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Effect of variety, age at maturity, and drying method on physicochemical properties of high quality cassava flour (HQCF)

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Abstract: *High quality cassava flour (HQCF) is one of the products derivable from cassava roots. Drying in HQCF production is a complex operation which changes the quality of a product physically and chemically. Thus, it is important to investigate some quality attributes of high quality cassava flour obtained from solar and flash drying methods and compare these with the acceptable standard values. Two improved cassava varieties (TMS98/0510 and TMS98/0505) were planted and harvested at different developmental stages of 7, 9 and 12 months after planting. The roots were processed into HQCF within 24 h of harvest using mechanized and solar dryers. The physicochemical properties: moisture, crude fibre, carbohydrate, pH, and cyanide contents of the flour samples were determined using standard laboratory procedures. Effect of variety, age at harvest, and drying method as well as their interactive effects were then statistically assessed on these properties. There was a significant difference in pH and cyanide contents of HQCF samples from the two cassava varieties. With respect to the carbohydrate and moisture contents, the variety, age, and drying method interaction had no significant ($p > 0.05$) effect while interaction significantly affected the pH, cyanide, and crude fibre contents. However, the values obtained in all the HQCF samples were within acceptable limits.*

Keywords: cassava, HQCF, variety, age, drying method, physicochemical properties

CASSAVA (*MANIHOT ESCULENTA* CRANTZ) is generally considered one of the most important root crops in the world and ranks second in consumption (FAO, 2014). It provides some features of a high level of food security, economic importance, and high crop yield among other staple crops in Africa, South-east Asia, and South America (Nweke et al., 2002). Cassava has also become a very important root crop, not only as a subsistence household crop, but is also extensively traded as a raw product, or in processed forms, in the Pacific Islands, tropics, and

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subtropics. The socio-economic development of rural and urban areas in Africa, which has gained recognition in the last two decades, is linked to the importance of cassava due to its efficient production of food energy, year-round availability, its strong ability to survive adverse environmental conditions, suitability for small-scale farming, and its various uses in non-food industries such as starch, bioethanol, and animal feed (Hahn and Keyser, 1985; Hahn et al., 1987; Maziya-Dixon et al., 2007).

Cassava is processed into various forms of which *gari* is known to be a popular product (Oluwole et al., 2004), consumed by almost all socio-economic groups across Nigeria. Other processed cassava products include *lafun*, *fufu*, starch, grits, tapioca, and high quality cassava flour (HQCF). HQCF serves as a raw material in some industries (Balagopalan, 2002; Aloys and Ming, 2006; Taiwo, 2006; Shittu et al., 2008). HQCF now performs most of the functions of other flours and this includes cooking or production of confectioneries (cassava-based products) such as breads, crackers, pastries, and cake. However, its substitution for wheat flour depends largely on its relative price and physical and chemical properties. The desired quality attributes of HQCF are that it is unfermented, odourless, and white in colour; it has low fibre content, fine particle size, minimal cyanide level, absence of foreign matter, acceptable moisture content, and no or low microbial load (Sanni et al., 2005).

Cassava with a number of varieties has been shown to grow well in a tropical climate and the level of its chemical composition varies considerably with geographical location (Cardoso et al., 2005; Oluwole et al., 2004; CAC, 2009). TMS98/0510 and TMS98/0505 are among the top 10 improved cassava varieties released by International Institute of Tropical Agriculture (IITA) and they have been widely adopted by many farmers in the western part of the country. Therefore, it is expedient to assess the required quality and safety attributes of HQCF produced from these varieties for appropriate utilization in various cassava-based products.

The processing of cassava into more storable forms and value-added products offers an opportunity to overcome the perishability of the fresh root, as the root contains 60–70 per cent moisture content on average. Conventional processing methods usually involve peeling, chopping, grating, soaking, boiling, fermenting, drying, and roasting. A key stage in the processing of cassava flour is drying. 'Drying is a unit operation that involves transfer of heat and mass along which both physical and chemical transformation occur leading to changes in the quality of the product' (Mujumdar and Devahastin, 2000). Different drying methods are employed by cassava processors, such as sun, solar, cabinet, oven, and flash (pneumatic) amongst others (Ajibola and Olapade, 2017).

