Extension of the shelf life of tomato fruit (*Solanum lycopersicum*) using wood ash

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Submission: 17 May 2020 Revised: 1 December 2022 Accepted: 12 December 2022

ABSTRACT

Despite the large volumes produced annually, postharvest decay is a significant challenge in the tomato industry. These losses are high due to poor storage technologies. This study investigated the preservative effect of wood ash on the physicochemical and microbiological quality of tomato (*Lycopersicum solanum*) fruits. Red, fully ripened tomato fruits were embedded separately in local wood ash (LWA) and *the Azadirachta indica* plant (AWA) ash. Fruits were stored at 28 ± 2°C in the ash for six weeks, and samples were analyzed weekly for spoilage signs and changes in physicochemical, nutritional, and microbiological contents. Results showed that wood ash effectively preserved the tomato fruits for four weeks, and the fruits maintained an acceptable quality up to this period. LWA showed a slightly better preservative effect regarding sensory attributes than AWA, with the latter offering a greater extent of deterioration. Control tomato fruits completely decayed within three days of storage. Both treatments increased the pH, titratable acidity, total sugars, weight loss, phenolics, ascorbic, and lycopene contents during storage. Microbial counts decreased during storage, with *Enterobacter* sp., *Bacillus thuringiensis*, and *Aspergillus* being the dominant organisms. These findings show that wood ash can extend the shelf life and preserve tomatoes' nutritional and antioxidant content.

Keywords: *Azadirachta*, shelf life, spoilage, tomato preservation, wood ash

Thai J. Agric. Sci. (2022) Vol. 55(3): 161−174

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a widely consumed fruit crop and a major component of household diets worldwide. The fruit is rich in carotenoids, minerals, and vitamin C. In addition, increased consumption of tomatoes has been associated with reduced risk of certain cancers, stroke, cardiovascular disease, and mortality (Kris-Etherton *et al*., 2002). Nigeria is the second largest producer of tomatoes in Africa and the 14th in the world. About 2.14 million tonnes of the crop was produced in Nigeria in 2014, and this represents a 100% increase in production compared to 2007 (FAOSTAT, 2017). This rapid increase shows that tomato production has seen a steady improvement in Nigeria. Surprisingly, the country imports a large volume of the crop yearly despite the huge production level (Shiyam *et al*., 2017); furthermore, Nigeria is not recognized among the top exporters. Annual postharvest losses of tomatoes in Nigeria are around 45–60%, and these losses have been attributed to poor transportation and storage practices (Amadi *et al*., 2019). Hence, a significant part of harvested tomatoes gets spoilt even before they reach the market.

Several methods have been reported for the preservation of tomatoes and the extension of their shelf life. Traditionally, methods such as refrigeration, modified atmosphere packaging, and the use of certain chemicals have been widely applied (Arah *et al*., 2016). However, these methods often

affect some of the desirable qualities of the fruit and are too expensive and technical for the use of local farmers. Furthermore, they are not always effective. The efficacy of more modern methods has also been demonstrated by many researchers. Some of them include coating with chitosan (Benhabiles *et al.*, 2013), UV-C irradiation (Mansourbahmani *et al.*, 2017), ultrasonication (Pinheiro *et al.*, 2016), hyperbaric pressure treatment (Liplap *et al.*, 2013) among others. The reality is that these methods are highly sophisticated and may not be practical for farmers in most Nigerian villages where the level of poverty is high. It is therefore expedient to explore alternative methods of preservation that are cheap and simple to use by local farmers (Arah *et al.*, 2015a).

One locally available material which has not been well-explored for the preservation of crops is wood ash. Wood ash is the inorganic residue that is left behind when the wood is combusted. Ash from various kinds of wood has been applied by local farmers in rural communities for the preservation of grains, seeds, and tubers (Eze *et al.*, 2015; Negi and Solanki, 2015). Studies have shown that wood ash contains components that can promote the growth of seedlings and that are inhibitory to certain pathogenic microorganisms (Oguntade and Adekunle, 2010; Nabeela *et al.*, 2015). Reports of the use of wood ash for the preservation of tomatoes are rare. Theu (2008) reported that wood ash was able to preserve tomato fruits for 4 weeks. However, the conclusion of the author was based only on fruit firmness as the only indicator of preservation. Furthermore, the effect of wood type was not examined. Since most rural farmers already use wood for cooking and other domestic purposes, the use of wood ash would be an easy and cheap alternative for them to preserve their produce.

The objective of this study was to evaluate the effect of wood ash treatment on the shelf life of tomato fruits. Ash of *Azadirachta indica* and wood ash obtained from local cottage industries were compared for their effect on the microbiological and physicochemical properties of embedded tomato fruits throughout the period of storage. To the best of our knowledge, this is the first report employing microbiological and physicochemical parameters, and not just mere visual assessment, to study the effect of wood ash on the preservation of tomato fruits.

