Agr. Foo. Nat. Res. J. Volume 3, Issue 2, Page 289 - 295

e-ISSN: 1597-7153 | p-ISSN: 3043-5420

Agriculture, Food and Natural Resources Journal

The Official Journal of the Faculty of Agriculture, Nnamdi Azikiwe University, Awka, Nigeria

Journal homepage: https://journals.unizik.edu.ng/afnrj

Original Article

Effect of processing techniques on the quality and cyanogenic glycoside content of fermented cassava flours

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DOI: https://www.doi.org/10.5281/zenodo.14252964

Editor: *Dr Onyekachi Chukwu, Nnamdi Azikiwe University, NIGERIA*

Received: *May 31, 2024*
Accepted: *August 27, 2024*
Available online: *September 30, 2024*

Peer-review: *Externally peer-reviewed*

Conflict of Interest: The authors have no conflicts of interest to declare

Financial Disclosure: *The authors declared that this study has received no financial support*

ABSTRACT

Cassava root (*Manihot esculenta* Crantz) is highly perishable and contains toxic compounds, necessitating processing and preservation to ensure safe consumption and the production of shelf-stable, value-added products. This study evaluated the effect of various processing techniques on the quality of fermented cassava flour (known as *lafun* in South-Western Nigeria). Cassava roots (TME 419) were processed using grated solid-state fermentation (GSSF), sliced-soaked fermentation (SSMF), and parboiled-soaked fermentation (PSMF), with products dried in a parabolic solar dryer. Flour quality was assessed based on proximate composition, cyanide content, functional properties, and pasting properties. Moisture content ranged from 11.17% - 12.86%, with the lowest in PSMF. Crude fat, protein, crude fibre, and carbohydrate contents varied from 1.17% - 2.65%, 6.16% - 7.42%, 0.41% - 0.55%, and 69.92% - 74.85%, respectively. Cyanide concentrations ranged from 1.720 - 1.780 mg/kg, indicating a 92.11% - 92.37% reduction from fresh cassava roots (22.55 mg HCN/kg). Water and oil absorption capacities ranged from 212.57% - 246.93% and 59.96% - 65.17%, respectively, with PSMF significantly higher. PSMF exhibited the highest swelling power (225.07%) and lowest water solubility (39.46%), along with the highest filling weight (0.785 g/cm³). Pasting temperature and peak time ranged from 75.48°C - 93.58°C and 4.53 - 6.97 min, with PSMF having the highest values. These results suggest that PSMF is the most effective method for producing high-quality fermented cassava flour.

KEYWORDS: *Cassava root, Cyanide, Fermentation, Functional properties, Proximate composition*

INTRODUCTION

Cassava (*Manihot esculenta* C.) holds significant importance in human and animal nutrition, earning its place among staple foods, especially in Africa, Latin America, and parts of Asia (Campos *et al.,* 2017). Many countries in these regions produce cassava in large quantities to meet the caloric needs of humans and livestock (Parmar *et al.*, 2017). It is a rich source of carbohydrates and essential minerals such as iron, calcium, potassium, copper, magnesium, manganese, and zinc. The edible portion of fresh cassava root consists of

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32–35% carbohydrates, 75–80% moisture, 2–3% protein, and minimal crude fibre, fat, and ash content (1.1%, 0.2% and 0.9%, respectively) (Edhirej *et al.,* 2017). Due to its high moisture content, the perishability of cassava makes it challenging to maintain product quality for more than two to three days, necessitating the conversion of fresh cassava into value-added products through appropriate processing techniques.

Cassava can be processed into various value-added products to reduce postharvest losses and improve the availability of cassava-based foods. Methods such as fermentation, drying, frying, grating, and cooking are commonly used, either individually or in combination, to achieve this. Processing is essential for reducing toxic compounds/antinutrients like cyanide phytates and oxalates, which otherwise can lead to acute food poisoning if not removed effectively. Techniques such as fermentation not only enhance food safety but also improve nutritional quality by biosynthesizing proteins, vitamins, and essential amino acids, boosting micronutrient bioavailability and improving digestibility (Samtiya *et al.,* 2021). Moreover, fermentation enhances fibre digestibility and breaks down anti-nutrients. The quality of cassava roots is crucial, especially regarding cyanide content, which should remain below 250 µg/g to meet the WHO's safety standards (Abass *et al.,* 2019). Processing technologies tailored to local resources and cassava varieties help ensure safety and meet nutritional needs (Falade & Akingbala, 2010).

