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Proximate Composition and Pasting Properties of Composite Flours from Cassava *(Manihot esculenta)* and Millet *(Panicum miliaceum)*

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ABSTRACT

Background and Objective: Cassava (*Manihot esculenta*) and millet (*Panicum miliaceum*) are important staple foods in many developing countries due to their adaptability to a variety of agro-climatic conditions and their nutritional benefits. This study investigates the incorporation of cassava flour with millet flour at varying proportions and their proximate and pasting properties. **Materials and Methods:** This experimental study was conducted at the Department of Agricultural Science Education, College of Education, Ekiadolor-Benin, Edo State, Nigeria, from February, 2014 to July, 2015. The samples were prepared in the following ratios: 100% cassava flour (control), 90:10, 80:20, 70:30, 50:50, 30:70 and 100% millet flour. Each flour blend was mixed using a straight dough method at a low speed of 85 rpm for 1 min to achieve optimal dough consistency. **Results:** The proximate analysis showed that cassava flour had higher moisture (12.35%) and carbohydrate (80.88%) content, while millet flour had higher crude protein (14.23%), fat (4.5%) and crude fiber (7.1%). All samples had moisture levels below the 14.5% threshold for proper storage. Pasting properties indicated significant differences: Cassava flour had a peak viscosity of 4346 cP, millet flour had 904 cP and composite flours exhibited intermediate viscosities decreasing with higher millet content. Stability and setback ratios varied, reflecting changes in the functional properties of the blends. **Conclusion:** This study highlights the potential of using composite flours of cassava and millet to leverage the unique nutritional and functional properties of both ingredients, providing valuable insights for food product development. The assessment of pasting properties highlighted distinct characteristics for both cassava and millet flours, underscoring their unique attributes and potential uses in food formulation.

KEYWORDS

Blend, proximate composition, millet, cassava, pasting properties, flour

INTRODUCTION

Cassava (*Manihot esculenta*) and millet (*Panicum miliaceum*) are staple crops in many developing regions due to their adaptability to various growing conditions and nutritional benefits[1-5]. Cassava is rich in carbohydrates, making it a crucial energy source, while millet is recognized for its high protein, fiber and mineral content, making it a nutrient-dense cereal. The combination of cassava and millet flours

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can potentially improve the nutritional profile of food products, addressing both energy and protein deficiencies commonly found in many regions[6-11].

Combining these flours can potentially enhance the nutritional profile and functional properties of food products. This study investigates the effects of incorporating millet flour into cassava flour on their proximate composition and pasting properties. Understanding these changes is essential for developing nutrient-dense, functional food products suitable for diverse dietary needs and improving food security. The results of this investigation provide insights into the optimal ratios for flour blending, balancing nutritional enhancement and functional application in food processing[12-16].

Previous studies have highlighted the nutritional and functional benefits of both cassava and millet. Cassava flour is predominantly composed of carbohydrates, with studies indicating an average carbohydrate content of about 80%. However, it is relatively low in protein, fat and fiber. Millet flour, conversely, has been shown to contain significantly higher levels of protein, averaging around 14%, as well as higher fat and fiber contents[17-21]. The integration of millet flour into cassava flour has been suggested as a means to enhance the protein content and overall nutritional quality of food products. Additionally, the functional properties of these flours, such as pasting characteristics, are crucial in determining their suitability for various food applications[22-26].

The primary aim of this study is to investigate the impact of incorporating millet flour into cassava flour on their proximate composition and pasting properties. By blending these flours in varying proportions, the study seeks to determine the optimal ratios that balance improved nutritional content with desirable functional properties for food processing. This study aims to provide valuable insights for the development of nutrient-dense, functional food products that can contribute to food security and nutritional well-being in regions relying on cassava and millet as staple foods.

The results from this study will provide a comprehensive understanding of the nutritional and functional implications of incorporating millet flour into cassava flour, guiding the development of improved food products for regions dependent on these staple crops.

MATERIALS AND METHODS

Study area and sites: Benin City, located in Edo State, Nigeria, is a significant urban center. Positioned at approximately 6.34°N Latitude and 5.63°E Longitude, it stands at an elevation of 88 m above sea level. With an estimated population of 1,125,058, Benin City is the most densely populated city in Edo State[27-30].

