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Post-harvest study of mandarin in cold storage condition and ambient condition at Syangja, Nepal

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Abstract
Mandarin (*Citrus reticulate,* Blanco) falls under Rutaceae family is the major fruit crop of mid-hills region of Nepal. Syangja being the Citrus super-zone, the Mandarin area and production in this district has been significantly expanded and increased. The Mandarin fruit industry grapples with major challenge of huge post-harvest losses. Two different postharvest studies were carried out in the same time at Syangja cold-store. Different concentration of calcium chloride (0, 2% and 4%) were used to enhance the shelf life of mandarin along with the study of physiology of mandarins (harvested and stored in different date) after removal from cold storage was done. Decay loss caused by Green and Blue mold (*Penicillium* spp) was reduced when mandarins were dipped in a 4% solution of calcium chloride and kept in cold storage. Mandarins harvested and kept in cold storage on 1st week of December had comparatively low weight loss and decay loss. In general, the mandarins produced in Syangja district must be picked safely from second fortnight of November to first week of December and stored them in cold storage by treating with 4% calcium chloride.

Keywords: Calcium chloride, harvesting date, shelf life, treatment

1. Introduction

Citrus species mainly: mandarin orange, sweet orange and acid lime are the main fruit crops of Nepal. The government of Nepal has given high priority to the research and development of the citrus species in the mid-hills regions of the country. Since 1960s, there have been systematic research and development efforts by the public sector, which has resulted in projects supported by various organizations and donors to commercialize these crops (Poudyal, 2015) [13]. Many technologies related to variety development and improvement, nursery management, orchard management, plant protection and post-harvest management have been developed (NCRP, 2021) [11]. Currently, the commercial cultivation and production of citrus crops is expanding in about 50 districts of the country. In the mid-hill region of Nepal, mandarin orange cultivation from 1000 to 1500 meters above sea level contributes 0.85 percent to the country's total agricultural production. The area, production and productivity of mandarin oranges in Nepal are 18, 369 ha, 1, 98, 406 tons and 10.80 tons/ha, respectively, in which the area, production and productivity in Syangja district is 1,225 ha, 18350 tons and 14.97 tons/ha respectively (MOALD, 2021) [9]. It is a major cash crop for the farmers of Syangja district. In the fiscal year 2073/74, the government declared Syangja district as Citrus Super Zone under the Prime Minister Agriculture Modernization Project. After that, the mandarin orange production area and production in this district has been significantly expanded and increased.

In general, 20-25% of mandarin fruits are wasted due to suboptimal post-harvest management, with 7% lost during harvesting, 25% during transportation, 3% during grading, 10% in the packaging process, and an additional 5% during marketing (Bhattarai *et al.*, 2013) [2]. As fruits are highly perishable, they cannot endure extended transportation and storage times. The failure to adopt improved techniques at both pre and post-harvest stages results in the loss of key chemical quality attributes both internally and externally. To mitigate these post-harvest losses, measures should be taken to prolong shelf life by controlling transpiration rates, respiration, preventing microbial infection, and maintaining membrane integrity (Sahu, 2016) [16].

The ripening period of mandarin oranges is from November to January in Nepal. During this period, the fruits produced were surplus to the market at one time, so they do not get a reasonable price. If consumers have to buy mandarin orange beyond this period, they have to buy low-quality fruits imported from another country at a higher price. The Nepalese fruit industry grapples with critical challenges including huge post-harvest losses (Rokaya, 2017) [14]. If improvements can be made in various post-harvest management practices (Appropriate time of fruit picking, method of fruit picking, fruit grading, packaging, transportation and storage), the storage period can be increased and the farmers will also get a reasonable price results in long time availability of Nepali oranges in the market. Various research works have been done to reduce post-harvest damage and prolong the post-harvest life of oranges and good technologies have also been developed. The use of low-cost technologies, such as applying edible coatings (Including oils, waxes, and chemicals), has garnered global attention due to their ability to preserve the quality even under typical storage conditions (Bisen *et al*, 2012) [4]. Edible coatings create a modified atmosphere around the fruit by sealing the fruit's pores, which reduces the respiration rate and enhances post-harvest quality (Kader, 2005) [7]. With these considerations in mind, this study was conducted to extend the life of mandarins after harvest and to store the fruit for a long time in cold store using different concentrations of calcium chloride along with the study of physiology of mandarins (Harvested and stored in different date) after removal from cold storage.

