Asian Journal of Research in Crop Science

2(1): 1-34, 2018; Article no.AJRCS.43137

Effect of Organic Preservatives on Postharvest Shelf Life and Quality of Tomato Fruits during Storage

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Authors' contributions

This work was carried out in collaboration between all authors. Author LK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ACI and KPA managed the analyses of the study. Author KPA managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJRCS/2018/43137
Editor(s):
(1) Moaed Al Meselmani, Professor, Department of Molecular Biology and Biotechnology, The University of Sheffield Firth Court, Sheffield, South Yorkshire.
Reviewers:
(1) Arkendu Ghosh, Bidhan Chandra Krishi Viswavidyalaya, India.
(2) Ogunlade, Adeleke University, Nigeria.
(3) Rosendo Balois Morales, Universidad Autonoma de Nayarit, Mexico.
Complete Peer review History: http://www.sciencedomain.org/review-history/26043

Original Research Article

Received 5th June 2018
Accepted 13th August 2018
Published 30th August 2018

ABSTRACT

Effect of organic preservatives on postharvest shelf life and quality of tomato fruits during storage was carried out. Healthy tomato fruits of three varieties Roma, Riogrande and UTC were obtained from the experimental farm at breaker stage. They were coated with *Moringa*, Neem and bitterleaf powders and stored at room temperature. Variety 3 (V3) produced significantly higher beta carotene content (0.182) than variety 1 (V1) (0.135) and variety 2 (V2) (0.127) on days 1 and 17 (0.205), (0.153) and (0.124). V2 produced significantly higher beta carotene value on days 21 (0.191) and 25 (0.233). Bitterleaf produced significantly higher beta – carotene content on days 1 (0.209), 5 (0.259) and 25 (0.191). No significant difference in firmness was observed within the varieties across the days. Moringa produced the lowest firmness value (2.917) on day 5 while control gave the lowest firmness value on days 13 (2.349), 17 (2.006), 21(1.273) and 25 (0.326). The highest lycopene content among the varieties was produced by V2 on day 21 (0.055) and V3

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(0.055). Bitterleaf generally gave higher lycopene value on days 1 (0.028), 13 (0.071), 21 (.0.59) and 25 (.0.59). Moringa produced significantly higher lycopene content on days 5(0.059) while Neem gave significantly higher lycopene on days 9 (0.041) and 17 (0.052). V3 gave higher marketability value on day 21 (7.525). While Neem gave the highest marketability value (8.322) and (6.422) respectively. Bitterleaf gave the highest pH value (6.461) on day 1followed by *Moringa* (6.614) and Neem (6.387). Control gave the highest pH value (6.798) and (5.356) but this was significantly higher than that produced by Neem. The shelf life of the treated tomato fruits ranged from days 1 -25 while the control ranged from 1- 21 days. V1 gave the significantly highest value of TSS (4.223), Neem gave the highest TSS values on days 5 (4.856), 9(4.856), 13(4.833), 17(4.11), 21 (4.689) and 25(4.510) while the least TSS was given by the control on days 9(4.557), 13(4.044), 17(4.214), 21(4.108) and 25 (3.984). V3 gave higher titratable acidity (TA) (0.549) than V2 (0.475) and V1(0.485) on day 5,9(0.587), (0.485) and 17(0.612), (0.526) and (0.579) respectively. V1 produced the highest titratable acidity on the days 13 (0.627) and 21(0.561). Bitterleaf gave the highest titratable acidity on days1 (0.508) and 13 90.679) respectively. *Moringa* produced the highest TA value on days 9(0.548), 17(0.622) and 21(0.612) while Neem gave the highest TA on day 25 (0.557). V1 gave the highest vitamin C content than V2 and V3 on days 1(9.480), (5.330), (6.880), 5(9.189), (8.584), (5.06) and 9(12.775), (10.620),(10.499) respectively. Neem gave the highest Vitamin C content on days 1(9.400), 5(10.126), 13(10.980), 21(6.996), and 25(6.029). V3 produced significantly higher fruits weight than all the other varieties in days 1 (37.150), 5(35.440), 99(33.620) and 13(31.470). Bitterleaf produced the highest fruit weight on days 1(37.210), 5(35.400) and 9(33.580). The temperature of the storage room ranged from 23.0 - 36.0 and the RH ranged from 45 – 93%. These botanicals are environmentally friendly, cost-effective, easy to produce and easy to apply formulations and are also safe for consumers.

Keywords: Organic preservatives; shelf life; quality; tomato; storage.

1. INTRODUCTION

Tomato is the second most important, most consumed and most widely grown vegetable in the world [1]. It is cosmopolitan in distribution and belongs to the family Solanaceae. It is rich in calcium, vitamins K, B, C, E, minerals and lycopene [2]. Tomato averages about 18% of the total amount of vegetables consumed by the average Nigerian [3]. Nigeria is the sixteenth largest producer of tomato in the world and the second largest producer in Africa [4]. Sadly, it is also estimated that about 50% of the tomato fruits produced in Nigeria is lost because of poor transportation, poor processing facilities which are almost non- existent and lack of proper storage systems. In Benue State, Nigeria, farmers throwing away baskets of tomato fruits are a common sight. Because of this, much needed food and thousands of valuable work hours are wasted. The high tomato production with a corresponding high spoilage rate has affected the nutritional and market value [5] and utilization of the crop. Solutions need to be those that transcend the laxity of government, the high cost of some solutions which never get to the farmers and the negative influence of fungi, bacteria and a cocktail of these organisms which foster postharvest losses.

The concept of using plant leaf powders as coatings to extend the shelf life of fresh produce and protect them from harmful environmental effects has been emphasized based on the need for high-quality fruits and storage technologies [6]. An ideal coating/film is defined as one that can extend the storage life of fresh fruit without causing anaerobosis and reduces decay without affecting negatively the quality of the fruit. The objective of this research is to study the effect of plant leaf powders as coatings /films on the changes in physicochemical parameters related to tomato quality during storage and its role in extending the shelf life of the fruits.

2. MATERIALS AND METHODS

2.1 Experimental Location

The experiment was carried out in the botany laboratory of the Benue State University, Makurdi. Makurdi, the capital of Benue state, Nigeria, is located in North central Nigeria along the Benue river, on latitude 07°43'N and longitude 08°35'E. It is situated within the Benue trough, at the lower Benue valley and found in the guinea savannah region.

2.2 Collection of Tomato Fruits

Healthy tomato fruits of three varieties; Roma, UC 82 and Riogrande were carefully harvested at breaker stage by hand picking from the experimental farm. Fruits were selected on the consideration that they were all of similar sizes and maturity level with absence of visual symptoms of disease and defects. The fruits were carefully placed in plastic crates and taken to the laboratory for further studies.

2.3 Experiment One

2.3.1 Evaluation of the preservative potential of dried and ground leaves on tomato fruits during storage

2.3.1.1 Collection and disinfection of plant leaves

Fresh leaves of *Moringa oleifera* (Drumstick tree), *Vernonia amygdalina* (Bitter leaf) and *Azadirachta indica* (Neem) were collected from different locations in Makurdi metropolis. A cutlass was used to cut branches while the leaves were harvested by handpicking. The leaves were put in clean polythene bags and taken to the laboratory. In the laboratory, the leaves of each plant were first prewashed carefully under a gentle stream of tap water for one to two minutes to remove surface dirt. This was followed by washing in sterile distilled water containing 1% sodium hypochloride for thirty seconds. The leaves were then removed and rinsed in three successions of sterile distilled water.

2.3.1.2 Preparation of leaf powders

The disinfected plant leaves were air dried on the laboratory bench for 7 - 9 days after which they were ground into fine powder first, with mortar and pestle and then with a blender. The powders of each plant were stored separately in well covered clean jars and kept in a dust free locker.

2.3.1.3 Treatment and storage of tomato fruits

Firm, smooth and healthy tomato fruits of the three varieties were washed in clean water to remove dirt and kept to air dry before treatment. The tomato fruits were coated / treated by dipping them in the powders of each plant species. The fruits were removed and arranged on wooden racks in plastic crates and kept at room temperature.

2.4 Experimental Design

4 x 3 factorial in Complete Randomized Design.

Treatment combinations = 4 x 3 = 12 treatments

Replications = 3

Total plots therefore = 3 x 12 = 36.

Each plot contained 35 fruits = 35 x 36 = 1260 fruits.

2.5 Data Collected Include

2.5.1 Weight percentage (g)

Tomato fruits were placed on a digital weighing balance and each reading was recorded throughout the storage period.

2.5.2 Total soluble solids (TSS) (° Brix)

The TSS content of the tomato fruits was determined using a hand held refractometer. A homogenous sample was prepared by blending the tomato fruits in a blender for one minute. Two drops of the sample were carefully applied on the refractometer using a plastic dropper, and the reading was obtained directly as percentage soluble solids concentration in ° brix [7].

2.5.3 Titratable acid (TA) (%)

Tomato fruits were chopped into small pieces and blended in an electric blender.10mls of the juice was filtered using a funnel with filter paper in a beaker. 5 ml of the filtrate was pipette into a conical flask then 10ml of sterile distilled water was added to make the fruit colour light to facilitate clear endpoint detection. Thereafter, two drops of phenolphthalein indicator was added. 0.1N NaOH was added dropwise and the solution shaken thoroughly until a pink colour was obtained. The acid content of the tomato sample was calculated using the formula below:

$$\% \text{ T.A.} = \frac{V \times M \times F}{\text{Volume of tomato juice}} \times 100$$

Where V = volume of 0.1N NaOH used, M = molarity of NaOH and F = factor of citric acid (0.0064).

2.5.4 Shelf life

Shelf lives of tomato fruits were evaluated by counting the number of days tomato fruits were still acceptable for marketing and consumption. It was decided based on appearance and spoilage of fruits.

2.5.5 Firmness (N/cm)

Firmness was measured as the maximum penetration force (N) reached during tissue breakage using a standard probe. The registered force at the penetration of a standard probe up to a certain depth (cm) was read as firmness. The firmness of the fruits was determined using a penetrometer [8].

2.5.6 Vitamin C/Ascorbic acid content

Ascorbic acid was determined using the method described by AOAC, [9]. Indolphenol blue solution was standardized using vitamin C by shaking 3.0ml of standard vitamin C solution (0.800 mg/ml) with 0.1% indolphenol blue solution in a graduated cylinder until the reaction mixture changed to a blue or purple colour. The final volume of the reaction mixture was recorded and used to calculate the molarity of indolphenol.

$$Molarity\ of\ indolphenol = \frac{Conc.of\ vitamin\ C\ \times Volume\ of\ vitamin\ C}{Volume\ of\ indolphenol}$$

Then exactly 3.0ml of the sample was introduced into a graduated cylinder and while shaking, indolphenol solution was added until the reaction mixture changed to a blue or purple colour. The final volume was recorded and the concentration of vitamin C in the sample was calculated and expressed in mg/ml using the formula above.

2.5.7 pH

Tomato fruits were chopped into small pieces and ground into a fine paste by an electric blender for one minute. 10mls of the tomato juice was transferred into a beaker and the pH of the paste was determined by inserting the pH meter into the paste and taking the readings [10].

2.5.8 Marketability

Marketable quality was evaluated according to the scoring method used by Mohammed et al. [11] with slight modification based on a 1 – 9 rating scale. Thus;

1 – 2.49 = unsalable
2.5 - 4.49 = saleable
4.5 - 6.49 = Good
6.5 - 8.49 = Very good
8.5 – 9.00 = Excellent

The marketable attributes were determined by observing colour, firmness, surface defects and signs of mold growth as visual parameters.

2.5.9 Beta - carotene (mg/100 g)

Tomato fruits were chopped into small pieces and ground into a fine paste by an electric blender for one minute. 10 ml of the juice was transferred into a beaker after which 10 ml of petroleum ether was added and the solution was vigorously shaken for 1 minute. The solution was filtered through Whatman filter paper and the filtrate was taken for spectrophotometric determination. Sample absorbance was measured at 451 nm and beta-carotene was calculated using the formula as given by Ibitoye [10].

ß-carotene = A451 x 19.96 [mg / 100 g]

Where: A451 - absorbance at 451 nm
19.96 - extinction coefficient

2.5.10 Lycopene (mg/100 g)

Lycopene was determined by the spectrophotometric method, which consists in its extraction using a solution of water and alcohol in a 1:1 ratio. The amount of lycopene extracted was the difference between absorbance at wavelength λ1 = 570 nm and absorbance at wavelength λ1 = 780 nm, [12]. Amount of lycopene in the sample was calculated using the formula:

$$Lycopene = \frac{A\lambda 1 - A\lambda 2}{m} \times 100\ [mg/100g]$$

2.5.11 Temperature and relative humidity

The temperature and relative humidity in the storage room were evaluated throughout the storage period using a wet and dry bulb thermometer. The thermometer was placed in the storage room and readings were recorded for both temperature and relative humidity in the mornings, afternoons and evenings.

3. RESULTS

3.1 Preservative Potential of Dried and Ground Leaves on Stored Tomato Fruits

3.1.1 Main and interaction effect of variety and botanicals on Beta – carotene content of tomato fruits during storage

Figs. 1, 2 and 3 show a general decrease from 0.07 to 0.37 in the beta – carotene content of the tomato fruits during storage. The main effect of variety and botanicals as well as the interaction effect of variety and botanicals on the beta-carotene content of the tomato fruits during storage was significant (P ≤ 0.05) on days 1, 5, 17, 21 and 25 as shown in Tables 1 and 2 while days 9 and 13 showed no significance (P ≥ 0.05) as shown in Tables 1 and 2. On day 1, variety 3 (V3) treated with bitter leaf produced the highest beta-carotene content (0.228) but this was not significantly different from that produced (0.226) when variety 2 (V2) was treated with bitter leaf. The lowest beta-carotene content (0.085) on day 1 was produced when V2 was treated with Neem as shown in Table 2. On day 5, variety 1 (V1) treated with *Moringa* gave the highest beta-carotene content (0.369) and this was significantly higher than that produced by any other treatment. Untreated V3 produced the lowest beta-carotene content (0.162) at day 5. No significant difference was observed among the interactions on days 9 and 13. On day 17, V1 treated with Neem gave the highest beta-carotene value (0.293) but this was not significantly different from that produced when V3 was treated Neem (0.263). Untreated V1 gave the lowest beta-carotene value on day 17 (0.039). On day 21, V2 treated with *Moringa* gave the highest beta-carotene content (0.278) and this was significantly higher than that produced by any other interaction. V1 gave the lowest beta-carotene value (0.041) on day 21 when it was treated with Neem. On day 25, V2 produced the highest beta-carotene content (0.251) when it was treated with bitter leaf and the difference was significantly higher than that produced by any other interaction as shown in Table 2.

