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A COMPARATIVE STUDY TO EVALUATE THE EFFECT OF $AgNO_3$ AND ALOEVERA GEL + IRON NANO-PARTICLES COATINGS FOR NUTRITIONAL ATTRIBUTES AND SHELF LIFE ON CLIMACTERIC (*MUSA ACUMINATE* L.) AND NON-CLIMACTERIC (*CITRUS SINENSIS* L.) FRUITS

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Abstract

A comparative study was conducted to assess the roles of silver nitrate, aloevera gel and iron nano-particles on the post-harvest quality and shelf life of banana (*Musa acuminata*) and citrus (*citrus sinensis*) for 20 days. The parameter studied were shelf life, fruit length, weight, diameter, firmness, pulp weight, peel weight, pulp to peel ratio, pulp pH, total soluble solids, and total phenolic content. The results showed that T4 (AVG + nano-emulsions in 5:0.5) significantly improved the shelf life of both banana and citrus fruits. Climacteric and non-climacteric (both types of) fruits responded equally well to the combination of aloevera gel and nano-emulsions. In terms of fruit length, none of the treatments had a significant effect on banana. T3 (AVG + nano-emulsions in 10:1) showed significant results for banana fruit weight. In citrus, 1% AgNO3 had the best results for fruit weight, while T3 (AVG + nano-emulsions in 10:1) showed the best results for fruit diameter. T1 (1% AgNO3) and T3 (AVG + nano-emulsions in 10:1) were effective in maintaining fruit firmness for a longer duration in both banana and citrus. T3 (AVG + nano-emulsions in 10:1) was effective in maintaining peel weight in both banana and citrus. However, in citrus, this combination was not significantly different from the control, and other treatments did not perform better than the control. For pulp weight, 1% AgNO3 had significant effects in citrus, while 0.5% AgNO3 performed better in banana. A 0.5% AgNO3 solution was also effective in maintaining pulp to peel ratio in both fruits. T3 (AVG + nano-emulsions in 10:1) performed best in maintaining pulp pH in banana, while T4 (AVG + nano-emulsions in 5:0.5) was excellent in maintaining citrus pulp pH. In terms of total soluble solids (TSS), the 5:0.5 solution of aloevera gel and nano-emulsions significantly influenced banana TSS, while 1% AgNO3 had a significant effect in increasing citrus TSS. Total phenolic content was significantly affected by the combination of aloevera gel and nano-emulsion concentrations in both banana and citrus. Overall, the effects of the treatments varied for different parameters and fruits. T4 (AVG + nano-emulsions in 5:0.5) showed the most significant improvement in shelf life for both banana and citrus. The combination of aloevera gel and nano-emulsions had positive effects on various parameters, and both climacteric and non-climacteric fruits responded well to these treatments.

Keywords: Post-Harvest, Silver Nitrate, Aloevera Gel, Iron Nano-Particles, Banana, Citrus.

1. INTRODUCTION

The ripening behavior of fruits allows researchers to classified them into climacteric and non-climacteric fruits (Fuentes, Figueroa, & Valdenegro, 2019). The ripening behavior is determined by the capacity of fruits to respond exogenous and endogenous ethylene production (Gundewadi, Reddy, & Bhimappa, 2018). The involvement of ethylene together with high respiration rate decides the category of fruit for being non-climacteric or climacteric nature (Trainotti, Tadiello, & Casadoro, 2007). Climacteric fruits are recognized due to bust of ethylene production during ripening while the term non-climacteric fruits are referred to those fruits in which bust of ethylene is not generated during ripening process (Y. Chen et al., 2018). Fruits like citrus, cherry, strawberry and grapes exhibited non-climacteric (NC) nature, while the ripening of apple, avocado, banana and mango showed peaks of ethylene production during ripening thus are termed as climacteric (CL) fruits (Fukano & Tachiki, 2021).

Ripening is associated with a series of biochemical pathways that decides the fate of softening, abscission, flavour and color production (Kou *et al.*, 2021). The production of volatile compounds (alcohols, aldehydes, apocarotenoids, esters and sulfur containing metabolites), biosynthesis of beta-carotene and abscisic acid production, all are influenced by ripening (He *et al*., 2020). Volatile compounds metabolise numerous microbes that can effect ripening process (Qi *et al*., 2021). Certain bacteria and fungus reside within fruits and vegetables can also make ethylene on their own that can also have an indirect impact on ethylene levels in plants (Ravanbakhsh, Sasidharan, Voesenek, Kowalchuk, & Jousset, 2018). It is anticipated that edible coatings and films are added to a broad range of commodities for the purpose of delaying senescence, prolonging shelf life, preventing oxidation processes, establishing respiratory chain reactions and for adequacy (Maringgal, Hashim, Tawakkal, Mohamed, & Technology, 2020). They are applied directly to the food surface by brushing, spraying and dipping to alter the food environment (Kumar, Ramakanth, Akhila, & Gaikwad, 2022). A successful coating is able to extend storage time without resulting in anaerobiosis and able to stop corrosion without lowering the general standard of the coated commodities (Irtiza, Wani, Khan, Murtaza, & Wani, 2019). Present research was designed to evaluate the effect of same dosage of different coating materials (Silver Nitrate and Aloevera Gel + Iron Nano-particles) on citrus (non-climacteric) and banana (climacteric) fruit.

Silver nitrate has recently seen increased usage in a variety of biotechnological applications (Haque, Siddique, Islam, & Biotechnology, 2015). Numerous microorganisms, including bacteria, fungi, actinomycetes, and viruses, may be inhibited in their development by silver nitrate (Elatafi & Fang, 2022). As post-harvest coating

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material, silver has been found to decrease physical weight loss of guava (Singh, Bakshi, & Mirza, 2018). Silver nitrate was found to act as respiration inhibitor that interrupts the respiration rate and delay senescence (Bayanati *et al.*, 2021). Same results of reduced respiration and shelf life prolongation was also observed in Banana (Nguyen *et al*., 2021) and Mango (Hmmam *et al*., 2021).

Using aloevera gel (AVG) coating to increase shelf life is a simple and environmentally friendly method (Sarker, Grift, & Characterization, 2021). By reducing oxygen and water movement, AVG coatings prolong the life of commodities (Hasan *et al*., 2021). Covering button mushrooms with 50% aloe vera gel while they are in storage prevents browning and preserves quality (Nicolau-Lapeña *et al*., 2021). Papaya fruits coated with an aloe vera-based coating significantly improved shelf life, antioxidant levels, and quality characteristics (Mendy, Misran, Mahmud, & Ismail, 2019). Some other research also exhibited a good effect of reducing oxidative browning and shelf life enhancement of various fruits like apples (Supapvanich *et al*., 2016) and apple slices (Farina, Passafiume, Tinebra, Palazzolo, & Sortino, 2020), cherry (Ozturk, Karakaya, Yıldız, & Saracoglu, 2019), fig (Allegra, Farina, Inglese, Gallotta, & Sortino, 2019), grapes (Nia, Taghipour, & Siahmansour, 2022), jujube (Islam *et al*., 2022), kiwi (Passafiume, Gaglio, Sortino, & Farina, 2020), mango (Shah, Hashmi, & Biotechnology, 2020), nectarine (Ahmed, Singh, Khan, & technology, 2009), pear (Jawandha, Gill, Kaur, Verma, & Chawla, 2017), raspberry (Hassanpour & Technology, 2015), strawberry (Rehman, Hameed, Ahmad, & Agriculture, 2022) and watermelon (Chrysargyris, Nikou, Tzortzakis, & Science, 2016).

Nanotechnology has developed quickly and is now extensively used in the physical, chemical and applied sciences (Wiesner & Bottero, 2017). Nanoparticles are often characterized as solid, colloidal particles with sizes between 10 and 100 nm (Ealias & Saravanakumar, 2017). Iron nanoparticles showed excellent antifungal efficacy (Parveen *et al*., 2018). The antifungal potential of synthetic iron nanoparticles has been documented in several research. *Alternaria mali, Diplodia seriata*, and *Botryosphaeria dothidea* have all been successfully prevented in their cycle by iron nano particles (Ahmad *et al*., 2020).

