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Assessment of cyanide content and nutritional composition of odourless fufu flour produced using different processing techniques

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Abstract

The quality of fufu flours has been identified to vary from one location to another and this may be as a result of the technique adopted for processing. This study was carried out to determine the effect of different processing methods on the cyanide content, nutritional composition, pasting and functional properties of odourless fufu flour samples -PMIMD (Processing method involves multi-crop drying procedure) and PMISF (Processing method involves stirred frying procedure) which were fermented before drying or frying and compared with the baseline sample, that was sundried. The results showed that the cyanide content ranged from 0.25 to 0.41 mg/100 g, with PMIMD having the lowest cyanide content of 0.254±0.02 mg/100 g, followed by PMISF 0.41±0.03 mg/100 g, which significantly reduced ($P<0.05$) when compared to the baseline flour. The moisture content ranged from 4.34 to 8.21%, with PMIMD having the lowest moisture content (4.34%), followed by PMISF (7.21%). PMIMD had the highest carbohydrate content. Crude fibre content was 3.12% (PMIMD), 3.34% (PMISF) and 3.38% (Baseline). PMISF had a better pasting temperature (78.15°C), while the final viscosity was highest in PMIMD (3797 cP). From the study, it can be concluded that the processed flours had a reduced cyanide content which therefore makes it safe for consumption, and its level of moisture content would greatly be beneficial for an increased shelf-life. Generally, the processed odourless fufu flours possessed good pasting and functional properties

1. Introduction

Cassava root tubers (*Manihot esculentus Crantz*) are mainly grown in the continents of Asia, South America and Africa with Nigeria as the world's largest producer (Forsythe *et al.,* 2016). The starch-rich root is a major staple and serves as a major source of carbohydrate and energy for most people in sub-Saharan Africa (Ferraro *et al.,* 2015; Sánchez *et al.,* 2017). According to Carvalho *et al.* (2018), there is a rising interest in the utilization of cassava towards improved storage and nutritional values.

The edible portion of the root (parenchyma) constitutes an average of 85% of the total weight (Franca and Chinyere, 2017). Cassava comprises a considerable amount of vitamin C (25 mg/100 g), phosphorous (40 mg/100 g), and calcium (50 mg/100 g) (Katz and Weaver, 2003), while the concentration of proteins, riboflavin, thiamin and niacin in cassava is very low making it one of highest sources of carbohydrates among tuber crops (Morgan and Choct, 2017). The carbohydrate content of cassava ranges from 64 – 72% starch (amylose and amylopectin) which is structurally different from that found in cereal, in its branch chain length distribution, amylose content and its granular structure. Approximately 17% of sucrose is also found predominantly in the sweet varieties and small quantities of fructose and dextrose have also been reported. The protein content is determined as between 1 – 2%, with low essential amino acid profiles; particularly methionine, tryptophan and lysine, whilst conversely possessing a high dietary fibre content (3.40 – 3.78% soluble, and 4.92 – 5.6% insoluble) (Abass *et al.,* 2018). The roots are highly perishable due to their high moisture content at harvest. Besides the advantage of preserving the root, the processing is also used to add value to the raw roots by converting them to several primary and secondary products of varying economic importance and to increase food safety, thereby reducing

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its level of cyanogenic compounds (Shittu *et al.,* 2016).

Cyanide occurs in cassava in the form of two cyanogenic glycosides: linamarin and lotaustralin. These two compounds release hydrogen cyanide (HCN). Cyanogenic glycosides are present in all parts of the plant, and they act as chemical defences and as a deterrent against pathogenic organisms and the activities of herbivores. Cassava toxicity in humans is a well-documented problem. Cassava tubers vary widely in their cyanogen content, although most varieties contain 15 to 400 mg HCN per kg fresh weight (Cressey and Reeve*,* 2019). The level of toxicity in humans is a well-documented problem. Cyanide doses of 50 to 100 mg are reportedly lethal to adults (Heuberger, 2005). Several diseases are associated with the consumption of inadequately processed cassava roots, such as tropical ataxic neuropathy, endemic goitre and spastic paraparesis, which is mainly a disease of women and children. It is an acute disease, rapidly and permanently crippling the victim by damaging nerve tracts in the spinal cord that transmit signals for movement, causing a spastic paralysis of both legs (Heuberger, 2005).