On a general note, V3 produced significantly higher beta-carotene content (0.182) than V1 (0.135) and V2 (0.127) on days 1 and 17 (0.205), (0.153) and (0.124). V1 produced significantly higher beta-carotene content (0.254) than V2 (0.223) and V3 (0.214) on day 5 while V2 produced significantly higher beta-carotene value on days 21 (0.191) and 25 (0.223) as shown in Table 1. Bitter leaf generally produced significantly higher beta-carotene content than all the other botanicals evaluated on days 1 (0.209), 5 (0.259), and 25 (0.191) while Neem and *Moringa* gave significantly higher beta-carotene content than all the other botanicals on days 17 and 21 respectively as shown in Table 1.

3.1.2 Main and interaction effect of variety and botanicals on firmness of tomato fruits during storage

Figs. 4, 5 and 6 show a general decrease in the firmness of tomato fruits from 3.50 to 0.10 during the storage duration. The main effect of variety and botanicals as well as the interaction effect of variety and botanicals on the firmness of tomato fruits on days 1 and 9 was not significant (P ≥ 0.05). On days 5, 21 and 25, the main effect of variety as well as the interaction effect of variety and botanicals was not significant (P ≥ 0.05) but the main effect of botanicals was significant (P≤ 0.05). On days 13 and 17, the main effect of variety was not significant (P≥ 0.05) but the main effect of botanicals as well as the interaction effect of variety and botanicals was significant (P ≤ 0.05). The firmness of tomato as influenced by the interaction effect of variety and botanicals was erratic across the days evaluated and not significant except on days 13 and 17. On days 13 and 17, V2 treated with Neem produced the highest firmness value (2.933) and (2.700) respectively and this was significantly higher than that produced by any other treatment except when V3 was also treated with Neem (2.900) and (2.667) as shown in Table 4.

Generally, no significant difference (NS) was observed within the varieties examined across the days. However, comparism between the botanicals showed that Neem extract gave the highest firmness value on all the days evaluated but no significant difference was observed on days 1 and 9. *Moringa* produced the lowest firmness value (2.917) on day 5 while the control gave the lowest firmness value on days 13 (2.349), 17 (2.006), 21 (1.273) and 25 (0.326) as shown in Table 3.

3.1.3 Main and interaction effect of variety and botanicals on lycopene content of tomato fruits during storage

Figs. 7, 8 and 9 show a general increase from 0.002 to 0.101 in the lycopene content of tomato fruits during storage. The main effect of variety and botanicals, as well as the interaction effects of variety and botanicals on the lycopene content of tomato, was significant (P ≤ 0.05). Data presented in Table 6 showed that the highest lycopene content of tomato on day 1 was produced when V3 was treated with bitter leaf (0.040) but this was not so on days 5 and 13 where V1 treated with *Moringa* produced the highest lycopene content (0.100) and (0.105) respectively. On day 9, V2 treated with Neem gave the highest lycopene value (0.055) and this was significantly higher than that produced by any other treatment. V1 gave significantly higher lycopene content on day 17 (0.023) and the difference was significant. V2 produced the highest lycopene content on days 21 (0.091) and 25 (0.091) respectively when treated with bitter leaf and this was significantly higher than that produced by any other interaction as shown in Table 6. V3 treated with *Moringa* gave the lowest lycopene value on days 1 (0.002) and 25 (0.008) respectively. On day 9, the control of V3 produced the lowest lycopene content (0.013). On day 13, V1 treated with Neem and V3 treated with *Moringa* gave the same lycopene content (0.005) and this represented the lowest lycopene value produced on day 13. The control of V1 gave the lowest lycopene value (0.002) on day 17. V1 treated with Neem produced the lowest lycopene value (0.003) on day 21 as shown in Table 6. On a general note, V3 produced the highest lycopene content (0.018) on day 1and this was only significantly higher than that produced by V1 (0.015). On day 5, V1 gave significantly higher lycopene content (0.055) than V3 (0.036) and V2 (0.026) respectively. V2 gave significantly higher lycopene content (0.064), (0.059) than V1 (0.062), (0.031) and V3 (0.031) (0.035) on days 13 and 25. On day 17, V3 produced the highest lycopene (0.041) content and the difference was significant. The highest lycopene content among the varieties on day 21 was produced by V2 (0.055) and V3 (0.055) as shown in Table 5. Among the botanicals evaluated, bitter leaf generally gave higher lycopene value on days 1 (0.028), 13 (0.071), 21 (0.059) and 25 (0.059) respectively. *Moringa* produced significantly higher lycopene content on day 5 (0.059) while Neem gave significantly higher lycopene on days 9 (0.041) and 17 (0.052) as shown in Table 5.

3.1.4 Main and interaction effect of variety and botanicals on the marketability of tomato fruits during storage

Figs. 10, 11 and 12 show a general increase in the marketability of tomato fruits from 1.0 to 8.5 during the storage period. The main effect of variety and botanicals, as well as the interaction effect of variety and botanicals, was not significant ($P \geq 0.05$) on the marketability of tomato fruits on days 1, 5, 9, 13 and 17. The main effect of variety and botanicals was significant ($P \leq 0.05$) on the marketability of tomato on day 21 but the interaction effect of variety and botanicals was not. On day 25, the main effect of variety and the interaction effect of variety and botanicals was not significant ($P \geq 0.05$) on the marketability of tomato fruits but the main effect of botanicals was significant ($P \leq 0.05$). Though no significant difference was observed throughout the storage period, V1 treated with bitter leaf produced the highest marketability value (1.433) on day 1. On days 5, 9 and 13, the control of V3 gave the highest marketability of (2.967), (4.100) and (5.267) respectively. On day 17, V3 treated with bitter leaf gave the highest marketability value (7.430) while V3 treated with Neem produced the highest marketability on day 21 (8.467) as shown in Table 8. V3 generally gave higher marketability value on day 21 (7.525) but this was only significantly higher than that produced by V1 (7.008). No significant difference was observed among the varieties on the other days. No significant difference was also observed among the botanicals on days 1, 5, 9, 13 and 17 but on days 21 and 25, Neem gave the highest marketability value (8.322) and (6.422) respectively as shown in Table 7.

3.1.5 Main and interaction effect of variety and botanicals on pH of tomato fruits during storage

The main effect of variety as well as the interaction effect of variety and botanicals was not significant ($P \geq 0.05$) on the pH of tomato fruits on days 1, 5, 13, 17, 21 and 25 but the main effect of botanicals was significant ($P \leq 0.05$). Figs. 13, 14 and 15 show a general decrease in the pH of the tomato fruits from 6.93 to 3.65 during storage. On day 9, the main effect of variety and botanicals as well as the interaction effect of variety and botanicals was not significant ($P \geq 0.05$). On all the days evaluated, no significant difference was observed within the interactions as shown in Table 10. Similarly, no significant difference was observed within the varieties as shown in Table 9. pH decreased steadily from days 1 to 25. For the botanicals, on days 1 and 13, the control generally gave the highest pH value (6.798) and (5.356) but this was only significantly higher than that produced by Neem. A dissimilar trend was observed on day 5 where bitter leaf gave the highest pH value (6.461) but this was also only significantly higher than that produced by Neem (6.041). Bitter leaf gave the highest pH value among the botanicals on day 1 (6.768) followed by *Moringa* (6.614) and Neem (6.387) as shown in Table 9.

3.1.6 Main and interaction effect of variety and botanicals on Shelf life of tomato fruits during storage

The main effect of variety and botanicals as well as the interaction effect of variety and botanicals on the shelf life of tomato on days 1, 5, 9, 13, 17, 21 and 25 was not significant at ($P \geq 0.05$). The shelf life of treated tomato fruits increased from days 1 to 25 while the controls increased from days 1 to 21, but no significant differences were observed between the treatments and the controls as shown in Tables 11 and 12.

3.1.7 Main and interaction effect of variety and botanicals on Total Soluble Solids (TSS) of tomato fruits during storage

Figs. 16, 17 and 18 show a general decrease in TSS of tomato fruits from 5.00 to 4.02. The main effect of variety and botanicals as well as the interaction effect of variety and botanicals on the TSS of tomato on days 1 and 5 was not significant ($P \geq 0.05$). On days 9, 13 and 17, the main effect of variety as well as the interaction effect of variety and botanicals was not significant ($P \geq 0.05$) on the total soluble solids of tomato fruits but the main effect of botanicals was significant ($P \leq 0.05$). On day 21, the main effect of variety was not significant on the total soluble solids of tomato fruits but the main effect of botanicals as well as the interaction effect of variety and botanicals were significant ($P \leq 0.05$). On day 25, the main effect of variety and botanicals was significant on the total soluble solids of tomato fruits as well as the interaction effect of variety and botanicals as shown in Tables 13 and 14. V1 produced the highest total soluble solids on days 21 (4.767) and 25 (4.650) when it was treated with Neem and the difference was significantly higher than that produced by any other interaction. No significant difference was observed among the interactions on the other days as shown in Table 14. Similarly, no significant difference was observed among the varieties with respect to TSS on days 1, 5, 9, 13, 17 and 21 except on day 25 where V1 gave significantly higher TSS (4.223) than all the other varieties. Neem gave the highest TSS values on days 5 (4.856), 9 (4.856), 13 (4.833), 17 (4.811), 21 (4.689) and 25 (4.510) respectively among the botanicals while the least TSS values was given by the control on days 9 (4.557), 13 (4.404), 17 (4.214), 21 (4.108) and 25 (3.984) as shown in Table 13.

3.1.8 Main and interaction effect of variety and botanicals on the Titratable acidity (TA) of tomato fruits during storage

The main effect of variety was not significant ($P \geq 0.05$) on the titratable acidity of tomato fruits on day 1 but the main effect of botanicals as well as the interaction effect of variety and botanicals was significant ($P \leq 0.05$) on the titratable acidity on day 1. Figs. 19, 20 and 21 show an increase from 0.303 to 0.834 then a decrease in the TA content of tomato fruits during storage. On day 5, the main effect of variety was significant ($P \leq 0.05$) on the titratable acidity of the tomato fruits but the main effect of botanicals as well as the interaction effect of variety and botanicals was not. On days 9, 13, 17 and 21, the main effect of variety and botanicals as well as the interaction effect of variety and botanicals was significant ($P \leq 0.05$) on the titratable acidity of the tomato fruits. On day 25, the main effect of variety was not significant ($P \geq 0.05$) but the main effect of botanicals as well as the interaction effect of variety and botanicals was significant ($P \leq 0.05$) as shown in Tables 15 and 16. On day 1, V1 treated with bitter leaf gave the highest titratable acidity (0.560) but this was not significantly different from that produced by the control of V3 (0.553). The lowest titratable acidity on day 1 was produced by the control of V1 (0.411). On day 9, the highest titratable acidity (0.673) was produced when V3 was treated with *Moringa* but this was not so on day 13 where V1 treated with Neem gave the highest titratable acidity (0.791). V1 produced the lowest titratable acidity (0.410) on day 9 when it was treated with bitter leaf while the control of V1 produced the lowest titratable acidity (0.367) on day 13. On day 17, V3 gave the highest titratable acidity (0.791) when it was treated with *Moringa* but the control of V3 was observed to produce the lowest titratable acidity (0.452) on day 17. V1 produced the highest titratable acidity (0.682) on day 21 when it was treated with Neem but this was not significantly different from that produced when V1 was treated with *Moringa* (0.648) but significantly higher than that produced by any other interaction. The control of V1 gave the lowest titratable acidity (0.314) on day 21. On day 25, V1 treated with Neem gave the highest titratable acidity value (0.645) and the difference was significant as shown in Table 16. Generally speaking, V3 gave higher titratable acidity (0.549) than V2 (0.475) and V1 (0.485) on day 5, 9 (0.587), (0.487), (0.485) and 17 (0.612), (0.526), (0.579) respectively and the differences were significant. V1 produced the highest titratable acidity on days 13 (0.627) and 21 (0.561). Among the botanicals evaluated, bitter leaf gave the highest titratable acidity on days 1 (0.508) and 13 (0.679) respectively. *Moringa* produced the highest titratable acidity value on days 9 (0.548), 17 (0.622), and 21 (0.612) respectively while Neem gave the highest titratable acidity value on day 25 (0.557). The control gave the lowest titratable acidity on days 5 (0.487), 17 (0.486), 21 (0.392) and 25 (0.310). Bitter leaf gave the lowest titratable acidity on day 9 (0.474) while *Moringa* produced the lowest titratable acidity on day 1 (0.461) as shown in Table 15.

3.1.9 Main and interaction effect of variety and botanicals on Vitamin C /Ascorbic content of tomato fruits during storage

The main effect of variety and botanicals as well as the interaction effect of variety and botanicals on the Vitamin C content of tomato fruits were significant ($P \leq 0.05$) on all the days under observation. Figs. 22, 23 and 24 show an increase in Vitamin C content from 1.04 to 16.200 and then a decrease towards the end of storage. On day 1, V1 treated with *Moringa* gave the highest Vitamin C content (10.960) and this was significantly higher than that produced by any other interaction except when V1 was treated with Neem (10.460) and bitter leaf (9.540) respectively. On day 5, V2 treated with Neem produced the highest Vitamin C content (12.200) and the difference was significantly higher than that produced by any other treatment. On day 9, V1 treated with *Moringa* gave significantly higher Vitamin C content (15.723). V1 treated with Neem gave the highest Vitamin C content on day 13 (11.600) but this was not significantly different from that (10.950) and (10.400) produced when V2 and V3 were treated with Neem and that produced by the control of V2 (9.860). V2 treated with bitter leaf gave significantly higher Vitamin C content (11.435) on day 17 and the difference was significant. On day 21, V3 gave the highest Vitamin C content (9.908) when it was treated with *Moringa* but this was statistically not different with that (9.794) produced when V1 was treated with bitter leaf. On day 25, V1 gave significantly higher Vitamin C content (7.891) when it was treated with bitter leaf as shown in Table 18. The control of V3 gave the lowest Vitamin C content on day 1 (3.300). On day 5, V3 treated with bitter leaf produced the lowest Vitamin C content (2.921). The control of V2 produced the lowest Vitamin C content on day 9 (8.718). V3 treated with *Moringa* gave the lowest Vitamin C content (3.540) on day 13. The control of V1 produced the lowest Vitamin C content on day 17 (5.224) while V1 treated with *Moringa* gave the lowest Vitamin C content on day 21 (2.607) and 25 (1.818) as shown in Table 18. V1 generally gave higher Vitamin C content than V2 and V3 on days 1 (9.480) (5.330), (6.880), 5 (9.189), (8.584), (5.061) and 9 (12.775), (10.620), (10.499) respectively. V2 produced higher Vitamin C content than V1 and V3 on days 13 (9.260), (8.800), (6.220) and 17 (8.840) (7.266), (6.385) respectively while V3 gave higher Vitamin Content than V1 and V2 on days 21 (6.714), (5.711), (5.727) and 25 (5.155), (4.587), (4.192) respectively as shown in Table 17. Neem gave the highest Vitamin C content among the botanicals evaluated on days 1 (9.400), 5 (10.126), 13 (10.980), 21 (6.996) and 25 (6.029). *Moringa* gave the highest Vitamin C content on day 9 (13.097) while bitter leaf produced the highest Vitamin C content on day 17 (9.222) as shown in Table 17.

