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Extension of post-harvest quality and storage life of kinnow as affected by various elements

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Abstract
These investigations were conducted in the research farm of Lovely Professional University, Phagwara at School of Agriculture in department of Horticulture on kinnow fruit. there were nine treatments *viz*. mustard oil, coconut oil, ginger extract- 8%, ginger extract- 10%, ginger extract- 8% + mustard oil + coconut oil, ginger extract- 10% + mustard oil + coconut oil, bees'wax-8% + carbendazim– 0.1%, bees'wax-10% + carbendazim– 0.1% including control treatment and all treatments were replicated thrice. Data on various Physico-chemical properties was recorded and significant difference were discovered for unalike treatments. Results of experimentation revealed that coconut oil exhibited highest mean TSS and acid ratio. Combination of 8% bees' wax + carbendazim- 0.1% showed highest vitamin C during storage, while 10% bees'wax + carbendazim- 0.1% proved to be best treatment for maintaining quality and extending shelf-life due to least lost in weight, decay percentage, higher titrable acidity, total soluble solids and juice recovery percentage during storage period of kinnow fruit.

Keywords: Kinnow, post-harvest treatments, storage, Physico-chemical properties, evaluation, and quality

1. Introduction
Kinnow mandarin, is a diverse crop and presently there are more than 100 countries in tropical, sub-tropical and Mediterranean regions of the world where it occupies an area of 9.15 lakh hectares with total production of 79.22 lakh tonnes (Anonymous, 2018) [3]. India ranks 6th concerning world's citrus fruit production while it occupies 3rd place production wise after mango and banana. In India, citrus is primarily cultivated in Haryana, Assam, Maharashtra, Andhra Pradesh, Gujarat, Punjab, Uttarakhand and Rajasthan. Kinnow is a hybrid of King mandarin × Willow leaf mandarin, emerged as number one fruit in Punjab and area under cultivation is increasing day by day (Pal *et al*., 2017). In Punjab total area under cultivation of citrus is 49,244 hectares out of which Kinnow occupies major share of 45,581 hectares (Anonymous, 2018) [3] and mainly grown in districts of Fazilka, Ferozepur, Muktsar, and Bathinda.

Under Punjab conditions harvesting of kinnow mandarin commences in November and continues til February. Different techniques of fruit harvesting, and prevailing weather conditions during harvesting plays significant role in subsequent storage of the fruit. Moreover, due to shorter shelf life, the fruit cannot be stored for longer period. During peak harvesting period, due to glut production, farmers get less price. Moreover, traditional post-harvest management practices, improper handling and non-availability of proper storage facilities lead to substantial losses especially during distant marketing. Singh and Mandal (2006) [13] mentioned two main reasons for reducing the shelf life of fruits like production of ethylene and fungal attack. The fruits of mandarin group are more prone to be attacked by various microorganisms. It has been documented that 25-30% (approximately) of mandarin fruits are wasted due to poor postharvest management including 7% wastage at harvesting time, 3% during grading, 10-15% at transportation, 5% during packaging, and 10% during marketing (Bhattarai *et al*., 2013) [5]. Reducing these losses would help farmers in getting more revenue and at the same time, will encourage more people to eat more nutritious foods hence per capita consumption will be inclined which is only half of the amount of recommendation. Since long, edible coatings have been used to maintain the quality and prolong the storage life of a various fruits. Such coatings act as the better substitute to natural coatings by improving appearance and altering internal atmosphere, which eventually improves the shelf life of the commodity (Sushmita and Singh, 2020). Wax coating plays an important role in checking the storage life of fresh fruits, especially kinnow.

Many fungicides with permissible limits are used to control post-harvest diseases. Ahmad *et al*. (2013) [2] had also advocated that shelf life of kinnow may be enhanced by 45-60 days through wax coatings & oils and may lead to reduction of post-harvest losses due to reduced fungal attack, transpiration, respiration, loss of water and flavours. Furthermore, control of post-harvest diseases and fungal infections in citrus fruits during storage is necessary to maintain the quality and shelf life. Kinnow mandarin fruit is highly perishable in nature and liable to be spoiled easily under ambient conditions. Keeping this fact in view, present investigation was designed to evaluate the effect of various post-harvest treatments on quality maintaince and shelf life of kinnow mandarin.