Sample collection and analysis

Cassava flour: Mature cassava roots, weighing 25 kg and aged over twelve months, were sourced from a farm within the Department of Agricultural Science Education at the College of Education, Ekiadolor-Benin, Edo State, Nigeria. This study spanned from February, 2014 to July, 2015. The cassava roots underwent thorough washing to remove sand and soil, followed by peeling with stainless steel knives. After a second wash to ensure cleanliness, the tubers were sliced into smaller pieces and laid out on a clean, flat surface for air and sun drying, facilitating fermentation and moisture reduction. Once adequately dried, the cassava chips were milled into flour, which was then sieved to reduce fiber content and packaged in air-tight containers for research use. The resulting cassava flour was white. Additionally, millet grains were procured from Uselu market in Benin-City, Edo State, Nigeria. These grains were meticulously examined, sorted, cleaned and dried before being ground into whole millet flour. This flour was also packaged in air-tight containers and used as research samples, with the color noted to be pale-green[31,32].

Table 1: Ratios of cassava flour to millet flour

Sample code (%)	Composition
CS/ML (100/0)	Control (100 g cassava flour)
CS/ML (90/10)	90% cassava flour+10% millet flour
CS/ML (80/20)	80% cassava flour+20% millet flour
CS/ML (70/30)	70% cassava flour+30% millet flour
CS/ML (50/50)	50% cassava flour+50% millet flour
CS/ML (30/70)	30% cassava flour+70% millet flour
CS/ML (0/100)	100% millet flour

Preparation of composite cassava flour and incorporation with millet flour: Composite cassava flour was created using the straight dough method outlined by Imoisi *et al.*[33]. The cassava and millet flours were measured on a laboratory scale and the dough was mixed to achieve optimal consistency at a low speed of 85 rpm for 1 min. The cassava flour was substituted with millet flour at varying percentages: 0, 10, 20, 30, 50, 70 and 100%. These substitutions corresponded to the following ratios: CS/ML(100/0)%, CS/ML(90/10)%, CS/ML(80/20)%, CS/ML(70/30)%, CS/ML(50/50)%, CS/ML(30/70)% and CS/ML(0/100)% (Table 1).

Proximate analysis of the composite cassava flour: The proximate composition analysis was conducted following the methods described by Imoisi *et al.*[6,13]. The functionality of cassava flours, influenced by its starch and protein content, is critical in determining the formulation and characteristics of the final product. Therefore, the flours were analyzed for their functional properties, essential for creating value-added composite bakery goods. Protein content was measured using the micro-Kjeldahl method (N×6.25), while fat content was assessed through solvent extraction. Carbohydrate content was calculated by subtraction.

Determination of moisture content: The moisture content was determined using the oven-drying method. Clean, dry Petri dishes were first weighed on a balance and their weights were recorded as W1. Approximately 5 g of the sample were then weighed into each dish and their weights were noted as W2. The dishes, now containing the sample, were placed in an oven set at 105°C and left to dry for about 3 hrs. After drying, the Petri dishes were removed, cooled in a desiccator and weighed again to get the final weight, W3. This process was repeated until a constant weight was achieved. The moisture content, expressed as a percentage, was calculated using the following formula, adapted by Imoisi and Michael[34]:

$$\text{Moisture (\%)} = \frac{W2 - W3}{W2 - W1} \times 100$$

Where:
W1 = Initial weight of the empty Petri dish
W2 = Weight of the empty Petri dish plus sample before drying
W3 = Weight of the empty Petri dish plus sample after drying

Ash determination: Approximately 1 g of finely ground sample was accurately weighed into clean, dried crucibles with lids (W1). The organic matter in the sample was then burned off using an open flame until the sample was charred. The crucibles were then placed in a muffle furnace set at 550°C, with the lids removed and heated until the sample turned into a light grey or white ash. After cooling in a desiccator, the crucibles were weighed again (W2). The percentage of ash content was calculated using the following formula, adapted by Imoisi and Michael[34]:

$$\text{Ash (\%)} = \frac{\text{W2 - W1}}{\text{Weight of sample}} \times 100$$

Where:
W2 = Final weight of the crucible plus ash
W1 = Initial weight of the empty crucible

Crude fat determination: A clean, dry thimble was initially weighed (W1) and 5 g of oven-dried sample was added and reweighed (W2). A round-bottom flask was filled about three-quarters full with petroleum ether (boiling point 40-60°C). The Soxhlet extractor was then attached to a reflux condenser and the solvent was heated to a gentle boil. The thimble containing the sample was placed into the Soxhlet apparatus and the extraction was performed under reflux with petroleum ether (40-60°C) for over 6 hrs. After the extraction, the thimble was removed and placed in an oven at 100°C for 1 hr. It was then cooled in a desiccator and reweighed (W3).

