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Comparative Study of Calcium Chloride and Wood-Ash Applications on Proximate and Vitamin Contents of Orange-Fleshed Sweet Potato

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Abstract

Tuberous roots of improved Orange Fleshed Sweet potato (OFSP) are susceptible to spoilage during storage. Research has shown that developing a storage method using concentrated $CaCl_2$ solution and wood-ash suspension methods could minimize this spoilage phenomenon. In this study, comparative study of the $CaCl_2$ and wood-ash applications were therefore, used to investigate the effect of these methods on proximate and vitamin contents of stored UMUSPO 3 variety of OFSP at different storage temperatures. The edible roots of the experimental OFSP variety were freshly harvested from National Root Crops Research Institute (NRCRI), Umudike Farm Centre. After washing and drying they were dipped into $CaCl_2$ solution and wood ash suspension and allowed to air-dry. They were then stored at different storage temperatures (4,7,10,12,15 and 18 °C) for the duration of 0, 2 and 4 weeks. At each of the storage period, the experimental chemical analyses were carried out in triplicates. Results from both treatment showed that higher temperatures of 12-18 °C were able to retain the experimental nutritional compositions of the OFSP samples at minimal loss of weight (1.672 - 14.422 %) after 4 weeks of storage with 18 °C giving the best result. Generally, the determined vitamins (A, C, E, Beta-carotene) and proximate were significantly different ($P \leq 0.05$) between the storage temperatures. Wood-ash method gave better preservative power than that of $CaCl_2$.

Keywords: Orange Fleshed Sweet Potato, $CaCl_2$, wood ash, proximate and vitamins,

Introduction

Sweet potatoes are a class of *Dicotyledoneae* tuberous vegetable of the family *Convolvulaceae-Ipomoea batatas*. This kind of vegetable grows underground. They have leafy green stems that grow above ground. Because root tuberous vegetables grow underground, they absorb a great amount of nutrients from the soil. They are packed with high concentration of antioxidants, Vitamins C, B, A, and iron, helping to cleanse body system. Several studies have shown that OFSP is a potential source of vitamin A, minerals (Fe, Zn, Mn), and other micronutrients such as polyphenols and carotenoids [1,2]. It is currently ranked as the seventh most important crop in the world with a total production of 103 million tonnes in 2013 [3]. OFSP has the added benefit of being nutritious type of sweet potato high in vitamin A, and therefore forms an important part of household's nutritional strategy. OFSP also has powerful antioxidants that help prevent cancers, as well as natural sugars, which are slowly released into the bloodstream, helping to ensure a balanced source of energy, without the spikes in blood sugar that are sometimes associated with fatigue and weight gain [4,5].

OFSP roots, like any other vegetables, are subjected to several forms of postharvest losses during transportation from farmers' field to market and in storage. Unprocessed sweet potatoes do not have an extremely long shelf life compared to other vegetables like carrots or potatoes. During storage, the roots are very perishable because they contain high moisture content (60-75%), hence low mechanical strength as well as high susceptibility to microbial decay. OFSP have high respiratory rate and the resultant heat production softens the textures which makes them susceptible to damage [6].

Proper storage that is able to rigid the cellwall of OFSP can lead to higher retention of the nutrient. An effect of elevated storage temperature is sprouting and below its storage temperature can result in chilling injury. Low humidity results in weight loss and may cause shriveling of the skin especially at the root ends. However, some chemicals can be used in preserving this crop [7,8,9]. Calcium chloride and wood ash have been used

previously on various produce including tomatoes, mangoes and strawberries [10,11,12], showing positive results in maintaining postharvest quality of the produce. This research was designed to investigate the comparative study of calcium chloride and wood ash application on proximate and vitamin contents of orange-fleshed sweet-potato using different storage temperatures

Materials and Methods

UMUSPO-3 variety of OFSP was used. It was sourced randomly from experimental farm of National Root Crops Research Institute, Umudike, Abia State, Nigeria. The obtained 100 kg of OFSP roots was washed with running tap water, cleaned dried in an open air. After drying, it was divided into three (3) portions. One portion was used as the control for proximate while the other two portions were treated with $CaCl_2$ solution and wood ash solutions, air dried, packaged with black polyethylene bag and stored at different refrigerator temperature (4,7,10,12,15,18 ◦C and room temperature) prior to analysis for 0, 2 and 4 weeks of storage for the main study [13]. These were stored at 18 ◦C for 0, 2 and 4 weeks of storage period for further analysis [14,15]. The comparative effect of the treatments on the proximate and vitamin properties of the OFSP root samples at different storage temperature were evaluated.

Proximate compositions

a. Fat content determination

The solvent extraction AOAC[16] method No 920.39 was used.

3.00 g of sample was wrapped in a porous paper (Whatman filter paper) and put in a thimble. The thimble was placed in a Soxhlet reflux flask and mounted in a weighed extraction flask containing 200 mL of petroleum ether. The upper end of the reflux flask was connected to a water condenser. The solvent (petroleum ether) was heated to boil, vaporized and condensed into the reflux flask. The sample in the thimble was covered with the solvent which extracted the fat. The sample remained in contact with the solvent until the reflux filled up and siphoned over, carrying its oil down to the boiling flask. This process was allowed to run repeatedly for 4 hours before the defatted sample was removed.

