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Evaluation of different coating materials for the shelf life and quality parameters of Nagpur mandarin (*Citrus reticulata*) fruits

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Abstract
The purpose of this study was to evaluate different edible coating materials and their concentrations on the shelf life and physiological loss in weight (PLW), fruit volume and TSS of Nagpur mandarin (*Citrus reticulata*) fruits. This trial included 11 treatments with 3 replications for each treatment. The treatments include control, aloevera gel (10%, 20%, and 30%), neem oil (10%, 20%, and 30%), coconut oil (10%, 20%, and 30%) and a mix of aloevera gel 10%, neem oil 10% and coconut oil 10%. The experiment was conducted under ambient storage condition in Completely Randomized Design for a period of 40 days. Among all the treatments T9 (coconut oil 30%) has shown the best result by having least physiological loss in weight (8.37%), less loss in fruit volume(9.97%) and minimum rise in TSS (8.97°B). From this result we can conclude that the 30% coconut oil can best retain the fruit weight, fruit volume and TSS of Nagpur mandarin fruits under ambient storage conditions. This will ultimately increase the shelf life of the fruits.

Keywords: Nagpur mandarin, aloevera gel, neem oil, coconut oil, PLW, fruit volume, TSS

Introduction
Citrus species is native to South-East Asia's tropical and subtropical regions, especially India and China, and belong to the Rutaceae family. Many citrus species have their origins in north-east India (Davies and Albrigo, 2003) [4]. Citrus is a non-climacteric fruit. The "Nagpur" mandarin is prized among mandarins for its distinct sweet and sour flavour. The Vidarbha region of Maharashtra which is a significant pocket of Nagpur mandarin and surrounding regions of Madhya Pradesh and Rajasthan (Jhalawar region) have similar agro-climatic conditions, hence cultivation of this mandarin cultivar is flourishing and increasing in these regions. Mandarins rank second in terms of production (26%) after sweet oranges (56%) in the world citrus production. Mandarins account for 5.27 million metric tonnes of India's total citrus production, produced on 0.42 million hectares, and rank first among the citrus fruits grown in the nation. In comparison to several sophisticated mandarin-growing nations, India's average national production of 12.54 tonnes ha^{-1} is rather low (Ladaniya *et al*., 2021) [8]. Mandarins fruits are rich in vitamin C and antioxidant content which provide health benefits.
Major postharvest losses in citrus are caused by weight loss and physiological disorders. Water loss is also an important factor for loss in quality of fruit (Palou *et al*., 2015) [10]. To reduce such postharvest losses, fruit coating is applied on the fruit surface. Now a days edible fruit coatings are mostly in use which can be eaten along with the food. These are the alternative of synthetic coatings and fungicides that can cause damage to health. Fruit coating is commonly practiced in citrus packing houses to replace natural waxes that are washed away during fruit washing and handling on the packing line. Polysaccharides or proteins are combined with lipids in composite coatings (Campos, 2011; Han, 2014) [3, 6]. These can be used alone or in combination also.
Here in this study edible coatings and films which are natural compounds such as essential oils (coconut and neem oil) or other natural plant extracts (aloe vera gel) are used. Essential oils which are lipids which have antimicrobial activity against a variety of common fungal pathogens. Lipid based edible films and coatings provide a moisture barrier and gloss to food surfaces. Aloe vera gel is primarily composed of polysaccharides and serves as a natural moisture and oxygen barrier and also has antifungal, antibacterial, and anti-inflammatory effects (Attri *et al*., 2018) [1]. The purpose of this study was to determine the efficacy of neem oil, coconut oil and aloe vera gel in extending the shelf life and keeping the fruit quality

parameters of Nagpur mandarin (*Citrus reticulata*) fruits.