2. Materials and Methods

2.1 Experimental period and location

Present studies were carried out during the period of December to February, 2020-21 in the post-harvest lab of School of Agriculture in department of Horticulture in Lovely Professional University, Phagwara. The location of the site is 31.22^0'N latitude and 75.77^0'E longitude with an elevation of 234 meter (768 ft) above from sea level.

2.2 Plant material and treatments

During experimentation, a total of 3.5 kg fruits per treatment were divided into equal lots for all three replications. Selected fruits were treated with various treatments and were designated as T_1- control, T_2- mustard oil, T_3- coconut oil, T_4- ginger extract- 8%, T_5- ginger extract- 10%, T_6- ginger extract- 8% + mustard oil + coconut oil, T_7- ginger extract- 10% + mustard oil + coconut oil, T_8- bee wax - 8% + carbendazim – 0.1%, T_9- bee wax -10% + carbendazim – 0.1%. Treated fruits treated were kept under ambient storage and examined at interval of 4 days up to 40 days.

2.3 Preparation of bee's wax emulsion and ginger extract

The wax emulsion was prepared by dissolving 80 and 100 g of bee's wax, depending on the concentration, into a 100 ml water, which was heated to 90°C to ensure that all of the wax dissolved in water. Add 20 ml of oleic acid, 60 ml of 0.1N NaOH and final volume was made up to 1000 ml. For preparation of ginger extract**,** ginger was cut into pieces and dehydrated overnight in the laboratory by putting them in a tray oven at 60 degrees, after dehydration grinded in fine powder and stored for further use. Then out of this powder, some ginger was taken (80 g, 100 g) and by added water volume was made to 1000 ml and left for 24 hours.

2.4 Parameters recorded

2.4.1. Peel, pulp weight and fruit volume

For estimating peel weight, initial weight of kinnow fruit was recorded by removing fruit peel and weighed. Similarly pulp weight was recorded. By using pan and beaker method, volume of fruit was calculated.

2.4.2. Physiological loss in weight (PLW) and juice recovery

PLW was recorded by determining fruit weight with a digital sensitive balance and to quantify the weight loss, calculated by using following formula:

$$PLW\ (\%) = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \times 100$$

Similarly juice recovery was calculated with help of following formula.

$$\text{Juice recovery} = \frac{\text{juice obtained (ml)}}{\text{Initial weight of the fruit}} \times 100$$

2.4.3 Decay (%) and total soluble solids (TSS)

Fruits infested with microbial infection were considered as decayed ones and were removed from storage and decay per centage was calculated. TSS was determined with the help of hand refractometer and expressed in ^{O}brix.

2.4.4 Titrable acidity, vitamin C, TSS: acid ratio

The Acidity content of fruits was calculated using the AOAC standard procedures (2005). For estimating vitamin C, the standard method using 2,6- Dichlorophenol indophenols (0.05%) was followed. A known quantity of sample (5 ml) was made to 50 ml with 3% meta phosphoric acid and filtered and titrated against the standard dye to a light pink colour persisting for at least 15 seconds. TSS/acid ratio was calculated by dividing TSS (°brix) by acidity (%).

2.4.5 Statistical analysis

According to Gomez and Gomez (1984) [7] data for various parameters were collected at various stages, intervals and tabulated in an excel sheet for analysis. The opstat software was used for statistical analysis. This software was used to generate a (CRD) test at 0.05 (p=0.05) and ANOVA was used to determine the significant difference between treatment means.

3. Results and Discussion

3.1 Decay

In kinnow fruits the extent of decay is exhibited in Fig 1, inclined with increase in storage period irrespective of the treatments. No decay loss was noticed during 4^{th} and 8^{th} day of the storage and decay occurred during 12^{th} day in control treatment. Similar observations were recorded in other treatments like T_3, T_5, T_6. Decay loss was significantly in the storage among all treatments. During 40 days of storage duration, the minimum decay (60.97%) was noticed highest in T_9 (bees'wax-10% + carbendazium-0.1%) and followed by T_8 (bees' wax- 8% + carbendazim -0.1% with value of 64.32%) whereas the maximum decay loss was recorded in control, T_6 (ginger extract- 8% + mustard oil + coconut oil), T_7 (ginger extract- 10% + mustard oil + coconut oil). The reason behind least decay loss especially in the wax treated fruits might be due to inhibition of moisture and microbial agent as carbendazim which inhibits the growth of postharvest disease like grey mould. Decay per centage is more in T_1, T_6, T_7 is due to weakening of the protection mechanism against fungus attack as time passes, as well as more respiration rate, which causes shrivelling and wrinkling. These research findings are further strengthened by Nurten *et al*. (2014) [10] in pomegranate.