2. MATERIAL AND METHODS

Fruits of banana and sweet orange were bought from local fresh fruit markets of Lahore. Trials were performed in the growth room of plant biotechnology laboratory of Department of Horticulture, Faculty of Agricultural Sciences, University of the Punjab, Lahore. Citrus and banana fruits of uniform size and appearance without blemishes and scratches were selected, dried and divided into six lots with three sub-lots indicating replication (each having six fruits). Except for the control (To), every lot received a pre-decided treatment that was 1% silver nitrate (T1), 0.5 % Silver nitrate (T2), Aloevera gel + Nano-emulsions 10:1 (T3), Aloevera gel + Nano-emulsions 5:0.5 (T4) and Silver nitrate+ Aloevera gel + Nano-emulsions (T5). For 15 days, a triplicate research study using a CRD (Completely Randomized Design) was conducted.

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2.1 Physiological Parameters

Physiological parameters like fruits length, fruit diameter, fruit weight, peel weight, pulp weight was studied by using measuring tape, Vernier caliper, electronic balance scale (model: HCB60.2H). Peel to pulp ratio was measured by using following formula as used by (Karmawan, 2009) and (Dwivany, 2014).

$$Peel\ to\ pulp\ ratio = \frac{pulp\ weight}{peel\ weight}$$

Firmness (kg/cm2) of the fruit is detected by the use of penetrometer (MODEL GY-4 digital) (Yang, Guo, Huang, Du, & Liu, 2020) with pressure depth of 10mm.

2.2 Physio and Biochemical Parameters

2.2.1 Total Soluble Solids (Brix)

The brix of both fruits were measured by using refractometer (LH-T90) and standard protocol was followed (AOAC, 1990).

2.2.2 Determination of Total Phenolics

Weighed amount of fruit sample was extracted with 80% methanol. The supernatant extract was then mixed with FCR (folin ciocalteu reagent) and Na_2CO_3 followed by incubation in darkness for 2 hours at room temperature. After that optical density was measured by using spectrophotometer at 765 nm. Total phenolics were determined against a Gallic acid standard curve and expressed as gallic acid equivalent (Velioglu, Mazza, Gao, Oomah, & chemistry, 1998).

2.2.3 pH of Fruit Pulp

pH meter (model) was used for measuring the pH of fruit pulp. The meter was dipped in the fruit juice and readings were noted (AOAC, 1990).

2.3 Shelf Life

The shelf life of banana and sweet orange was observed by measuring the qualitative and quantitative changes that occurred during the storage time period.

2.4 Statistical Analysis

Data of all the parameters were subjected to analysis of variance (ANOVA) and means were compared by LSD test (least significance difference) at 0.05 (Chase, 1997), by using Statistics 8.1 software.

3. RESULTS AND DISCUSSION

3.1 Mean Effect Of Post-Harvest Treatments On Various Parameters Of Banana And Citrus

The mean effect of treatments; T_0 (Control), T_1 (1 % $AgNO_3$), T_2 (0.5 % $AgNO_3$), T_3 (AVG + Nano-emulsions in 10:1), T_4 (AVG + Nano-emulsions in 5: 0.5) and T_5 ($AgNO_3$ + AVG

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+ Nano-emulsions) on mean values of parameters like shelf life, fruit length, fruit weight, fruit diameter, fruit firmness, pulp weight, peel weight, pulp to peel ratio, pulp pH, total soluble solids and total phenolic of banana and citrus are mentioned in table 3.1 and 3.2 The details are listed below:

Table 3.1: Effect of Various Treatments on Different Parameters of Banana

Parameters	Mean Treatment					
	T0	T1	T2	T3	T4	T5
Shelf life	17.67	20.67	20.00	21.00	21.67	21.00
Fruit length	11.760	12.618	12.332	12.689	12.760	11.903
Fruit weight	27.14	32.48	33.63	33.44	32.74	32.48
Fruit diameter	7.332	7.380	7.703	7.932	7.425	7.536
Fruit firmness	2.07	2.80	2.29	2.41	2.27	1.93
Pulp weight	20.66	22.91	25.55	21.33	22.33	22.49
Peel weight	6.98	8.06	8.23	8.93	8.28	7.55
Pulp : peel	3.4	3.3	3.6	2.8	3.2	3.5
Pulp pH	4.3	4.8	4.6	5.1	4.8	4.6
Total Soluble Solids	9.76	11.33	12.34	12.40	13.05	12.92
Total Phenolic	1.10	1.20	1.20	1.19	1.20	1.15

Table 3.1: Effect of Various Treatments on Different Parameters of Citrus

Parameters	Mean Treatment					
	T0	T1	T2	T3	T4	T5
Shelf life	18.00	19.67	19.00	20.00	21.00	19.00
Fruit weight	100.54	109.06	102.37	99.87	104.07	107.97
Fruit diameter	7.4	8.19	8.16	8.63	8.23	7.61
Fruit firmness	1.68	1.78	1.80	1.78	1.76	1.75
Pulp weight	76.53	85.28	80.11	75.66	80.50	85.83
Peel weight	24.00	23.77	22.26	24.20	23.57	22.14
Peel : pulp	3.19	3.59	3.60	3.13	3.41	3.88
Pulp pH	3.91	3.63	3.74	3.63	3.91	4.10
Total Soluble Solids	13.18	13.73	13.91	13.35	13.91	13.85
Total Phenolics	**126.96**	**131.47**	**133.08**	**132.02**	**133.10**	**133.69**

3.2 Effect Of Postharvest Treatments On The Shelf Life Of Banana And Citrus

The table 3.1 displayed the average values, indicating that T4 (AVG + Nano-emulsions in 5: 0.5) had the longest shelf life of 21.67 days. T3 (AVG + Nano emulsions in 10:1) and T5 (AgNO3 + AVG + Nano-emulsions) followed it with average of 21 days. T1 (1% AgNO3) and T2 (0.5 % AgNO3) had slightly shorter shelf lives, with mean durations of 20.67 and 20 days respectively. T0 (Control) had the shortest shelf life with a mean of 17.67 days. Notably, at a significance level of 0.05, the observed treatment T4, T2 and T0 showed significant results as depicted in figure 3.1 (A).

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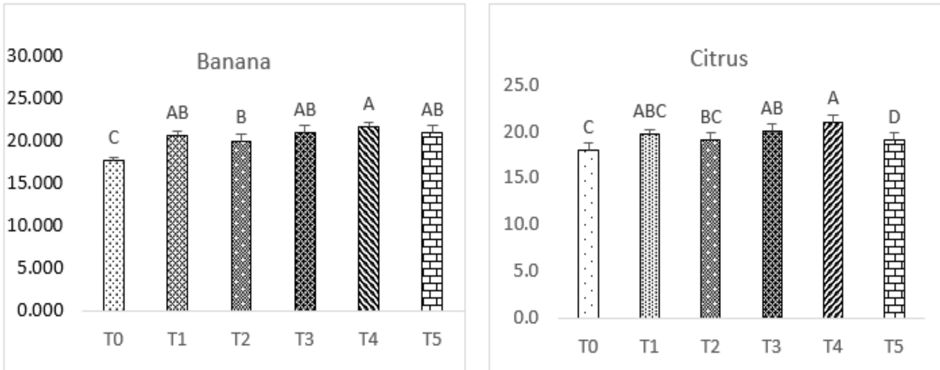

T0 = Control
T1 = 1 % AgNO3
T2 = 0.5 % AgNO3
T3 = AVG + Nano-emulsions (10: 1)
T4 = AVG + Nano-emulsions (5: 0.5)
T5 = AgNO3 + AVG + Nano-emulsions

Figure 3.1: Effect of Post-Harvest Treatments on the Shelf Life of Banana (A) and Citrus (B)

Mean values of the table 3.2 revealed that T4 exhibited maximum shelf life (21 days), T3 and T1 followed it with average of 20 days and 19.67 days respectively. T2 and T5 followed it with the same mean of 19 days. Minimum shelf life (18 days) was observed by T0. Statistically, among the observed treatments T0, T4 and T5 exhibited significant results. T1, T2 and T3 are statistically similar to each other and showed non-significant results at 0.05 significance level as shown in fig 3.1 (B).