2. Materials and Methods

2.1 Experimental Site

A post-harvest experiment was conducted at Syangja cold store and post-harvest laboratory (Ambient condition) of Horticulture Research Station, Malepatan, Kaski in 2022/23 (Nov-March) in collaboration with Prime Minister Agriculture Modernization Project, Project Implementation Unit, Syangja. Two different studies were carried out accordingly at the same time.

2.2 Experimental Setup and Management

In first study, the experimental setup consisted of three treatments (Table 1) and allocated in the completely randomized design (CRD) with three replications. Mandarins were treated with different amounts of calcium chloride (2% and 4%) and untreated mandarins were kept in cold storage for 1 month and the same mandarins were taken out of cold storage after 1 month and brought to the laboratory at Horticulture Research Centre, Malepatan, Kaski for quality analysis. The solutions of Calcium Chloride (2% and 4%) were prepared by dissolving 117.6 gm and 235.2 g Calcium Chloride in 4 liters of water. All total, 25 uniform fruits were kept per treatment per replication.

Table 1: Treatment details

S. N.	Treatment details
1	T_1: Control
2	T_2: Fruit treated with 2% Calcium Chloride
3	T_3: Fruit treated with 4% Calcium Chloride

In second study, the mandarins harvested and kept in cold storage in different date were taken as a treatment. According to this, the mandarins kept by the farmers in cold storage in different dates were collected 4 times at 15 days interval and kept them at the laboratory of HRS, Malepatan. On each sampling, 15 fruits were taken as samples from the crates of fruits kept in cold storage. The shelf life of mandarins after removal from cold storage was observed for two weeks.

During both study periods, cold storage temperature was (4-6 °C) and relative humidity was (80-85%) whereas laboratory temperature was (11-17 °C) and relative humidity (62-82%).

Table 2: Treatment details

S. N.	Harvest date and Storage date of mandarin
1	T1: 1st December, 2022
2	T2: 11th December, 2022
3	T3: 21st December, 2022

2.3 Parameters Observed

During storage at cold store and after removal from there, changes in post-harvest quality of mandarin were observed and their data was recorded accordingly in a week interval. Different qualitative parameters of fruits: physiological loss in weight (PLW), decay loss (Losses due to green mold, blue mold and cold rot), total soluble solid (TSS), and titrable acidity (TA) were recorded. For both studies, average weight (Per fruit) of mandarins was 125 g, average total soluble solid (TSS) was 9.91% and the average titrable acidity was 1.5%.

2.3.1 Physiological loss in weight (PLW)

For PLW, 5 fruits from each treatment were separated and marked so as to observe their changes in weight and recorded it accordingly. PLW was calculated based on change in weight (Difference between initial and final weight of fruit) divided by initial weight and expressed in percentage.

$$\text{PLW}(\%) = \frac{\text{Initial weight of fruit (g)} - \text{Final weight of fruits (g)}}{\text{Initial weight of fruti (g)}} \times 100$$

2.3.2 Decay loss percent

Fruits were evaluated visually for symptoms of decay during the entire storage period (Cold storage and ambient condition). Samples having decayed and diseased symptoms were counted and discarded. Decay loss was calculated based on number of discarded fruits (Decayed and diseased) divided by the total number of fruit expressed in percentage.

$$\text{Decay loss } (\%) = \frac{\text{Number of discarded fruit}}{\text{Total fruit number}} \times 100$$

2.3.3 Total soluble solid (TSS)

For TSS determination in °Brix, the hand-held refractometer (Model: Atago, Japan, N-1 Brix 0-32%) was used by placing two to three drops of clear juice on the prism surface.