Solar drying is facilitated by the circulation of hot air with an average temperature of 45 °C, the spreading density of the products, and the nature of the product itself (Eswara and Ramaskrishnarao, 2012). It is considered safe as the product is protected from foreign material. It ensures minimal microbial loads and uniform drying due to higher temperatures; however, the initial cost is higher.

Technology advancement paved the way for the adoption and use of mechanized flash dryers which are more effective and cost efficient making the mechanized

Figure 1 Solar dryer

Figure 2 Flash dryer

drying method safer and faster. This also makes HQCF more accessible to the users in the value chain. The flash dryer has the shortest drying time with a capacity of 250 kg of HQCF per hour at a temperature of 120 °C (Myriam Vitovec, 2015).

However, removal of water by heat has been reported to affect the nutritional contents of foods; it either increases or decreases the concentration of some nutrients, thereby making them more or less available (Morris et al., 2004; Hassan et al., 2007). Sakyi-Dawson et al. (2006) reported that both variety and processing methods had significant effect on the chemical composition and cyanide level of cassava products. This study aimed at evaluating the effect of solar and flash drying methods on HQCF produced from two commonly grown cassava varieties harvested at three different developmental stages. This will help in determining a suitable drying method based on the physicochemical properties of HQCF.

Materials and methods

Materials

Two improved cassava varieties (TMS98/0510 and TMS98/0505) were grown on a hectare of experimental field at the Federal University of Agriculture, Abeokuta, Nigeria, according to standard commercial practices of 1 m × 1 m spacing in cassava planting. Fresh cassava roots were harvested at different developmental stages of 7, 9, and 12 months after planting.

Sample preparation

The cassava roots harvested were processed into HQCF using the method described by Sanni et al. (2006). Freshly harvested cassava roots were sorted, peeled, washed, grated, dewatered, and pulverized. The first portion of the mash was dried in a locally constructed solar house at an average temperature of 45 °C for 8 h while the second portion was dried using a Nobex fabricated flash dryer at 120 °C for 5 mins. The dried products were milled in a fabricated milling machine, allowed to cool, and then packaged in low density polyethylene bags which were kept at ambient temperature and relative humidity prior to laboratory analyses.

Laboratory analyses

Both the fresh root and HQCF samples were assayed for moisture content, crude fibre, carbohydrate content, pH, and cyanide content.

Moisture content determination. The moisture content of the samples was determined using the method described by AOAC (2005). Crucibles were cleaned and dried in an oven at 105 °C, cooled to room temperature in desiccators with dry silica gel for 40 min, and weighed as (W_1). Of each sample, 5 g was weighed into the crucible and the weight was recorded as (W_2), all the crucibles and their content were transferred into the Gallemkamp hot air oven at a temperature of 105 °C for 3 h. Thereafter the samples were cooled in the desiccators and weighed. The crucibles and the final