The percentage of fat content was calculated using the following equation, adapted by Imoisi and Michael[34]:

$$\text{Fat (\%)} = \frac{\text{Weight of fat}}{\text{Weight of sample}} \times 100 = \frac{\text{W2 - W3}}{\text{W2 - W1}} \times 100$$

Where:
W1 = Initial weight of the empty thimble
W2 = Weight of the thimble plus sample before extraction
W3 = Weight of the thimble plus sample after extraction

Crude protein determination: Approximately 1 g of each sample was weighed into a micro Kjeldahl digestion flask. To this, one selenium catalyst tablet and 15 mL of concentrated H_2SO_4 were added. The mixture was digested on an electro-thermal heater until it turned clear, all performed within a fume cupboard for safety. After cooling, the solution was diluted with distilled water to a total volume of 50 and 5 mL of this diluted solution were transferred to the distillation apparatus.

In a separate 100 mL conical flask (receiver flask), 5 mL of 2% boric acid and four drops of screened methyl red indicator were added. The digested sample was treated with 50% NaOH until it turned cloudy, indicating alkalinity. The solution was then distilled into the acid solution in the receiver flask, with the delivery tube submerged below the acid level. As distillation proceeded, the pink solution in the receiver flask turned blue, indicating the presence of ammonia. Distillation continued until about 50 mL remained in the round-bottom flask, after which the condenser was rinsed with distilled water. Finally, the solution in the conical flask was titrated with 0.1M HCl. The percentage of protein content was calculated using the following equations, adapted by Imoisi and Michael[34]:

$$\text{Nitrogen (wet \%)} = \text{(A-B)} \times 1.4007 \times 100 \text{ weight (g) of sample}$$

Where:
A = Volume (mL) of standard HCl × Normality of standard HCl
B = Volume (mL) of standard NaOH × Normality of standard NaOH

$$\text{Nitrogen (dry \%)} = \frac{\text{Nitrogen (wet \%)}}{\text{100 - moisture (\%)}}$$

$$\text{Protein (\%)} = \text{Nitrogen (dry \%)} \times 6.25 \text{ (protein nitrogen conversion factor)}$$

Crude fibre determination: The 2.0 g (W1) of the sample underwent defatting with petroleum ether in a separating funnel. The defatted sample was then transferred to a 1 L conical flask, where it was treated with 200 mL of boiling 1.25% H_2SO_4 and gently boiled for 30 min. After filtration through muslin cloth and thorough rinsing with hot distilled water, the filtered sample was returned to the flask with a spatula.

To this, 200 mL of boiling 1.25% NaOH was added and boiled gently for another 30 min. The mixture was filtered through muslin cloth again and the residue was washed with hot distilled water, followed by rinsing with 10% HCl once and twice with industrial methylated spirit. The resulting residue was transferred to a crucible, dried in an oven at 105°C, cooled in a desiccator and weighed (W2).

Subsequently, the residue was ashed at 550°C for 90 min in a muffle furnace, cooled in a desiccator and weighed again (W3). The percentage of crude fiber content was calculated using the following equation, adapted by Imoisi and Michael[34]:

$$\text{Crude fiber (\%)} = \frac{\text{W2 - W3}}{\text{W1}} \times 100$$

Where:
W1 = Represents the weight of the sample used
W2 = Represents the weight of the crucible+oven-dried sample
W3 = Represents the weight of the crucible+ash

Determination of carbohydrate content: The percentage of carbohydrate content was determined using the equation referenced by Ajenu *et al.*[14] and Ajenu *et al.*[35].

$$\text{Carbohydrate (\%)} = 100 - \text{\% (protein+fat+fibre+ash+moisture content)}$$

