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ORIGINAL RESEARCH ARTICLE

Evaluating the efficacy of different botanicals on prolonging shelf life and maintaining quality of mandarin (*Citrus reticulate* Blanco var. Banshkharka Local)

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ABSTRACT

Mandarin (*Citrus reticulate* Blanco) has been cultivated in 56 districts of Nepal. Huge losses in mandarin were reported and use of safer alternatives to synthetic chemicals to solve post-harvest losses is a matter of great concern. An experiment was conducted at the Directorate of Agricultural Research, Lumle for two consecutive years 2019 and 2020. Mandarin having similar maturity indices were harvested and transported to DoAR, Lumle. The fruits were treated with five different botanicals (garlic extract @ 10 %, ginger extract @ 10 %, aloe vera extract @ 10 %, neem extract @ 10 %, and control) allocated in randomized complete block design with four replications. The post-harvest study was conducted for 3 weeks under laboratory conditions (7.9 ± 3° C and RH 74 ± 4%). Different parameters such as physiological loss in weight (PLW), decay loss, total soluble solid (TSS), titrable acidity (TA) and fruit weight to juice ratio were recorded. Fruit treated with ginger extract @ 10 % recorded the minimum physiological loss in weight (6.31% and 5.15%), minimum decay loss (16 % and 17%) in the year 2019 and 2020, respectively. Highest TSS: TA ratio (13.54 and 12.79) and fruit weight to juice ratio (0.33 and 0.35) was also observed in fruit treated with ginger extract @ 10 % in both years. In both years, results obtained in the fruits treated with ginger extract was followed by fruit treated with aloe vera extract and garlic extract. Control treatment gave the poor result as compared to ginger extract @ 10 %. Thus, this study concluded that the use of ginger is suitable for postharvest treatment of mandarin fruit to increase its shelf life and maintain its quality parameters.

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INTRODUCTION

Citrus fruits are the most widely consumed fruits; over 100 countries are grown chiefly in the countries and regions characterized by Mediterranean-like climates (FAOSTAT, 2021). Mandarin (*Citrus reticulate* Blanco) is a most promising fruit crop that stands in third position of the total fruit industry in Nepal. The country produces a large quantity of mandarin in hilly areas (1000-1500 masl) of 56 districts from east to west contributing 13.08 percent to the country's total fruit production MoALD, 2023). The productive area, total production and productivity of mandarin oranges in Nepal are 19,481 ha, 1,85,346 tons and 9.51 tons/ha respectively (MoALD, 2023). Systematic research and development in citrus crops have been started since the 1960s so as to promote its commercialization (Poudyal, 2015). Most commercial citrus growers in Nepal marketed their fruits immediately after harvest without storing and postharvest treatments but few farmers have stored fruits in cellar storage to maintain the quality and shelf life of the fruits (Bhattarai, 2018). Now, cold storage facilities have also been established in

different parts of the country to maintain fruit quality and make fruit available for a long time (Khanal *et al*., 2023).

Since mandarin is a non-climacteric and perishable fruit, it cannot be kept for a long-time during transportation and storage. The loss starts right after harvesting and increases many folds during the postharvest steps (PHLRD, 2005). In Nepal, the postharvest losses of fruits and vegetables were reported up to 20-50% (Bhattarai *et al*., 2013). Nepal faces significant losses of mandarin every year due to inadequate postharvest handling practices during harvesting, transportation and storage (Rokaya *et al*., 2016). The most common causes of the losses are mechanical damage, environmental factors such as temperature and humidity, inadequate packaging materials, rough handling during loading and unloading and hygiene at the market yard (Chitranshi *et al*., 2020). Fungal pathogens remain dormant during fruit growth, but severe damage occurs at the time of ripening and storage, which ultimately contributes to significant losses to the growers leading to heavy losses of national economy (Nath *et al*., 2013). Different studies reported the use of different physical treatments, chemical treatments, botanical treatments, bio-control and edible coatings to reduce the postharvest losses in citrus fruits (Strano, 2022).

