European Journal of Nutrition & Food Safety

Volume 16, Issue 7, Page 34-42, 2024; Article no.EJNFS.117856
ISSN: 2347-5641

Effects of Neem, Moringa, and Synthesized Silver Nanoparticles Coating on Postharvest Shelf Life and Quality Retention of Tomato (*Solanum lycopersicum* L.)

Tolulope S. Ewekeye [a*], Olasunkanmi K. Awote [b], Wahab M. Lawal [a], Esther O. Famokunwa [a], Abdulrazak O. Adebayo [a], Titilola S. Osinaike [a] and Oyedamola A. Oke [a]

[a] Department of Botany, Faculty of Science, Lagos State University, Ojo, Nigeria.
[b] Department of Biochemistry, Faculty of Science, Lagos State University, Ojo, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. Authors TSE and OKA designed the study. Authors TSE, OKA, TSO and OAO wrote the protocol. Authors WML, EOF and AOA managed the analyses of the study and literature searches. Authors EOF and OKA wrote the first draft of the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ejnfs/2024/v16i71454

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/117856

Original Research Article

Received: 24/03/2024
Accepted: 29/05/2024
Published: 03/06/2024

**Corresponding author: Email: tolulope.ewekeye@lasu.edu.ng;*

Cite as: *Ewekeye, T. S., Awote, O. K., Lawal, W. M., Famokunwa, E. O., Adebayo, A. O., Osinaike, T. S., & Oke, O. A. (2024). Effects of Neem, Moringa, and Synthesized Silver Nanoparticles Coating on Postharvest Shelf Life and Quality Retention of Tomato (Solanum lycopersicum L.). European Journal of Nutrition & Food Safety, 16(7), 34–42. https://doi.org/10.9734/ejnfs/2024/v16i71454*

ABSTRACT

This study aimed to investigate the effects of synthesized silver nanoparticles (AgNPs), *Azadirachta indica* (neem), and *Moringa oleifera* (moringa) leaf extracts on the shelf life and quality retention of tomato (*Solanum lycopersicum* L.) fruits during storage. Thirty-five (35) red, matured tomato fruits were collected, rinsed and grouped for each treatment with AgNPs, 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), respectively. The firmness, shelf life, and postharvest decay percentage of the tomato fruits were determined. 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 *Aspergillus flavus*, were isolated from the decayed tomato 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; Postharvest; shelf life; Preservatives.

1. INTRODUCTION

Crop postharvest shelf life extension and quality retention remain a key global issue. Since food is a crucial part of human life, it is important to prevent postharvest losses and increase the shelf life of food. Tomato (*Solanum lycopersicum* L.) 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 meeting consumer demands and ensuring a stable tomato supply [3].

Plant nutraceuticals are sourced from different plant parts as antioxidant and antimicrobial agents in food preservations due to their excellent source of 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 (*Moringa oleifera*) 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]. The embedded bioactive compounds of its leaves contribute to its attributed pharmacological properties [8-13]. Neem (*Azadirachta indica*) on the other hand, is a widely available plant that contains phytochemicals [14], which can inhibit spoilage-causing micro-organisms in tomatoes, and also preserve its level of nutrients [15]. Various phytoconstituents of its leaves contribute to various attributed biological activities including, antioxidant, antidiabetic, antimicrobial, antifungal, anti-inflammatory, anti-tumor, anti-cancer, and anti-fertility [16].

Most recently, green-synthesized coatings such as plant-derived silver nanoparticles which contain considerable bioactive compounds have been investigated as a potential option to minimize fruit respiration, spoilage, and microbial growth, and thus promote postharvest shelf life and quality retention of fruits [17,18]. Here in this study, the various biological activities associated with the abundant bioactive compounds of neem and moringa have informed and necessitated the investigation into their use for silver nanoparticle synthesis and their effects on shelf life and quality retention of tomato fruits during storage.

2. MATERIALS AND METHODS

2.1 Coating Materials Preparation and Fruit Samples Collection

Fresh leaves of neem and moringa were collected 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.

Thirty-five (35) red matured, firm, smooth, and healthy tomato fruits were obtained from a local food and fruits market, Iyana Iba market, Ojo, Lagos State, Nigeria. The tomatoes were divided into five for each treatment and control group. The tomatoes were procured based on their firmness and reddish matured color before being stored at room temperature. The tomato fruits were washed under running tap 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 of distilled water separately.