The sample was recovered with a pre-weighed flask and the oil extracted was left in the flask. The flask containing the oil extracted was dried in the oven at 60 ◦C for 30 minutes (to remove the residual solvent), cooled in a desiccator and weighed. By difference, the weight of fat extracted was determined and expressed as a percentage of the weight of the analyzed sample and is given by the expression in equation 1:

$$\text{Fat (\%)} = \frac{W3-W2}{W1} \times \frac{100}{1} \qquad 1$$

Where W_1 = weight of sample, W_2 = weight of empty extraction flask and

W_3 = weight of empty extraction flask + fat extracted

b. Determination of crude fiber

The Wended method described by Onwuka [17] was used for the determination of the crude fiber content. A measured weight of the defatted sample, 3 g (W_1), from the fat analysis was boiled under reflux for 30 min with 200 mL of 1.25 g of H_2SO_4 solution. After that, the sample was washed with several portions of hot boiling water using a twofold muslin cloth to trap the particles until there was no longer acid. The washed sample was carefully transferred quantitatively back to beaker and 200 ml of 1.25% sodium hydroxide (NaOH) solution was added and boiled for 30 min. This was washed again with hot boiled water using a twofold muslin cloth to trap the particles and the particles was transferred to porcelain crucible and dried in an oven at 105 °C for 3 hrs and cooled in a desiccator, and was reweighed (W_2) and then put in a hot electric oven and incinerate at 105 °C for 2 hrs (until they turned into ash), cooled in a desiccator and weighed. The crude fiber content will be calculated gravimetrically as equation 2.

$$\text{Crude fibre (\%)} = \frac{W3-W2}{W1} \times \frac{100}{1} \qquad 2$$

W_1 = weight of sample analysed,

W_2 = weight of crucible + sample after washing and drying, and

W_3 = weight of crucible + sample after incineration

c. Determination of total ash

Furnace Incineration Gravimetric method described by Onwuka [17] was used to estimate the total ash content. 2 g of sample was put in a previously weighed porcelain crucible (W_1) and the weight of the sample plus the crucible was taken (W_2) and allowed to incinerate in a pre-heated muffle furnace at 550 °C for 2 hours or until a white or light gray ash resulted. The crucible and its ash content was cooled in a desiccator and then weighed (W_3), total ash is given by the formula in equation 3.

$$\text{\% Ash (dry basis)} = \frac{W3-W1}{W2-W1} \times \frac{100}{1} \qquad 3$$

Where W_1 = weight of empty crucible, W_2 = weight of empty crucible + sample and W_3 = weight of crucible + ash

d. Moisture content determination

The solvent extraction AOAC [16] method 934.06 (37.1.10) was used. 10.00 g of the sample was accurately weighed into clean, dried moisture can (W_1) and allowed in an oven at 105 ◦C for 6-12 hrs until a constant weight was obtained. It was allowed to cool in the desiccator for 30 min after which it was weighed (W_2). Then the weight of moisture lost was calculated as a percentage of the weight of sample analyzed. This is given by the expression in equation 4.

$$\text{Moisture content (\%)} = \frac{W3-W2}{W1} \times \frac{100}{1} \qquad 4$$

Where W_1 = Weight of sample, W_2 = Initial weight of moisture can + sample (before drying) and

W_3 = Final weight of moisture can + sample (after drying)

e. Dry matter content determination

AOAC [16] method 934.06 (37.1.10) was used. Here, the percentage dry matter was calculated by the subtraction of moisture content from 100. The resultant difference gave the dry matter content.

% Dry matter = 100- (% moisture) 5

f. Determination of protein

Semi-micro Kjedahl method was used for the protein determination as described by AOAC [18] method 955.04.

Protein was determined by mixing 2 g of the test sample with 10 mL of conc. H_2SO_4 in a Kjedahl digestion flask in addition to a tablet of selenium catalyst and heated strongly under a film cupboard as the digestion process until a clear solution was obtained. A reagent blank was digested as well but without any sample. All digests were carefully diluted with distilled water and transferred quantitatively to a 100 mL volumetric flask and make up to mark with distilled water. An aliquot 10 mL of the mixture was mixed with equal volume 10 mL of 45 % NaOH solution in a Kjeldahl distillation apparatus. The mixture was distilled and the distillate was connected into 10 ml of 4 % boric acid solution containing three drops of mixed indicator solution (methyl red and bromocressol green), a total of 50 mL of distillate was collected and titrated against 0.01M H_2SO_4 solution. The end point was marked by a colour change from green to deep red colour. Both the sample and the reagent blank digest were distilled and titrated.

The equation 6 was used to calculate the nitrogen and protein content:

Protein (%) = % N_2 x 6.25 6

$\%\ N_2 = \frac{100}{W} \times \frac{14 \times M}{1000} \times \frac{Vt}{Va} \times T - B$ 7

Where W = weight of sample analyzed (g),
M = Molarity (concentration) of titration (0.01M-H_2SO_4),
Vt = total volume of digest (100 mL),
Va = volume of digest analyzed (mL),
T = Titre value of sample (mL) and
B = Titre value of blank (mL)

g. Determination of carbohydrate

The carbohydrate content was calculated by the Difference method as described by Onwuka, [17]. In this method, the carbohydrate was obtained by calculation after estimating all other fractions by proximate analysis. Hence, it was calculated using the formula in equation 8.

