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**Research Article**

**Quality assessment of stored fresh Cassava Roots and ‘fufu’ flour produced from stored roots**

**Abstract**

The aim of this study was to assess the quality characteristics of cassava roots and fermented cassava flour (fufu). Matured cassava was carefully uprooted and stored in high density polyethylene bag for a period ranging from 0 to 10 days. Fermented cassava flour was produced using standard methods. The stored roots were assessed for various quality properties like percentage loss, discoloration, peel to pulp ratio. Also physico-chemical and sensory of ‘fufu’ flour produced from stored roots were assessed using standard methods. There was found a decrease in the percentage pulp obtained and a corresponding increase in the percentage peel from 22.10% to 35.90% as the period of storage progressed. The moisture and starch contents decreased while the ash, crude-fibre and sugar contents increased during the study. The yield of ‘fufu’ flour and cyanogenic potential decreased as the storage period progressed. There was no significant difference among ‘fufu’ samples produced from roots stored for the first seven days with respect to sensory qualities. The study shows that cassava roots can be stored effectively in high density polyethylene bag and result in acceptable product.

**Introduction**

Cassava is an important food staple, providing a cheap energy source for more than 800 million people around the world [1,2]. Worldwide production is estimated to be approximately 230 million tonnes per annum, according to recent FAO statistics [3,4]. Due to the high moisture content of cassava roots which is between 65% and 70% on dry weight basis [5], the utilization of cassava has been limited by the extreme perishability of the fresh roots when stored [6].

Normally, fresh cassava roots are transported in bulk or sacks or stored in the soil until needed. Ideal operating conditions demand that the roots be processed on the day of harvesting or one or two days later [7], as primary deterioration normally commenced within two days of harvesting followed by secondary deterioration by the action of micro-organisms on the tissue, causing tissue-rot, which is evident in the root 5–7 days after harvesting [8,9].

Many storage methods to preserve cassava roots have been utilized such as storage in sawdust with an approximately equal weight of water [10]. According to Nabney J [11], roots can be preserved fresh for longer periods if treated with fungicides prior to storage. Moreover [7], reported the storage of cassava roots in the pit for 14 days. Successful as these storage methods may be; it is not without its shortcomings; some of the methods are labour intensive and space for the storage may pose challenge in most cases, the quality of the stored products has not been fully assessed in food production. This study was however designed to proffer solution to some of the shortcomings of the former methods. The design entails storing fresh cassava roots in high density polyethylene bag, very well closed, as an alternative to earlier methods, to assess the quality parameters of the stored roots and to produce ‘fufu’ from fresh and stored cassava roots.

**Materials and Methods**

**Materials**

Matured cassava roots (TMS 30572) were carefully uprooted and transported to the laboratory where the packaging and preservation took place. Five (5 kg) of the roots were packed together to form a sample. There were five samples for the 10 days storage period.

**Methods**

**Storage of fresh cassava roots**: The fresh cassava roots were weighed and neatly packaged but not washed in the high density polyethylene bags well closed. The packaged roots were stored for 0, 2 days, 4 days, 7 days and 10 days. The packaged roots were kept in the laboratory at ambient temperature. Meanwhile, samples were taken for assessment of selected quality parameters on the stored roots.
**Physical assessment**

i) Percentage loss of root

The stored cassava roots were examined and weighed at the end of the storage period. The percentage loss of roots was computed using the following expression:

\[
\% \text{ Loss of root} = \frac{\text{Weight of spoiled roots}}{\text{Weight of whole roots}}
\]

ii) Percentage loss of peel and pulp

The stored roots were peeled and the ratio of the peels to pulp was computed by the following expression:

\[
\% \text{ Pulp} = \frac{\text{Weight of Pulp}}{\text{Weight of whole roots}}
\]

**Production of ‘fufu’ flour from stored cassava roots**

The stored roots were re-weighed and carefully peeled using hand peeling with a sharp knife. The peeled roots were washed in clean water. It was soaked in clean water for 72 hours during which fermentation set in and the pulp softened. The softened pulp was dissolved in clean water to remove the shaft and wet sieve using the traditional sieve meant for ‘fufu’ production. The resulting slurry was left to settle. The mash was thereafter packed in a jute bag and presses to remove excess water before drying. The dried ‘fufu’ was packaged. The process flow chart is presented in [12] (Figure 1).