3.3 Effect of Postharvest Treatments On The Average Fruit Length Of Banana

The mean values of banana depicted in table 3.1 indicate that T4 had the highest average fruit length (12.76 cm). T3, T1 and T2 followed it with average length of 12.68 cm, 12.61 cm and 12.33 cm respectively. T5 and T0 showed the shortest fruit length 11.87 cm and 11.76 cm respectively. Interestingly, the statistical analysis conducted at a significance level of 0.05 yield significant results for the observed treatments, as illustrated in figure 3.2. T2 is statistically significant than all other treatments. T0 and T5 and non-significant with each other but exhibited significant results from other treatments. Similarly, T1, T3 and T4 are non-significant with each other but significant than the results of other applied treatments. Day-wise analysis of data revealed that increase in storage time decreased the fruit length of banana, however, that length decrease is different among various applications. The maximum decrease of trend was observed in control. T1, T3 and T4 exhibited statistically similar results in controlling the reduction of fruit length in storage life of banana.

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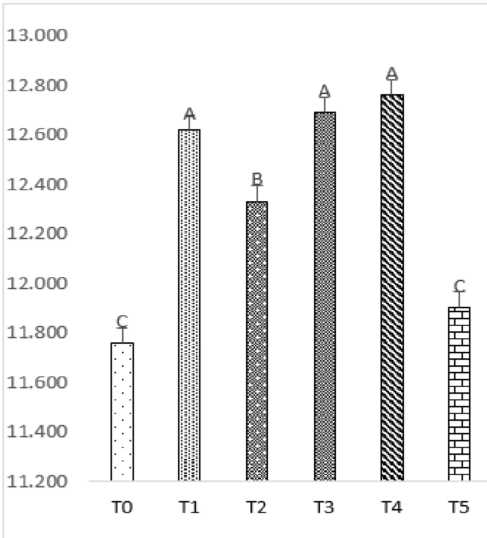

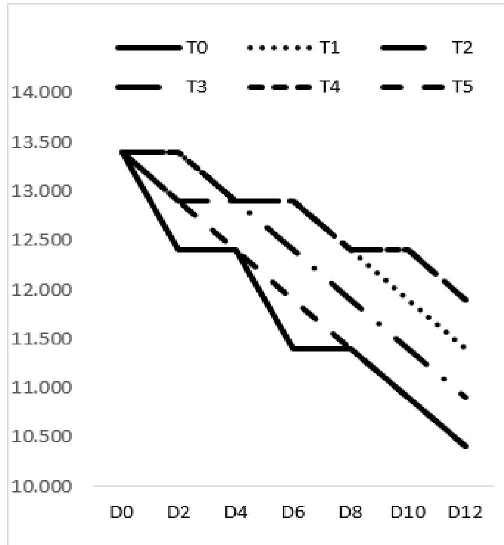

T0 = Control
T1 = 1 % AgNO3
T2 = 0.5 % AgNO3
T3 = AVG + Nano-emulsions (10: 1)
T4 = AVG + Nano-emulsions (5: 0.5)
T5 = AgNO3 + AVG + Nano-emulsions

Figure 3.2: Effect of Post-Harvest Treatments on the Average Fruit Length of Banana

3.4 Effect Of Postharvest Treatments On The Average Fruit Weight Of Banana And Citrus

Upon analyzing the figures presented in table 3.1, it becomes apparent that T2 had the highest average fruit weight (33.55 g), closely trailed by T3 with a weight of 33.43 g. T4, T5 and T1 followed them with average weight of 32.70 g, 32.56 g and 32.48 g respectively. The minimum fruit weight was observed in T0 i.e. 27.13 g. It is important to note that T0 showed significant results. In contrast to this, T1, T2, T3, T4 and T5 are statistically similar to each other were better than T0 at 0.05 significance level, as shown in figure 3.3.

Upon analyzing the figures related to citrus that is presented in table 3.2, it becomes apparent that T1 had the highest average fruit weight (109.78 g), closely trailed by T5 with a mean weight of 108.06 g. T4 and T2 followed them with average weight of 104.97 g and 102.87. In comparison, T0 and T3 had lowest mean weight of 101.26 g and 100.82 g respectively. It is important to note that all the observed treatments expect T0 and T3 expressed significant results. T0 and T3 proved statistically similar to each other but significant with all other treatments at a 0.05 significance level, as shown in figure 3.3. Throughout storage period of citrus, the average weight of citrus was observed to decline over time. The T0 (Control) showed maximum decline of citrus fruit weight while T1 can be marked as most effective treatment in controlling fruit weight loss of citrus.

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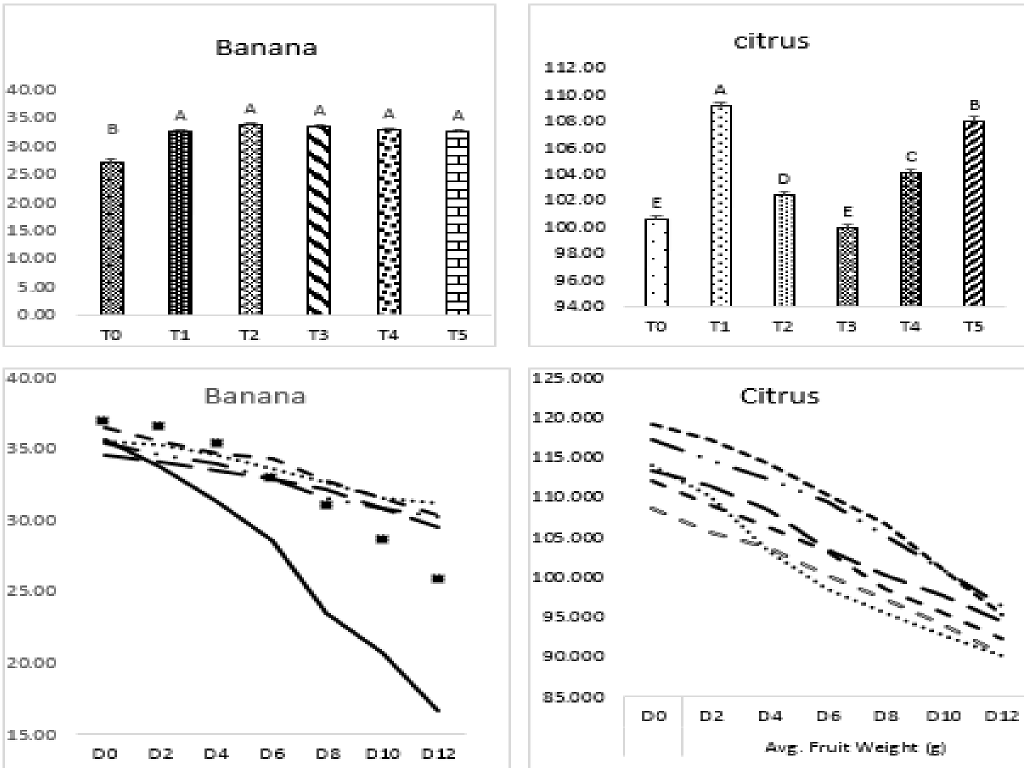

T0 = Control
T1 = 1 % $AgNO_3$
T2 = 0.5 % $AgNO_3$
T3 = AVG + Nano-emulsions (10: 1)
T4 = AVG + Nano-emulsions (5: 0.5)
T5 = $AgNO_3$ + AVG + Nano-emulsions

Figure 3.3: Effect of Post-Harvest Treatments on the Average Fruit Weight of Banana

3.5 Effect Of Postharvest Treatments On The Average Fruit Diameter Of Banana

The mean values of banana derived from table 3.1 illustrate that T3 results in highest fruit diameter i.e. 7.91 cm. T2 followed closely with a diameter of 7.70 cm. T5, T4, and T1 had relatively similar readings, averaging 7.53 cm, 7.42 cm and 7.38 cm respectively. On the other hand, T0 had the smallest diameter of 7.33 cm. notably, the statistical analysis conducted at a 0.05 significance level which shows statistically significant results for the observed treatments, as depicted in figure 3.4. Statistically, T2, T3 and T5 exhibited significant results, while T0 and T1 are statistically similar with each other but different from all other treatments. The results of T4 can be observed as non-significant. Day-wise, the average diameter of banana decreases with time. By analyzing the results T4 can be stated as best for retaining diameter for longer time. The mean values of citrus derived from table 3.2 illustrate that T3 results in highest fruit diameter i.e. 9.34 cm, T1, T2 and T4 followed closely with a diameter of 8.91 cm, 8.90 cm and 8.89 cm respectively. On the other hand, T0 and T5 had the smallest diameter of 8.12 cm and 7.63 cm respectively. Notably, the statistical analysis conducted at a 0.05 significance level yield significant results for the observed treatments T0, T3 and T5 as depicted in figure 3.4. Statistically,