% CHO = 100-% (Protein + Fat + Fibre + Ash + Moisture content) on wet basis 8

h. Vitamin A

Onwuka [17] and AOAC Method 992.04, 50.1.02 [19] methods were applied. 5 g of sample was homogenized in 30 mL of absolute alcohol (ethanol) and mixed with 3 mL of 5 % potassium hydroxide. The mixture was boiled under reflux for 30 mins, cooled rapidly with running water and filtered. 30 mL of distilled water was added to the filtrate and transferred to a separatory funnel. 3 portions of 50 mL of ether was used to wash the mixture, the aqueous layer was discarded while the upper layer (organic layer) was washed with 50 mL of distilled water. The aqueous phase was discarded and the Vitamin A extract was evaporated to dryness and dissolved in 10 mL of isopropyl alcohol. The absorbance was then measured spectrophotmetrically at 325 nm wavelength. Vitamin A was calculated as in equation 9

Vit. A (mg/100g)= $\frac{100}{w} x \frac{Au}{As} x C$ 9

Where w = weight if sample analysed (g), Au= Absorbance of the test sample, As = Absorbance of the standard solution and c = Concentration of the standard

i. β-carotene analysis

The procedure was outlined in AOAC [20] Official Method 941.15 and Rodriguez-Amaya and Kimura [21] as described by Adie *et al.* [5].

A triplicate of 5.00 g of wet sample was homogenized with 50.00 mL acetone and a pinch of celite in a mortar and pestle. This was filtered with a Whatman filter paper No1 using Buchner funnel and suction pump into conical flask. 30.00 mL acetone was added again to the residue, homogenized and filtered again until all the carotenoids were extracted (residue became colourless). The filtrate was poured to a well cleaned and dried separatory funnel. About 30.0 mL petroleum ether (40-60 °C) was added to rinse the acetone. A partition of two layers formed. This was gently washed with distilled water until the aqueous layer became a clear solution. Brine solution was used to wash the carotene (organic layer) for purification. The aqueous was drained gradually, and the carotene (organic content) was collected using collection funnel packed with 0.5 g anhydrous sodium sulphate into a 50.00 mL volumetric flask (amber bottle). The absorbance of the samples and the blank was read at 450 nm spectrophotometrically with 1 cm glass cuvette.

The carotenoid content will be calculated in microgram per gram (µg/g) as in equation 10.

Carotene content (µg/g) = $\frac{A \times V \times DF \times 10^4}{A^{1\%}_{1CM} \times S}$ 10

Where A = Absorbance, V = Volume of extract used (mL), DF= Dilution factor, 10^4= Constant, A= Absorption coefficient of β-carotene in Petroleum ether (2592); S = Sample weight

j. Extraction and determination of tocopherol equivalents (vitamin E)

This is to be determined by the AOAC [22] method. 2g of sample was mixed with 10 mL of absolute alcohol (ethanol) and 20 mL of molar ethanolic sulphur acid solution was added to it. This was wrapped in aluminum foil to avoid direct light effect on the contents, boiled under reflux for 45 mins and allowed to cool before adding 50 mL of distilled water. The mixture was transferred to a separating funnel (wrapped with foil) and 50 mL distilled water was added to wash out the walls of the container into the funnel. 150 mL of diethyl ether was added, mixed and allowed to separate into phases. The extract layer (ether layer) was collected and evaporated to dryness in a desiccators over

sodium sulphate (anhydrous). The residue (Vitamin E extracts) was dissolve in 10 mL absolute ethanol and used for the analysis.

1 mL aliquot of the extract was dispersed into a test tube. Meanwhile, a standard Vitamin E solution was prepared and diluted to a desire concentration. 1 mL of the solution (Vitamin E) and 1 mL of ethanol was dispersed into separate tubes to serve as standard and reagent blank respectively. 5 mL of ethanol was added to each tube followed by dropwise addition of 1 mL of concentrated HNO_3 with great caution. The tubes was then boiled at 90 °C in a water bath for 3 mins, cooled in running water tap and the absorbance was spectrophometrically taken at 470 nm wavelengths. The reagent blank is use to calibrate the instrument at zero. The Vitamin E was calculated in equation 11.

Vit E (mg/100mg) =Au x As x C x F 11
Where F = 100/w x Vf/Va x D 12
AS = Absorbance of the standard vitamin E,
Au = Absorbance of the unknown (sample)
Vf = Total extract volume, (mL),
Va = Volume of extract analysed (mL),
C = Concentration of standard Vitamin E,
F= Experimental factor, D = Dilution factor
W = weight of sample (g).

Vitamin C (Ascorbic acid) determination

AOAC [23] Method 967.21, 45.1.14 as described by Onwuka [17] was used. 10 g of the sample was extracted with 50 mL EDTA/TCA extracting solution for 1 hour and filtered through a whatman filter paper into a 50 ml volumetric flask and made up to the mark with the extracting solution. 20 ml of the extract was pipette into a 250 mL conical flask and 10 ml of 30 % KI was added and also 50 ml of distilled water added. This was followed by 2 mLof 1 % starch indicator. This was titrated against 0.01 M CuSO4 solution to a dark end point as calculated in equation 13.

Vit. C (mg/100 g) = $0.88\ x\ \frac{100}{s}\ x\ \frac{Vf}{20}\ x\ \frac{T}{1}$ 13

Where Vf = volume of extract, T = sample – blank titre

I. Postharvest losses and quality deterioration

The percentage of post-harvest losses and quality deterioration at different channels of post-harvest were measured by using the modified equation described by Debele *et al.* [24] as calculated in equation 14.

PLQD (%) = $\frac{W1-W2}{W1}$ x $\frac{100}{1}$ 14

Where PLQD = Postharvest loss and quality deterioration
W_1 = the original weight (g) of sample and W_2 = weight (g) of sample after storage.

