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Enhancing Cassava Root Storage Stability and Quality Using Innovative CB4G Bags: A Possible Pathway to Reduced Postharvest Losses and Improved Food Security

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ABSTRACT: Cassava, a vital agricultural crop in sub-Saharan Africa, holds significance as both a subsistence and cash crop. Its cultivation and consumption are widespread across the continent. Beyond direct consumption, cassava and its derivative, starch, plays a pivotal role as a raw material for consumables, pharmaceuticals, and industrial products, including confectionery, sweeteners, textiles, paper, biodegradable goods, animal feed and bioethanol, However, the potential of cassava is hampered by its rapid postharvest deterioration, commencing shortly after harvest. This limits its shelf life, leading to substantial postharvest losses and adversely affecting market quality and product starch yield. The adoption of innovative materials capable of mitigating the extent of cassava tuber deterioration following harvest would be a valuable solution for producers and processors. This research focuses on evaluating the nutritional quality and storage stability of cassava roots stored for seven days using the cassava bag for garri (CB4G) approach, a product developed by the Natural Resources Institute, University of Greenwich, United Kingdom. Specifically, cassava roots of the TME 419 variety were meticulously harvested and stored in CB4G bags for a week. Parameters such as weight loss, temperature, pH, humidity, colour alterations, and nutritional indicators (reflecting stability and quality) were assessed at intervals of day 1 (control), 3, 5, and 7.). The findings revealed that postharvest deterioration became noticeable after day 5 inferring that cassava roots can be effectively stored in CB4G for up to five days, maintaining satisfactory quality and minimizing postharvest losses. This approach thus, facilitates easy transportation and alleviates pressures faced by farmers and processors of cassava thereby, bolstering the food and nutrition security of cassava roots.

KEYWORDS: Cassava root, CB4G, Postharvest Loss, Food and Nutrition Security

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INTRODUCTION

Cassava, one of the oldest root crop tube crops used by human being for food, is produced in over 100 countries (Parmar, et al., 2017). It constitutes the most important staple food crop of many households in Sub-Saharan Africa (Spencer & Ezedinma, 2017). Nigeria is the world's leading producer and consumer, with annual production of 59.47 million metric tons, 65% of which is consumed locally (FAO, 2018). About 70% of cassava produced in Nigeria is processing into garri (Knoema, 2023).

Postharvest physiological deterioration (PPD) of fresh cassava roots, which affects its nutritional value and limits their shelf-life starts barely within 2-3 days of harvest (Olaleye, et al., 2018). PPD, in addition to direct physical loss of the tubers, reduces the quality and quantity of products derivable from the tubers and also renders the roots unmarketable and inedible (FAO, 1991). As a result, cassava requires considerable postharvest timely operations that involve intensive labour to be processed into storable forms soon after harvest. Such situation can put the farmers, transporters and processors under undue pressure. Several attempts have been made in the past to store fresh cassava in various conditions to control PPD and enhance the overall shelf-life of the fresh roots. Many storage methods to preserve cassava roots have been utilized such as storage in sawdust with an approximately equal weight of water (Olaleye, et al., 2018; Omosuli et al., 2017). According to Omosuli et al. (2017), roots can be preserved fresh for longer periods if treated with fungicides prior to storage. Abass et al. (2014) reported the storage of cassava roots in the pit for 14 days. Successful as these storage methods may be, they have not been without their shortcomings; some of the methods are labour intensive and space for the storage posed a challenge in most cases, and the quality of the stored products has not been fully assessed in food production.

The introduction of any material/bag that may help to reduce the high – level of deterioration of cassava roots immediately after harvest will be a timely intervention to stakeholders in cassava value chain. The University of Greenwich, United Kingdom, in trying to address this issue has developed a Cassava Bag for Garri, CB4G, for storage of fresh cassava for a period long enough for transportation from harvest to processing factory. This study was, therefore, undertaken to determine the storage stability of and nutritional quality of cassava roots stored using the bags (CB4G).

