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Postharvest Proximate and Mineral Compositions of Orange-Fleshed Sweet Potato Treated with Different Concentrations of Calcium Chloride

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ABSTRACT

Freshly harvested orange-fleshed sweet potato (OFSP) starts deteriorating after about one week of storage, unless treated, even at 18°C. Postharvest chemical treatment has been found to prolong the shelf-life of the root. In this study, treatment with different concentrations (1, 2, 3, 4, 5 and 6 %) of $CaCl_2$ were used to investigate the effect of storage time (0,2 and 4 weeks) on the proximate and mineral contents of UMUSPO 3 variety of OFSP in triplicates. Results showed that among the different concentrations, 4 % had more positive effect on the OFSP root minerals (Ca, Na, Mg, P, K, Zn) compositions which were significantly different ($P \leq 0.05$) between 0 -2 weeks, and 0- 4 weeks of storage but was not scientifically different between week 2 and week 4. Also, the minerals were significant ($P \leq 0.05$) between $CaCl_2$ concentrations. While, in all the proximate analysis significant ($P \leq 0.05$) difference was found. The effect of $CaCl_2$ concentrations did not negatively affect the proximate and mineral compositions despite the level of concentrations. It could be deduced that minimal deterioration occurred at the cell wall of the roots and extended to the starchy parenchyma regions as a result of $CaCl_2$ applications. The high retention of stored OFSP (UMUSPO 3) quality could be as a result of the accumulation of Ca in the cell walls which led to facilitation in the cross linking of the pectic polymers that increases the wall strength and cell cohesion. Finally, postharvest application of 4 % of $CaCl_2$ is advisable to farmers in storing and maintaining a healthy and nutritious OFSP roots for consumptions.

Keywords: Minerals, Postharvest, Potato, Proximate

INTRODUCTION

Sweet potato (*Ipomoea batatas* Lam) is a dicotyledonous plant that belongs to the family, *Convolvulaceae*. Its large, starchy, sweet-tasting, tuberous roots are a root vegetable. The young leaves and shoots are sometimes eaten as greens. Due to its tropical root nature, it has started playing an important role in food security, nutrition and economy of Nigeria and many other tropical Sub-Sahara African (SSA) countries (FAO, 1990, Horton, 1998). OFSPs are the most packed with provitamin A that helps in combating vitamin A deficiency (VAD) in over 43 million children in most African countries (Rodriguez-Amaya *et al.*, 2011). It also helps in fighting poverty such that ninety-five percent (95%) of OFSP are grown in developing countries, mostly by small-scale farmers and at home gardens for family consumption and the extra are sold to supplement their income (The US Government, 2014).

Postharvest physiological deterioration (PPD) has been a major constraint on freshly harvested crops. This activity causes spoilage in such a freshly harvested food crop which leads to loss of some amounts of its micronutrient (Wenham, 1995, Beeching *et al.*, 1997). These physiological changes affect their nutritional quality and bio-availability as well as the tissue microstructure during storage period. The extent at which the crop is stored has a long way to determine the retention of the quality of the produce. Proper treatment during storage may to an extent retain some appreciable quantities of the nutrients (Tumuhimbisie *et al.*, 2010).

OFSP roots are subjected to several forms of postharvest losses after harvest. Unprocessed OFSP does not have longer shelf life when compared to some other crops such as carrots or potatoes. In storage, the roots are very perishable as a result of high moisture content (60-75%), and high respiratory rate. The heat production softens the textures resulting in its susceptible to damage (Okporie *et al.*, 2022).

Storage using unharmful chemical treatment that is able to rigid the cellwall of the experimental sample can lead to higher retention of the nutrient The use of chemicals on food crops in store is an effective storage treatment but is, however, complicated by the fact that some of these chemicals have been found to have serious limitations such as toxicity and excessive cost. However, some chemicals used in preservation are not harmful during consumptions example is calcium chloride (Fattahi *et al.*, 2010, Adekunle and Uma, 2005). Calcium chloride has been used previously on various produce including apples, mangoes, loquat and strawberries (Souza *et al.*, 1999, Aktar *et al*., 2010, Hussain *et al.*, 2012 and Dhillon and Kaur, 2013) showing positive results in maintaining postharvest quality of the produce. A research carried out by Okporie *et al*. (2022) also showed that calcium chloride is a good preservative substance for sweet potato. This research was, therefore, designed to investigate the postharvest proximate and mineral compositions of orange-fleshed sweet potato treated with different concentrations of calcium chloride.

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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) sections. One portion was used as the control and the other two portions were treated with $CaCl_2$ and wood ash solutions (Garcia *et al.*, 2019). These two divisions were dipped into 1, 2, 3,4, 5 and 6 % $CaCl_2$ solutions, air dried and packaged with black polyethylene bags. These were stored at 18 ^oC for 0, 2 and 4 weeks of storage period for further analysis (Ubani *et al*., 2008, Artès *et al*., 2006). The effect of the treatments on the mineral and proximate properties of the OFSP root samples was evaluated.