2.2 Silver Nanoparticles (AgNPs) Synthesis

The leaf powder of neem and moringa (100 g each) was separately dissolved in 1000 mL distilled water, filtered, and stored. The silver nanoparticles were prepared according to the methods of [19,20] with some modifications. A freshly prepared 2 mM silver nitrate solution was mixed with neem and moringa aqueous leaf extract separately in ratios 1:9 and 6:4, respectively. The color change indicated silver nanoparticle synthesis and was further confirmed by observing the absorption peak between 400 – 450 nm using a UV-visible spectrophotometer.

2.3 Treatment of Tomato with NALE, MALE, NALE-AgNPs and MALE-AgNPs

The tomato samples were immersed in neem and moringa aqueous leaf extract separately before being arranged in a clean container and kept at room temperature on the Laboratory table. Changes were observed and data were recorded for the 15 days of treatment to ascertain the effects of the extracts. Conversely, another set of tomatoes was immersed in each AgNP solution for 2 hours before being placed in a clean container in the laboratory at 25°C. Changes were also observed and data were recorded for the 15 days of treatment to ascertain the effects of the synthesized AgNPs.

2.4 Data Collection

The post-harvest decay percentage (PDP), marketability, shelf-life, and firmness of the tomato fruits were calculated [21] using:

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

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

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/inch^2). 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 the modified procedures of [22].

2.6 Statistical Analysis

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

3. RESULTS

The 15-days experiment showed that the control group's tomatoes spoiled by the 8th day, losing their firmness from the 5th day. However, tomatoes coated with neem aqueous leaf extract synthesized silver nanoparticles (NALE-AgNPs) solution (6:4) lasted 12 days, with significant weight loss from day 6. Another variant (1:9) 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.

The 15-days experiment revealed that all the tomato fruits 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) and some lasting until the 10th day (in a 1:9). Significant differences in weight loss were observed on specific days between moringa-coated and control fruits, as well as between silver nanoparticle-coated and control fruits.

Table 1. Effects of NALE and NALE-AgNPs coatings on the weight of *S. lycopersicum*

Groups/Days	Control	NALE	Nano 1	Nano 2
IW1	91.50 ±4.64^{a}	74.57 ±12.26^{b}	80.87 ±4.92^{c}	83.23 ± 8.14^{c}
IW2	91.50 ± 4.64^{a}	84.3^{0}± 12.50^{b}	81.97 ± 4.88^{b}	84.80 ± 8.41^{b}
DAT 1	89.60 ± 4.32^{a}	79.03 ± 12.08^{b}	80.83 ± 3.85^{b}	83.00 ± 8.29^{b}
DAT 2	88.07 ± 4.16^{a}	76.70 ± 12.08^{b}	78.83 ± 3.23^{b}	81.47 ± 8.11^{b}
DAT 3	82.33 ± 3.61^{a}	75.33 ± 13.25^{b}	76.13 ± 4.37^{b}	80.23 ± 7.88^{a}
DAT 4	79.30 ± 6.67^{a}	75.30 ± 11.98^{b}	72.57± 5.50^{b}	78.37 ±7.04^{a}
DAT 5	75.80 ±6.05^{a}	73.37 ±13.20^{a}	73.30 ±4.03^{a}	78.83 ± 8.34^{b}
DAT 6	70.30 ± 4.21^{a}	72.60 ±13.10^{a}	71.10 ± 4.33^{a}	76.50 ±7.02^{b}
DAT 7	66.57 ± 4.10^{a}	71.87 ± 12.64^{b}	68.57± 5.31^{a}	74.27 ± 6.12^{b}
DAT 8	61.93 ± 4.73^{a}	71.40 ± 12.47^{b}	67.27 ± 5.14^{c}	69.20± 4.50^{c}
DAT 9	0.00 ± 0.00^{a}	70.93 ± 12.14^{b}	65.97 ± 4.97^{c}	67.40 ± 2.94^{c}
DAT 10	0.00 ± 0.00^{a}	67.60 ± 11.00^{b}	64.73 ± 4.73^{c}	65.00 ±1.39^{c}
DAT 11	0.00 ± 0.00^{a}	64.33 ± 11.75^{b}	63.83± 4.39^{b}	57.33± 0.75^{c}
DAT 12	0.00 ± 0.00^{a}	62.87 ± 12.24^{b}	62.87 ± 4.27^{b}	49.40± 0.35^{c}