The different techniques of processing cassava roots aim to reduce the levels of cyanogenic compounds in order to obtain a safe food, thereby reducing toxicity. The traditional methods usually include chipping, soaking, fermentation, cooking, steaming, drying and roasting. These methods permit the enzyme linamarase to interact with the cyanogenic compounds to release HCN. The HCN then either dissolves in water or escapes into the air. However, it is often impossible to remove all the cyanogenic compounds through conventional processing (Heuberger, 2005).

Cassava is usually consumed in processed forms - fufu, gari, lafun amongst others (Ihekoronye, 2009; IITA 2012). In Nigeria, fufu is a fermented white paste made from cassava and it is ranked next to gari as an indigenous food in the South West and South East. Fufu is prepared traditionally mostly in Southern Nigeria by women at the village level, working individually or prearranged into informal groups or cooperatives, with their fufu products usually in wet form with an offensive odour and perishable with a short shelf life (Nweke and Enete, 2004; Owolarafe *et al.,* 2018; Ume *et al.,* 2020). According to Nweke and Enete (2004), a large number of consumers de-taste the offensive characteristic odour of fufu, hence reducing considerably its acceptability. Therefore, for fufu to have wide acceptability, it is important to adopt relevant processing methods that would reduce the level of cyanogenic compounds and improve their sensorial properties. Hence, this work is aimed at assessing the cyanide content and nutritional composition of odourless fufu flour produced using different processing techniques.

2. Materials and methods

2.1 Materials

Freshly harvested cassava roots used in this study were procured from the international institute of Tropical Agricultural, Nigeria with a batch number 1WDC2SYN. All chemicals used for analysis were of analytical grade.

2.2 Sample preparation

Cassava roots were sorted, cleaned, peeled and washed in running portable water to remove extraneous materials, sliced into pieces before further processing into flours. Odourless fufu flours preparation was carried out according to the procedure of Nkoudou and Essia (2017) modified. The sliced cassava was sundried for 72hours and ground served as the control (baseline flour). The initial soaking and part-fermentation for the odourless flour samples PMIMD (Processing Method involves multi-crop drying procedure) and PMISF (Processing method involves stirred frying procedure) was for 48 hours, before pulping and final fermentation for 24hours. After which, the odourless samples PMIMD and PMISF were dried using the multi-crop dryer and stirred frying method respectively before being converted to flour.

2.3 Determination of cyanide content

A weight of 100 g samples of cassava products was added to a small plastic bottle, a buffer/enzyme paper was added, followed by 1 L of 1M pH 6 phosphate buffer, a picrate paper and a screw cap lid. The bottles were allowed to stand overnight at 30°C, the picrate papers were removed from the plastic support and 5.0 L of water was added to elute the colour. The absorbance was measured in a spectrophotometer at 510 nm and the total cyanide content in mg HCN equivalents/100 g fresh weight was evaluated and values were reported in triplicate.

2.4 Determination of proximate composition

The proximate composition of the samples includes the moisture, crude protein, crude fat, crude fibre, ash and carbohydrate contents, which were determined according to the standard analytical method by the Association of Official Analytical Chemists (AOAC 2005).

2.5 Determination of vitamin C

The concentration of vitamin C was determined by redox titration using standardized iodine solution, according to a slightly modified method described by

Patel, (2017). Vitamin C in the sample reacts with iodine to produce dehydroascorbic acid and iodide ions. Excess iodine then reacts with the starch indicator to produce a violet colour and indicate the endpoint of the titration.

