Effect of wood ash treatment on quality parameters of matured green tomato fruit (*Solanum lycopersicum M.*) during storage

Abstract

Post-Harvest challenge accounts for 40–50% of losses in tomato value-chain in Nigeria and other parts of the world. This study evaluated the effects of wood ash treatment on the sensory, physicochemical, nutritional and mineral compositions of green tomato stored under ambient conditions (28.3^{0}C, 67%). Green tomato (kerewa var.) was harvested from University of Ilorin, Nigeria and brought to the Chemistry/Biochemistry laboratory of Nigerian Stored Products Research Institute, Ilorin, Nigeria, cooled by aeration, weighed and divided into 3 lots (A0=control; A1=1: 1, tomato: wood ash; A2=1: 2, tomato: wood ash). These were kept in uniformly sized paper carton (170 mm × 120 mm × 140 mm) on the shelf for 28 days. Sensory attributes were assessed on 5-point hedonic scale after storage, moisture and mineral analyses were conducted using [11], pH, acidity, soluble solids and carotenoids were estimated using [13] methods while vitamin C content was evaluated with [14] methods. No significant ($p>0.05$) difference between A1 and A2 in their sensory scores whereas both were significantly ($p<0.05$) higher than control (A0). Weight loss (%) and decay incidence (%) were significantly ($p<0.05$) higher in control (29.39% and 16.42% respectively) compared to A1 (4.61% and 4.65% respectively) and A2 (8.22% and 4.76% respectively). Moisture content of control (90.48%) was significantly ($p<0.05$) higher than A1 (85.78%) and A2 (87.99%). Similarly, the pH, brix-acid ratio and vitamin C of control were significantly ($p<0.05$) higher than those of A1 and A2, the acidity of control was significantly ($p<0.05$) lower than A1 and A2 while there was no significant ($p>0.05$) difference in the soluble solid contents of control, A1 and A2. The study showed that wood ash could be used in the post-harvest handling of matured green tomato as the results indicated that groups treated with wood ash demonstrated good indices of storability at ambient conditions for 28 days.

Introduction

Tomato (*Solanum lycopersicum* Mill.*)* is a major horticultural crop with an estimated global production of 120 million metric tons [1]. Nigeria is the sixteenth largest producer out of 144 countries producing tomato in the world with her estimated production for year 2013 being 1,738,128.35 tones [2] of which 40–50% were lost between the farm and the table [3].

Depending on the market and production areas, tomatoes are harvested at stages of maturity ranging from physiological maturity (mature-green stage) through full-ripe. Tomatoes harvested at the mature-green stage (M-3 or M-4) will ripen to high quality if handled properly [4]. Tomatoes harvested at the immature green (M-2) stage will ripen to moderate quality, while those harvested at M-1 stage will not ripen to acceptable levels of quality. When harvested at matured green stage, the fruits may later ripen spontaneously or after treatment with ethylene before shipment to retailers [5].

Major challenges along tomato value chain in Nigeria had been identified to include deficiency in critical inputs such as lack of improved technology, low yield and productivity, high post-harvest losses, lack of processing and marketing infrastructure [3]. The most serious of these challenges is high post-harvest losses. To this end, consumers and farmers are in constant demand for safe and eco-friendly method of extending shelf life thereby reducing post-harvest losses of tomatoes.

Wood ash is a non-hazardous agricultural waste which is generated as a result of oxidation process during combustion of wood [6,7] It results from burning or gasifying wood and consists mainly of minerals that the trees have absorbed over their lifetime except for carbon, hydrogen and nitrogen which evaporate during the firing of wood [6,8]. Serafimova *et al*. [6] confirmed in their studies the presence of several major crystalline phases with the predominant one being calcite-$CaCO_3$, with smaller quantities of quartz-SiO_2, K and fairdice-K_2Ca (CO_3) and it has been used to neutralize acidic soils due to its ability to form alkaline extracts when dissolved in water. The study further stated that the content and mobility of toxic elements in the wood ash is in full compliance with the regulatory requirements to protect soil quality and agricultural productions.

Wood ash is highly basic with a pH around 12 [8]. In most cases, ash from the combustion of plant wastes does not contain heavy metals and other toxic elements in concentration that could lead to secondary contamination of soil and agricultural products for recycling as a soil improver [6].

Following a recent discovery regarding the storage of tomatoes in wood ash in Burundi [9] there is need for scientific trial in order to support the claim. Hence this study was designed to investigate the storability, physicochemical properties, sensory attributes and mineral contents of matured green tomato using wood ash.