Chemical Analysis

Proximate compositions

a. Fat content determination

The solvent extraction AOAC (2010) 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 ^oC 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 equation 1:

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

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 (2005) 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 minutes 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 were transferred to porcelain crucible, dried in an oven at 105 °C for 3 hours, cooled in a desiccators, was reweighed (W_2) and incinerate at 105 °C for 2 hours until they turned into ash. The ash obtained was cooled in a desiccator and weighed (W_3). The crude fiber content was calculated gravimetrically using equation 2 as:

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

Where 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 (2005) 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), it was then 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 were cooled in a desiccator and then weighed (W_3), total ash is given by equation 3.

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

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 (2010) 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 ^{o}C for 6-12 hours until a constant weight was obtained. It was allowed to cool in the desiccator for 30 minutes 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.

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

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 (2010) 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 (equation 5) gave the dry matter content.

$$\% \text{ Dry matter} = 100 - (\% \text{ moisture}) \quad 5$$

f. Determination of protein

Semi-micro Kjedahl method was used for the protein determination as described by AOAC (International, 2007) method 955.04.

Protein was determined by mixing 2 g of the test sample with 10 mL of concentrated 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.

Equation 6 was used to calculate the nitrogen and protein content:

$$\text{Protein (\%)} = \% \text{ N}_2 \times 6.25 \quad 6$$

$$\% \text{ N}_2 = \frac{100}{W} \times \frac{14 \times M}{1000} \times \frac{Vt}{Va} \times \text{T} - \text{B}$$

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 (2005). In this method, the carbohydrate was obtained by calculation after estimating all other fractions by proximate analysis. Hence, it was calculated using equation 7.

$$\% \text{ CHO} = 100 - \% \text{ (Protein + Fat + Fibre + Ash + Moisture content) on wet basis} \quad 7$$

MINERAL COMPOSITIONS

a. Determination of phosphorus

Phosphorus in the samples was determined by using the vanado-Molybdate (yellow) method using spectrophotometer as described by Onwuka (2005). 2 mL extract of sample was dispensed into a 50 mL volumetric flask, similarly the same volume of standard phosphorus solution as well as standard and blank respectively. The content of each tube was mixed with 2 mL of the vanadomolybdate for 15 minutes at room temperature. The test mixture was diluted to the 50 mL mark with distilled water and the absorbance was taken in Jenway electronic spectrophotometer at wavelength of 540 nm. Measurement was given with the blank at zero and phosphorus calculated in equation 8.

$$\text{Phosphorus (mg/100g)} = \frac{100}{W} \times \frac{AU}{AS} \times c \times \frac{Vt}{Va} \quad 8$$

Where W = Weight of sample analyzed (g), AU = Absorbance of test sample, AS = Absorbance of standard solution, Vt = Total volume of filtrate (mL), Va = Volume of filtrate analyzed (mL) and c = Total volume of extract (mL).

b. Determination of calcium and magnesium

Calcium and magnesium content of the test samples were determined by the Versanale EDTA complexometric titration. This method was described by Onwuka (2005).

20 mL of each extract was dispersed into a conical flask, pinches of the masking agents (hydroxylamine, hydrochlorate, sodium cyanide

and sodium potassium ferrocyanide) was added. The mixture was shaken to dissolve, followed by the addition of 20 mL of ammonia indicator solution to raise to pH 10.0 (a point at which calcium and magnesium form complexes with EDTA). The pinch of the indicator (Erichrome black-T) was added and the mixture was shaken very well. A titration against 0.01M of EDTA solution and colour changed from mauve to a permanent blue colouration. A reagent blank consisting of 20 mL distilled water was also treated as described above. The titration gave a reading for combined Ca and Mg complexes in samples. A separate titration was then conducted for calcium alone. Titration for calcium alone was a repeat of the previous one with slight change, 10% NaOH solution at pH 12.0 was used in place of the ammonia buffer while solochrome dark blue (calcon) was used as indicator in place of erichrome black. Calcium and magnesium contents were calculated separately using the equation 9.

$$\% \text{ Calcium or Magnesium} = \frac{100}{W} \text{ x T-B (N x Ca/Mg) x } \frac{Vt}{Va}. \quad 9$$

Where W = Weight of sample analyzed (g), B =Titre value of blank, Ca = Calcium equivalent, Mg = Magnesium equivalent, Vt= Total volume of extract (mL), N = Normality of EDTA (0.02N EDTA), Va = Volume of extract titrated, T = Titer value less blank.

c. Determination of sodium (Na) and potassium (K)

This was carried out using flame photometry Na and K contents were determined by an emission flame photometer (Corning, model 403, UK) (Abdualrahman, 2015). Jaway digital photometer was set up according to the manufacturer's instruction. The equipment was turned on and allowed to stay for about 10 to 15 minutes to equilibrate. The gas and air lets were opened as the start knob was turned on. The equipment being self-igniting and the flame were adjusted to a non-luminous level (blue colour flame). Meanwhile, standard K and Na solutions were prepared separately and each was diluted to concentration of 2, 4, 6, 8 and 10 g respectively. When analyzing for specified element, K or Na, the appropriate filter was selected and the instrument flushed with distilled water. The highest concentrated standard solution was put in place and the reading was adjusted to 100 mL. Thereafter, starting with least concentration of 2 g, after equilibrating the instrument, 1 mL of each standard was aspirated into the instrument and caused to spray over the non-luminous flame. The readings were recorded and later plotted into a standard curved use to extrapolate the K level in the sample. Before filtering, the appropriate element (Na or K) was put in place with the standards measured, and the sample digests were carefully siphoned in turns into the instrument, their readings recorded. The samples were repeated with sodium (Na) standard and the place of the K filter. The concentration of the test mineral in the sample was calculated and obtained using equations 10 and 11.

$$\text{Na/100g} = \frac{100}{W} \text{ x } \frac{Vt}{1} \text{ x } \frac{N}{10^5} \text{ x } \chi \text{ x D} \quad 10$$

Where W = Weight of sample used (g), Vt = Total extract volume (mL) since 1m was siphoned into the instrument, X = Concentration from the graph, D = Dilution factor where applicable similarly.