Ascorbic acid $C_6H_8O_6$ + I_2 → Dehydroascorbic acid ($C_6H_8O_6$) + $2I^-$

2.6 Determination of total carotenoids

Total carotenoid (TC) content using the spectrophotometer 5 mg of the sample was ground with the aid of hyflosupercel (3.0 g) in 50mL of cold acetone and vacuum filtered. The filtrate was extracted using 40 mL petroleum ether (PE). Saturated sodium chloride was used to prevent the formation of an emulsion. The lower aqueous phase was discarded while the upper phase was collected and filtered through 15 g of anhydrous sodium sulfate to eliminate residual water. The separating funnel was washed with PE and the flask was made up to 50 mL. The absorbance of the solution was measured at 450 nm and the total carotenoid content was calculated using the Beet-Lambert law (Equation 1).

$$TC\ (\mu g/g) = \frac{A \times V\ (mL) \times 104}{A^{1\%}\ 1\ cm \times P\ (g)} \quad (1)$$

Where A = is the absorbance, V = Total extract volume after second extraction, P = Sample weight, $A^{1\%}$1 cm = 2592 (beta carotene extinction coefficient in petroleum ether).

2.7 Determination of pasting properties

The pasting properties of odourless fufu flour were examined using a Rapid Visco-Analyzer (Newport Scientific, Australia) as previously reported (Oyeyinka *et al.,* 2020). Briefly, samples (2.8 g) were weighed into the test canister containing 25 mL of distilled water. The mixture was agitated by mixing manually before inserting the canister into the instrument. Starch was stirred at 960 rpm for 10 s before the shear input was decreased and held constant at 160rpm during the subsequent heating and cooling cycles.

2.8 Determination of functional properties

The bulk density of the sample was determined using the method described by Akpapunarn *et al.* (1981). The water absorption capacity of the sample was determined using the method described by Bencham (1977). The water absorption capacity was expressed as the volume of water absorbed per gram of flour. The solubility index of the flour blend was determined using the method described by Singh *et al.* (2005). Dispersibility was determined by the method described by Kulkarni *et al.* (1991). Swelling power was determined using the method described by Oyeyinka *et al.* (2015) with slight modifications.

2.9 Statistical analysis

Analyses were carried out in triplicates and the data obtained were subjected to one-way analysis of variance (ANOVA), using Statistical Package for Social Sciences (SPSS version 20.0 Inc.). Values were represented as mean±standard deviation (SD), statistical differences among means were (P<0.05).

3. Results

3.1 Effect of different processing methods on the cyanide content of odourless fufu flours

The results of the effect of different processing methods on the cyanide content of the fufu flour samples presented in Figure 1 shows that the cyanide content ranged from 0.25 to 0.41 mg/100 g, with PMIMD having the lowest cyanide content of 0.254±0.02 mg/100 g, followed by PMISF 0.41±0.03 mg/100 g, which significantly reduced (P<0.05) when compared to the baseline flour having the highest cyanide concentration (1.34±0.12 mg/100 g).

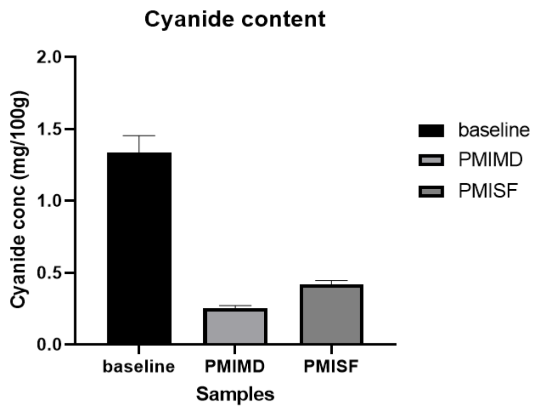

Figure 1. Effect of a different processing procedure on the cyanogenic compound of odourless fufu produced from cassava

3.2 Effect of different processing methods on the proximate composition of odourless fufu flours

The results of the effect of different processing methods on the proximate composition of the fufu flour samples presented in Table 1 shows that the moisture content ranged from 4.34 to 8.21%, with PMIMD having the lowest moisture content (4.34%), followed by PMISF (7.21%) and Baseline (8.21%). However, the moisture content of PMIMD was significantly lower than that of the Baseline sample (P<0.05).