Excessive use of chemical fungicides on controlling plant diseases has left a negative effect on human health and the environment complemented with high costs, residues in plants and development of resistance in pathogen populations (Kumar *et al*., 2007). With growing health consciousness among people and increasing consumer demand for pesticide residue free agricultural commodities (Cutler and Cutler, 1999; Serrano *et al*., 2005) it is important to find better alternatives that are cost effective, non-toxic and eco-friendly. A possible alternative to solve post-harvest losses is the use of plant based products having antifungal properties (Acharya *et al*., 2020). Among the safer alternatives, use of plant products has attracted researchers for the management of diseases with maintaining the quality and shelf life of several fruits and vegetables (Bautisia-Banos *et al*., 2003). Many studies have reported the use of plant extracts as environmentally friendly alternatives to synthetic fungicides (Siripatrawan and Vitchayakitti, 2016; Nxumalo *et al*., 2021). The botanical extracts can help to reduce the use of harmful chemicals in postharvest treatment of fruits as these extracts have several anti-microbial properties (Shrestha *et al*., 2018). Many plant parts (seed extracts, leaf extracts and whole plant) are used as an edible coating material which mostly contain polysaccharides, proteins and lipids (Bai *et al*., 2003) and have qualities that couldn't be synthesized artificially (Falcao-Rodrigues *et al*., 2007). Moreover, plant extracts have the ability to decompose rapidly and do not cause any negative hazards to the environment (Fokialakis *et al*., 2006). Extracts from plants such as *Azadirachta indica*, *Allium sativum*, *Lippea javanicum*, *Urtica massaica*, *Adhatoda spp* and *Zingiber officinaleare* reported to possess antimicrobial activity against a wide range of phytopathogens (Makeredza *et al*., 2005). In Nepal, the post-harvest loss minimization of mandarin is a great concern. Mandarin growers will be convinced on the use of locally available products for the postharvest fruit treatment. To minimize the postharvest losses and to maintain the quantitative and qualitative parameters along with prolongation of shelf life, postharvest treatments of mandarin with botanicals is urgent. So, the present study was carried out to evaluate the effectiveness of various plant extracts for elongation of shelf life of mandarins at ambient storage conditions.

MATERIALS AND METHODS

Mandarin was harvested from farmers' orchards located at Banshkharka, Jaljala, Parbat. Banshkharka Local (popular in terms of heavy production, good taste and late maturing) variety was selected for our purpose. Harvesting was done carefully by using secature so as to minimize the bruise and get uniformly matured fresh and healthy fruits. Then the fruits were transported to the laboratory of Directorate of Agricultural Research (DoAR), Lumle, Kaski by keeping in cardboard boxes lined and layered with cushioning materials. An experiment was conducted at DoAR, Lumle to increase the post-harvest life of mandarin by using different botanicals. The experiment set up consisted of five different botanical treatments allocated in randomized complete block design (RCBD) with four replications (Table 1). The experiment was conducted in the month of January for two consecutive years in 2019 and 2020.

The extracts were prepared on a weight to volume basis. For preparation of 10 % extract of each botanical, 500 gm paste of each were mixed with 5 liters of distilled water. Treatment application in fruit was done by dipping the fruits in the designated solution for 10 minutes and letting it dry very well in shade. The dried treated fruits were kept in a perforated plastic tray during the storage period. According to the experiment set up, each experimental unit received 25 treated fruits for further observation and data were recorded accordingly. The experiment was conducted for 3 weeks in ambient room condition with average temperature 7.9 ± 3° C and average relative humidity 74 ± 4%. Different qualitative parameters of fruits: physiological loss in weight (PLW), decay loss, total soluble solid (TSS), titrable acidity (TA) and fruit weight to juice ratio were recorded. On the observation date, two fruits from each experimental unit were used as a destructive sample for TSS, TA and fruit weight to juice ratio determination.

Parameter observed

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.

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

Decay loss percent

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

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

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.

Titrable acidity (TA)

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

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

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

Fruit weight to juice ratio

In each observation day, 4 fruits were removed randomly from the tray and the pericarp and aril were removed thoroughly from that fruit. The weight of the whole fruit, weight of the aril was measured. Then the juice was squeezed from them and measured accordingly. The data of fruit weight and juice volume were taken to calculate the ratio.

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).

Table 1. Treatment details of the experiment.

Treatment Symbol	Treatment details
T1	Garlic extract @ 10 % (prepared from garlic clove)
T2	Ginger extract @ 10 % (prepared from ginger rhizome)
T3	Aloevera extract @ 10 % (prepared from aloevera gel removed from the leaf)
T4	Neem extract @ 10 % (prepared from neem seed)
T5	Control (not any treatment)

RESULTS AND DISCUSSION

Physiological loss in weight (PLW %)

Different treatments exhibit varying levels of physiological loss in weight (Table 2). Whether the results were not significantly different in both years, the findings of the study indicate that use of botanicals helps to reduce the PLW. Among the different treatments, fruits treated with ginger extract @ 10 % have recorded minimum PLW (6.31 % and 5.15 %) in 2019 and 2020 respectively. Aloe Vera extract @ 10 % also helps to minimize PLW in both years (6.58 % and 6.49 %). PLW in 2019 and 2020 (7.90 % and 7.65 % respectively) was maximum in fruits with control treatment. Botanicals have been used as a positive measure to improve fruit quality, reducing the metabolism rate of horticultural crops to maintain their freshness (Fawole *et al*., 2020). It helps to create a semi-permeable film around harvested fruits reducing moisture loss and ultimately reducing the PLW (Ncama *et al*., 2018). Polyphenols content in botanicals helps to maintain the quality and prolong the shelf life of horticultural crops (Nxumalo *et al*., 2021). The results of this study were in accordance with the findings of the previous study of Chahal and Bal (2003) and Bisen *et al.* (2008).

