



Influence of Neem and Moringa Leaf Extract on Quality and Shelf Life of Tomato



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Abstract

Edible film coatings are frequently employed as a protective barrier to lower transpiration and respiration, which slows down the ripening process and improves the quality of fruits and vegetables. The present investigation "Influence of neem and moringa leaf extract on quality and shelf life of tomato" was conducted in Horticulture at the University of Haripur, Khyber Pakhtunkhwa, Pakistan during 2022, with the objective of finding the best coating material to increase the storage duration of tomato. Four treatments i-e T0= Control, T1= 10% Moringa Leaf Extract, T2= 10% Neem Leaf Extract, T3= 10%+10% Moringa leaf extract +Neem leaf extract was used. Fruits were stored for a maximum of 12 days. Various parameters like, Fruit weight (g), Fruit firmness (Nm), Fruit Decay (%), Fruit pH, Total phenolic contents, Total antioxidant activity (% DPPH Inhibition), Total Soluble Solids (%), Catalase Determination, Peroxidase Determination, Superoxide dismutase and phytochemical screening of tomato fruit were observed. Tomato fruit coated with 10%+10% MLE+NLE showed promising results regarding increasing the shelf life and maintaining the quality of the fruits. From this study it is concluded that coating of 10% MLE + 10% NLE helps in enhancing the shelf life of tomato fruits and found very effective in maintaining the quality of tomato fruit under different storage durations. Post-harvest application of these organic extracts can be helpful in increasing the shelf life of tomatoes.

Keywords: Tomato; Shelf life; Moringa; Neem

Abbreviations: MLE: Moringa Leaf Extract; NLE: Neem Leaf Extract; Nm: Newton Meters; TPC: Total Phenolic Contents; CRD: Complete Randomized Design; ANOVA: Analysis of Variance; LSD: Least Significant Difference; TSS: Total Soluble Solids; POD: Peroxide Determination; SOD: Superoxide Dismutase

Introduction

Tomato (*Lycopersicon lycopersicum*), remains as one of the most frequently produced and consumed vegetables across the world. Depending on their growth tendencies, tomato cultivars are classified as determinate or indeterminate; the former type is good to produce uniformly ripened fruits, whilst the latter type is suitable for the continuous production of fruit throughout the year [1]. Tomato is botanically classified as a fruit. The producers have been enticed to produce the crop all year long, especially in areas with warmer weather, due to the low cost, ease of tomato

production, short duration, and significant economic returns [2]. Prior to being accepted as safe for consumption, tomatoes were only cultivated as aesthetic garden plants since they were formerly believed to be toxic. One of the most significant commercial and nutritional vegetable crops today is the tomato [3].

Due to high perishability, tomatoes cannot be kept for an extended period. Farmers are losing a significant amount of product each year due to perishability. According to [4] post-harvest tomato loss might reach 50%. Since tomatoes are

climacteric fruits, they gradually deteriorate following harvest. As a result, they have a limited postharvest life since many processes that lead to quality degradation begin after the crop is collected [5]. After harvesting, there may be several changes that impact quality factors including color, texture, and flavor as tomato fruits transition from the ripe green to the fully mature stage. Tomato fruit preservation is hampered by transpiration, senescence, and fungus infection [6]. Fresh-market tomatoes are a widely consumed and adaptable fruit. Moreover, it is a vegetable that significantly improves human nutrition by providing a diversity of food nutrients [7]. The chemical and nutrient makeup of tomatoes is directly impacted by the ripening procedures and storage temperature [8]. Additional elements that impact fruit and vegetable quality include harvesting techniques, biological maturity, and postharvest handling [9].

Neem (*Azadirachta indica* A. Juss) is a large, evergreen, hardy tree, native to the Indian sub-continent [10]. Neem compound show many biological activities different extracts of neem are medicinal the most closely related neem species are *Melia azedarach* Linn A. *indica* and A.juss, due to many medicinal uses neem is used in wide range of homeopathic, unani and ayurveda medicines. About 135 different compounds are extracted from neem different parts having different structural and chemical diversity the extracted compounds are divided in to two groups triterpenoids and diterpenoids which contain azadirone, photomedicines, limonoids, gedunin and its derivatives [11]. C-secomeliacins like salanin, azadirachtin nonisoprenoids and nibin and a compound vilasinin which act as carbohydrate, proteins and amino acid, polyphenolics like flavonoids and its glycosides, coumarin tannins and dihydrochalcone, and also aliphatic compounds. [12].

Depending on the growth circumstances, ripening stage, and genotypic diversity, antioxidants serve different functions in tomatoes [13]. The chemical and nutrient makeup of tomatoes is directly impacted by the ripening procedures and storage temperature [8]. Additional elements that impact fruit and vegetable quality include harvesting techniques, biological maturity, the environment after harvest, handling, and storage conditions [14]. Because of its numerous uses, moringa leaf extract (MLE), which is derived from the moringa plant, is one of the most popular plants bio stimulants [15]. Amino acids, cytokinins such as zeatin, flavonoids, antioxidants such ascorbic acid, carotenoids, phenolics, vitamin A, and macro- and micronutrients are all present in MLE [16,17]. The family Moringaceae, to which *Moringa oleifera* belongs, is said to have the most widely distributed tropical plants. [18]. The moringa leaf extract (MLE), which contains proteins, vitamins E, phenolics, ascorbic acid, essential amino acids, and several mineral components, is thought to be a natural plant growth regulator. This makes it a possible natural growth stimulant. Additionally, Moringa leaf extract significantly enhanced the average plant height, number of leaves, number of branches, and yield of tomato plants, according to [19]. According to [20], MLE foliar spray acquired the greatest values of black

cumin plant growth and yield metrics. Considering these facts, the current study was conducted to evaluate different concentrations of moringa leaf extract and neem leaf extract for improving the storage of tomato fruits. The study was conducted with the following objectives:

Objectives

- What are the effects of different concentrations of Moringa leaf extract and Neem leaf extract on tomato during storage life?
- Does storage interval have any influence on physical and biochemical characteristics of tomatoes?
- Do Moringa leaf extracts and Neem leaf extracts differ in their action in preserving the quality and postharvest quality of tomato?