Materials and method

The experiment was conducted in lab conditions at Lovely Professional University in Jalandhar, Punjab between 2021 and 2022. A completely randomized methodology was used to test all treatments. Fresh, mature green Nagpur mandarin (*Citrus reticulata*) fruits were purchased from the local market in Phagwara, Punjab for this study. The fruits were taken to the lab and inspected to remove those that were diseased or damaged. To remove dirt and spray substance contamination, the fruits were rinsed with tap water and then with chlorinated water (100 ppm). After washing, fruits were dried in shade under fan. Fresh Aloe vera leaves were harvested from Lovely Professional University field and disinfected with 25 % chlorine solution. The aloe vera matrix was then extracted from the leaves and blended into a colourless gel. The fibres were filtered out of the blended gel to get the fresh Aloe vera gel. Then the aloe vera gel was pasteurized for 45 minutes at 70 °C to remove any type of contamination before cooling to room temperature. After that gel was diluted to get the desired concentration with distilled water for fruit coating. Edible neem oil and coconut oil were purchased from the local market in Phagwara, Punjab. These were then diluted using distilled water to the desired concentration for the fruit coating.

In this experiment there were total 11 treatments with 3 replications each. Here the treatments applied were, T0 (Control), T1 (10% Aloe vera gel), T2 (20% Aloe vera gel), T3 (30% Aloe vera gel), T4 (10% neem oil), T5 (20% neem oil), T6 (30% neem oil), T7 (10% coconut oil), T8 (20% coconut oil), T9 (30% coconut oil) and T10 (10% Aloe vera gel+ 10% neem oil+ 10% coconut oil). Each treatment consists of 30 fruits (10 fruits per replication). The fruits were coated with the above treatments by dipping the fruit in the coating solution for 20 minutes and after that these fruits were taken out and dried under shade. After drying, these were then stored separately at ambient temperature for a period of 40 days and these were examined regularly at 10 days interval that is at 0, 10, 20, 30 and 40 days. The evaluation of the fruit quality under storage was observed by the measurement of physiological loss in weight (PLW), fruit volume and TSS.

For the determination of Physiological loss in weight (PLW in g), fruit weight was measured using electronic weighing balance before storage as well as at every 10 days interval until end of storage period. Then the difference in fruit weight was calculated for each interval and following formula was used for the determination of PLW %.

$$\text{PLW \%} = \frac{\text{Initial fruit weight} - \text{final fruit weight}}{\text{Initial fruit weight}} \times 100$$

For determination of fruit volume (cm^3), water displacement method was used. Fruits were dipped in a beaker containing fixed volume of water and the amount of water displaced by dipping of the fruit in the beaker was noted down which is equal to the fruit volume.

For determining the Total soluble solids (TSS), firstly the fruit juice was extracted using a hand held juicer and the fresh juice was used for the determining the TSS by using hand refractometer and the readings were obtained in °Brix (Ranganna,1991) [13].

Result and Discussion

The data revealed that essential oil and plant extract based coatings significantly influence the shelf life of Nagpur mandarin under ambient storage condition in respect to physiological loss in weight, loss in fruit volume and total soluble solid.

Physiological loss in weight (PLW %)

The figure 1 shows loss in weight during 40 days under ambient storage period. Statistically significant findings were found in the data. During storage, the weight of the fruit slowly declined in all treatments. The PLW steadily increased in all treatments with increase in storage time. After 10 days of storage period the physiological loss in weight in different treatments were 8.55%, 7.75%, 7.59%, 7.45%, 7.31%, 6.64%, 6.52%, 6.26%, 6.05%, 5.77% and 6.38%, after 20 days PLW were 12.23%, 11.19%, 10.76%, 10.43%, 10.13%, 9.98%, 9.63%, 8.93%, 8.82% and 8.23%, after 30 days PLW were 19.14%, 16.04%, 15.94%, 15.62%, 15.19%, 14.96%, 14.81%, 14.25%, 14.16%, 13.36%, 14.65% and 9.16%, and after 40 days PLW were 15.23%, 11.79%, 11.69%, 11.83%, 11.00%, 10.22%, 10.06%, 9.42%, 9.39%, 8.37%, and 11.44% in treatment T0, T1, T2, T3, T4, T5, T6, T7, T8, T9 and T10 respectively.

When compared to the control (T0), all of the treatments exhibited lower PLW. At the end of storage period, treatment T0 has maximum loss in weight (15.23%) followed by T1, T2, T3, T4 and T5.