2.3.4 Titrable acidity (TA)

TA determination was done by acid-base titration method (Tyl and Sadler, 2017) [21]. Five ml of fresh lime juice was titrated against 0.1 N NaOH (Sodium Hydroxide). The amount of NaOH consumed till end point was represented by the appearance of pink coloration, and that volume of NaOH was noted. TA was calculated by following formula,

$$TA(\%) = \frac{0.1\,N\,(NaOH) \times V1\,(ml) \times 0.064 \frac{g}{mol})}{V2\,(ml)} \times 100 \quad (3)$$

Where, V1= Volume of NaOH consumed during titration of sample (ml), a V2= Volume of sample (ml) and $(0.064 g/mol)$ = Acid milli equivalent conversion factor

2.4 Data Analysis

The data occurred during the study period was entered in Microsoft excel 2010. The analysis of variance was determined by using the statistical tool for agricultural research (STAR) version 2.0.1 and the significance was determined using Fisher's least significant difference at $p<0.05$ (Gomez and Gomez, 1984) [19].

3. Results

3.1 First Study: Total soluble solids (TSS °Brix), titrable acidity (TA %), PLW (%) and decay loss (%) of mandarins were recorded just after removal of mandarins from the cold storage and after 15 days of its removal. Significant difference was observed among the treatment methods in mandarin. According to Table 3, TSS and TA of untreated oranges were found to be 8.47% and 1.49% respectively, just after removal from cold storage. After 15 days of removal from cold storage, it was found to be 8.53% and 1.15% respectively. TSS and TA of mandarin treated with 2% calcium chloride were 9.06% and 1.19% just after removal, while TSS and TA of same were 10.2% and 0.89% after 15 days of removal from cold storage. The TSS and TA of oranges treated with 4% calcium chloride were 9.83% and 1.32% just after removal from cold storage, while TSS and TA were 11.13% and 0.89% after 15 days of removal from cold storage. TSS of mandarin was gradually increased and TA was gradually decreased after 15 days of removal from cold storage. The result showed that TSS of mandarins treated with 4% calcium chloride was higher than that of untreated oranges.

Table 3: Effect of different dose of Calcium Chloride on post-harvest quality parameters of Mandarin immediately after removal from the cold storage and after 15 days of its removal

Treatment details	TSS (%)		TA (%)	
	Immediate after removal from cold storage	After 15 days of removal from cold storage	Immediate after removal from cold storage	After 15 days of removal from cold storage
Control	8.46	8.53	1.49	1.15
Fruit treated with 2% Calcium Chloride	9.06	10.2	1.19	0.89
Fruit treated with 4% Calcium Chloride	9.83	11.13	1.32	0.89

Significant differences were also observed in physiological weight loss (%) and decay loss (%) between the mandarins treated with different amounts of calcium chloride (2 and 4%) and untreated mandarins. According to Figure 1, the physiological weight loss of untreated fruits, fruits treated with 2% calcium chloride and fruits treated with 4% calcium chloride during one-month storage at cold store were 25.6%, 24.8% and 24% respectively. And after 15 days of its removal from cold storage the physiological weight loss was 46.45%, 40.97% and 37.09% respectively. In mandarins treated with 4% of calcium chloride, the physiological weight loss was found to be less than others. Similarly, the decay loss of untreated fruits, fruits treated with 2% calcium chloride and fruits treated with 4% calcium chloride during one-month storage at cold store were 58.33%, 12% and 4.16% respectively while after 15 days of its removal from cold storage, the decay loss was 100%, 62.5% and 31.25%, respectively. In untreated fruits, 100% decay loss was recorded.