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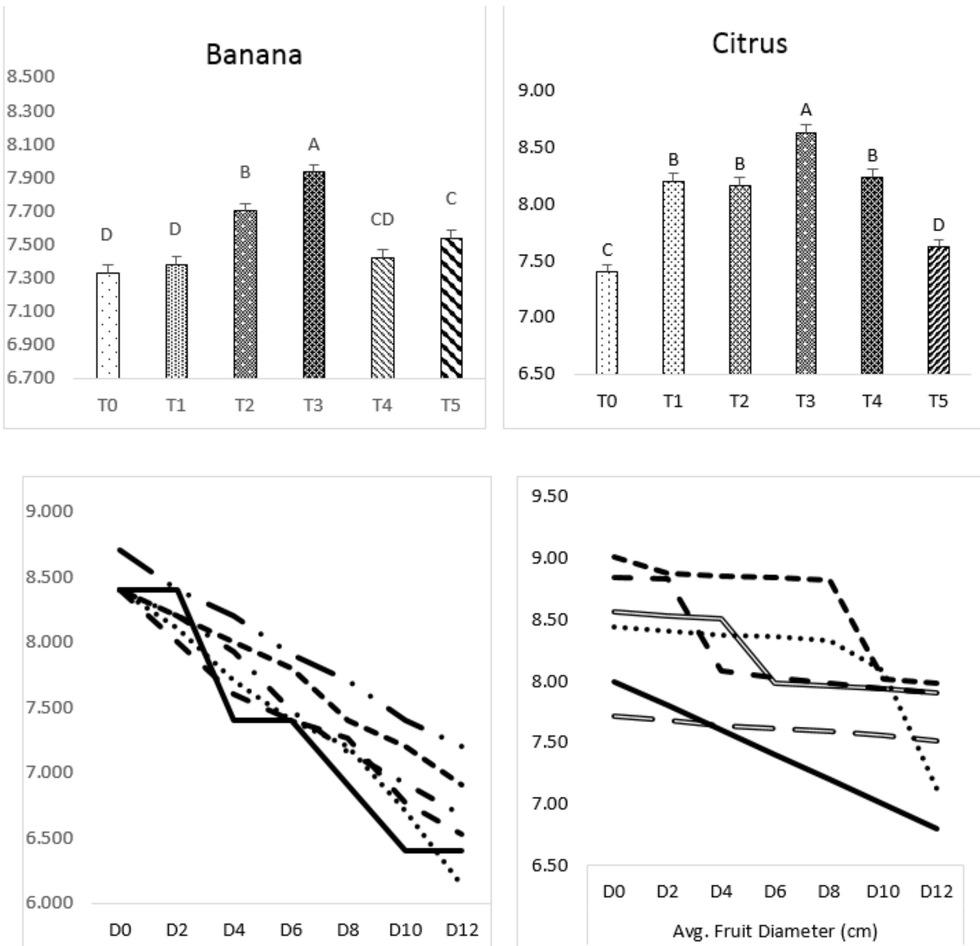
T1, T2 and T4 exhibited statistically similar result with each other. Generally, a decreasing trend was observed in diameter of citrus from harvesting to storage life. Maximum reduction of fruit diameter was observed in T0 while T3 proved excellent result in retaining valuable diameter throughout storage period.



T0 = Control
T1 = 1 % AgNO3
T2 = 0.5 % AgNO3
T3 = AVG + Nano-emulsions (10: 1)
T4 = AVG + Nano-emulsions (5: 0.5)
T5 = AgNO3 + AVG + Nano-emulsions

Figure 3.4: Effect of Post-Harvest Treatments on the Average Fruit Diameter of Banana and Citrus

3.6 Effect Of Postharvest Treatments On The Average Fruit Firmness Of Banana And Citrus

Table 3.1 presents the mean values, indicating that T1 had the maximum fruit firmness observed in the study i.e. 2.80 kg/cm2. T3 and T2 closely followed with a firmness of 2.39 kg/cm2 and 2.30 kg/cm2. Subsequently, T4 and T0 exhibited slightly less firmness with averages of 2.26 kg/cm2 and 2.09 kg/cm2 respectively. The lowest average firmness was

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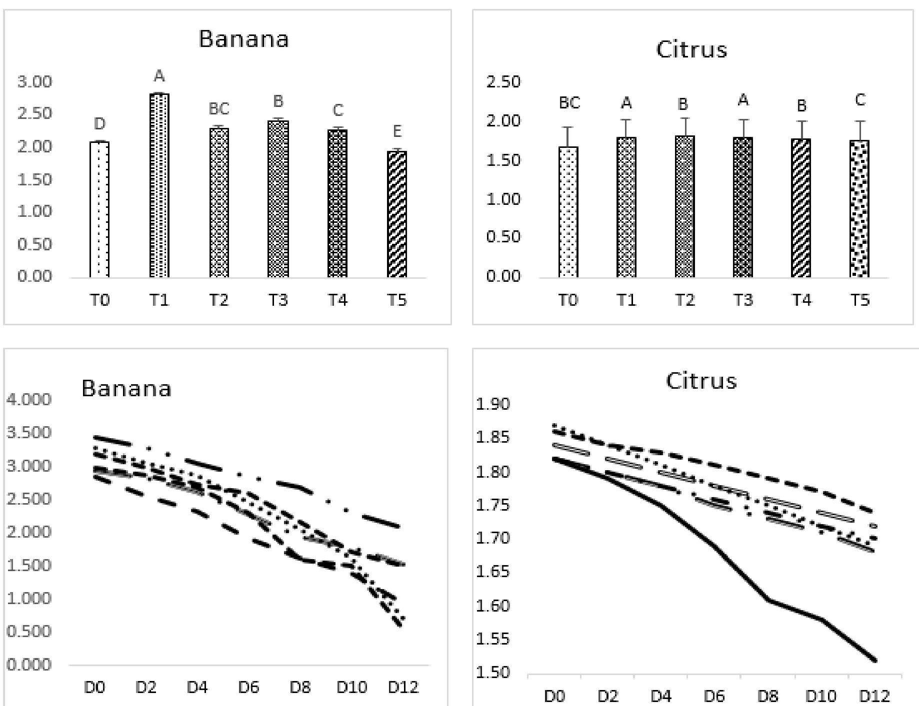
recorded in T5 recorded as 1.92 kg/cm2. It is essential to note that all the treatments except T2 exhibited significant results at a 0.05 significance level in retaining fruit firmness, as shown in figure 3.5. From harvesting throughout storage the average firmness of banana declined. However, the trend of decline is different for each application. T0 (Control) revealed maximum decline of firmness, and T1 showed maximum firmness throughout storage period.

Table 3.2 presents the mean values, indicating that T1 had the maximum fruit firmness observed in the study i.e. 3.357 kg/cm2. T3 closely followed it with a firmness of 3.356 kg/cm2. Subsequently, T2, T4 and T0 exhibited slightly less firmness with averages of 2.537 kg/cm2, 2.480 kg/cm2 and 2.40 kg/cm2 respectively. The lowest average firmness was recorded by T3 as 1.74 kg/cm2. It is essential to note that T5 exhibited significant results. The result of T1 and T3 were statistically similar to each other but were different from all other treatments. Similarly, T2 and T4 also exhibited similar results. However, T0 exhibited non-significant results at 0.05 significance level as can be observed in Fig 3.5. Predominantly, the fruit firmness tended to decrease over time and T0 marked worse in controlling fruit firmness as compare to other treatments.



T0 = Control
T1 = 1 % AgNO3
T2 = 0.5 % AgNO3
T3 = AVG + Nano-emulsions (10: 1)
T4 = AVG + Nano-emulsions (5: 0.5)
T5 = AgNO3 + AVG + Nano-emulsions

Figure 3.5: Effect of Post-Harvest Treatments on the Average Fruit Firmness of Banana

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3.7 Effect Of Postharvest Treatments On The Average Pulp Weight Of Banana And Citrus

The table 3.1 displays the mean values, revealing that T2 exhibited the highest pulp weight (25.439 g) among the treatments. T1, T5, and T4 showcased slightly reduced pulp weight, with averages of 22.90 g, 22.57 g and 22.25 g respectively. Furthermore, T3 followed them with average weight of 21.30 g.

