

EFFECTS OF DRYING METHODS ON NUTRITIONAL QUALITY OF PRO-VITAMIN A CASSAVA (*MANIHOT ESCULENTA CRANTZ*) FLOURS

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Abstract

High quality cassava flour (un-fermented cassava flour) is currently being used to replace wheat flour in most bakeries, pasta products and some local dishes. Yellow fleshed cassava roots were obtained from International Institute of Tropical Agriculture, Ibadan and processed into flours by employing three different drying methods: flash, cabinet and sun drying. The proximate, pasting, functional, total carotenoid and beta carotene (β -carotene) profiling of the flours were investigated and compared.

The proximate composition of the samples was significantly ($P \leq 0.05$) different from one another, but the pasting properties were not significantly difference ($P \geq 0.05$) except in their peak and breakdown viscosities. The peak viscosity, trough, breakdown viscosity, final viscosity, setback, peak time and pasting temperature values of the samples were in the range of 473–565.75 RVU, 198.67–214.92 RVU, 273.33–366.17 RVU, 277.58–326.33 RVU, 77.58–124.92 RVU, 4.00–4.07 min and 71.7–72.6 °C respectively. The total carotenoids contents revealed that samples were significantly ($P \leq 0.05$) different from one another. Flash and cabinet dried samples were not significantly different from each other in their β -carotene contents.

The drying methods had significant influences on proximate, total carotenoid content and colour of the tested samples but had no significant influences on pasting properties except peak and breakdown viscosities.

Keywords: Yellow fleshed cassava, Pasting properties, Drying methods, Cassava flour, Carotenoids.

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1.0 INTRODUCTION

Efforts have begun in many developing countries to promote the use of composite flours from local crops in many food applications especially in production of convenient foods to promote the utilisation of these local crops. According to Adetuyi *et al.* (2009), the possibility of replacing wheat flour with flour from starchy tubers in foods depends on their chemical and physical properties. For instance, viscosity, gelatinisation and setback value of the flour affect the texture of the final product. In order to be widely accepted by the food industry, cassava flour needs to meet the high quality requirements in terms of physico-chemical characteristics, food safety and cyanogenic glucoside content. However, the success of completely or partially replacing wheat flour with high quality cassava flour (HQCF) in bakery and other applications could be better achieved, if cassava flour is adequately characterised in terms of its physical, chemical and functional properties.

There are many obstacles that can hinder this ideal scenario, among which are the perishability and bulky nature of the crop. To

overcome these limitations, appropriate strategies and technologies for postharvest processing should be adopted. These will provide means of producing shelf-stable products thereby reducing postharvest losses, adding value in all ramifications and reducing the bulk to be marketed thereby saving transportation costs. Furthermore, establishment of a strong relationship between small-scale cassava producers and new cassava products is very essential in promoting cassava utilisations (Dufour *et al.*, 2002). Apart from these aforementioned benefits of processing of cassava roots into flour, it also improves palatability and minimises its cyanide content. Although, more efforts are still required to enhance utilisation of this crop especially in production of fast foods such as snacks. Among these strategies that have been adopted to promote cassava utilisation is the introduction of HQCF processing to local processors, small and medium enterprises and food industries at large (Cardoso *et al.*, 2005). This can be greatly achieved by ensuring HQCF availability at an affordable price to the processors.

Drying is one of the critical unit operations in HQCF processing that requires continuous improvement to improve the yield and quality. According to Moses *et al.* (2014), drying of foods is an essential technique in food industry and offers possibilities of developing ingredients and novel products to consumers. It provides multiple benefits among which are: prolonging product shelf-life, reducing packaging materials thereby saving costs on storage, handling and transportation. This enhances products availability throughout the year and encouraging production of a wide range of products to consumers. The efforts of minimising postharvest losses and the contamination that arise from long duration of drying foods have initiated the need for alternative drying methods. This provides opportunity of choosing the suitable methods from array of drying methods available.

There are different types of drying systems that are widely in use by most processors in most African countries. Among which are open air or sun drying and oven drying. Recent and emerging dryers include flash dryer, rotary dryer, tunnel dryer, solar cabinet dryer and hybrid drying system. Recent efforts from International donors driven projects and government collaborations have resulted in the use of efficient flash drying systems for HQCF with higher industrial drying efficiency (Fomba *et al.*, 2012). These efforts have greatly increased the availability of HQCF to both small and medium scale enterprises and large scale industries at large.

