storage resulted in minimal decay loss.

2.3 Fruit firmness

As the storage period progressed, the firmness of the fruits decreased across all treatments. The results indicate that this decline began in the first week and continued until the end of storage in all treatments (Table 2). In the initial week, fruits treated with Cinnamomum oil and salt solution exhibited the highest firmness, while the lowest firmness was observed in the control and $CaCl_2$-treated fruits. At the end of the storage duration, the fruits treated with $CaCl_2$ showed the highest level of firmness, followed by those treated with Cinnamomum, whereas the fruits treated with salt solution displayed the lowest firmness.

Table 2 Effect of postharvest treatments on fruit firmness

TREATMENT	FRIMNESS D1	FRIMNESS D5	FRIMNESS D10	FIRMNESS D15	FIRMNESS D20
Control	4.73^{c}	4.61^{b}	3.91^{c}	3.60^{d}	3.24^{c}
Calcium chloride	4.79^{c}	4.61^{b}	4.51^{a}	4.37^{a}	3.95^{a}
Cinnamomum oil	5^{a}	4.97^{a}	4.60^{a}	4.25^{b}	3.55^{b}
Bavistin	4.76^{c}	4.79^{ab}	4.25^{b}	3.88^{c}	3.26^{c}
Salt solution	4.9^{ab}	4.15^{c}	3.4^{d}	3^{e}	2.20^{d}
CV	1.46	2.59	2.04	1.25	4.40
F-VALUE (TREATMENT)	9.61	25.52	135.10	526.59	82.21
LSD	0.10	0.18	0.13	0.07	0.22
MEAN	4.83	4.63	4.13	3.82	3.24
SE	0.04	0.13	0.22	0.24	0.28

Note: Means with the same letter within a column do not differ significantly at p= 0.05, CV = Coefficient of variation, LSD = Least Significant Difference, and SE = Standard Error

The decline in the firmness might be due to moisture loss from the fruit cells. Softening of fruits can result from either the breakdown of insoluble proto-pectins into soluble pectin or the hydrolysis of starch (Virkar and Garande, 2023). The observed greater firmness in fruits treated with $CaCl_2$ compared to other treatments may be attributed to calcium's role in binding polygalacturonic acid molecules together, consequently strengthening and rigidifying the cell membrane, as suggested by Sharma et al. (2012).

2.4 Total soluble solid (TSS)

TSS serves as a key indicator for assessing mandarin fruit quality. TSS levels increased over the storage period across all treatments, with a more pronounced rise observed in untreated (control) fruits compared to those treated with various chemicals (Table 3).

Table 3 Effect of postharvest treatments on TSS

Treatment	TSS D1	TSS D5	TSS D10	TSS D15	TSS D20
Control	8.85^{a}	9.06^{a}	11.29^{a}	12.25^{a}	12.24^{a}
Calcium chloride	9.77^{a}	10.06^{a}	10.72^{a}	11.16^{b}	11.54^{a}
Cinnamomum oil	9.15^{a}	10.45^{a}	11.12^{a}	11.55^{ab}	11.70^{a}
Bavistin	8.87^{a}	9.83^{a}	10.83^{a}	11.3^{ab}	11.09^{a}
Salt solution	9.75^{a}	9.87^{a}	10.53^{a}	10.85^{b}	12.36^{a}
CV	7.65	8.86	5.26	5.25	9.46
F-value (Treatment)	1.64	1.35	1.13	3.12	0.87
LSD	1.09	1.34	0.88	0.92	1.71
Mean	9.28	9.86	10.90	11.42	11.79
SE	0.20	0.22	0.13	0.23	0.23

Note: Means with the same letter within a column do not differ significantly at p= 0.05, CV = Coefficient of variation, LSD = Least Significant Difference, and SE = Standard Error

During the storage period, the untreated (control) fruits consistently displayed the highest TSS content, starting from 8.85˚ Brix in the 1st week and reaching 12.36˚Brix by the 4th week. In contrast, fruits treated with Bavistin consistently maintained the lowest TSS levels, ranging between 8.875˚ Brix and 11.09167˚ Brix from the 1st to the 4th week. The trend observed suggests that fruits treated with Bavistin exhibited superior qualities due to a gradual increase in TSS content, contrasting with the faster pace of increase seen in untreated (control) and salt solution-treated fruits.

The gradual TSS increment in Bavistin-treated fruits could be attributed to the effective inhibition of metabolic activities, particularly respiration and transpiration. Bavistin, being a fungicide, likely played a role in slowing down these metabolic processes, which are known to influence TSS levels. By inhibiting microbial growth and activity, Bavistin may have helped to maintain fruit quality and slow down the breakdown of sugars into simpler compounds, leading to a more controlled rise in TSS over time.