2. MATERIALS AND METHODS

2.1 Materials

Cassava Bag for Garri (CB4G) bags with dimension of 1350 mm long by 780 mm wide by 0.8 mm thick, produced by the Natural Resources Institute, University of Greenwich, United Kingdom were supplied to the Africa Centre of Excellence for Food Technology and Research, Benue State University, Makurdi-Nigeria. The dimension of each bag is such that it can easily be handled by smallholder farms and small-scale processors. Matured cassava roots (TME 419) were purchased from a local farmer in Ama Village in Makurdi Local Government Area of Benue State, Nigeria. The variety, TME 419, was selected because it is mostly preferred by farmers and commercial industries in Nigeria, due to its high yields and higher starch content (Parmar et al., 2017). The fresh roots were carefully uprooted and transported to the Chemistry Department Laboratory, Benue State University, Makurdi. They were subjected to cooling, cleaning, sorting and packaging into CB4G for storage.

Figures 1, 2, 3 and 4 show freshly uprooted cassava stick with tubers, heap of harvested cassava roots, sample CB4G bags and the CB4G bags stacked fresh roots for the experiments, respectively. Freshly harvested roots heaped on bare floor served as the control for the weight loss. Each bag was stacked with roots weighed 25 kg and kept for a period of seven (7) days, when prominent PPD was observed.

Figure 1: Fresh Uprooted Cassava Roots

Figure 2: Heaps of Freshly Harvested Cassava Root

Figure 3: Samples CG4B bags on display prior to loading with cassava roots

Figure 4: Fresh Cassava Roots Packed in CB4G Bags for Storage

2.2 Experimental Methods

The cassava roots were manually carefully harvested and sorted, and transported very carefully from the farm to the research station within 2 hours of harvest, with avoidance of the roots exposure to direct sunlight. Each bag was stacked with roots weighed 25 kg and same weight heaped on bare floor, and kept for a period of seven (7) days, and the weight loss checked through the period. The nutritional parameters which were proximate composition, total acidity and cyanogenic content, as well as the storage stability of the roots in terms of PPD and pH measurement over the storage period were determined using standard methods. The fresh sample on day 1 served as the control treatment for nutritional quality assessment.

RESULTS AND DISCUSSION

The weight loss, nutritional compositions, PPD and pH of the stored roots were determined using the standards methods and results presented below.

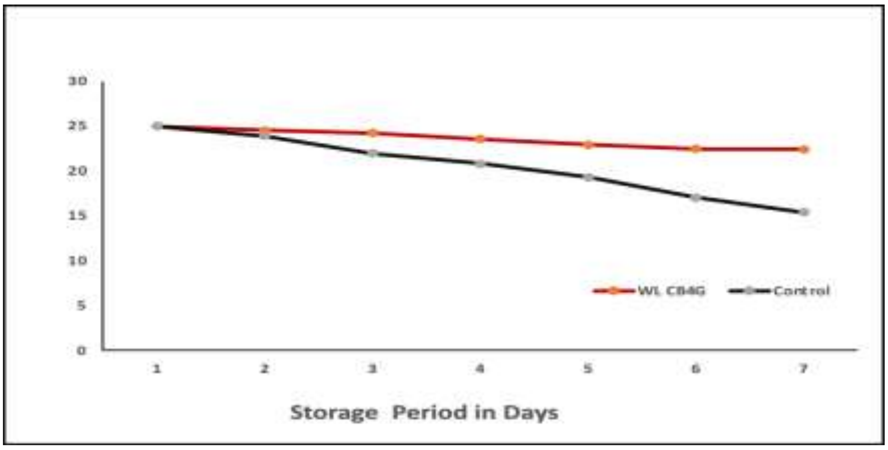

Figure 5: Storage Period in Days

Table 1: Starch content of stored cassava roots (%)

Day	*HCN*	*TTA*
1	2.84d ± 0.03	0.80a ± 0.01
3	4.09a ± 0.08	0.75b ± 0.00
5	3.30b ± 0.02	0.75b ± 0.00
7	2.97c ± 0.01	0.75b ± 0.00

Key: Values are means of triplicate determinations ± SD. Means followed by different superscript letters in the same column indicate significant difference at P ≤ 0.05

Table 2: Table of Proximate Analysis of Stored Fresh Cassava Roots (%)