Most of these drying methods utilise heat to remove water from food by evaporation. Moreover, removal of water by heat has been reported to have nutritional effects on foods in various ways. It can either increase or decrease the concentration of some nutrients by making them more or less available (Ladan *et al.*, 1997; Morris *et al.*, 2004., Hassan *et al.*, 2007). Therefore, this study was aimed at investigating the effects of three drying methods: flash, cabinet and sun drying on nutritional quality of HQCF. This will help in determining the suitable drying method for a

particular food based on the nutritional requirement of that food.

2.0 MATERIALS AND METHODS

2.1 Materials

Yellow fleshed cassava roots of variety (070593) of 10 to 12 months after planting were collected from International Institute of Tropical Agriculture (IITA) cassava processing unit, Ibadan.

2.2 Sample Preparation

The cassava roots were processed into HQCF as described by Aniedu and Omodamiro (2012). Freshly harvested cassava roots were peeled, washed, grated, pressed and pulverised. The pulverised mash was divided into three portions. The first portion was sun dried at an average temperature of 34 °C and relative humidity of 80% for 10 h, the second portion was dried in Niji Lukas cabinet dryer at 60 °C for 8 h. while the third portion was flash dried using Niji Lukas cassava flash dryer at 120 °C for 30 sec residence time. Each portion was milled, sieved with 250 µm sieve, cooled, packaged with low density polyethylene bag, labelled and kept on a shelf prior to laboratory analysis.

2.3 Chemical Analyses

i. Proximate composition of cassava flours

The percentage moisture and ash contents of the samples were determined using the method of AOAC (2005). Protein contents were determined by using Kjeltac™ model 2300 protein analyser as described in Foss Analytical Manual, AB. (FOSS, 2003). The digested samples were inserted into the apparatus to give the percentage nitrogen content of the samples. These nitrogen values were then multiplied by 6.25 to obtain protein contents. Fat contents of the samples were determined by using FOSS Soxtec™ extraction unit. This was done by weighing 3 g of the samples into filter papers, plunged into the thimbles and these were inserted into the apparatus. Seventy

millimetres of n-hexane was measured into the previously weighed extraction cups. These extraction cups with the solvents were inserted into the apparatus in such that each thimble entered into an extraction cup to extract the fat in that sample. The apparatus was operated to extract the fat automatically and displayed extraction complete at the end. The extraction cups were removed, dried in the oven, cooled and weighed. The fat contents of the samples were calculated as depicted.

$$\% \text{ Fat} = \frac{[(\text{weight of cup + fat}) - \text{weight of empty cup}]}{\text{weight of sample}} \times 100 \quad (1)$$

The crude fibre contents of the samples were determined using FOSS Fibertec™ 2010 equipment. The equipment was turned on and heated for 30 min to warm it. The reagents were prepared, weights of the empty crucibles were taken, 0.5 g of celite and 1 g of each sample was weighed into labelled crucibles. These crucibles containing samples and celite were inserted into the apparatus and few drops of anti-foaming agent were added. Acid and alkaline hydrolyses were performed automatically one after the other followed by washing and draining off the acids and alkali from the samples with the use of hot water. The crucibles with samples were removed, dried, cooled and weighed. These were ashed, cooled and re-weighed. The crude fibre contents of the samples were then calculated as displayed:

$$\% \text{ Crude fibre} = \frac{(A-B)}{\text{sample weight}} \times 100 \dots (2)$$

Where A= Weight of sample after drying in an oven, B = weight of sample after ashing

The total carbohydrate and total energy were calculated by difference as reported by Kona *et al.*, (2012) and FAO (2003) as depicted respectively.

$$\text{Carbohydrate content} = 100 - (\% \text{Moisture} + \% \text{Ash} + \% \text{Fat} + \% \text{Protein} \dots) (3)$$

$$\text{Total energy} = [(\text{Protein} \times 4) + (\text{Carbohydrate} \times 4) + (\text{Fat} \times 9)] \text{Kcal/g} \dots (4)$$

ii. **Pasting properties:** These were determined as described by AACC (2005) method 61-02-01 using a Rapid Visco Analyser.

iii. **Anti-nutritional factors, pH and titratable acidity of cassava flours**

The method of Onwuka (2005) was adopted for the determination of hydrogen cyanide (HCN). Tannin and phytate were determined as described by Ajayi (2011) and Markkar *et al.* (1993) respectively. The pH and titratable acidity of the samples were determined as described by Eriksson *et al.* (2014).