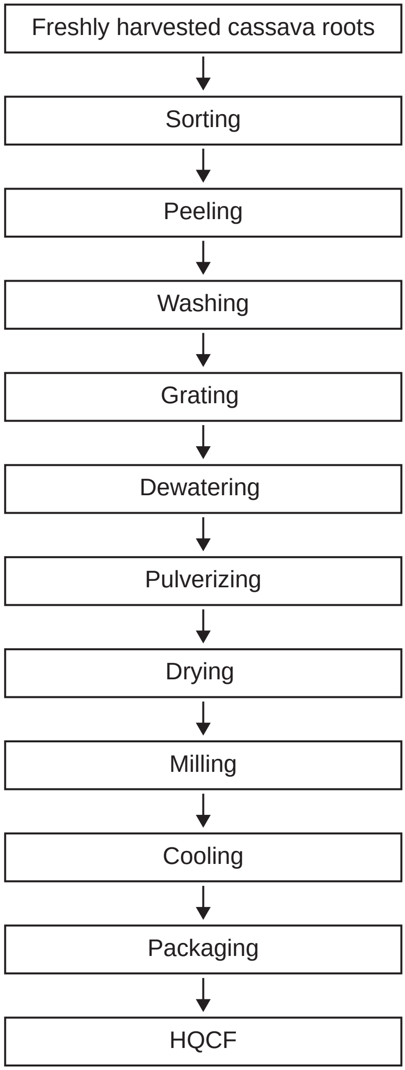

Figure 3 Flow chart for HQCF production (Sanni et al., 2006)

weight were taken as (W_3). The percentage moisture content was calculated using the formula:

$$\% \text{ Moisture} = \frac{\text{loss in weight due to drying}}{\text{weight of sample taken}} \times 100 = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \qquad (1)$$

Crude fibre determination. The crude fibre content was determined using the method described by AOAC (2005). Approximately 3 g of sample was weighed and extracted with petroleum ether. It was allowed to boil (under reflux condenser) for

40 minutes. Filter paper was placed in the funnel and the sample was drained by applying suction. The insoluble material was washed first with boiling water, then with 1 per cent HCl, twice with alcohol and thrice with ether. The filter paper was dried at 100 °C to a constant weight. The paper and the contents were weighed and then incinerated to ash and the remaining ash was weighed. The difference between the weight of the paper plus the insoluble material and that of the ash represented the fibre content.

$$\%\ \text{fibre} = \text{Difference in weighing} \times 100 \qquad (2)$$

Carbohydrate determination. Total carbohydrate was determined by difference. An approximation was made by subtracting the measured crude protein, crude fibre, total ash, and moisture content from the total weight (Egunlety and Aworh, 1990).

pH determination. Exactly 5 g of sample was suspended in deionized water for 5 min at a ratio of 1:5 (w/w) and pH measured using a digital pH meter (Orion Research Inc., Model 720A, USA) as reported by Sanni (1999).

Cyanide analysis

Extraction of cyanide in the sample. Exactly 5 g of each sample was weighed using a weighing balance into a conical flask; 50 ml of distilled water was added and the flask corked. This was left overnight and then filtered. The extract was used for cyanide determination.

Preparation of alkaline picrate solution. Exactly 25 g of anhydrous sodium carbonate and 5 g of anhydrous picric acid were added to 1 l volumetric flask. The mixture was dissolved in 100 ml of warm distilled water and the solution was made up to the mark with cold distilled water. The alkaline picrate method as described by Ikediobi et al. (1980) and Olugboji (1987) was used.

Construction of a standard curve for cyanide assay using alkaline picrate method. A sample of potassium cyanide to be used as standard was first dried in the oven to constant weight. A stock solution was prepared by dissolving 8 mg of this salt in 100 ml of distilled water. This gives a concentration of 32 µg CN/ml. From this stock solution, a series of 10 ml plastic stopper test tubes containing 3.2–64 µg of cyanide was set up. The volume of each was made up to 2 ml with distilled water and 4 ml of alkaline picrate was added and mixed. The resulting solution was incubated in a water bath at 95 °C for 5 min. Upon cooling to room temperature, the absorbance of the deep orange colour formed was read in a spectrophotometer (CECIL: CE 2021, 2000 Series) at 490 nm. The absorbance at 490 nm was plotted against cyanide concentration. The cyanide concentration was extrapolated from a standard curve previously prepared with potassium cyanide as standard and calculated using Equation (3) (Onwuka, 2005).

$$\text{mg/kg HCN} = \frac{\text{conc.obtained in mg/l} \times \text{vol.of sample} \times \text{dilution factor (if any)}}{\text{Sample weight}} \times 1000 \qquad (3)$$

Statistical analysis

Statistical analysis was carried out using SPSS 21.0 (SPSS Inc. NY) statistical software. Data obtained were subjected to analysis of variance (ANOVA) using the general linear model (multivariate).