2.0 Materials and methods

2.1 Reagents and test samples

All the reagents used were of analytical grade from SIGMA-ALDRICH, Germany and BDH, England products. Green tomato (local name; kerewa) was harvested from a farm within University of Ilorin campus and brought to the Chemistry/Biochemistry Laboratory of Nigerian Stored Products Research Institute (NSPRI), Ilorin, Nigeria. The sample was allowed to cool down by aeration and then sorted to get wholesome matured green tomato. The tomato was weighed and sub-divided into three equal parts and stored in wood ash as follow:

A0=control, stored without wood ash

A1=1:1; tomato: wood ash (500 g of matured green tomato stored with 500 g of wood ash)

A2=1:2; tomato: wood ash (500 g of matured green tomato stored with 1000 g of wood ash)

All the treatments and control set-up were kept in 170 mm x 120 mm x 140 mm paper carton and placed on the laboratory shelf for 28 days under ambient condition (28.3^0C, 67.7%).

2.2 Sensory evaluation

Evaluation of the sensory attributes was carried out on stored tomatoes after 28 days. Samples were presented to 20-member untrained panelists who are conversant with buying tomatoes to evaluate colour, appearance, odour, firmness and general acceptability using a five-point hedonic scale as described by [10].

2.3 Determination of moisture contents

The moisture content was determined with [11] methods. A weighed portion (5 g) of homogenized tomato sample was dried to a constant weight first at 80^0C (for 4 h) and subsequently at 105^0C for 2 h.

2.4 Estimation of weight loss (%) and decay incidence (%)

Weight or moisture loss (%) was determined by weighing the samples on a digital balance (SNOWREX ELECTRONIC SCALE 56503238, LONDON) and was reported as percentage loss in weight/moisture based on the original mass [12] as follow;

$$\text{Weight or moisture loss (\%)} = \frac{W1 - W2}{W2} x100$$

Where; W_1 = previous weight

W_2 = current weight

Decay incidence (%) was evaluated by recording the number of decayed fruits at 28th day of the storage for all the treatments and dividing by the total number of fruits initially packaged according to the formulae below;

$$Decay\ incidence\ (\%) = \frac{Number\ of\ decayed\ fruits}{Total\ number\ of\ fruits} x100$$

2.5 Measurement of pH, titratable acidity (%) and soluble solid

The pH, titratable acidity and total soluble solid was determined using the method described by Sharoba [13] with little modification as follows; 10 g of sample was homogenized and centrifuged (5000 g, for 20 min), at 4°C. The supernatant was recovered for pH, titratable acidity, and soluble solids measurements. The pH was measured at 20 °C with a pH meter (SEARCHTECH PHS-3C). Titratable acidity was determined by titration with 0.1 N NaOH until pH 8.1 was reached (rose pink colour) and reported as gram citric acid/100 g fresh weight. Soluble solids content was determined at 20°C with a refractometer (ABBE MARK II 10481; Cambridge Instrument Inc. NY) and reported as °Brix [13].

2.6 Determination of vitamin C content (mg/100 g)

The 2, 6-dichlorophenol indophenol titration method described by Ndawula *et al* [14] was adopted for the determination of ascorbic acid content. This method was slightly modified and used as follow; 2 g of sample was homogenized in a mortar containing 10 ml of 0.5% oxalic acid (extraction solution) and the content transferred into 100 ml volumetric flask. More extraction solution was added up to the mark. The content being mixed thoroughly, filtered immediately (Whatman No. 4) and aliquots (10 ml) of extract were titrated against standardized 2, 6-dichlorophenol indophenol solution. An equivalent amount of the extraction solution was titrated against standard 2, 6-dichlorophenol indophenol solution as blank at the same time.

2.7 Carotenoids determination

The tomato samples were homogenized using a mortar and pestle in the presence of water bath contains squash ice [13]. Exactly 16ml of acetone–hexane (4:6) solvent were added to 1.0 g of homogenized sample and mixed in a test-tube to extract the carotenoids, an aliquot was taken from the upper solution from the two phases formed and its optical density (OD) was measured at 663, 645, 505, and 453 nm in a UV-VIS spectrophotometer (SEARCHTECH

INSTRUMENTS; UV1902PC, ENGLAND). Lycopene and β-carotene contents were calculated according to the Nagata and Yamashita [15] equations below as reported by [13].