For potassium concentration it was given,

$$\text{K/100g} = \frac{100}{W} \text{ x } \frac{VT}{1} \text{ x } \frac{N}{10^5} \text{ x D} \quad 11$$

d. Determination of zinc (Zn)

Zn was determined using atomic absorption spectrophotometer with its hollow cathode lamps (Perkin-Elmer model 403, USA) and an atomic absorption standard solution was used for the construction of calibration curve as described by Bombatkar *et al.* (2010) and Ekpete *et al. (*2013). 5 mL of the digest was diluted to 100 ml with distilled. This was served as sample solution for AAS. Zinc lamp was installed into the spectrometer and the wavelength of 213.9 nm (Zn) was programmed into a detector. The sample was then analyzed by spectrometer and Zn concentration was displayed in parts per million (equation 12). Also a standard solution of respective elements was prepared in concentration of 0.0, 0.2, ……1.0 percent.

$$\text{Zn (mg/100g)} = \frac{Vf}{Vs} \text{ x } \frac{x}{103} \text{ x } \frac{100}{w} \text{x D} \quad 12$$

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

RESULTS AND DISCUSSION

Table 1 shows the mineral compositions of a freshly harvested OFSP. The K content had the highest percentage of 296.385±5.223, this was followed by P (43.797±0.017), Ca (27.726±0.007), Mg(24.774±0.008), Na (23.282) and the least was Zn (0.253±0.005). The result indicates that OFSP is a good source of minerals which could reach a daily intake of it for human as recorded by US Department of Agricultural Research Service (2009).

The proximate composition of the OFSP samples which include; moisture, carbohydrates, protein, crude fibre, fat and ash were evaluated as shown in Table 2. Moisture is the percentage of water in food product. Table 2 indicated that the percentage moisture content of treated OFSP at 1% was the highest (74.387) at week 0, which reduced to 72.020% and 68.604% at weeks 2 and 4 respectively; while the one treated with 4% $CaCl_2$ gave the lowest percentage of 69.106-66.233% (weeks 0 and 4 respectively) as compared to other OFSP roots treated at different $CaCl_2$ concentrations. This started depreciating at 5% concentration. This showed that the root treated with 4% $CaCl_2$ concentration was significantly ($p \leq 0.05$) different from those at 1,2,3,5 and 6% concentration. In comparing this to the control, the highest values (74.387 – 68.675%) at weeks 0 and 4, were seen in control which significantly differed ($P \leq 0.05$) from the treated roots except at 1% concentration. It can be deduced that the increase of $CaCl_2$ concentration to its optimum level leads to the decrease of moisture content. This could be due to the increase of Ca^{2+} ion which then could form more of calcium pectate complex. This showed an agreement to a report by Tiwari *et al.* (2018) on potato, Kazemi *et al.* (2011) on swales and Prakash *et al*. (2007) on tomatoes.

The result also showed that the percentage lipid (fat) content of treated OFSP at 2% was the highest (1.266, 0.982 and 0.836%) at weeks 0, 2 and 4 respectively; while the one treated in 3% $CaCl_2$ gave the lowest percentage of 1.166-0.865% (weeks 0 and 4 respectively) among the OFSP roots treated at different concentrations. This showed that the root treated with 2% $CaCl_2$ concentration was significantly ($p \leq 0.05$) different from those at 1,3,4,5 and 6% concentration. In comparing this to the control, the highest values (1.337-0.722%) at weeks 0 and 4, were seen in control which significantly differ ($P \leq 0.05$) to the treated roots concentrations. This result is also in line with the report of Kazemi *et al*. (2011) on swales.

The percentage crude fiber content of treated OFSP at 4 and 6% were the highest (0.617, 0.551 and 0.526%, and 0.614, 0.550 and 0.521%) at weeks 0, 2 and 4 respectively; while the one treatment at 1% $CaCl_2$ gave the lowest percentage of 0.530-0.421% (weeks 0 and 4 respectively) among the OFSP roots treated at other concentrations. This showed that the root treated with 4 and 6% $CaCl_2$ were not significantly different ($p \geq 0.05$) at each other but were significantly ($p \leq 0.05$) different from those at 1,2,3 and 5% concentration. In comparing this to the control, the lowest values (0.502-0.407%) at weeks 0 and 4, were seen in control were significantly different ($P \leq 0.05$) to the treated roots concentrations during the storage periods. This showed an agreement to a report by Chen *et al.* (2011) on strawberries and Garcia *et al.*(2019) on jabuticaba variety.