**Chemical analysis**

i) Moisture Content

The moisture content was determined by hot air oven method as described by [13]. An empty crucible was weighed and 2 g of the sample was transferred into the crucible. This was taken into the hot air oven and dried for 24 hours at 100°C. The crucible and its contents were cooled in the desiccator and their weights taken. The loss in weight was regarded as moisture content and expressed as:

\[
\% \text{ Moisture content} = \frac{\text{Weight loss}}{\text{Weight of sample}} \times 100
\]

ii) Ash Content

Ash content was determined using the method of [13]. About 5 g of each sample was weighed into crucibles in duplicate, and then the sample was incinerated in a muffle furnace at 550°C until a light grey ash was observed and a constant weight obtained. The sample was cooled in the desiccator to avoid absorption of moisture and weighed to obtain ash content.

\[
\% \text{Ash} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100
\]

iii) Crude Fibre

Crude fibre was determined using the method of [13]. About 5g (W,) of each sample was weighed into a 500ml Erlenmeyer flask and 100 ml of trichloroacetic acid reagent (TCA) digestion reagent was added. It was then brought to boiling and refluxed for exactly 40 minutes counting from the start of boiling. The flask was removed from the heater, cooled a little, and then filtered through a 15.0cm number 4 Whatman paper. The residue was washed with hot water stirred once with a spatula and transferred to a porcelain dish. The sample was dried overnight at 105°C. After drying, it was transferred to a desiccator and weighed as W₂. It was then burnt in a muffle furnace at 500°C for 6 hours, allowed to cool, and reweighed as W₁.

\[
\% \text{ Crude fibre} = \frac{W₂ - W₁}{W₁} \times 100
\]

\[
W₁ = \text{weight of crucible + fiber + ash}
\]

\[
W₂ = \text{weight of crucible + ash}
\]

\[
W₀ = \text{dry weight of food sample}
\]

iv) pH determination

The pH of the flour samples were determined by mixing 10 g of the flour samples with 25ml of distilled water, stirring thoroughly and measured with a pH meter (Corning pH meter model 220) at 20°C [12].

**The total titrable acidity (TTA) and Sugar determinations**

The TTA was determined as described by [3]. The total reducing sugar was determined by the phenol sulphuric acid method as described by [14]. Starch was determined after hydrolysis to sugar. The sugar was converted to starch using the factor 0.9. The cyanogenic potential of the roots and ‘fufu’ were determined by the method of [15].

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Sensory evaluation of reconstituted 'fufu' flour

The various samples of 'fufu' were subjected to sensory evaluation. The products were reconstituted, coded and served warm to the semi trained sensory panellists consisting of people who are used to 'fufu' consumption. The samples were assessed for colour, taste, smoothness/texture, flavour, and overall acceptability. The panellists were made to assess the samples and recorded their observations using a 7-point hedonic scale where, 1- Dislike extremely, 2- Dislike moderately, 3- Dislike slightly, 4- No disliked nor liked, 5- Like slightly, 6- Like moderately, 7- Like extremely.

Statistical analysis

All the analysis was done in triplicate and the data obtained were subjected to One way Analysis of Variance (ANOVA).

Results and Discussion

Physical assessment of stored roots

The stored roots were found to be discolored in the pulp changing from whitish to brownish yellow as the period of storage progressed. This observation may be due to physiological changes resulting from respiration and transpiration processes, microbial activities and pathological changes occurring in the root during storage in high polyethylene bag.

In addition, the percentage peel and pulp of the stored roots ranged between 22.10% - 35.90% and 77.90% - 47.60% respectively (Table 1). The loss of the root increased as the period of storage increases. It was observed that the ease of peeling reduced with the increase in period of storage. The peel tends to adhere more to the pulp this was responsible for the reduction in yield during storage. The moisture content of the root during storage was responsible for the firm adherence of the pulp to the peel. This made peeling difficult and increase pulp loss to peel.

Chemical composition of the stored roots

The results of the selected chemical composition are presented in (Table 2). The moisture content of the samples gradually reduced as the period of storage progressed. The moisture was 68.40% in fresh cassava while it was 58.80% on the tenth day of storage. Although the stored roots were kept under ambient temperature in a high density polyethylene bag certain physiological activities still took place which were responsible for the loss in moisture. This observation agrees with the reports of [16-18].