Cassava fermentation can be achieved through two primary methods: submerged fermentation and solid-state fermentation. Solid-state fermentation involves grating or slicing cassava roots, which are then allowed to ferment in the open air or packaged in bags, producing products like *garri* (fried cassava grits) and *lafun* (fermented cassava flour). In contrast, submerged fermentation entails soaking whole peeled, cut, or unpeeled cassava roots in water for a period of three to five days, depending on environmental conditions such as temperature and humidity (Oyewole *et al.,* 2023; Ajao *et al.,* 2023). Studies have shown that fermentation significantly reduces the cyanogenic content of cassava, with percentage reductions reported as 35%, 41%, 50%, and 80%, (Udoro *et al.,* 2021; Panghal *et al.,* 2021; Jumare *et al.,* 2024).

The varying qualities of fermented cassava products, which differ among processors and processing batches, pose a challenge to commercializing these processes (Abass *et al.,* 2022). Key factors contributing to these variations include the processing methods used, the variety and age of cassava roots, environmental conditions, and the quality of water (Uchechukwu-Agua *et al.,* 2015). To mitigate toxicity, some processors have adopted parboiling as a pre-treatment before submerged fermentation, while others have switched to grating before solid-state fermentation. Additionally, some processors have embraced slicing before submerged fermentation to reduce cassava product toxicity. Providing relevant information on these techniques is essential for developing sustainable processing methods that yield improved, high-quality *lafun*, ensuring it is safe for human consumption.

MATERIALS AND METHODS

Procurement of Cassava Roots

Cassava roots used for this work are the variety developed by the International Institute of Tropical Agriculture (IITA), namely TME 419 cassava. They were obtained at 12 months old from the farm of the Stop Hunger Women group, Akinyele area, Ibadan, Oyo state, Nigeria. All the chemicals and equipment used where of analytical grade.

Preparation of Fermented Cassava Flour

The harvested cassava roots were manually sorted to separate wholesome roots from unwholesome ones. The selected wholesome roots were manually peeled, washed, and the roots were divided into three equal parts using a digital weighing balance, with each part processed into cassava flour using different methods. The first part was manually grated in a polypropylene sack and allowed to undergo solid-state fermentation for 24 hours on a concrete platform. The second part was sliced into 4-5 cm pieces and soaked in water at a ratio of 1:5 (one part cassava to five parts water, weight: weight) for 72 hours. Following fermentation, it was dewatered in a polypropylene sack using a hydraulic press for 6 hours before drying. The third part underwent heat treatment by parboiling the whole roots at 70°C for 20 minutes, according to Ogbonnaya *et al.* (2018). After cooling, it was sliced and soaked in water at the same ratio for 72 hours, followed by dewatering for 6 hours. The cassava mash samples were then crumbled and dried in the NSPRI parabolic-shaped solar dryer for 72 hours at an average temperature of 33±3°C.

Determination of Proximate Composition

Proximate composition was determined using AOAC (2000) methods for protein, fat, ash, moisture, and crude fibre determination. Carbohydrate was obtained by difference.

Determination of Cyanide Content

The hydrocyanic acid (HCN) content in raw cassava mash and flour samples from the three processing techniques was determined using the AOAC method (2019).

Determination of Functional Properties

Bulk and loose densities were determined using the modified method of Danbaba *et al.* (2014). Water solubility index and swelling capacity were determined by the Yousf *et al.* (2017) method while the procedure of Umoh & Iwe (2023) was used to compute water absorption capacity and oil absorption capacity. Dispersibility was determined using the method described by Kulkarni *et al.* (1991). The pH of the cassava flour was determined using a pH meter based on the method described by Atlaw (2018).

Determination of Pasting Properties

The pasting properties of the flour were characterized by using a rapid visco-analyzer (RVA) as described by Yuan *et al.* (2021) for peak viscosity, breakdown viscosity, setback, pasting temperature, and final viscosity.

Statistical Analysis

All determinations were made in triplicate and the data generated were subjected to a one-way analysis of variance at a 5% level of significance using SPSS to establish differences among the variables under study.

RESULTS AND DISCUSSION

Proximate Composition of Fermented Cassava Flours

The proximate compositions of the three samples are presented in Table 1. The initial moisture content of the fresh cassava root was 75.7%. After drying, the final moisture content of the flour samples ranged was 11.17% - 12.86%, showing significant differences ($p<0.05$) attributed to the various processing techniques employed. The Grated Solid-State Fermented (GSSF) flour had the highest ash content at 8.45%, significantly ($p<0.05$) more than Sliced-Soaked Fermented (SSMF) at 5.14% and Parboiled-Soaked Fermented (PSMF) at 5.81%. This difference could be attributed to mineral leaching during soaking, which reduced the ash content in SSMF and PSMF. These values are higher than those reported by Adebayo-Oyetoro *et al.* (2017), possibly due to differences in processing methods or cassava varieties. In terms of crude fat, SSMF had the highest content (2.65%), aligning with findings from Adamafio *et al.* (2020), who linked fermentation to fat metabolism. The GSSF sample had the highest protein content at 7.42%, supporting Akusu *et al.* (2023), who found that fermentation time influences protein retention. Carbohydrate content varied, with PSMF at 74.85%, reflecting efficient starch degradation during fermentation, indicating better starch conversion in the PSMF process.