Materials and Methods

Current study "Influence of Neem and Moringa leaf extract on quality and shelf life of tomato" was conducted at Department of Horticulture, The University of Haripur, Khyber Pakhtunkhwa Pakistan during April-July 2022

Collection of fruits

Fresh and uniform sized tomatoes will be collected from Haripur.

Preparation of moringa and neem leaf extracts

Tomatoes were treated with the following concentration of MLE and NLE. Each treatment was prepared by methods described by AOAC 2001. Fruits were dipped for 15 minutes in each treatment.

T₀ = Control

T₁ = 10% Moringa Leaf Extract

T₂ = 10% Neem Leaf Extract

T₃ = 10%+10% MLE+NLE

Storage duration

After MLE and NLE application Tomato fruits were stored for 12 days at ambient temperature in horticulture laboratory. The storage duration was comprised of the following durations.

Storage Duration 1 (SD) = 0 day

Storage Duration 2 (SD) = 3 day

Storage Duration 3 (SD) = 6 day

Storage Duration 4 (SD) = 9 day

Storage Duration 5 (SD) = 12 day

Parameters

Data regarding enzymatic activity, physical and biochemical attributes, phytochemical analysis along with phytochemical screening were carried out during the study period.

Physical Analysis

Fruit weight loss (%)

Fruit weights were measured using a digital balance (MJ-W176P, Panasonic Japan) both before and after storage. Using the formula below, the fruits' percentage weight loss was calculated [21].

$$\text{Weight Loss (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

Fruit firmness (Nm)

Ripe, uniform tomatoes were chosen, and damaged specimens were excluded. Fruit firmness was measured in Newton meters (Nm) with a calibrated penetrometer. The measurements were repeated for accuracy, and the data was examined by computing average hardness values and assessing statistical significance [22].

Titrateable acidity

In a 100 mL conical flask, ten mL of juice was extracted and mixed with purified water. After being titrated against 0.1N NaOH, the solution was used to indicate 2-3 drops of phenolphthalein before pink was observed. Using the thousand equivalent factor for malic acid, the primary acid in the tomato at maturity was 0.067 [23]. The proportion was then calculated using the following formula:

TA (%) = 0.1 NaOH used multiplied by 0.067 per 100 mL of juice consumed

Fruit Decay (%)

[24] described the method of fruit decay. Fruit decay from each treatment was investigated at each storage interval as the part of the fruit where the peel became softer. Fruit decay percentage was recorded for this purpose. After observing the physical look of the fruit, the fruit decay percentage was calculated every storage day.

Total number of decayed fruits from each treatment was counted.

$$\text{Fruit decay \%} = \frac{\text{Decayed fruits}}{\text{Total number of fruits}} \times 100$$

Phytochemical Screening

Form each crude extract stock solution was prepared. The stock solution was then subjected to different tests for analysis of phytochemicals by using the standard procedures as mentioned by described by [25].

Total phenolic contents (mg GAE/100g)

[26] used the Folin Ciocalteu reagent procedure to calculate total phenolic contents (TPC). In 100 ml of distilled water, 10ml of FC-reactive was dissolved. Each sample (100ml) received a

generous quantity of FC-reagent (200L) and a vortex. The 700 mM Na₂CO₃ (800L) is introduced and incubated for 2 hours in each sample. Each sample (200L) was then transferred to a transparent 96-pit plate and estimated at 765 nm. TPC concentration was determined using a Gallic acid reference curve. The findings were equivalent to gallic acid.

Total antioxidant activity (mg 100 mL⁻¹)

Absolute plant-based antioxidant activities were measured in samples using the spectrophotometrically performed 2, 2-diphenyl-1-picrylhydrazyl stable radicles reported by [27]. 5 mL 0.004 percent methanol is added to aliquots (50 L) of peeling and pulp extraction at various concentrations (50-150 g mL⁻¹). After a 30-minute incubation period at room temperature, the absorption was measured at a blank distance of 517 nm. DPPH inhibition (%) = 100 (Ablank = Asample/Ablank)

The absorbance of the control reaction (containing DPPH but no sample) is ablanck. Asample is the absorbance of DPPH after the sample has been added.

Bio-Chemical analysis

pH

pH of 1% and 10% aqueous solutions of fruit juice was determined according to the AOAC (1990) Method No: 981.12. The pH metre was adjusted, 60 ml of sample was added to the 100 ml clean beaker, and the key was pressed to determine the pH of the tomato juice. As the metre turned "Ready," the pH metre's digital screen was read, measured, and computed at 18°C±2°C (HI 98107, Hanna, Mauritius) [28].

Total Soluble Solid (Brix°)

Using a hand-held refractometer (KROSS HRN-16), the fruit juice from the selected fruit was collected, and the gross soluble solid was calculated. First, distilled water was used to adjust the refractometer to a zero reading. One drop of each sample was put onto the refractometer's prism plate. On the prism plate, the readings were recorded at a single decimal place. After each examination, the prism plate was cleaned with distilled water and a soft tissue. The average and recorded data was expressed in Brix° degrees [29].