$$\textit{Lycopen}\ (\textit{mg per}\ 100\ \textit{mL}) = -0.0458 \text{ x OD } 663 + 0.204 \text{ x OD } 645 + 0.372 \text{ x OD } 505 - 0.0806 \text{ x OD } 453$$

$$\textit{Beta Carotene}\ (\textit{mg per}\ 100\ \textit{mL}) = 0.216 \text{ x OD } 663 - 1.22 \text{ x OD } 645 - 0.304 \text{ x OD } 505 + 0.452 \text{ x OD } 453$$

Where OD=optical density

2.8 Mineral analysis

Dry digestion methods described by [16] was adopted in the present study. One gram (1 g dry matter) of homogenized sample was weighed into a crucible and placed in a muffle furnace at 600^0C for 5 h to ash and then transferred into desiccators to cool to room temperature. The ash was dissolved in 10% hydrochloric acid (10 ml), filtered and diluted to 100 ml volume with distilled water. From the digest, various elements were determined; Na and K were measured by the use of Jenway digital flame photometer as described by [17]. Ca, Mg, Fe, Cu, and Zn were measured using atomic absorption spectrophotometer (AAS 969 Bulk Scientific VGP 210) in accordance with [11] and compared with absorption of standards of the elements. Heavy metal; Cr, Pb, and Cd were measured according to [11].

2.9 Statistical analysis

The experiments were arranged in completely randomized design (CRD) with three replicates, each consisting of fruit of relative weight for each observation. Data was subjected to analysis of variance (ANOVA) and tested for significance difference among treatments by New Duncan's Multiple Range F-Test (DMRT) at ($p<0.05$) using SPSS software package version 20.0.0 (IBM Statistics).

3.0 Results and discussion

Sensory attributes

The effect of wood ash treatment on the sensory attributes of green tomato (Solanum lycopersicum L.) after 28 days storage was as presented in Table 1. A1 and A2 were rated higher than the control (A0) in colour, appearance, firmness, odour and general acceptability and the difference was significant ($p<0.05$).

Table 1: Effect of wood ash treatment on the sensory attributes of green tomato (*Solanum lycopersicum L.*) after storage (28 days)

Sample	Colour	Appearance	Firmness	Odour	General Acceptability
A0	2.25^{b}	2.40^{b}	2.45^{b}	3.30^{b}	2.55^{b}
A1	3.25^{a}	3.25^{a}	3.30^{a}	4.20^{a}	3.40^{a}
A2	3.75^{a}	3.45^{a}	3.60^{a}	4.10^{a}	3.45^{a}
LSD	0.561	0.61	0.567	0.583	0.560

Readings show mean of 20 panelist members on 5-pont hedonic scale where 5 indicates like extremely and 1 indicates dislike extremely. A0=control, A1=ratio 1:1 (tomato: wood ash), ratio 1: 2 (tomato: wood ash)

Weight (moisture) loss (%) and decay incidence (%)

The weight or moisture loss (%) of stored green tomato is as shown (Figure 1). The control (A0) sample lost from 11.39–29.37% of its initial weight within the storage period (28 days). Treatment A1 (1:1; tomato: wood ash) and A2 (1: 2; tomato: wood ash) lost 0.72–11.61% and 0.40–8.22% of their initial weight during the storage period respectively. The results showed that the weight loss (%) was higher in control than the treated samples. Also, the longer storage time, the wider the weight loss for both control and the treated samples. [12] also recorded similar results when avocado was treated with pectin-base coating. These authors opined that; weight or moisture loss could occur as result of transfer of water vapour from the sample to the air. Weight or moisture loss could also be due to change in the carbohydrate composition of the fruit as the density of starch is much higher than that of sugar [18].