Table 1: Proximate composition of fermented cassava flour produced from three different processing techniques

Samples code	Moisture Content (%)	Ash (%)	Crude fat (%)	Crude fibre (%)	Protein (%)	Carbohydrate (%)
GSSF	$12.19^b±0.04$	$8.45^a±0.08$	$1.61^b±0.14$	$0.41^c±0.01$	$7.42^a±0.09$	$69.92^c±0.18$
SSMF	$12.86^a±0.16$	$5.14^c±0.33$	$2.65^a± 0.13$	$0.55^a±0.03$	$6.16^b±0.31$	$72.64^b±0.01$
PSMF	$11.17^c±0.18$	$5.81^b±0.06$	$1.17^c±0.18$	$0.45^b±0.01$	$6.55^b±0.20$	$74.85^a±0.61$

**Values are mean±standard deviation of triplicate determinations. Values with different alphabets are significantly different at (p<0.05). GSSF: Grated fermented cassava flour, SSMF: Sliced-soaked fermented cassava flour, PSMF: Parboiled-soaked fermented cassava flour*

Cyanide Concentration in the Cassava Flours

The cyanide concentrations ranged from 1.72mg/kg to 1.780 mg/kg, significantly ($p<0.05$) lower than the safe level of 10 mg/kg recommended by the Codex Alimentarius (FAO/WHO, 2008; EFSA, 2019). The three fermentation techniques reduced the cyanide concentration from 22.55mg HCN/kg in fresh cassava to below permissible levels, achieving a reduction from 92.1% - 92.37%. This indicated that the processing methods have the potential to effectively reduce the cyanide levels in fresh cassava when properly implemented.

Table 2: Cyanide concentration of fresh cassava and fermented cassava flours produced from three different processing techniques

Samples	Fresh cassava root	GSSF	PSMF	SSMF
Cyanide Concentration (mg/kg)	$22.55^a±0.02$	$1.722^b±0.034$	$1.720^b±0.006$	$1.780^b±0.039$
%cyanide reduction	-	$92.36^a±0.16$	$92.37^a±0.03$	$92.11^a±0.17$

**Values are mean±standard deviation of triplicate determinations. Values with different alphabets are significantly different at (p<0.05). GSSF: Grated fermented cassava flour, SSMF: Sliced-soaked cassava flour, PSMF: Parboiled-soaked fermented cassava flour fermented*

Functional Properties of Fermented Cassava Flours

The functional properties obtained for the flour samples are presented in Table 3. The water absorption capacity (WAC) of cassava flour samples ranged from 212.5% - 246.9%, with PSMF showing the highest capacity. This increased WAC is attributed to the heat treatment before fermentation, enhancing softening and digestibility but also raising water activity, potentially leading to spoilage (Sharma *et al.*, 2020). Understanding WAC is crucial for food applications, influencing texture and quality in baked goods while highlighting the importance of optimizing processing methods for improved flour properties.

The oil absorption capacity (OAC) of the cassava flour samples varied significantly ($p<0.05$), ranging from 59.9% - 65.17%. PSMF had the highest OAC (65.17%), attributed to its heat treatment. High OAC is beneficial for lipid-based products, enhancing flavour retention and absorption of fat-soluble vitamins (Aidoo *et al.*, 2022). The swelling capacity ranged from 113.88 - 225.07%, with PSMF showing the highest swelling power (225.07%) and the lowest solubility (39.46%), consistent with Oladunmoye *et al.* (2014), who noted an inverse relationship between swelling power and solubility. Loose bulk density ranged from 0.593g/cm³ - 0.625g/cm³, while packed bulk density ranged from 0.687g/cm³ - 0.785g/cm³. PSMF had the highest packed bulk density, indicating a higher filling weight, which is beneficial for packaging and raw material handling in the food industry (Offiah *et al.*, 2018). The pH values ranged from 4.81 - 6.52, consistent with Daramola & Aina (2007), serving as an indicator of flour quality

Table 3: Functional properties of fermented cassava flours produced from three different processing techniques

Samples	Water Absorption Capacity (%)	Oil Absorption capacity (%)	Dispersibility (%)	Swelling Capacity (%)	Water Solubility Index (%)	Packed Density (g/cm³)	Loosed density (g/cm³)	pH
GSSF	212.57^{c}± 2.40	59.96^{b}± 0.40	51.60^{b}± 1.51	113.88^{c}± 0.77	95.07^{a}± 0.33	0.775^{b}± 0.002	0.625^{a}± 0.015	6.52^{a}± 0.11
SSMF	220.03^{b}± 1.90	60.35^{b}± 0.80	71.17^{a}± 1.26	214.75^{b}± 0.22	43.44^{b}± 1.02	0.687^{c}± 0.003	0.593^{b}± 0.005	5.80^{b}± 0.05
PSMF	246.93^{a}± 5.97	65.17^{a}± 1.03	42.25^{c}± 2.25	225.07^{a}± 0.70	39.46^{c}± 2.16	0.785^{a}± 0.005	0.624^{a}± 0.006	4.81^{c}± 0.07