MATERIALS AND METHODS

Collection of Tomato Fruits

Fresh samples of mature red ripe, bruise-free tomato fruits were collected from the Mandate market in Ilorin, north-central Nigeria. The samples were authenticated as *Solanum lycopersicum* at the Herbarium Unit of the Department of Plant Biology, University of Ilorin, with voucher number UILH/002/158

Preparation of Wood Ash

Two types of wood ash were investigated for their ability to preserve the tomato fruits. Local wood ash (LWA) was obtained from local producers of garri, an indigenous fermented cassava product. The type of wood used in preparing these ash samples was not known exactly but the most used wood type in the community is the African locust beans (*Parkia biglobosa*) tree and less of other tree types. The collected ash was allowed to cool and was then sieved (sieve size 75 µm with 200 mesh) to remove large particles. The fine ash powder was stored in a dry airtight container and kept pending usage in the laboratory. Fresh stems of the *Azadirachta* plant were collected and authenticated at the Herbarium Unit of the Department of Plant Biology, University of Ilorin, with voucher number UILH/001/986. Azadirachta wood ash (AWA) was prepared by burning the stem and bark of the neem (*Azadirachta indica*) plant in a muffle furnace at 600°C for 8 hours. The produced ash was sieved and kept as described for the LWA.

Characterization of Wood Ash

The morphology of each ash sample was studied using a Hitachi S-4500 Scanning Electron Microscope (SEM) equipped with a Thermo Energy-Dispersive X-Ray Spectroscopy (EDX) unit. A small amount of the sample was placed on a carbon-coated copper grid and examined at a magnification of up

to 5Kx. Elemental analysis was performed using EDX. The pH of the samples was determined by adding 1 g of ash to 50 mL of distilled water and measuring with an Inolab pH7310 pH meter (WTW, Germany).

Preservation of Tomato Fruits with Wood Ash

A total of 72 tomato fruits, each weighing approximately 50 g, were mixed with wood ash at the ratio of 1:10 (w/v) in a clean paper carton box, with 12 tomato fruits per carton. The bottom of the box was lined with paper and 2,000 g of ash was layered onto it. Tomato fruits were then placed onto the ash separately while ensuring that the fruits did not touch each other or the sides of the box. Storage was carried out at room temperature at 28 ± 2°C. The remaining wood ash (4,000 g) was then used to cover the fruits completely. The entire setup was covered with the carton top without complete sealing. Triplicate boxes were set up and one fruit sample was taken from each box weekly, making a total of 3 samples per week for each ash type. Another box, which served as control was set up in a similar manner but without the application of ash. The experiment was continued for 6 weeks and collected samples were subjected to microbiological and physicochemical analysis.

Microbiological Analysis of Tomato Fruits

Samples of tomato fruits collected weekly were analyzed for the presence of bacteria and fungi. A suspension of the sample was prepared by adding 1 g to 10 mL of sterile distilled water. Appropriate dilution of the suspension was inoculated onto nutrient agar (NA) or potato dextrose agar (PDA) for bacteria and fungi respectively using the pour plate technique. Plates were then incubated at 37°C for bacteria and 25°C for fungi. Colonies appearing after incubation were purified on sterile plates of the respective media and pure cultures were stored on agar slants. Bacterial isolates were identified using standard morphological and biochemical tests as described by Fawole and Oso (2004). Identities of the bacterial isolates were confirmed by molecular characterization using 16S rDNA sequencing at the Bioscience Center, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Fungal identification was done by observing the morphological and microscopic characteristics of the colonies and confirming their identities in a reference fungal compendium (Watanabe, 2002).

Physicochemical Analysis of Tomato Fruits

The tomato samples were rinsed in three changes of distilled water and patted dry with filter paper before physicochemical analysis. The pH of the tomato fruits was determined using an Inolab pH 7310pH meter (Inolab, Germany). A mass of 1 g of tomato was weighed into 50 mL of distilled water and pH readings were taken (Nabeela *et al.*, 2015). Titratable acidity (TA) was determined using the titrimetric method described by AOAC (2005).

The vitamin C content was determined using a modification of the method described by Omaye *et al.* (1979). 25 µL of sample homogenate, 25 µL of water, and 50 µL of ice-cold 10% TCA were added, mixed thoroughly, and centrifuged at 3,500 g for 20 minutes. The supernatant (50 µL) was then mixed with 10 µL of DTC reagent (0.4 g thiourea + 0.05 g $CuSO_4.5H_20$ + 3.0 g 2,4-dinitrophenylhydrazine made up to 100 mL with 9 N H_2SO_4) and incubated at 37°C for 3 hours. Then 75 µL of ice-cold 65% H_2SO_4 was added, mixed well and the solution was allowed to stand for 30 minutes at room temperature. The color developed was read at 520 nm in a spectrophotometer. Ascorbic acid standards were prepared in the range of 0 to 20 µg/mL and processed in a similar manner as the blank (5% TCA).