Results and discussion

Effects of variety and age at harvest on the physicochemical properties of cassava roots are shown in Table 1.

The moisture, crude fibre, carbohydrate, pH and cyanide contents of the fresh root samples varied from 55.75 to 61.05 per cent, 0.57 to 1.68 per cent, 36.09 to 41.58 per cent, 7.00 to 7.15 and 17.63 to 48.86 mg/kg, respectively. Variety TMS98/0510 was significantly higher in moisture, fibre, and cyanide contents. Both the moisture and cyanide contents in the two varieties decreased as the roots advanced in age with the 7th month having the highest values. The crude fibre and carbohydrate contents on the other hand were observed to increase as the roots aged, with the 12th month having the highest values. The moisture content value obtained for the roots in this study is in line with various ranges reported by Sanchez et al. (2009), Bakayako et al. (2012), and Agiriga and Iwe (2016). It has been reported that varieties with lower moisture content have higher carbohydrate content due to differences in the percentage of other proximate composition (Nwabueze and Anoruoh, 2011). Thus, variety TMS98/0505 produced the higher carbohydrate content. The crude fibre also increased as the moisture content decreased; this can be attributed to an increase in the dry matter as the roots advanced in age.

Table 1 Effect of variety and age at maturity on physicochemical properties of fresh cassava roots

Variety	*Age at harvest (months)*	*% Moisture*	*% Crude fibre*	*% Carbohydrate*	*pH*	*HCN (mg/kg)*
TMS98/0510	7	61.05	0.59	36.09	7	48.86
	9	58.65	0.84	38.22	7.15	48.01
	12	56.15	1.68	40.31	7.1	21.14
TMS98/0505	7	61	0.57	36.35	7.05	46.18
	9	57.75	0.73	39.88	7.05	45.51
	12	55.75	1.08	41.58	7.05	17.63
SE		0.18	0.01	0.19	0.02	0.13
Range		55.75–61.05	0.57–1.68	36.09–41.58	7.00–7.15	17.63–48.86
P of variety		*	*	*	ns	*
P of age at harvest		*	*	*	ns	*
P of variety *Age		*	*	*	ns	*

Note: * significant; ns, not significant

Production of cyanide by various cultivars is affected by soil, weather, and other geographical conditions (Bokanga et al., 1994; Dixon et al., 1994). Chotineeranat et al. (2006) reported significant reduction in the cyanide concentration as the root advanced in age. TMS98/0510 produced the highest cyanide value (48.86 kg/mg, 7th month).

The physicochemical properties of the dried samples are shown in Table 2. There were no significant differences in the values obtained in moisture, crude fibre, and carbohydrate contents of the HQCF across the varieties but significant differences in pH and cyanide contents of the samples. TMS98/0510 produced the higher residual cyanide in the HQCF samples and this could be attributed to the initial content as observed in the root samples. There were significant differences in the values obtained for age at harvest and the drying method across all the parameters.

The moisture content varied from 8.00 to 10.26 per cent with the flash drying producing the lowest value while the solar drying produced the highest values. The lower values with the flash drying could be a result of the short time required in drying the sample compared with solar drying which takes a longer time to achieve the required moisture level.

The lower moisture content observed for the flash dried HQCF samples could be attributed to the high temperature (120 °C) used for drying compared with the solar drying temperature of 45 °C. The moisture content values obtained for both flash and solar drying were within the recommended moisture value (12 per cent); this favours the shelf-life and quality of the products as it inhibits microbial activities (Eleazu et al., 2012). Age negatively impacted the crude fibre content of the flour (acceptable limit of <3 per cent), which was observed to increase with age. Variety TMS98/0505 had the highest crude fibre content in the 12th month in the solar dried sample, suggesting that, ideally, it is better to harvest at 9 months. The dry matter (carbohydrate values) in both drying methods was above the recommended minimum value of 70 per cent; this serves as a good indicator for starch content in these varieties. Thus, moisture, crude fibre, and carbohydrate contents in the dried samples are within 12 per cent maximum, <3 per cent, and 70 per cent minimum, respectively, of the standard requirements for HQCF by SON (2004) as reported by Sanni et al. (2005).