From the Table 1 shown, the percentage protein content of treated OFSP at 4 and 5% (w/v) was the highest (6.644, 5.845 and 5.475%, and 6.598, 5.743 and 5.540%) at weeks 0, 2 and 4 respectively. These levels were not significant ($P \geq 0.05$) to roots dipped in 6% concentration but significantly different ($P \leq 0.05$) to others, while the one treated in 2% $CaCl_2$ gave the lowest percentage of 5.969, 5.214 and 4.891% (weeks 0, 2 and 4 respectively) among the OFSP roots treated at other concentrations but was significant to 1,2 and 3% concentrations. This showed that the root treated with 4 and 5% $CaCl_2$ concentration was significantly ($p \leq 0.05$) different from those at 1,2 and 3% concentrations during the storage. In comparing this to the control, the lowest values (5.073, 4.518 and 4.222%) at weeks 0, 2 and 4, were seen in control which was significantly different ($P \leq 0.05$) to the treated roots except at 1% concentration. This showed an agreement to a report by Kazemi *et al*. (2011).

The Table 1 also revealed that the ash content gave the highest level in concentration of 4% concentration (1.565-1.093%) followed by 3% concentration (1.540-1.017%) at weeks 0 and 4 respectively. The highest level was significantly different ($P \leq 0.05$) to other treated roots. The lowest level among the treated samples occurred in 1 (0.618-0.516%). The control was significantly different ($P \leq 0.05$) to all the treated samples but had higher value than that of 1%. This result is in concurrence with report of Tjandra *et al.* (2019).

The carbohydrate content resulted in the highest level in 4 (w/v) (19.312-25.658%) followed by 5% (20.347-25.501%) at weeks 0 and 4 respectively. These two concentrations were not significantly different ($P \geq 0.05$) from 6%. The lowest level of carbohydrate was found in 1% (16.626-24.065%). Concentrations 4, 5, and 6 (w/v) were seen highly significantly different ($P \leq 0.05$) to other treated samples and were significantly different ($P \leq 0.05$) to the control which yielded the carbohydrate percentage of 18.184-25.358 at weeks 0 and 4 respectively during the storage. From the observation, there was percentage increase in the carbohydrate composition, as the storage period increases the carbohydrate level increased. The increase in carbohydrate content after storage could be attributed to possible non activities of fungi. It is expected that the presence of fungi will possibly result in carbohydrate reduction in samples since it serves as a source of food for energy for survival, establishment and multiplication of the fungi (Tanuja *et al.,* 2012). Because there was no possible fungal infestation, therefore, carbohydrate content of OFSP increased due to the non utilization of carbohydrates by the fungi through amylolytic activities. This could also be as a result of the treatment of $CaCl_2$ concentrations on the OFSP which minimized the level of deterioration.

Generally, increased proximate parameters could be because of corresponding concentration of nutrients due to reduction in moisture content as a result of the treatment. This result is in accordance with Kazemi *et al*., (2011) on swales, Alam *et al.* (2016) and Haile and Getahun (2018) on OFSP.

The mineral compositions of the OFSP root samples which include calcium (Ca), sodium (Na), magnesium (Mg), Phosphorus (P) and potassium (K) were evaluated. The results of the analysis are shown in Fig. 1. Results obtained showed that storage of 1 % concentration had significant difference ($p\leq0.05$) on the mineral composition of the OFSP. The Ca content of the sample ranged from 26.780-22.965% at storage period of 0 to 4 weeks which was significantly difference ($p\leq0.05$). It had depreciation from week 2 with 23.472%. This result has similarly been reported by Pila *et al* (2010) and, Youryon and Wongs-Aree (2015) on sweet-potato and fruits dipped in $CaCl_2$ which was significant ($p\leq0.05$) compared to that of the other concentrations. Garcia *et al.*(1996)have noted that fruits dipped in 1% $CaCl_2$ solution though in 3 minutes at room temperature had significantly higher concentration of calcium during storage. While Na gave 28.663-22.890% at storage period of 0 to 4 weeks, which starts reducing at week 2 of storage with 23.505%. This result is agreement with the report of Secilmis *et al.* (2013).

Mg reduced from 24.604% (week 0) to 22.606% (week 4) which was significantly different ($p\leq0.05$) during the storage period. The reduction showed the effect from week 2 of storage giving the value of 23.198%. P content of the treated samples was high and ranged from 46.644-43.323 mg/100g during the storage period. Its deterioration was discovered from week 2 of storage to be 43.730 mg/100g, While K had the highest level among other mineral compositions. At 1% $CaCl_2$ K yielded 296.445 mg/100g at week 0 which started depreciating from the 2nd week (week 2) of storage from 293.568 mg/100g to 292.165 mg/100g on week 4 of storage. At 1% $CaCl_2$, the mineral compositions showed significant difference ($P\leq0.05$) between the storage at week 0 and week 2, and between week 0 and week 4. While week 2 was significantly different to week 4 during the storage. Therefore, 1% was significant ($p\leq0.05$) over the mineral compositions during the storage periods (0, 2 and 4weeks) of the OFSP roots.