Day	*Moisture Content*	*Fat*	*Protein*	**Ash**	**Fibre**	**Carbohydrate**
1	57.60a± 0.10	0.25**a**± 0.00	1.03d± 0.06	1.50a±0.06	1.80d± .06	37.82**d** ± 0.00
3	56.53**b**± 0.06	0.27**a**± 0.00	1.25**b**± 0.06	1.54**d**±0.06	1.83**c**± .06	38.58**c** ± 0.00
5	56.07**c**± 0.06	0.29**a**± 0.00	1.30**b**± 0.00	1.62**b**±0.06	1.90**b**± .06	38.82**b** ± 0.00
7	55.47**d**± 0.06	0.32**a**±0.00	1.33**a**±0.00	1.70**b**±0.00	1.95**a**±0.06	39.23**a** ± 0.00

Key: Values are means of triplicate determinations ± SD. Means followed by different superscript letters in the same column indicate significant difference at P ≤ 0.05.

Table: 3: Total Titratable Acidity and Cyanogenic Content of Stored Cassava Roots

Day	*HCN*	*TTA*
1	2.84d ± 0.03	0.80a ± 0.01
3	4.09a ± 0.08	0.75b ± 0.00
5	3.30b ± 0.02	0.75b ± 0.00
7	2.97c ± 0.01	0.75b ± 0.00

Key: Values are means of triplicate determinations ± SD. Means followed by different superscript letters in the same column indicate significant difference at P ≤ 0.05.

Table 4: Storage Stability in terms of PPD and pH of stored Cassava

Day	*PPD*
1	0.00a ± 0.00
2	
3	0.00a ± 0.00
4	
5	1.12b ± 0.02
6	
7	2.08c ± 0.09

Key: Values are means of triplicate determinations ± SD. Means followed by different superscript letters in the same column indicate significant difference at P ≤ 0.05.

DISCUSSION

4.1. Colour change with storage period

Colour tracking was first stage of this research work. The colour of the cassava roots stacked in the CB4G bags remained normal until the 5th day, while noticeable change started on 3rd day for the control. However, after the 5th day, rapid deterioration was very noticeable in all the samples kept in the bags. It implies, therefore, that the average number of days that the cassava bags may hold back the harvested cassava roots before significant spoilage sets in, if not processed, is five (5). The cassava quality will deteriorate very significantly beyond the fifth day of storage. It is worthy to note here also that the cassava roots that were properly harvested with their starks (dependables) attached and with little or no injury occurred to them lasted longer. This implies that careful harvesting of cassava roots has significant effect on the duration that such roots can last in the cassava bags before deterioration may set in and quality of products that it may be produced from the roots, thereof.

4.2 Weight loss and starch content of the cassava roots over the storage period

The temperature and relative humidity of the storage environment during research were between 27.53 oC and 30.20 oC and 68.49% and 76.09%, respectively. These two factors play important in postharvest stability of food crops. Temperature of stored produce greatly drives water loss, changes in metabolic activity, loss of flavour, texture and nutrients and rot. The major change that was observed in samples was color change. The colour noticed across the days of storage are shown in figure 5a to 5d.