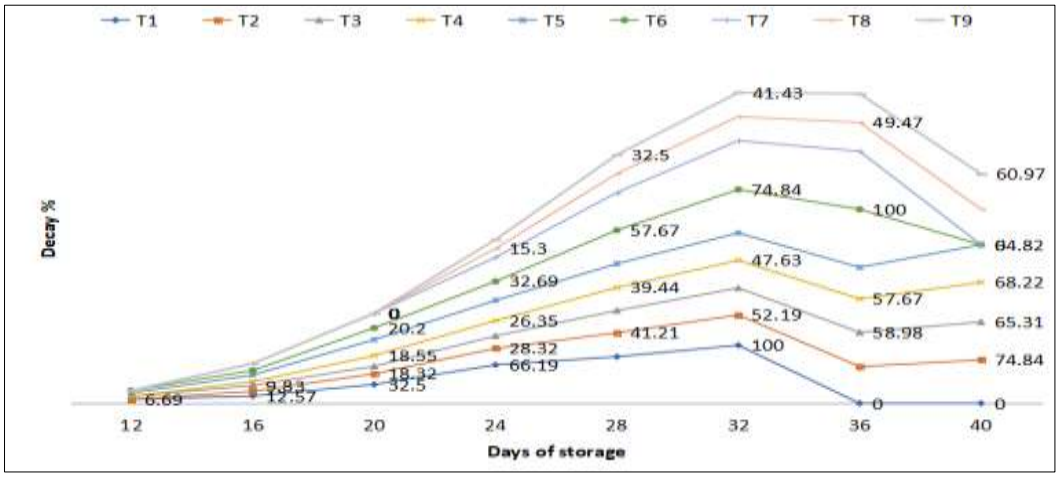

Fig 1: Effect of post-harvest treatments on decay (%) of kinnow under ambient storage 2020-21

3.2 Physiological loss in weight (PLW)

In kinnow fruit physiological loss in weight (PLW) inclined with increased duration of storage in all the treatments as showed in Fig 2. On 4th day of storage, minimum PLW was observed in fruits treated with T_9 (Bees'wax 10% + carbendazim 0.1%, 0.90%) followed by T_8 whereas maximum PLW was noted in control fruits to the tune of 1.78%. On 8th, 12th, 16th, 20th, 24th, 28th, 32nd, 36th and 40th day inclining trend was recorded. On 4th day of storage minimum PLW was recorded in T_9 while in all other treatments, it constantly inclined with progression of storage days. At the end of storage minimum PLW was recorded in the same (T_9) treatment with a value of 11.98% and followed by T_3 treatment where it was only 12.08%. PLW was highest under controlled conditions and ranged from 1.78% to 11.91%. No fruit was available under control conditions for evaluation during 36th day and 40th day. Fruits being a living entity, different physiological processes particularly the transpiration and respiration are going on, which exploits the substrate inside the fruit so above said losses in weight because of these processes. During investigation, applied applications made additional surface coating over the surface which act as a barrier for diffusion of gases and restricted occurrence of various physiological processes. Best results were obtained in T_9 throughout storage. This may be because bees 'wax, forms a stable coating on surface which controlled the physiological process to greater extent and carbendazim which obstructs the development of post-harvest diseases and overall, hence combination reduced PLW to greater extent. Analogous results are reported by Malekshahi and Babak (2021) [9] in pomegranate.