**Values are mean±standard deviation of triplicate determinations. Values with different alphabets are significantly different at (p<0.05). GSSF: Grated fermented cassava flour, SSMF: Sliced-soaked cassava flour, PSMF: Parboiled-soaked fermented cassava flour fermented*

Pasting Properties of Fermented Cassava Flours

The pasting temperature of the *lafun* samples varied from 75.48°C - 93.58°C, with the highest in PSMF, while GSSF and SSMF had similar lower pasting temperatures, indicating faster cooking and reduced energy costs (Sanni & Jaji, 2003). The peak time for the samples ranged from 4.53 minutes to 6.97 minutes, significantly lower than the times for dried *fufu* and *pupuru*, suggesting efficient processing. SSMF exhibited the highest peak viscosity (4926 RVU), while PSMF had the lowest (570 RVU). Peak viscosity, essential for product quality, is influenced by swelling capacity and solubility, with higher swelling leading to greater viscosity (Oyeyinka *et al.*, 2020). The breakdown viscosity ranged from 24RVU - 1785.5RVU, indicating the paste's resilience to shear stress during thermal processing (Falade & Okafor, 2015). A lower breakdown viscosity, as seen in PSMF, suggests better stability under high temperatures and shear, crucial for maintaining starch integrity in cooking processes. This attribute positions PSMF as suitable for heat-stable applications, highlighting its importance in food processing where thermal stability is required (Liu *et al.*, 2017). Understanding these pasting characteristics is vital for optimizing *lafun* production and ensuring high-quality end products.

Table 4: Pasting properties of fermented cassava flour produced from three different processing techniques

Samples	Peak Viscosity (RVU)	Trough (RVU)	Breakdown	Final Viscosity (RVU)	Setback	Peak Time (min)	Pasting Temperature (°C)
GSSF	4002^{b}±1.0	2216.5^{b}±58.5	1785.5^{a}±59.5	2,924^{b}±3.0	707.5^{b}±55.5	4.53^{c}±0.1	75.48^{b}±0.38
SSMF	4926^{a}±0.0	3340.5^{a}±117.5	1585.5^{b}±117.5	4322^{a}±108.0	981.5^{a}±9.5	5.40^{b}±0.13	76.65^{b}±0.75
PSMF	570^{c}±9.0	546^{c}±3.0	24^{c}±6.0	935^{c}±5.0	389^{c}±2.0	6.9^{a} ±0.03	93.58^{a}±0.83

**Values are mean±standard deviation of triplicate determinations. Values with different alphabets are significantly different at (p<0.05). GSSF: Grated fermented cassava flour, SSMF: Sliced-soaked cassava flour, PSMF: Parboiled-soaked fermented cassava flour fermented*

CONCLUSION AND RECOMMENDATION

This study demonstrated that processing techniques significantly influence the quality of fermented cassava flour. The three processing techniques (Grated fermentation, Sliced-soaked fermentation and Parboiled-soaked fermentation) effectively reduced the cyanide levels in fresh cassava. Parboiled-soaked fermentation (PSMF) excelled in key quality parameters, including carbohydrate content, water absorption capacity, swelling capacity, thermal stability, filling weight, solubility, and oil absorption capacity indicating that PSMF is particularly effective for producing high-quality fermented cassava flour. The study provides valuable insights into different processing techniques and their specific effects on cassava flour properties. Its findings contribute essential information toward developing standardized processing methods to enhance the food safety, nutritional value, and market appeal of fermented cassava flour, benefiting both producers and consumers.

Future research should explore the optimization of PSMF by investigating different cassava varieties, fermentation times, and conditions to further enhance flour quality and safety. Additionally, further studies focusing on the nutritional benefits of PSMF-processed flour for vulnerable populations could provide valuable insights into dietary improvements.

Acknowledgment

Special thanks to the Nigerian Stored Products Research Institute for allowing this research and using their laboratory facilities. Acknowledgement is also given to the Stop Hunger Women group for providing the cassava roots for the study.

Authors' Contributions

OOS coordinated the research and drafted the manuscript, while OOA managed research and data collection. IO and OK handled literature searches and provided materials. OSN supervised and reviewed the manuscript, and ATO performed statistical analysis and data interpretation. FJO and AAO developed the methodology, and AFS conducted laboratory analyses and data collection. All authors approved the final manuscript.

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