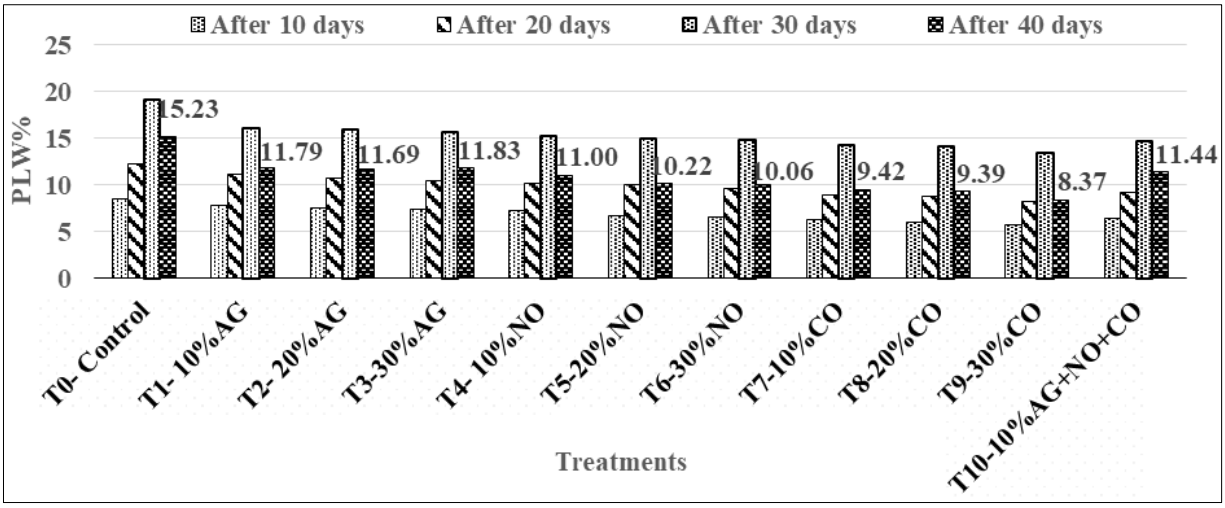

Fig 1: Effect of different organic coating material on Physiological loss in weight (PLW %) of Nagpur Mandarin fruits in ambient storage

Whereas treatment T9 had the lowest PLW (8.37%) after 40 days of storage followed by T8, T7, T10 and T6. During the complete storage duration, minimum loss in weight was recorded after 10 days of storage. After that loss in weight went on increasing till 30th day of storage in all the treatments, further loss in weight reduced in each treatment. Coated fruits has shown lower PLW than control fruits which may be due to the impact of these coatings as a semi-permeable barrier against oxygen, carbon dioxide, moisture, and solute movement, hence lowering respiration, water loss, and oxidation reaction rates. The untreated fruits lost water at a quicker rate, resulting in the highest PLW (Park, 1999; Baldwin *et al*., 1999) [11, 2]. Higher concentration of coconut oil has shown best result which might be related to the solidification of coconut oil on the fruit surface at low temperatures during storage (during winter month), which may have blocked the pores of the peel. Similar result was found by Randhawa *et al*., (2009) [12] and Rashid *et al*., (2020) [14] by applying edible oil and wax coating on Kinnow mandarin.

Loss in fruit volume (%)

The loss in fruit volume during storage period is depicted in Figure 2. There was a decrease in fruit volume with time in all the treatments. After 10 days of storage decrease in volume was 4.89%, 3.16%, 2.98%, 2.85%, 2.72%, 2.62%, 2.45%, 2.32%, 2.23%, 2.03 and 2.97%, after 20 days decrease was 7.04%, 6.87%, 6.45%, 6.16%, 6.02%, 5.47%, 5.01%, 4.62%, 4.36%, 3.62% and 5.11%, after 30 days decrease was 18.66%, 13.73%, 12.57%, 12.19%, 11.97%, 11.81%, 11.31%, 11.22%, 11.14%, 10.65% and 11.97%, and at last after 40 days decrease in volume was 15.27%, 12.78%, 12.24%, 12.03%, 11.30%, 10.86%, 10.78%, 10.30%, 10.33%, 9.97% and 11.97% in treatment T0, T1, T2, T3, T4, T5, T6, T7, T8, T9 and T10 respectively.