3.3 Effect of different processing methods on the vitamin C and total carotenoid content of odourless fufu flours

The vitamin C and total carotenoid content of the samples are presented in Figure 2. The results thus

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Table 1. Effect of different processing methods on the proximate composition of odourless fufu flour

Processing Methods	Moisture (%)	Lipids (%)	Ash (%)	Fibre (%)	Protein (%)	Carbohydrates (%)
Baseline	8.21±1.32[a]	1.59±0.11[a]	3.34±0.13[a]	3.38±0.19[a]	2.11±0.09[a]	81.37±3.15[a]
PMIMD	4.34±1.32[b]	2.71±0.12[b]	3.10±0.12[a]	3.12±0.21[a]	2.22±0.07[a]	84.51±4.12[a]
PMISF	7.21±1.32[a]	1.33±0.02[a]	2.14±0.11[b]	3.34±0.26[a]	1.87±1.32[a]	84.11±3.23[a]

Values presented are mean±SD, n = 3. Values with different superscript within the same column are significantly different (P<0.05). Baseline: Fresh cassava grated, dried and homogenized, PMIMD: Processing Method involves multi-crop drying procedure, and PMISF: Processing method involves stirred frying procedure.

revealed that samples PMISF, PMIMD and baseline had 0.32, 0.47 and 0.52 mg/100 g vitamin C content respectively. It was observed that the PMIMD sample had significantly high vitamin C content when compared to PMISF. However, the total carotenoid content was 0.020, 0.021 and 0.023 mg/100 g for PMISF, PMIMD and the baseline samples respectively.

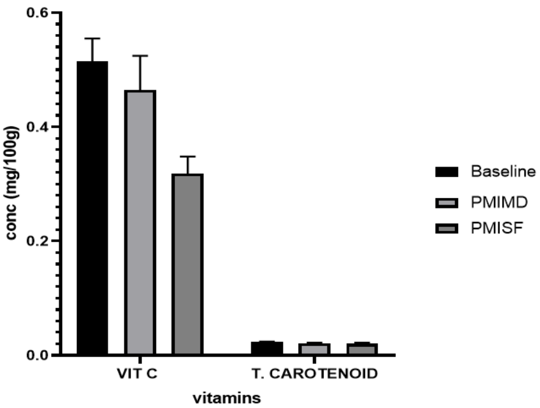

Figure 2. Effect of different processing methods on the Vitamin C and Total carotenoid concentrations of odourless fufu produced from cassava.

3.4 Effect of different processing methods on the pasting properties of odourless fufu flours

Table 2 summarizes the results of the effect of different processing methods on the pasting properties of the odourless fufu flour. The pasting temperature of the flours- PMISF (78.15°C) was highest when compared to the other samples. PMIMD (71.85°C) and the baseline flour (71.21°C) indicate a weak granular structure, unlike PMISF. The pasting temperature indicates the minimum temperature required to cook or gelatinize the flour. The peak viscosity, breakdown viscosity, set back and peak time of PMISF was significantly different from the baseline flour sample.

3.5 Effect of different processing methods on the functional properties of odourless fufu flours

The results of the effect of different processing methods on the functional properties of odourless fufu flours revealed that for starch solubility index, PMIMD (8.50%) was significantly high (P<0.05) when compared to the baseline sample. The dispersibility decreased in fermented flours when compared to the baseline flour. The PMIMD had a significantly low (P<0.05) loose bulk density (0.39 g/cm^3), a similar trend was observed for the water absorption index, with PMIMD having a low value of 217.96 (%) when compared to the baseline sample. However, PMIMD had the lowest packed bulk density (0.49 g/cm^3).

