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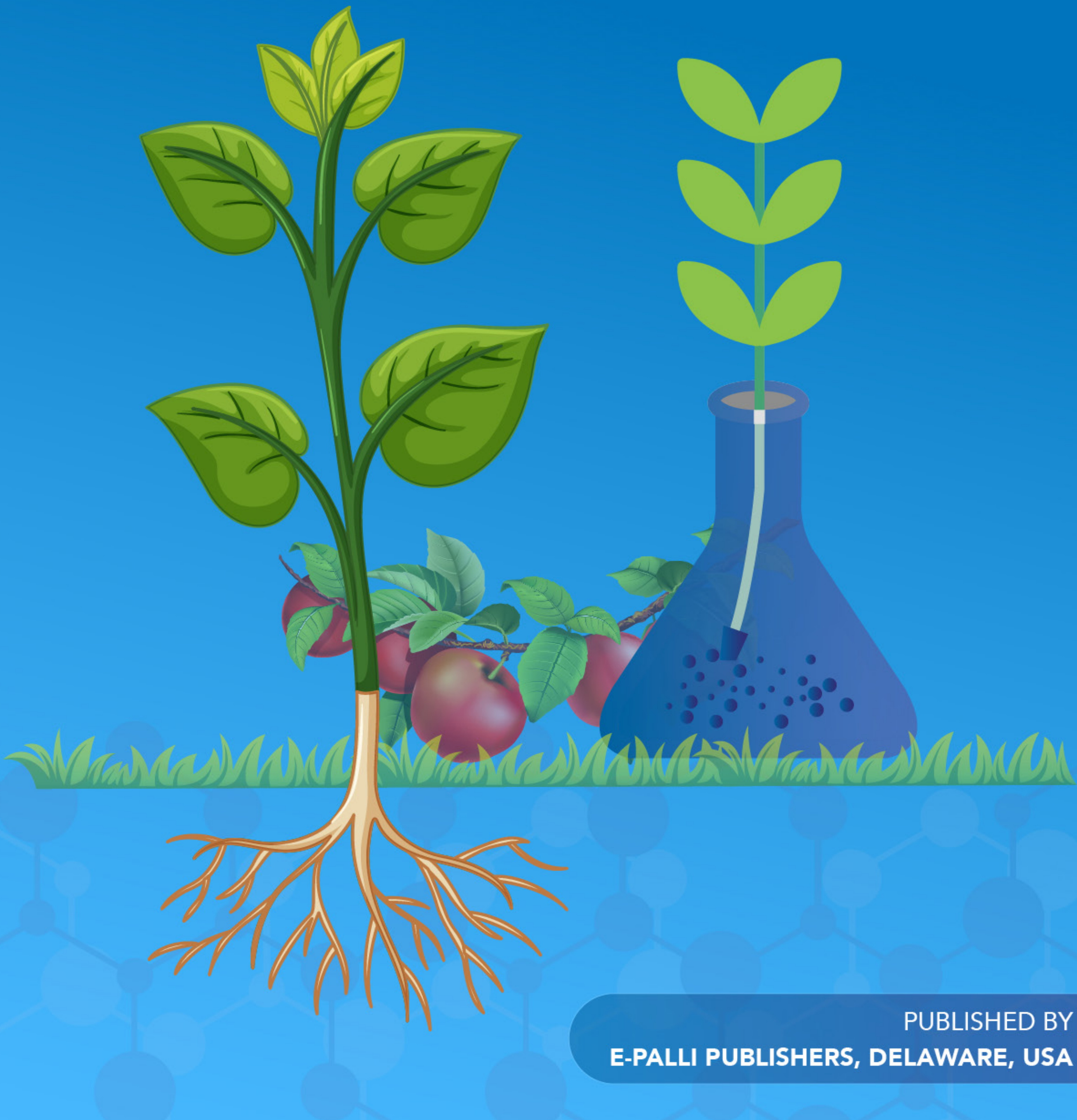

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Proximate Composition and Functional Properties of Soyabeans (*Glycine Max*) Enriched Carbohydrate Diets

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ABSTRACT

This study explored enhancing the nutritional value and functional properties of carbohydrate-rich diets by incorporating soybeans into millet, cassava, and yam. Soybeans, known for their high protein, unsaturated fats, and micronutrients, were used to fortify these staple foods. Proximate analysis assessed the macronutrient content of both the original and soybean-enriched samples, while functional properties such as water and oil absorption capacities, swelling index, bulk density, and gelation capacity were evaluated. Results showed significant increases in protein content, particularly in the millet-soybean mixture (29.81%), with relatively low levels of fat and ash. Functional assessments indicated millet's highest gelation capacity and cassava's superior water absorption. These findings suggest that soybean fortification can improve carbohydrate-rich diets' nutritional quality and versatility. Further research is recommended to assess the impact of these dietary modifications on human health and consumer acceptance.

