Original Research Article

Postharvest shelf life and quality retention potentials of Neem, Moringa and synthesized silver nanoparticles coatings on Solanum lycopersicum L. (Tomato) fruits

---

ABSTRACT

The aim of this research was to evaluate the effect of *Azadirachta indica* and *Moringa oleifera* leaf extract on the shelf life and quality retention of *Solanum lycopersicum* L. (Tomato) fruits during storage. Thirty-five (35) matured tomato fruits were collected, rinsed and grouped for each treatment with neem and moringa coating: Control (n=5), Moringa aqueous leaf extract (MALE) (n=5), Neem aqueous leaf extract (NALE) (n=5), 1:9 and 6:4, Moringa aqueous leaf extract synthesized silver nanoparticles (MALE-AgNPs) (n=5), 1:9 and 6:4, Neem aqueous leaf extract synthesized silver nanoparticles (NALE-AgNPs) (n=5). The firmness, shelf life, and post-harvest decay percentage of the tomato fruits were determined using standard procedures. Additionally, fungi associated with the postharvest deterioration of the fruits were isolated and identified using standard procedures. From the results of this study, tomato fruits coated with either neem or moringa crude extract showed the longest shelf life, as compared to the coating with AgNPs. Additionally, two fungi, namely *Aspergillus niger* and *A. flavus*, were isolated from the decayed fruits. In conclusion, the neem and moringa leaf extracts are effective in the extension of the shelf life and retention of the quality of tomato fruits.

Keywords: Azadirachta indica, Moringa oleifera, Tomato fruits, Post-harvest, Shelf-life, Preservatives

1. INTRODUCTION

Solanum lycopersicum L. (tomato) is widely grown and consumed in Nigeria, serving as a valuable source of vitamins and minerals [1]. Tomato is a commonly consumed fruit that is vital for health, and therefore available fresh or in paste form [2].However, the perishability of tomatoes poses challenges for farmers and consumers, affecting the quality and safety of the fruits. Addressing the shelf life is crucial to meet consumer demands and ensure a stable tomato supply [3].

Plant nutraceuticals as antioxidant and antimicrobial agents in food preservations are sourced from different plant parts, and contains excellent natural bioactive compounds like polyphenols and terpenoids [4]. The extracts of these plants are increasingly considered natural preservatives, potentially replacing synthetic counterparts such as Sodium hypochlorite, Sodium metabisulphite, and Calcium chloride in various applications [5]. Moringa oleifera (Moringa) is recognized for its abundance of bioactive compounds, particularly in its leaves, which are rich in vitamins, carotenoids, polyphenols, phenolic acids, flavonoids, alkaloids, glucosinolates, isothiocyanates, tannins, and saponins [6,7]. These embedded numerous bioactive compounds of *Moringa oleifera* leaves contributes to its various pharmacological properties [8,9.10]. *Azadirachta indica* (Neem) on the other hand, is a widely available plant that contains phytochemicals [11], that can inhibit spoilage-causing micro-organisms in tomatoes, and also preserve its level of nutrients [12]. The various phytoconstituents of *A. indica* leaves contributes to its various attributed biological activities including, antioxidant, antidiabetic, antimicrobial, antifungal, anti-inflammatory, anti-tumor, anti-cancer, anti-fertility[13]. As a result of various phytochemical and bioactive compounds richness of neem and moringa, this study aimed to investigate the effect of the leaf extracts of these plants and its synthesized silver-nanoparticles on the shelf life and quality retention of tomato fruits during storage.

2. MATERIAL AND METHODS

2.1Collection of Samples and Extraction Process

Fresh leaves of *A. indica* (neem) and *M. oleifera* (moringa)were obtained at the back of the Lagos State University sports center and a residential area at Adexson, Lagos State, respectively, and were identified and authenticated at the Herbarium of the Department of Botany, Lagos State University, Ojo, Lagos State, Nigeria. The dried leaves were blended to get the powder. The powder was then sieved and kept in separate air-tight conical flasks.