Figure 5a: Appearance of cassava root on day 1

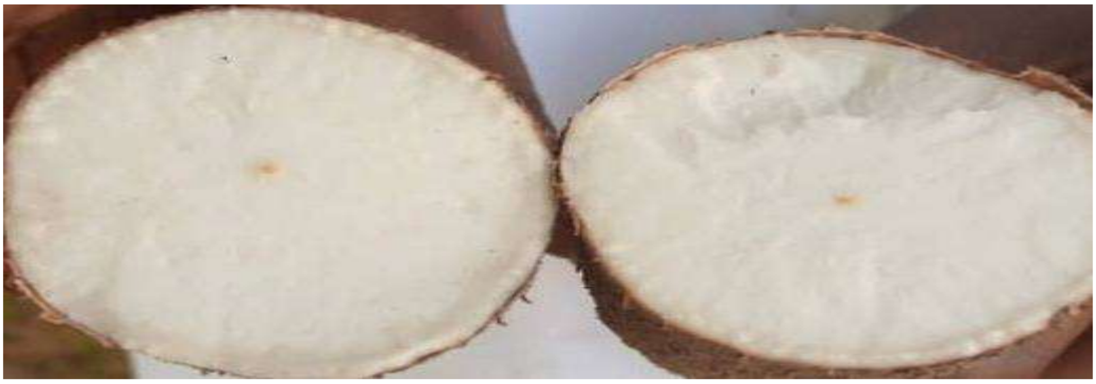

Figure 5b: Appearance of cassava root on day 3

Figure 5c: Appearance of cassava root on day 5

Figure 5d: Appearance cassava root stored in CB4G on day 7

Weight loss results for both cassava roots in the CB4G and control stored for seven days are as shown in figure 1. The weight analysis of the produce stored in CB4G and open heap indicated that the weight loss of the cassava roots just heaped exposed on the bare floor was higher (final weight = 15.40 kg) than the roots stacked in the designed cassava bag (final weight = 22.40 kg) on day 7. There is a significant difference ($p>0.05$) in weight loss between the two methods of storage. The increased weight loss can cause postharvest deterioration the roots. Sanchez *et al.,* (2006) reported that method of storage has actually has effect on weight loss of cassava roots.

The starch content evaluated at two days interval for the roots in CB4G are presented in Table 1. The starch content of the stored roots in CB4G decreased from 0.34% on day 1 to 0.23% on day 7. A previous study by Sanchez *et al.,* (2013) reported starch loss of stored fresh cassava roots occurs at a rate of about 1% per day. Interestingly our present study has recorded an average loss of only 0.03% per day, which has demonstrated the good quality of the CB4G bags as storage material for fresh cassava roots. However, the decrease in starch content must have occurred due to the hydrolysis of starch to sugar by the endogenous enzymes of the roots which can lead to quality deterioration (Girma *et al.,* 2015). Unfortunately, for the starch industry the gradual loss of starch as experienced in the study limits the extent to which the roots stored using CB4G bags can suited for their utilization.

The pH value of the samples indicated slight shift from acidity to alkalinity. The near anerobic condition of the roots was a possible cause for the alkalinity of the stored cassava roots. This agrees with the report of Omosuli and Olumayede (2010).

4.3 Proximate composition of the stored cassava roots

Results of the proximate composition are presented in Table 2, day1 has the highest value of moisture 57.60%, while day 7 had the least (55.47%). It can be seen from the result that there is no significant decrease in moisture content as a result of increase in the number of storage days. The decrease in the moisture contents is in line with the report of Omosuli *et al.* (2017). Although, the stored roots were kept under ambient temperature in the CB4G bags, certain physiological activities still took place which was responsible for the loss in moisture. The decrease in moisture content might have had effects that resulted to improved shelf-life of the cassava roots.

Crude fat ranged from 0.25% to 0.32%, no significant difference ($p\leq0.05$) among the storage days. The fat content of the fresh cassava roots increased from Day 1 to Day 7 with higher value observed in Day 7 (0.32%). The marginal increase could have been as the result of decrease in the moisture content. The high fat content of this study is an indication that, the storage period of cassava roots using CB4G bags has no negative effect on fat content of the cassava. Fat provides energy and is essential as it carries along fat soluble vitamins A, D, E and K (Olapade and Oluwole, 2013).

Crude protein ranged from 1.03 % to 1.33 %, showing no significant increase in protein content in respect to increase in the storage period of fresh cassava roots. Higher protein value was observed in Day 7 of the storage, even though cassava roots deterioration was witness to have occur, this implies that CB4G bags has no effect on the nutritional quality of cassava protein. The increase in protein content of stored cassava roots would impact positively on the end product as protein is needed for body building which is, necessary for growth and repair of damaged tissues (Wardlaw, 2004).

Ash content of the 7 Days stored cassava roots ranged between 1.50 % to 1.70 %, with the highest value been observed on Day 7 (1.70%). Ash content gives an insight into the mineral content of food, hence low ash content in this study is accrued to the fact that roots have low minerals (Ikujenlola and Opawale, 2007).

