

## Effect of Surface Coatings on the Shelf life and Quality of Cassava

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### Abstract

Cassava (*Manihot esculenta*) is grown as an important dietary source of carbohydrates for communities in a number of African countries. However, Cassava is susceptible to postharvest physiological deterioration which affects its quality and leads to the unpalatability and unmarketability of roots after harvest. Edible surface coatings have been found to be effective in preserving the quality of various perishable food products. This study was undertaken with the objective of determining the best combinations and concentrations of both xanthan gum and guar gum capable as a technology for extending the shelf life of harvested cassava roots. Cassava (variety KME 1) was harvested at physiological maturity. The coating formulations used were: 1%, 1.5%, 2% guar gum, 1.5%, 2%, 2.5% xanthan gum, and 1%, 1.5%, and 2.5% xanthan guar/gum combination in the ratio of 1:1 with some roots left as control. Sampling was done at 2-day intervals for 20 days. The coated cassava showed lower respiration and ethylene production rates than the control samples while change in quality parameters; phenols, colour, flesh firmness, weight loss and dry matter content was significantly ( $P \leq 0.05$ ) delayed in the coated samples. The results suggested that using 1.5% xanthan guar/gum as an edible coating, cassava shelf life can be extended by upto 20 days at 25 °C.

**Keywords:** cassava; postharvest loss; xanthan gum; guar gum; edible coatings; quality deterioration

### 1. Introduction

Cassava (*Manihot esculenta*) is one of the major tropical root crops in Africa, Latin America and Asia (Liu, Zheng, Ma, Gadidasu & Zhang, 2011). It is an important dietary source of carbohydrates for approximately 800 million people in these areas (Sowmyapriya et al., 2017). In addition, it is increasingly being used as animal feed and also processed industrially into starch and other products. The crop is able to endure the most adverse climatic conditions where other food crops fail. Hence, cassava can have better crop yield as compared to other crops especially in the areas of low agricultural potential.

Africa is the main producer of cassava, with Nigeria leading in its production while Thailand and Indonesia are the major exporters in the world (FAO, 2009). In East Africa, Tanzania and Uganda produce higher quantities of cassava compared to Kenya (FAO, 2009). Over the years, there has been a gradual increase in its production due to the addition of new cassava varieties in the country. Most of the cassava produced locally is consumed either as boiled, deep fried or is ground into flour (USAID, 2010).

Despite the fact that cassava is considered a drought resistant crop, the root is susceptible to physiological stress response after harvest commonly referred to as the postharvest physiological deterioration (PPD) (Zidenga, 2012). The PPD leads to loss of market value and acceptance and greatly reduces the postharvest shelf life to between 2-3 days after harvest depending on the cultivar, age and environmental conditions (Iyer, Scott Mattinson & Fellman, 2010). The crop undergoes PPD primarily due to the wounding which occurs during harvesting and subsequent microbial deterioration which occurs 5-7 days after harvest (Venturini, M. T., Santos, V. D. S., & Oliveira, 2015). The PPD is accompanied by unpleasant odor and flavor and occurs as blue-black streaks on the vascular tissues of the xylem (Salcedo & Siritunga, 2011). It is estimated that the postharvest

losses due to PPD in cassava can be as high as 25%. Therefore developing technologies to extend the shelf life of cassava can save upto \$2.9 billion over a 20 year period in Nigeria alone (Rudi, Norton, Alwang, & Asumugha, 2010).

In other parts of the world, PPD is delayed by heating food grade (paraffin) wax to a temperature between 140 °C - 160 °C and dipping the root tuber for 1-2 seconds (Zidenga, Leyva-guerrero, Moon, Siritunga, and Sayre, 2012). However, adoption of paraffin wax coating for cassava is a challenge to small holder farmers in areas such as Kenya since the temperature of the wax and the timing has to be precise otherwise it leads to charring of the root. In addition, concerns about non-biodegradable or inorganic chemical based waxes has recently become a major issue of interest, and focus is more on usage of waxes from renewable and biodegradable polymer of agricultural origin. Edible films and coatings are useful materials mainly produced from edible biopolymers and food-grade additives. Coatings are a type of films directly applied on the food product surface. The application of edible coatings can improve the physical features of food products, reduce clustering of food particles and improve visual features on the product surface (Baraiya, Rao, & Thakkar, 2015). Many factors determine the success of edible coatings in improving quality and extending shelf-life of foods. These include chemical composition, structure, method used to form coatings and storage conditions of the food product. Moisture loss is the most critical quality degradation factor in fresh produce (Tumuhimbise, Melis, & Shanahan, 2015) including cassava. Oxidation of the phenolic content of the cassava root and cyanide production have also been associated with the decreased shelf life of the cassava due to their various activities. Phenol oxidation has been found to lead to the production of highly reactive quinones that form the blue/black colored complexes on the vascular bundles of the cassava root (Salcedo & Siritunga, 2011). The wounding that occurs during harvesting of the cassava roots leads to production of hydrogen cyanide. This production leads to an accelerated production of reactive oxygen species that have been found to induce the PPD onset (Zidenga, 2012). Moisture barrier and oxygen barrier properties of edible films can be useful in preventing dehydration which leads to loss in quality (Janjarasskul & Krochta, 2010).

Xanthan gum is a polysaccharide derived from *Xanthomonas campestris* through microbial fermentation systems which is a biotechnological process. At high concentrations it shows weak gel-like properties and at low concentrations it gives a highly viscous solution. The optimum temperature for its preparation is 40 °C. It thickens when dissolved in water due to the formation of strong hydrogen bonds with water and intermolecular friction during application of shear (Nieto, 2009). It has been used to form edible coatings in *Carica papaya* (Adetunji C.O, Ogundare, Ogunkunle, Kolawole, & Adetunji J.B, 2014) and grapes (Baraiya, Rao, & Thakkar, 2016). Guar gum is a galactomannan that is extracted from guar seed *Cyamopsis tetragonolobus* (Raghav, Agarwal, & Saini, 2016). It is soluble in both hot and cold water with formation of very highly viscous solutions at very low concentrations due to its high molecular weight. It is considered as a very economical thickener mostly used for juices and can also be used for film-forming solutions (Nieto, 2009). Guar gum has been used to extend the shelf life of guava for 9 days (Wijewardane, 2013).