3.1.10 Main and interaction effect of variety and botanicals on Weight of tomato fruits during storage

Figs. 25, 26 and 27 show a general decrease in weight of the tomato fruits from 40.9 to 10.3 during storage. The main effect of variety and botanicals, as well as the interaction effect of variety and botanicals on the weight of tomato fruits during storage, were significant ($P \leq 0.05$) on days 1, 5 and 9. On days 13 and 17, the main effects of variety, as well as the interaction effect of variety and botanicals, were significant ($P \leq 0.05$) but the main effect of botanicals was not. On days 21 and 25, the main effect of variety and botanicals were not significant ($P \geq 0.05$) but the interaction effect of variety and botanicals were significant ($P \leq 0.05$). On all the days evaluated, V3 produced the highest fruit weight when it was treated with Neem. V2 consistently gave the lowest fruit weight in all the days when it was treated with Neem as shown in Table 20. V3 produced significantly higher fruit weight than all the other varieties on days 1 (37.150), 5 (35.440), 9 (33.620) and 13 (31.470). On day 17, V3 also produced the highest fruit weight (29.570) but this was not significantly different from that produced by V1 (26.600). Bitter leaf gave the highest fruit weight among the botanicals evaluated on days 1 (37.210), 5 (35.400) and 9 (33.580). Neem showed the lowest fruit weight among the botanicals on all the days evaluated as shown in Tables 19 and 20.

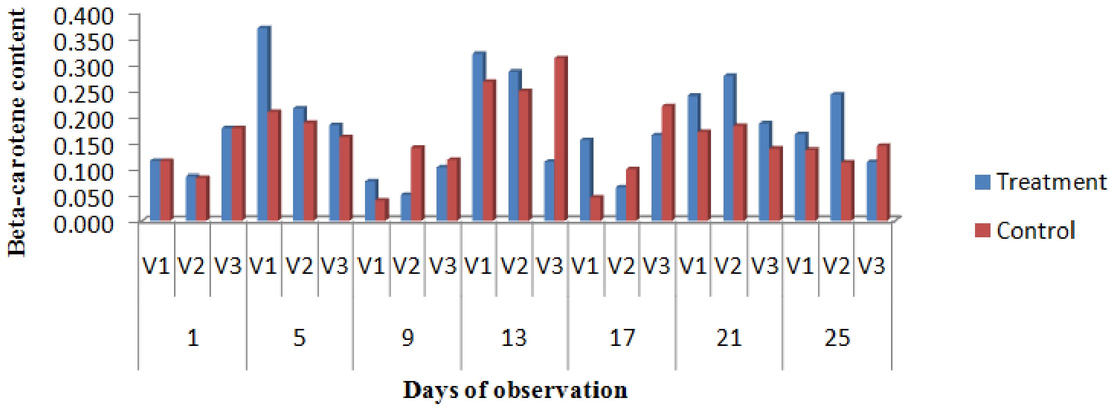

Fig. 1. Effect of *Moringa* leaf powder on Beta-carotene content of tomato fruits during storage

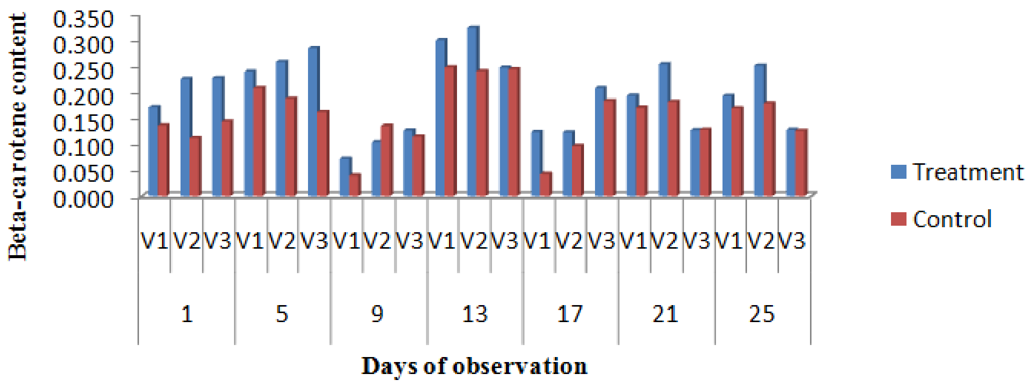

Fig. 2. Effect of Neem leaf powder on Beta-carotene content of tomato fruits during storage

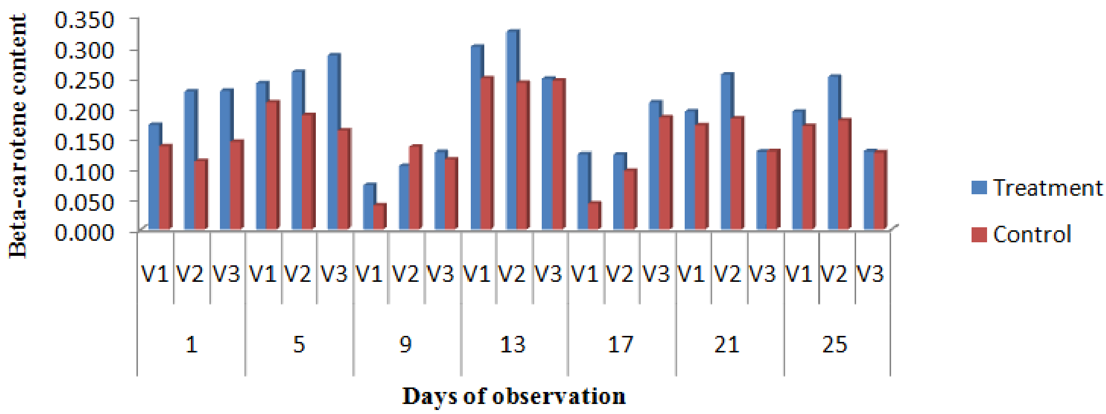

Fig. 3. Effect of bitter leaf powder on Beta – carotene content of tomato fruits during storage

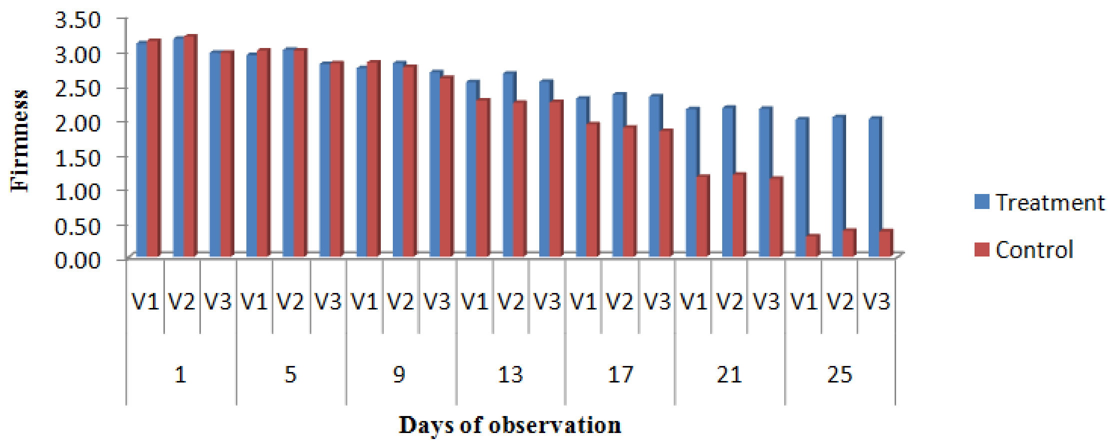

Fig. 4. Effect of *Moringa* leaf powder on Firmness of tomato fruits during storage

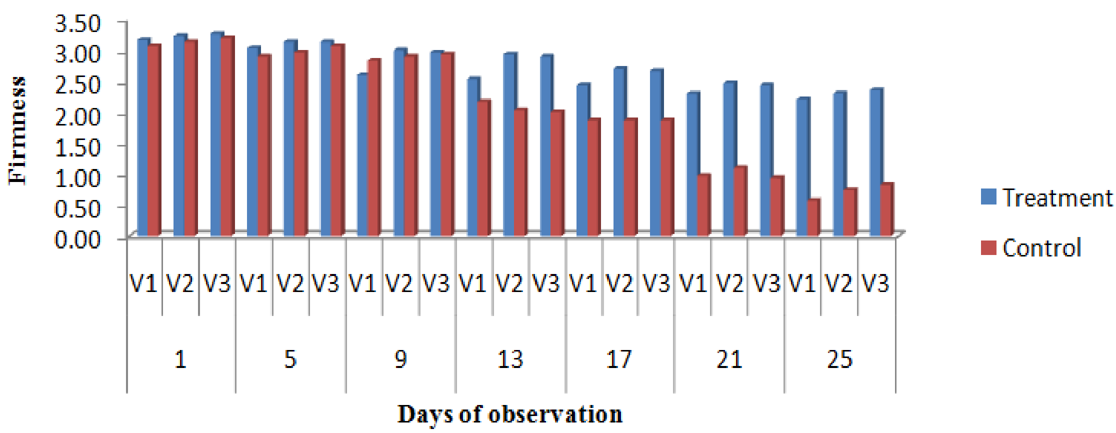

Fig. 5. Effect of Neem leaf powder on Firmness of tomato fruits during storage

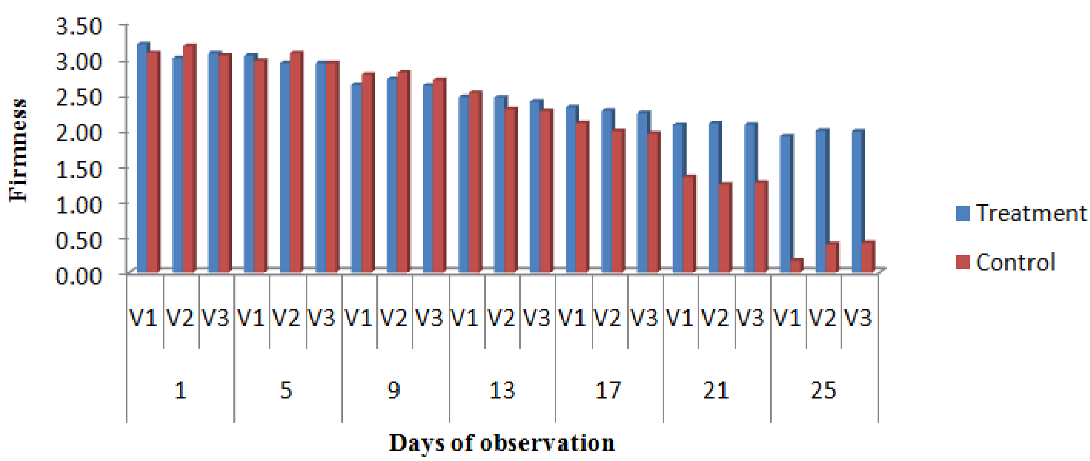

Fig. 6. Effect of bitter leaf powder on Firmness of tomato fruits during storage

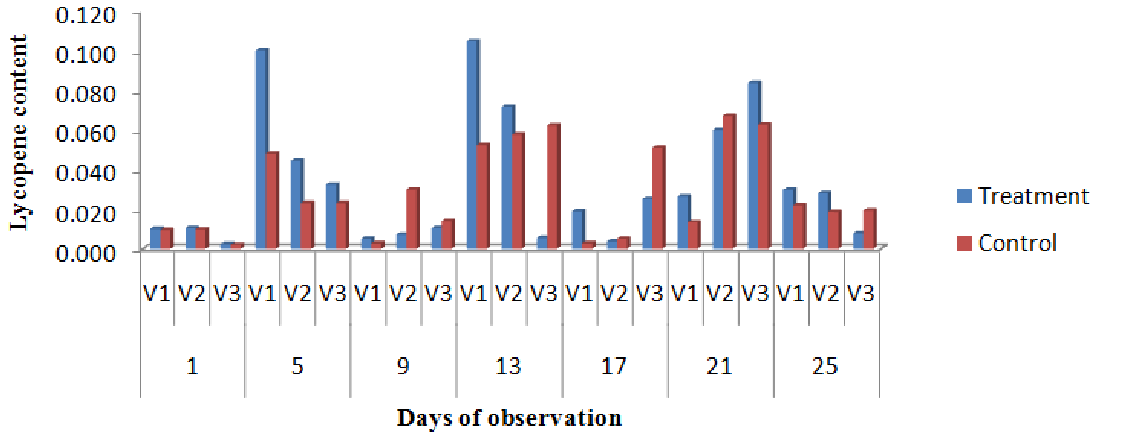

Fig. 7. Effect of *Moringa* leaf powder on the Lycopene content of tomato fruits during storage

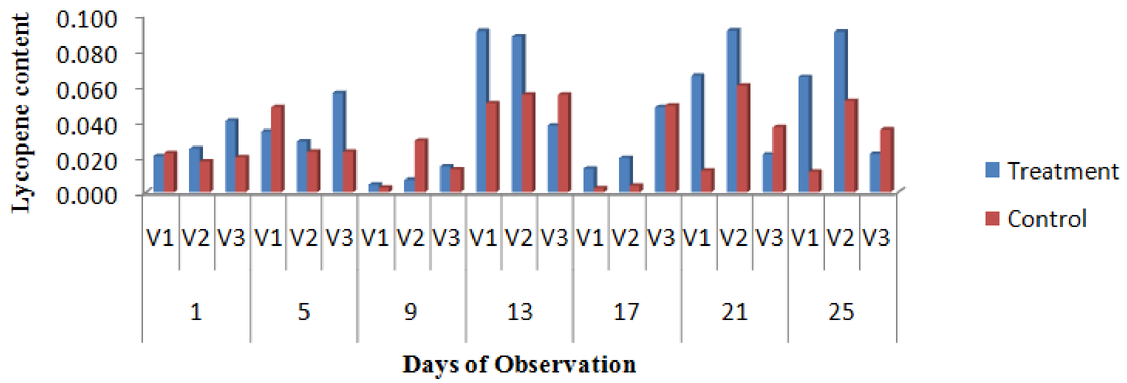

Fig. 8. Effect of Neem leaf powder on the Lycopene content of tomato fruits during storage