The ash and crude fibre contents (Table 2) of the roots increased with an increase in the storage period. The increase in ash content (0.60 – 1.30%) may be attributed to loss of nutrient such as starch which might have been mobilized for use during respiration [19]. The sugar content (5.60– 10.80%) increased with a corresponding decrease in starch content over the storage period. This might be due to the hydrolysis of starch to sugar by the endogenous enzymes of the roots leading to quality deterioration [6].

The pH of cassava roots was 6.3 and increased with storage period to 7.3 probably due to the near anaerobic condition of the roots [19]. It was reported that hydrolysis of starch to sugar under anaerobic condition causes alkalinity [20]. However, the total titrable acidity (TTA) (0.02 – 0.05%) of the roots decreased over the storage period. The cyanogenic potential of the roots decreased from 12.7 to 7.4 mg/kg over the storage period, probably due to enzymatic reactions or biochemical changes which detoxify the roots during storage.

Percentage yield of ‘fufu’

The percentage yield of ‘fufu’ is a function of the pulp that was available for fermentation. From (Table 1) it was discovered that the percentage pulp, reduced as the storage period progressed expectedly the yield of the resulting ‘fufu’ followed a similar trend. The yield ranged between 14.20% (10th day) and 27.80 (fresh cassava). One of the major reasons for the reduction in yield during storage was the pulp loss to peel during the process of peeling. The reduction in moisture content of the root during storage was responsible for the firm adherence of the pulp to the peel. This made peeling difficult and increase pulp loss to peel.

Chemical composition of ‘fufu’

The selected chemical composition of the fermented cassava product- ‘fufu’ is presented in (Table 3). The moisture content of the ‘fufu’ flour ranged between 8.10% and 11.30%. The moisture content determines to a large extent the ability of floury product to store well. The moisture content is below 12%, it is expected that the ‘fufu’ flour will store for a reasonably long period. The ash and crude fibre contents increased in the

Table 1: Effect of storage in HDP bag on some physical properties of cassava roots.

| Storage period (days) | Loss of roots (%) | Pulp (%) | Peel (%) |
|-----------------------|-------------------|----------|----------|
| 0                     | -                 | 77.90a   | 22.10c   |
| 2                     | 4.70c             | 70.50a   | 24.80bc  |
| 4                     | 9.30b             | 63.10ab  | 27.60ab  |
| 7                     | 12.10b            | 55.80b   | 32.10a   |
| 10                    | 16.50a            | 47.60c   | 35.90a   |

1. Mean of three replicates.
2. Means with the same letters in a column are not significantly different (P>0.05).

Table 2: Mean Chemical composition of roots over the storage period.

| Storage periods (days) | Moisture (%) | Ash (%) | Crude fibre (%) | Sugar (%) | Starch (%) | Cyanogenic potential (mg/kg) | pH | TTA (%) |
|------------------------|--------------|---------|-----------------|-----------|------------|-----------------------------|-----|--------|
| 0                      | 68.40a       | 0.60b   | 1.20c           | 5.60c     | 79.90a     | 12.70a                      | 6.30a | 0.05a  |
| 2                      | 65.60a       | 0.70b   | 1.30c           | 6.90c     | 77.60a     | 11.20a                      | 6.40b | 0.05a  |
| 4                      | 62.30a       | 0.90b   | 1.50c           | 8.00bc    | 75.50a     | 9.50a                       | 6.70b | 0.03a  |
| 7                      | 60.50a       | 1.10ab  | 1.60b           | 9.10bc    | 69.00ab    | 8.10ab                       | 7.00ab | 0.02a  |
| 10                     | 58.80b       | 1.30a   | 2.00a           | 10.80a    | 60.10b     | 7.40b                       | 7.30a | 0.02a  |

1. Mean of three replicates.
2. Means with the same letters in a column are not significantly different (P>0.05).
‘Fufu’ flour as storage periods of cassava roots increases. This agrees with the trend in the stored roots, also the observation agrees with the result of [7]. ‘Fufu’ flour from freshly harvested cassava roots had 1.50 % ash content and 1.40% fibre content, and as the holding period increases, the ash and fibre contents increased to 2.20 % and 1.90 % on the 10th days respectively.