Determination of pasting properties of samples: The pasting properties of starch were evaluated using the Rapid Visco Analyser-Super 4 from Newport Scientific Pty. Ltd., Warriewood, New South Wales, Australia. The STDI test profile, following the Standard Method of the AACC (no. 61-02) for cereal flours, was employed to determine pasting characteristics. A slurry was prepared by mixing 3.5 g of flour with 25 mL of de-ionized water. Subsequently, a programmed heating and cooling cycle lasting 780 sec (13 min) was initiated. This cycle included holding the starch suspension at 50°C, heating to 95°C at a specified rate, maintaining at 95°C for a set duration, controlled cooling from 95 to 50°C and a final hold at 50°C. The resulting pasting curve was analyzed using RVA control software, specifically Thermocline for Windows (TCW), to extract parameters such as pasting temperature (PSTMP), peak viscosity (PV), peak time, hot paste viscosity (HPV), cool paste viscosity (CPV), breakdown (BD), setback (SB), stability ratio and setback ratio[13,33].

Statistical analysis: Statistical analysis was performed using the BMDP 2R program for stepwise multiple regression. Results were expressed as the mean of triplicate analyses[36].

RESULTS AND DISCUSSION

Table 2 provides the proximate analysis of cassava flour (CS) and millet flour (ML). It compares their moisture, ash, crude protein, fat, crude fiber and carbohydrate content, highlighting significant nutritional differences between the two flours.

The proximate analysis of cassava and millet flours, as presented in Table 2, reveals significant differences in their nutritional profiles. Cassava flour, predominantly composed of carbohydrates (80.88%), has lower levels of protein (2.74%), fat (0.95%) and fiber (1.75%). Conversely, millet flour exhibits a higher protein content (14.23%), fat (4.5%) and fiber (7.1%), but a lower carbohydrate content (65.17%). These differences underline the complementary nutritional attributes of cassava and millet flours[37-39]. The moisture content of cassava flour (12.35%) is higher than that of millet flour (8.87%). The lower moisture content in millet flour suggests better shelf stability, as high moisture levels can lead to microbial growth and spoilage. The recommended maximum moisture content for proper storage is 14.5%, indicating that both flours are within acceptable limits for prolonged storage under appropriate conditions. The ash content, indicative of the total mineral content, is slightly higher in cassava flour (1.33%) compared to millet flour (1.0%). While both values are relatively low, the slight difference suggests that cassava flour may contribute marginally more minerals than millet flour. However, the overall mineral contribution from these flours remains limited.

One of the most notable differences between the two flours is in crude protein content. Millet flour contains significantly more protein (14.23%) compared to cassava flour (2.74%). This stark contrast highlights the potential nutritional enhancement that millet flour can provide when blended with cassava flour, especially in regions where protein malnutrition is prevalent. The fat content in millet flour (4.5%) is considerably higher than in cassava flour (0.95%). This higher fat content could be advantageous in enhancing the energy density of food products[40,41]. However, it also necessitates careful storage to prevent rancidity, especially in hot and humid climates. The lower fat content in cassava flour suggests it has a longer shelf life compared to millet flour. Millet flour has a significantly higher crude fiber content (7.1%) than cassava flour (1.75%). Dietary fiber is crucial for digestive health and the inclusion of millet flour in composite flours can improve the fiber content of the final product. This could have beneficial implications for gut health and overall digestion. Cassava flour is predominantly carbohydrate (80.88%), while millet flour contains less (65.17%). The high carbohydrate content of cassava flour makes it an excellent energy source, essential for meeting daily caloric needs. The incorporation of millet flour reduces the overall carbohydrate content but enhances the protein and fiber profile, making the blend nutritionally balanced[42-44].

The pasting properties of flours are critical for determining their suitability in various food applications, such as baking and thickening. These properties include peak viscosity (PV), trough viscosity (TV), breakdown viscosity (BDV), final viscosity (FV), setback viscosity (SBV), peak time (PKT) and pasting temperature (PST). The pasting characteristics of cassava and millet flours and their blends, are presented in Table 3 and 4[13,45].