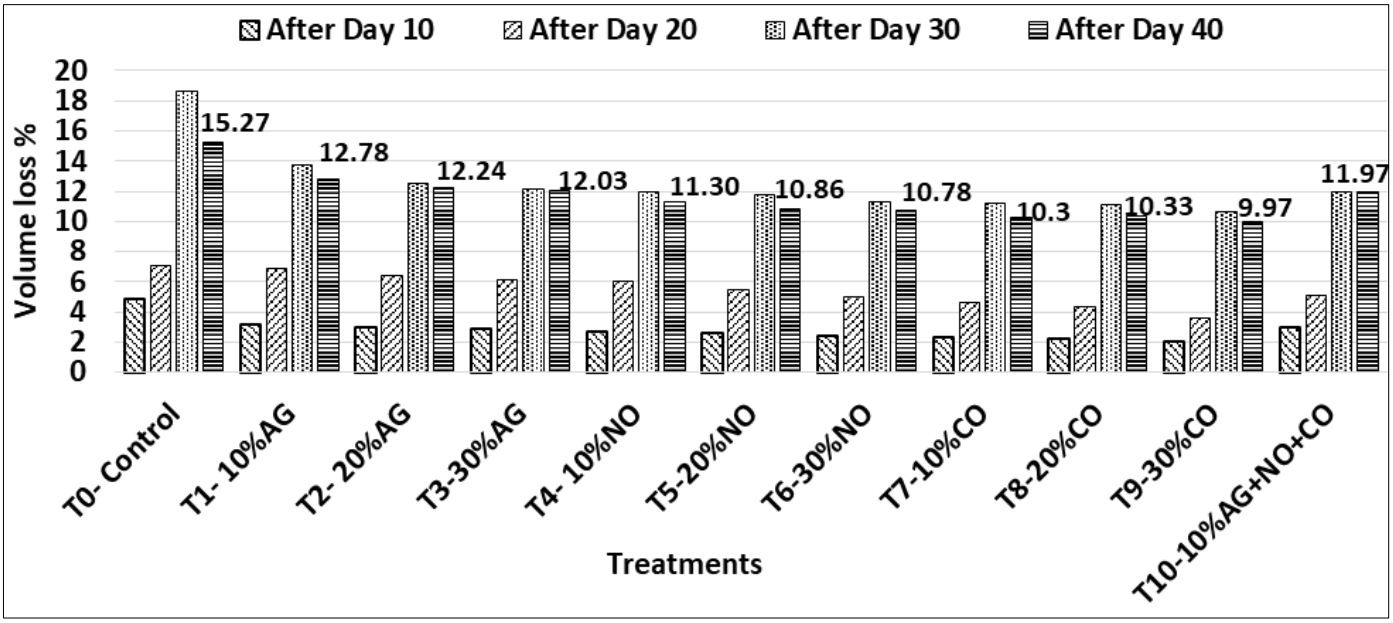

Fig 2: Effect of different organic coating material on loss in fruit volume (%) of Nagpur Mandarin fruits in ambient storage.

The rate of decrease fruit volume was faster in T0 (control) as compared to other treated fruits. After 40 days, maximum loss in volume was observed in T0 (control) i.e., 15.27% followed by T1, T2, T3, T10 and T4, whereas minimum loss in volume was observed in T9 (30% coconut oil) i.e., 9.97% followed by T8, T7, T6 and T5. Overall, maximum decrease in fruit volume was observed after 30 days and minimum after 10 days storage in all the treatments. The coconut oil kept the fruits' respiration rate constant while also preventing them from losing water through transpiration. The fruits under treatment were coated with a thin layer of coconut oil which prevented moisture loss and resulted in less turgidity loss. Also because it makes impacts on ripening by decreasing ethylene evolution, firmness is retained and shrinking appears at a slower pace. This might be the explanation for the fruits' volume reduction being lower. Kumar *et al*. (2017) [7] in guava fruits and Nasrin *et al*. (2020) [9] in lemon also support the findings.