Total phenol was determined using the Folin Ciocalteu reagent method as described by McDonald *et al.* (2001). An extract of the sample homogenate was prepared with 1 g of the sample and 10 mL of methanol: water (50:50, v/v). The extract (10 µL) was diluted (1:10) and mixed with 100 µL of Folin Ciocalteu reagent (1:10 diluted with distilled water) and 80 µL of aqueous Na_2CO_3 (1M). Gallic acid which served as the reference phenolic standard was mixed in a similar manner. The mixture was then allowed to stand for 15 minutes and the optical density of the mixture was determined against the blank at 765 nm. Total phenol values

were expressed as gallic acid equivalent (g/100 g fresh weight of fruit) extrapolated from a standard curve of varying gallic acid concentrations in 100 µL methanol: water (50:50, v/v).

Total sugars were determined using the dinitrosalicylic acid method as described by Bernfeld (1955). The homogenate was centrifuged for 10 minutes and 10 mL of supernatant was diluted with 1 mL of saline solution and mixed with 50 mL of DNS reagent. The mixture was incubated in a boiling water bath for 5 minutes and cooled to room temperature (28 ± 2°C). The reaction mixture was then diluted by adding 5 mL of distilled water and absorbance was measured at 540 nm. The concentration of glucose in each sample was quantified by extrapolating from the glucose standard curve.

Lycopene concentration was determined using the method of Fish *et al.* (2002). Lycopene content was determined spectrophotometrically at 503 nm after extraction with hexane using the molar extinction coefficient of 17.2 $Lmol^{-1}mL^{-1}$.

Physiological Weight Loss

Tomato fruits were weighed using an Analytical Mettler Balance. Samples were weighed periodically on a weekly basis. The resultant weight loss was calculated and expressed as a percentage of the fresh weight (Abebe *et al.*, 2017).

Ash Content

Ash from firewood and neem-tree branches was determined using the method of AOAC (2005).

Sensory Characteristics

The samples were also examined for color, texture, and odor throughout the period of storage and were compared with the control samples.

Statistical Analysis

Experiments were conducted in triplicates and results were recorded as mean ± standard deviation. One-way repeated measures ANOVA and Tukey's HSD post hoc analysis were conducted to compare the effects of LWA and AWA on the studied parameters over the duration of the study. All statistical analyses were done using Minitab 17 statistical software package (Minitab Inc, USA). The significant differences were considered at $P < 0.05$.

RESULTS AND DISCUSSION

Characterization of Wood Ash

The pH for both ash samples was found to be highly alkaline (Table 1), with LWA having a slightly lower pH (10.41) than AWA (10.66). The percentage compositions of the wood ash samples as determined by Energy Dispersive X-Ray (EDX) spectroscopy also showed that LWA had a higher percentage of alkali/alkaline earth metals and moderately active non-metals compared to AWA; the latter had a lower percentage of those metals but a higher amount of highly volatile non-metals. Furthermore, the percentage of transition, metalloid, and poor metals in AWA was slightly higher than that of LWA. The percentage of ash composition for AWA was 89.11% while that of LWA was 93.23% (Table 1).

Table 1 Physicochemical characterization of local and *Azadirachta* wood ash samples

Physicochemical parameters	LWA (%)	AWA (%)
pH	10.41	10.66
Ash composition	93.23	89.11
Alkali and alkaline earth metals	46.46	37.80
Transition, metalloid and poor metals	12.12	12.60
Moderately active non-metals	21.21	17.32
Highly volatile non-metals	20.21	32.28
Total metals	100.00	100.00

Note: LWA = local wood ash sample, AWA = *Azadirachta* wood ash sample

The scanning electron microscopic (SEM) images of both LWA (Figure 1) and AWA (Figure 2) showed that most of the particles in both ash samples had a size of about 20 µm. The LWA particles were more uniform in size while those of AWA showed a broad particle size distribution.