Decay loss (%)

According to Table 2, the decay loss was significantly different among the treatments in both years. The loss percentage in 2019 and 2020 was minimum (16% and 17 % respectively) in Ginger extract @ 10 % treated fruit followed by aloe vera extract @ 10 % treated fruit (19% and 26 % respectively). In both years, maximum decay loss was recorded in control treatment with 33 % and 60 % respectively. The result reflects that the fruits without any treatment were prone to attack by severe pathogens causing rotting of fruits and decayed on the ambient storage. Use of botanicals as coating in the fruits before its storage helps in reducing gaseous exchange (O_2 and CO_2), retarding ethylene production rate and minimizes the fruit decay (Riva *et al*., 2020). Ilondu *et al* (2001) reported that some plants contain phenolic substances and essential oils that restrict the growth of micro-organisms. The compounds present in extract of ginger rhizomes have been reported to have antifungal properties controlling different fungi (Ahmed and Stoll, 1996). The finding of this study is consistent with the findings of Navarro *et al* (2011), Jhalegar *et al.* (2014).

TSS: TA ratio

TSS: TA of fruit was measured in weekly intervals. In both year 2019 and 2020, different botanical treatments exhibit varying levels of TSS: TA ratio which tends to increase with prolonged storage days for all treatments (Figure 1 and Figure 2). The TSS of fruits gradually increases after harvest and the TA content gradually decreases so the TSS: TA ratio is in increasing trend. The mandarin treated with ginger extract @ 10 % recorded the maximum TSS: TA ratio (In 2019: 13.05, 13.17 and 13.54) and (In 2020: 11.04, 12.53 and 12.79) in three observation done in weekly interval followed by fruits treated with other botanicals.

Table 2. Physiological loss in weight (PLW) and decay loss of botanicals treated mandarin at DoAR, Lumle in 2019 and 2020.

Treatment	Physiological loss in weight (PLW %)		Decay Loss (%)	
	2019	2020	2019	2020
Garlic extract @ 10 %	6.68	6.84	26	30
Ginger extract @ 10 %	6.31	5.15	16	17
Aloe vera extract @ 10 %	6.58	6.49	19	26
Neem extract @ 10 %	7.13	7.07	34	33
Control	7.90	7.65	33	60
Mean	6.92	6.64	25.60	33.20
CV (%)	16.29	17.72	33.60	25.68
P-value	0.35	0.09	0.03	0.00
LSD (0.05)	ns	ns	13.25	13.13