Forty (40) matured, ripe, firm, smooth, and healthy tomato fruits were obtained from a local food and fruits market, Iyana Iba market, Ojo, Lagos State, Nigeria.

2.2 Treatment of Tomato with Neem and Moringa

The tomato fruits were washed under running clean water and air-dried at room temperature. Neem/Moringa aqueous leaf extracts were prepared by dissolving 70g of Neem/ Moringa leaf powder in 350 mL distilled water separately. Five tomato samples each were immersed in either neem/ moringa aqueous leaf extract before being arranged in a Petri dish, and kept at room temperature on the Laboratory table. Changes were observed and data recorded to ascertain the effects of the extracts.

2.3 Silver nanoparticles (AgNPs) preparation

The leaf powder of Neem and Moringa (100 g each) were dissolved in 1000 mL distilled water, filtered, and stored separately. According to a modified method of [14], a freshly prepared 2 mM silver nitrate solution was mixed with Neem and Moringa aqueous leaf extract separately in ratios 1:9 and 4:6, respectively. The color change indicated silver nanoparticle synthesis, and further confirmed by an absorption peak between 400 – 450 nm using UV-visible spectrophotometer. Five tomatoes each were immersed in each AgNPs solution for 2 hours before being placed in a Petri dish in the laboratory at 25°C. Changes were observed and data recorded to ascertain the effects of the synthesized AgNPs.

2.4 Data collection

The collected data were recorded and calculated using post-harvest decay percentage (PDP), marketability, shelf-life, and firmness

$$\text{Post-harvest decay percentage (PDP)} = \frac{number\ \ of\ decaying\ \ fruits}{total\ \ number\ \ of\ fruits} \times 100$$

$$\text{Marketability} = \frac{number\ \ of\ Marketable\ \ fruits}{total\ number\ \ of\ fruits} \times 100$$

Firmness = rating scale 1 - 5
Where 1= is very poor, 2 is poor, 3 is Acceptable, 4 is good, and 5 is excellent.

2.5 Isolation and Identification of fungi causing spoilage of Tomato fruits during storage

Potato dextrose agar was used for the isolation of fungi from the tomato fruits and the preparation of pure culture. Thirty-nine grams (39g) of potato dextrose agar was dissolved in 1000 mL of distilled water in a sterile conical flask covered with cotton wool and aluminum foil paper. The mixture was shaken thoroughly and autoclaved at 121°C for 15 minutes under a pressure of 15 pounds per square inch (15lb/inch2). The medium was cooled after autoclaving to 45°C and then dispensed aseptically into a sterile Petri dish. Chloramphenicol was added to the medium to prevent the growth medium. The workbench was disinfected, and a sterilized cork-borer was used to extract pieces from a diseased tomato, which were placed into the medium. After 5 days of incubation at 37°C, mixed cultures were re-isolated until obtaining a pure culture. Identification was based on morphological features and microscopic examination using lactophenol cotton blue solution, following [15] description.

2.6 Statistical Analysis

The daily weight of the coated tomatoes wasrecorded triplicates and the data were subjected univariate statistical analysis such as mean and standard deviation (SD) using Statistix 10 software. The means were separated using analysis of variance and comparison were made Least Significance Difference (LSD) at 95% confidence level.

3. RESULTS

The 15-day experiment showed that the control group tomatoes spoiled by the 8th day, losing its firmness from the 5th day. However, tomatoes coated with Neem aqueous leaf extract synthesized silver nanoparticles (NALE-AgNPs) solution (4:6 ratio) lasted 12 days, with significant weight loss from day 6. Another variant (1:9 ratio) lasted 14 days before significant weight loss led to complete deterioration by day 15. Tomatoes coated with neem aqueous leaf extract had the longest shelf life, losing firmness at day 8 and deteriorating completely by day 15.