4. Discussion

The various laboratory analyses were carried out to determine the changes in the cyanide content, nutritional composition, pasting and functional properties of the odourless fufu flours processed and dried using multi-crop drying (PMIMD), and stirred frying methods (PMISF). The results obtained were compared against a baseline fufu flour sample. The result in Figure 1 thus revealed that the concentration of cyanide in the processed flours reduced by 60% as a result of the adopted method of processing, as the most cyanide reduction was observed in the fermented flours. Kobawila *et al.* (2005) reported a high percentage of cyanide reduction in fermented cassava roots. A major hindrance to the utilization of cassava is the cyanogenic potential of the roots and its toxicity. Since chronic exposure to cyanide causes a variety of illnesses such as neurological, cardiac and metabolic dysfunction which can be fatal (Nath *et al.,* 2013), there is a concern regarding the levels of residual cyanide remaining in cassava after processing. According to Eleazu and

Table 2. Effect of different processing methods on the pasting properties of odourless fufu flour

Sample	Peak viscosity (cP)	Trough (cP)	Breakdown (cP)	Final viscosity (cP)	Setback (cP)	Peak Time (mins)	Pasting Temp (°C)
Baseline	6671±21[a]	2807±10[a]	2665±57[a]	3675±88[a]	1020±76[a]	5.80±0.2[a]	71.21±8[a]
PMIMD	5389±32[b]	2817±17[a]	2582±87[a]	3797±76[a]	990±65[a]	5.07±0.9[a]	71.85±6[a]
PMISF	2778±16[c]	1924±11[b]	854±12[b]	2620±53[b]	696±32[b]	5.53±0.7[a]	78.15±7[a]

Values presented are mean±SD, n = 3. Values with different superscript within the same column are significantly different (P<0.05). Baseline: Fresh cassava grated, dried and homogenized, PMIMD: Processing Method involves multi-crop drying procedure, and PMISF: Processing method involves stirred frying procedure.

Eleazu (2012) and FAO (2019), cassava roots are classified according to their potential toxicity to humans as non-toxic (less than 50-100 mg HCN/kg in fresh root), moderately toxic (50-100 mg HCN/kg in fresh root) and highly toxic (above 100 mg HCN/kg in fresh root). The low levels of cyanide in the processed flours (PMIMD and PMISF), when compared to the baseline flour sample, was a result of the processing method which involved pulping, fermentation, dewatering and subsequent drying using the multi-crop dryer or stir-frying. Since the levels of cyanide obtained in this study are below 10 mg/kg it, therefore, suggests that the produced flours are safe for consumption and may not be toxic. From the results obtained in Table 1, the processing of the cassava roots to flour allows for a sufficient loss of moisture by means of the drying process and according to Udoro *et al.* (2020), the low moisture content of cassava flours confers a high level of resistance to microbial infestation, which is an obvious benefit for extended shelf life during storage.

Furthermore, crude fibre was 3.12% (PMIMD), 3.34% (PMISF) and 3.38% (Baseline). Although, there was no significant difference across the group. This result, therefore, agrees with the findings of Afoakwa *et al.* (2012) and it corroborates the recommendations of Gil and Buitrago (2002) that the fibre content in cassava should not be more than 4%. It is worthy of note that the consumption of an adequate amount of dietary fibre reduces the risk of diseases such as constipation, obesity, coronary heart diseases, colon cancer and other related diseases (Dahl and Stewart, 2015).