Peak viscosity reflects the water-holding capacity and swelling of starch granules during heating. Cassava flour exhibits a higher peak viscosity (4346 cP) compared to millet flour (904 cP). This indicates that cassava flour has a higher ability to absorb water and swell, which is beneficial in thickening applications. As the proportion of millet flour increases in the blends, the peak viscosity decreases, suggesting a reduced water-holding capacity and swelling[18,33].

Trough viscosity represents the minimum viscosity after peak viscosity, indicating the stability of the gelatinized starch to shear. Breakdown viscosity, the difference between peak and trough viscosity, measures the starch's stability to heating and mechanical shear. Cassava flour has higher trough (2407 cP) and breakdown viscosities (1939 cP) compared to millet flour (676 and 228 cP, respectively). This suggests that cassava flour is less stable under shear and heat compared to millet flour. The blends show a gradual decrease in trough and breakdown viscosities with increasing millet flour content, indicating enhanced stability[33].

Final viscosity indicates the viscosity of the flour paste after cooling and setback viscosity measures the recrystallization tendency of the gelatinized starch upon cooling. Cassava flour has a higher final viscosity (3292 cP) compared to millet flour (1769 cP), suggesting a thicker paste upon cooling. The setback

Table 2: Proximate analysis of sample

Sample (%)	Cassava flour (CS)	Millet flour (ML)
Moisture	12.35	8.87
Ash	1.33	1.0
Crude protein	2.74	14.23
Fat	0.95	4.5
Crude fibre	1.75	7.1
Carbohydrate	80.88	65.17

Table 3: Pasting properties of cassava and millet flours sample

Sample (%)	PV (cP)	TV (cP)	BDV (cP)	FV (cP)	SBV (cP)	PKT (mins)	PST (°C)	STB ratio	SB ratio
CS (100)	4346	2407	1939	3292	885	4.3333	73.35	0.5538	1.3677
ML (100)	904	676	228	1769	1093	5.6	88.9	0.7478	2.6169

CS: Cassava flour, ML: Millet flour, PV: Peak viscosity, TV: Trough viscosity, BDV: Breakdown viscosity (i.e., PV-TV), FV: Final viscosity, SBV: Setback viscosity (i.e., FV-TV), PKT: Peak time, PST: Pasting temperature, cP: Centipoises i.e., units of viscosity, STB ratio: TV/PV (stability ratio) and SB ratio: FV/TV (setback ratio) viscosity unit is either in centipoises (cP) or rapid visco units (RVU), but 1RVU = 12 cP

viscosity of cassava flour (885 cP) is lower than that of millet flour (1093 cP), indicating that millet flour has a higher tendency to retrograde and form a gel upon cooling. The blends demonstrate intermediate final and setback viscosities, balancing the properties of both flours[18,46].

Peak time is the time taken to reach peak viscosity and pasting temperature is the temperature at which viscosity starts to increase. Cassava flour has a shorter peak time (4.33 min) and a lower pasting temperature (73.35°C) compared to millet flour (5.6 min and 88.9°C, respectively). This indicates that cassava flour gelatinizes faster at a lower temperature. The blends show a gradual increase in peak time and pasting temperature with higher millet flour content, indicating a delay in gelatinization and higher thermal stability[33].

The blending of cassava and millet flours results in composite flours with improved nutritional and functional properties. The inclusion of millet flour enhances the protein, fat and fiber content of the composite flours, making them more nutritionally balanced. The pasting properties are also modified, with the blends exhibiting intermediate viscosities, stability and gelatinization characteristics. These changes can influence the textural and sensory qualities of food products, potentially broadening their applications[18,47].

The incorporation of millet flour into cassava flour offers a promising approach to enhance the nutritional quality and functional properties of food products. The complementary nature of these flours can address protein and fiber deficiencies while maintaining desirable carbohydrate levels. Understanding the proximate composition and pasting properties of these blends is crucial for developing nutrient-dense, functional food products that can contribute to food security and nutritional well-being, particularly in regions reliant on cassava and millet as staple foods[28].

The proximate analysis presented in Table 2 highlights distinct nutritional differences between cassava and millet flours. Cassava flour is rich in carbohydrates (80.88%), whereas millet flour is characterized by higher levels of protein (14.23%), fat (4.5%) and crude fiber (7.1%), but lower carbohydrates (65.17%). These variations underscore their complementary nutritional profiles, suggesting potential for blending to enhance overall dietary balance and health benefits. The moisture content, crucial for shelf stability, indicates both flours are suitable for storage under proper conditions.