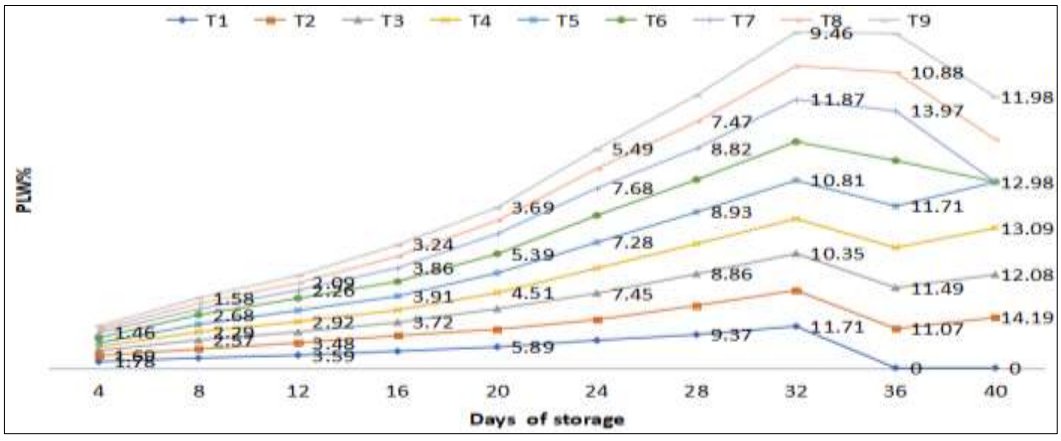

Fig 2: Effect of post-harvest treatments on PLW (%) of kinnow under ambient storage 2020-21

3.3 Juice recovery

Juice recovery of kinnow fruits is demonstrated in Fig 3, declined with increase in storage duration. T_9 (bees'wax10% + carbendazim 0.1%) exhibited the highest per cent juice recovery during 40 days of storage period. on 4th day of storage, highest juice recovery % was found in T_9 to the tune of 46.40%, statistically at par with T_6 (ginger extract- 8% + mustard oil + coconut oil) with a value of 45.55% while it was lowest in control (42.50%). On 8th, 12th, 16th, 20th, 24th, 28th, 32nd, 36th and 40th days of storage, declining trend was noted. The minimum decrease per centage was observed in the case of T_9 where fruits were treated with bees 'wax 10% + carbendazim 0.1%. It is important to note that during commencement of storage, recovery was 46.40% and as we move towards the end of storage period, it remained only 36.10% while in control (T_1) it declined from 42.50% to 36.40%. Above all, 32nd day no fruit was available for analysis. It can be concluded from the data that juice recovery was much improved in T_9 (bees 'wax 10 % + carbendazium-0.1%) which is proved to be best treatment as showed lesser reduction values during storage duration as compared to other treatments. This might be because of coatings, formed a layer upon the fruit surface which resulted in decrease in loss of evaporation. In this concern Sakeena *et al*. (2021) in kinnow have submitted similar outcomes.

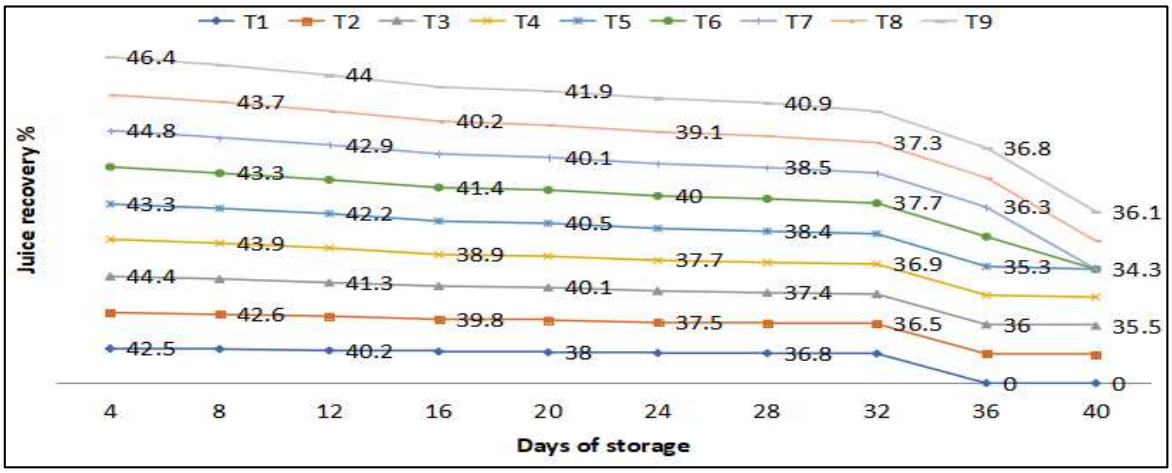

Fig 3: Effect of post-harvest treatments on juice recovery (%) of kinnow under ambient storage 2020-21