Crude fibre ranged from 1.80% to 1.95 %, there was an increase in the fibre content of stored cassava roots as the number of days increased. High levels of fibre in food help in digestion of foods and also contribute to the health of the gastrointestinal tract and system in man by aiding normal bowel movement thereby reducing constipation problems which can lead to colon cancer (Ikujenlola and Lawson, 2005).

Carbohydrate provides energy for all forms of body activities and as such its inadequacy can cause the body to divert proteins and body fat to produce needed energy, which might lead to depletion of body tissues (Shirika *et al*., 2015). Carbohydrate content of this study increased significantly from Day 1 to Day 7. Higher carbohydrates were observed as the storage period progressed and increased with decrease in moisture content. The increase in the carbohydrate could be attributed to fermentation or deterioration process of the cassava roots (Omosuli and Olumayede, 2010).

4.4 Total Titratable Acidity and Cyanogenic Content of Cassava Roots Over the Storage Period

The hydrogen cyanide was not significantly different on days 1 and 7 but in between (3& 5) significantly different was observed. The hydrogen cyanide content ranged between 2.84 to 4.09. The secretion of hydrogen cyanide begins immediately after harvest as a defense mechanism which is the reason for its low value on day 1. It was highly concentrated on day 3 but began to decrease from day 5 as the storage progressed and on day 7 had reached the lowest measurement throughout the duration of the experiment. The cyanogenic potential of the roots decreased over the storage period, probably due to enzymatic reactions or biochemical changes which detoxify the roots during storage.

The total titratable acidity remained same for all days [0.75%] except on day 1 [0.80%]). Omosuli *et al.* (2017) also reported that hydrolysis of starch to sugar under anaerobic condition causes alkalinity, which result decrease in TTA. The total titratable acidity (TTA) of the roots does not decrease over the storage period which agrees with the report of Omosuli *et al.* (2017).

4.5 Determination of the storage stability (PPD and pH) of stored cassava roots

The results of the physiological properties of the stored cassava roots presented in Table 4 show that the postharvest physiological deterioration (PPD) increased with increasing number of days. The PPD indicated no rots from 1 to 3, however, rots began from day 5 during the storage period. The increased levels of PPD in roots may be attributed to the presence of lower sugar levels in the roots. An increase in PPD value meant a reduced shelf-life which agrees with the findings of Reilly *et al.* (2004); El-Sharkawy (2007); Blagbrough *et al.* (2010); Zainuddin *et al*. (2017) and Tomlins *et al*. (2021).

5. CONCLUSION

The CB4G can retain good qualities of cassava roots for five (5) days as observed from the results. Except otherwise, carefully harvested cassava roots can only last for five (5) days in the bags before processing, without significant change in the roots' quality. One factor that was observed to have significant impact on the success of the CB4G bags was careful handling of the cassava roots right from the time of harvest. As it was observed in course of the research, cassava roots with injury or severe cuts were more susceptible to early deterioration than those without cuts. There is every need for capacity building for cassava farmers, transporters and processors on the package of practice (PoP) or best harvesting technologies that will minimize postharvest losses.

Colour of roots stored in the bags remained almost normal until the 5th day, while the controlled sample started deteriorating on 3rd day. It implies, therefore, that the average number of days that the cassava bags may hold back the harvested cassava roots before it may start spoiling significantly if not processed, is five (5). The cassava qualities may begin to deteriorate very significantly on day 7 using the CB4G bags. For ethnic uses of cassava roots, such as the preparation of garri and fufu, the CB4G storage method of fresh cassava roots could be advantageous, at least in terms of appearance, since the products would not present the grayish blue color that is typical of products made from deteriorated roots.

Going by the results of this work, fresh cassava roots can retain good qualities if stored in the CB4G bags at ambient temperature in a place like Benue State up to seven days with minimal deterioration or loss in starch. The advantage would be reduction in postharvest loss handling and pressure on farmers, transporters and processors of cassava roots. It is also possible that other varieties of cassava roots may have differing storage characteristics, and this would need to be tested.

DECLARATION

I hereby declare that the above study is the outcome of the original research I carried out in collaboration with the other co – authors whose names are listed above. All authors whose works are cited in this research are dully acknowledged.

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