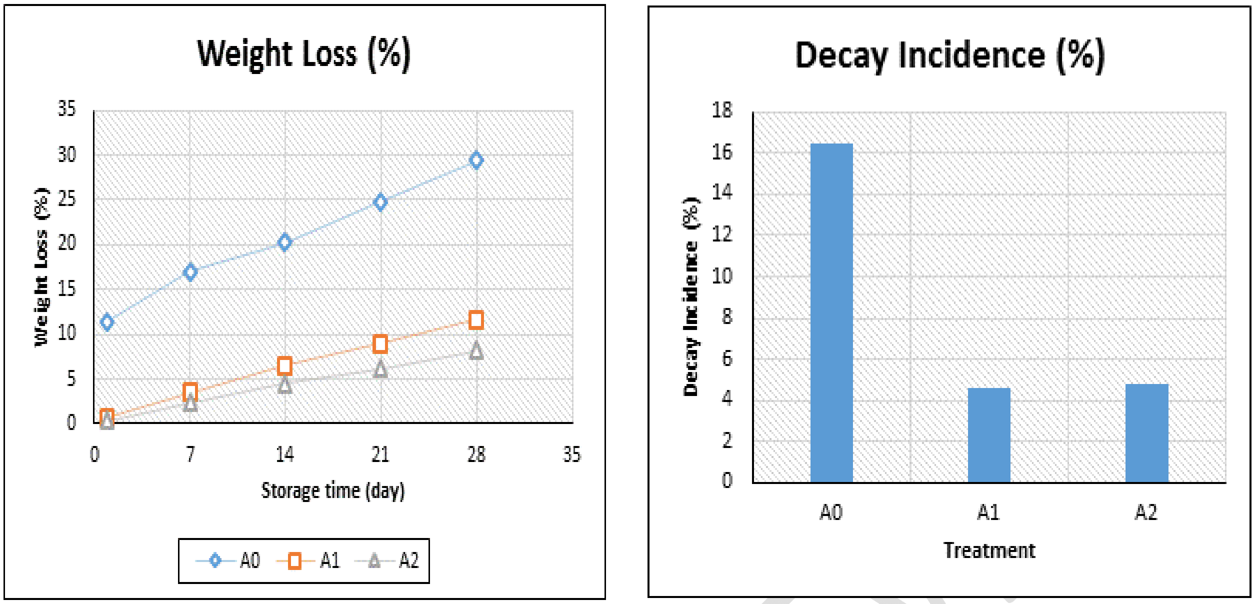

Figure 1: Effect wood ash treatment on weight or moisture loss (%) and decay incidence (%) of stored green tomato. A0= control, A1=1:1 (wood: tomato), A2= 2:1(wood ash: tomato).

Similarly, the results of decay incidence follow the same trend as was recorded for weight or moisture loss. The result indicated that decay incidence (Figure 1) recorded for A0 (16.42%) in the study was higher than both treatment A1 (4.65%) and in A2 (4.76%).

Moisture content

The moisture contents (MC) of control and treated samples ranged from 85.78–92.06% in the current study under review (Figure 2). The MC of A0 reduced significantly ($p<0.05$) from day 0 to day 7 of the storage period. Henceforth, there was no significant difference ($p>0.05$) in the MC of the control from day 14 to 28 of the study period. Change in the MC of control might be due to change in the atmospheric conditions during the storage period. At day 28, the MC of control was significantly ($p<0.05$) higher than both treatments A1 and A2, also the MC of A1 was significantly ($p<0.05$) higher than that of A2. This is an indication that wood ash reduced the MC of green tomato significantly ($p<0.05$) during 28 days storage. In addition, reduction in moisture was higher in treatment A1 than treatment A2. Reduction in moisture content of tomato in the current study could be due to high sorption capacity of wood ash causing a moisture drift [6].