3.4 Total soluble solid (^{0}brix)

TSS content of the kinnow fruits is demonstrated in Fig 4, reveals that content inclined with progression of storage duration. Minimum average TSS was estimated on 4th day of storage (10.16 ^{0}brix) and it increased to (12.06 ^{0}brix) up to end of storage. It was highest under controlled conditions where it ranged from 10.50^0 brix to 12.40^0 brix for 32 days storage period and after that no fruit was available for evaluation during 36th and 40th days. Among all treatments, average minimum TSS was observed in fruits coated with bees'wax10% + carbendazium-0.1% with a value of 11.14 ^{0}brix followed by bees 'wax 8% + carbendazim 0.1% to the tune of 11.28 ^{0}brix. Average maximum value observed in coconut oil coated fruits, 11.40 ^{0}brix followed by ginger extract 8% where it was 11.34 ^{0}brix. All the treatments successfully resulted in reduction of TSS content in fruits to unlike extent. Overall, there was inclining trend. On commencement of storage, minimum TSS was recorded in fruits coated with bees'wax10% + carbendazim 0.1% while in all other treatments, it inclined as the storage days increased. After 40th day minimum TSS was recorded in the same treatment to the tune of 12.40 ^{0}brix followed by T_4 treatment where it was only 12.48 ^{0}brix. TSS might increase due to loss of water or due to conversion of organic acids into sugary substrate (Owolabi *et al*., 2021) [11].

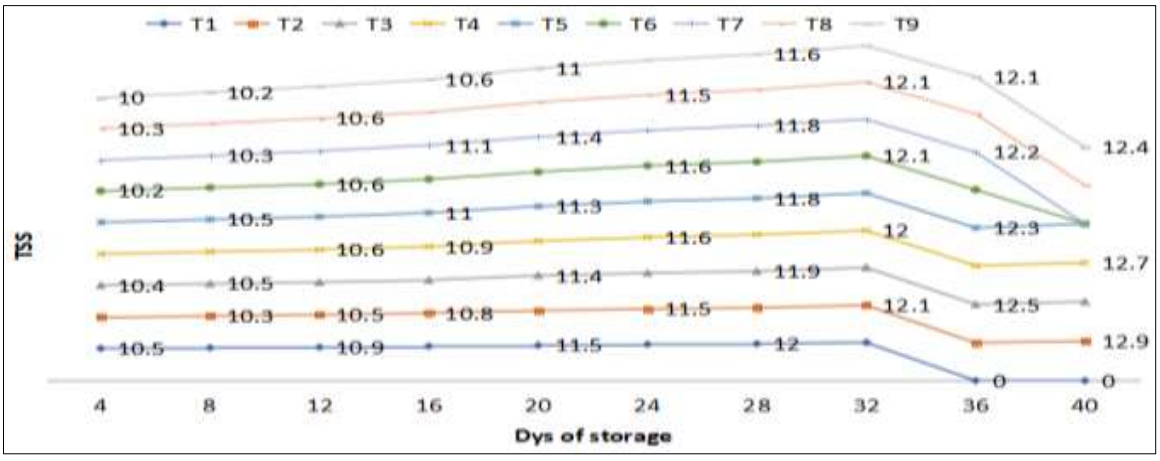

Fig 4: Effect of post-harvest treatments on TSS of kinnow under ambient storage 2020-21

3.5 Acidity

Acidity in kinnow fruits declined as the storage duration progressed, as showed in Fig 5. Fruits in T_9 (bees' wax 10% + carbendazim 0.1%) exhibited the highest acidity % during 40 days of storage period. On 4th day of storage, the higher acidity percentage was found in T_9 (bees wax 10% + carbendazim 0.1%, 1.14%) which was statistically at par with T_3 (coconut oil, 1.10%) compared to control (0.99%). During 8th, 12th, 16th, 20th, 24th, 28th, 32nd, 36th and 40th day declining trend was noted in this parameter. On the other hand, maximum decrease in acidity percentage was noted in T_9 (bees 'wax 10% + carbendazim 0.1%) from 1.14% to 0.71% against control fruits (0.99%-0.71%) whereas no fruit was available under control conditions for evaluation during 36th day and 40th day. Decease in acidity may be attributed to usage of organic acid in pyruvate decarboxylation reaction occurs during the fruit ripening (Echeverria and Valich, 1989) [6]. From present experiment, it may be concluded that fruits treated with bees 'wax 10% + carbendazium-0.1% (T_9) showed higher reduction in acidity during storage. Comparable results are described by Abu and Ahoron (2021) [1] in strawberries.