The pH of the ‘fufu’ flour increased with the increasing storage period of the cassava roots with a corresponding decrease in total titrable acidity. The pH varied from 4.10 to 4.80 while the TTA varied from 0.10% to 0.70% respectively. The cyanogenic potential (Table 3) decreased with the increasing storage period of the roots and ranged from 1.00 (10th day) to 11.10mg/kg (fresh sample). The reduction in the cyanogenic potential of ‘fufu’ flour was due to a reduction in the cyanogenic potential of cassava roots during storage which was used in ‘fufu’ production. Also, pressing of the cassava mash aided the cyanogenic potential reduction. It was reported by [21], that pressing and fermentation remove cyanide as glucosides (which are water soluble), or as water soluble free cyanide after hydrolysis of the glucosides. Furthermore, drying process may further reduce the cyanogenic potential of the cakes as free cyanide was volatilized by heat during drying of the flour. It was reported by [22], that the boiling temperature of hydrogen cyanide is 25.70°C. The cyanogenic potential of the ‘fufu’ flour from cassava roots held in high density polyethylene bag was below a specified standard of 30mg/kg dry weight. It has been observed that traditional processing of cassava roots reduces the cyanogenic potential to an allowable level for human consumption [23-28].

**Sensory evaluation of ‘fufu’**

The result of the sensory evaluation is as shown in (Table 4) ‘Fufu’ flours from the stored roots were significantly different (p > 0.05) from each other in all the sensory quality attributes assessed. ‘Fufu’ from freshly harvested roots was ranked best in terms of colour, taste, odour, texture and overall acceptability with mean scores of 4.70, 4.40, 4.10, 4.40 and 4.80 respectively. The colour of ‘fufu’ from roots stored for 10 days had a dark colour and this was as a result of the discoloration of the pulp during storage. Biochemical and physiological reactions coupled with microbial activities are responsible for the deterioration and discoloration which also accounted for the dark colour in ‘fufu’ from the 10th day storage. There was no significant difference (p < 0.05) in the overall - acceptability of ‘fufu’ obtained from roots stored for the first four days [29], reported that storage of cassava roots for up to 8 weeks does not significantly affect the colour, smell, elasticity and taste of cassava ‘fufu’.

**Conclusion**

The conclusion from the study was that it was possible to store fresh cassava roots in high density polyethylene bag for about seven days without any pronounced deterioration. Also the quality of the fermented product ‘fufu’ from the stored roots declined as the days of storage increases. However, “fufu” be produced from stored roots for seven days was considered to be of good quality. Post-harvest losses could be prevented by adopting the process of storage in high density polyethylene bag.

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| Table 3: Mean chemical composition of ‘fufu’ flour during the storage period. |
|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| Storage period (days) | Moisture (%) | Ash (%) | Crude fibre (%) | pH | TTA (%) | Cyanogenic potential (mg/kg) |
|---------------------|----------------|----------|----------------|-----|---------|---------------------------|
| 0                   | 11.30a          | 1.50c    | 1.40b          | 4.10b | 0.70ab  | 11.10a                   |
| 2                   | 10.40b          | 1.80bc   | 1.50b          | 4.60a | 0.60ab  | 9.20a                    |
| 4                   | 9.80b           | 1.90bc   | 1.50b          | 4.70a | 0.50bc  | 4.10b                    |
| 7                   | 8.90c           | 2.00ab   | 1.60ab         | 4.70a | 0.30c   | 2.70bc                   |
| 10                  | 8.10c           | 2.20a    | 1.90a          | 4.80a | 0.10c   | 1.00c                    |

1. Mean of three replicates.
2. Means with the same letters in a column are not significantly different (P>0.05).

| Table 4: Mean sensory scores of ‘fufu’ flour in percentage. |
|------------------|------------------|------------------|------------------|------------------|
| Storage period (days) | EColour | Taste | Odour | Texture | Overall Acceptability |
|----------------------|---------|-------|-------|---------|----------------------|
| 0                    | 94.00a  | 88.00a | 82.00a | 88.00a  | 96.00a               |
| 2                    | 92.00a  | 72.00b | 76.00b | 76.00b  | 82.00b               |
| 4                    | 74.00b  | 60.00bc| 70.00ab| 62.00c  | 82.00db              |
| 7                    | 64.00c  | 52.00c | 60.00b | 58.00c  | 70.00c               |
| 10                   | 54.00c  | 48.00c | 58.00b | 40.00d  | 36.00d               |

1. Mean of sensory scores in percentages.
2. Means with the same letters in a column are not significantly different (P>0.05).
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