The results of the OFSP treated with 2% analysis are shown in Fig. 2. The results gotten showed that storage 2% concentration had significant difference ($p\leq0.05$) on the mineral composition of the OFSP. The Ca content of the sample ranged from 26.296 -22.840% at storage period of 0 to 4 weeks which was significantly difference ($p\leq0.05$). It had depreciation from week 2 with 23.290%. While Na 29.632-23.733% at storage period of 0 to 4 weeks which starts reducing at week 2 of storage with 24.488%. In Na, the reduction was highly significant between week 0 and week 4. Mg reduced from 23.238% (week 0) to 21.312% (week 4) which was significantly different ($p\leq0.05$) during the storage period. The reduction showed effect from week 2 of storage giving the value of 21.773% .There was no significant difference ($p\geq0.05$) in Mg between week 2 and week 4. P content of the sample was high and ranged from 47.948-45.302 mg/100g during the storage period. Its deterioration was discovered from week 2 of storage to be 45.718 mg/100g. While K had the highest level among other mineral compositions. At 2% $CaCl_2$ K yielded 284.441 mg/100g at week 0 which depreciated from week 2 of storage to 282.638 mg/100g and 282.130 mg/100g on week 4 of storage. At 2% $CaCl_2$, the mineral compositions showed significant difference ($P\leq0.05$) between the storage at week 0 and week 2, and between week 0 and week 4. While week 2 was significantly different to week 4 during the storage. Therefore, 2% was significant ($p\leq0.05$) over the mineral compositions during the storage periods (0, 2 and 4weeks) of the OFSP roots. Similar report was observed by Sanoussi *et al.* (2016) who evaluated Ten Elites Sweet Potato, and also Chen *et al.* (2011) who reported on strawberries (*Fragaria annanassa* Duch.).

Fig. 3 shows the effect of storage period on mineral composition of OFSP with 3% $CaCl_2$. The results showed that storage of root treated with 3% $CaCl_2$ concentration had significant difference ($p\leq0.05$) on the mineral composition of the OFSP during the storage periods. The Ca content of the sample ranged from 25.942-22.151% at storage period of 0 and 4 weeks which was significantly difference ($p\leq0.05$). It had depreciation from week 2 with 23.008%. While Na 30.368-25.028% at storage period of 0 to 4 weeks which starts reducing at week 2 of storage with 25.482%. In Na, the reduction was significant ($p\leq0.05$) between week 0 and week 4 but no significant difference ($P\geq0.05$) between week 2 and week 4 storage periods. Mg reduced from 23.549% (week 0) to 21.530% (week 4) which was significantly different ($p\leq0.05$) during the storage period. The reduction showed effect from week 2 of storage giving the value of 21.904% .There was no significant difference ($p\geq0.05$) in Mg between week 2 and week 4. P content of the sample was high and ranged from 47.808-44.826mg/100g during the storage period. Its deterioration was discovered from week 2 of storage to be 45.284mg/100g. While K had the highest level among other mineral compositions. At 3% $CaCl_2$ K yielded 285.104mg/100g at week 0 which depreciating from the 2nd week (week 2) of storage to 281.380mg/100g and 280.824 mg/100g on week 4 of storage. At 3% $CaCl_2$, the mineral compositions showed significant difference ($P\leq0.05$) between the storage at week 0 and week 2, and between week 0 and week 4. While week 2

was not significantly difference ($P\geq0.05$) between week 2 and week 4 during the storage. The reduction could be as a result of some minor effect of microbial activities which might have occurred during the storage. This finding also has similar report observation with that of Sanoussi *et al.* (2016) who evaluated Ten Elites Sweet Potato, and also Chen *et al*. (2011)who reported on strawberries (*Fragaria annanassa* Duch.).

Fig. 4 indicated that at 4% $CaCl_2$ treatment, the mineral compositions had significant difference ($p\leq0.05$) on the OFSP. The Ca content of the sample had mean values of 29.920-26.195% at storage period of 0 and 4 weeks which was significantly difference ($p\leq0.05$). It had depreciation from week 2 with 26.687%. While Na 30.674-25.208% at storage period of 0 to 4 weeks which started reducing at week 2 of storage with 25.482%. In Na, the reduction was significant ($p\leq0.05$) between week 0 and week 4 but no significant difference ($P\geq0.05$) between week 2 (25.655%) and week 4 storage periods. Mg reduced from 26.438% (week 0) to 24.509% (week 4) which was significantly different ($p\leq0.05$) during the storage period. The reduction showed effect from week 2 of storage giving the value of 24.807% .There was no significant difference ($P\geq0.05$) in Mg between week 2 and week 4. P content of the sample was high and ranged from 48.428-46.356mg/100g during the storage period. Its deterioration was discovered from week 2 of storage to be 46.759 mg/100g. While K had the highest level among other mineral compositions. At 4% $CaCl_2$, K yielded 314.762mg/100g at week 0 which depreciated to 312.559mg/100g and 311.963mg/100g on week 2 and 4 respectively of storage. At 4% $CaCl_2$, the mineral compositions showed significant difference ($P\leq0.05$) between the storage at week 0 and week 2, and between week 0 and week 4. While no significant difference was found between week 2 and week 4 during the storage. The retention of minerals analysed was more appreciable in 4%. At 4% $CaCl_2$, it could be the optimum concentration needed for calcium to diffuse to the matrix of sweet potato. It indicates that the samples treated with 4% did not cause rupture than other treated OFSP samples, owing to the fact that negatively charged galacturonic acid residues in pectin form ionic bonds in the presence of calcium. This results in the formation of a calcium-pectate structure, which strengthens cell walls (Rico *et al.*, 2007). Calcium pectate is playing a crucial role in the freshness of sweet potato roots. The mechanism of calcium pectate in affecting the freshness of sweet potato is that the crosslinking will attract the water to bond with. Therefore, water molecules will penetrate the wall and the matrix of sweet potato roots (Chen *et al.*, 2016). This finding has similarly been reported by Kayisoglu and Demirci (2016) on Grape Pekmez, Bombatkar *et al* (2010), Ekpete *et al* (2013) on some Nigerian fruits and Secilmis *et al.* (2013) on Enamel.