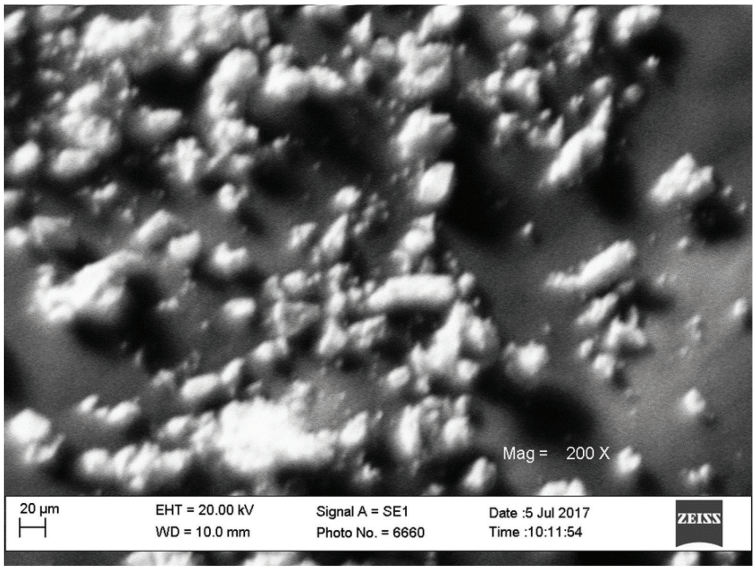

Figure 1 Scanning electron microscope image of local wood ash particles

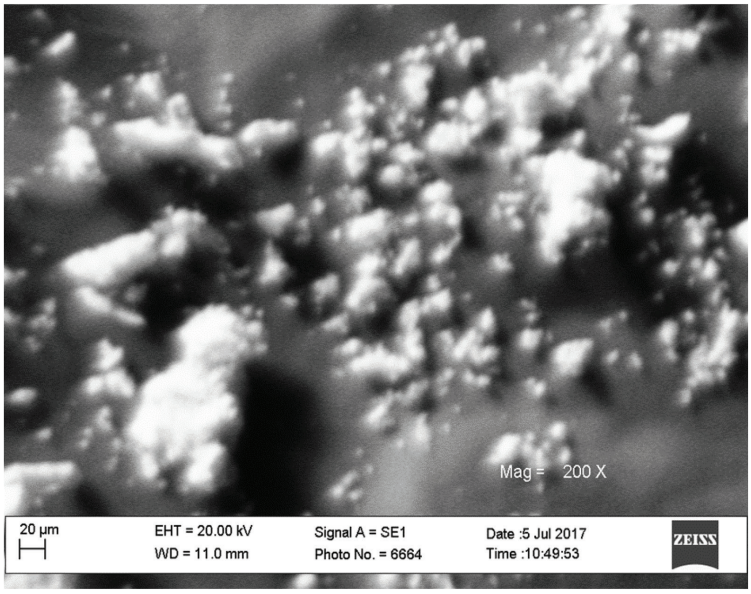

Figure 2 Scanning electron microscope image of *Azadirachta* wood ash particles

The characteristics of the wood ash are expected to offer some level of protection against spoilage of the tomato fruits. The high pH recorded with both wood ash samples in this study is in line with previous reports, which have shown that wood ashes are usually highly alkaline; as high as 13.3 in certain wood types (Kuokkanen, 2009). This has been attributed to the presence of basic metal salts in the ash (Nabeela *et al*., 2015). The higher ash content of LWA may be due to the higher rate of combustion and the presence of higher amounts of non-combustible metals (transition, metalloids, and poor metals). A higher combustion rate may also result in finer particles, resulting in uniform particle size distribution as observed in the microstructural examination of the ashes. Pitman (2006) reported that variations in the chemical compositions of different ash samples can be due to differences in tree species, the tree component used as fuel, and the temperature of combustion.

Microfilms from polymeric substances such as chitosan have been employed in preserving tomato fruits and extending their shelf life. Formation of films in sub-micron ranges has been shown to reduce respiration rate and absorption of moisture, and maintain water content level, rigidity of fruits, and protection of the pectin layer of tomato fruits (Thumula, 2006; Benhabiles *et al*., 2013; Nisha *et al*., 2016). The particle sizes of the ashes used in this study can form a microstructural protecting layer around the tomato fruits, therefore protecting them in a similar manner as a polymeric microfilm. In addition, the more uniform microparticle size distribution observed in the LWA may also lead to fine and smooth self-assembly of protective layers than AWA resulting in better preservation capability of the LWA as observed.

Effect of Preservation with Wood Ash on the Appearance of Tomato Fruits

The control tomato samples were completely decayed by the third day of storage. Little difference in appearance was observed between fruits preserved with both LWA and AWA in the first 3 weeks (Figure 3). Fruits from both treatments maintained firm and smooth skin in the first week but slight wrinkles in the skin became noticeable in the second week. In the third week, both samples began to have fragile and wrinkled skin, and this was the same observation in the fourth week, except that the AWA-treated fruits became more extensively shrunken and started giving off an unpleasant odor. In the fifth and sixth weeks, samples from both treatments deteriorated significantly with extensive shrinking, wrinkled skin, and an unpleasant odor. Generally, the fruits maintained an acceptable quality up to the fourth week while they became unacceptable beyond this period. AWA-treated samples showed a greater extent of decay than the LWA-treated ones. Shrinkage of tomato fruits is due to the loss of moisture, which was caused by the low relative humidity of storage. The delay in shrinkage of the tomatoes preserved by both ash types can be attributed to the prevention of moisture loss from the surface of the fruits by ash during storage (Arah *et al.*, 2015b). The unpleasant odor observed at the end of the period was attributed to putrefaction caused by microbial activity.