The values of carbohydrates ranged between 81.37-84.51%, with PMIMD having the highest carbohydrate content. The high starch content makes them suitable for starch production and the values reported in this study are within the range of values reported by Alamu *et al.* (2017). In Figure 2, It was observed that the PMIMD sample had significantly high vitamin C content when compared to PMISF. However, the total carotenoid content was 0.020, 0.021 and 0.023 mg/100 g for PMISF, PMIMD and the baseline samples respectively. Biochemically, vitamins have been identified to play the role of antioxidants thus helping to combat free radicals and foods from plant sources have been identified to be good sources of vitamins. Eleazu and Eleazu (2012) reported that carotenoids are the colourful plant pigments, some of which the body can convert to vitamin A, are also powerful antioxidants that have been suggested to contribute to the resistance against certain forms of cancer and heart diseases, and also enhances the immune response to infections. These relatively low values obtained in the flour samples after processing could be attributed to the exposure to light and heat treatment (Montagnac *et al.,* 2009). Table 2 summarizes the results of the effect of different processing methods on the pasting properties of the odourless fufu flour. The pasting temperature of the flours- PMISF (78.15°C) was highest when compared to the other samples. PMIMD (71.85°C) and the baseline flour (71.21°C) indicate a weak granular structure, unlike PMISF. The pasting temperature indicates the minimum temperature required to cook or gelatinize the flour. Ezeocha and Okafor (2016) previously reported that starches for tubers are within the range of 60 – 80°C.

The peak viscosity, breakdown viscosity, set back and the peak time of PMISF was significantly different from the baseline flour sample. This indicates that a major modification occurred in the starch granules of the sample as a result of fermentation. A variety of other factors such as the chain length distribution of the amylopectin chain and amylase content may influence the peak viscosity of the flours. The final viscosity which was highest in PMIMD (3797cP) gives an idea of the ability of the flour to gel after cooking. However, the breakdown viscosity measures the susceptibility of the starch granule to disintegrate during heating and this may affect the stability of the flour (Oyeyinka *et al.,* 2019) and is regarded as a measure of paste stability (Maziya-Dixon *et al.,* 2004). The functional properties in Table 3 showed that the PMIMD had a significantly low ($P<0.05$) loose bulk density (0.39 g/cm^3), a similar trend was observed for the water absorption index, with PMIMD having a low value of 217.96% when compared to the baseline sample. However, PMIMD had the lowest packed bulk density (0.49 g/cm^3). Research has shown that the bulk density is important for determining packaging requirements and material handling in the food industry (Ocloo *et al.,* 2010) and according to Oluwalana *et al.* (2011), flours with low bulk density

Table 3. Effect of different processing methods on the functional properties of odourless fufu flour

Parameters	Loose Bulk Density (g/cm^3)	Packed Bulk Density (g/cm^3)	Water Absorption Index (%)	Dispersibility (%)	Swelling Power (%)	Starch Solubility Index (%)
Baseline	0.49±0.08^a	0.51±0.10^a	220.4±4.62	87.12±3.15^a	11.80±1.42^a	4.02±0.19^a
PMIMD	0.39±0.01^b	0.49±0.08^a	217.96±4.72	69.00±1.41^b	4.31±0.22^b	8.50±0.49^b
PMISF	0.50±0.01^a	0.50±0.05^a	283.0±5.12	56.00±2.12^c	6.50±0.21^c	5.23±0.1^c

Values presented are mean±SD, n = 3. Values with different superscript within the same column are significantly different ($P<0.05$). Baseline: Fresh cassava grated, dried and homogenized, PMIMD: Processing Method involves multi-crop drying procedure, and PMISF: Processing method involves stirred frying procedure.

will be an advantage in bulk storage and transportation of the flour.

5. Conclusion

With increasing awareness of the toxicity of cyanide in cassava and given that cassava is mainly consumed as a staple, it is important that methods of processing be improved and put into cognizance of its micro and macronutrient. It can therefore be concluded that odourless fufu flour obtained through NSPRI multicrop-drying methods had significantly low levels of cyanide, low moisture content, nutrient retention and improved pasting properties when compared to flour obtained via stir-frying methods. Thus, it is recommended that NSPRI multi-crop dryer should be employed as a means of drying in odourless fufu flour production.

Conflict of interest

The authors declare no conflict of interest.

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