Xanthan and guar gum have been found to have synergistic effects (Xue, D., & Sethi, 2012). Their mixture exhibits an increase in viscosity as compared to the different gums separately. The galactomannan and the polysaccharide interact to form solutions having high viscosity at very low concentrations.

There is increasing demand for cassava in specific markets due to its increasing utilization as food, feed and industrial crop. However, since most of the cassava producers tend to be located in areas further from the target markets, the PPD disorder is a major limitation to the cassava value chain negatively impacting the farmers, traders, processors and consumers.

This study was undertaken with the objective of determining the best combinations and concentrations of both xanthan gum and guar gum capable of extending the shelf life of harvested cassava roots.

## 2. Materials and Methods

### 2.1 Acquisition of Raw Materials

In the preliminary study, xanthan and guar gum were sourced from Sigma-Aldrich. The preliminary experiments indicated that the effectiveness of the gums sourced from Sigma-Aldrich was similar to the food grade gums sourced from a food ingredient supplier in Nairobi. Hence for the main experiment, the gums were sourced from the food ingredient supplier. Fresh cassava root crops of variety KME 1 at physiological maturity were obtained from the Jomo Kenyatta University of Agriculture and Technology (JKUAT) farm. The cassava roots were transported to the JKUAT postharvest laboratory and sorted according to size (50-60 cm long) and the amount of injuries. They were then cleaned using a soft brush to avoid bruising; no water was used.

## 2.2 Preparation and Application of Coating Formulation

Xanthan gum was prepared by dispensing 1.5 g, 2.0 g, and 2.5 g powder into 100 ml of water to make 1.5%, 2% and 2.5% w/v, respectively. These concentrations had been predetermined during the preliminary study. The solutions were heated at 40 °C for one hour with stirring then filtered to remove any undissolved impurities. Guar gum was prepared by dispensing 1.5 g and 2.0 g in 100 ml of distilled water to make 1.5% and 2% w/v and stirred at 80 °C for one hour using a magnetic stirrer to enable complete dispersion. The xanthan guar gum combination was prepared in concentrations of 1%, 1.5% and 2% w/v by dissolving the gums in ratios of 1:1 and heated at 60 °C on a magnetic stirrer for one hour.

The coating solutions were then applied to the unpeeled roots by dipping for three minutes into the coating solution. They were then placed in clean crates for air drying and stored at 25 °C. Cassava roots under the different treatments were then tested to determine the effect of the coatings on the physical, physiological and chemical properties of the cassava roots for the entire storage duration at two-day intervals. Each day, 27 whole roots were analyzed (three roots for each treatment including the control root sample). For each analytical experiment, three replicates were used from the three roots from each treatment cut at the proximal, mid and distal end.

Coating was performed on the same day that the cassava roots were harvested.

## 2.3 Determination of Flesh Firmness

A hand held penetrometer (CRD-100D, Sun Scientific Co., Ltd, Japan) was fitted with a probe was allowed to penetrate the root flesh to a depth of 10 mm and the corresponding force required to penetrate this depth was determined according to Famiani *et al* (2012). A cylindrical cork borer was used to get even samples of 2 cm length.

## 2.4 Determination of Colour Change

The colour of the cassava samples (3 replicates per treatment) was determined using a hunter lab colour difference meter (Minolta, Tokyo, Japan) according to Hernández-Muñoz, Almenar, Del Valle, Velez, and Gavara (2008). Results were tabulated and the L\* values used to determine the rate of color changes of the flesh with time.

## 2.5 Determination of Weight Loss

Cassava samples (3 replicates per treatment) were weighed while fresh and at an interval of two days for twenty days. The difference between initial and final root weight was determined for that storage period and expressed as a percentage on a fresh weight basis according to Paniagua, East, Hindmarsh, and Heyes (2013). This was calculated as shown:

$$\% \text{ weight loss} = \frac{\text{Initial weight of sample} - \text{current weight of sample}}{\text{Initial weight of sample}} * 100 \quad (1)$$

## 2.6 Determination of Dry Matter Content

This was determined according to Ebah-Djedji, Dje, Zue, Zohouri, and Amani (2012) with slight modifications. 20 g of the chopped and ground roots were oven-dried at 105 °C for 24 hours. Dry matter was then expressed as a percentage of the dry weight relative to the fresh weight using the equation below:

$$\% \text{ dry matter content} = 100 - \left( \frac{\text{Dish and Sample weight} - \text{Dish weight}}{\text{Sample weight}} \right) * 100 \quad (2)$$

## 2.7 Determination of Ethylene Production Rate

This was done according to Fugate, Suttle, and Campbell (2010) with a few modifications. Modification included one-hour incubation period and the use of a gas chromatograph (Shimadzu Corp., Kyoto, Japan, model GC-9A) fitted with a flame ionization detector.

## 2.8 Determination of Respiration Rate

Air tight containers of specific known volume fitted with self-sealing rubber septums were used. The weight of each cassava to be used was taken. The samples were then incubated in the air-tight plastic containers for one hour. After one hour, 1 ml of the headspace gas was drawn from each container using an air-tight syringe and injected into a gas chromatography (Shimadzu Corp., Kyoto, Japan, model GC-8A). The detector used were thermal conductivity detector fitted with Propak N column for respiration. Rate of carbon dioxide production

was reported as ml CO<sub>2</sub>/kg/hour.