Table 1. Effects of *Azadirachta indica* aqueous leaf extract and *Azadirachta indica*-synthesized AgNPs on the shelf life of *Solanum lycopersicum*

Groups/Days	Control	NALE	Nano 1	Nano 2
IW1	91.5±4.64^{a}	74.57±12.26^{ab}	80.87±4.92^{ab}	83.23± 8.14^{a}
IW2	91.50± 4.64^{a}	84.3± 12.50^{a}	81.97± 4.88^{a}	84.80± 8.41^{a}
DAT 1	89.60± 4,32 ^{a}	79.03 ± 12.08^{ab}	80.83± 3.85^{abc}	83.00± 8.29^{a}
DAT 2	88.07 ± 4.16^{ab}	76.70± 12.08^{ab}	78.83± 3.23^{abc}	81.47± 8.11^{a}
DAT 3	82.33 ± 3.61^{bc}	75.33± 13.25^{ab}	76.13± 4.37^{abcd}	80.23± 7.88^{a}
DAT 4	79,30 ± 6.67^{c}	75.30± 11.98^{ab}	72.57± 5.50^{bcde}	78.37±7.04^{ab}
DAT 5	75.80 ±6.05^{cd}	73.37±13.20^{ab}	73.30±4.03^{cde}	78.83± 8.34^{ab}
DAT 6	70.30± 4.21^{de}	72.60 ±13.1^{ab}	71.10± 4.33^{def}	76.50±7.02^{abc}
DAT 7	66.57 ± 4.10^{de}	71,87± 12.64^{ab}	68.57± 5.31^{defg}	74.27± 6.12^{abcd}
DAT 8	61.93 ± 4.73^{f}	71.40 ± 12.47^{ab}	67.27 ± 5.14^{efg}	69.20± 4.50^{bcd}
DAT 9	0	70.93 ± 12.14^{ab}	65.97± 4.97^{efg}	67.40 ± 2.94^{cde}
DAT 10	0	67.60± 11.00^{ab}	64.73 ± 4.73^{fg}	65.00 ±1.39^{de}
DAT 11	0	64.33 ± 11.75^{ab}	63.83± 4.39^{fg}	57.33± 0.75^{ef}
DAT 12	0	62.87 ± 12.24^{b}	62.87 ± 4.27^{g}	49.40± 0.35^{f}

Means ± S.D values on the row showing different alphabet are significantly different at P< 0.05, where, NALE= Neem aqueous leaf extract, Nano 1 = Neem aqueous leaf extract dissolved in $AgNO_3$ at 100:900 mL, and Nano 2 = Neem aqueous leaf extract dissolved in $AgNO_3$ at 600:400 mL, IW1= Initial weight before Coating, IW2= Initial weight after coating.
Mean ± SEM values with the same alphabet in the same row are not significantly different from each other at p<0.05.

The 15-day experiment revealed that all fruit samples deteriorated by the 15th day, with observable decay starting from the 5th day. White mold appeared from the 3rd day before decay. Tomato fruits coated with Moringa aqueous leaf extracts deteriorated from the 8th day, but some lasted until the 15th day. However, those coated with Moringa aqueous leaf extract synthesized silver nanoparticles (MALE-AgNPs) showed preservation until the 8th day (in a 6:4 ratio) and some lasting until the 10th day (in a 9:1 ratio). Significant differences in weight loss were observed on specific days between Moringa-coated and control fruits, as well as between silver nanoparticle-treated and control fruits.

Table 2. Effects of Moringa oleifera aqueous leaf extract and Moringa oleifera-synthesized AgNPs on the shelf life of Solanum lycopersicum