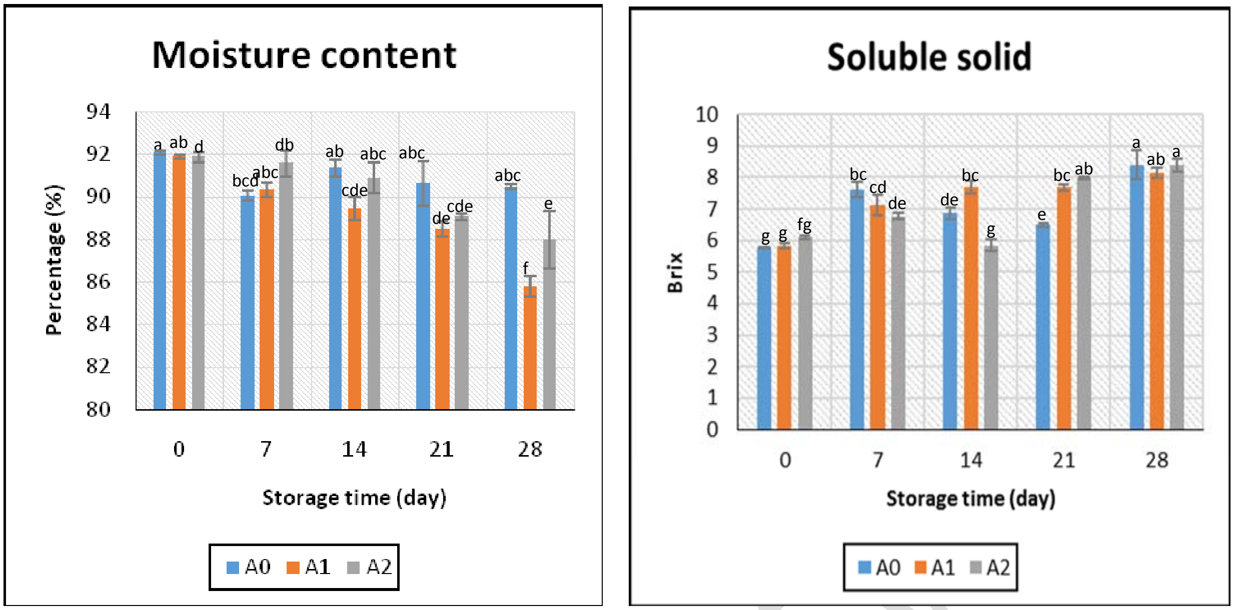

Figure 2: Effect of weight of wood ash treatment on moisture content (MC) and total soluble solid (TSS); A0 is control; A1is 1:1(wood ash to tomato); A2 is 2:1(wood ash to tomato).

Total soluble solid

The Total Soluble Solid (TSS) of treated tomato samples (Figure 2) ranged from 5.77–8.40 ^{0}Brix for the control and test group. There was no significant ($p>0.05$) difference in the TSS of both control and treated samples (A1 and A2) at day 0 and day 28, showing that storage with wood ash had no significant influence on the total soluble solid of green tomato during 28 days storage. The increase in soluble solid in both the treated and the control group might be due to change in carbohydrate composition from starch to sugar as well as complete change in color of the fruit, this may be due to the fact that harvested fruit that is stored at elevated temperature hastens the respiratory loss of carbohydrates along with the acceleration of ripening [19].

The effect of wood ash treatment on the pH and titratable acidity (TTA) of green tomato is as shown (Figure 3). The pH value recorded for the storage period ranged from 4.67–5.20. There was no significant ($p>0.05$) difference in the pH values of both control and treated samples at day 0 while significant ($p<0.05$) increase was observed in the pH of control at day 28. This indicates that wood ash reduced the pH of fresh matured green tomato during 28 days storage. The pH of a ripe tomato typically ranges from 4.1–4.8 [19].

On the other hand, the TTA value recorded within the storage period ranged from 0.89–4.39%. There was no significant ($p>0.05$) difference in the TTA of control and treated samples at day 0, this was expected because they were all from the same source. Conversely, a significant ($p<0.05$) increase was recorded at day 28 between control, treatments A1 and A2. Similarly, it showed that wood ash treatment increased the acidity of matured green tomato fruits during 28 days storage. The results of pH and acidity are in agreement because, increase in fruit acidity correspond to decrease in pH. The results in the present study agreed with the view of [20] who stated that; the acid content of tomato was found to be lower when the fruit is under mature then increases to the peak at the point when color appeared with a rapid decrease as the fruit ripened at ambient condition. This was what happens between day 0 and 7 in the current study when pH reduced significantly ($p<0.05$). In addition, citric acid is the major constituent of total acid in tomato and malic acid may occur in small quantity [20].