iv. **Total carotenoid determination:**

These were determined as described by Carvalho *et al.* (2012). Ten grams of each sample was weighed into a mortar and 30 ml of cold acetone was added. This was left for 5 min and a teaspoon of celite was added to aid the extraction. Pestle was used to crush the sample thrice for at least 5 min each time. This was filtered through a Buchner funnel with filter paper and the filtrate was washed with distilled water to remove all the acetone in the extract. This was extracted with 40 ml of petroleum ether (P.E.) using separating funnel. Saturated sodium chloride solution was added to prevent emulsion formation. The lower phase being water was discarded while the upper phase was collected into a 50 ml volumetric flask, making the solution pass through a small funnel containing anhydrous sodium sulfate to remove residual water. The separating funnel was washed with P.E. and the standard flask was made up to 50 ml mark. The absorbance of each sample was taken at 450 nm using Genesys 10S UV-VIS spectrophotometer and the total carotenoid contents of the samples were calculated as follows:

$$\text{Total carotenoid} (\mu \text{g/g}) = \frac{(A \times \text{volume (ml)} \times 10^4)}{(A^{1\%1\text{cm}} \times \text{sample weight (g)})} \quad (5)$$

Where A = absorbance, Volume = total volume of extract (50 ml), $A^{1\% 1\text{ cm}}$ = absorption coefficient of β -carotene in P.E. (2592).

v. **β -carotene profiling:** This was quantified as described by Carvalho *et al.* (2012). Fifteen millimetres of the extract was pipetted into a concentrator tube and concentrated at 40 °C for 25 min. in TurboVap® LV concentration workstation. The concentrate was diluted in 1 ml of dichloroethane and 1 ml of methanol. This was shaken in a vortex mixer and transferred to a 2-ml amber flask of HPLC apparatus. The apparatus was turned on and generated corresponding graph for each sample. The values obtained from the graph were input into the equation to determine total beta carotene and its isomers.

$$\text{Total } \beta\text{-carotene} \left(\frac{\mu\text{g}}{\text{g}}\right) = \frac{A_x * C_s (\mu\text{g/ml}) * V(\text{ml})}{A_s * P(\text{g})} \quad (6)$$

Where A_x = carotenoid peak area, C_s = standard concentration, A_s = standard area, V = total extract volume, and P = sample weight.

vi. The colour attributes of the samples were determined based on Choy (2011). This was done by using ColorTec-PCM colorimeter of model CE 06373. The instrument was calibrated using the white calibration tile supplied by the manufacturer. Three different colour parameters; l^* , a^* and b^* were recorded. The l^* value measures the lightness with higher number being brighter, a^* value measures the balance between redness and greenness whereas b^* value measures the balance between yellowness and bluish colour of the samples which was indicated by positive and negative numbers respectively.

2.4 Functional Properties Determination

i. The bulk and loose densities were determined as described by Onwuka (2005). Ten grams of each sample was weighed into a clean 100 ml graduated measuring

cylinder. The volume of each sample was noted before tapping and the bottom of the cylinder was tapped repeatedly on a padded table until no further reduction in volume was noted. This volume was recorded as the packed volume. The bulk density and loose densities were determined using the general formula below.

$$\text{Bulk density (g/ml)} = \frac{\text{weight of sample}}{\text{volume of sample after tapping}} \times 10 \quad (7)$$

$$\text{Loose density (g/ml)} = \frac{\text{weight of sample}}{\text{volume of sample before tapping}} \times 100 \quad (8)$$

ii. Water absorption and oil absorption capacities were determined according to the method described by Olapade *et al.* (2003) with slight modification. For water absorption or oil absorption capacity, 1.5 g of the flour sample was measured into a weighed centrifuge tube, 10 ml of distilled water or refined oil was added. This was allowed to stand at room temperature for 30 min and centrifuged at 3000 rpm for 20 min. Water or oil absorption capacity was expressed as mass of water or oil bound by the sample.

iii. The dispersibility of the samples was determined as described by Chijioke *et al.* (2016). Ten grams of sample was weighed into 100 ml measuring cylinder and distilled water was added to reach 100 ml mark. The set up was stirred vigorously and allowed to settle for 3 h. The volume of settled particles was noted and subtracted from 100. The difference was recorded as % dispersibility.

2.5 Statistical Analysis

All analyses were carried out in triplicate. Mean and standard deviation were obtained as data were subjected to one-way analysis of variance (ANOVA) using the Statistical Package for Social Sciences (SPSS) version 20. Mean comparison and separation were done using Duncan's New Multiple Range Test (DNMRT) and LSD at ($P < 0.05$).