Statistical analysis

The mean, standard deviation and analysis of variance (ANOVA) of the data obtained from the study were computed using Statistical Package for Social Sciences (SPSS) version 20. Means were separated using least significant

Analysis of variance (ANOVA) was specifically performed to check for significant difference ($P<0.05$) between means.

Results and Discussion

Table 1: Effect of Refrigeration Temperature on the Proximate Composition (%) of OFSP Treated with $CaCl_2$ solution at different Storage Times

Tempt. (°C)	Storage Period (Week)	Moisture	Lipid	Crude fiber	Protein	Ash	Carbohydrate
	0	74.539±0.158^{l}	1.332±0.009^{kl}	0.539±0.002^{c}	5.412±0.011^{k}	1.262±0.004^{b}	17.915±0.147^{ef}
4	2	75.626±0.010^{n}	1.106±0.006^{g}	0.426±0.007^{a}	5.060±0.036^{ef}	1.185±0.014^{a}	17.597±0.042^{de}
	4	76.492±0.310^{p}	0.999±0.058^{ef}	0.406±0.006^{a}	4.752±0.091^{c}	1.172±0.010a	17.179±0.413^{c}
	0	73.517±0.426^{j}	1.229±0.027^{i}	1.599±0.001^{q}	5.584±0.023^{m}	1.782±0.005^{j}	16.290±0.422^{b}
7	2	75.207±0.006^{m}	0.980±0.008^{de}	1.158±0.015^{m}	5.123±0.040^{fg}	1.551±0.012^{h}	15.982±0.034^{ab}
	4	76.171±0.258^{o}	0.882±0.011^{c}	1.049±0.022^{k}	4.855±0.049^{d}	1.249±0.015^{g}	15.793±0.213^{a}
	0	71.424±0.486^{h}	1.367±0.002^{m}	0.900±0.001^{i}	5.739±0.008^{n}	2.665±0.002^{n}	17.905±0.491^{ef}
10	2	70.536±0.017^{f}	1.176±0.008^{h}	0.824±0.004^{h}	5.233±0.018^{hi}	2.260±0.011^{m}	19.970±0.036^{h}
	4	70.366±0.259^{f}	1.020±0.012^{f}	0.769±0.003^{g}	5.035±0.015^{e}	2.020±0.022^{k}	20.791±0.260^{j}
	0	70.536±0.008^{f}	1.362±0.007^{lm}	1.246±0.011^{n}	5.756±0.011^{n}	2.125±0.005^{l}	18.974±0.026^{g}
12	2	69.329±0.008^{e}	1.206±0.005^{i}	1.029±0.060^{k}	5.262±0.020^{ij}	1.972±0.007^{k}	21.202±0.065^{k}
	4	67.784±0.388^{c}	1.094±0.014^{g}	0.963±0.052^{j}	5.090±0.020^{ef}	1.610±0.064^{i}	23.459±0.297^{m}
	0	69.341±0.012^{e}	1.363±0.001^{lm}	1.292±0.008^{o}	5.865±0.007^{o}	2.016±0.011^{k}	20.122±0.028hi
15	2	68.540±0.005^{d}	1.212±0.004^{i}	1.102±0.014^{l}	5.331±0.022^{j}	1.983±0.00^{5k}	21.831±0.016^{l}
	4	67.517±0.169^{c}	1.097±0.020^{g}	1.018±0.048^{k}	5.177±0.037^{gh}	1.656±0.027^{i}	23.536±0.193^{m}
	0	68.676±0.010^{d}	1.368±0.001^{m}	1.337±0.011^{p}	6.049±0.015^{p}	2.138±0.005^{l}	20.432±0.017^{i}
18	2	66.219±0.018^{b}	1.258±0.014^{j}	1.188±0.004^{m}	5.866±0.007^{o}	2.013±0.028^{k}	23.456±0.034^{m}
	4	65.711±0.013^{a}	1.152±0.012^{h}	1.155±0.007^{m}	5.495±0.055^{l}	1.812±0.153^{j}	24.675±0.193^{n}
Trmt	0	73.831±0.150^{ik}	1.313±0.012^{k}	0.735±0.002^{g}	5.769±0.008^{n}	0.997±0.007^{f}	17.354±0.160^{cd}
	2	71.040±0.015^{g}	1.027±0.019^{f}	0.644±0.004^{e}	5.240±0.010^{hi}	0.848±0.025^{e}	21.201±0.038^{k}
	4	68.675±0.056^{d}	0.841±0.017^{b}	0.601±0.003^{d}	4.856±0.019^{d}	0.802±0.006^{e}	24.384±0.102^{n}
	0	74.104±0.027^{k}	1.337±0.016^{klm}	0.502±0.003^{b}	5.073±0.025^{ef}	0.799±0.015^{e}	18.184±0.051^{f}
Control	2	72.020±0.004^{j}	0.955±0.020^{d}	0.437±0.005^{a}	4.518±0.109^{b}	0.712±0.002^{d}	21.358±0.134^{k}
	4	68.675±0.056^{d}	0.722±0.010^{a}	0.407±0.005^{a}	4.222±0.109^{a}	0.617±0.005^{c}	25.358±0.084^{o}

Key: Values are mean±Standard deviation of triplicates, means with different superscript (s) are significantly different (p≤0.05) while those with the same superscript (s) are significantly not different (p>0.05).' Trmt = Treated but stored under room temperature.