The pasting properties detailed in Table 3 and 4 demonstrate significant differences between pure and composite flours. Cassava flour exhibits higher peak viscosity (PV) and stability ratios compared to millet

Table 4: Pasting properties of composite flours of cassava and millet (cs/mL %)

Sample (%)	PV (cP)	TV (cP)	BD	FV (cP)	SB (cP)	PKT (mins)	PST(°C)	STB ratio	SB ratio
CS/ML (100/0)	4346	2407	1939	3292	885	4.3333	73.35	0.5538	1.3677
CS/ML (90/10)	3191	1523	1668	2516	993	4.1333	75.15	0.4773	1.652
CS/ML (80/20)	2438	1104	1334	1903	799	4.1333	75.1	0.4528	1.7237
CS/ML (70/30)	1814	773	1041	1542	769	4.0667	74.25	0.4261	1.9998
CS/ML (50/50)	964	572	392	1341	769	5.4	74.95	0.5934	2.3444
CS/ML (30/70)	889	651	238	1610	959	5.7333	76.55	0.7323	2.4731
CS/ML (0/100)	904	676	228	1769	1093	5.6	88.9	0.7478	2.6169

CS: Cassava flour, ML: Millet flour, PV: Peak viscosity, TV: Trough viscosity, BD: Breakdown (i.e., PV-TV), FV: Final viscosity, SB: Setback i.e., (FV-TV), PKT: Peak time, PST: Pasting temperature, STB ratio: (TV/PV) Stability ratio, SB ratio: (FV/TV) Setback ratio and cP: Centipoises i.e., units of viscosity.

flour, while millet flour shows lower PV but higher setback ratios, indicating differing textural qualities. Composite flours display intermediate viscosities dependent on blend ratios, suggesting tailored functional characteristics suitable for diverse food applications.

This study's findings have implications for food formulation, particularly in optimizing nutritional content and textural attributes of bakery and processed food products. The use of composite flours can leverage the strengths of both cassava and millet, offering improved dietary diversity and enhanced product quality in regions facing nutritional challenges. Based on the results, it is recommended to explore further the sensory attributes and consumer acceptance of products formulated with cassava-millet blends. Future research should also investigate processing techniques that preserve nutritional integrity and optimize functional properties in composite flour applications. Limitations include the focus on laboratory-scale analyses, which may differ from large-scale production realities. Variability in raw material quality and regional differences in crop varieties could also impact findings, necessitating further localized studies for broader applicability. These insights contribute to advancing food science and technology, offering pathways to develop nutritious and sustainable food solutions tailored to diverse consumer needs and preferences.

CONCLUSION

The incorporation of millet flour into cassava flour significantly enhances the nutritional and functional properties of the resulting blends. Proximate analysis reveals that millet flour contributes higher protein, fat and fiber content, thus improving the overall nutritional profile of the composite flours. Cassava flour, rich in carbohydrates, provides a high-energy source, while millet flour enhances protein and fiber intake, crucial for balanced nutrition. The pasting properties of the composite flours indicate that increasing millet content decreases peak viscosity and enhances thermal and mechanical stability. This suggests that millet-cassava blends can be tailored for specific food applications, offering better stability and textural qualities. Blends with higher millet content also show delayed gelatinization and higher pasting temperatures, beneficial for processes requiring extended cooking times. Overall, the strategic blending of cassava and millet flours can produce nutritionally enriched, functionally versatile flours suitable for diverse dietary needs and food product formulations.

SIGNIFICANCE STATEMENT

The incorporation of millet flour into cassava flour significantly alters the proximate composition and pasting properties of the blends. Increasing millet flour proportion enhances protein, fat and fiber contents while reducing carbohydrate levels, offering a nutritionally superior alternative to pure cassava flour. Additionally, the pasting properties, including peak viscosity and stability ratio, indicate varied functional behaviors, with higher millet content resulting in reduced peak viscosity and increased setback viscosity. These findings suggest potential applications in diverse food products, leveraging the enhanced nutritional profile and modified functional properties of cassava-millet composite flours.

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