Fig. 5 showed the effect of 5% $CaCl_2$ treatment on the mineral compositions of OFSP. The Ca content of the sample gave the mean values of 28.823-25.650% at storage period of 0 and 4 weeks which revealed scientifically difference ($p\leq0.05$). It had depreciation from week 2 with 26.037%. While Na 29.217-24.148 mg/100g at storage period of 0 to 4 weeks which starts reducing at week 2 of storage with 24.453 mg/100g. In Na, the reduction was significant ($p\leq0.05$) between week 0 and week 4 but no significant difference ($P\geq0.05$) between week 2 (25.655%) and week 4 storage periods. Mg reduced from 25.837% (week 0) to 24.026% (week 4) which was significantly different ($p\leq0.05$) during the storage period. The reduction showed effect from week 2 of storage giving the value of 24.470% .There was no significant difference ($P\geq0.05$) in Mg between week 2 and week 4. P content of the sample was high and ranged from 46.497-44.789 mg/100g during the storage period. Its deterioration was discovered from week 2 of storage to be 45.203 mg/100g. While K had the highest level among other mineral compositions. At 5% $CaCl_2$ K gave 287.350 mg/100g at week 0 which depreciated from the 2nd week (week 2) of storage to 282.732 mg/100g and 282.322 mg/100g on week 4 of storage. At 5% $CaCl_2$, the mineral compositions showed significant difference ($P\leq0.05$) between the storage at week 0 and week 2, and between week 0 and week 4. While week 2 was not significantly difference between week 2 and week 4 during the storage. This result indicates that the samples treated with 5% caused also no rupture as this could be due to the more calcium penetrate to the cell wall resulted in the higher formation of calcium pectate. This finding also has similarly been reported by Kayisoglu and Demirci (2016) on Grape Pekmez, Ekpete *et al.* (2013) on some Nigerian fruits and Secilmis *et al.* (2013) on Enamel.

The effect of storage period on mineral composition of OFSP treated with 6% is presented in Fig. 6. The Ca content of the sample result to the mean values of 27.909-25.255% at storage period of 0 and 4 weeks which was significantly difference ($p\leq0.05$). It had depreciation from week 2 with 25.687%. While Na 30.128-24.719 mg/100g at storage period of 0 to 4 weeks which starts reducing at week 2 of storage with 25.149mg/100g. In Na, the reduction was significant ($p\leq0.05$) between week 0 and week 4 but no significant difference ($P\geq0.05$) between week 2 25.149%) and week 4 storage periods. Mg reduced from 25.372% (week 0) to 23.715% (week 4) which was significantly different ($p\leq0.05$) during the storage period. The reduction showed effect from week 2 of storage giving the value of 24.176% .There was no significant difference ($P\geq0.05$) in Mg between week 2 and week 4. P content of the sample was

high and ranged from 46.582-45.373mg/100g during the storage period. Its deterioration was discovered from week 2 of storage to be 45.913 mg/100g. While K had the highest level among other mineral compositions. At 6% $CaCl_2$ K gave 288.634 mg/100g at week 0 which depreciated from the 2nd week (week 2) of storage to 285.681 mg/100g and 285.269 mg/100g on week 4 of storage. At 6% $CaCl_2$, the mineral compositions showed significant difference ($P \leq 0.05$) between the storage at week 0 and week 2, and between week 0 and week 4. While week 2 was not significantly difference to week 4 during the storage. At this concentration level, there was a decrease in the retention of the mineral compositions as compared to 4% and 5%. This could be that at 6% concentration, excess of the substance (above optimum concentration might have weakened the firmness of the root thereby causing the cellwall of the roots became less active. This finding also has similarly been reported by Garcia *et al.* (2019), Kayisoglu and Demirci (2016) on Grape Pekmez and Secilmis *et al.* (2013) on Enamel.

Table 1: Mineral contents of freshly harvested OFSP without treatment

Ca (%)	Na (mg/100g)	Mg (%)	P (mg/100g)	K (mg/100g)	Zn (mg/100g)
27.726 ± 0.007^{l}	23.282 ± 0.073^{o}	24.774 ± 0.008^{j}	43.797 ± 0.017^{d}	296.385 ± 5.223^{h}	0.253 ± 0.005^{f}

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 ($p > 0.05$).