### 2.9 Determination of Total Phenolic Content

The amount of total phenolic contents was determined by the Folin-Ciocalteu method as described by Ainsworth and Gillespie (2007) with modifications. Two grams (2 g) of the cassava root was ground in an ice-cold mortar and pestle using 20 ml of ice-cold 95% (vol/vol) methanol. The samples were then vortexed and incubated at 25 °C for 72 hours in the dark. The puree was then filtered to remove debris and the residue centrifuged at 13,000 g for 10 minutes at room temperature and the supernatant collected. The sample was then passed through a 0.45 µl membrane filter. To 1 ml of the sample extract and the standard, 2 ml of 10% (vol/vol) Folin-Ciocalteu reagent was added and vortexed and 4 ml of saturated Na<sub>2</sub>CO<sub>3</sub> solution was then added. The mixture was then allowed to stand at 25 °C for 2 hours and the absorbance measured at 765 nm using UV-vis spectrophotometer. A standard curve was generated using the absorbances of the gallic acid standards in ppm. The amount of total phenols was expressed as gallic acid equivalents per 100 g of the sample.

### 2.10 Determination of Cyanide Content

Total HCN was analyzed using the alkaline titration method according to Famurewa and Emuekele (2014).

### 2.11 Data Analysis

Comparisons among the various treatments and storage duration effects was determined by ANOVA using Genstat Discovery 12<sup>th</sup> Edition, in a completely randomized design in replicates so as to determine the effect of the different treatments and storage duration on the cassava shelf life and quality parameters.

## 3. Results and Discussion

### 3.1 Firmness

The flesh firmness between the various treatments was significantly ( $P \leq 0.05$ ) affected by the storage duration. The flesh firmness of the cassava roots increased regardless of the treatments and then gradually declined during the storage duration. The 1.5% guar treated sample had a flesh firmness of 96.6N at 8DAH while the 2% guar treated sample had a firmness of 96.6N at 12 Days after harvest (DAH) after which there was general a decline as it approached 20DAH. The 2% guar treated root sample had a flesh firmness of 21.1N while the 1.5% guar treated root sample had a firmness of 8.9N which was not significantly different from control which had 8.9N as shown in Figure 1.

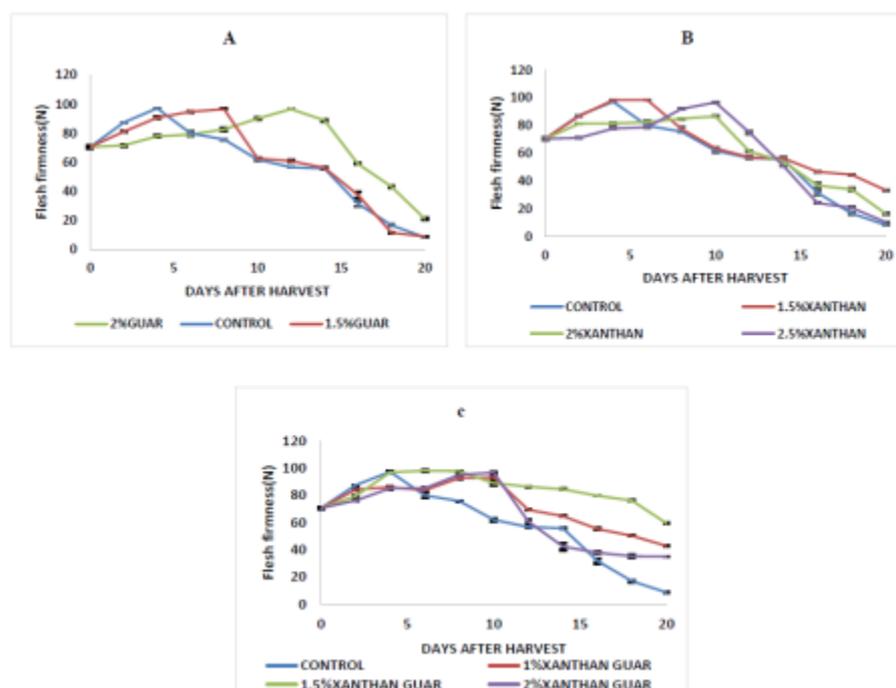


Figure 1. Changes of flesh firmness of cassava during storage when coated by guar gum(A), xanthan gum(B) and xanthan guar gum combination (C). Each value is the mean for 3 replicates. The vertical bars indicates the standard error

The root samples coated using the 1.5% xanthan attained a firmness peak of 98.4N at 8DAH while the 2% and 2.5% xanthan treated root samples reached their peaks of 86.7N and 96.7N at 10DAH. This was followed by a general decline in the firmness towards 20DAH. At this point, the 2% xanthan treated sample had a firmness of 16.5N while the 1.5% and 2.5% xanthan treated samples had firmness of 33.4N and 10.3N, respectively as compared to the control that reached 8.4N at 20DAH.

Cassava roots coated with 1.5% xanthan/guar gum attained a flesh firmness peak of 98.0N at 6DAH while the 1% and 2% xanthan/guar gum treated samples attained their peaks of 93.1N and 96.6N, respectively at 10DAH. There was a decrease in firmness as the storage time approached 20DAH. The 1.5% xanthan/guar gum treated and the control root samples had flesh firmness of 59.3N and 8.4N respectively whereas the 1% and 2% xanthan/guar gum treated root samples had a firmness of 42.6N and 34.8N, respectively.

Coating using the 1.5% xanthan/guar gum produced roots with the highest flesh firmness as exhibited by a force of 59.3N at 20DAH while the 1.5% guar treated root had a force of 8.9N translating to the lowest flesh firmness as compared to the control root that had firmness of 8.4N on the same day.