3.0 RESULTS AND DISCUSSION

The proximate composition of the samples was depicted in Table 1. The moisture, protein, fat, crude fibre, ash and carbohydrate contents of the flours ranged from 9.73-10.83%, 1.51-1.89%, 0.32-0.56%, 0.51-0.70%, 0.99-1.39% and 86.35-87.12%, respectively. Samples were significantly ($P \leq 0.05$) different from one another based on their proximate composition, except cabinet and sun dried samples that were not significantly different from each other in terms of their protein and crude fibre contents. The moisture, ash and carbohydrates contents of the samples fell within the acceptable limit based on SON (2004) of 12% maximum, 3% maximum and 70% minimum, respectively as reported by Sanni *et al.* (2015). It was observed that drying methods had an influence on proximate composition of the samples.

The pasting properties of the samples were shown in Table 2. The samples' peak and breakdown viscosities ranged from 473-565 RVU and 274-363 RVU respectively. Flash dried sample had the highest peak and

breakdown viscosities, while sun dried sample had the lowest. It was revealed that samples' pasting properties were not significantly ($P \geq 0.05$) different from one another except their peak and breakdown viscosities. This suggests that drying methods had an influence on peak and breakdown viscosities of the flour samples. The samples' pasting temperatures fell within the acceptable limit of 75 °C as reported by EAC (2012) for HQCF. This implies that samples will form paste with hot water below boiling temperature which suggests cost saving. Adebowale *et al.* (2005) opined that gelatinisation and pasting properties of flours are very essential in the food industry because they influence the texture, uses and digestibility of starch based foods. For instance, high peak viscosity values of the flour may suggest the suitability of the flour for products requiring high gel strength and elasticity. Sanni *et al.* (2004) defined peak viscosity as the ability of starch to swell freely before their physical breakdown. Hence, this property is of utmost importance in food industry.

Table 1: Proximate composition of cassava flours

Drying methods	Protein (%)	Fat (%)	Ash (%)	Moisture (%)	Crude fibre (%)	Carbohydrate (%)	Total energy (Kcal/g)
Flash	1.89 ^a	0.56 ^a	1.39 ^a	9.73 ^b	0.70±0.03 ^a	86.44±0.01 ^b	358.34±0.34 ^a
Cabinet	1.53 ^b	0.41 ^b	1.16 ^b	9.79 ^b	0.57±0.01 ^b	86.35±0.16 ^b	358.25±0.08 ^a
Sun	1.51 ^b	0.32 ^c	0.99 ^c	10.83 ^a	0.51±0.03 ^b	87.12±0.11 ^a	354.32±0.69 ^b

Mean triplicate determinations.

Mean values having different superscript within column are significantly different ($P < 0.05$)

Table 2: Pasting properties of cassava flours

Drying methods	Peak Viscosity (RVU)	Trough (RVU)	Breakdown (RVU)	Final Viscosity (RVU)	Setback (RVU)	Peak Time (min)	Pasting Temperature °C
Flash	565.00 ^a	201.50 ^b	363.50 ^a	325.00 ^a	101.00 ^a	4.00 ^a	72.00 ^a
Cabinet	533.00 ^b	213.50 ^a	320.00 ^b	326.00 ^a	79.00 ^a	4.00 ^a	72.50 ^a
Sun	473.00 ^c	199.00 ^b	274.00 ^c	326.00 ^a	78.50 ^a	4.00 ^a	73.00 ^a

Mean triplicate determinations.

Mean values having different superscript within column are significantly different ($P < 0.05$).

Table 3: Anti-nutritional factors, pH and titratable acidity of cassava flours

Drying methods	HCN (mg/kg)	Phytate (mg/g)	Tannin (mg/g)	pH	Titratable acidity (%)
Flash	3.00 ^a	1.38 ^a	0.34 ^a	5.92 ^a	0.11 ^a
Cabinet	3.00 ^a	0.84 ^b	0.05 ^b	6.01 ^a	0.11 ^a
Sun	4.00 ^a	0.97 ^b	0.07 ^b	5.72 ^a	0.11 ^a

Mean triplicate determinations, HCN means hydrogen cyanide.

Mean values having different superscript within column are significantly different (P<0.05)

Table 4: Total carotenoid, beta carotene and colour variations of cassava flours

Drying methods	Total carotenoid (µg/g)	Beta carotene (µg/g)	L*	A*	B*
Flash	16.07 ^a	7.57 ^a	80.00 ^b	-1.00 ^a	32.00 ^a
Cabinet	11.90 ^b	7.38 ^a	84.00 ^a	-2.00 ^a	29.50 ^b
Sun	2.23 ^c	6.88 ^b	84.50 ^a	-3.00 ^a	21.00 ^c

Mean triplicate determinations.

Mean values having different superscript within column are significantly different (P<0.05).