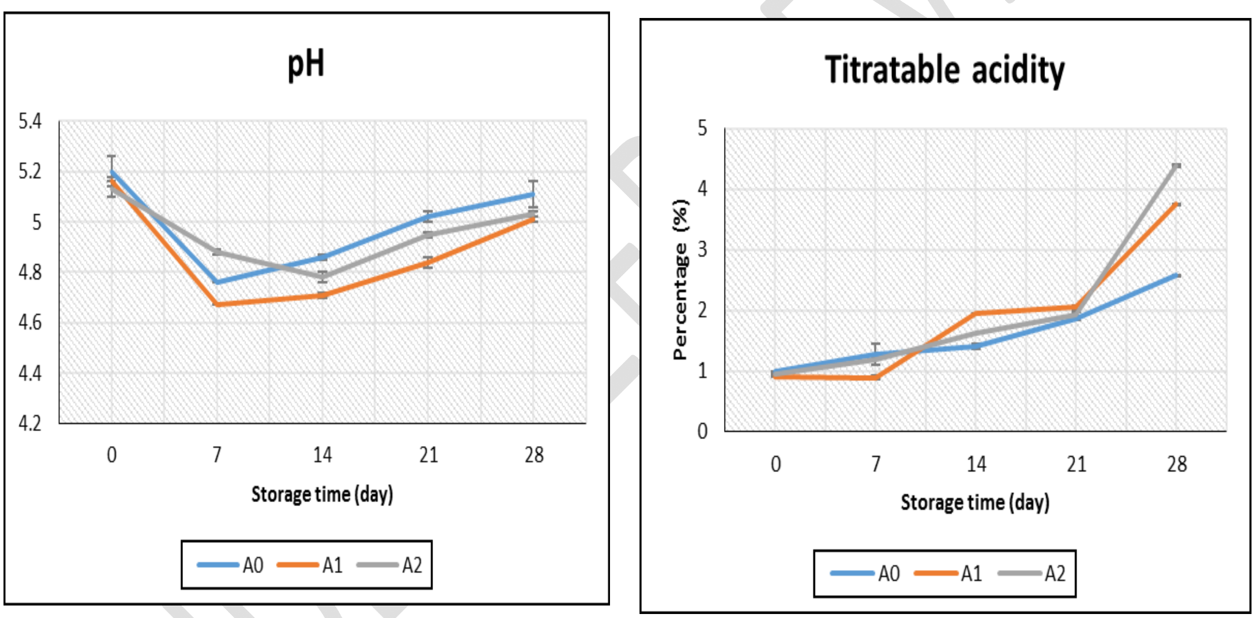

Figure 3: Effect of wood ash treatment on pH and Titratable acidity (TTA); A0 is control; A1is 1:1(wood ash to tomato); A2 is 2:1(wood ash to tomato).

The effect of wood ash treatment on the sugar (Brix)-acid ratio is as shown (Figure 4). The brix-acid ratio of the control and treated green tomatoes ranged from 1.90–7.99. There was no significant ($p>0.05$) difference recorded in the brix-acid ratio of control and treated samples at day 0 whereas the brix-acid ratio recorded for control was significantly higher ($p<0.05$) than both treatments A1 and A2 at day 28 of the storage. This was an indication that wood ash affected the brix-acid ratio of matured green tomato during the 28 days trials. Brix-acid ratio is an index of ripeness in any fruit. Unripe fruit has low sugar and high acidity, increase in ripeness leads to increase sugar content due to degradation of carbohydrates and correspondent decrease in acidity [21,19]. Therefore, decrease in brix-acid ratio on 28th day showed that ripening was brought under control due to effect of wood ash.

Vitamin C content

Ascorbic acid (Vitamin C) content of the control and treated tomato samples ranged from 7.67–44.25 mg per100 g (Figure 5). There was no significant ($p>0.05$) difference in the vitamin C contents of control and treated samples (A1 and A2) at day 0, whereas at day 28, the control (A0) had significantly($p<0.05$) high vitamin C content compared to other treatments. This indicates that wood ash treatment brought about reduction in vitamin C contents of the treated samples during 28 days storage. Increase in vitamin C content of the control (A0) may be attributed to progression in ripening [22].

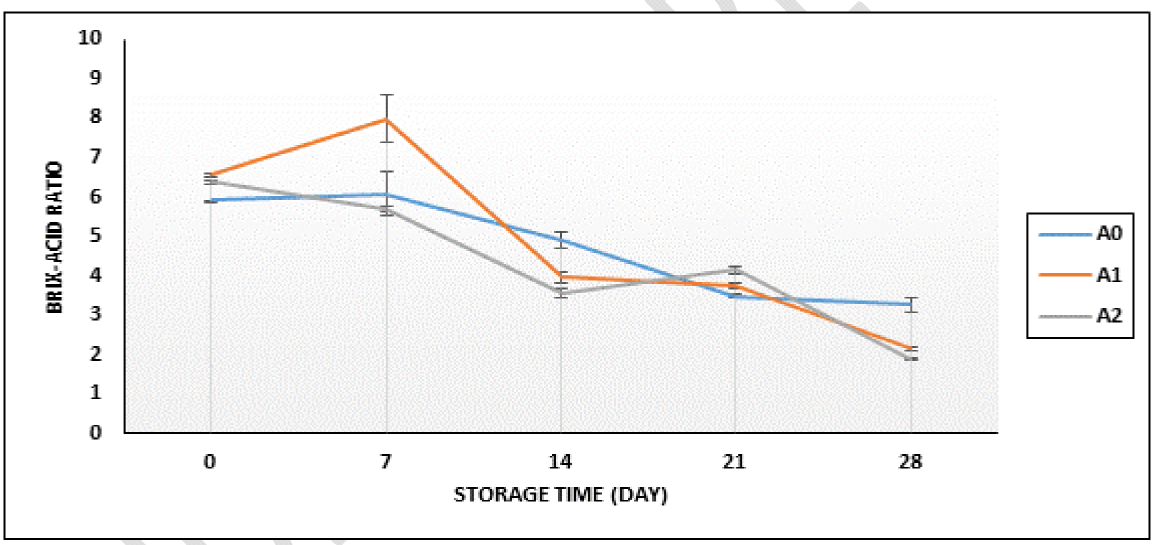

Figure 4: Effect of wood ash treatment on brix-acid ratio of matured green tomato during storage. A0 is control; A1is 1:1(wood ash to tomato); A2 is 2:1(wood ash to tomato).