Physicochemical Characteristics of Tomato Fruits

The results of the changes in various physicochemical parameters studied shown in Figures 4–8 indicated that the pH of the tomato samples increased steadily in both LWA- and AWA-treated samples from the acidic to the alkaline range at the end of the sixth week of storage (Figure 4A). Although AWA-treated fruits had slightly higher pH than LWA-treated ones in the sixth week, there was no significant difference ($P > 0.05$) between them throughout the storage period. This observation is consistent with the close pH values of both wood ash samples as indicated in Table 1.

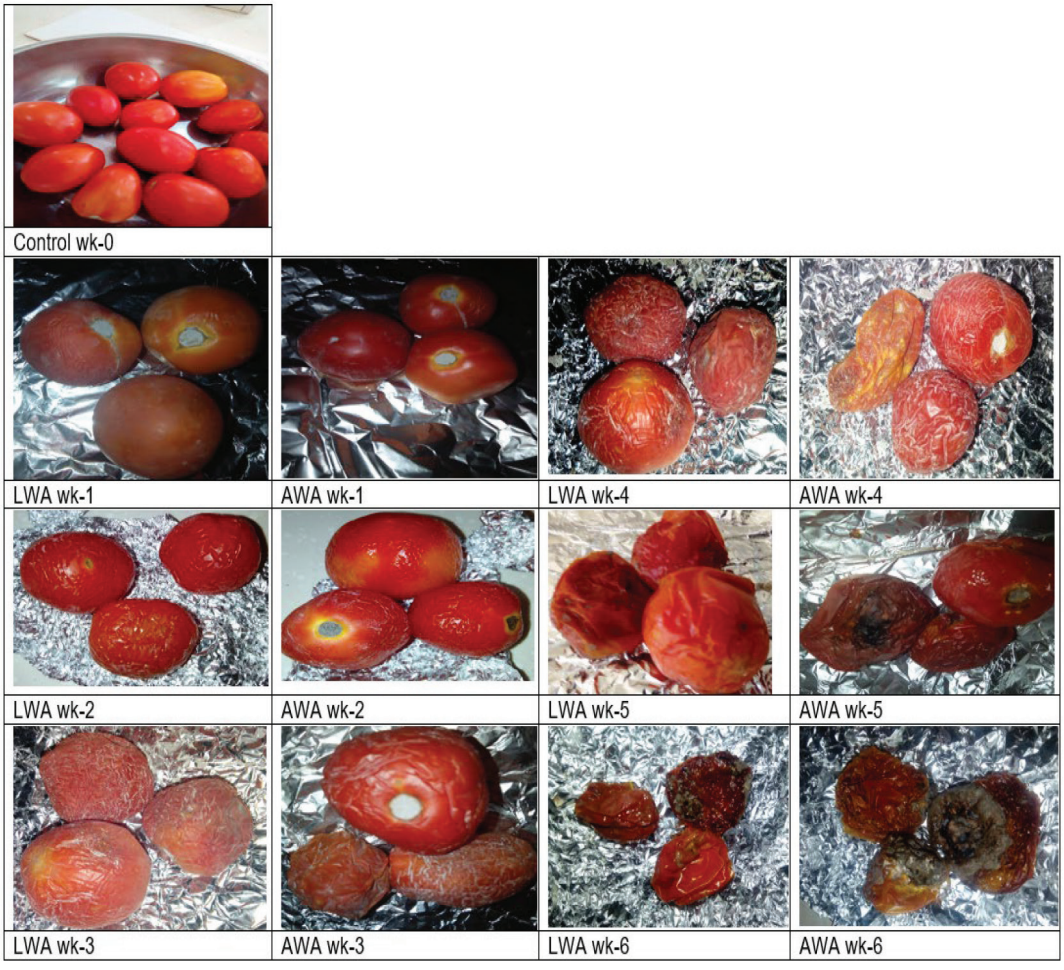

Figure 3 Appearance of tomato fruits preserved with LWA and AWA for a period of 1 to 6 weeks

Titratable acidity in tomatoes preserved with both ashes initially declined in the first 7 days and then increased till the end of the storage period (Figure 4B). This may be due to the loss of weight of the tomato fruits, which led to a concentration of the total acids in the tomato samples. This observation contradicts previous findings (Ali *et al.*, 2010; Benhabiles *et al.*, 2013), which reported a decrease in acidity during storage with various treatments. However, the fruits used in this study were mature red ripe fruits unlike in other studies that used partially ripened fruits (Ali *et al.*, 2010; Benhabiles *et al.*, 2013; Candir *et al.*, 2017). In climacteric fruits like tomatoes, respiration that occurs during ripening causes a reduction in acidity due to the use of organic acids as substrates for respiration. However, respiration is not expected to occur at such a high rate in completely ripened red fruits. Calegario *et al.* (2001) observed that fully matured tomato fruits had low respiration rates and incipient red tomato fruits had higher respiration rates than matured fruits. Therefore, the increase in TA in this study might be due to the conversion of sugars into organic acids by the fermentative microorganisms associated with the fruits. It is not clear why AWA-treated fruits had higher acidity ($P < 0.05$) than LWA-treated ones, but it is possible that the non-uniform distribution of the AWA (Figure 2) might have led to a lower shielding effect of the ash on the surface of the tomatoes.