Table 5: Functional properties of cassava flours

Drying methods	Bulk density (g/ml)	Loose density (g/ml)	Water absorption capacity (g/g)	Oil absorption capacity (g/g)	Dispersibility (%)
Flash	0.62 ^a	0.34 ^a	3.50 ^a	2.76 ^b	55.00 ^b
Cabinet	0.56 ^{ab}	0.34 ^a	3.00 ^a	3.00 ^a	67.00 ^a
Sun	0.54 ^b	0.35 ^a	3.00 ^a	3.00 ^a	68.00 ^a

Mean triplicate determinations.

Mean values having different superscript within column are significantly different (P<0.05)

The anti-nutritional factors, pH and titratable acidity of the samples were shown in Table 3. The samples' pH and titratable acidity values ranged from 5.72–6.01 and (0.11) respectively. The HCN contents of the samples ranged from 3.00-4.00 mg HCN_{eqv} /kg. There existed no significant difference among the samples in terms of their pH, titratable acidity and HCN contents. The phytate and tannin contents ranged from 0.84-1.38 mg/g and 0.05-0.34 mg/g respectively with flash dried sample having the highest and cabinet dried sample having the lowest. Flash dried sample was significantly (P≤0.05) different from other samples based on their phytate and tannin contents. The samples' pH and titratable acidity fell within the acceptable range characteristic of HQCF based on EAC (2012) of (5.5-7) and

(< 0.25) respectively. Samples HCN fell within a safe level of 10 mg HCN_{eqv} /kg of cassava flour as recommended by the Food and Agriculture Organisation of the United Nations and World Health Organisation, FAO/WHO (2013) and the African Organisation of Standards ARSO (2012). The drying methods had no influence on samples' HCN, pH and titratable acidity but were influenced by samples' phytate, tannin, total carotenoid contents and colour composition of the flours with the exception to a* (reddish) colour. The effect of drying methods on total carotenoid, β-carotene content and colour of the samples were depicted in Table 4 with the total carotenoid and β-carotene contents ranged from 2.23-16.07 µg/g and 6.88-7.57 µg/g respectively. Flash dried sample had the

highest total carotenoid, β -carotene contents and b^* (yellowness) value among the flour samples, while the sun dried sample had the lowest. The b^* value was most prominent in flash dried sample while, the least prominent was observed in sun dried sample. There existed significant ($P \leq 0.05$) differences in terms of samples' total carotenoid contents and b^* values. It was observed that high temperature short time resulted in higher carotenoid retention compared to low temperature longer time. This result was in agreement with the work of Chavez *et al.* (2007). Vimala *et al.* (2011) reported that retention of carotenoids in different processing methods assists in assessing the best technique for obtaining food products of higher nutritional quality.

The functional properties of the flours were shown in Table 5. The bulk and loose densities ranged from 0.54-0.62 g/ml and 0.34-0.35 g/ml respectively. It was observed that sun drying produced the flour with the lowest bulk density, while flash drying on the other hand had the highest bulk density. There existed significant ($P \leq 0.05$) differences among the samples' bulk densities. Water and oil absorption capacities ranged from 3.00-3.50 g/g and 2.76-3.00 g/g, while the dispersibility values ranged from 55-68%. Samples were not significantly different from one another in terms of their loose densities and water absorption capacities. Flash dried sample was significantly ($P \leq 0.05$) different from other samples based on its bulk density, oil absorption capacity and percentage dispersibility. According to Hayata *et al.* (2006), drying decreases the bulk density of flour and gives an indication of the relative volume of packaging material required. It was observed that drying methods had no significant influence on samples' loose density but were greatly influenced by their bulk densities. Agunbiade and Sanni (2003) opined that low bulk density of flour is a desirable physical attribute for saving cost in transportation and storage. Thus, this property is of utmost importance in the industry as it

helps in determining transportation and storage costs.

4.0 CONCLUSION

Drying methods do have a significant influence on nutritional quality of the flours, except on HCN, pH, titratable acidity, reddish colour, loose density and water absorption capacity. The higher temperature short time (flash drying) method resulted in higher retention of total carotenoid, beta carotene contents and yellowish colour while, the lowest retentions were noted in sun drying. The reduction in total carotenoid and beta carotene retention of sun dried sample compared to those of flash and cabinet dried samples suggested a significant detrimental effect of sunlight on the stability of this pigment. Therefore, sun drying method may not be an adequate method in producing cassava flour from yellow fleshed roots. In lieu of this, flash drying is preferred to preserve its quality attributes such as proximate composition, carotenoid content and to achieve maximum yield of the flour due to its high drying efficiency.

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