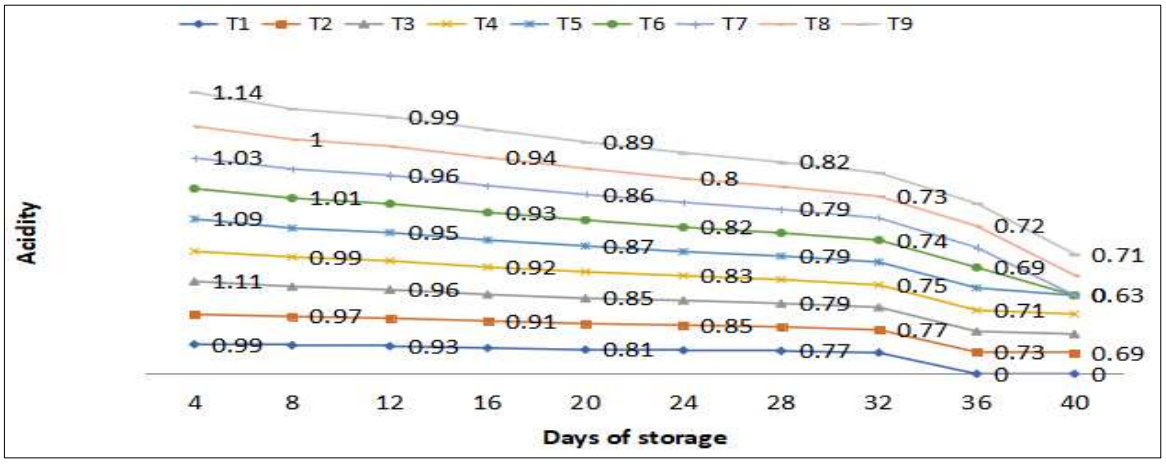

Fig 5: Effect of post-harvest treatments on acidity of kinnow under ambient storage 2020-21

3.6 Vitamin C

Vitamin C in kinnow fruits is presented in Fig 6, declined throughout the storage. T_8 (bees 'wax 8% + carbendazim 0.1%) treated fruits recorded the highest vitamin C during 40 days of storage. On 4th day, highest vitamin C was found in T_8 (34.52mg/100ml) which was statistically at par with T_6 (ginger extract- 8% + mustard oil + coconut oil, 33.02 mg/100ml) as compare to control where it was 30.14mg/100ml. During 8th, 12th, 16th, 20th, 24th, 28th, 32nd, 36th and 40th day of storage declining trend was observed. At the end of storage i.e., 40th day, maximum vitamin C was recorded in T_8 treatment to the tune of 18.04 mg/100ml and followed by T_3 treatment where it was 16.75mg/100ml. Maximum loss of vitamin C had occurred under controlled conditions where it ranged from 30.14mg/100 ml to 15.34 mg/100 ml. It is important here to note that after 36th and 40th days, no fruit was available for analysis. Concerning retention of vitamin C, better response was seen in wax treated fruits, as there was less degradation of the ascorbic acid during storage. The decrease in vitamin C content during storage period was attributed by oxidation of ascorbic acid into dehydroascorbic acid as stated by Willis *et al.* (1981). Equivalent results are reposted by Sakeena *et al.* (2021) in kinnow who revealed maximum loss in vitamin C in control fruits.