The changes in the ascorbic acid content of the ash-treated tomatoes showed a steady increase during storage (Figure 5A). This observation correlates with those of some earlier studies, which indicated that the ascorbic acid content of tomato fruits increased during storage (Ali *et al.*, 2010; Benhabiles *et al.*, 2013). This high content of acid can be linked to the high titratable acidity of the fruits following ash treatment. High titratable acidity and the presence of phenolic compounds have been reported to help maintain ascorbic acid levels in fruits (Toor and Savage, 2006). Furthermore, the loss of moisture of the tomatoes during storage (Figure 7) could lead to the concentration of the total ascorbic acid content of the samples. The LWA-treated tomatoes had higher ascorbic acid levels ($P < 0.05$) than the AWA-treated ones, especially after the first week of storage. This may be due to the reduced permeability to oxygen of the LWA ash because of its microstructure, which could result in a reduced rate of ascorbic acid oxidation in the LWA-treated fruits.

There was an increase in the total sugar content of the tomatoes with no significant difference ($P > 0.05$) between the two ash samples (Figure 5B). The increase in the sugar content of the preserved tomato may be due to the concentration of the sugars due to weight loss during storage as well as the degradation of the fruit starch by the amylases in the fruits (Benhabiles *et al.*, 2013).

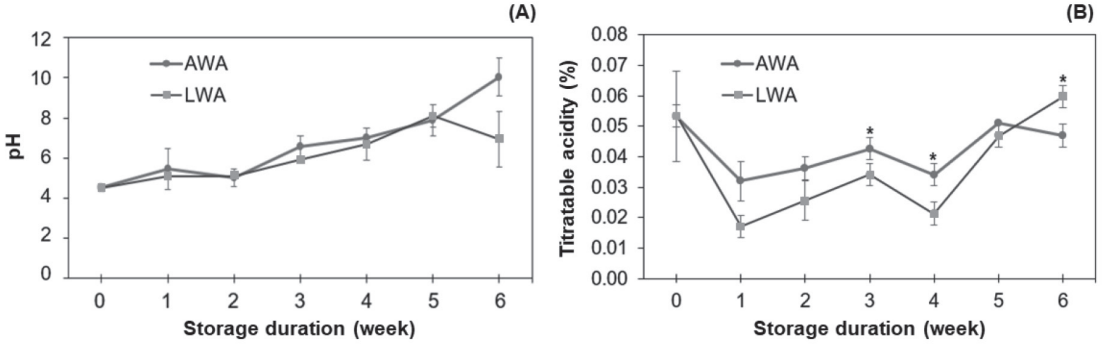

Figure 4 Changes in pH (A) and titratable acidity (B) during storage of tomato fruits preserved with local (LWA) and *Azadirachta* wood ash (AWA). Treatments with the * symbol are significantly different ($P < 0.05$).

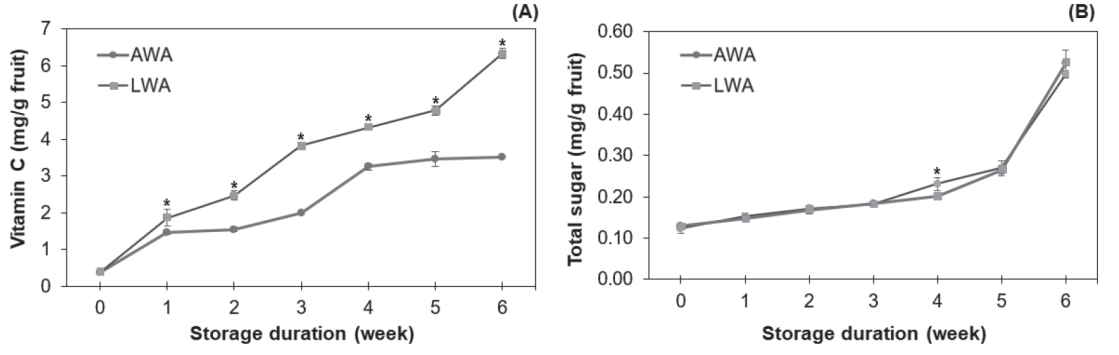

Figure 5 Changes in vitamin C (ascorbic acid) content (A) and total sugars (B) during storage of tomato fruits preserved with local (LWA) and *Azadirachta* wood ash (AWA). Treatments with the * symbol are significantly different ($P < 0.05$).