Table 2: Effect of $CaCl_2$ Concentration on the Proximate Composition (%) of OFSP during different Storage Times at 18°C

Amount (%)	Storage Period (Week)	Moisture	Lipid	Crude fiber	Protein	Ash	Carbohydrate
1	0	74.104±0.027^{l}	1.263±0.004^{k}	0.530±0.003^{n}	6.176±0.046^{hi}	0.618±0.005^{c}	16.626±0.354^{a}
	2	72.020±0.004^{j}	0.838±0.006^{c}	0.472±0.006^{m}	5.647±0.017^{ef}	0.543±0.004^{b}	19.931±0.274^{d}
	4	68.604±0.008^{d}	0.749±0.006^{b}	0.421±0.004^{l}	5.525±0.620^{de}	0.516±0.004^{a}	24.065±0.624^{i}
	0	72.891±0.142^{k}	1.266±0.001^{k}	0.566±0.002^{h}	5.969±0.495^{fgh}	0.833±0.001^{g}	18.475±0.604^{b}
2	2	70.522±0.005^{h}	0.982±0.008^{f}	0.460±0.007^{d}	5.214±0.301^{bcd}	0.673±0.013^{d}	22.148±0.330^{f}
	4	68.590±0.020^{d}	0.836±0.010^{c}	0.422±0.008^{b}	4.891±0.337^{b}	0.631±0.011^{c}	24.631±0.381^{j}
	0	71.573±0.336^{i}	1.166±0.001^{i}	0.602±0.002^{ij}	6.060±0.053^{ghi}	1.540±0.006^{n}	19.119±0.426^{c}
3	2	69.584±0.008^{g}	0.973±0.006^{f}	0.557±0.021^{gh}	5.453±0.014^{cde}	0.240±0.007^{k}	22.193±0.032^{f}
	4	67.391±0.044^{c}	0.865±0.010^{d}	0.517±0.019^{f}	5.206±0.016^{bcd}	1.017±0.012^{h}	25.003±0.074^{jk}
	0	69.106±0.029^{h}	1.230±0.002^{j}	0.617±0.005^{k}	6.644±0.008^{j}	1.565±0.002^{o}	19.312±0.098^{c}
4	2	68.978±0.007^{ef}	1.080±0.008^{g}	0.551±0.011^{g}	5.845±0.007^{efgh}	1.281±0.008^{l}	22.366±0.010^{fg}
	4	66.233±0.016^{a}	0.950±0.020^{e}	0.526±0.006^{f}	5.475±0.113^{cde}	1.093±0.009^{j}	25.658±0.060^{l}
	0	69.713±0.173^{g}	1.233±0.011^{j}	0.589±0.005^{i}	6.598±0.011^{j}	1.521±0.004^{m}	20.347±0.178^{d}
5	2	68.336±0.012^{d}	1.083±0.002^{gh}	0.4577±.006^{d}	5.743±0.008^{efg}	1.247±0.004^{k}	23.032±0.029^{n}
	4	66.563±0.157^{ab}	0.977±0.016^{f}	0.427±0.006^{bc}	5.540±0.051^{de}	1.057±0.014^{i}	25.501±0.048^{kl}
	0	70.632±0.095^{f}	1.243±0.002^{j}	0.614±0.008^{jk}	6.419±0.304^{ij}	1.521±0.002^{m}	21.098±0.306^{e}
6	2	68.512±0.583^{d}	1.098±0.005^{h}	0.550±.006^{g}	5.741±0.012^{efg}	1.241±0.015^{k}	22.857±0.607^{gh}
	4	66.752±0.425^{b}	0.949±0.015^{e}	0.521±0.005^{f}	5.436±0.201^{cde}	1.047±0.016^{i}	25.294±0.555^{kl}
	0	74.387±0.382^{l}	1.337±0.016^{l}	0.502±0.003^{e}	5.073±0.025^{bc}	0.799±0.015^{f}	18.184±0.051^{b}
Control	2	72.167±0.273^{j}	0.955±0.020^{e}	0.437±0.005^{c}	4.518±0.109^{a}	0.712±0.002^{e}	21.358±0.134^{e}
	4	68.675±0.056^{de}	0.722±0.010^{a}	0.407±0.005^{a}	4.222±0.109^{a}	0.617±0.005^{c}	25.358±0.084^{kl}

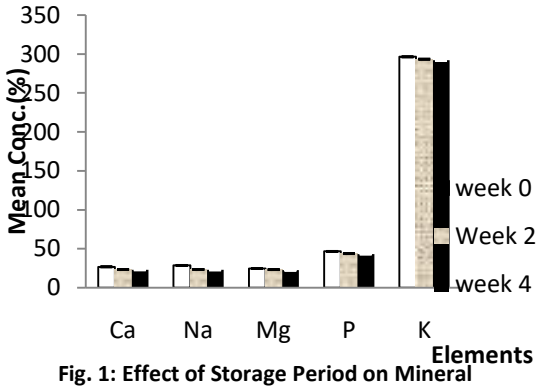

Fig. 1: Effect of Storage Period on Mineral Composition of OFSP treated with 1% $CaCl_2$