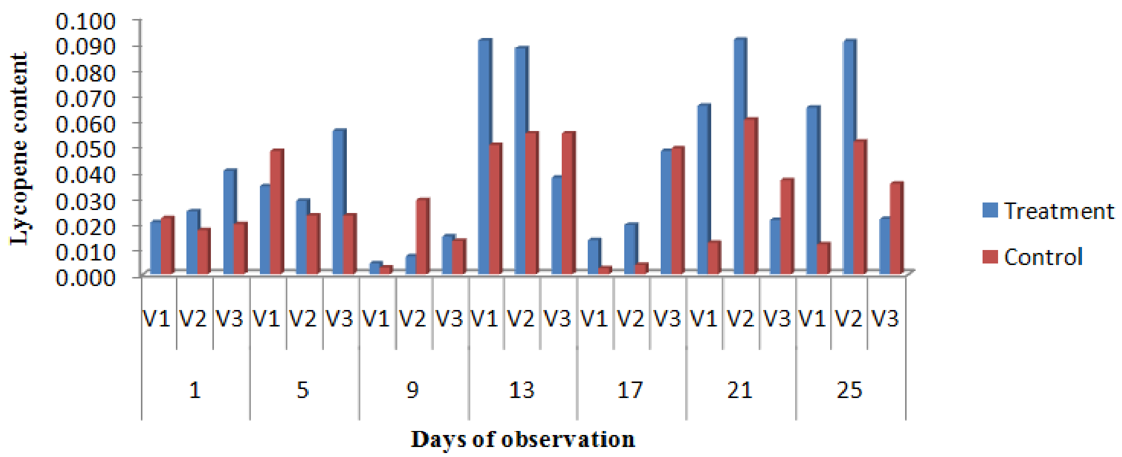

Fig. 9. Effect of bitter leaf powder on the Lycopene content of tomato fruits during storage

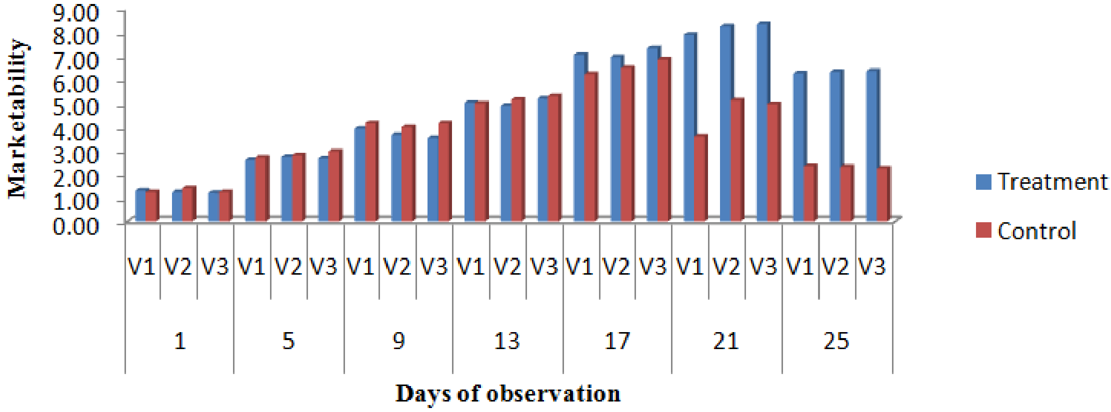

Fig. 10. Effect of *Moringa* leaf powder on Marketability of tomato fruits during storage

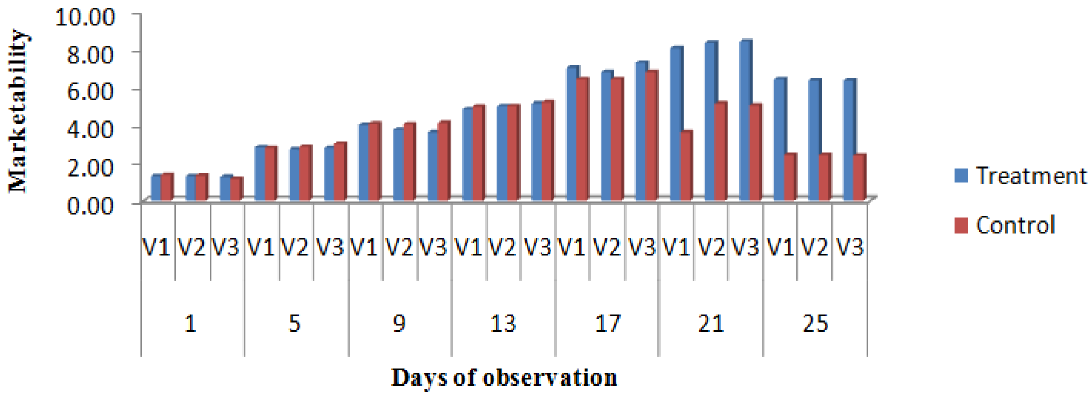

Fig. 11. Effect of Neem leaf powder on Marketability of tomato fruits during storage

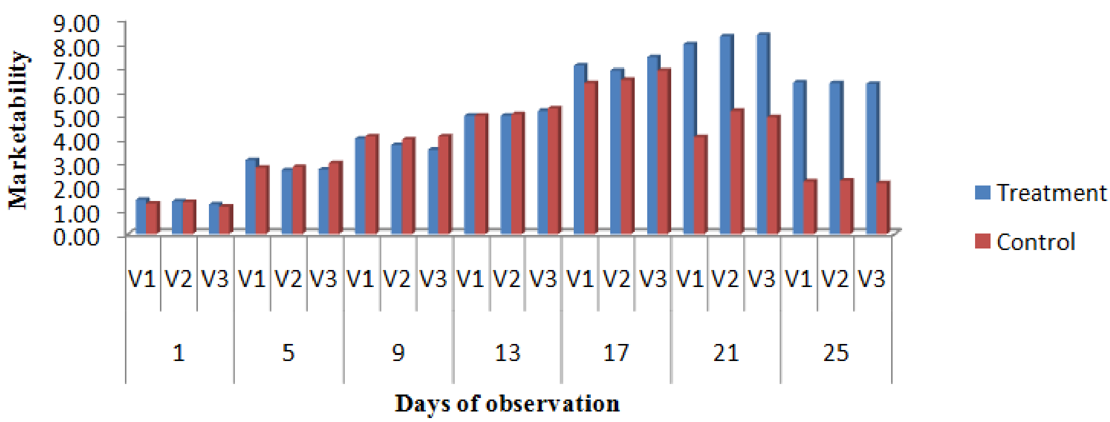

Fig. 12. Effect of bitter leaf powder on Marketability of tomato fruits during storage

3.1.11 Temperature and Relative humidity of room during storage

The temperature of the storage room ranged from 23.0 to 27.5 in the mornings, 32.0 to 36.0 in the afternoons and 27.1 to 29.0 in the evenings as shown in Fig. 28. Relative humidity ranged from 62% to 93% in the mornings, 45% to73% in the afternoons and 77% to 92% in the evenings as shown in Fig. 29.

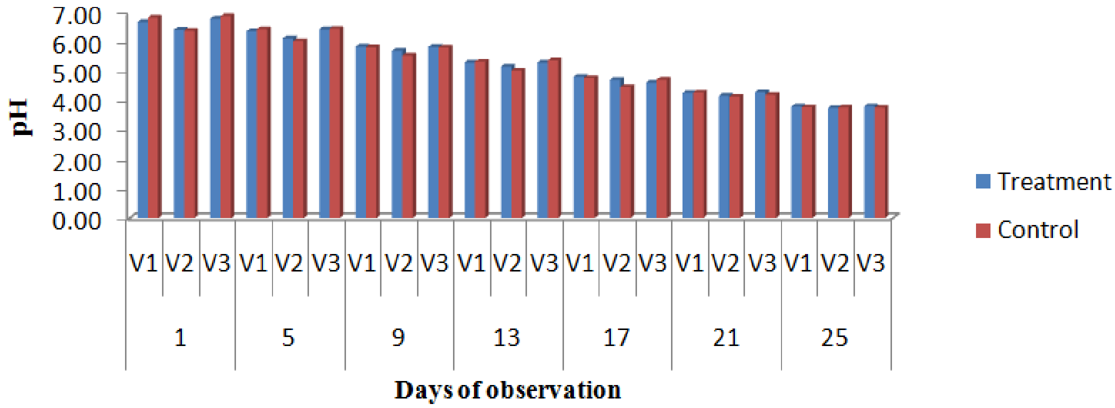

Fig. 13. Effect of *Moringa* leaf powder on pH of tomato fruits during storage

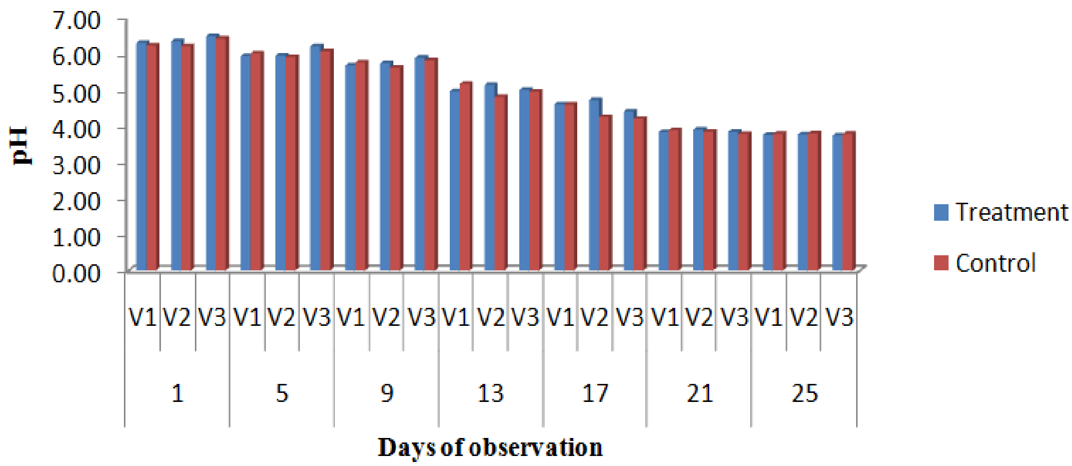

Fig. 14. Effect of Neem leaf powder on pH of tomato fruits during storage

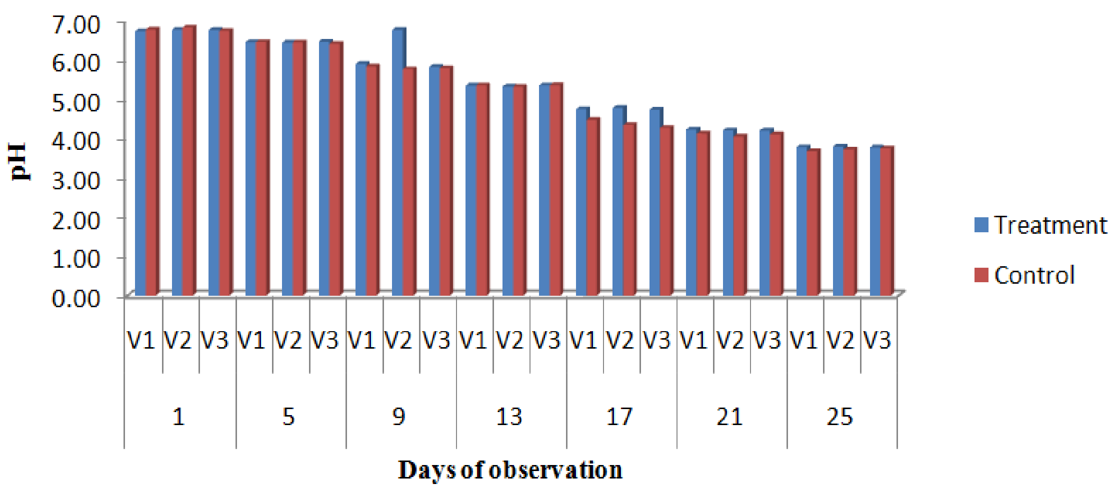

Fig. 15. Effect of bitter leaf powder on pH of tomato fruits during storage

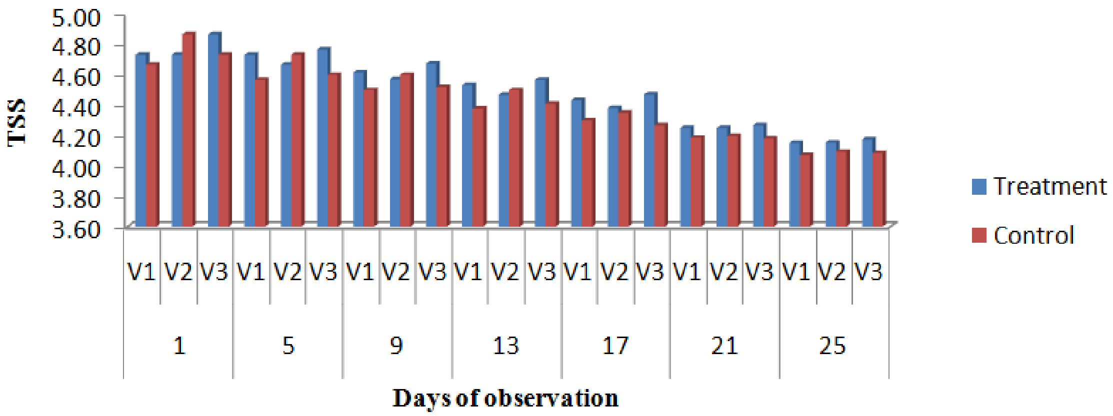

Fig. 16. Effect of *Moringa* leaf powder on Total Soluble Solids of tomato fruits during storage

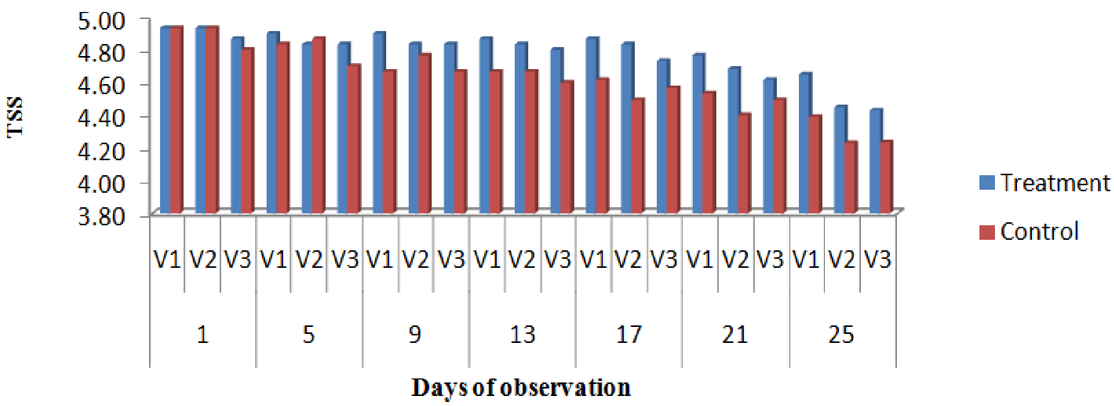

Fig. 17. Effect of Neem leaf powder on Total Soluble Solids of tomato fruits during storage