The initial increase in the firmness of the cassava samples may be described to be due to water loss which is as a result of various processes. Starch hydrolysis which permeabilizes the cellular membrane might have enabled water to exit from the cell wall hence hardening the flesh of the cassava (Akely *et al.*, 2016). Dark respiration processes which lead to water loss from the cassava might have also lead to hardening of the flesh. With increased storage duration, there's an increase in polysaccharide production which lignifies the cell wall hence increasing the firmness (Akely *et al.*, 2016). The later decline in the firmness may have been due to the action of pectin enzymes which cause a dramatic loss of firmness.

### 3.2 Colour

The L\* value declined over time with the storage duration as shown in Figure 2. The hunter L\*a\*b\* colour scale is a visually uniform mode of evaluating the colour of substances including the cassava flesh. The L\* value is mostly preferred in reporting cassava flesh and starch colour as it indicates the values from white (100) and this reduces as the flesh colour darkens (Pérez Elevina and Pérez Liz, 2009; Acedo & Acedo Jr., 2013).

Cassava flesh colour was significantly ( $P \leq 0.05$ ) different between the control roots and the treated samples throughout the storage duration. The 1.5% guar treated roots had a value of 79.2 while the 2% had 70.9 at 20 days after harvest (DAH). This was a decline of 15.05% and 23.88%, respectively. The 1.5% xanthan treated root had a decline of 33.70% while 2% and 2.5% had 21.59% and 20.34%, respectively. At this day, the 2% xanthan was significantly ( $P \leq 0.05$ ) different from 1.5% xanthan and 2% xanthan treated roots. The 1% xanthan/guar treated root had a decline of 20.02% while the 1.5% and 2% had a decline of 12.94% and 11.37% decline, respectively by 20DAH. The 1.5% xanthan/guar gum treated root was significantly ( $P \leq 0.05$ ) different from the 1% and 2% xanthan/guar gum treated roots. The lowest L\* value was 62.1 detected in the untreated root, while the highest L\* value of 82.6 was in the samples treated with 2% xanthan/guar gum at 20DAH. The decline of the L\* values seemed to be accompanied by the PPD development of the cassava roots. The coated root samples were significantly ( $P \leq 0.05$ ) different from the control roots.

These results correlate to those reported by Acedo and Acedo Jr (2013) who determined the effects of hot water dipping to elongate the cassava root shelf life. The treated cassava roots showed a delayed colour change as compared to the control samples. The change in colour is due to the onset of PPD as there's formation of blue/black streaks along the roots cross sectional area as reported by Tumuhimbise *et al* (2015) and Del Valle *et al* (2010). The vascular discoloration is accompanied by a decline in the L\* values denotes which translates to the onset of root deterioration.

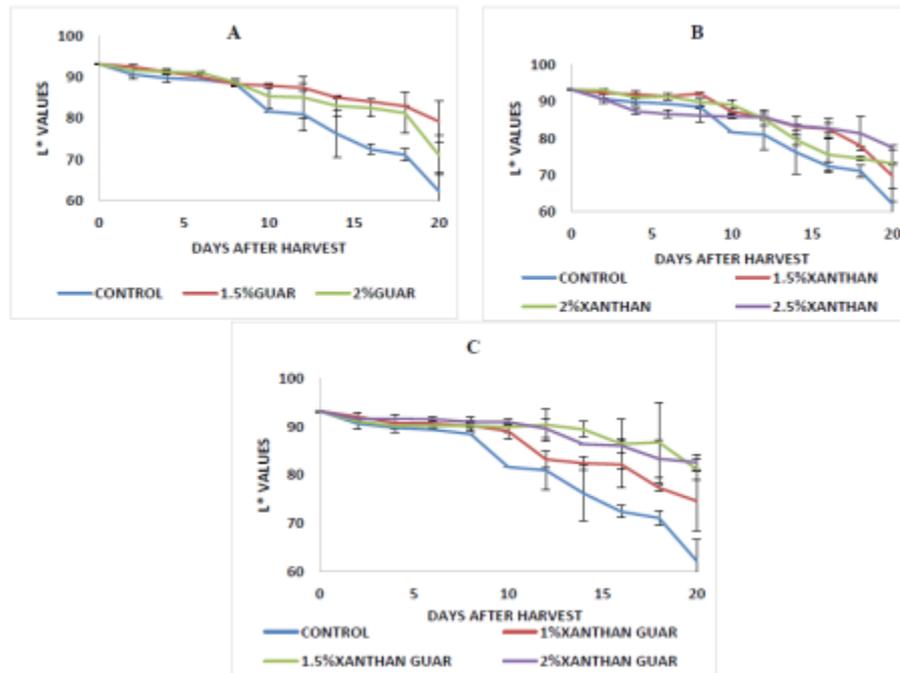


Figure 2. Changes in flesh colour of cassava during storage as affected by guar gum(A), xanthan gum(B) and xanthan guar gum combination (C). Each value is the mean for 3 replicates. The vertical bars indicates the standard error

### 3.3 Weight Loss

There was an increase in the rate of weight loss as it approached 20DAH as shown in Figure 3. The rate of weight loss was affected by the treatment induced and the storage time. The 1.5% guar treated roots had a weight loss of 23.56% while the 2% guar treated root had a weight loss of 21.17% at 20DAH. The 1.5% xanthan treated roots had a percentage weight loss of 23.12% while the 2% and 2.5% xanthan treated roots had 25.35% and 24.45%, respectively at 20DAH. The 1% xanthan/guar gum treated root had 24.57% weight loss while the 1.5% and 2% xanthan/guar gum treated roots had 24.71% and 17.54%, respectively at 20DAH. The highest percentage weight loss at day 20 was recorded in the control sample at 33.35% while the lowest weight loss recorded was 17.54%, 21.17% and 23.12% in 2% xanthan guar/gum combination, 2% guar and 1.5% xanthan, respectively. There were significant ( $P \leq 0.05$ ) differences of the treatments at 20DAH.