Table 2: Effect of Refrigeration Temperature on the Vitamin Compositions of OFSP Treated with $CaCl_2$ solution at different Storage Times

Tempt. (°C)	Storage Period (Week)	Vit. A (mg/100g)	Vit. E (mg/100g)	Vit. C (mg/100g)	β-carotene (µg/g)
4	0	642.872±1.725^{f}	0.513±0.016^{hi}	19.564±0.418^{f}	181.647±0.182^{m}
	2	605.925±0.996^{e}	0.405±0.007^{de}	16.214±0.116^{d}	180.754±0.022^{l}
	4	544.637±2.468^{b}	0.336±0.013^{b}	12.127±0.418^{b}	180.491±0.029^{l}
7	0	724.155±1.882^{g}	0.530±0.007^{i}	20.301±0.876^{fg}	180.619±0.123^{l}
	2	649.392±2.351^{f}	0.481±0.006^{g}	17.755±0.837^{e}	179.046±0.452^{hijk}
	4	591.364±6.900^{d}	0.363±0.008^{c}	14.070±0.921^{c}	178.608±0.499^{ghij}
10	0	806.089±9.136^{k}	0.594±0.014^{j}	22.579±1.228^{h}	180.557±0.117^{l}
	2	773.707±4.141^{i}	0.525±0.018^{hi}	19.698±0.725^{f}	178.538±0.098^{ghij}
	4	649.976±0.553^{f}	0.378±0.011^{c}	16.080±0.532^{d}	178.120±0.055^{fgh}
12	0	887.372±5.795^{m}	0.706±0.003^{mn}	25.728±0.201^{i}	179.254±0.246^{ijk}
	2	795.440±1.725^{j}	0.641±0.008^{k}	22.847±0.506^{h}	178.070±0.285^{fg}
	4	761.536±4.072^{h}	0.415±0.019^{ef}	20.770±0.307^{g}	177.576±0.330^{f}
15	0	924.971±2.290^{o}	0.723±0.004^{n}	32.093±0.418^{l}	179.451±0.131^{ijk}
	2	906.715±4.341^{n}	0.688±0.004^{lm}	29.212±0.307^{k}	178.693±0.221^{ghij}
	4	837.820±6.900^{l}	0.499±0.048^{gh}	26.733±0.402^{j}	178.139±0.295^{fgh}
18	0	1011.904±4.56^{r}4	0.767±0.010^{o}	39.597±0.402^{o}	179.625±0.551^{k}
	2	974.096±4.275^{q}	0.711±0.016^{mn}	37.386±0.603^{n}	178.398±0.613^{fghi}
	4	961.580±2.545^{p}	0.680±0.014^{l}	35.711±0.307^{m}	177.943±0.607^{fg}
Trtm	0	804.351±0.753^{k}	0.717±0.008^{n}	25.058±0.706^{i}	119.342±0.295^{e}
	2	779.140±1.304^{i}	0.665±0.018^{kl}	23.517±0.402^{h}	117.785±0.185^{d}
	4	643.673±5.732^{f}	0.576±0.011^{i}	20.770±0.307^{g}	117.321±0.136^{d}
Control	0	595.493±0.996^{d}	0.436±0.005^{f}	18.559±0.464^{e}	89.532±0.008^{c}
	2	576.151±3.011^{c}	0.387±0.015^{cd}	15.343±0.232^{d}	81.881±0.197^{b}
	4	520.513±5.916^{a}	0.302±0.017^{a}	9.380±0.116^{a}	74.821±2.011^{a}

Key: Values are mean±Standard deviation of triplicates, means with different superscript (s) are significantly different ($p \leq 0.05$) while those with the same superscript (s) are significantly not different ($p > 0.05$). Trmt = Treated but stored under room temperature.

Table 3. Effect of Refrigeration Temperature on the Proximate Composition (%) of OFSP Treated with Wood Ash at different Storage Times