Total phenolics of tomatoes preserved with the wood ashes increased with the storage period (Figure 6A) with LWA-treated samples having a higher concentration of phenolic content ($P < 0.05$) than samples treated with AWA. This increase in the number of phenolics can be attributed to the shielding effect of the ash samples on phenol oxidase and peroxidase enzymes in the fruits. These two enzymes are responsible for the degradation of phenolic compounds in fruits. Postharvest treatments that prevent the free entry of oxygen, which could facilitate the action of these enzymes help in preserving the phenolics (Tomás-Barberán and Espín, 2001). The higher concentration of phenolics in the LWA-treated fruits is an indication of the greater shielding and coating of the tomato by LWA. In addition, phenolic substances are reported to have a protective effect on ascorbic acid (Miller and Rice-Evans, 1997).

The lycopene content of the AWA-treated tomatoes remained fairly constant throughout the storage period while that of the LWA-treated fruits increased steadily with significantly higher levels ($P < 0.05$; Figure 6B). The bright red coloration of ripe tomato fruits is due to their high lycopene content (Shi *et al.*, 1999). During ripening, chloroplasts are converted to chromoplasts with the simultaneous conversion of chlorophyll to lycopene, which is manifested as a change in color from green to red (Abebe *et al.*, 2017). Toor and Savage (2006) reported that the lycopene content of light red tomatoes may be increased up to 3-fold when stored between 15–25°C. The increase in lycopene content observed in this study correlates with the findings of Ali *et al.* (2013) and Abebe *et al.* (2017).

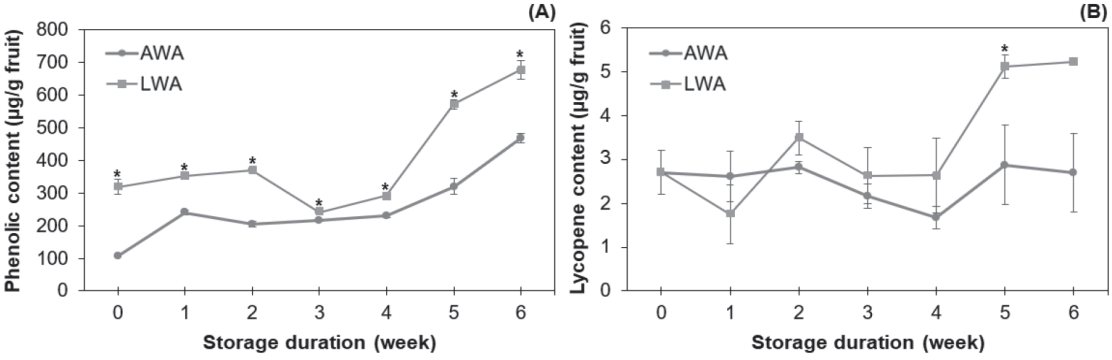

Figure 6 Changes in phenolic (A) and lycopene (B) content during storage of tomato fruits preserved with local (LWA) and *Azadirachta* wood ash (AWA). Treatments with the * symbol are significantly different ($P < 0.05$).

Weight loss in tomato fruits preserved by both ashes was found to have increased progressively with storage time (Figure 7). LWA-treated samples recorded significantly higher ($P < 0.05$) weight loss than the AWA-treated ones. Moisture loss occurs in fruits due to respiration and transpiration as a result of the water vapor pressure difference between the fruit and the atmosphere and also the storage temperature (Abebe *et al.*, 2017). Treatments that coat the surface of tomato fruits can form a low permeability hydrophobic barrier against water loss from the fruits. This has been demonstrated with materials such as chitosan and N,O-carboxymethyl chitosan (NOCC; Benhabiles *et al*., 2013). One effect of the loss of moisture in the tomato samples is that it leads to a concentration of the chemical components per gram of the fruit (Tigist *et al*., 2013).

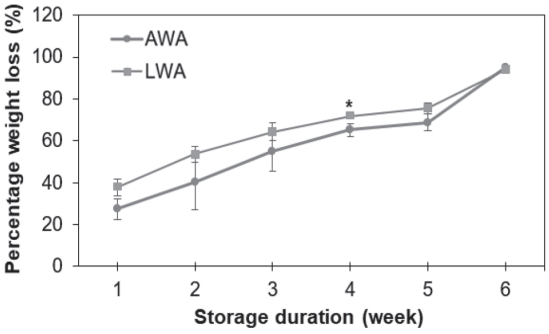

Figure 7 Change in percentage weight loss during storage of tomato fruits preserved with local (LWA) and *Azadirachta* wood ash (AWA). Treatments with the * symbol are significantly different ($P < 0.05$).