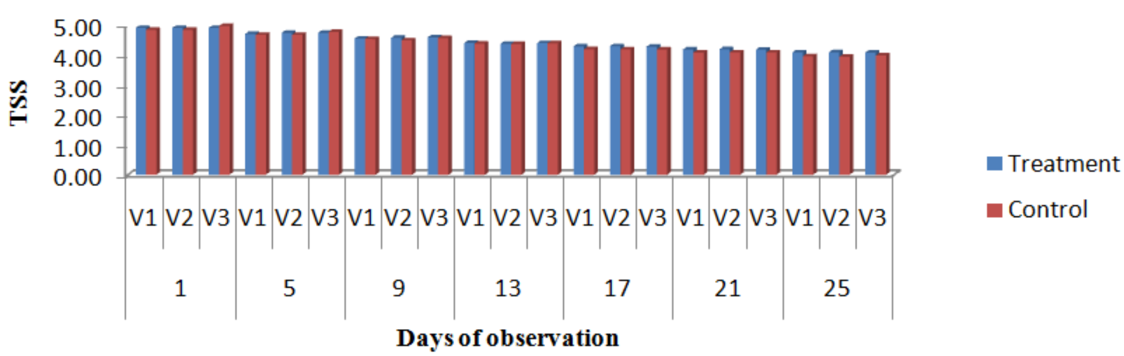

Fig. 18. Effect of bitter leaf powder on Total Soluble Solids of tomato fruits during storage

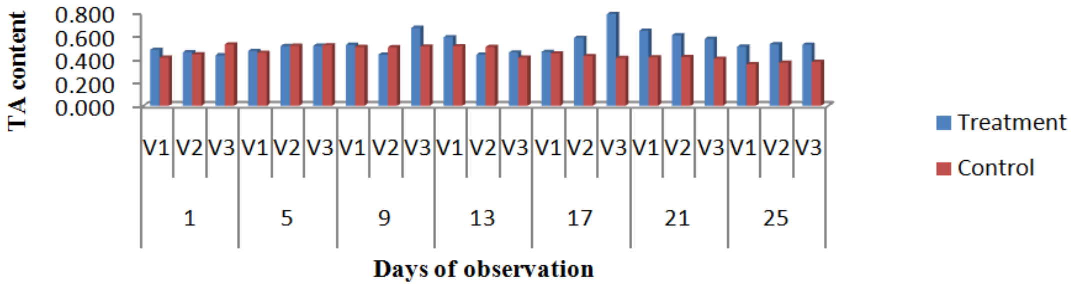

Fig. 19. Effect of *Moringa* leaf powder on Titratable Acidity of tomato fruits during storage

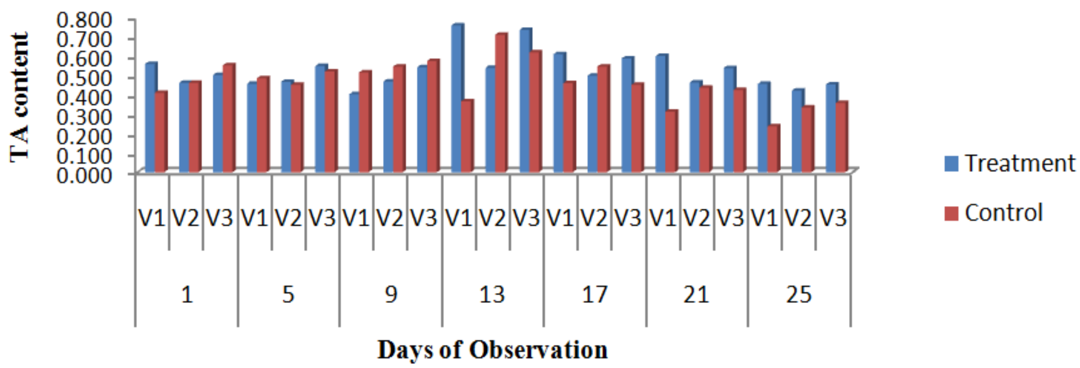

Fig. 20. Effect of Neem leaf powder on Titratable Acidity of tomato fruits during storage

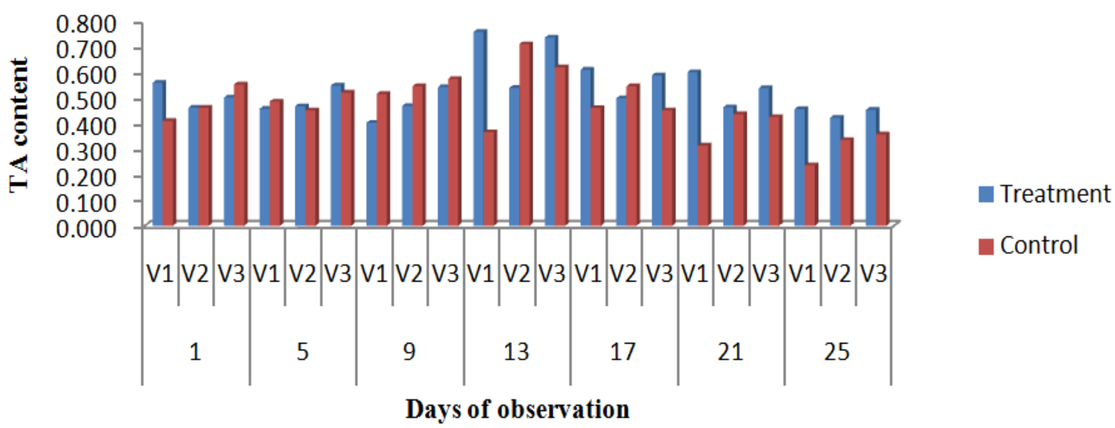

Fig. 21. Effect of bitter leaf powder on Titratable Acidity of tomato fruits during storage

4. DISCUSSION

The effect of plant leaf powders/films/coatings on tomato fruits during storage was evaluated. This consists of the application of a layer of an edible material on the surface of the fruit. Coating agents are usually used to extend the shelf life and quality of fruits during their storage and actions of these agents deal with the decrease of moisture and the improvement of the general appearance and quality of the products during storage as reported by Olivas and Barbosa-Canoras, [13].

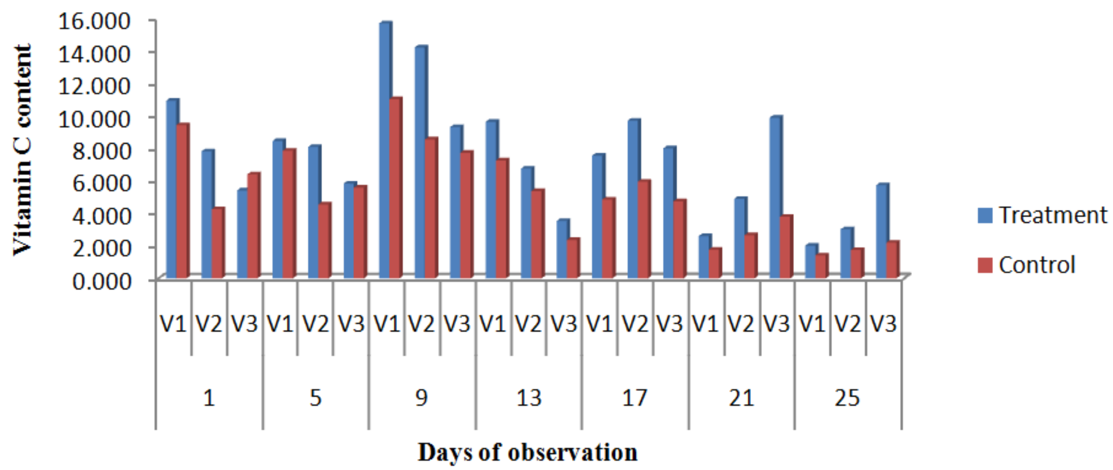

Fig. 22. Effect of *Moringa* leaf powder on Vitamin C content of tomato fruits during storage

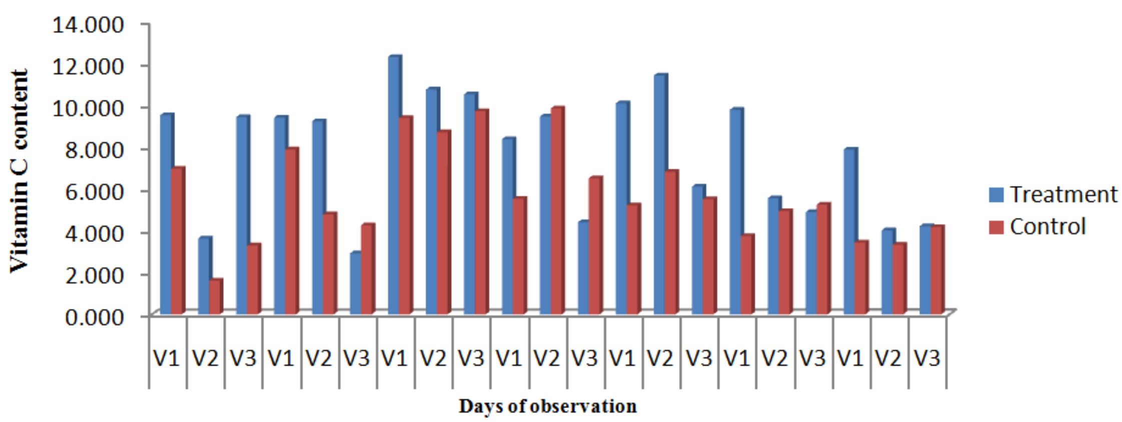

Fig. 23. Effect of Neem leaf powder on Vitamin C content of tomato fruits during storage

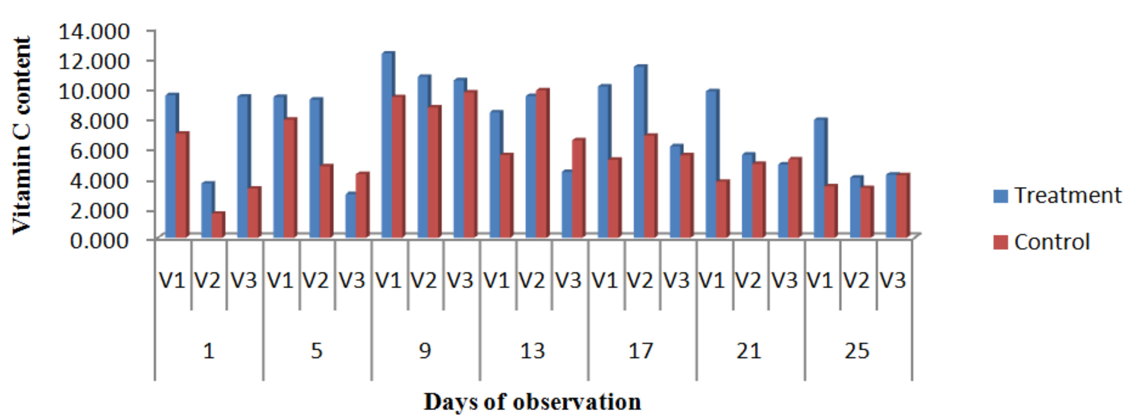

Fig. 24. Effect of bitter leaf powder on Vitamin C content of tomato fruits during storage

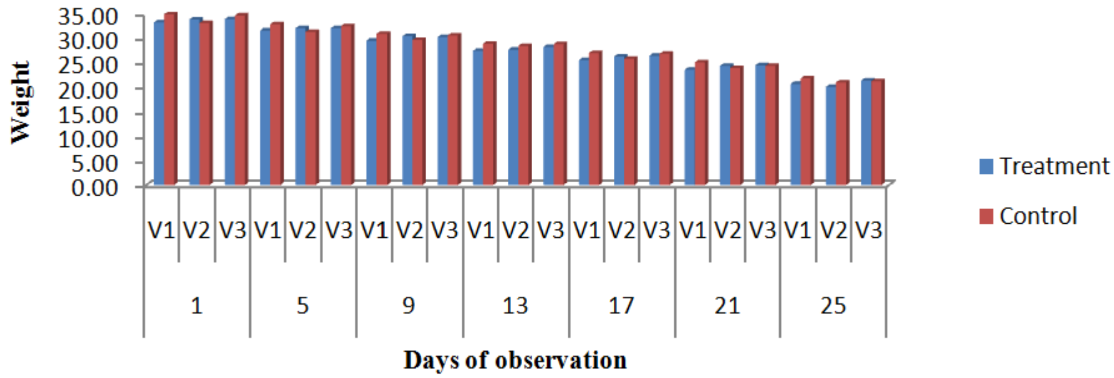

Fig. 25. Effect of Moringa leaf powder on Weight of tomato fruits during storage

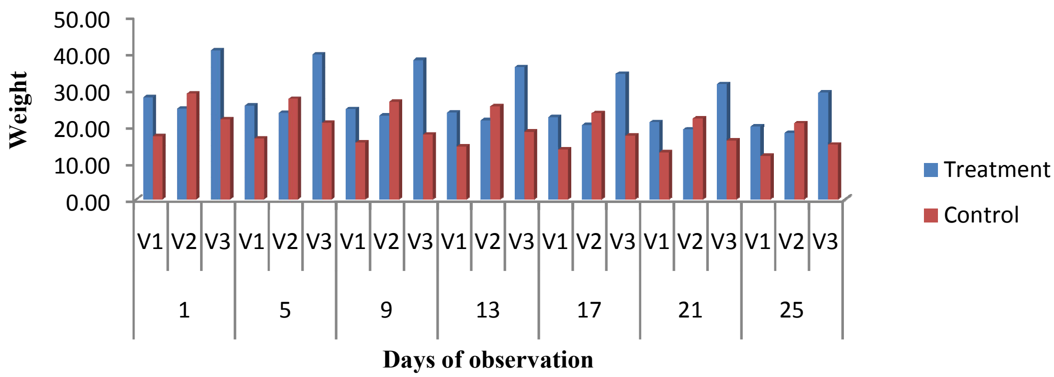

Fig. 26. Effect of Neem leaf powder on Weight of tomato fruits during storage

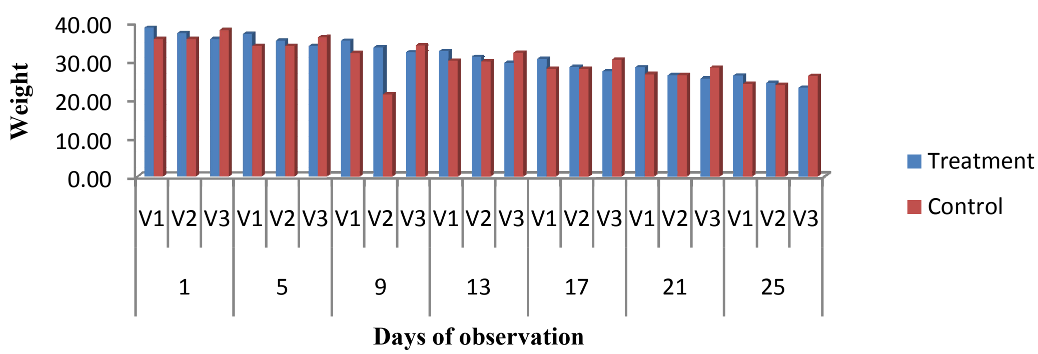

Fig. 27. Effect of bitter leaf powder on Weight tomato fruits during storage

During this study, the green colour of the tomato fruit decreased with the accumulation of a yellowish red colour during the storage period. The yellowish colour could be due to the presence of carotenoids. Carotenoids are naturally occurring coloured compounds that are present as pigments in plants, responsible for the pleasing yellow, orange, red colour of fruits and vegetables [14]. It was also observed that degradation of chlorophyll was higher when the storage room was between 30°C and 35°C. In other words, faster colour change took place when there was a rise in temperature. This implies that the rate of ripening processes which is associated with increasing carotenoid content in tomato fruits was slowed down at lower temperatures. This effect has also been observed by Aljouni et al. [15]. One of the most noticeable characteristics of ripening is the dramatic increase in the carotenoid content of the fruit. The change in pigmentation is due to the massive accumulation of lycopene within the plastids and the disappearance of chlorophyll. The chloroplasts of matured green fruit change into chromoplasts, which contains lycopene in membrane, bound crystals. Based on the present results, it seemed that temperature also had a large effect on degradation of chlorophyll as well as carotenoid development. It has been reported that the formation of lycopene depends on the temperature range [16]. As fruit develops from immature green to ripe, the progressive increase in carotenoid content is directly proportional to the increase in all-trans-lycopene concentration within the plastids whose synthesis is favoured at a temperature above 30°C [17]. In this study, the accumulation rate of the beta-carotene content in the control fruits was lower compared to the leaf powder or film treated fruits, this is contrary to the report of Tigist and Wosene [18] who stated higher carotene content in control fruits with treated fruits having lower carotene content. The difference in opinions may be due to the fact that carotenoid composition of fruits and vegetables vary significantly among other factors, by types as well as a variety of a given crop [19]. Their levels are affected by factors such as climatic conditions, part of the plant utilized (Peels, seeds, fleshy portion) storage and the presence of other carotenoids [20].