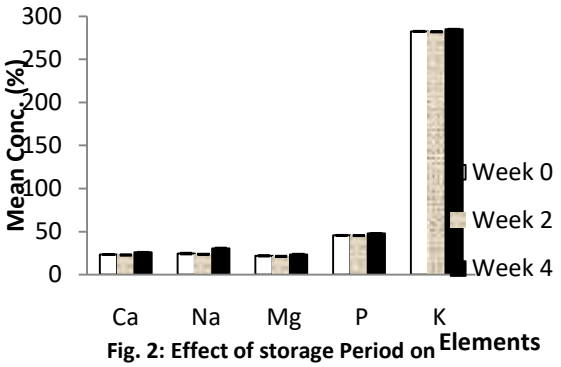

Fig. 2: Effect of storage Period on MineralComposition of OFSPwith 2 % $CaCl_2$

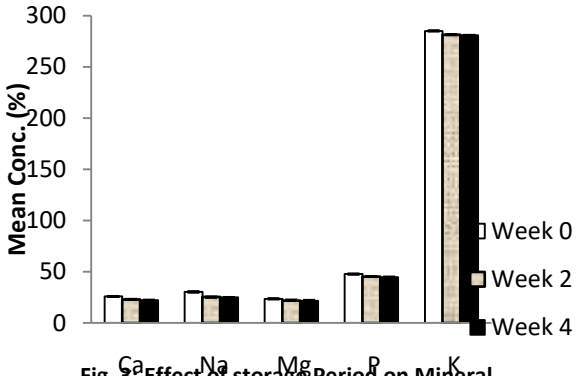

Fig. 3: Effect of storage Period on Mineral Composition of OFSP with 3 % $CaCl_2$

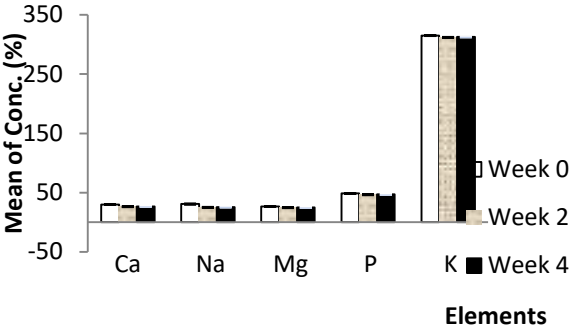

Fig. 4: Effect of storage Period on Mineral Composition of OFSP with 4 % $CaCl_2$

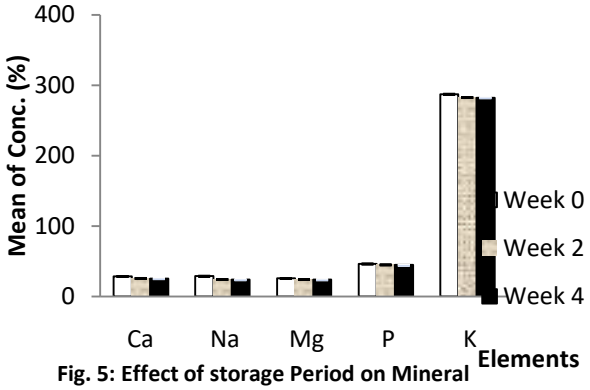

Fig. 5: Effect of storage Period on Mineral Composition of OFSP with 5 % $CaCl_2$

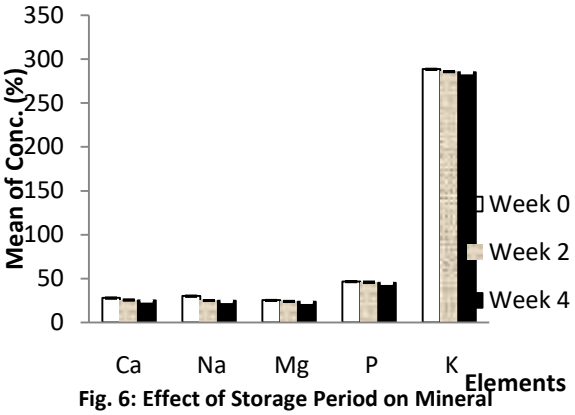

Fig. 6: Effect of Storage Period on Mineral Composition of OFSP treated with 6 % $CaCl_2$

CONCLUSION

Postharvest physiological deterioration (PPD) activities occur in a freshly harvested food crop which leads to loss of some amounts of its compositions. These physiological changes affect the nutritional quality and bio-availability as well as the tissue microstructure during storage period. The extent at which the crop is stored has a long way to determine the retention of the quality (proximate and mineral compositions of OFSP.

The different concentrations of calcium chloride applied in this study showed varying responses in the treated OFSP. The fourth concentration of 4% $CaCl_2$ resulted in less decay and a lower postharvest deterioration in all samples thereby showing significant effect on the experimental (OFSP) samples. The lowest level among the treated samples was found in 1 %. Applications of $CaCl_2$ at the different concentrations delayed the onset and development of postharvest spoilage symptoms in experimental sweet potato roots. However, the concentrations used in this study reduced the severity of postharvest deterioration. Calcium pectate is playing a crucial role in the freshness of sweet potato. The mechanism of calcium pectate in maintaining of sweet potato quality is that the crosslinking attracts the water to bond with. Therefore, water molecules will penetrate the wall and the matrix of sweet potato root. The pre-treatment of $CaCl_2$ can decrease the moisture content of sweet potato, increase the ash content, and raise the calcium content of sweet potato. $CaCl_2$ is a promising material as substitute with additional benefit in reducing food waste.

It could be deduced that reactions associated with the oxidative deterioration, poly ethylene used for packaging the roots before storage and reagent conditions seemed to have contributed in a limited level to the minute level of deterioration of the experimental samples.

However, the specific effect of the salt concentration on the proximate and mineral compositions was specific to each treatment. By considering the above effects, 4 % $CaCl_2$ was the best concentration and storage period did not show vast significant difference in this study for OFSP, resulting in optimum characteristics studied throughout the study period.

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