On the other hand, untreated fruits and those treated with salt solution experienced a faster increase in TSS. This could be due to the absence of any treatment to regulate metabolic activities. In untreated fruits, metabolic processes such as respiration and transpiration likely occurred at a faster rate, resulting in quicker changes in TSS levels. Rokaya et al. (2016) found that fruits with control treatment had the highest sugar content during storage.

In summary, Bavistin-treated fruits demonstrated a superior trend in TSS content due to the controlled metabolic activities facilitated by the fungicide. In contrast, the faster TSS increment in untreated fruits and those treated with salt solution may be attributed to the absence of such regulation mechanisms, allowing metabolic processes to proceed at a faster pace. Purbiati and Supriyanto (2013) reported that the rise in Total Soluble Solids (TSS) could be linked to the conversion of starch and other insoluble carbohydrates into soluble solids.

Jholgiker and Reddy (2007) claimed that the coating material on fruits helps reduce transpiration losses and creates a modified atmosphere, leading to increased Total Soluble Solids (TSS).

2.5 Titrable acidity (TA)

The information highlights the significant impact of various treatment levels on the titratable acidity (TA) of mandarin fruits at the end of storage (Table 4). TA decreased notably as the storage period progressed, a trend likely attributed to the utilization of acids in the tricarboxylic acid cycle during respiration.

Table 4 Effect of postharvest treatments on TA

TREATMENT	TA D1	TA D5	TA D10	TA D15	TA D20
Control	0.93[a]	0.6[a]	1.16[a]	0.92[a]	0.58[a]
Calcium chloride	1.18[a]	0.62[a]	1.03[a]	0.84[a]	0.68[a]
Cinnamomum oil	1.05[a]	0.61[a]	1.12[a]	0.84[a]	0.82[a]
Bavistin	1.01[a]	0.53[a]	0.98[a]	0.64[a]	0.64[a]
Salt solution	1.08[a]	0.67[a]	1.19[a]	0.75[a]	0.70[a]
CV	22.86	19.72	21.09	29.96	28.40
F-VALUE (TREATMENT)	0.57	0.66	0.56	0.84	0.95
LSD	0.37	0.18	0.35	0.37	0.30
MEAN	1.05	0.60	1.09	0.80	0.68
SE	0.04	0.02	0.03	0.05	0.04

Note: Means with the same letter within a column do not differ significantly at p= 0.05, CV = Coefficient of variation, LSD = Least Significant Difference, and SE = Standard Error

At the end of storage, the highest TA was observed in fruits treated with Cinnamomum oil, contrasting with the control group. This suggests that Cinnamomum oil treatment may have helped maintain higher acidity levels in the fruits compared to the untreated ones.

Cinnamomum oil-treated fruits retained higher acidity possibly because they used acids less during storage, potentially due to slower respiration. Conversely, untreated fruits likely had lower acidity because they utilized acids faster in the respiration process during storage (Rokaya et al., 2017).

The findings are consistent with the results reported by Sonkar et al. (2009) in kinnow mandarin and Deka et al. (2006) in Khasi mandarin.

3 Conclusion and Recommendations

From these results, it can be concluded that the application of diverse chemicals can significantly minimize postharvest losses in mandarin fruits. Among these chemicals, Cinnamomum oil effectively decreased both weight loss and decay loss, contributing to an overall improvement in fruit quality and shelf life. The fruits treated with $CaCl_2$ displayed the highest firmness, followed by those treated with Cinnamomum oil. Minimum TSS was recorded in the fruits treated with Bavistin (11.09˚ Brix) and the maximum TA was recorded in the fruits treated with Cinnamomum oil (0.82). Bavistin and Cinnamomum oil-treated fruits can be preserved for up to four weeks under controlled conditions: temperatures ranging from 13 °C to 18 °C and relative humidity maintained between 75% and 90%.

Based on the findings, it is advisable for farmers to utilize a variety of chemicals and botanicals such as cinnamomum oil, Bavistin, and calcium chloride to enhance the quality and prolong the shelf life of mandarin fruits. While the residue effects were not examined in this study, it is recommended to prioritize the use of botanicals over chemicals due to the potential residue issues associated with chemical treatments, which could lead to adverse side effects.

Authors' contributions

KPU: Contribution to design and implementation of the research, interpretation of the results, writing the manuscript. AC: analysis of data, interpretation of the results, writing the manuscript. BM, RR, RP, SB: Sample preparation, data collection, perform the experiments and manuscript preparation. All authors read and approved the final manuscript.