Mean ± SEM values with the same alphabet in the same row are not significantly different from each other at p<0.05, where, NALE= Neem aqueous leaf extract, Nano 1 = Neem aqueous leaf extract dissolved in $AgNO_3$ at 1:9, and Nano 2 = Neem aqueous leaf extract dissolved in $AgNO_3$ at 6:4, IW1= Initial weight before coating, IW2= Initial weight after coating. DAT= Days after treatment

Table 2. Effects of MALE and MALE-AgNPs coatings on the weight of *S. lycopersicum*

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

Mean ± SEM values with the same alphabet in the same row are not significantly different from each other at $p<0.05$, where, MALE= Moringa aqueous leaf extract, Nano 3 = Moringa aqueous leaf extract dissolved in $AgNO_3$ at 1:9, and Nano 4 = Moringa aqueous leaf extract dissolved in $AgNO_3$ at 6:4, IW1= Initial weight before coating, IW2= Initial weight after coating. DAT= Days after treatment

Table 3. Post-harvest decay percentage of tomato fruits coated with NALE, MALE, 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	*	*	*

** Denotes null set (totally decayed sample)*

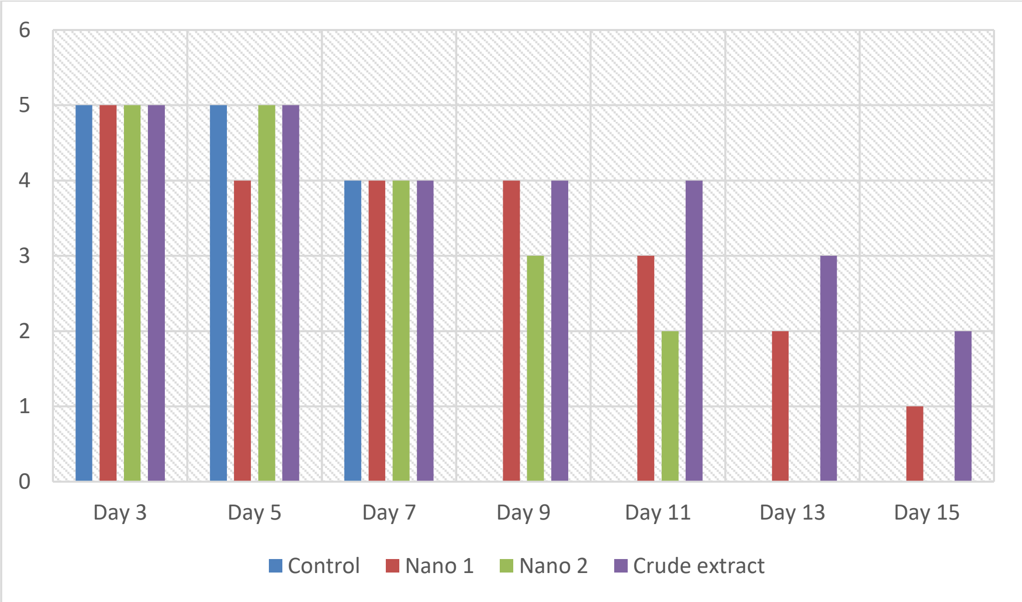

Fig. 1. Firmness of Tomato coated with NALE crude and NALE-AgNPs during storage

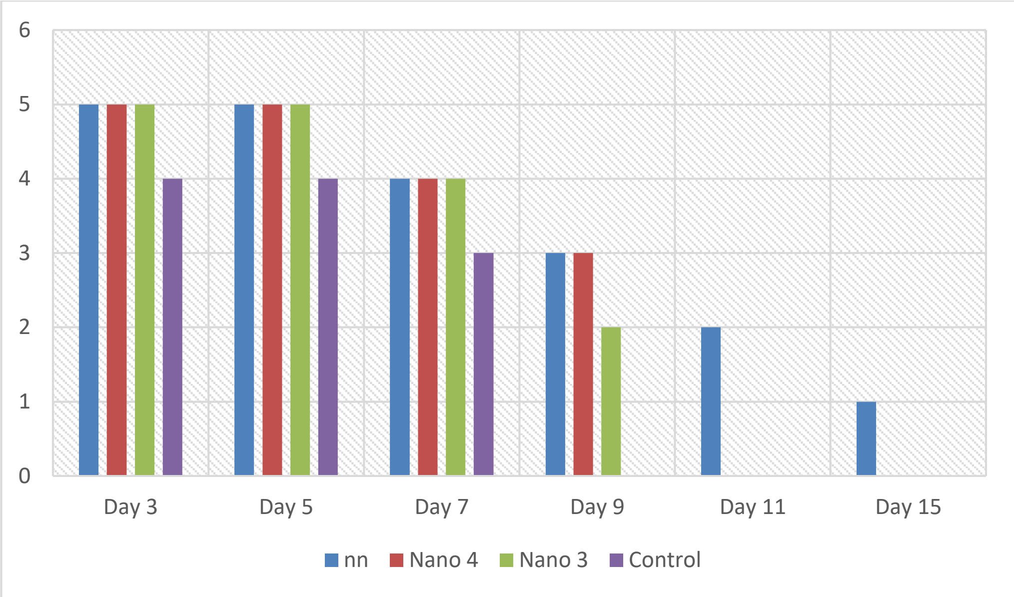

Fig. 2. Firmness of Tomato coated with MALE crude (nn) and MALE-AgNPs during storage

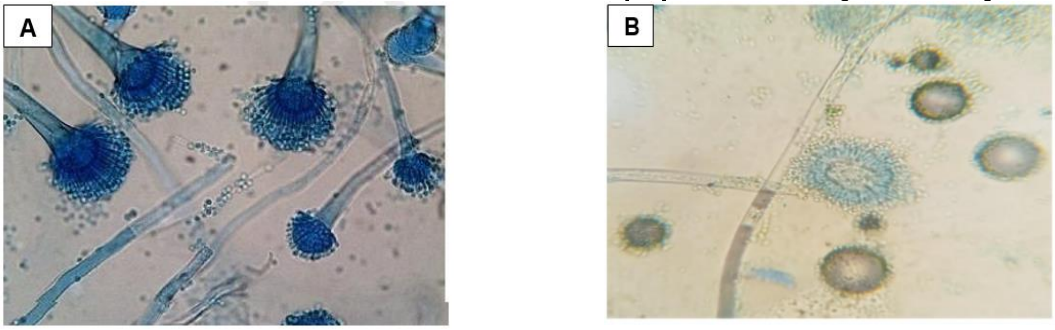

Fig. 3. Photomicrograph of (a) *Aspergillus niger* (X400) (b) *Aspergillus flavus* (X400) isolated from deteriorated tomato fruits

Table 3 illustrates the postharvest decay of tomato fruits during the 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.

Figs. 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.

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

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

4. DISCUSSION

The prevention of fruit spoilage by pathogenic fungi and the 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 [23], 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 [24], who highlighted the effectiveness of extracts from medicinal plants like *Allium sativum*, *Azadirachta indica*, *Mentha arvensis*, and *Psoralia corlylifolia* in preserving fruits from pathogenic and environmental factors. Moreover, in this study, neem aqueous leaf extract increased the shelf life of the fruits, possibly by reducing the fungal and bacterial spoilage during storage.