Conversely, T0 demonstrated the minimum average pulp weight of 20.66 g. It is important to emphasize that the statistical analysis conducted at a 0.05 significance level yield different results for the observed treatments, as depicted in figure 3.6.

T2 exhibited significant result among all treatments. T0 and T3 are statistically same but are different from all other treatments. Similarly, T1, T4 and T5 are also statistically similar to each other but are dissimilar to all other treatments.

Overall, pulp weight tended to reduce from harvesting to storage time. T0 (Control) and T3 exhibited almost similar and maximum decline of pulp weight while T2 showed maximum readings.

The mean values presented in table 3.2 indicate that T1 had the highest pulp weight with 86 g of pulp. Close behind was T5 and T4 with pulp weight of 85.92 g and 81.48 g respectively. Similarly, T2 and T0 exhibited pulp weight of 80.51 g and 77.25 g respectively. Notably, T3 had the minimum pulp weight 76.63 g. It is crucial to note that all treatments except T1 and T5 exhibited statistically significant results.

T1 and T5 were statistically similar to each other but significant than all other treatments at a 0.05 significance level, as evidenced by the data in figure 3.6. A diminution of pulp weight throughout storage period was observed. T0 and T5 can be regarded as worst treatments for preventing weight loss of citrus pulp.

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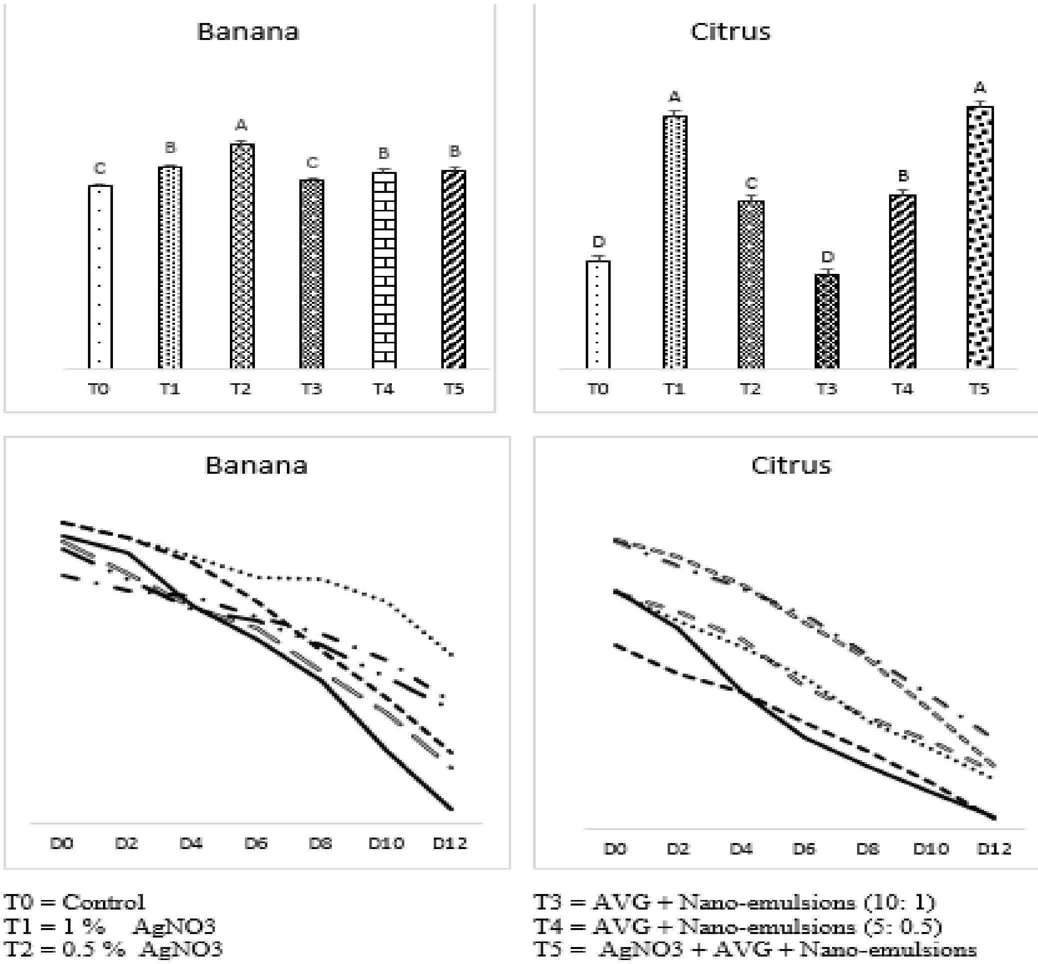

Figure 3.6: Effect of Post-Harvest Treatments on the Average Pulp Weight of Banana

3.8 Effect Of Postharvest Treatments On The Average Peel Weight Of Banana And Citrus

The mean values presented in table 3.1 indicate that T3 had the highest peel weight with 8.89 g of peel. Close behind was T4, T2 and T1 with peel weight of 8.26 g, 8.02 g and 8.05 g. Similarly, T5 exhibited less peel weight of 7.53 g. Notably, T0 (Control) had the minimum peel weight 6.98 g. It is crucial to note that T3 exhibited significant results at 0.05 significance level as evidenced by the data in figure 3.7. Similarly, T0 and T5 also exhibited significant results. T1, T2 and T4 can be marked as statistically similar treatments due to non-significant results. Similar to pulp and fruit weight, the peel weight of banana also exhibited a decline trend throughout storage life. Maximum decline was observed in T0 (control) while T3 can be marked as good for retaining weight for longer time.

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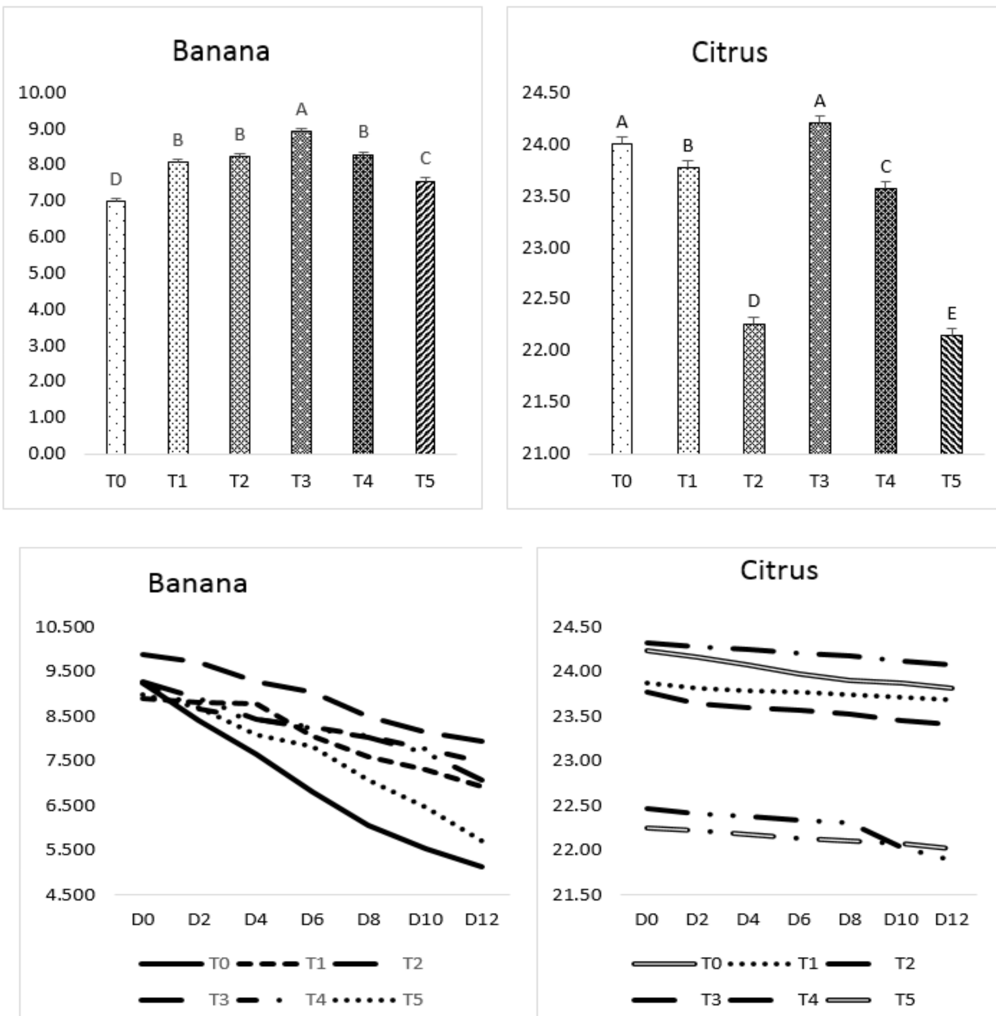
The table 3.2 displays the mean values, revealing that T3 and T0 exhibited the highest peel weight (24.89 g and 24.72 g respectively) among the treatments. T1 followed closely by displaying peel weight of 24.49 g. Furthermore, T4 showcased slightly reduced pulp weight of 24.21 g. Conversely, T2 and T5 demonstrated the minimum average peel weight of 23.06 g and 22.15 g respectively. It is important to emphasize that the statistical analysis conducted at a 0.05 significance level yield significant results for all treatments expect for T0 and T3 as depicted in fig 3.7. A declined trend o peel weight was observed in relation to storage time where T5 exhibited least results.