Groups/Days	Control	MALE	Nano 3	Nano 4
IW1	91.50 ± 4.64[a]	81.73 ± 3.90[abc]	93.77 ± 2.64[abc]	94.07 ± 6.31[ab]
IW2	91.50 ± 4.64[a]	95.50 ± 5.24[a]	99.30 ± 5.27[a]	100.73 ± 7.94[a]
DAT 1	89.53 ± 4.21[a]	86.93 ± 10.47[ab]	97.50 ± 5.15[ab]	98.67 ± 7.72[a]
DAT 2	88.07 ± 4.16[ab]	82.90 ± 10.12[abc]	95.03 ± 4.73[abc]	95.80 ± 7.01[ab]
DAT 3	82.33 ± 3.61[bc]	83.83 ± 11.07[abc]	89.13 ± 7.90[abcd]	92.77 ± 6.92[ab]
DAT 4	80.80 ± 4.08[cd]	80.73 ± 9.64[abc]	87.77 ± 7.42[bcd]	91.50 ± 6.29[ab]
DAT 5	75.80 ± 6.05[de]	77.53 ± 7.75[bcd]	86.57 ± 6.75[cd]	90.17 ± 5.71[abc]
DAT 6	72.77 ± 4.25[ef]	74.13 ± 5.81[bcd]	87.87 ± 6.12[bcd]	89.43 ± 6.84[abc]
DAT 7	68.93 ± 4.19[fg]	70.67 ± 7.11[cd]	85.30 ± 4.85[cd]	88.00 ± 6.76[abc]
DAT 8	64.67 ± 4.73[g]	73.87 ± 6.12[bcd]	82.60 ± 3.12[d]	85.47 ± 5.77[bcd]
DAT 9	0.00 ± 0.00[h]	65.33 ± 11.61[d]	69.97 ± 4.79[e]	77.97 ± 7.08[cde]
DAT 10	0.00 ± 0.00[h]	64.83 ± 11.56[d]	62.13 ± 7.04[e]	74.47 ± 8.31[de]
DAT 11	0.00 ± 0.00[h]	64.33 ± 11.51[d]	49.73 ± 13.28[f]	68.07 ± 16.17[e]
DAT 12	0.00 ± 0.00[h]	63.20 ± 11.01[d]	0.00 ± 0.00[g]	0.00 ± 0.00[f]

Means ± S.D values on the row showing different Alphabet are significantly different at P< 0.05, where, MALE= Moringa aqueous leaf extract, Nano 3 = Moringa aqueous leaf extract dissolved in $AgNO_3$ at 100:900 mL, and Nano 4 = Moringa aqueous leaf extract dissolved in $AgNO_3$ at 600:400 mL, IW1= Initial weight before Coating, IW2= Initial weight after coating.
Mean ± SD values with the same alphabet in the same row are not significantly different from each other at p<0.05.

Table 3 illustrates the postharvest decay of tomato fruits during storage period of 15 days. The percentage of decay was observed to increase as the days increased. The deterioration of tomato fruits started on the 5th day with only 20 percent of both control and NALE-AgNPs (6:4) observed. Meanwhile, it was observed that, the different concentrations of MALE-AgNPs (1:9 and 6:4) delayed decay up to the 15th day.

Table 3. Post-harvest decay percentage of tomato fruitstreated with Moringa aqueous leaf extracts and their synthesized silver nanoparticles at different concentrations

	Day 3	Day 5	Day 7	Day 9	Day 11	Day 13	Day 15
Control	0	20	`60	100	100	100	100
NALE	0	0	20	40	40	60	80
MALE	0	0	40	40	40	60	80
Nano 1	0	0	80	80	80	80	100
Nano 2	0	20	60	60	60	100	100
Nano 3	0	0	40	40	*	*	*
Nano 4	0	0	60	60	*	*	*

Nano 1 = Neem dissolved in AgNO3 at 100:900, Nano 2 = Neem dissolved in AgNO3 at 400:600,
Nano 3 = Moringa dissolved in AgNO3 at 100:900, Nano 4 = Moringa dissolved in AgNO3 at 400:600, NALE = neem dissolved in distilled water and MALE = Moringa dissolved in distilled water.

Figures 1 and 2 illustrate the firmness of the Tomato fruits. It was observed that the tomatoes coated with the aqueous leaf extracts of neem and moringa have the longest shelf life of 15 days compared with 8 days of Moringa and Neem silver nanoparticles and the control.