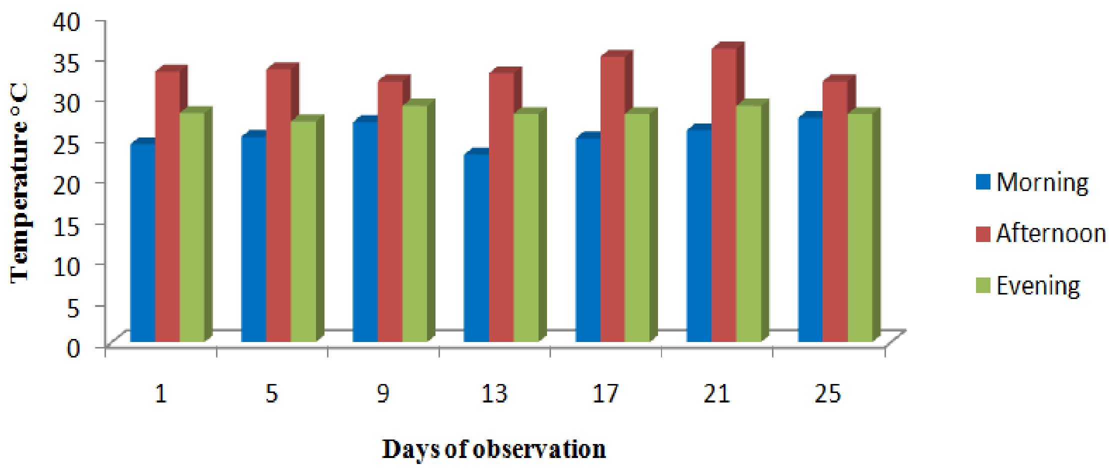

Fig. 28. Temperature range of store during storage of tomato fruits

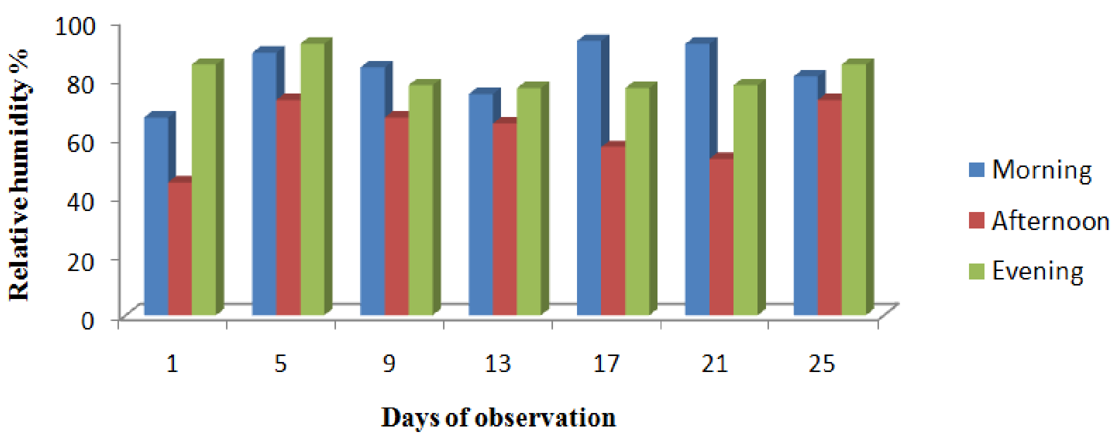

Fig. 29. Relative humidity of the store during storage of tomato fruits

Table 1. Main effect of variety and botanicals on Beta-carotene content of tomato fruits during storage

Variety	1	5	9	13	17	21	25	(DAYS)
V1	0.135	0.254	0.119	0235	0.153	0.161	0.171	
V2	0.127	0.223	0.127	0.410	0.124	0.191	0.223	
V3	0.182	0.214	0.252	0.194	0.205	0.172	0.137	
F-LSD (0.05)	**0.011**	**0.001**	**NS**	**NS**	**0.018**	**0.001**	**0.001**	
Botanicals								
Moringa	0.126	0.256	0.076	0.240	0.128	0.235	0.174	
Neem	0.126	0.221	0.389	0.344	0.266	0.112	0.183	
Bitter Leaf	0.209	0.259	0.101	0.291	0.152	0.192	0.191	
Control	0.131	0.186	0.097	0.244	0.096	0.160	0.159	
F-LSD (0.05)	**0.012**	**0.001**	**NS**	**NS**	**0.021**	**0.001**	**0.001**	

NS – No significant difference

Table 2. Interaction effect of variety and botanicals on Beta-carotene content of tomato fruits during storage

Variety	Botanicals	1	5	9	13	17	21	25	(DAYS)
V1	*Moringa*	0.115	0.369	0.076	0.320	0.155	0.240	0.167	
	Neem	0.115	0.199	0.286	0.073	0.293	0.041	0.149	
	Bitter Leaf	0.172	0.240	0.073	0.300	0.124	0.194	0.193	
	Control	0.136	0.209	0.004	0.248	0.039	0.171	0.171	
V2	*Moringa*	0.086	0.216	0.50	0.286	0.065	0.278	0.242	
	Neem	0.085	0.229	0.218	0.789	0.240	0.049	0.220	
	Bitter Leaf	0.226	0.259	0.104	0.325	0.123	0.254	0.251	
	Control	0.112	0.188	0.135	0.241	0.066	0.182	0.180	
V3	*Moringa*	0.178	0.184	0.103	0.113	0.164	0.187	0.113	
	Neem	0.179	0.231	0.663	0.169	0.263	0.246	0.181	
	Bitter Leaf	0.228	0.279	0.127	0.248	0.209	0.128	0.128	
	Control	0.144	0.162	0.115	0.244	0.184	0.128	0.126	
F-LSD (0.05)		**0.021**	**0.001**	**NS**	**NS**	**0.031**	**0.001**	**0.002**	

NS – No significant difference

Table 3. Main effect of variety and botanicals on Firmness of tomato fruits in storage

Variety	1	5	9	13	17	21	25	(DAYS)
V1	3.133	2.992	2.677	2.509	2.283	1.991	1.571	
V2	3.142	3.037	2.834	2.583	2.327	1.982	1.679	
V3	3.083	2.951	2.702	2.524	2.293	1.978	1.689	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	
Botanicals								
Moringa	3.078	2.917	2.744	2.583	2.331	2.187	2.014	
Neem	3.222	3.100	2.811	2.789	2.600	2.400	2.290	
Bitter Leaf	3.088	2.967	2.651	2.433	2.268	2.074	1.956	
Control	3.091	2.989	2.744	2.349	2.006	1.273	0.326	
F-LSD (0.05)	**NS**	**0.126**	**NS**	**0.097**	**0.075**	**0.137**	**0.136**	

NS – No significant difference

Table 4. Interaction effect of variety and botanicals on Firmness of tomato fruits during storage

Variety	Botanicals	1	5	9	13	17	21	25	(DAYS)
V1	*Moringa*	3.100	2.933	2.740	2.543	2.300	2.260	2.000	
	Neem	3.167	3.033	2.600	2.533	2.433	2.300	2.207	
	Bitter leaf	3.197	3.033	2.627	2.457	2.310	2.067	1.910	
	Control	3.070	2.967	2.740	2.503	2.090	1.337	0.167	
V2	*Moringa*	3.167	3.013	2.813	2.660	2.360	2.150	2.033	
	Neem	3.233	3.133	3.000	2.933	2.700	2.467	2.303	
	Bitter leaf	3.000	2.933	2.710	2.450	2.263	2.087	1.983	
	Control	3.170	3.067	2.813	2.287	1.983	1.227	0.397	
V3	*Moringa*	2.967	2.803	2.680	2.547	2.333	2.150	2.010	
	Neem	3.267	3.133	2.833	2.900	2.667	2.433	2.360	
	Bitter Leaf	3.067	2.933	2.617	2.393	2.230	2.070	1.973	
	Control	3.033	2.933	2.680	2.257	1.943	1.257	0.413	
F-LSD (0.05)		**NS**	**NS**	**NS**	**0.169**	**0.131**	**NS**	**NS**	

NS – No significant difference

Table 5. Main effect of variety and botanicals on Lycopene content of tomato fruits during storage

Variety	1	5	9	13	17	21	25	(DAYS)
V1	0.015	0.055	0.012	0.062	0.023	0.027	0.031	
V2	0.016	0.026	0.024	0.064	0.021	0.055	0.059	
V3	0.018	0.036	0.017	0.031	0.041	0.055	0.035	
F-LSD (0.05)	**0.002**	**0.004**	**0.004**	**0.002**	**0.005**	**0.002**	**0.001**	
Botanicals								
Moringa	0.008	0.059	0.007	0.061	0.016	0.056	0.022	
Neem	0.011	0.025	0.041	0.024	0.052	0.031	0.050	
Bitter Leaf	0.028	0.041	0.009	0.071	0.027	0.059	0.059	
Control	0.021	0.031	0.015	0.053	0.019	0.036	0.033	
F-LSD (0.05)	**0.002**	**0.004**	**0.005**	**0.002**	**0.001**	**0.002**	**0.001**	

Table 6. Interaction effect of variety and botanicals on Lycopene content of tomato fruits during storage

Variety	Botanicals	1	5	9	13	17	21	25	(DAYS)
V1	*Moringa*	0.010	0.100	0.005	0.105	0.019	0.026	0.031	
	Neem	0.009	0.037	0.036	0.005	0.058	0.003	0.012	
	Bitter Leaf	0.020	0.034	0.004	0.088	0.013	0.066	0.065	
	Control	0.022	0.048	0.003	0.050	0.002	0.012	0.012	
V2	*Moringa*	0.010	0.044	0.007	0.072	0.004	0.060	0.028	
	Neem	0.011	0.008	0.055	0.041	0.056	0.007	0.064	
	Bitter Leaf	0.025	0.029	0.007	0.088	0.019	0.091	0.091	
	Control	0.017	0.023	0.029	0.055	0.004	0.060	0.052	
V3	*Moringa*	0.002	0.032	0.010	0.005	0.025	0.080	0.008	
	Neem	0.010	0.032	0.031	0.027	0.041	0.081	0.074	
	Bitter leaf	0.040	0.056	0.015	0.038	0.048	0.021	0.022	
	Control	0.021	0.023	0.013	0.055	0.049	0.037	0.035	
F-LSD (0.05)		**0.003**	**0.001**	**0.001**	**0.004**	**0.001**	**0.003**	**0.002**	

Table 7. Main effect of variety and botanicals on Marketability of tomato fruits during storage

Variety	1	5	9	13	17	21	25	(DAYS)
V1	1.325	2.742	4.017	4.958	6.880	7.008	5.325	
V2	1.308	2.733	3.783	4.983	6.780	7.517	5.325	
V3	1.208	2.783	3.700	5.200	7.240	7.525	5.300	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**0.270**	**NS**	
Botanicals								
Moringa	1.244	2.667	3.711	5.044	7.120	8.178	6.322	
Neem	1.289	2.789	3.811	5.022	7.080	8.322	6.422	
Bitter Leaf	1.344	2.711	3.756	5.033	7.120	8.211	6.333	
Control	1.244	2.844	4.056	5.089	6.560	4.689	2.189	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**0312**	**0.081**	

NS – No significant difference

Table 8. Interaction effect of variety and botanicals on Marketability of tomato fruits during storage

Variety	Botanicals	1	5	9	13	17	21	25	(DAYS)
V1	*Moringa*	1.300	2.600	3.933	5.033	7.070	7.900	6.267	
	Neem	1.300	2.833	4.033	4.867	7.070	8.100	6.467	
	Bitter Leaf	1.433	2.767	4.000	4.967	7.070	7.967	6.367	
	Control	1.267	2.767	4.100	4.967	6.330	4.067	2.200	
V2	*Moringa*	1.233	2.733	3.667	4.900	6.970	8.267	6.333	
	Neem	1.300	2.733	3.767	5.033	6.830	8.400	6.400	
	Bitter Leaf	1.367	2.667	3.733	4.967	6.870	8.300	6.333	
	Control	1.333	2.800	3.967	5.033	6.470	5.100	2.233	
V3	*Moringa*	1.200	2.667	3.533	5.200	7.330	8.367	6.367	
	Neem	1.267	2.800	3.633	5.167	7.330	8.367	6.400	
	Bitter Leaf	1.233	2.700	3.533	5.167	7.430	8.367	6.300	
	Control	1.133	2.967	4.100	5.267	6.870	4.900	2.133	
F-LSD (0.05)		**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	

NS – No significant difference

Table 9. Main effect of variety and Botanicals on pH of tomato fruits during storage

Variety	1	5	9	13	17	21	25	(DAYS)
V1	6.629	6.306	5.819	5.246	4.645	4.111	3.754	
V2	6.593	6.245	5.750	5.239	4.643	4.081	3.759	
V3	6.703	6.379	5.840	5.257	4.567	4.108	3.777	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	
Botanicals								
Moringa	6.614	6.290	5.777	5.237	4.776	4.224	3.779	
Neem	6.387	6.041	5.777	5.043	4.581	3.856	3.750	
Bitter Leaf	6.768	6.461	5.847	5.354	4.739	4.217	3.790	
Control	6.798	6.448	5.812	5.356	4.377	4.103	3.726	
F-LSD (0.05)	**0.221**	**0.136**	**NS**	**0.160**	**0.183**	**0.072**	**0.036**	