T0 = Control
T1 = 1 % AgNO3
T2 = 0.5 % AgNO3
T3 = AVG + Nano-emulsions (10: 1)
T4 = AVG + Nano-emulsions (5: 0.5)
T5 = AgNO3 + AVG + Nano-emulsions

Figure 3.7: Effect of Post-Harvest Treatments on the Average Peel Weight of Banana

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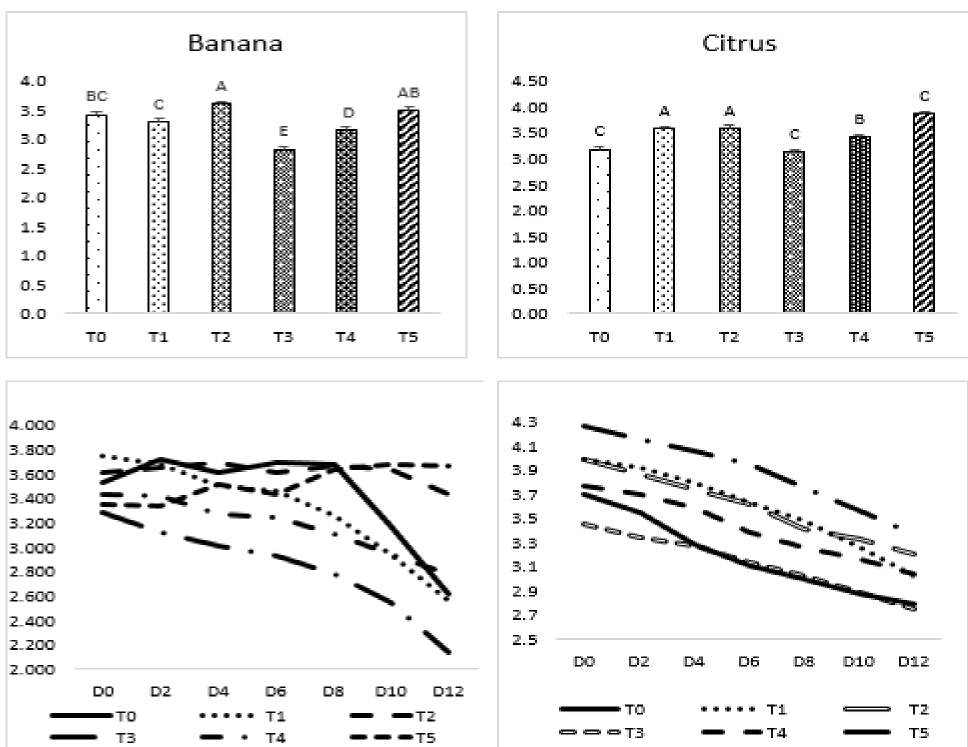
3.9 Effect Of Postharvest Treatments On The Average Pulp To Peel Ratio Of Banana And Citrus

The table 3.1 displayed the average values, indicating that T2 had the maximum pulp to peel ratio (3.59), followed closely by T3 (3.53). T0, T1 and T4 had slightly reduced ratio, with mean values of 3.43, 3.30 and 3.16 respectively. T3 had the smallest ratio with a mean value of 2.83. Notably, at a significance level of 0.05, the observed treatments T1, T2, T3 and T4 are statistically significant from other treatments. In contrast to this, T0 and T5 are statistically dissimilar from other treatments as depicted in figure 3.8.

The table 3.2 displayed the average values, indicating that T1 had the maximum pulp to peel ratio (4.3), followed closely by T2 (4.2). T4 followed it with mean ratio of 4.1. T0, T5 and T3 had slightly reduced but almost same ratio, with mean values of 3.9, 3.88 and 3.85 respectively. Notably, at a significance level of 0.05, the observed treatment T4 exhibited statistically significant result as compare to all other treatments. T0, T3 and T5 exhibited statistically similar results. Similarly, T1 and T2 showed statistical similarity at 0.05 significance level. Overall, the pulp to peel ratio decreased as storage time increased.



T0 = Control
T1 = 1 % AgNO3
T2 = 0.5 % AgNO3
T3 = AVG + Nano-emulsions (10: 1)
T4 = AVG + Nano-emulsions (5: 0.5)
T5 = AgNO3 + AVG + Nano-emulsions

Figure 3.8: Effect of Post-Harvest Treatments on the Average Pulp to Peel Ratio of Banana

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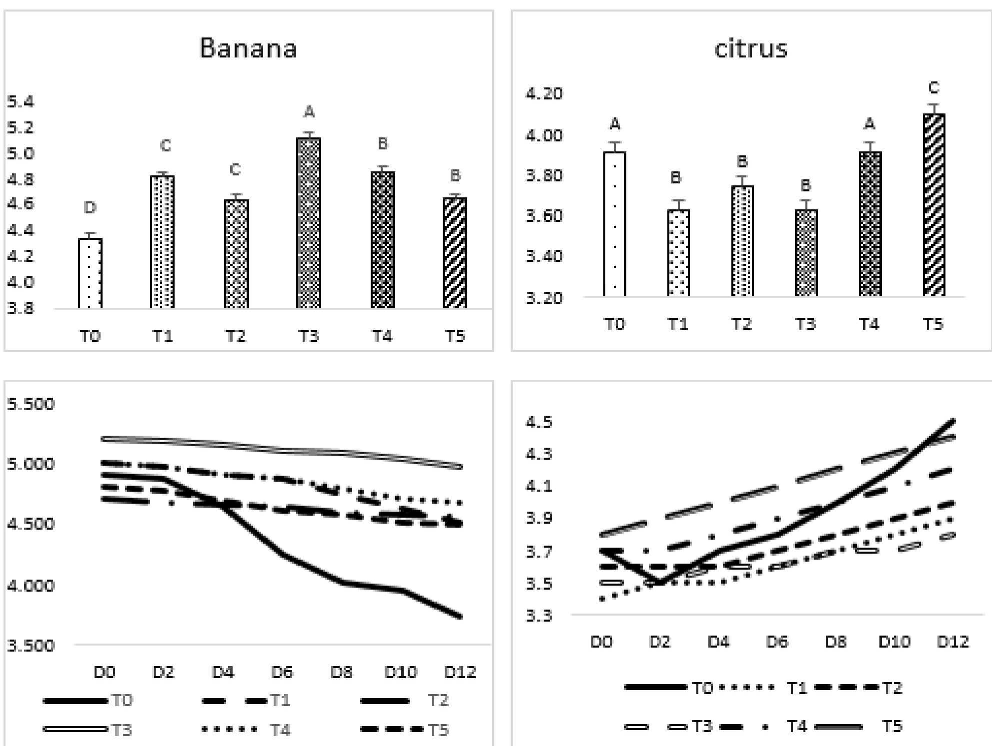
3.10 Effect Of Postharvest Treatments On The Average Pulp Ph Of Banana And Citrus

Mean values of the table 3.1 revealed that T3 exhibited maximum pulp pH (5.1), T4 and T1 followed it with pH of 4.8. T2 and T5 also exhibited reduced pH 4.6. Minimum pH (4.3) was observed by T0. Statistically, the observed treatments T3 exhibited significant results while T4 and T1 were statistically similar to each other. Similarly, T2 and T5 exhibited statistically similar result and did not show significant differences at 0.05 significance level as shown in fig 3.9. Day wise analysis of fruits exhibited an inclining trend of pulp pH.