Acknowledgments

We extend our heartfelt gratitude and warmest appreciation to the Gokuleshwor Agriculture and Animal Science College, Tribhuvan University, Nepal, for providing us with a valuable platform and unwavering support throughout this endeavor. The authors are thankful to Assistant Professor Ramesh Upreti and our esteemed colleagues for their guidance and assistance.

References

Ahmad M.S., Thakur K.S., and Kaushal B.B.L., 2005, Post-harvest treatments to reduce postharvest losses in Kinnow mandarin, Indian Journal of Horticulture, 62(1): 63-67.

Bhattarai R.R., Rijal R.K., and Mishra P., 2013, Post-harvest losses in mandarin orange: A case study of Dhankuta District, Nepal, African Journal of Agricultural Research, 8(9): 763-767.

Deka B.C., Sharma S., and Borah S.C., 2006, Post-harvest management practices for shelf-life extension of Khasi mandarin, Indian Journal of Horticulture, 63(3): 251-255.

FAOSTAT, 2017, Database of Food and Agriculture Organization of the United Nations. http://www.fao.org/faostat/en/ (accessed 10 March 2017).

Jholgiker P., and Reddy B., 2007, Effect of different surface coating material on post-harvest physiology of *Annona squamosa* L. fruits under ambient and zero energy cool chamber storage, Indian Journal of Horticulture, 64(1): 41-44.

Kabas J., 2010, Study on post harvest loss of mandarin orange of Dhankuta district, Dhankuta: District Agriculture Development Office.

Kader A.A., 1985, Postharvest handling systems: subtropical fruits, pp.375-383.

MoALD, 2016 (n.d.), Retrieved February 19, 2024, from https://moald.gov.np/wp-content/uploads/2022/04/STATISTICAL-INFORMATION-ON-NEPALESE-AGRICULTURE-2072-73.pdf

PMD, 2012, Postharvest Management and Value Addition of Fruits in Production Catchments in Nepal, A Project Submitted to SAARC Development Fund (SDF) Secretariat, Postharvest Management Directorate, Shreemahal, Kath-mandu, Nepal, 1-16.

Purbiati T., and Supriyanto A., 2013, Effects of harvesting method and storage temperature on shelf life of mandarin fruit cultivar 'SoE' from East Nusa Tenggara, Indonesia, Acta Horticulturae, 989: 149-152. https://doi.org/10.17660/ActaHortic.2013.989.18

Rokaya P.R., Baral D.R., Gautam D.M., Shrestha A.K., and Paudyal K.P., 2016, Effect of postharvest treatments on quality and shelf life of mandarin (*Citrus reticulata* Blanco), American Journal of Plant Sciences, 7(7): 1098-1105. https://doi.org/10.4236/ajps.2016.77105

Rokaya P.R., 2017, Effect of Altitude and Various Pre and Postharvest Factors on Quality and Shelflife of Mandarin (*Citrus reticulata* Blanco) (Pd.D. thesis), Agriculture and Forestry University, Rampur, Chitwan, Nepal, 2017.

Reuther W., 1967, The Citrus Industry: crop protection, postharvest technology, and early history of citrus research in California (Vol. 3326). UCANR Publications.

Sahu B.A.L.R.A.M., and Vishwavidyalya I.G.K., 2016, Effect of different postharvest treatments on prolonging shelflife of sugar apple (*Annona squamosa* L.), M. Sc.(Horti.) Thesis, Indira Gandhi Krishi Vishwavidyalya, Raipur (CG).

Sharma S., Sharma R.R., Pal R. K., Jhalegar Md. J., Singh J., Srivastav M., and Dhiman M.R., 2012, Ethylene absorbents influence fruit firmness and activity of enzymes involved in fruit softening of Japanese plum (*Prunus salicina* Lindell) cv. Santa Rosa. Fruits, 67(4): 257-266.

Sonkar R.K., Sarnaik D.A., Dikhshit S.N., and Saxena R.R., 2009, Individually stretch cling film wrapped kinnow mandarin under ambient storage, Indian J Hort., 66(1): 22-27.

Virkar A.M., and Garande V.K., 2023, Effect of different post-harvest treatments on shelf life and quality of sweet orange (*Citrus sinensis* Osbeck.) Fruit#, Asian Journal of Dairy and Food Research, pp.1-6. https://doi.org/10.18805/ajdfr.DR-2118

Wills R., McGlasson B., Graham D., and Joyce D, 2007, Postharvest: An Introduction to the Physiology and Handling of Fruit, Vegetables and Ornamentals. 2nd Edition, University of New South Wales Press, Sydney. https://doi.org/10.1079/9781845932275.0013

Yadav M., Kumar N., Singh D.B. and Singh G.K., 2010, Effect of Postharvest Treatments on Shelf Life and Quality of Kinnow Mandarin. Indian Journal of Horticulture, 67: 243-248.