Tomatoes coated with moringa and neem aqueous leaf extracts exhibited reduced post-harvest decay, as reflected in the reduced number of decayed fruits compared to the control, NALE, and MALE-AgNPs. 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 coated tomato fruits still maintained and retained their colour and number but became completely rotten on the 15th day. The tomato fruits coated with MALE-AgNPs at different concentrations had lower postharvest decay percentages. This implied that coating with MALE-AgNPs could help tomato fruits resist environmental and pathogenic attacks better than other treatments. The observed progressive weight loss in neem-coated tomatoes and control aligns with the report of [25], 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.

Another possible reason why the incorporation of silver nanoparticles showed lower preservative effects on tomatoes compared to the leaf extracts of neem and moringa could be attributed to the complex interactions between silver nanoparticles and the tomato surface, as well as the distinct antimicrobial properties of the leaf extracts. AgNPs exert antimicrobial activity primarily through the release of silver ions that disrupt microbial cell membranes and inhibit cellular processes [26], the antimicrobial mechanisms of neem and moringa leaf extracts are multifaceted and may involve the inhibition of microbial enzymes and disruption of cell membranes, which interferes with microbial metabolism [27]. This diversity in antimicrobial mechanisms could contribute to the superior preservation effects of the leaf extracts on tomatoes compared to AgNPs.

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 are *Aspergillus niger* and *A. flavus*, which have previously been reported as pathogens of tomato fruits [28,29]. They have also been found in other crops including orange, sour-sop, and garri (fried mashed fermented cassava) [3]. Association of these fungi with these fruits or foods may suggest their omnipresent, non-host-specific, and non-geographical-specific nature.