Counts of bacteria and fungi of the LWA- and AWA-treated tomatoes in this study declined with increasing storage time (Figure 8). The reduction can be linked to the protective effect of the ash, which may have limited access to oxygen, water, and other nutrients, all of which promote the growth of microorganisms (Duguma, 2022). Studies have shown that generally, coatings of various types act as barriers against oxygen transfer, thereby inhibiting the growth of microorganisms (Arshad and Batool, 2017). This has been demonstrated with materials such as guar gum (Ruelas-Chacon *et al.*, 2017), chitosan (Benhabiles *et al.*, 2013), and nano-silicon oxides (SiOx)/chitosan complex film (Zhu *et al.*, 2019). Extracts of the *Azadirachta* tree have been reported to exert protective effects on the seeds and grains of some crops (Ogunwolu and Odunlami, 1996; Odeyemi and Ashamo, 2005). This may also be partly responsible for the delayed spoilage of the LWA- and AWA-treated tomatoes compared to the control. Bacteria counts of AWA-preserved samples were significantly higher ($P < 0.05$) than that of LWA-preserved samples. This may have been responsible for the faster onset of decay observed in the AWA-treated tomato fruits (Figure 3). The two most predominant isolates that were found were *Enterobacter* sp. and *Bacillus thuringiensis*. Other researchers have also reported the isolation of different strains of these organisms from tomatoes of various origins (Shi and Sun, 2017). *Enterobacter* may contaminate the tomato fruits through soil-borne contamination while *B. thuringiensis* is a naturally occurring soil-borne bacterium that has been used as a natural insect control. The fungal count was higher ($P < 0.05$) with LWA than with AWA. Fungi isolated from the samples included *Saccharomyces cerevisiae, Aspergillus niger, Aspergillus flavus*, *Aspergillus fumigatus*, *Fusarium* sp. and *Candida tropicalis*, with *A. niger* and *A. flavus* being the most prevalent. These findings are in agreement with the work of Muhammad *et al.* (2004) who found that *A. niger* and *A. flavus* were the dominant fungi associated with tomato samples collected from a market in northern Nigeria.

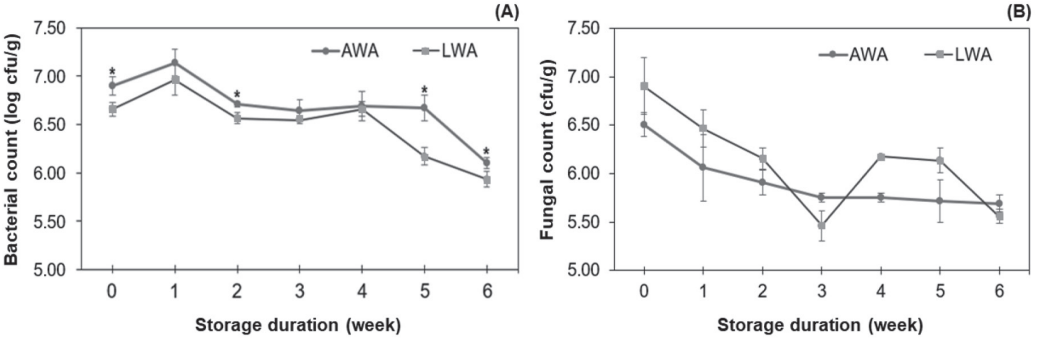

Figure 8 Changes in bacterial (A) and fungal (B) counts during storage of tomato fruits preserved with local (LWA) and *Azadirachta* wood ash (AWA). Treatments with the * symbol are significantly different ($P < 0.05$).

Other soil-borne fungi have been implicated in the spoilage of tomato fruits. These include fungi such as *Phytophthora capsici*, *Alternaria solani*, *Septoria lycopersici*, and *Fusarium oxysporum* (Hausbeck and Lamour, 2004; Etebu *et al.*, 2013). However, some of the fungi isolated in this study have been reported in biological control strategies in the preservation of tomatoes. *Bacillus subtilis, S. cerevisae,* and *Candida tanuis* have been observed to greatly inhibit the growth of *Botrytis cinerea, Rhizopus stolonifer,* and *Alternaria alternata*, which are known to cause decay in postharvest tomato fruits (Abd-Alla *et al.*, 2009; Etebu *et al.*, 2013). These fungi may also have played a role in keeping the quality of the tomatoes.

CONCLUSIONS

This study has shown that the use of wood ash is an effective alternative for extending the shelf life and preventing spoilage of tomatoes. Both LWA and AWA extended the shelf life of the tomato fruits for up to 4 weeks while the control fruit got completely decayed in days under similar ambient conditions. LWA showed a slightly better preservative effect than AWA, and this might be due to the superior microstructural characteristics of the former. Both treatments also restricted the proliferation of spoilage microorganisms which contributed to the delay in the spoilage of the fruits. Ash treatment used in this study also preserved the antioxidant components of tomatoes such as lycopene, phenolics, and ascorbic acid contents. Therefore, the use of wood ash in preserving tomatoes is a promising option for preventing recurring postharvest losses from microbial spoilage and loss of product quality. This is especially important in less developed countries where proper storage facilities and funds to procure them are inadequate. Furthermore, this method can be easily adopted by local farmers without incurring extra costs.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. J.O. Akolade, a researcher at the Biotechnology Advanced Research Centre, Sheda Science and Technology Complex, Abuja, Nigeria, for his kind assistance with the SEM/EDX analysis.

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