Tempt. (°C)	Storage Period (Week)	Moisture	Lipid	Crude fiber	Protein	Ash	Carbohydrate
	0	71.734±0.256^{l}	1.333±0.001^{j}	0.730±0.004^{hi}	6.108±0.007^{h}	0.692±0.004^{cd}	19.404±0.261^{d}
4	2	72.744±0.011^{p}	1.231±0.006^{i}	0.684±0.005^{e}	5.925±0.041^{f}	0.614±0.008^{b}	18.802±0.053^{c}
	4	74.258±0.056^{pq}	1.101±0.004^{gh}	0.632±0.014^{c}	5.551±0.064^{d}	0.576±0.009^{a}	17.881±0.075^{a}
	0	70.679±0.385^{k}	1.464±0.004^{gh}	0.633±0.001^{l}	6.113±0.007^{h}	0.857±0.005^{g}	20.253±0.394^{f}
7	2	72.122±0.010^{no}	1.274±0.006^{ef}	0.599±0.007^{f}	5.975±0.006^{fg}	0.742±0.009^{e}	19.288±0.013^{d}
	4	72.296±0.068^{o}	1.184±0.009^{d}	0.541±0.029^{d}	5.580±0.016^{d}	0.671±0.019^{c}	19.728±0.076^{e}
	0	70.322±0.004^{j}	1.489±0.007^{gh}	0.632±0.001^{mn}	6.120±0.007^{h}	1.198±0.005^{l}	20.239±0.014^{f}
10	2	69.557±0.014^{i}	1.278±0.006^{efg}	0.607±0.005^{f}	5.987±0.008^{fg}	1.011±0.013^{j}	21.560±0.006^{h}
	4	68.171±0.045^{g}	1.186±0.009^{e}	0.581±0.007^{d}	5.614±0.008^{d}	0.933±0.012^{i}	23.515±0.060^{j}
	0	68.339±0.015^{g}	1.510±0.008^{k}	0.763±0.010^{n}	6.253±0.012^{ij}	1.557±0.009^{q}	21.578±0.053^{h}
12	2	67.443±0.014^{e}	1.349±0.023^{j}	0.715±0.006^{i}	6.080±0.030^{gh}	1.337±0.011^{n}	23.076±0.067^{i}
	4	65.438±0.036^{b}	1.269±0.014^{ij}	0.704±0.045^{f}	5.901±0.028^{f}	1.158±0.012^{k}	25.530±0.107^{n}
	0	67.842±0.012^{f}	1.583±0.003^{n}	1.226±0.007^{o}	6.353±0.006^{ik}	1.585±0.013^{r}	21.411±0.016^{h}
15	2	66.344±0.016^{c}	1.390±0.011^{m}	1.165±0.009^{j}	6.111±0.003^{h}	1.372±0.007^{o}	23.617±0.016^{j}
	4	65.339±0.180^{b}	1.306±0.010^{l}	1.097±0.029^{g}	5.901±0.037^{f}	1.189±0.005^{l}	25.168±0.138^{m}
	0	66.741±0.016^{d}	1.653±0.050^{q}	1.505±0.023^{p}	6.941±0.077^{n}	1.680±0.004^{s}	21.480±0.162^{h}
18	2	65.229±0.015^{b}	1.436±0.008^{p}	1.363±0.012^{k}	6.449±0.193^{l}	1.473±0.009^{p}	24.049±0.195^{k}
	4	64.000±0.317^{a}	1.385±0.010^{o}	1.332±0.015^{j}	6.240±0.085^{i}	1.283±0.030^{m}	25.761±0.236^{o}
Trmt	0	71.837±0.006^{lm}	1.466±0.008^{i}	0.680±0.008^{lm}	6.737±0.009^{m}	0.899±0.036^{h}	18.381±0.055^{b}
	2	70.321±0.012^{j}	1.323±0.005^{h}	0.650±0.014^{gh}	6.229±0.015^{i}	0.755±0.027^{e}	20.722±0.049^{g}
	4	67.339±0.101^{e}	1.122±0.006^{fgh}	0.622±0.009^{c}	5.754±0.110^{e}	0.694±0.005^{cd}	24.469±0.179^{l}
	0	74.104±0.027^{q}	1.337±0.016^{c}	0.502±0.003^{hi}	5.073±0.025^{c}	0.799±0.015^{f}	18.184±0.051^{b}
Control	2	72.020±0.004^{mn}	0.955±0.020^{b}	0.437±0.005^{b}	4.518±0.109^{b}	0.712±0.002^{d}	21.358±0.134^{h}
	4	68.675±0.056^{h}	0.722±0.010^{a}	0.407±0.005^{a}	4.222±0.109^{a}	0.617±0.005^{b}	25.358±0.084^{mn}

Key: Values are mean ± Standard deviation of triplicates, means with different superscript (s) are significantly different ($p \leq 0.05$) while those with the same superscript (s) are significantly not different ($p > 0.05$); Trmt = Treated but stored under room temperature

Table 4: Effect of Refrigeration Temperature on the Vitamin Composition (%) of OFSP Treated with Wood ash at different storage times

Tempt. (°C)	Storage Period (Week)	Vit. A (mg/100g)	Vit. E (mg/100g)	Vit. C (mg/100g)	Vit. β-Carotene (µg/g)
4	0	691.555±4.141^{g}	0.560±0.002^{ef}	22.512±0.348^{f}	317.837±0.971^{q}
	2	638.525±3.707^{e}	0.497±0.011^{de}	19.296±0.532^{de}	316.962±0.720^{pq}
	4	549.636±3.630^{b}	0.374±0.010^{b}	15.276±1.119^{b}	316.299±0.828^{p}
7	0	843.905±18.549^{l}	0.587±0.012^{fg}	25.259±0.614^{g}	281.005±1.146^{o}
	2	778.488±2.842^{i}	0.532±0.013^{ef}	20.234±0.580^{e}	279.097±1.476^{n}
	4	667.213±0.376^{f}	0.384±0.008^{bc}	17.621±0.950^{c}	278.672±1.481^{n}
10	0	876.288±2.988^{n}	0.667±0.012^{hi}	27.202±0.307^{h}	259.204±0.026^{m}
	2	833.908±4.564^{k}	0.625±0.005^{gh}	22.579±0.464^{f}	257.410±0.013^{l}
	4	739.585±3.081^{h}	0.444±0.013^{cd}	19.564±0.307^{de}	256.796±0.056^{l}
12	0	914.321±7.415^{o}	0.770±0.008^{ijk}	30.150±0.348^{ijk}	196.553±0.759^{k}
	2	885.633±3.930^{n}	0.700±0.017^{i}	25.125±0.532^{g}	194.295±0.223^{j}
	4	794.571±2.290^{j}	0.512±0.058^{e}	22.981±0.812^{f}	193.819±0.106^{j}
15	0	941.271±6.265^{p}	0.909±0.013^{m}	34.572±0.603^{l}	182.318±0.009^{i}
	2	908.453±3.282^{o}	0.825±0.023^{kl}	30.418±0.906^{k}	180.226±0.012^{gh}
	4	879.113±9.456^{n}	0.696±0.035^{i}	29.279±0.307^{ij}	179.619±0.047^{g}
18	0	1167.949±4.341^{r}	1.362±0.010^{p}	40.937±1.012^{o}	181.422±0.005^{hi}
	2	1158.540±5.218^{q}	1.225±0.010^{o}	39.329±0.837^{n}	180.735±0.007^{gh}
	4	1154.124±4.463^{q}	1.000±0.030^{n}	38.123±0.506^{m}	180.428±0.057^{gh}
Trmt	0	859.336±0.652^{m}	1.052±0.059^{n}	28.743±0.201^{i}	125.112±0.015^{f}
	2	837.603±2.290^{kl}	0.882±0.007^{lm}	25.929±0.532^{g}	123.391±0.011^{e}
	4	786.095±0.996^{ij}	0.716±0.138^{ij}	23.048±0.506^{f}	121.743±0.049^{d}
Control	0	595.493±0.996^{d}	0.436±0.005^{bcd}	18.559±0.464^{cd}	89.532±0.008^{c}
	2	576.151±3.011^{c}	0.387±0.015^{bc}	15.343±0.232^{b}	81.881±0.197^{b}
	4	520.513±5.916^{a}	0.302±0.017^{a}	9.380±0.116^{a}	74.821±2.011^{a}