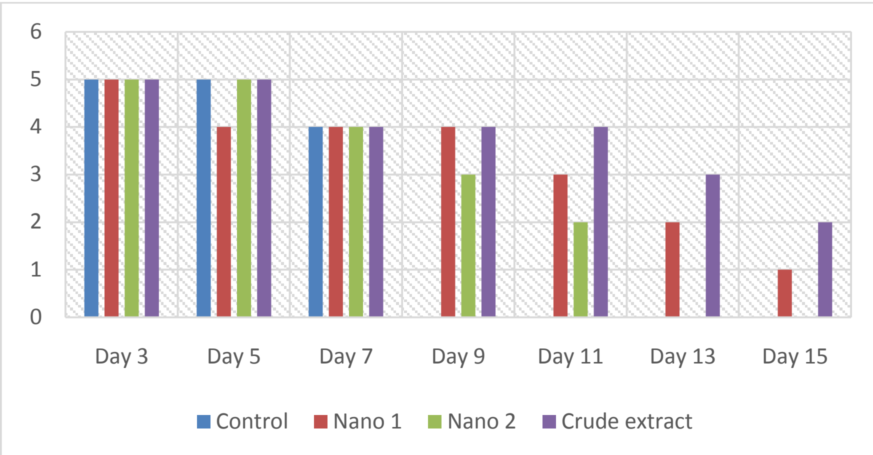

Figure 1. Firmness of Tomato Neem aqueous leaf extracts and its synthesized AgNPs during storage.
Crude extract = Neem aqueous leaf extract (NALE), Nano 1= NALE-AgNPs at 100:900 mL and Nano 2= NALE-AgNPs at 600:400 mL.

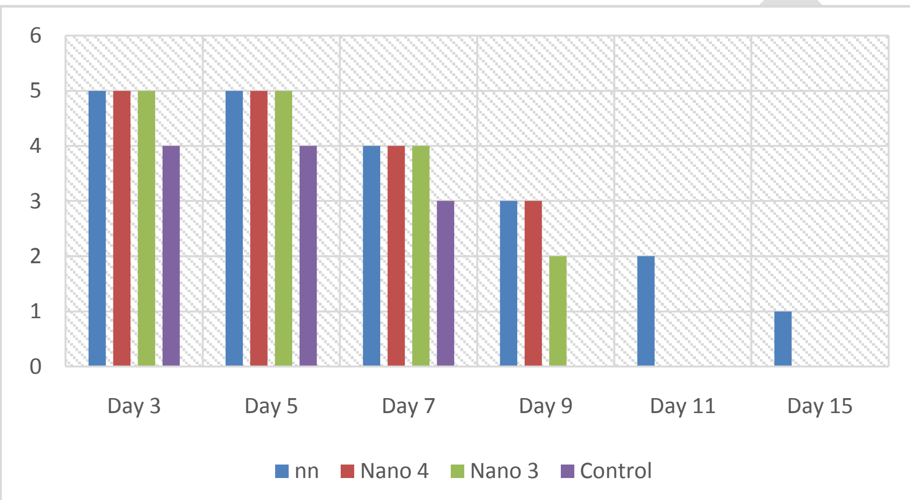

Figure 2. Firmness of Tomato coated with Moringa aqueous leaf extracts and synthesized AgNPs during storage.
nn= Moringa aqueous leaf extract (MALE), Nano 1= MALE-AgNPs at 100:900 mL and Nano 2= MALE-AgNPs at 600:400 mL.

A total of two fungi, *Aspergillus* specieswere isolated, identified, and characterized from the deteriorated tomato samples. These were*A.niger* and *A. flavus*.

Aspergillus niger: The conidia are dark brown to black and spherical having a sporulated surface growth on the culture media, with visible aseptate hyphae (without cross-wall).
A. flavus: The conidia are smooth with green dispersed spores, and septate (cross-walled) hyphae are present with phialides.