Enzymes Activities

Catalase determination (U mg⁻¹ protein)

With few modifications, the [30] method has been used to calculate the catalase activity in tomato peel. To stimulate enzyme reactions, a freshly prepared 5.9 mM 100 µL H₂O enzyme extract (100 µL) has been mixed. Utilizing an ELX800 Microplate Reader (Bio-Tek Instruments, Inc., Winooski, VT, USA), catalastic activity at 240 nm was generated and expressed as U mg⁻¹ Protein. Catalysis was defined as absorbance shifts of 0.01 units per minute.

Peroxide determination (U mg⁻¹ protein)

The [31] method has been used to investigate peroxidase activity with a specific modification (2009). A novel reaction mechanism was created by adding guaiacol (20 mM 100 µL) and phosphate buffer (pH 5) of 50 mM 800 µL in 40 mM 100 µL H₂O₂. After adding 100 µL of enzyme extract absorption to 100 µL of reaction mixtures, the microplate reader (ELX800) from Winooski, Vermont, USA, detected the results as U mg⁻¹ protein at 470 nm. It was said that one unit of peroxide activity corresponded to the absorbent shift of 0.01 units per minute.

Superoxide dismutase determination (U mg⁻¹ protein)

The method [32] described for determining the 50% photochemical reduction in nitro blue tetrazolium (NBT) was used to the superoxide dismutase study. Each test tube included the following: 200 µL (22 µM) of methione (12 µM), 500 µL phosphate buffer (50 mM, pH 5), and a combination of 100 µL filtered water and 100 µL enzyme extract. Phosphate buffer (50 mM, pH 5) containing 500 µL was placed in each test tube. A 15-minute container held test tubes equipped with fluorescent bulbs. The ELX800 Microplate Reader (Bio-Tek Instruments, Inc., Winooski, VT, U.S.) was used to report the absorbance at the level of 560 nm.

Statistical Analysis

Data was analyzed by application of standard error and analysis of variance (ANOVA) using two factorial designs under complete randomized design (CRD) using Least significant difference (LSD) at p<0.01 by using latest version of Statistix 8.1 [33].

Results and Discussion

Fruit weight loss (%)

Figure1 shows fruit weight loss as affected moringa leaf extract (MLE) and neem leaf extract (NLE) coatings. Analysis of variance showed that fruit weight loss was significantly influenced by coating materials and storage durations as well as their interaction. Weight loss in tomato fruits gradually increases with an increase in storage durations. Fruits stored for 12 days showed maximum fruit weight loss. Treatments applications also helped to reduce fruit weight loss. Maximum fruit weight loss was observed in fruits stored for 12 days without application of MLE and NLE. Due to an increase in transpiration and respiration, this weight loss is associated with an increase in water loss [34]. This might be explained by the tomato high surface to volume ratio and low skin diffusion resistance [35]. Similar findings with different edible coatings were reported in earlier investigations, which concluded that edible films acted as a physical barrier against moisture loss and decreased transpiration rates [36].

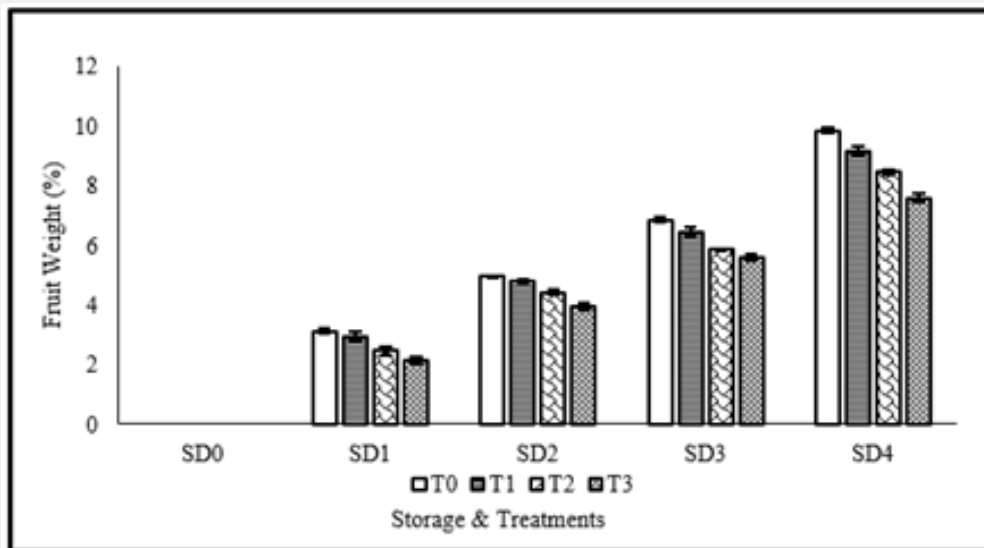


Figure 1: Fruits weight loss of tomato as affected from storage durations and treatments application.