Key: Values are mean±Standard deviation of triplicates, means with different superscript (s) are significantly different ($p \leq 0.05$) while those with the same superscript (s) are significantly not different ($p > 0.05$); Trmt = Treated but stored under room temperature

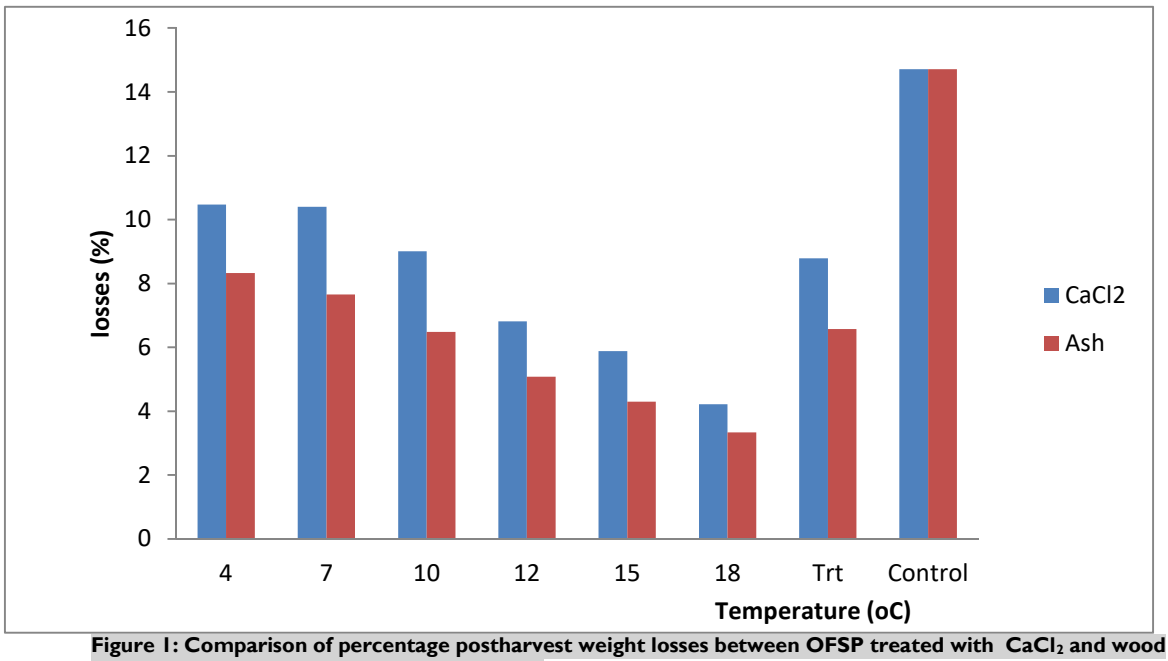

Figure 1: Comparison of percentage postharvest weight losses between OFSP treated with $CaCl_2$ and wood Ash during storage at different temperature.

Table 1 explains how different storage temperatures (4,7,10,12,15,18 and ambient temperature °C) influenced the proximate compositions of OFSP treated with $CaCl_2$ solution during storage. It has been recorded that storage temperature has a large influence on OFSP storage. Low temperatures had severe negative effect on the storage of OFSP. From the result recorded, refrigeration temperature did not really have negative effect (P≥0.05) on the proximate composition of OFSP. Except in moisture content where lower temperatures (4-7 °C) increased it with increase in storage weeks. It was observed that temperatures between 12 and 18 °C gave better result even in treated samples stored at room temperature while the control had the least among all the analysed samples. The control was scientifically highly difference (P≤0.05) from the treat experimental samples during the storage periods. This result corresponds with research done by Adie *et al* [5].

The result in Table 2 showed that storage with different refrigeration temperatures had significant difference (P≤0.05) to the OFSP, though the effect was minimal as a result of the $CaCl_2$ solution treatment. It was observed that 18 °C gave the highest retention during the storage compared to other storage temperatures. Also, the treated OFSP roots including the ones stored at room temperature were better stored compared to the control. The lower temperatures were found to decrease the vitamins more than that of the higher temperatures except in the issue of β-carotene (pro-vitamin A). Vitamin C content decreased during storage with the advancement of storage period. For as long as 4 weeks of storage, there was no significant difference (P≥0.05) between roots stored at 12 and 15 °C in Vitamins A, E and C. The higher values were found between 12 and 18 °C during the storage weeks. However, there was significant decrease in the treated samples stored in 4, 7 and 10 when compared to 12, 15 and 18 °C. The samples stored at room temperature had significant decrease (P≤0.05) in the vitamins as the storage period increased. It was found that 4 °C gave the highest value of β-carotene followed by 7 °C and 10 °C which showed no significant difference (P≥0.05) during the storage. This proves the report that lower storage temperature has a better preservative power over the β-carotene level by preventing the denaturation of this nutrient as reported by Adie *et al* [5]. The results above showed similar findings reported by Abidin *et al*. [25] and Tumuhimbise *et al.,* [13].