4. DISCUSSION

The prevention of fruit spoilage by pathogenic bacteria and preservation of fruit freshness poses a serious challenge in the fruit industry. Concerns over the use of synthetic preservatives have led to a shift towards exploring plant-based alternatives. The effectiveness of Neem and Moringa aqueous leaf extracts in reducing tomato decay observed in this study suggests that it could be a viable alternative for combating pathogen-related decay in tomatoes. This observation aligns with a study reported by [16], who reported that treating various kinds of fruits with chitosan and guava leaf extract significantly increased the shelf life of the fruits. Similarly, our findings are consistent with the report of [17], who highlighted the effectiveness of extracts from medicinal plants like Allium sativum, *Azadirachta indica*, *Mentha arvensis*, and *Psoraliacorlylifolia* in preserving fruits from pathogenic and environmental factors. Moreover, the extract of neem increases the shelf life of the fruits by reducing the fungal and bacterial spoilage during storage.

Tomatoes coated with moringa and neem aqueous leaf extracts exhibited reduced post-harvest decay, reflected in the lower number of decayed fruits compared to both control and NALE and MALE-synthesized silver nanoparticles.These plants also showed higher marketability with a greater number of marketable fruits in both categories. While control fruits lasted for only 8 days, most of the treated tomato fruits still retained their color and number, and became completely rotten on the 15th day. Among the treated tomato fruits with low post-harvest decay percentage were the tomato fruits treated with MALE-AgNPs different concentrations. This is an implication that treatment with MALE-AgNPs could help tomato fruits resist environmental and pathogenic attack better than other treatments. The observed progressive weight loss in neem-coated tomatoes and control aligns with the report of [18], who stated that post-harvest weight change in fruits is typically linked to temperature and storage time, often attributed to water loss through transpiration. Thus, the higher the temperature, the higher the respiratory rate of the fruits and the higher its metabolic activity, which may lead to an increase in weight loss during storage. The higher decrease in the firmness of the control tomato fruits compared to the treated fruits may be attributed to a higher rate of metabolic activities and activity of cell wall degrading enzymes that loosens the fruit skin which result in higher permeability of the cell for higher rate of moisture loss.

In addition, the findings of this study also revealed some of the fungi associated with the post-harvest decay of the tomato fruits in storage. These fungi *Aspergillus niger* and *A. flavus* which have previously been reported as pathogens of tomato fruits by [19,20]. These fungi have also been reportedly found in other fruits including orange fruits, Sour-sop fruits, and garri (fried mashed fermented cassava) [3]. Association of these fungi with these fruits/ foods may suggest their omnipresent, non-host specific and non-geographical-specific nature.

CONCLUSION

Our findings from this study demonstrated that Neem (*Azadirachta indica*) and Moringa (*Moringa oleifera*)leaf powder can effectively prolong the shelf life and also preserve the quality of tomato fruits beyond their typical limits. This offers a valuable information on plant leaves' potential in post-harvest preservation in addition to their known nutraceutical properties. Future studies may explore the phytochemical composition, *in vitro* and *in vivo* potentials of the leaf extract powder of the plants in preventing disease development in tomato fruits, which may possibly explicate their postharvest shelf life and quality retention potentials on tomato fruits.

REFERENCES

1. Sualeh A, Daba A, Kiflu S, Mohammed A. Effect of storage conditions and packing materials on shelf life of tomato. Food Sci. Qual. Manag. 2016;56: 60-67.

2. Babatola LA, Ojo DO, Lawal OI. Effect of storage conditions on tomato (Lycopersicon esculentum Mill.) quality and shelf life. Journal of Biological Sciences. 2008;8(2):490-493. https://doi.org/10.3923/jbs.2008.490.493.

3. Hosea ZY, Liamngee K, Owoicho AL, David T. Effect of neem leaf powder on post-harvest shelf life and quality of tomato fruits in storage. International Journal of Development and Sustainability. 2017; 6(10):1334-1349.

4. Gutiérrez-del-Río I, Fernández J, Lombó F. Plant nutraceuticals as antimicrobial agents in food preservation: Terpenoids, polyphenols and thiols. International Journal of Antimicrobial Agents. 2018;52(3):309-315.

5. Awad, A. M., Kumar, P., Ismail-Fitry, M. R., Jusoh, S., Ab Aziz, M. F. &Sazili, A. Q. (2022). Overview of plant extracts as natural preservatives in meat. Journal of Food Processing and Preservation, 46(8), e16796.