LSD for treatments = 0.17

LSD for storage durations = 0.2

LSD for treatments × storage durations = 0.54

Fruit firmness (Nm)

The degree of firmness, which has a significant impact on customer acceptance, is primarily correlated with the food's water content and metabolic processes. Loss of firmness may

have an impact on financial gains. Figure 2 presents the effect of storage durations and application of treatment's extract coating on fruit firmness of tomatoes. Fruit firmness was significantly affected from storage durations, treatments application as well as their interaction during the study. Maximum fruit firmness was

observed with application of combined treatment of 10%+10% MLE+NLE, whereas minimum fruit firmness was observed in control. Regarding storage durations, maximum fruit firmness was observed in fresh fruits (without storage), whereas minimum fruit firmness was observed in fruits stored for maximum duration of time. Concerning the interaction, maximum fruit firmness was observed in zero day stored fruits, regardless of the treatment's application. Whereas storage gradually decreases fruit firmness and minimum value was observed in fruits stored for 12 days without any coating. With a longer length of storage, the firmness loss grew over time. This may be caused by the coordinated activity

of cell wall-modifying enzymes and proteins, which results in the destruction of cell wall components [37]. Similar observations were reported by [38], who came to the same conclusion that hardness reduces with storage. Neem leaf extract's and MLE ability to suppress the growth of bacteria that cause rotting and increase metabolic rate may also contribute to the lesser firmness losses of tomatoes treated with the extract [39]. Previous studies showed that the cell wall-degrading enzymes' inhibitory activities were directly associated to softening and helped to maintain firmness by slowing down the pace of metabolic process during ripening [40].

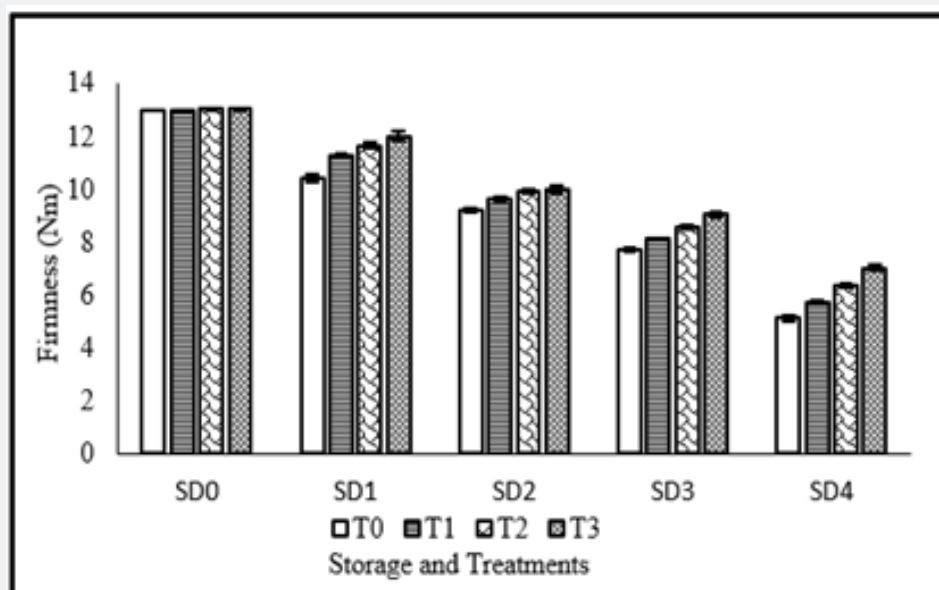


Figure 2: Fruits firmness of tomato as affected from storage durations and treatments.
 LSD for treatments = 0.17
 LSD for storage durations = 0.2
 LSD for treatments × storage durations = 0.55

pH

Application of coating materials, days of storage as well as their interaction significantly affected pH of tomato fruit juice. Maximum pH (4.63) was recorded without coating materials, followed by 10% MLE, whereas minimum pH (4.42) was observed with application of MLE 10% + NLE 10%. Regarding storage durations, maximum pH was recorded in 12 days of stored fruits, followed by 9 days, whereas fresh fruits showed minimum pH. Concerning the interaction, maximum pH was recorded in 12 days stored fruits without application of coatings. pH gradually increases with increase in storage durations (Figure 3). The gradual pH increases in tomatoes treated with neem leaf extract may be due to the extract's ability to prevent microbial deterioration during storage because of its antimicrobial activity. This increase in pH over the time of storage suggests that organic acids in tomatoes degrade

during storage. The stability of the pH value of tomatoes during storage is greatly influenced by the slowing in physiological activity and the reduced breakdown of organic acid by neem leaf extract. [41,42] both came to similar conclusions.

Fruit decay (%)

Figure 4 depicts tomato fruit decay as affected by different coatings. Analysis of variance indicated that there was significant effect of coating materials, storage days as well as their interaction on fruit decay. There was no decay in the tomato for 9 days. Decay started after the 9th day. Decay was observed in controlled fruits stored for 12 days. Fruits coated with 10% MLE only and fruits coated with NLE 10% also showed decay on the 12th day. The lower decay or rotting rate in MLE + NLE treated tomatoes may also be attributable to the incorporation of bioactive compounds from neem leaf extract in fruit that enhanced the fruit's resistance to

pathogen-induced decay. Similarly, the lower decay or rotting rate in neem leaf extract-treated tomatoes may also be attributable to the incorporation of bioactive compounds from neem leaf extract

in fruit that enhanced the fruit's resistance to pathogen-induced decay Our findings agree with the conclusion reached by [24,43].