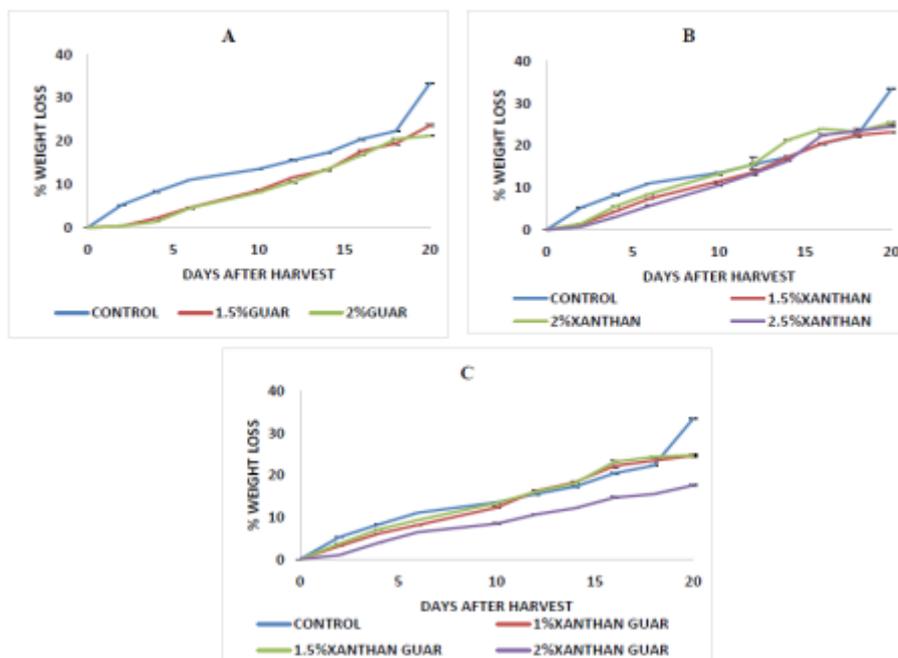


Figure 3. Changes in percentage weight loss of cassava during storage when coated by guar gum(A), xanthan gum(B) and xanthan guar gum combination (C). Each value is the mean for 3 replicates. The vertical bars indicates the standard error

These findings were similar to those reported by Sánchez *et al* (2013) as the treated samples had a significant ( $P \leq 0.05$ ) delay in the rate of weight loss as compared to the control samples at 20DAH. However, the various treatments had differing rates of weight loss. An increase in the concentration led to an increase in the efficiency of the coating against weight loss during the storage period. The loss in weight is usually due to respiration and transpiration which are normal metabolic processes of the cassava root crop (Abbasi, Iqbal, Maqbool, & Hafiz, 2009). This is caused by diffusion of water vapor due to a pressure gradient between the inside and the outside of the cassava root. The coating solutions may have acted as barriers for water loss with a thicker film reducing the water loss even further by acting as a semi-permeable membrane around the surface of the cassava (Wijewardane, 2013).

### 3.4 Dry Matter Content

Upon coating, there was an increase in the dry matter content of the root samples until 20DAH as shown in Figure 4. The 1.5% guar gum treated root had an increase of 10.88% while the 2% guar gum treated root had 24.23% at 20DAH, whereas 1.5% xanthan treated root an increase of 12.02% while 2% and 2.5% xanthan treated root had 11.58% and 16.57% increase, respectively. The 1% xanthan/guar gum treated root had a 10.94% increase while the 1.5% and 2% xanthan/guar gum treated roots had 9.54% and 6.94%, respectively at 20DAH.

Generally, there were significant ( $P \leq 0.05$ ) differences among the various treatments during the storage duration. The control samples attained a much higher dry matter content of 72.8% at 20DAH which was a 26.91% increase as compared to the treated samples. Sánchez *et al* (2013) suggested that cassava varieties that have a high dry matter content are more liable to PPD occurrence as compared with the ones with low dry matter content. The rate at which the control roots formed dry matter directly correlates to the high rate of PPD onset. On the contrary, the coated cassava samples had a delay in formation of dry matter content which may have been due to the reduced water loss enabled by the formation of the coat.

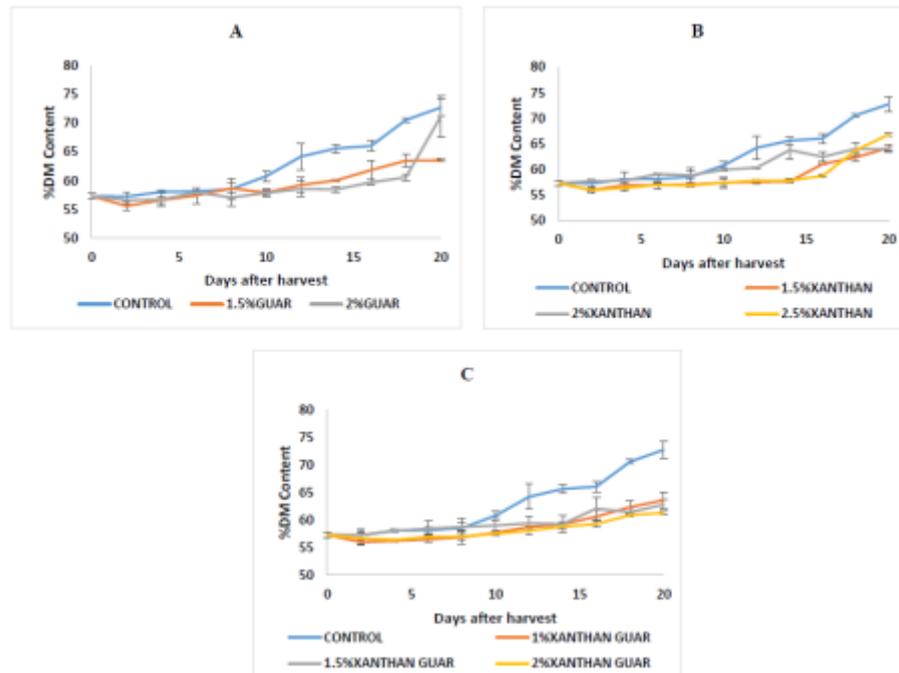


Figure 4. Changes in percentage dry matter content of cassava during storage when coated by guar gum (A), xanthan gum (B) and xanthan guar gum combination (C). Each value is the mean for 3 replicates. The vertical bars indicates the standard error