Carotenoids contents

Lycopene and beta-carotene contents of control and treated green tomato samples is as shown (Figure 6). The lycopene content of control and treated green tomato ranged from 3.09–13.64×10^{-3} mg per 100 mL. There was no significant ($p>0.05$) difference in the lycopene contents of control and treated samples at the commencement of the study but a significant ($p<0.05$) rise was recorded in the lycopene content of sample A1 at day 28 of the experiment but no significant ($p>0.05$) difference between control and sample A2. Indicating that wood ash treatment had positive effect on treatment A1 only in terms of lycopene content. This might as well be attributed to the fact that there was progression in ripening process in that same treatment according to [22].

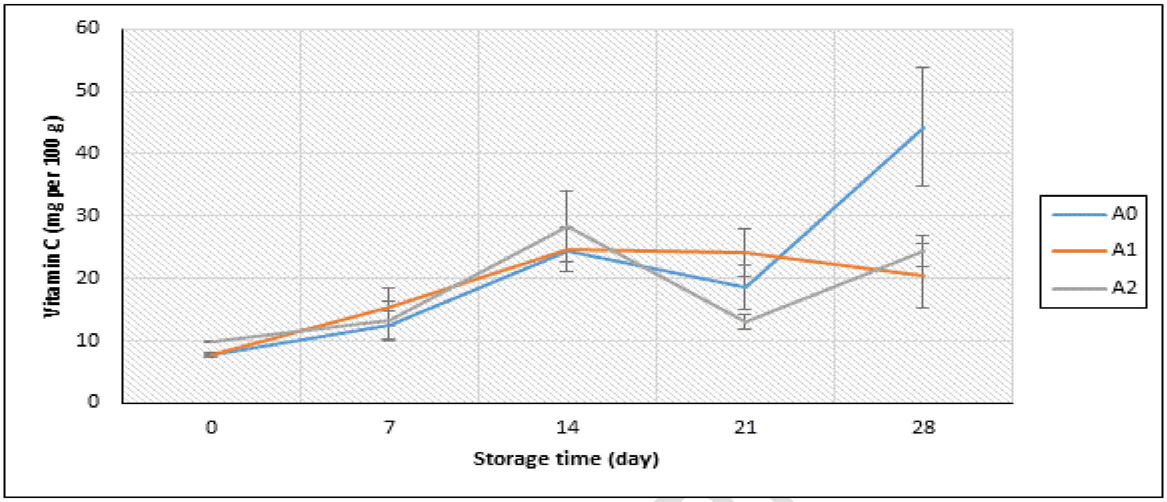

Figure 5: Effect of wood ash treatment on Vitamin C content (mg per 100 g) of matured green tomato during storage. A0 is control; A1is 1:1(wood ash to tomato); A2 is 2:1(wood ash to tomato)

The beta-carotene contents of both control and treated samples ranged from $1.098–2.075 \times 10^{-2}$ mg per 100 mL. There was no significant ($p>0.05$) difference in the beta-carotene contents of control and treated samples at the beginning of the set up (day 0) whereas the beta-carotene content of sample A1 was significantly ($p>0.05$) higher than that of both control and treatment A2 at day 28. The indication here is that, wood ash treatment had positive influence on the beta-carotene content of treatment A1 (ratio 1: 1; tomato: wood ash) during the 28 days storage. Generally, in the current study, beta-carotene contents of control and treated samples were higher than lycopene contents. This was contrary to the assumption of [23] who said that lycopene is the most abundant carotenoid in ripe tomato. It could then be deduced from the study that, the ratio of lycopene to beta-carotene in tomato is a function of cultivar. As stated by [19], lycopene and beta-carotene are predominantly responsible for the colour in tomato, thus it was observed in the study that both control and treated green tomato got ripened to orange colour after being stored for 28 days. These results of nutritional studies (vitamin C, lycopene and beta-carotene) was in support of an assertion by [24]. who stated that; tomato has a remarkable combination of antioxidants, which includes lycopene, beta-carotene, polyphenols and vitamin C. Notwithstanding, the results in the current study contradict the idea put forward by [22] who stated that vitamins A and C increase as tomato fruits ripen on the vine but does not increase when matured green fruits ripen off the vine.