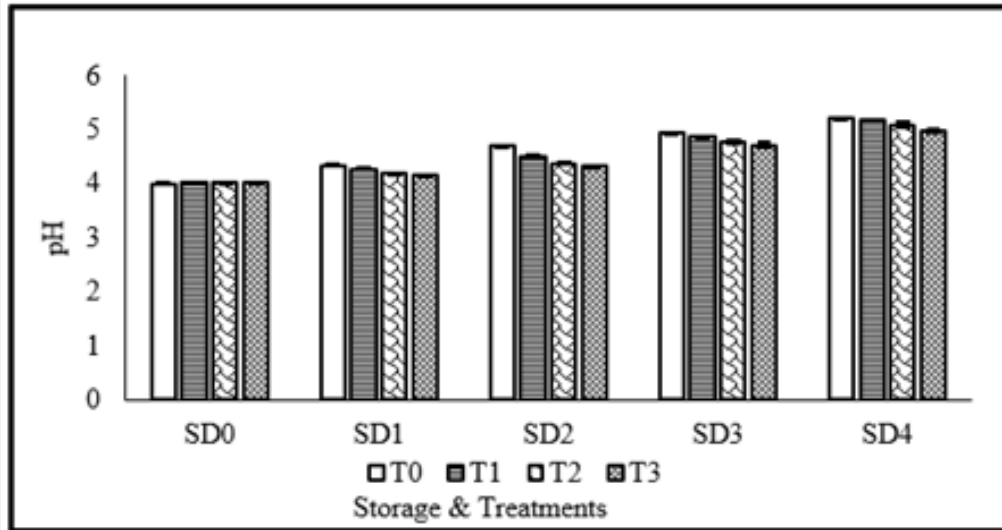


Figure 3: pH of tomato as affected from storage durations and treatments application.
 LSD for treatments = 0.03
 LSD for storage durations = 0.04
 LSD for treatments × storage durations = 0.11

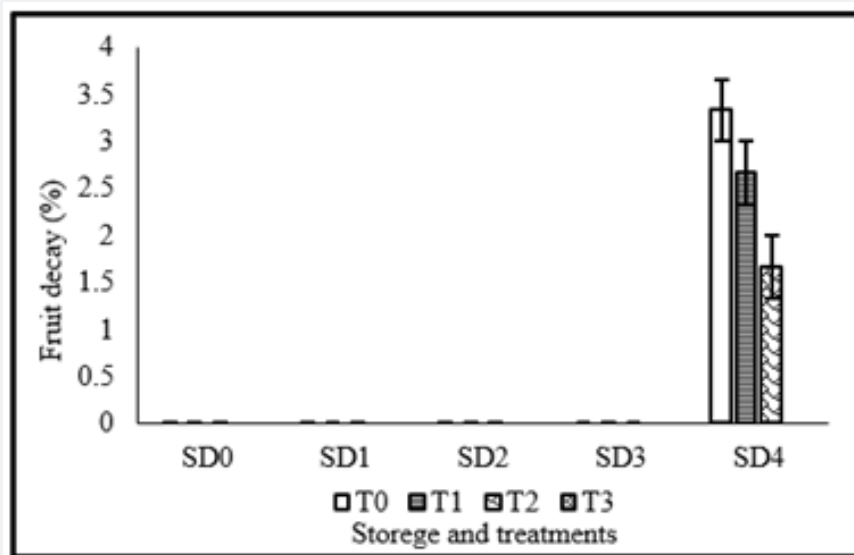


Figure 4: Fruit decay of tomato as affected from storage durations and treatments application.
 LSD for treatments = 0.22
 LSD for storage durations = 0.26
 LSD for treatments × storage durations = 0.7

Total soluble solids (Brix⁰)

Total soluble solid contents are regarded as the fundamental criterion for evaluating fruit ripening. Coating materials, storage

durations as well as their interaction significantly affected total soluble solids of tomato fruits. Maximum TSS was recorded without application of coating materials, whereas application of MLE 10% + NLE 10% resulted in minimum TSS. Regarding storage

durations, maximum TSS was observed in 12 days stored fruits, whereas lowest TSS value was observed in fresh fruits. Concerning the interaction, maximum TSS was recorded in 12 days of stored fruits without coatings, whereas fresh fruits showed minimum TSS. Its sluggish ripening process and respiration may be the cause of the little rise in sugar levels in NLE + MLE treated tomatoes compared to control and other treatments [44]. Due to its natural yield intrinsic activity, 10% NLE combined with 10%

MLE decreased the rate of respiration, transpiration, and other metabolic processes [45]. The highest concentration of sugars in the untreated control might be the consequence of starch converting quickly to sugars due to moisture loss and a drop in acidity brought on by physiological changes during storage. Our findings concur with those of [46]. By employing tomato varieties [47,48] reported similar outcomes (Figure 5).

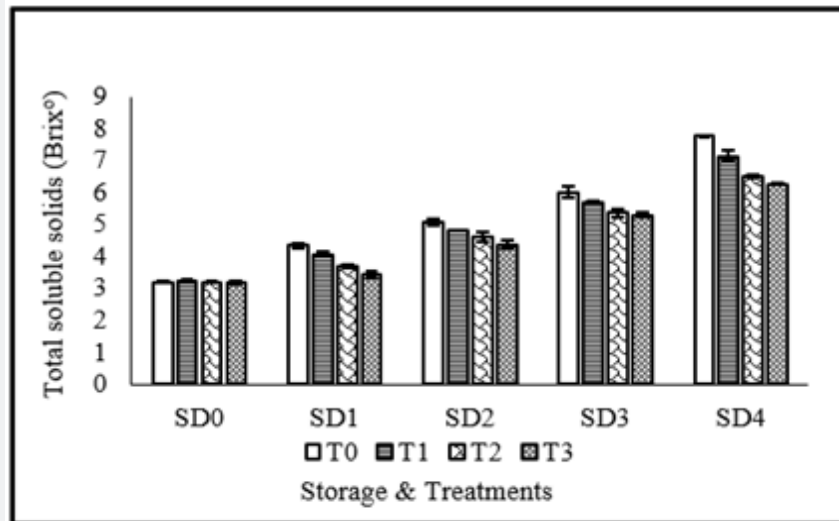


Figure 5: Total soluble solids of tomato as affected from storage durations and treatments application.
 LSD for treatments = 0.15
 LSD for storage durations = 0.18
 LSD for treatments × storage durations = 0.49