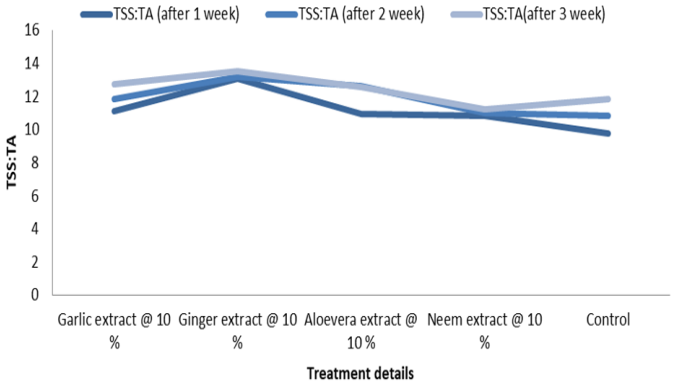

Figure 1. *TSS: TA ratio of botanicals treated mandarin at DoAR, Lumle in 2019.*

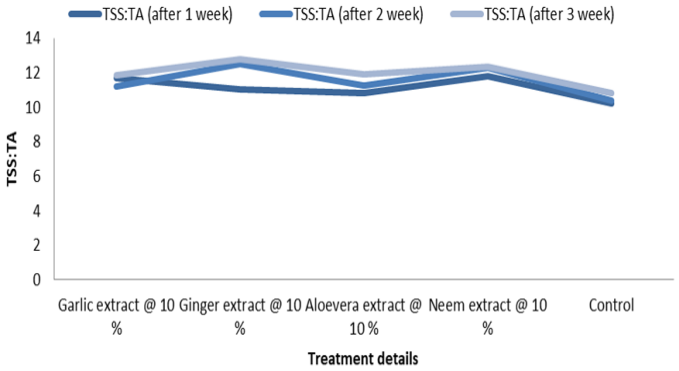

Figure 2. *TSS: TA ratio of botanicals treated mandarin at DoAR, Lumle in 2020.*

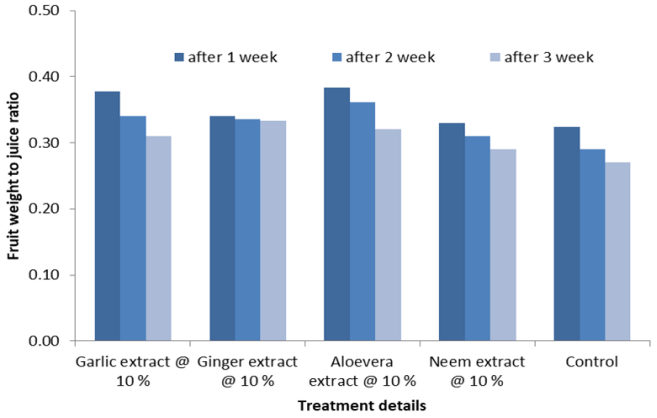

Figure 3. Fruit weight to juice ratio of botanicals treated mandarin at DoAR, Lumle in 2019.

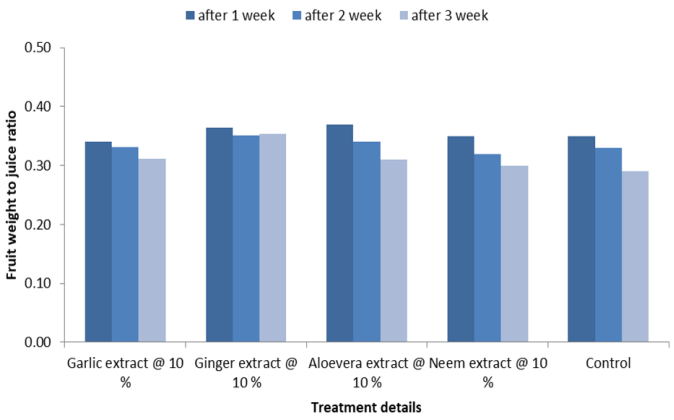

Figure 4. *Fruit weight to juice ratio of botanicals treated mandarin at DoAR, Lumle in 2020.*

Control treatment has recorded a minimum TSS: TA ratio in both years. TSS and sugar content gradually increases, while acidity decreases with the advancement of fruit maturity (Zhang *et al.*, 2022). Botanicals were able to retain postharvest quality of Kinnow fruits without any adverse effect on quality parameters such as TSS and TA (Jhalegar *et al.*, 2014). It is in accordance with the findings of Nxumalo and Fawole (2022) in Passion fruit, Kubheka *et al.* (2020) in Avocado and Shrestha *et al.* (2018) in Mango on maintaining their physiochemical properties.

Fruit weight to juice ratio

In all treatments and in both years (2019 and 2020) the fruit weight to juice ratio was decreased gradually with time during storage. No significant difference was recorded among different treatments on each observation day. At the end of the experiment (after 3rd week), the maximum fruit weight to juice ratio (0.33 and 0.35) was observed in 2019 and 2020 respectively from fruits treated with ginger extract @ 10 % followed by fruits treated with aloe vera extract @ 10 % and garlic extract @ 10 %. Minimum ratio was recorded in control (0.27 and 0.29) in both years. The trend of decrease in juice throughout the storage period might be due to loss of moisture from fruit. Botanical extract showed anti-mocrobial properties with reduced evapotranspiration and respiration rate in the treated fruits that reduced the moisture loss and ultimately resulted in higher juice recovery percentage (Singh and Acharya, 2000). This is in accordance with the findings of Acharya *et al.* (2020) and Haseeb *et al.* (2021).

Conclusion

Different botanical extracts in this study showed a variation in post-harvest quality of Mandarin. Throughout the study period, the fruits treated with 10 % ginger extract, aloe vera extract and garlic extract maintained the fruit quality parameters: fruit weight, TSS: TA ratio and juice content. By observing the data, ginger extract @ 10 % was found to be best in minimizing loss percentage (PLW and decay loss), maintaining TSS: TA ratio and fruit weight to juice ratio as compared to other treatments. Fruit treated with ginger extract @ 10 % recorded the minimum physiological loss in weight (6.31% and 5.15%), minimum decay loss (16 % and 17%) with highest TSS: TA ratio (13.54 and 12.79) and fruit weight to juice ratio (0.33 and 0.35) in the year 2019 and 2020, respectively. The plant's extracts can replace the use of synthetic chemicals in post-harvest treatments of fruits. Thus, it can be concluded that dipping the fruit in ginger extract @ 10 % helps to increase the post-harvest life of mandarin by minimizing its losses.

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Conflict of interest

The authors declare no conflicts of interest regarding publication of this manuscript.

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