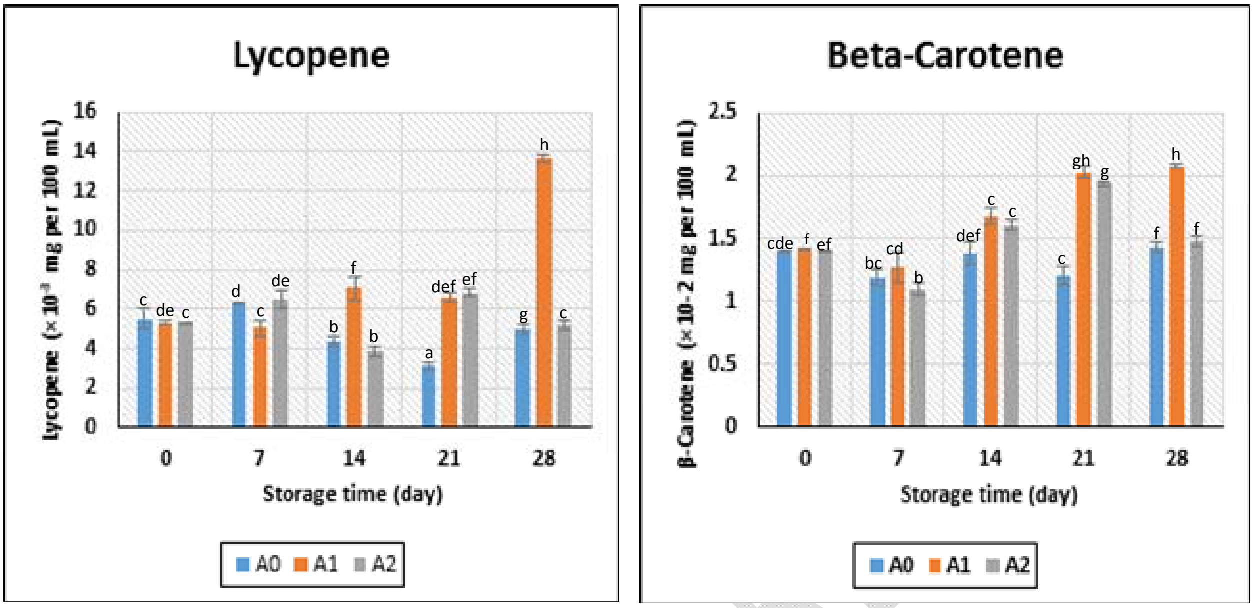

Figure 6: Effect of wood ash treatment on lycopene (mg per 100 mL) and beta-carotene (mg per 100 mL) of matured green tomato during storage; A0 is control; A1is 1:1(wood ash to tomato); A2 is 2:1(wood ash to tomato)

Table 2: Effects of wood ash treatment on the mineral composition of green tomato

Mineral (mg per 100 g)	A	A0	A1	A2
Na	1.04±0.00	0.29±0.00	0.30±0.07	0.25±0.07
K	365.00±7.07	86.00±0.00	90.00±0.00	82.00±0.70
Zn	0.01±0.00	0.18±0.00	0.10±0.00	0.12±0.00
Fe	0.02±0.00	0.11±0.00	0.10±0.00	0.09±0.00
Ca	0.60±0.00	0.58±0.00	0.48±0.00	0.53±0.00
Mg	1.60±0.00	1.78±0.00	1.76±0.00	1.64±0.00
Mn	0.01±0.00	0.04±0.00	0.04±0.00	0.03±0.00
Cu	0.01±0.00	0.03±0.00	0.02±0.01	0.02±0.01
Pb	nd	nd	Nd	nd
Cr	nd	nd	Nd	nd
Cd	nd	nd	Nd	nd

Conclusion

The study showed that groups treated with wood ash demonstrated good indices of storability in terms of sensory attributes, moisture or weight loss, decay incidence and some nutritional qualities such as lycopene and beta-carotene especially in the fruits treated with equal portion of wood ash (A1). Therefore, wood ash could be applied in the post-harvest handling or storage of matured green tomatoes at ambient conditions for 28 days.

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