Total soluble solids (TSS)

Change in total soluble solids (TSS) during 40 days at ambient storage is presented in figure 3. At the starting of storage, TSS recorded was 8.65°B, 8.62°B, 8.60°B, 8.64°B, 8.65°B, 8.61°B, 8.64°B, 8.63°B, 8.65°B, 8.66°B and 8.65°B, in treatment T0, T1, T2, T3, T4, T5, T6, T7, T8, T9 and T10 respectively. After 10 days of storage it increased to 8.91°B, 8.81°B, 8.78°B, 8.76°B, 8.74°B, 8.72°B, 8.71°B, 8.69°B, 8.70°B, 8.68°B and 8.76°B, after 20 days it increased to 9.34°B, 9.05°B, 8.99°B, 8.97°B, 8.95°B, 8.88°B, 8.87°B, 8.83°B, 8.81°B, 8.79°B and 8.92°B, after 30 days it increased to 9.71°B, 9.31°B, 9.19°B, 9.15°B, 9.10°B, 9.01°B, 8.97°B, 8.92°B, 8.91°B, 8.84°B and 9.13°B and at last after 40 days it again increased to 10.04°B, 9.54°B, 9.39°B, 9.32°B, 9.27°B, 9.16°B, 9.11°B, 9.05°B, 9.02°B, 8.97°B and 9.31°B in treatment T0, T1, T2, T3, T4, T5, T6, T7, T8, T9 and T10 respectively.

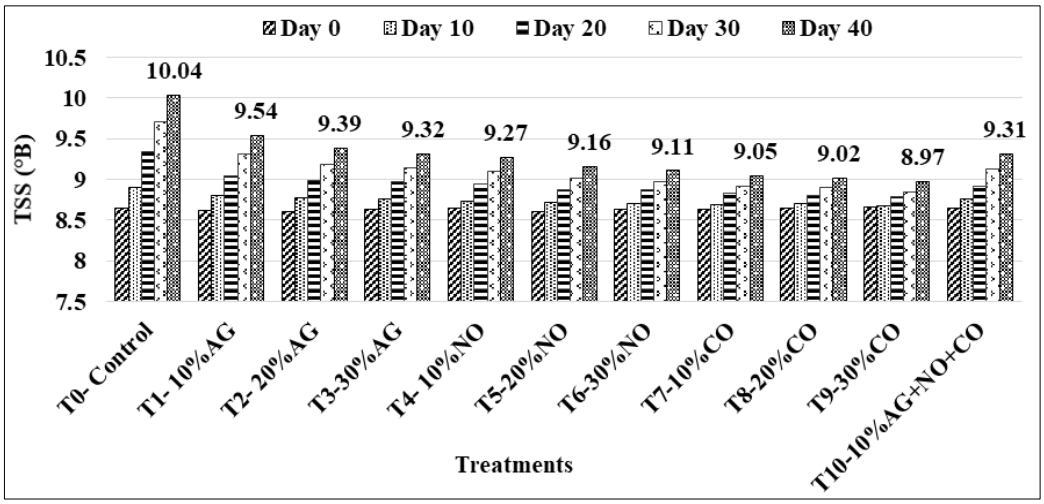

Fig 3: Effect of different organic coating material on total soluble solids of Nagpur Mandarin fruits in ambient storage.

The TSS steadily increased in all treatments with increase in storage time. The control treatment had a faster rise in total soluble solids than the treated fruit during the storage duration. At the end of the storage period (after 40 days), T0 control fruits have shown the maximum TSS 10.04°B followed by T1, T2, T3 and T10. Whereas, the fruits treated with 30% coconut oil (T9) had the lowest total soluble solid content i.e., 8.97 °B among all the treatments followed by T8, T7, T6, T5 and T4. Overall, maximum increase in TSS was observed after 20 days and minimum after 10 days storage in all the treatments. Coconut oil has a favourable effect in controlling the rate of increase in TSS of fruits. Less increase in TSS in 30% coconut oil may be due to less hydrolysis of starch into sugars. The rise in TSS during storage is most likely owing to increased carbohydrate hydrolysis into mono and disaccharides as fruits goes ripen, as well as higher juice concentration due to dehydration. Salunkhe *et al*. (1968) [15] and Dhatt *et al*. (1991) [5] reported nearby findings in peach, apricot and 'Kinnow' mandarin fruits.

Conclusion

Among all the treated Nagpur mandarin fruits, fruits treated with coconut oil 30% has shown the best result by showing least physiological loss in weight (8.37%), less loss in fruit volume (9.97%) and minimum rise in TSS (8.97°B) when stored for 40 days. From this result it can be concluded that the coconut oil 30% can improve the shelf life of Nagpur mandarin better than all the other fruit coatings used in this study by retaining the quality parameters upto 40 days. This edible coating material can be used without any harmful effects as these are from natural origin and free from any kind of chemical.

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