It has been reported that increase in the dry matter is caused by the reduction of water content on the cassava root during the storage period. Water loss is a normal phenomenon that occurs gradually from the harvest period (Quevedo, Ramos, & Iglesia, 2014). The decrease in the water content of the cassava root may have led to the increased dry matter content hence the increased PPD development. The increased dry matter content has also been associated with a shorter shelf life

### 3.5 Ethylene Production Rate

The coating process reduced the ethylene production rate of the cassava roots as shown in Figure 5. The 1.5% guar gum treated roots formed the second peak of 4.0 nl/kg/h while the 2% guar gum coated root had a peak of 0.9 nl/g/h at 12DAH. The 1.5%, 2% and 2.5% xanthan treated roots had peaks of 2.4 nl/g/h, 0.3 nl/g/h and 0.5 nl/g/h respectively while the 1%, 1.5% and 2% xanthan/guar gum treated roots formed peaks of 2.0 nl/g/h, 0.5 nl/g/h and 1.6 nl/g/h at 12DAH. The 1.5% xanthan treated root and 1.5% xanthan/guar gum treated root were significantly ( $P \leq 0.05$ ) different from other treated roots and the control at the 20<sup>th</sup> day after harvest.

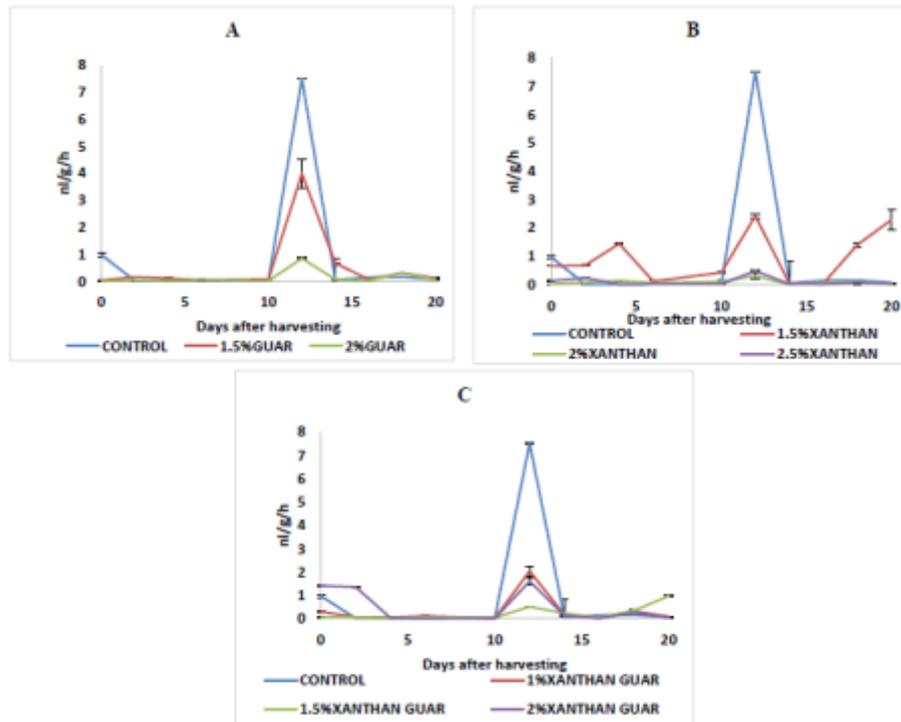


Figure 5. Changes in ethylene production rate of cassava during storage when coated by guar gum(A), xanthan gum(B) and xanthan guar gum combination (C). Each value is the mean for 3 replicates. The vertical bars indicates the standard error

There were significant ( $P \leq 0.05$ ) differences among the treated roots and the control roots. There was a general increase in ethylene production to 12DAH forming a peak after which there was a decrease as it approached 20DAH. The uncoated cassava produced a higher amount of ethylene as compared to the coated cassava. This was similar to the findings by Hirose, Data, Tanaka, and Uritani (1984). The initial high concentration of the ethylene produced may have been due to the production of wound ethylene which is produced in response to injury that was caused during harvesting of the cassava root samples (Bull, 2011; Iyer *et al* 2010; Raju, Velumani, Roy, Sheriff, & George, 2016). The second peak formation at 12DAH did not seem to have any effect on PPD as was recorded by Hirose *et al* (1984).

### 3.6 Respiration Rate

Two peaks were observed during cassava respiration as recorded by Salcedo and Siritunga (2011). These two peaks occurred generally at the second day after coating while the second peak depended on the efficiency of the coating solution (Figure 6). No significant difference was observed between the different treatments.