Mean values of the citrus in table 3.2 revealed that T4 and T0 exhibited maximum pulp pH of 4.63, T2 followed it with pH of 4.45. T3 and T1 also exhibited reduced pH i.e. 4.35 and 4.34 respectively. Minimum pH (4.11) was observed by T5. Statistically, the observed treatments did not show significant differences at 0.05 significance level except the T5 as shown in fig 3.9. Generally, the pH of citrus pulp started to increase with increase of storage duration.



T0 = Control
T1 = 1 % AgNO3
T2 = 0.5 % AgNO3
T3 = AVG + Nano-emulsions (10: 1)
T4 = AVG + Nano-emulsions (5: 0.5)
T5 = AgNO3 + AVG + Nano-emulsions

Figure 3.9: Effect of Post-Harvest Treatments on the Average Pulp Ph of Banana

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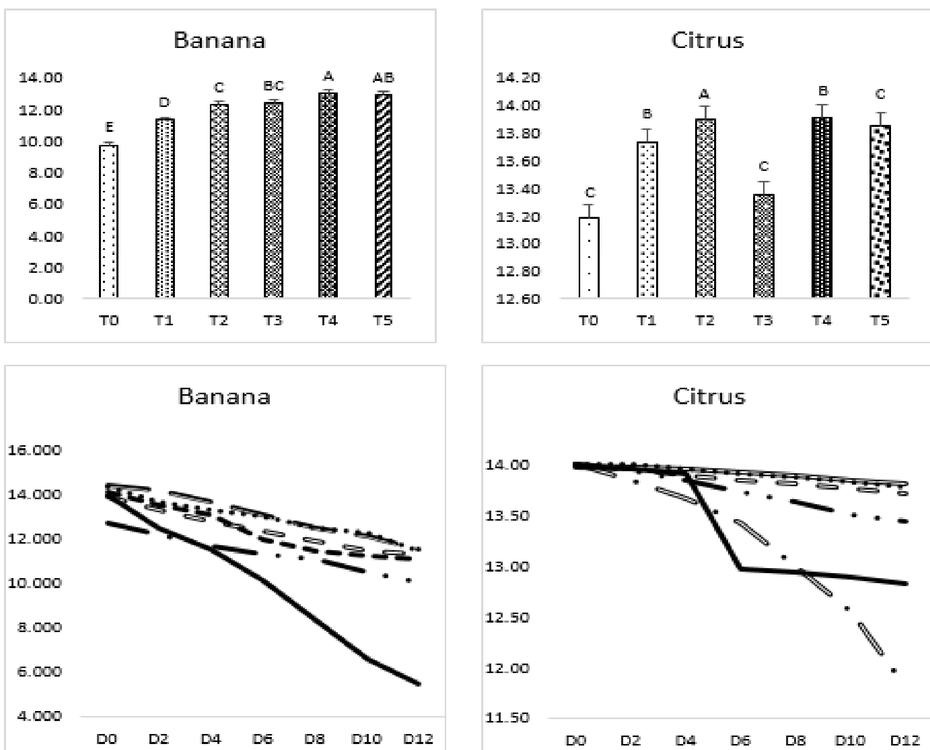
3.11 Effect Of Postharvest Treatments On The Average Total Soluble Solids Of Banana And Citrus

The table 3.1 displayed the average values, indicating that T4 had the highest total soluble solids (TSS) i.e. (13.04), followed closely by T5 (12.94). T3 and T2 had slightly less but almost same TSS value 12.43 and 12.31 respectively. T1 also showed less TSS (11.33). T0 had the minimum TSS with a mean of 9.76. Notably, at a significance level of 0.05, almost all the observed treatment except T3 and T5 exhibited significant results as depicted in figure 3.10. During storage period a decline of TSS was observed among all treatments, however, the degree of TSS reduction varied among treatments. T4 proved best regarding the prevention of TSS reduction while maximum loss was observed in control (T0).

The table 3.2 displayed the average values, indicating that T2 had the highest total soluble solids (TSS) i.e. (15.30), followed closely by T4 (14.63) and T1 (14.45). T3, T0 and T5 had least TSS, with mean value of 14.07, 13.90 and 13.85 respectively. Remarkably, at a significance level of 0.05, the observed treatments exhibited statistically non-significant results except T2 as depicted in figure 3.9.



T0 = Control
T1 = 1 % AgNO3
T2 = 0.5 % AgNO3
T3 = AVG + Nano-emulsions (10: 1)
T4 = AVG + Nano-emulsions (5: 0.5)
T5 = AgNO3 + AVG + Nano-emulsions

Figure 3.10: Effect of Post-Harvest Treatments on the Average Total Soluble Solids of Banana

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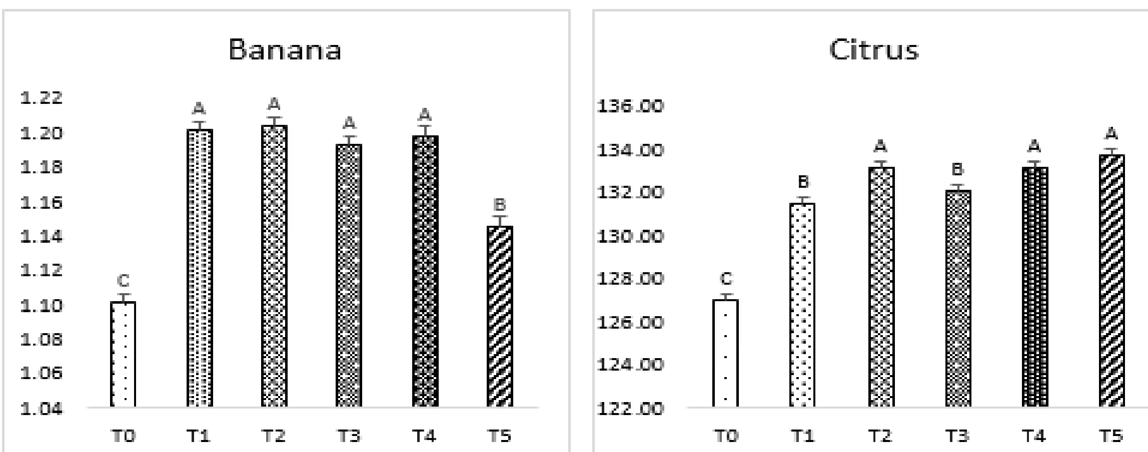
3.12 Effect Of Postharvest Treatments On The Average Total Phenolics Of Banana

According to the data presented in table 3.1, it can be deduced that T2 had the maximum phenolic compounds (1.203). T1 followed closely behind with total phenolic of 1.201. T4 and T3 had almost similar mean total phenolic with values of 1.198 and 1.191 respectively. T6 followed them with 1.143 total phenol content. The lowest value was observed in T0 with an average of 1.101. It is worth mentioning that the results of the treatments in figure 3.11 exhibited significant results in case of T0 and T5. However, from T1 to T4 the treatment proved statistically similar towards total phenol content at a significance level of 0.05 as can be observed in fig 3.11. From harvesting to storage period, the total phenols tend to decrease with time. Almost all treatments resulted good in retaining total phenols for longer time expect T5. However, control (T0) exhibited maximum loss of phenolic content.

According to the data presented in table 3.1, it can be deduced that T4 had the maximum phenolic compounds (133.84). T5 and T2 followed closely behind with total phenolic of 133.76 and 133.70 respectively. T3 and T1 had almost similar mean total phenolic with values of 132.79 and 132.19 respectively. The lowest total phenolic was observed in T0 with an average of 127.68. It is worth mentioning that the results of the treatments in figure 3.11 exhibited statistically non-significant findings at a significance level of 0.05 except treatment T0. T1 and T3 can be marked as statistically similar treatment in increasing total phenolic content of citrus. Similarly, T2, T4 and T5 also proved similar to each other but significant than all other treatments.