6. Arora S, Arora S. Nutritional significance and therapeutic potential of *Moringa oleifera*: The wonder plant. Journal of Food Biochemistry. 2021; 45(10): e13933.

7. Hassan MA, Xu T, Tian Y, Zhong Y, Ali FAZ, Yang X. et al. Health benefits and phenolic compounds of Moringa oleifera leaves: A comprehensive review. Phytomedicine. 2021; 93, 153771.

8. Abd El-Hack ME, Alqhtani AH, Swelum AA, El-Saadony MT, Salem HM, Babalghith AO et al. Pharmacological, nutritional and antimicrobial uses of Moringa oleifera Lam. leaves in poultry nutrition: an updated knowledge. Poultry Science, 2022;101(9):102031.

9. Azlan UK, Mediani A, Rohani ER, Tong X, Han R, Misnan NM. et al. A comprehensive review with updated future perspectives on the ethnomedicinal and pharmacological aspects of Moringa oleifera. Molecules. 2022;27(18), 5765.

10. Pareek, A., Pant, M., Gupta, M.M., Kashania, P., Ratan, Y., Jain, V. et al. Moringa oleifera: An updated comprehensive review of its pharmacological activities, ethnomedicinal, phytopharmaceutical formulation, clinical, phytochemical, and toxicological aspects. International Journal of Molecular Sciences. 2023;24(3): 2098.

11. Patil SM, Shirahatti PS, Ramu R. Azadirachta indica A. Juss (neem) against diabetes mellitus: A critical review on its phytochemistry, pharmacology, and toxicology. Journal of Pharmacy and Pharmacology. 2022;74(5):681-710.

12. Hamza A, Gumi AM, Aliero AA, Umar A, Sarkingobir Y, Tambari U. Potential of neem leaves on the preservation of selected elemental compositions in two tomato cultivars from Sokoto, Nigeria. Journal of Bioresources and Environmental Sciences. 2023;2(1):15-20.

13. Devi J, Sharma RB. Medicinal Importance of Azadirachta indica: An Overview. Journal of Drug Delivery and Therapeutics. 2023;13(6):159-65.

14. Awote OK, Kazeem MI, Ojekale AB, Ayanleye OB, Ramoni HT. Prospects of silver nanoparticles (AgNPs) synthesized by Justicia secunda aqueous extracts on diabetes and its related complications. Proceedings of the Nigerian Academy of Science. 2023; 16(1): 87-105.

15. Al-Hindi RR, Al-Najada AR, Mohamed SA. Isolation and identification of some fruit spoilage fungi: Screening of plant cell wall degrading enzymes. African Journal of Microbiology Research. 2011;5(4): 443-448.

16. Islam T, Afrin N, Parvin S, Dana NH, Rahman KS, Zzaman W. et al. The Impact of chitosan and guava leaf extract as preservative to extend the shelf life of fruits. International Food Research Journal. 2018;25(5), 2056-2062.

17. Raheja S, Thakore B. Effects of physical factors, plant extracts and bio-agent on Collectrotrichumgloeosporiodes Penz, the causal organism of anthracnose of Yam. Journal of Mycology and Plant Pathology. 2002;32:293-294.

18. Žnidarčič D, Požrl T. Comparative study of quality changes in tomato cv. 'Malike' (Lycopersicon esculentum Mill.) whilst stored at different temperatures. Acta AgriculturaeSlovenica. 2006; 87(2): 235-243.

19. Barkai-Golan R, Paster N. Mouldy fruits and vegetables as a source of mycotoxins: part 1. World Mycotoxin Journal. 2008;1(2):147-159.

20. Ijato J, Otoide J, Ijadunola J, Aladejimokun A. Efficacy of antimicrobial effect of Vernonia amygdalina and Tridax procumbens in in vitro control of tomato (Lycopersicon esculentum) post-harvest fruit rot. Report and Opinion. 2011;3(1):120-123.