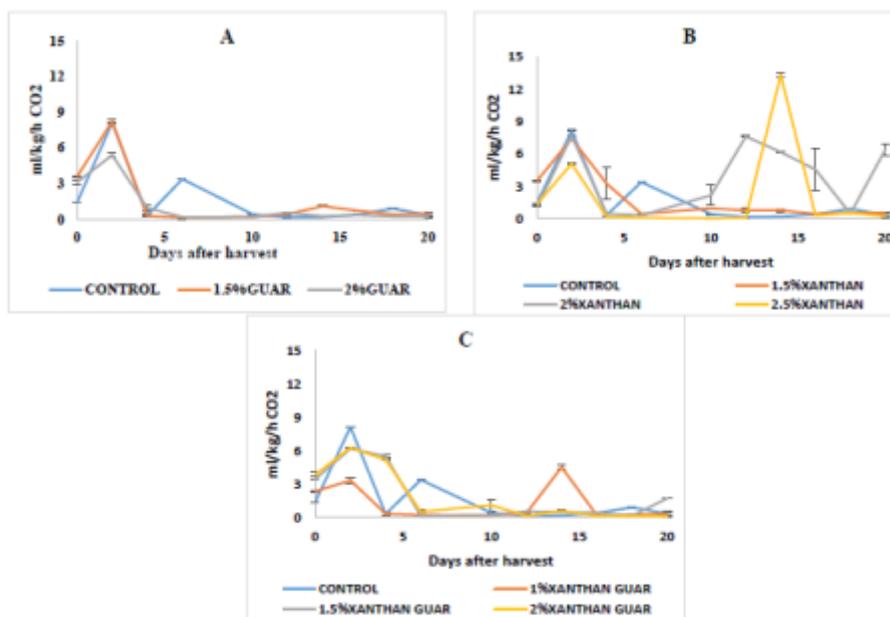


Figure 6. Changes in respiration rate of cassava during storage when coated by guar gum(A), xanthan gum(B) and xanthan guar gum combination (C). Each value is the mean for 3 replicates. The vertical bars indicates the standard error

The cassava roots coated with 1.5% guar gum reached their second peak of 1.1 ml/kg/h on 14 days after harvest (DAH) while 2% guar gum coated roots reached their second peak of 0.6 ml/kg/h on the 12<sup>th</sup> day after coating. The 1.5% xanthan treated roots reached the second peak of 0.9 ml/kg/h at 10DAH while 2% and 2.5% xanthan treated roots reached peaks of 7.6 and 13.3 ml/kg/h at 12DAH and 14DAH, respectively. The 1%, 1.5% and 2% xanthan guar treated samples reached their second peaks of 4.5, 1.7 and 1.1 ml/kg/h at 14DAH, 20DAH and 10DAH, respectively. This was compared to the control that reached its second peak of 3.4 ml/kg/h at 6DAH. From the point where there's formation of a second peak, there's decline of the respiration rate towards zero as it approached 20DAH. 2% xanthan/guar gum treated root had the least respiration rate as exhibited by 0.1 ml/kg/h while the highest respiration rate at 20DAH was 6.4 ml/kg/h by 2% xanthan treated root in comparison to the control sample that had 0.4 ml/kg/h.

The first peak was described to be due to the wounding and it occurs within the first 24 to 48 hours after harvest to suggest the onset of PPD. The second peak is due to biochemical changes induced by the development of the PPD (Iyer *et al.*, 2010). In the current study, all the samples had their first peak 2DAH though the intensity was reduced for the coated cassava samples unlike the control samples. The second peak formation varied between the different treatments based on their functionality. The two coating solutions may have formed a thin film on the cassava surface and this may have reduced the gaseous exchange and respiration rate as was reported by Dhall (2013). The different concentrations of the coating solutions led to the significant difference ( $P \leq 0.05$ ) in their slowed respiration rate. Respiration rate of cassava continues after harvest and this brings about biochemical changes that lead to the eventual deterioration of the root. This process may have been delayed by the use of coating solutions.

### 3.7 Total Phenolic Content

The total phenolic content of the cassava root samples declined with storage duration and treatment as shown in Figure 7. There was a decline in the total phenolic content by 91.88% for the 1.5% guar gum treated root and by 77.71% for the 2% guar gum treated root at 20 days after harvest (DAH). The phenolic content among the treatments was significantly ( $P \leq 0.05$ ) different at 20DAH.

Root samples coated using the 1.5% xanthan treated roots decreased by 66.71% while the 2% and 2.5% xanthan treated roots decreased by 81.53% and 89.09% respectively. There were significant ( $P \leq 0.05$ ) differences among these treatments at 20DAH. The 1% xanthan/ guar gum treated roots decreased by 52.58% while 1.5% and 2% xanthan/guar gum treated roots decreased by 74.01% and 69.73% at 20DAH.

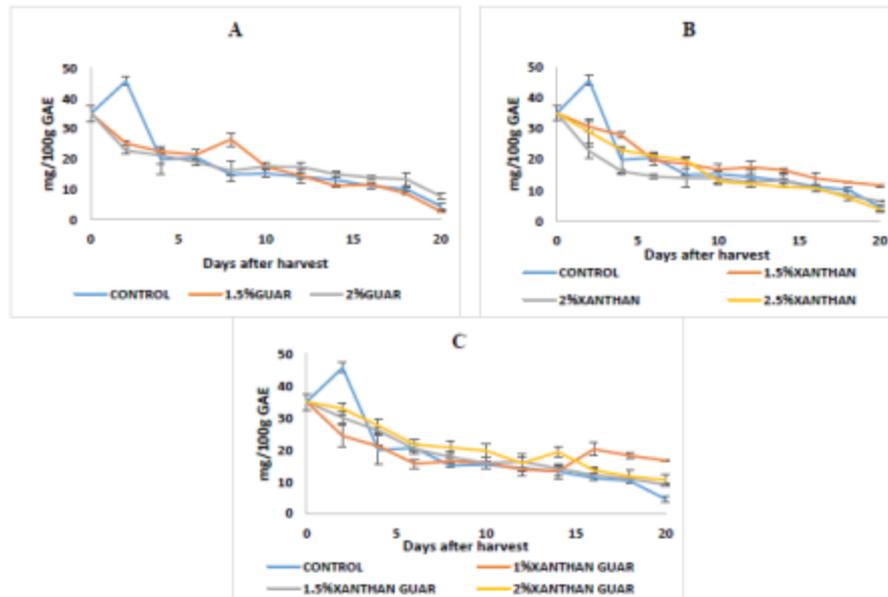


Figure 7. Changes in total phenolic content of cassava during storage when coated by guar gum(A), xanthan gum(B) and xanthan guar gum combination (C). Each value is the mean for 3 replicates. The vertical bars indicates the standard error

The treated root samples varied in their delay in phenol reduction and this may have been due to the different efficiencies of the coating solutions to delay PPD and oxygen depletion which caused enzyme inactivation (Salcedo & Siritunga, 2011). There was also notable delay in the browning of the coated cassava roots which may have been due to the inhibition of oxygen penetration by the coating solution as was reported by Baraiya *et al* (2015).