5. CONCLUSION

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

ACKNOWLEDGEMENTS

The authors are grateful to Mr. Mautin Ogun for assisting with the statistical analysis.

COMPETING INTERESTS

The authors have declared that no competing interests exist.

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.
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 AM, Kumar P, Ismail-Fitry MR, Jusoh S, Ab Aziz MF, Sazili AQ. Overview of plant extracts as natural preservatives in meat. Journal of Food Processing and Preservation. 2022;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 MM, 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. Mwankunda LJ, Nyamete F, Kilima B. Exploring the Influence of *Moringa oleifera* Leaves Extract on the shelf life of ground beef during refrigerated storage. Euro. J. Med. Plants. 2023 Nov. 25 [cited 2024 May 19];34(10):42-5. Available:https://journalejmp.com/index.php/EJMP/article/view/1164
12. Arun AT, Pramod R, Radhakrishnan NV, Thara SS, Reji Rani OP, Anuradha T. Role of chitosan in post harvest disease management. J. Adv. Biol. Biotechnol. 2024 May 11 [cited 2024 May 19];27 (6):235-51. Available:https://journaljabb.com/index.php/JABB/article/view/882
13. Zambrano-Zaragoza ML, Mercado-Silva E, Ramirez-Zamorano P, Cornejo-Villegas MA, Gutiérrez-Cortez E, Quintanar-Guerrero D. Use of solid lipid nanoparticles (SLNs) in edible coatings to increase guava (*Psidium guajava* L.) shelf-life. Food Research International. 2013 May 1;51(2):946-53.
14. 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.
15. 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.
16. Devi J, Sharma RB. Medicinal Importance of *Azadirachta indica*: An Overview. Journal of Drug Delivery and Therapeutics. 2023;13(6):159-65.
17. Vieira ACF, de Matos Fonseca J, Menezes NMC, Monteiro AR, Valencia GA. Active coatings based on hydroxypropyl methylcellulose and silver nanoparticles to extend the papaya (*Carica papaya* L.) shelf life. International Journal of Biological Macromolecules. 2020;164:489-498.
18. Nayab DE, Akhtar S. Green synthesized silver nanoparticles from eucalyptus leaves can enhance shelf life of banana without penetrating in pulp. Plos one. 2023;18(3):e0281675.
19. Awote OK, Kazeem MI, Ojekale AB, Ayanleye OB. and 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. 2023a;16(1):87-105.
20. Awote OK, Adeyemo AG, Apete SK, Awosemo RB, Azeez HD, Salako DS. et al. *Jatropha tanjorensis* aqueous extracts synthesized silver nanoparticles possesses antidiabetic, antiglycation, antioxidant and anti-inflammatory potentials. Journal of Research and Reviews in Science. 2023b;10:41-55.
21. Monerzumma KM, Hossain ABMS, Sanni W, Saifuddin M, Alinazi M. Effect of harvesting and storage condition on the postharvest quality of *Lycopersicum esculentum* (Tomato). Aust J. Crop Sci. 2009;3:113-121.
22. 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.
23. 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.
24. Raheja S, Thakore B. Effects of physical factors, plant extracts and bio-agent on *Collectrotrichum gloeosporiodes* Penz, the causal organism of anthracnose of Yam. Journal of Mycology and Plant Pathology. 2002;32:293-294.
25. Žnidarčič D, Požrl T. Comparative study of quality changes in tomato cv. 'Malike' (*Lycopersicon esculentum* Mill.) whilst stored at different temperatures. Acta Agriculturae Slovenica. 2006;87(2):235-243.
26. Awote OK, Anagun OS, Adeyemo AG, Igbalaye JO, Ogun ML, Apete SK. et al. Green-synthesized silver nanoparticles by using fresh *Justicia Secunda*, *Telfairia occidentalis*, and *Jatropha tanjorensis* aqueous leaf extracts against clinical and environmental bacterial isolates. Asian J. Green Chm. 2022;6(4):284-296.
27. Morones JR, Elechiguerra JL, Camacho A, Holt K, Kouri JB, Ramírez JT. et al. The bactericidal effect of silver nanoparticles. Nanotechnology. 2005; 16(10):2346.
28. Barkai-Golan R, Paster N. Mouldy fruits and vegetables as a source of mycotoxins: part 1. World Mycotoxin Journal. 2008;1(2):147-159.
29. 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.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/117856