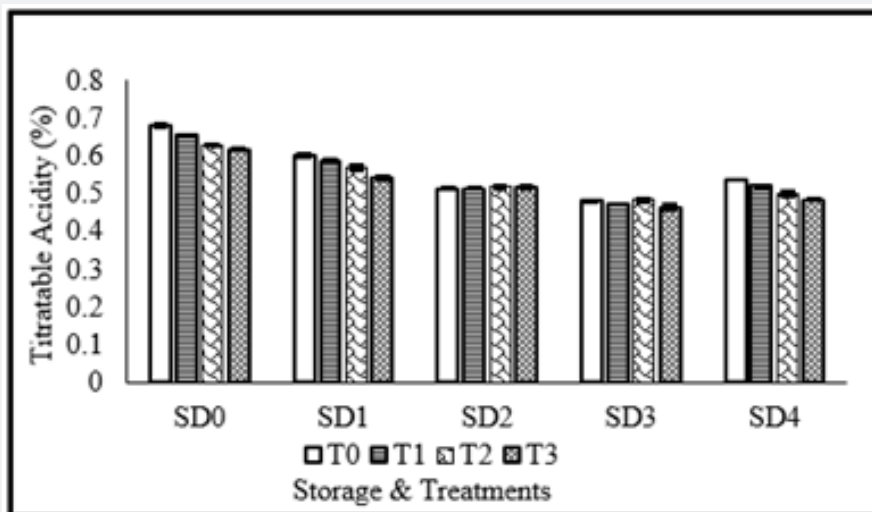


Figure 6: Titratable acidity of tomato as affected from storage durations and treatments.
 LSD for treatments = 0.007
 LSD for storage durations = 0.009
 LSD for treatments × storage durations = 0.02

Titrateable acidity (%)

As fruit ages, its titrateable acidity tends to decline while its total soluble solid content rises. Figure 6 illustrates titrateable acidity of tomato fruits as affected by MLE and NLE coatings. Analysis of variance suggested that titrateable acidity was significantly affected from coating materials, storage durations as well as their interaction during the study. Maximum titrateable acidity was observed in fresh fruits, as time goes on, titrateable acidity of tomato fruits tends to decline, and minimum value was recorded for the fruits stored for 12 days. The anti-microbial capabilities of neem leaf extract, which slow down the microbial decomposition of organic acids, may be the cause of the tomatoes treated with neem's sluggish drop in titrateable acidity [23]. It is further reinforced by [49], who found that coated fruits' rate of titrateable acidity decrease is slower than uncoated fruits' because of oxygen availability restrictions, which slow down respiration

rate.

Total phenolic content (mg GAE/100g)

The effect of MLE and NLE coating on total phenolic content of tomato is presented in figure7. The total phenolic content of tomato was significantly affected from coating materials, storage durations as well as their interaction. Maximum TSS was recorded without application of coating materials, whereas application of MLE 10% + NLE 10% resulted in minimum TSS. Regarding storage durations, statistically similar results of total phenolic content were observed in 12 days stored fruits and fruits stored for 9 days, whereas lowest TSS value was observed in fresh fruits. Concerning the interaction, maximum TPC was recorded with application of T₃ in fruits stored for 9 and 12 days respectively. [50] also reported significant differences in phenolic content of tomato fruits treated with different organic coatings.

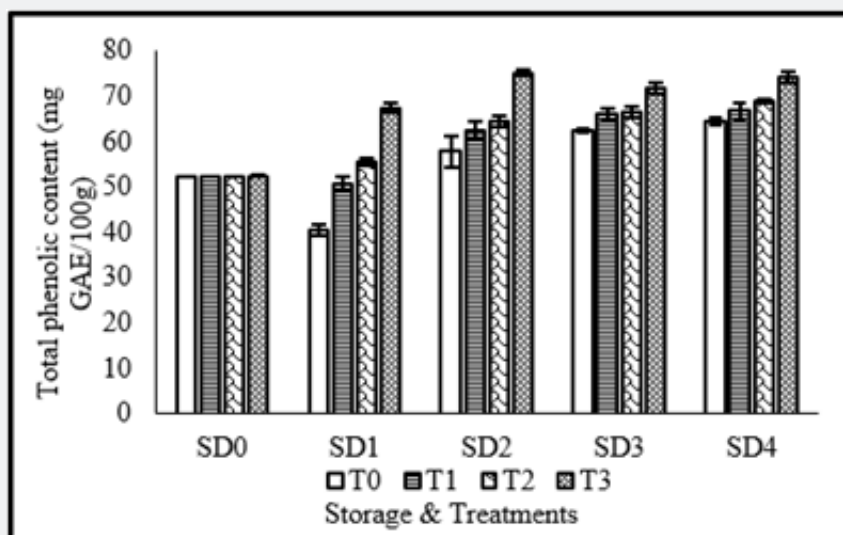


Figure 7: Total phenolic content of tomato as affected from storage durations and treatments application.
 LSD for treatments = 2.18
 LSD for storage durations = 2.6
 LSD for treatments × storage durations = 6.91

Total antioxidants activity (mg 100 mL⁻¹)

Total antioxidant activity of tomato fruits was significantly affected from storage durations, treatments application as well as their interaction during the study (Figure 8). Maximum total antioxidant activity was observed in fruits treated with 10% MLE + 10% NLE, whereas lowest total antioxidant activity was observed in control treatments. Regarding storage durations, minimum total antioxidant activity was observed in 12 days of stored fruits. Total antioxidant activity gradually decreases with the increase in number of storage days. Maximum total antioxidant activity was recorded in fresh fruits. Concerning the interaction, maximum

antioxidant activity was observed in fresh fruits regardless of the treatment application. The alteration of the internal environment brought on by edible coatings, which initially causes the buildup of phenolic chemicals, may have contributed to the rise in overall antioxidant activity [51]. It was discovered that coating coated Ficus hirta fruit and grapefruits with MLE + NLE increased their overall antioxidant activity [52]. Within the first six days, strawberry fruit coated with chitosan showed a rise in the AOA, according to [53]. The Maillard process linked to the synthesis of brown melanoidins with high AOA may also be able to explain this phenomenon [54].