The effect of phenols on PPD is due to oxidation by polyphenol oxidase (Blagbrough, Bayoumi, Rowan, & Beeching, 2010; Iyer *et al.*, 2010). After harvesting cassava, polyphenol oxidase causes oxidation and polymerization of the total phenols leading to the visible symptoms of blue/black discoloration on the vascular bundles as stated by Saravanan *et al* (2015). By inhibiting oxygen penetration to the cassava root sample by coating, this process was deterred hence delayed PPD development.

### 3.8 Total Cyanide Content

There was a decline in the total cyanide content of the root samples as shown in Figure 8. This was affected by the storage duration and PPD development as was reported by Salcedo and Siritunga (2011). The decline was between 73.57% and 76.81% for the 1.5% guar gum treated root and the 2% guar gum coated root. The 1.5% xanthan treated root had a decline of 85.35% at the 20<sup>th</sup> day while the 2% and 2.5% xanthan treated root had 79.12% and 70.15% respectively which were significantly ( $P \leq 0.05$ ) different from the control. The 1% xanthan/guar gum treated root had a decline in cyanide content of 89.50%, while the 1.5% and 2% xanthan guar gum treated samples 86.33% and 86.94% respectively. However, the control root sample had a decline of 62.36% which was the least recorded. The total cyanide content in both the coated and treated samples was below the acceptable limit given by WHO which is 10mg/kg (Burns, Bradbury, Cavagnaro, & Gleadow, 2012).

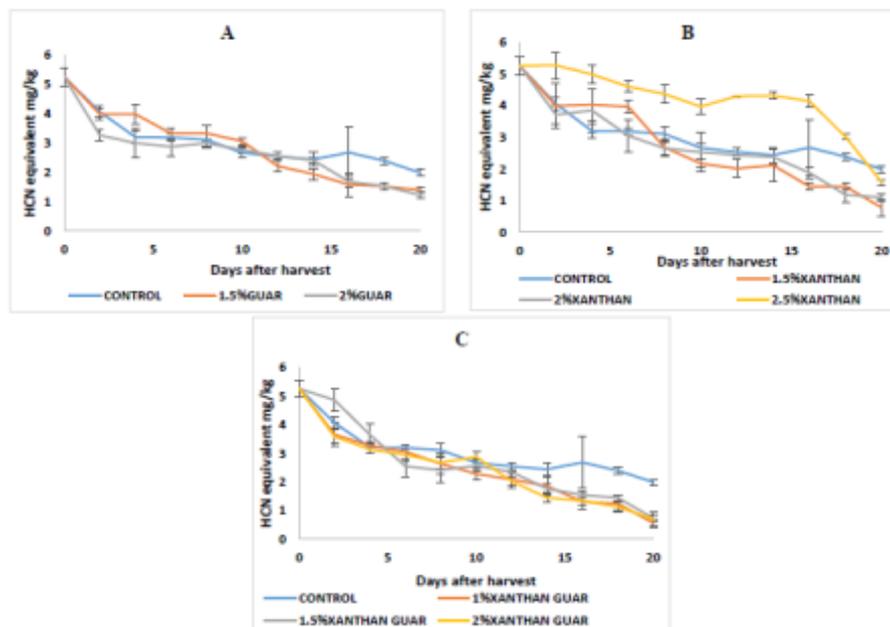


Figure 8. Changes in total cyanide content of cassava during storage when coated by guar gum(A), xanthan gum(B) and xanthan guar gum combination (C). Each value is the mean for 3 replicates. The vertical bars indicates the standard error

Cassava samples have two different forms of cyanogenic glucosides which is linamarin and lotaustralin (Kamalu & Oghome, 2012). The main cyanogenic glucoside that leads to cyanogenesis is linamarin and it is found in higher concentrations in the skin of the cassava. Linamarin reacts with the linamarase enzyme leading to production of cyanide just after the cassava has been harvested. This may explain the high cyanide content that was recorded during the first days of the analysis. The burst in production of the cyanide during the early days after harvest leads to inhibition of normal biological reactions that occur in the mitochondrial electron transfer chain of the cassava root leading to production of reactive oxygen species (ROS) which induce the onset of PPD (Zidenga, 2012).

The general decline in the cyanide content may have also been due to the hydrolysis of the hydrogen cyanide (Famurewa & Emuekele, 2014).

#### 4. Conclusion

The coated samples exhibited better postharvest quality as compared to the control samples during the 20 days of storage. The 1.5% xanthan/guar gum coating combinations was able to extend the shelf life of the cassava sample for upto 20 days at room temperature. The treated roots had better physical, physiological and chemical qualities as compared to the other treatments 20DAH. The change in colour, firmness, weight loss and dry matter was significantly delayed by the application of the coating solutions. CO<sub>2</sub> and ethylene production were suppressed in the coated samples hence a delay in the PPD onset. The decrease in the total phenolic content of the coated roots was delayed whereas the total cyanide content synthesis in the same roots was suppressed. This study recommends the use of 1.5% xanthan/guar gum coating as an effective strategy in delaying the PPD onset with minimal alterations to the quality of the cassava.

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