NS – No significant difference

Table 10. Interaction effect of variety and botanicals on pH of tomato fruits during storage

Variety	Botanicals	1	5	9	13	17	21	25	(DAYS)
V1	*Moringa*	6.667	6.350	5.823	5.283	4.793	4.247	3.793	
	Neem	6.310	5.947	5.683	4.973	4.607	3.830	3.750	
	Bitter leaf	6.750	6.460	5.917	5.360	4.690	4.233	3.787	
	Control	6.790	6.467	5.853	5.367	4.490	4.133	3.687	
V2	*Moringa*	6.397	6.113	5.690	5.143	4.697	4.153	3.740	
	Neem	6.357	5.960	5.747	5.147	4.727	3.897	3.763	
	Bitter Leaf	6.773	6.450	5.783	5.337	4.787	4.210	3.803	
	Control	6.843	6.457	5.780	5.330	4.360	4.063	3.730	
V3	*Moringa*	6.780	6.407	5.817	5.283	4.837	4.273	3.803	
	Neem	6.493	6.217	5.900	5.010	4.410	3.840	3.737	
	Bitter Leaf	6.780	6.473	5.840	5.367	4.740	4.207	3.780	
	Control	6.760	6.420	5.803	5.370	4.280	4.113	3.760	
F-LSD (0.05)		**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	

NS – No significant difference

Table 11. Main effect of variety and botanicals on Shelf life of tomato fruits during storage

Variety	1	5	9	13	17	21	25	(DAYS)
V1	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
V2	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
V3	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	
Botanicals								
Moringa	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
Neem	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
Bitter Leaf	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
Control	1.00	5.00	9.00	13.00	17.00	21.00	21.00	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	

NS – No significant difference

Table 12. Interaction effect of variety and botanical on Shelf life of tomato fruits during storage

Variety	Botanicals	1	5	9	13	17	21	25	(DAYS)
V1	*Moringa*	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
	Neem	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
	Bitter Leaf	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
	Control	1.00	5.00	9.00	13.00	17.00	21.00	21.00	
V2	*Moringa*	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
	Neem	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
	Bitter Leaf	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
	Control	1.00	5.00	9.00	13.00	17.00	21.00	21.00	
V3	*Moringa*	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
	Neem	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
	Bitter leaf	1.00	5.00	9.00	13.00	17.00	21.00	25.00	
	Control	1.00	5.00	9.00	13.00	17.00	21.00	21.00	
F-LSD (0.05)		**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	

NS – No significant difference

Table 13. Main effect of variety and botanicals on Total Soluble Solids of tomato fruits during storage

Variety	1	5	9	13	17	21	25	(DAYS)
V1	4.867	4.767	4.662	4.558	4.457	4.333	4.223	
V2	4.867	4.742	4.630	4.523	4.436	4.315	4.172	
V3	4.917	4.792	4.681	4.551	4.429	4.299	4.178	
F-LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.042**	
Botanicals								
Moringa	4.778	4.722	4.621	4.522	4.428	4.256	4.159	
Neem	4.911	4.856	4.856	4.833	4.811	4.689	4.510	
Bitter Leaf	4.933	4.756	4.598	4.417	4.310	4.120	4.110	
Control	4.911	4.733	4.557	4.404	4.214	4.108	3.984	
F-LSD (0.05)	**NS**	**NS**	**0.106**	**0.079**	**0.064**	**0.033**	**0.049**	

NS – No significant difference

Table 14. Interaction effect of variety and Botanicals on Total Soluble Solids of tomato fruits during storage

Variety	Botanical	1	5	9	13	17	21	25	(DAYS)
V1	*Moringa*	4.733	4.733	4.617	4.533	4.433	4.250	4.150	
	Neem	4.933	4.900	4.900	4.867	4.867	4.767	4.650	
	Bitter Leaf	4.933	4.733	4.573	4.427	4.310	4.210	4.110	
	Control	4.867	4.700	4.560	4.407	4.220	4.103	3.980	
V2	*Moringa*	4.733	4.667	4.567	4.467	4.380	4.250	4.153	
	Neem	4.933	4.833	4.833	4.833	4.833	4.683	4.450	
	Bitter Leaf	4.933	4.767	4.603	4.400	4.317	4.218	4.117	
	Control	4.867	4.700	4.517	4.393	4.213	4.110	3.967	
V3	*Moringa*	4.867	4.767	4.680	4.567	4.470	4.267	4.173	
	Neem	4.867	4.833	4.833	4.800	4.733	4.617	4.430	
	Bitter leaf	4.933	4.767	4.617	4.423	4.303	4.203	4.103	
	Control	5.000	4.800	4.593	4.413	4.210	4.110	4.007	
F-LSD (0.05)		**NS**	**NS**	**NS**	**NS**	**NS**	**0.057**	**0.085**	

NS – No significant difference

Table 15. Main effect of variety and botanicals on Titratable Acidity of tomato fruits during storage

Variety	1	5	9	13	17	21	25	(DAYS)
V1	0.486	0.468	0.485	0.627	0.579	0.561	0.462	
V2	0.459	0.475	0.487	0.561	0.526	0.512	0.451	
V3	0.486	0.549	587	0.592	0.612	0.517	0.451	
F-LSD (0.05)	**NS**	**0.046**	**0.013**	**0.032**	**0.028**	**0.036**	**NS**	
Botanicals								
Moringa	0.461	0.503	0.548	0.499	0.622	0.612	0.523	
Neem	0.464	0.509	0.511	0.629	0.614	0.581	0.557	
Bitter Leaf	0.508	0.492	0.474	0.679	0.567	0.535	0.445	
Control	0.475	0.487	0.546	0.566	0.486	0.392	0.310	
F-LSD (0.05)	**0.029**	**NS**	**0.015**	**0.037**	**0.032**	**0.042**	**0.027**	

NS – No significant difference

Table 16. Interaction effect of variety and botanicals on Titratable Acidity of tomato fruits during storage

Variety	Botanicals	1	5	9	13	17	21	25	(DAYS)
V1	*Moringa*	0.484	0.474	0.527	0.592	0.487	0.648	0.510	
	Neem	0.491	0.456	0.487	0.791	0.756	0.682	0.645	
	Bitter Leaf	0.560	0.458	0.410	0.759	0.611	0.602	0.457	
	Control	0.411	0.486	0.516	0.367	0.461	0.314	0.237	
V2	*Moringa*	0.464	0.516	0.442	0.443	0.587	0.611	0.531	
	Neem	0.448	0.465	0.491	0.546	0.471	0.536	0.515	
	Bitter Leaf	0.462	0.468	0.469	0.541	0.499	0.464	0.423	
	Control	0.462	0.452	0.546	0.711	0.546	0.437	0.336	
V3	*Moringa*	0.436	0.518	0.673	0.461	0.791	0.578	0.528	
	Neem	0.453	0.606	0.556	0.550	0.614	0.526	0.509	
	Bitter leaf	0.502	0.549	0.543	0.737	0.589	0.539	0.454	
	Control	0.553	0.522	0.575	0.620	0.452	0.426	0.358	
F-LSD (0.05)		**0.051**	**NS**	**0.027**	**0.065**	**0.056**	**0.072**	**0.046**	

NS – No significant difference

Table 17. Main effect of variety and botanicals on Vitamin C content of tomato fruits during storage

Variety	1	5	9	13	17	21	25	(DAYS)
V1	9.480	9.189	12.775	8.800	7.266	5.711	4.587	
V2	5.330	8.584	10.620	9.260	8.840	5.727	4.192	
V3	6.880	5.061	10.499	6.220	6.385	6.714	5.155	
F-LSD (0.05)	**0.823**	**0.407**	**0.499**	**0.873**	**0.435**	**0.356**	**0.227**	
Botanicals								
Moringa	8.020	7.476	13.097	6.660	8.440	5.805	3.530	
Neem	9.400	10.126	11.519	10.980	6.469	6.996	6.029	
Bitter Leaf	7.540	7.195	11.253	7.420	9.222	6.751	5.379	
Control	3.960	5.648	9.322	7.300	5.857	4.649	3.640	
F-LSD (0.05)	**0.950**	**0.471**	**0.576**	**1.008**	**0.502**	**0.411**	**0.262**	

Table 18. Interaction effect of variety and botanicals on Vitamin C content of tomato fruits during storage

Variety	Botanicals	1	5	9	13	17	21	25	(DAYS)
V1	*Moringa*	10.960	8.479	15.723	9.670	7.573	2.607	1.818	
	Neem	10.460	10.963	13.393	11.600	6.152	6.687	5.197	
	Bitter Leaf	9.540	9.420	12.457	8.390	10.114	9.794	7.891	
	Control	6.970	7.893	9.525	5.530	5.224	3.754	3.442	
V2	*Moringa*	7.670	8.107	14.238	6.780	9.729	4.900	3.029	
	Neem	8.400	12.200	8.758	10.950	7.364	7.510	6.383	
	Bitter Leaf	3.630	9.244	10.766	9.470	11.435	5.558	4.022	
	Control	1.620	4.787	8.718	9.860	6.831	4.938	3.334	
V3	*Moringa*	5.420	5.842	9.330	3.540	8.017	9.908	5.744	
	Neem	9.350	7.216	12.407	10.400	5.891	6.790	6.506	
	Bitter leaf	9.440	2.921	10.534	4.410	6.116	4.902	4.224	
	Control	3.300	4.263	9.724	6.520	5.516	5.254	4.145	
F-LSD (0.05)		**1.646**	**0.814**	**0.998**	**1.746**	**0.869**	**0.712**	**0.454**	

Table 19. Main effect of variety and botanical on Weight of tomato fruits during storage

Variety	1	5	9	13	17	21	25	(DAYS)
V1	33.930	32.040	30.320	28.400	26.600	24.860	22.680	
V2	32.920	31.270	29.620	27.510	25.710	24.000	21.530	
V3	37.150	35.440	33.620	31.470	29.570	27.390	24.890	
F-LSD (0.05)	**3.105**	**3.186**	**3.230**	**3.147**	**3.120**	**NS**	**NS**	
Botanicals								
Moringa	33.720	31.960	30.100	27.810	26.110	24.170	20.730	
Neem	31.240	29.700	28.540	27.140	25.700	23.900	22.440	
Bitter Leaf	37.210	35.400	33.580	30.940	28.670	26.620	24.420	
Control	36.500	34.610	32.510	30.600	28.690	26.980	24.530	
F-LSD (0.05)	**3.586**	**3.679**	**3.730**	**NS**	**NS**	**NS**	**NS**	

NS – No significant difference

Table 20. Interaction effect of variety and botanicals on Weight of tomato fruits during storage

Variety	Botanicals	1	5	9	13	17	21	25	(DAYS)
V1	*Moringa*	33.300	31.630	29.530	27.470	25.570	23.600	20.700	
	Neem	28.030	25.670	24.670	23.730	22.500	21.070	19.970	
	Bitter Leaf	38.670	37.030	35.130	32.430	30.400	28.270	26.130	
	Control	35.730	33.830	31.930	29.970	27.930	26.500	23.930	
V2	*Moringa*	33.900	32.100	30.470	27.700	26.300	24.400	20.100	
	Neem	24.830	23.800	22.900	21.600	20.300	19.130	18.170	
	Bitter Leaf	37.230	35.330	33.430	30.970	28.370	26.230	24.170	
	Control	35.73	33.830	31.670	29.770	27.870	26.230	23.670	
V3	*Moringa*	33.970	32.130	30.300	28.270	26.470	24.500	21.400	
	Neem	40.870	39.630	38.070	36.100	34.300	31.500	29.200	
	Bitter leaf	35.730	33.830	32.170	29.430	27.230	25.370	22.970	
	Control	38.030	36.170	33.930	32.070	30.270	28.200	26.000	
F-LSD (0.05)		**6.211**	**6.373**	**6.461**	**6.294**	**6.241**	**5.785**	**5.431**	

During the study, fruit firmness for both control and coated tomatoes gradually decreased during the storage period. Fruit texture or firmness is an important post-harvest attribute regards to shelf life and quality of tomato. The treated fruits showed a statistical difference in firmness when compared to untreated (control) fruits on days 13 and 17 while the other days of storage showed no significant differences, however, firmness of tomato fruits decreased significantly during storage at ambient conditions. The decrease in firmness in both the treated and untreated fruits may be due to the fact that during the ripening process, cell wall modifying activity of several enzymes, including polygalacturonase, pectin-methyl-esterase, endo-β-mannase, α - and β - galactosidases and β-glucanases cause softening of the whole fruit by altering the texture due to the degradation of the structural components necessary to reinforce the cell wall and the adhesion of cells thereby affecting fruit quality loss as reported by Remon et al. [21]. Also, Ramirez et al. [22] reported that loss of firmness during the storage period is a normal behaviour during the maturation of tomatoes, since the increase in the ethylene concentration in this stage promotes the synthesis of polygalacturonase, the enzyme responsible for softening. Also, Othman [23] reported that fruit firmness decreased as fruit ripens and softening of vegetative tissues is usually accompanied by catabolism of cell wall polysaccharides (hemi cellulose). The breakdown of polymeric carbohydrates, especially pectic substances and hemi cellulose, weaken cell wall and caused retardation in fruit firmness. The plant leaf powders and or films exerted a beneficial effect on the fruit firmness such that by the end of the storage period, the treated tomato fruits gave rise to fruits with higher firmness values than the untreated fruits (Control). Similar results for table grapes and cherries coated with *Aloe vera* gel were reported by Matinez-Romero et al. [24] and Valverde et al. [25] during postharvest storage. Lerdthanangkul and Krochta [26] also made similar observations and concluded that coating and/or films significantly affected firmness of fruits in storage. Firmness is an important factor that influences consumer acceptability of fresh cut fruits and it is related to water content and metabolic changes [27]. Also, Ezhilarasi et al. [28] reported that loss in firmness is mainly due to fruits softening /ripening which is due to the degradation of cell wall components, mainly pectins by the action of specific enzymes such as polygalacturonase. Fruit firmness is a major attribute that dictates the postharvest life and quality of fruits. It is associated with the susceptibility of tomato fruit cell walls to different postharvest handling factors. Maftoonazad and Ramaswamy [29] also indicated that as the length of storage period extended, uncoated peach fruits showed a significant decrease in firmness, while the loss of texture and softening were delayed in coated fruits. Avina et al. [30] reported that tomato fruits either coated with mineral oil wax or carnauba wax had the higher firmness of fruits than control. Wax coatings create barriers for moisture loss and therefore maintain better cell turgidity to show higher fruit firmness than control. In their work, Maftoonazad and Ramaswamy [31] reported that firmness value in avocados coated with methylcellulose was almost 1.5 times higher than that of uncoated fruits. Similarly, Chauhan et al. [32] indicated that Shellac based surface coating retained tomatoes firmness better than control fruits. Delay in loss of cell wall firmness might be associated with the limited availability of oxygen from the ambient atmosphere for the respiratory process leading to subsequent delay in cell wall degradation.