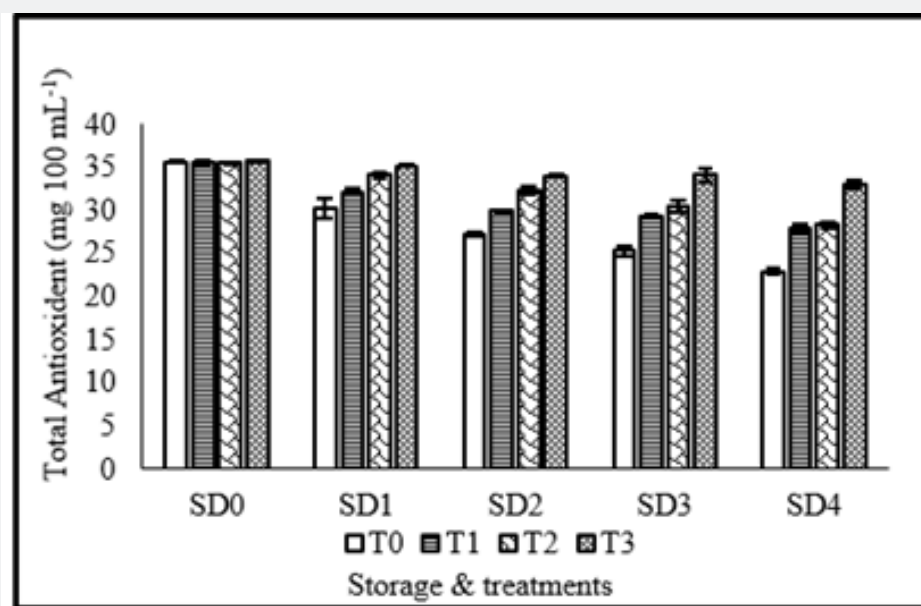


Figure 8: Total antioxidants activity of tomato as affected from storage durations and treatments.
 LSD for treatments = 0.76
 LSD for storage durations = 0.91
 LSD for treatments × storage durations = 2.43

Catalase Determination (U mg⁻¹ protein)

Table 1 depicting catalase determination (U mg⁻¹ protein) of tomato fruits. Analysis of variance showed that Catalase (U mg⁻¹ protein) activity of tomato was significantly affected from coating treatments as well as storage durations, whereas their interaction remained non-significant during the study. Maximum CAT was observed with application of MLE 10% + NLE 10%, whereas control treatment showed lowest CAT activity. Regarding storage durations, maximum CAT was observed in fresh fruits, increasing number of days of storage gradually resulted in decrease in CAT activity of tomato fruits. The lowest catalase activity was recorded in 12 days of stored fruits. The use of organic coatings on citrus fruits increased the activity of plant defense-related enzymes like CAT, as was previously noted [55]. The findings support the conclusion reached by [2].

Peroxide Determination (U mg⁻¹ protein)

Figure 9 shows Peroxide Determination (U mg⁻¹ protein) of tomato as affected from different coatings and various storage durations. Peroxide Determination (U mg⁻¹ protein) was significantly affected from coating application, storage durations as well as their interaction. Maximum POD (5.64U mg⁻¹ protein) was recorded with application of 10% MLE + 10% NLE, whereas minimum was observed in control. Regarding storage durations, maximum POD was recorded in fruits stored for 12 days, statistically similar observations were recorded in fruits stored

for 9 days. Fresh fruits showed minimum POD. Concerning the interaction, maximum POD was recorded in fruits stored for 12 days with application of MLE 10% + NLE 10%. In general, it is understood that fruits' POD rises when being stored [4]. Analysis showed that as storage time ended, POD of the fruits increased in response to ripening and treatments. This research closely resembles that of [56]. Particularly, MLE therapies were more successful than controls at maintaining POD. The same findings were recorded by [56].

Superoxide dismutase (U mg⁻¹ protein)

All live cells contain the enzyme superoxide dismutase (SOD). An enzyme is a substance that quickens some bodily chemical processes. In cells, superoxide dismutase aids in the degradation of potentially damaging oxygen molecules [32]. Table 2 shows Superoxide dismutase value of tomato fruits as affected from different coatings and different storage durations. Analysis of variance (ANOVA) showed that Superoxide dismutase showed non-significant results for treatments applications, storage durations as well as their interaction during the study.

Phytochemical Screening

Quantitative phytochemical analysis of tomato fruits is presented in Table 3. Saponins shows their high presence in fruits treated with 10% MLE + 10% NLE stored for 3 and 6 days. Phytosterol showed high presence in fruits treated with 10% MLE

+ 10% NLE. Regarding Tannins, it showed the resences regardless of the storage duration and chemical application. Flavonoids are moderately present in all treatments stored for 3- and 6-days'

fruits. After increasing the storage duration of the fruit, flavonoids presence gradually increases and showed its highest presence when stored for more than 12 days.