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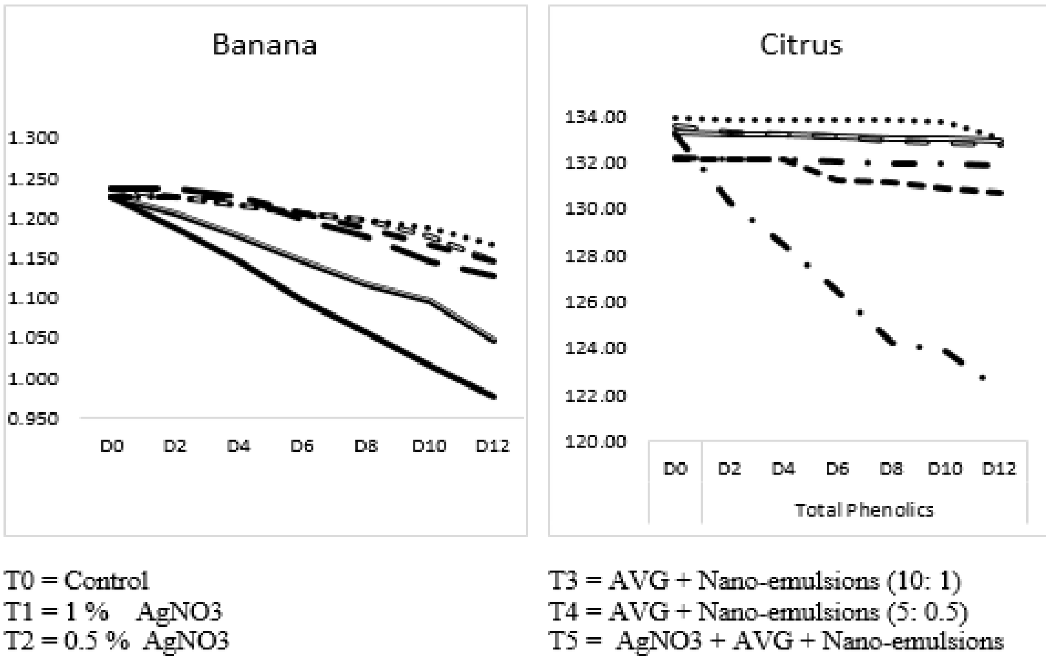

Figure 3.11: Effect of Post-Harvest Treatments on the Average Total Phenolics of Citrus

4. DISCUSSION

The mean effect of treatments; T0 (Control), T1 (1 % AgNO3), T2 (0.5 % AgNO3), T3 (AVG + Nano emulsions in 10:1), T4 (AVG + Nano-emulsions in 5: 0.5) and T5 (AgNO3 + AVG + Nano-emulsions) on mean values of parameters of banana and citrus like shelf life, fruit length, fruit weight, fruit diameter, fruit firmness, pulp weight, peel weight, pulp to peel ratio, pulp pH, total soluble solids and total phenolic were measured. Each parameter exhibited different response. However, it can be observed that the shelf life of both banana and citrus was improved markedly by T4 (AVG + Nano-emulsions in 5: 0.5). T3 (AVG + Nano emulsions in 10:1) and T1 (1 % AgNO3) also exhibited good and statistically similar results. Regardless of difference in respiratory nature, both climacteric and non-climacteric fruits were equally improved by the combination of aloevera gel and nano-emulsions.

The length of banana fruit expressed non-significant results. Hence we can conclude that none of the treatment applied affect the banana fruit length significantly. However, fruit weight and diameter of banana were affected by the applied treatments. In case of banana, aloevera gel in combination with the nano-emulsion of 10:1 showed significant results. AgNO3 in both concentrations and the combination of AVG with nano-emulsion evinced statistical similarity. In case of citrus, 1 % AgNO3 indicated best results regarding

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fruit weight. However, similar to banana, aloevera gel in combination with the nano-emulsion of 10:1 revealed best results in retaining fruit diameter for longer duration.

The data regarding fruit firmness also revealed similar results. T1 (1 % AgNO3) and T3 (AVG + Nano emulsions in 10:1) proved effective in marinating fruit firmness for longer duration in banana and citrus. During storage, banana go through a ripening process where the fruits softens and the firmness decreases gradually (J. Chen, Li, Li, Hong, & Yuan, 2022). This softening is primarily due to conversion of starches to sugar which affects the texture and taste of fruit (Maduwanthi & Marapana, 2019). Unlike bananas, citrus fruits maintain their firmness relatively well during storage. The peel of citrus acts as a protective layer, helping to maintain the firm texture and prevent moisture loss from the fruit. However, as the citrus undergo prolonged storage they can experience a slight decrease in firmness (Champa et al., 2020). The silver nitrate and combination of aloevera gel with nano-emulsion proved best for retaining firmness for longer duration as compare to all other treatments.

Peel weight, pulp weight and pulp to peel ratio also manifested different results in both fruits. Peel weight of banana and citrus was efficiently retained good during storage with application of AVG and nano emulsions in 10:01 (T3). However, in citrus that combination was statistically non-significant with peel weight of control (T0) and all other treatments did not perform better than control. In contrast to this, pulp weight of citrus was significantly improved with the application of T1 (1 % AgNO3). However, in banana T2 (0.5 % AgNO3) provided more efficient results. In case of Pulp to peel ration excellent results were obtained by the application of 0.5 % AgNO3 in both fruits (banana and citrus). Pulp to peel ratio during storage of banana tend to decrease due to reduction of peel size and increase of pulp weight however citrus typically maintained a relatively stable peel weight during storage thus the pulp to peel ratio also tends to maintain relatively constant during storage (Ganduri & Preservation, 2020).

The pulp pH of citrus and banana showed different results. The pH of banana increases during storage, however, it decreases in the case of citrus during storage. In banana, the starch in the fruit converted into sugar which contributed in the development of acid that resulted in tangy taste. In case of citrus, the acidity of fruits slightly increased due to the breakdown of organic acids in the fruit. T3 (AVG + Nano emulsions in 10:1) proved best for maintaining pulp pH in banana while T4 (AVG + Nano emulsions in 5:0.5) proved excellent in mainlining pH of citrus. However, Total soluble solids (TSS) of banana was significantly affected by 5:05 solution of aloevera gel and nano-emulsions. In case of citrus, 1% AgNO3 exhibited significant results in increasing the TSS value. The increase of TSS value is crucial for determining the shelf life of fruit. Higher TSS lowers the reparation rate and microbial attack on fruit thus proved efficient in increasing the shelf life of fruits. By analyzing current study, it can be claimed that climacteric and non-climacteric fruits responded differently towards applied treatment. In contrast to TSS, total phenolic compounds of citrus and banana were significantly affected by the combination of both aloevera gel and nano-emulsion concentrations. Total phenolic can help to extend shelf life of fruits by delaying or preventing deterioration caused by oxidative damage. It

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can inhibit the activity of certain enzymes like polyphenol oxidase and peroxides, thereby slowing down enzymatic browning and reducing microbial load, they maintain the quality of fruits (Hasan et al., 2021).

CONCLUSION

Climacteric and non-climacteric (both types of) fruits responded equally well to the combination of aloevera gel (AVG) and nano-emulsions, but none of treatment can be considered as a best treatment in controlling all study parameters at a time because all treatments respond differently to various parameters. In banana, combination of aloevera gel and nano-emulsions were effective for fruit weight, fruit firmness, peel weight, pulp pH and TSS. While, AgNO3 had the significant results for pulp weight, fruit firmness and pulp to peel ratio. In terms of citrus, AgNO3 respond well for fruit weight, fruit firmness, pulp weight, pulp to peel ratio and TSS. AVG + nano-emulsions showed the best results for fruit diameter, fruit firmness, peel weight and pulp pH. Furthermore, Total phenolic content was significantly affected by the combination of aloevera gel and nano-emulsion concentrations in both banana and citrus. Overall, the effects of the treatments varied for different parameters and fruits. Combinational AVG + nano-emulsions 5:0.5 demonstrated the most pronounced improvement in shelf life for both banana and citrus, suggesting its efficacy in preserving post-harvest quality.

Future Prospects

These findings contribute to the understanding of effective post-harvest preservation techniques for banana and citrus fruits, offering valuable insights for the industry and consumer alike.

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