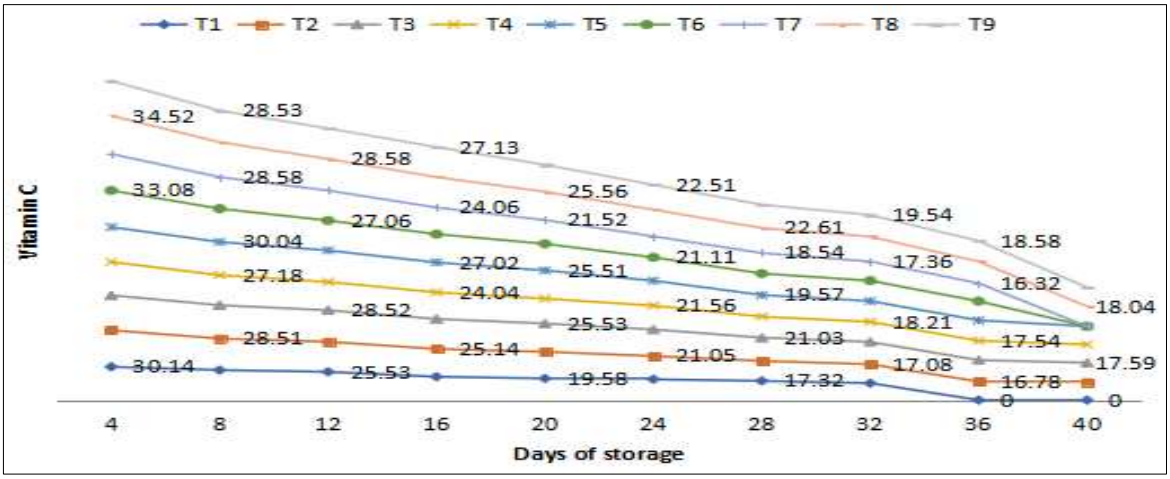

Fig 6: Effect of post-harvest treatments on Vitamin C of kinnow under ambient storage 2020-21

3.7 TSS/Acid ratio

TSS/TA ratio of mandarin fruit showed increasing trend throughout storage duration as presented in Fig 7. In the beginning of storage period from 4th day to 12th day, no significant changes were observed among the various treatments. On the 4th day of storage, the maximum TSS/acid ratio was recorded in control and T_4 treatment, with a value of 10.10, followed by ginger extract- 8% + mustard oil + coconut oil to the tune of 9.77 while minimum TSS/acid ratio was observed in T_9 (9.21). On 40th day of storage maximum TSS/acid ratio was recorded in T_5 (20.00) followed by coconut oil to the tune of 19.67. TSS/acid ratio is mainly ruled by the acidity, so a slight decrease or increase in acidity content is attended by a larger change in magnitude of the ratio. TSS/acid ratio is also considered as legal maturity (Khan *et al.*, 2008) [8].

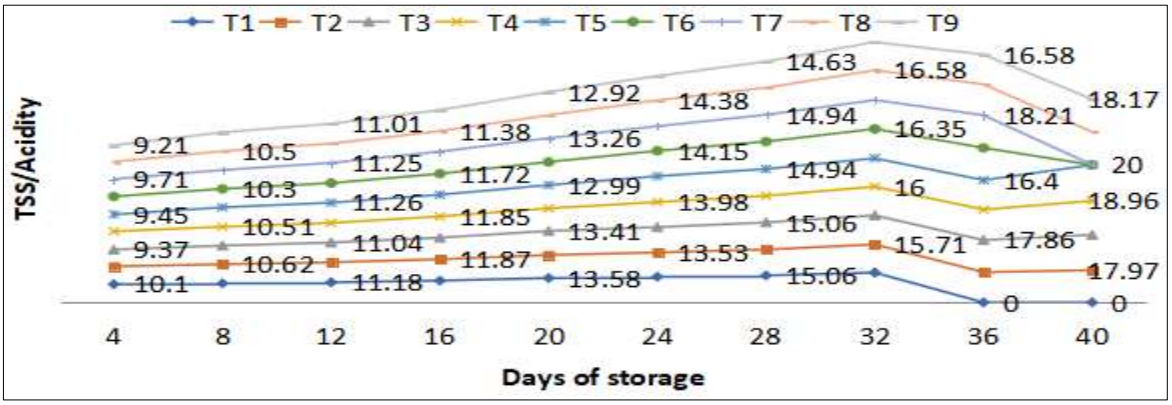

Fig 7: Effect of post-harvest treatments on TSS/Acid ratio of kinnow under ambient storage 2020-21

4. Conclusion

As kinnow is non-climacteric in nature so prolongation of storage life and quality of mandarin fruit, could be possible only with the use of different surface coatings. During present investigation, treatment of mandarin fruits with bees 'wax 10% + carbendazim @ 0.1%, is supposed to be best for extending their shelf life and effective in stabilizing the market demand.

5. Further research

To enhance quality or adding some bio-chemical and sensory related substances in fruit, various applications (combinations) can be tried along with outcome of present investigation. For evaluation purpose various quality parameters can be studied.

6. Acknowledgements

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