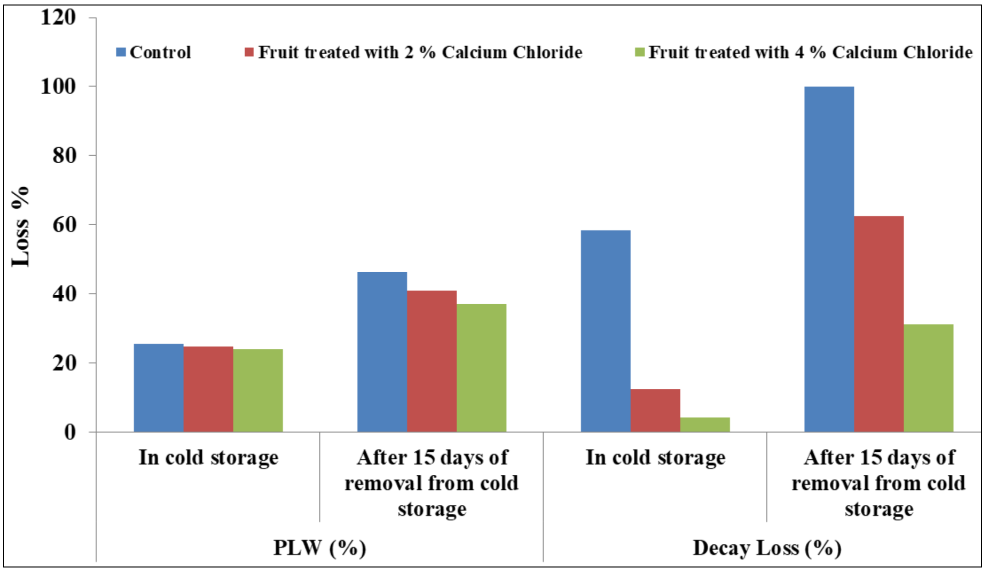

Fig 1: Physiological weight loss and decay, loss of mandarin (Treated and untreated with calcium chloride) in cold storage and after 15 days of removal from cold storage.

3.2 Second Study

According to Table 4, the mandarins kept in cold storage on 1st December, 2022 were taken out after 3 weeks for the first time and at each 15 days interval they were taken out for second, third and fourth time and kept for 15 days under ambient conditions. Changes in their quality parameters and damages were recorded accordingly. TA was decreased in second week as compared to the first week in every removal from cold storage, but the TSS increased gradually in the first and second removal whereas in third and fourth removal TSS decreased in the second week. Physiological weight loss in first week (1.89%) and second week (11.05%) were less in first removal of mandarin as compared to rest of three removals. Decay loss was found to be nil at first week and only 10% at second week in the second and fourth removal of mandarin from cold storage.

Table 4: Details of quality parameters and damage of mandarin (sample taken for 4 times and observed them in the laboratory for 2 weeks) kept in cold storage on 1st December

Quality of mandarin ➡	After first week				After second week			
Sample collection ⬇	TSS (%)	TA (%)	PLW (%)	Decay Loss (%)	TSS (%)	TA (%)	PLW (%)	Decay Loss (%)
First removal	10.1	2.17	1.89	10	10.8	1.66	11.05	20
Second removal	10.9	1.02	9.49	0	12	1.02	18.62	10
Third removal	9.3	0.9	4.91	10	7.6	0.76	17.85	30
Forth removal	10.4	1.53	5.32	0	9.6	0.89	17.51	10

According to Table 5, the mandarins kept in cold storage on 11th December 2022 were taken out after 2 weeks for the first time and at each 15 days interval they were taken out for second, third and fourth time and kept for 15 days under ambient conditions. As compared to the first week, TSS and TA of mandarin were decreased gradually in the second week. But in fourth removal, TSS was higher (11.6%). The physiological weight loss of mandarin after first week was less (7.99%) in first removal as compared to others. But the physiological weight loss in the second week was less (19.94%) in third removal. Although, the decay loss was less in the first week, it was found to be 40% and 60% at second week in second and third removal respectively and its acceptability was also very poor. In forth removal, the decay loss of mandarin was only 10% in both first and second weeks.

Table 5: Details of quality parameters and damage of mandarin (sample taken for 4 times and observed them in the laboratory for 2 weeks) kept in cold storage on 11th December

Quality of mandarin ➡	After first week				After second week			
Sample collection ⬇	TSS (%)	TA (%)	PLW (%)	Decay Loss (%)	TSS (%)	TA (%)	PLW (%)	Decay Loss (%)
First removal	9.5	2.68	7.99	10	7.7	1.53	23.40	20
Second removal	9.2	1.41	25.64	0	7.2	0.76	35.53	40
Third removal	8.8	0.9	8.49	30	7.6	0.7	19.94	60
Forth removal	11.6	1.28	12.03	10	8.6	1.28	24.87	10

According to Table 6, the mandarins kept in cold storage on 21st December 2022 were taken out after 2 weeks for the first time and at each 15 days interval they were taken out for second, third and fourth time and kept for 15 days under ambient conditions. Changes in their quality parameters and damages were recorded accordingly. As compared to the first week, TSS and TA of mandarin were decreased gradually in the second week. But in second and fourth removal, TSS was higher (11.0%). The physiological weight loss of mandarins in fourth removal was minimum in the first week and second week (7.83% and 14.99% respectively). Decay loss of mandarin in the first week was zero in first and second removal, but at second week it was 40% with poor acceptability. Decay loss was found to be zero at first and second week in the fourth removal of mandarin from cold storage.