During the present investigation, it was observed that chlorophyll content reduced with increasing amount of lycopene. Chlorophyll degradation and increased lycopene synthesis result in the characteristic colour development during ripening of tomatoes [33]. Lycopene is the major carotenoid compound in tomatoes, its gives the fruit its characteristic red colour [34]. During ripening, chlorophyll content decreases, and there is a rapid synthesis of the red pigment lycopene. In the current study, significant ($P < 0.05$) difference was observed on the lycopene content of tomato fruits due to the interaction effect of maturity stage and plant leaf powder/film. Generally, lycopene content of the tomato fruits increased with the storage time in all treated and untreated fruits. However, the content of untreated fruits increased sharply and reached maximum level after 17 days of storage. But similar lycopene concentration was noted from powder coated fruits on 13th day of storage. The ripening and antioxidant index of the tomatoes (lycopene) also varied from one ripening stage to the other and the variations were also observed with coated and uncoated fruits. The results of the study established that the content of lycopene from all treatments increased with storage time but at different rates. The lowest concentration of lycopene (0.002 mg/100g); was recorded in coated fruits on the 1st day of storage while the highest concentration 0.105mg/100g for coated fruits on 13th day of storage. The early increase in lycopene content in the fruits might be due to faster ripening rate of fruits which leads to the conversion of chloroplasts to chromoplasts and lycopene accumulation in internal membrane system [35]. Results of this study are also similar with Ali et al. [36] who reported that lycopene content of uncoated tomatoes increased sharply and reached a maximum peak after 12 days of storage but those coated with gum Arabic stayed for fewer days. It has also been reported that the formation of lycopene depends on the rate of respiration during storage which is affected by high temperature [37]. Turk et al. [38] reported that temperature to optimized lycopene content of tomato was between 16 - 18°C and 26°C.

During the study, it was observed that the commercial quality of the tomato fruits increased to a certain point and then started declining towards the end of the storage. However, the untreated (Control) fruits declined faster in their marketable value compared to the treated tomato fruits. This finding is in agreement with Sai et al. [39] who reported a decrease in marketable quality of Chitosan coated tomato fruits during storage. They added that at the end of the storage period, marketability was found to be better in the coated fruits while the uncoated fruits lost marketable quality. In this study, a general trend of decrease in marketable tomato fruits was observed as the storage period advanced which is in agreement with the findings of Mohammed et al. [40] and Hiru et al. [41]. During the study, unmarketable tomato fruits showed visible signs of mould growth, blotchy ripening, loss of firmness and shrivelling which is in agreement with the findings of Pal and Roy [42] and Mohammed et al. [40]. The ability of the plant leaf powders/films to maintain the marketability of the tomato fruits may be due to the ability of the powder to form a protective layer thereby preventing oxygen and moisture loss and inhibiting the action of microorganisms. Plant films/coatings have been shown to prevent loss of moisture and firmness, control respiratory rate and maturation development, delay oxidative browning and reduce oxygen proliferation in fruits [43,44].

In this study, pH values showed an increase in acidity of the fruits with an increase in days of storage. The pH of tomato fruits is determined primarily by the acidic content of the fruit. The acidity of tomato plays a major role and imparts taste to the fruit. Borji and Jafarpour [45] and Moneruzzaman et al. [46] also indicated that pH values indicated an increase in acidity of tomato fruit with advancement in maturity stage from mature-green to full ripe stage. The higher acidity in coated fruits observed in this study might be because of reduced respiration rate due to limited availability of oxygen [47]. Athmaselvi et al. [48] also reported that *Aloe vera* treated tomato fruits were better in keeping pH and showed a better effect in comparison with untreated fruits.

During the study, the postharvest treatment used exhibited pronounced effect in extending the shelf life of tomato fruits during storage. Shelf life implies the time period, whereby a product is not only safe to eat, but still has acceptable taste, texture and appearance after being removed from its natural environment [49]. The shelf life of the tomato fruit was considerably influenced by the coating/film of the plant powders. The longest shelf life (25 days) was found in tomato fruits preserved with plant leaf powder and films whereas minimum shelf life (21 days) was found in untreated (control) fruits. This may be due to their capacity to reduce postharvest decay incidence [50]. Similar results were reported by Mandal et al. [51]. They stated that waxed coated tomato fruits got maximum shelf life (26.33 days) followed by fruits coated with chitosan at 2% (22.00 days). Similarly, Maftoonazad and Ramaswamy [29] also used a pectin-based composite coating on avocados and evaluated the extent of quality changes under different storage temperatures for predicting the quality loss. Their results showed that pectin-based composite coating significantly reduced the rate of physical, chemical and physiological changes in avocados during storage and extended their storage. Felix and Mahendran [52] in their study reported that coated red tomatoes fruits took 15 days to ripen at 30°C, whereas the uncoated ones ripened within 5 days. Also Dilmacunal et al. [53] reported that tomato wax gave the best results and provided bunch tomatoes at good quality for 12 days as chitosan coatings have the capacity to delay ripening and reduce postharvest decay incidence [50,54] which results in longer shelf life.

During this study, total soluble solids (TSS) for both the treated and untreated (control) fruits declined from the beginning to the end of storage. This is in agreement with Ergum and Satici [55] who reported a decrease in TSS of tomato fruits coated with *Aloe vera* gel and the untreated during storage. It was also observed that TSS of the untreated (control) fruits recorded faster decline than the treated fruits. This may be because the leaf powders/films decreased respiration and eventually the metabolism of sugars on the treated fruits. The decrease in TSS is caused by a decline in the amount of carbohydrates and pectins, partial hydrolysis of protein and decomposition of glycosides into sub-units during respiration causing a decrease in TSS [48,56]. Coatings provide an excellent semi permeable film around the fruit, modifying the internal atmosphere by reducing oxygen availability for respiration and degradation of macromolecules. Decreased respiration rates slow down the synthesis and use of metabolites resulting in slower rate of decrease on TSS [57]. It has been documented that reducing sugars (fructose and Glucose) generally correlates with the total soluble solids [58]. Hence taking total soluble solids measurements provide a good estimate of the sugar level. Sugar constitutes an important component of tomato fruits as they determine sweetness and influence the overall tomato flavour [59]. Stevens et al. [60] also reported that sugars constitute an important part of the total soluble solids in tomato and accounts for its sweet taste.

Due to the effect of the plant leaf powder and/or films on tomato fruits, titratable acidity (TA) varied significantly. It was observed that the tomato fruits treated with plant leaf powders gave the maximum titratable acidity of (0.791) on the 13^{th} day of Storage whereas the minimum (0.237) titratable acidity was found in the untreated fruits (control). The retention of titratable acid content by the coated tomato fruits was due to the protective effect of the leaf powders /films, which served as a barrier to oxygen from the surrounding atmosphere [25] and reduction of respiration [61]. The acidity of tomato plays a major role and imparts taste to the fruits. TA is an important consumer variable as the balance of TSS and TA relates to overall taste and consumer acceptability. The TA values of coated and uncoated fruits decreased with storage time and the value was significantly higher ($P < 0.05$) in treated fruits compared to the untreated. This confirms that edible coating materials reduce the rate of acid metabolism [57] as compared to control. Since organic acids, such as malic or citric acids, are primary substrates for respiration, reduction in acidity is expected in terms of rate of increase in respiration of cells of fruits [62]. The decreasing acidity at the end of storage might be due to use of acids as energy source with an increase in ripening [63,64]. In another study, Abassi et al. [65] reported that chitosan coatings slowed the changes in TA of Mango, but on control fruits the rate of decline was significantly higher. Results of this study are also in agreement with Ali et al. [66] who analysed the effects of gum Arabic as an edible coating for preservation of TA in tomato fruit.

During the study, the ascorbic / vitamin C content was higher in tomato fruits treated with the leaf powder and/or films and lower in the untreated (control fruit). Also, an increase in ascorbic content at the beginning of the experiment and a decrease at the end of the storage period was observed. Similar results were also reported by Tigist et al. [67], where a general trend of increase in ascorbic acid content, followed by a falling at the end of storage was observed. Ascorbic acid content increases with ripening and storage time; however once the fruit is fully ripe, the ascorbic content starts to decline [68]. Results obtained in this study show reduction in ascorbic acid content along with the storage period not only for coated fruits but also for the control. However, a decrease in ascorbic acid content during storage was significantly higher in control fruits as compared with coated fruits. High ascorbic acid in coated fruits could be attributed with slow ripening rate due to semi-permeable membrane films of the leaf powder since coatings serve as a protective layer and reduce the diffusion of oxygen [69] which is critical to initiate respiration processes [70]. Ali et al. [66] reported a similar slowdown of ascorbic acid degradation for gum Arabic coated tomato during ripening. Likewise, Ali et al. [71] also reported that papaya fruits coated with Chitosan showed a slower initial increase in ascorbic acid as compared to uncoated fruits. This suggests that Chitosan and pectin coating slowed down the synthesis of ascorbic acid during ripening and also slowed down the rate of loss in coated fruits which can be attributed with oxygen availability for respiration and oxidation. Ascorbic acid is lost due to the activities of Phenoloxidase and ascorbic acid oxidase enzymes during storage [72]. Weichmann [73] while studying green bean, spinach and broccoli, postulated that the lower oxygen content of the storage atmosphere, the lesser is the loss of ascorbic acid. The claim was that the oxidation of vitamin C was mainly regulated by ascorbic acid oxidase and other oxidases, most of which had low affinity for oxygen. Preservation of ascorbic acid content during storage is a difficult task since it undergoes oxidation [74]. A decrease in ascorbic acid content of fruits indicates senescense [75].

Tomato fruits both treated and untreated showed a decrease in weight during the storage period. However, the untreated fruits (Control) showed a significant difference in weight loss compared with the treated fruits. The mechanism for these positive effects is based on the hygroscopic properties of the plant leaf powders, which enables formation of a barrier to water diffusion between the fruit and the environment, thus avoiding its external transference. This is in agreement with Martinez-Romero et al. [24] and Valverde et al. [25] who reported that *Aloe vera* was an effective coating which served as a physical barrier and thus reduced weight loss and lowered the respiration rate of table grapes and cherries respectively during postharvest storage. Hong et al. [76] also reported that coating of guava fruit with Chitosan was clearly effective in conferring a physical barrier to moisture loss, therefore a decreased weight loss in the chitosan coated fruit was observed. Zakki et al. [77] also reported a progressive weight loss among UTC, Shase and Hoozua varieties of tomato fruits during storage. They stated that variation in weight loss among the different varieties in both the treated and control fruits could be due to the variation in their pericarp thickness as thin pericarp leads to aggravating weight loss due to higher rate of moisture loss. Thick pericarp on the other hand, reduces moisture loss and hence lowers weight loss. Also Perez-Gago et al. [78] reported that composite coatings are known to increase water barrier efficacy and in turn more reduction of weight loss could be achieved. Weight loss mainly occurs due to water loss by transpiration and loss of carbon reserves due to respiration [79]. The rate at which water is lost depends on the water pressure gradient between the fruit tissue and the surrounding atmosphere. The plant leaf powders served as a barrier, thereby restricting water transfer. Results obtained in this study are also in agreement with those of Mahmoud and Savello [80] and Avena-Bustillos et al. [81] who concluded that coating /films significantly conserved water content. Postharvest weight changes in fruits and vegetables are usually due to the loss of water through transpiration. Transpiration is a mechanism in which water is lost due to differences in vapour pressure of water in the atmosphere and the transpiring surface. Respiration causes a weight reduction because a carbon atom is lost from the fruit each time a carbon dioxide molecule is produced from an absorbed oxygen molecule and evolved into atmosphere [82]. This loss of water can lead to wilting and shrivelling which both reduce a commodity's marketability. Moisture loss and gaseous exchange from fruits is usually controlled by the epidermal layers provided with guard cells and stomata. The film formed on the surface of the fruit act as a physical barrier to reduce moisture migration from the fruits [83]. This barrier property also reduces the oxygen availability and uptake by the fruit for respiration process and hence slows down rate of respiration and associated weight [84]. Coatings /films can offer a possibility to extend the shelf life of fresh cut produce by providing a semi permeable barrier to gases and water vapour and thereby reduce respiration and water loss [85]. Weight loss is an important index of postharvest storage life in fresh produces. It is mainly attributed to the loss of water during metabolic processes like respiration and transpiration. Both processes are affected by storage environment of the fruit and the loss in weight is an indicator of how the product is handled and stored. Because of this, physiological weight loss appears to be the major detrimental factor of storage life and quality of tomato fruits in particular and horticultural crops in general [86].

During the study, the temperature and relative humidity of the storage room varied from 24.3°C to 35°C and 48% to 93% respectively. This is similar to the report of Castro et al. [64] who reported that for longer-term storage, ripe tomatoes can be stored at temperatures of about 10 - 15°C and 85 - 95% relative humidity. At these temperatures, both ripening and chilling injuries are reduced to the minimal levels. These conditions are difficult to obtain in most tropical countries like Nigeria and therefore losses of appreciable quantities of harvested tomatoes have been reported [87,88]. This is consistent with the claim that the quality of tomato is compromised when exposed to high temperatures and high relative humidity [89]. Respiration and metabolic activities within harvested climacteric fruits like tomato are directly related to the temperature of the ambient environment. High temperature can hasten the rate of respiration (CO_2 production) in harvested or stored fruits products. Keeping harvested fruits at low temperature of about 20°C will slow down many metabolic activities leading to ripening [90]. An understanding of the correct temperature management during storage of tomatoes is vital in extending the shelf life of the fruit whilst maintaining fruit qualities.

During the study, it was observed that tomato fruits were shrinking during storage. This may be due to the variation in relative humidity. The optimal values of relative humidity for mature green tomatoes are within the range of 85 to 95% (v/v) but 90 to 95% (v/v) for firmer fruits. Below optimal range, evapotranspiration increases resulting in shrivelled fruits [90]. Tomato fruits are very high in moisture content and susceptible to shrinkage after harvest. Water loss from harvested fruit produce is predominantly caused by the amount of moisture present in the ambient air expressed as relative humidity [76]. At very high relative humidity, harvested produce maintain their nutritional quality appearance weight and flavour white reducing the rate at which wilting, softening and juiciness occurs.

5. CONCLUSION

The results of this study has established that plant powders possess antifungal potential and have the ability to increase the shelf life and maintain the physicochemical quality of tomato fruits during storage. These botanicals are not only environmentally friendly, cost effective, easy to produce and easy to apply formulations, they are also safe for consumers and provide alternative means for maintaining postharvest physiology and management of crops.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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