Table 3 explains the level of effect of different storage temperatures on the proximate compositions of the treated OFSP. The lower the storage temperature the lower the amount of the compositions. While higher temperatures gave higher results [26,27]. Refrigeration temperature had effect scientifically (P≤0.05) on the moisture composition (MC) of OFSP treated as shown in Table above. At 4 °C, the MC gave the highest values while the lowest occurred in 18 °C. The lipid (crude fat), crude fiber, protein and ash contents showed the highest values in 18 °C at week 0 which decreased as storage weeks increased. The ash content was not scientifically ((P>0.05) affected by storage temperature, this indicated that ash was insusceptible to environment conditions and less physiological activity. Also, fat had significant change (P≤0.05) which indicates that the losses might be attributable to the fact that fats are rich in unsaturated fatty acid, which is susceptible to oxidation degradation. But carbohydrate increased with increase in temperature and storage periods in which the highest value occurred at week 4 of storage. The control had significant difference (P≤0.05) compared to the treated roots. The wood ash treatment had a positive effect on the proximate composition even with the storage at different refrigerator temperatures. This report is in line with the report of Zhang *et al.* [28], Liu *et al* [29] and Lee and Cho [30].

There was a similar trend of reduction of vitamins noticed in Table 4 as storage period increases. The water soluble vitamin C increased with increase in the storage temperature which diminished with storage periods, likewise vitamins A and E. But it was observed that β-Carotene decreased with increase in storage temperature where 4 °C yielded the highest amount at weeks 0 to

4 (317.837-316.299 µg/g) while the lowest amount occurred in 18 °C. At room temperature (RMT), the treated roots had better results in all other vitamin compositions than at 4 and 7 °C except in β-Carotene where RMT gave the least values (125.112-121.743 µg/g). There was significant difference (P≤0.05) between the storage temperatures as storage weeks increased. It was discovered that the control had the least values in all the vitamin compositions, this showed highly significant difference (P≤0.05) when compared to the treated samples stored at different temperatures. This finding showed similar result to that reported by Mudau *et al* [31] and Zhang *et al.* [29]. It is observed that wood ash application significantly increased the nutrient content of OFSP. This reflects to the report of Akinmutimi,*et al* [32].

According to Chandrasekaram *et al.* [33], β-carotenes suffer minimal losses because of increase in fat content and also high dry matter content in OFSP, which protected the β-carotenes from deteriorating faster than it showed in this study. Several factors could have contributed to the effect of the postharvest application of wood ash on OFSP nutritional contents during storage such as variety of food crops, maturation stage, interaction of the sample to the compositions of the packaging materials and the storage environment, climatic condition, the conditions of the reagents used, mechanical damage, microbial activities, enzymatic reactions, heat could have been one of the main factors that cause the degradation of these bioactive compounds, and losses up to 22.093% of deterioration even at room temperature, etc., although the effect of these factors were not analysed

Figure 1 Indicates the comparative study of the percentage postharvest losses between OFSP treated with different storage temperatures of $CaCl_2$ solution and wood ash suspension during storage. At different storage temperatures, wood ash suspension showed the best as compared to storage of samples treated with $CaCl_2$ solution. Scientifically (P≤0.05), wood ash treated samples were better preserved in all the storage temperature, most especially at 18 °C. This may be attributed to the fact that wood ash contains more of the elements (Ca and potassium) that can make the cell walls of OFSP more rigid thereby prolonging the shelf-life of the produce. No work has been done in regards to this.

Kays [34] reported that the weight loss in fruit may be largely associated with water loss through transpiration and, to a lesser extent, respiration, which increases when fruit are exposed to higher temperatures. This fact was not observed in the present study, once the higher the storage temperature, the lesser the weight loss. Thus, the storage temperature of 18 °C led to the lowest weight loss as shown in Figure 1. Brunini and Coelho [35] studied the effect of packages associated with different temperatures in jabuticaba variety 'Sabará' and observed that the fruit stored at room temperature (21 °C to 26.5 °C) exhibited the highest fresh weight losses, differently from observed in the present study.

Conclusion

The experiment showed that postharvest wood ash suspension and $CaCl_2$ solution treatments prevented OFSP from spoilage and decreased weight losses. Increase in the temperature decrease the weight loss of the experimental samples, increases the firmness and the dry matter of the experimental samples. From the investigation, it was observed that samples untreated that were stored under ambient temperature (26–32 °C) suffered a huge amount of losses of the quality given their condition at the beginning of the study. The storage temperature showed more interesting result at 18 °C followed by 15 and 12 °C while the least amount of the parameters analysed occurred at storage temperature of 4 °C. It was observed that at ambient temperature, the retention of the nutrients of the treated samples was encouraging as related to some other treated samples stored at different storage temperatures while the control gave the highest losses of the proximate and vitamin compositions of OFSP.

Hence, wood ash suspension is more recommendable for prolonging the shelf life of OFSP than $CaCl_2$ solution. Likewise, temperatures below 12 °C and above 18 °C is not recommended for the storage of OFSP as observed from this study.

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Declaration of conflicting interest

The authors declared no potential conflicts of interest.

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