Table 6: Details of quality parameters and damage of mandarin (sample taken for 4 times and observed them in the laboratory for 2 weeks) kept in cold storage on 21st December

Quality of mandarin ➡	After first week				After second week			
Sample collection ⬇	TSS (%)	TA (%)	PLW (%)	Decay Loss (%)	TSS (%)	TA (%)	PLW (%)	Decay Loss (%)
First removal	9	2.81	8.73	0	9	0.89	28.68	40
Second removal	11	1.28	23.42	0	10	1.53	33.74	40
Third removal	7.4	0.82	17	20	6.4	0.64	25	30
Forth removal	11	1.66	7.83	0	10.8	1.02	14.99	0

4. Discussion

According to the first study, it was observed that the damage caused by Green and Blue mold (*Penicillium* spp.) was reduced when mandarins were dipped in a 4% solution of calcium chloride and kept in cold storage. Although there was not more difference in weight loss between untreated and treated mandarins during cold storage, decay loss was minimum in mandarins treated with 4% calcium chloride. Chlorine in calcium chloride helps to deactivate and cleans all kinds of pathogens in the peel of the mandarin fruit, and there is not any growth of pathogens in cold storage so that mandarins can be stored for a long time. As well as the calcium helps to delay shriveling of fruit with minimum weight loss of fruit and it also protects against rotting. The findings were in consonance with the findings of the (Ahmad and Siddiqui, 2013) [1] in Kinnow fruit, (Rokaya, 2017) [14] in Mandarin and (Sahu, 2016) [16] in custard apple. The faster rate in the TSS increment in the calcium chloride treated and untreated fruits were might be due to faster metabolic activities through respiration and transpiration. Similarly, the results are in line with the results of (Bisen *et al*., 2012) [4] in Kagzi lime, (Shahid and Abbasi, 2011) [17] in sweet orange and (Hassan *et al*., 2014) [6] in tangerine citrus. According to the second study, mandarins kept in cold storage at 3 different dates showed less damage when they were taken out after 8-9 weeks (2 months). Mandarins harvested and kept in cold storage on 1st week of December had comparatively low weight loss and decay loss. Mandarins harvested after second week of December were over matured and the segments were separated from the peel, so the damage is more. Maturity at harvest is the most important factor that determines final fruit quality as well as storage life (Bhusal *et al*., 2007) [3]. Moreover, the harvesting date especially affected fruit weight, rind thickness, juice content, fruit marketability, fruit disorders, titrable acidity and soluble solids in citrus varieties (Dou, 2005) [20]. The late harvest causes more water loss of fruits. It can be the main causes of deterioration, since it is not only resulting in indirect quantitative losses, but also causes losses in appearance (due to wilting and shriveling) and nutritional quality (Kader, 1986) [8]. The TSS was higher in the fruits harvested earlier and was lower rest of other harvest. These results agree with those reported by (Nasciment *et al*, 2011) [10] on Murcott mandarins and (Gemail *et al*, 2015) [5]. TSS levels increase as citrus matures. However, it can be reduced due to the over-maturity of fruits. Rokaya *et al*., 2016 [15] also observed a greater increase in the TSS of Feutrell's Early and Kinnow fruits. The findings of the present research also agree with the observations for TSS, TA, and sugar content of Gannan navel orange, indicating that TSS and sugar content gradually increases, while acidity decreases with the advancement of fruit maturity (Zhang *et al*, 2022) [18].

5. Conclusion
From this study, it seems necessary to facilitate the farmers to treat the mandarins with 4% of calcium chloride before storage. The mandarins produced in Syangja district must be picked safely from second fortnight of November to first week of December and stored them in cold storage by treating with 4% calcium chloride. To conduct these activities, it is most crucial to manage the temperature, relative humidity and bio-security of cold storage.

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