The pH value is a vital indicator for assessing the quality of HQCF; it is known to reduce the substitution level of the flour used in baking and also improves the quality of the product. The values obtained in this study fell within the recommended pH range between 5.5 and 6.5 for flours (Aryee et al., 2006). The pH value was higher in solar dried samples compared with the flash dried samples; this could perhaps be a result of the gradual removal of moisture from the samples attributed to solar drying.

Removal of about 90 per cent of the cyanide content from the roots during processing to less than 10 ppm for production of cassava-based foods guarantees their safety for human consumption (FAO/WHO, 2002; Iglesias et al., 2002). For both drying methods used in this study, residual cyanide contents ranged from 0.29 to 1.88 mg/kg. The lower residual cyanide observed in the flash dried HQCF samples could be attributed to the high temperature, short duration drying operation

Table 2 Effect of variety, age at maturity, and drying method on physicochemical properties of freshly processed HQCF

Variety	*Age at harvest (months)*	*Drying method*	*% Moisture*	*% Crude fibre*	*% Carbohydrate*	*pH*	*HCN (mg/kg)*
TMS98/0510	7	Flash	8.00	1.99	86.47	5.31	0.77
		Solar	9.59	3.59	83.81	5.75	1.25
	9	Flash	9.39	2.34	85.40	5.15	1.26
		Solar	10.22	3.80	82.92	6.05	1.58
	12	Flash	8.49	2.60	85.69	5.50	0.60
		Solar	9.93	4.03	83.17	6.30	1.54
TMS98/0505	7	Flash	8.05	1.92	86.60	5.25	0.50
		Solar	9.07	3.42	84.37	6.03	1.10
	9	Flash	10.04	2.13	85.02	5.45	0.45
		Solar	10.26	3.59	83.17	6.10	1.43
	12	Flash	8.01	2.47	86.33	5.95	0.29
		Solar	9.64	4.49	83.04	6.25	1.88
SE			.07	.02	.08	.03	.02
Range			8.00–10.26	1.92–4.49	82.92–86.60	5.15–6.30	0.29–1.88
P of variety (Var)			ns	ns	ns	*	*
P of age			*	*	*	*	*
P of drying method (DM)			*	*	*	*	*
P of Var *Age			ns	*	ns	ns	*
P of Var *DM			ns	ns	ns	ns	*
P of Age *DM			*	ns	ns	ns	*
P of Var *Age *DM			ns	*	ns	*	*

Note: * significant; ns, not significant technique. This observation was similar to the findings of Milena et al. (2013) who reported that drying at higher temperature (≥60 °C), even for a shorter duration, reduces the cyanide content of cassava products by a substantial level. These values are far lower than the World Health Organization (WHO) recommended a maximum acceptable level for cyanide (10 mg/kg) in foods meant for human consumption (FAO, 2007). Thus, the value of residual cyanide in this study creates safety assurance of the high quality cassava flour for further utilization, irrespective of the drying method used.

Conclusion

The two varieties (TMS98/0510 and TMS98/0505) have potential to meet the desired quality for HQCF at 9 months harvest. Drying methods significantly influence the physicochemical properties of flours. The high temperature, short duration (flash drying) method gave a lower retention of moisture and cyanide contents compared with the solar drying method. The solar dryer needs more attention when it is the only option available; the temperature could be raised further in order to reduce the drying time and also to achieve comparable quality attributes with the flash dried product. This will help meet industrial demands both in terms of standards and volume. Industrially, the flash dryer is therefore considered most effective in producing HQCF of desired quality as well as the required volume.

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