Table 1: Catalase Determination (U mg⁻¹ protein) of tomato as affected from storage durations and treatments application.

| | SD0 | SD1 | SD2 | SD3 | SD4 | MEANS |
|-------|-----------|---------|---------|---------|--------|-----------|
| T0 | 14.500 NS | 12.067 | 11.333 | 10.267 | 9.033 | 11.440 C |
| T1 | 14.667 | 12.267 | 11.6 | 10.567 | 9.133 | 11.647 BC |
| T2 | 14.733 | 12.6 | 11.7 | 10.667 | 9.6 | 11.860 B |
| T3 | 14.7 | 13.267 | 12.1 | 11.033 | 10.067 | 12.233 A |
| MEANS | 14.65 a | 12.55 b | 11.68 c | 10.63 d | 9.45 e | |

LSD for treatments = 0.23

LSD for storage durations = 0.28

LSD for treatments × storage durations = NS

Table 2: Superoxide dismutase (U mg⁻¹ protein) of tomato as affected from storage durations and treatments application.

| | SD0 | SD1 | SD2 | SD3 | SD4 | MEANS |
|-------|-----------|--------|--------|--------|--------|-----------|
| T0 | 371.43 NS | 386.9 | 379.27 | 374.13 | 387.73 | 379.89 NS |
| T1 | 369.77 | 373.9 | 385.63 | 380.43 | 375.7 | 377.09 |
| T2 | 372.17 | 386.3 | 373.43 | 388.1 | 382.73 | 380.55 |
| T3 | 378.8 | 371.97 | 387.6 | 375.17 | 393.8 | 381.47 |
| MEANS | 373.04 NS | 379.77 | 381.48 | 379.46 | 384.99 | |

LSD for treatments = NS

LSD for storage durations = NS

LSD for treatments × storage durations = NS

Table 3: Qualitative Tests of Phytochemical in tomato

| Storage days | Treatments | Saponins | Phytosterol | Tannins | Flavonoids |
|--------------|------------|----------|-------------|---------|------------|
| SD0 | T0 | ++ | ++ | +++ | ++ |
| SD0 | T1 | +++ | ++ | ++ | ++ |
| SD0 | T2 | ++ | +++ | ++ | ++ |
| SD0 | T3 | ++ | ++ | +++ | +++ |
| SD1 | T0 | +++ | +++ | ++ | ++ |
| SD1 | T1 | +++ | ++ | +++ | ++ |
| SD1 | T2 | ++ | +++ | +++ | ++ |
| SD1 | T3 | +++ | ++ | +++ | +++ |
| SD2 | T0 | +++ | +++ | ++ | +++ |
| SD2 | T1 | +++ | +++ | +++ | +++ |
| SD2 | T2 | +++ | ++ | +++ | +++ |
| SD2 | T3 | +++ | ++ | +++ | +++ |
| SD3 | T0 | +++ | +++ | - | +++ |
| SD3 | T1 | ++ | ++ | ++ | +++ |
| SD3 | T2 | ++ | ++ | +++ | +++ |
| SD3 | T3 | ++ | ++ | +++ | +++ |
| SD4 | T0 | ++ | + | + | +++ |

| | | | | | |
|-----|----|----|----|-----|-----|
| SD4 | T1 | ++ | ++ | + | +++ |
| SD4 | T2 | ++ | + | +++ | +++ |
| SD4 | T3 | ++ | ++ | +++ | +++ |

+++ = Highly present, ++ = Moderate presence, - = Absent

In this investigation, secondary metabolites that differ from one another in polarity and structure were extracted using water (aqueous) as a polar solvent, ethanol as a solvent of intermediate polarity, and chloroform as a solvent of excellent polarity. Each solvent had unique biological characteristics. Solvents often penetrate plant materials during the extraction process, and substances with comparable polarities solubilize [57]. The polarity of the solvent has an impact on the content and quality of secondary metabolites in an extract. Traditional healers prepare plant extracts with water, but organic solvents like methanol provide more constant antibacterial action and high-quality secondary metabolites than aqueous solutions [58]. For antibacterial research, aqueous, methanolic, chloroform, hexane, and ethanol were most often utilized as solvents [59]. Although tomato lacks extensive chemical analysis, in recent years many saponins, saponinins, furostane and spirostane glycosides have been isolated [60]. Nevertheless, there are studies of qualitative phytochemical analyses in Safed Musli. It comprises a large variety of phytochemicals, including saponins, alkaloids, flavonoids, and phenolic acids [61].

Conclusion

Our extensive research reveals that the best strategy to extend the shelf life and maintain the quality of tomato fruits during storage is to apply a coating containing 10% Moringa leaf extract and 10% Neem leaf extract. Our findings provide persuasive evidence of these organic extracts' exceptional effects on several crucial variables required for post-harvest fruit management.

Throughout the study, the MLE and NLE coatings consistently demonstrated superior performance in terms of reducing fruit weight loss, maintaining fruit firmness, preventing decay, and influencing key biochemical characteristics such as pH, total soluble solids, titratable acidity, total phenolic content, and total antioxidant activity. Furthermore, the coatings displayed effective modulation of enzyme activities such as catalase and peroxide determination, which are critical for minimizing oxidative stress and preserving fruit quality.

The synergistic action of MLE and NLE, which offer a strong physical barrier against moisture loss, limit microbial development, and regulate metabolic processes during storage, is responsible for the reported improvements in fruit quality and shelf life. Furthermore, the fact that coated fruits include bioactive substances such as tannins, flavonoids, phytosterols, and saponins highlights the possible contributions of these substances to the advantages that have been noted.

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