INTRODUCTION

Our diets are mostly composed of foods high in carbohydrates, which account for more than half of our daily caloric intake. This is in line with the DRIs' recommendations, which indicate that 45–65% of our calories come from carbohydrates (Marriott *et al.*, 2020). This macronutrient is particularly crucial in economically disadvantaged populations, where carbohydrate-rich staples are often the most accessible food sources. While carbohydrates provide essential energy, the type of carbohydrate consumed significantly impacts health outcomes. In recent decades, there has been growing concern over the excessive intake of added sugars. The World Health Organization (WHO, 2015) and other health authorities have issued guidelines recommending a substantial reduction in free sugar consumption to mitigate the risks of obesity, dental caries, and type 2 diabetes. This has prompted a global shift towards healthier carbohydrate choices, emphasizing whole grains, legumes, and other minimally processed options. To address the dual challenges of reducing sugar intake and promoting nutrient-rich diets, innovative food formulations are required. One promising approach involves fortifying carbohydrate-based foods with protein sources, such as soybeans.

Soybeans contain isoflavones, proteins, carbohydrates, and lipids, and have been shown to significantly impact the management of metabolic disorders like obesity and hyperglycemia (Chatterjee *et al.*, 2018 and Basson *et al.*, 2021). Soy protein, which makes up 35-40% of soybeans, is the only complete plant-based protein, providing all the essential amino acids found in animal proteins (Chatterjee *et al.*, 2018). Additionally, soybean extracts have been associated with inhibiting key enzymes linked to type 2 diabetes and hypertension, as well as exhibiting anti-inflammatory and antioxidant properties (Ademiluyi and Oboh, 2013).

Millets are excellent sources of micronutrients, especially iron and zinc, in addition to vitamins and other minerals (Dias-Martins *et al.*, 2018; Kaur *et al.*, 2014; United States Department of Agriculture (USDA), 2016). They are affordable and readily available food crops that are attracting industry attention due to their natural antioxidants and other vital bioactive phytochemicals and minerals (Kaur *et al.*, 2019). Cassava (Manihot esculenta) is widely acknowledged as one of the most important tuber crops grown in tropical and subtropical areas, serving as a major food source for over 800 million people globally (McCallum *et al.*, 2017). It is a staple ingredient in the diets of many developing countries and was identified by the FAO in 2003 as Africa's most vital root crop and a significant source of nutritional calories (Nassar and Ortiz, 2007). Yam (Dioscorea spp.), prevalent in West Africa, Asia, and the Caribbean, is rich in carbohydrates, dietary fiber, vitamins, and essential minerals like potassium, manganese, and iron, and is associated with improved digestive health and blood sugar regulation (Bhandari & Kawabata, 2004).

Analyzing the proximate composition of food components such as moisture, ash, protein, fat, fiber, and carbohydrates is vital for assessing their nutritional value and suitability for dietary needs. This analysis is particularly important for optimizing the use of soybeans, millet, cassava, and yam in food formulations to ensure nutritional adequacy. Additionally, understanding the functional properties of these foods, including water and oil absorption capacity, foaming capacity, and emulsification properties, is essential. These properties

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affect the processing behavior and the texture, flavor, and overall acceptability of food products.
This study aims to analyze the proximate composition and functional properties of soybeans, millet, cassava, and yam, providing a comprehensive understanding of their nutritional profiles and potential applications in food systems. This information will be valuable for developing nutritionally balanced diets and enhancing the utilization of these important food resources.

MATERIALS AND METHODS

Food Samples

Soybeans, millet, cassava, and yam were sourced from North Bank Market in Makurdi, Benue State, Nigeria. Grains were washed with tap water and sun-dried. Milling was performed at the Food Science and Technology Laboratory of the University of Agriculture Makurdi, Benue State, Nigeria using a Brook Crompton Hammer mill (Huddersfield, England). The resulting flours were packed into polyethylene sacs and stored in airtight containers until further use.

Chemical Analysis

Proximate analysis was conducted to measure the moisture, protein, fat, fiber, ash, and carbohydrate content in all three flour samples (Table 1). The food samples were analyzed for moisture, protein, fat, ash, and crude fiber content using the methods specified in the AOAC (2012) publication. The total carbohydrate content was calculated by subtracting the combined percentages of fat, moisture, ash, crude fiber, and protein from 100.

Dry Matter Determination

An empty crucible was weighed, and 0.5-2 g of the thoroughly mixed sample was transferred into the crucible. The crucible was then placed in a hot air oven and dried at 100°C for 2 hours. After drying, the crucible and sample were cooled in a desiccator, and the weight of the crucible with the dry sample was recorded.

Calculation

% DM = (W2-W1)/W X 100

where W2 = Weight of the crucible and dry sample, W1 = Weight of the empty crucible, and W= Weight of the sample/

Ash Determination

The weight of an empty crucible was recorded. 0.5-2 g of the thoroughly mixed sample was transferred into the crucible and placed in a furnace at 550°C for 3 hours. After ashing, the crucible and its contents were cooled in a desiccator, and the final weight was noted.

Calculation

% Ash = (W2-W1)/W X 100

where W2 = Weight of the crucible and ash, W1 = Weight of the empty crucible, and W = Weight of the sample.

Fat and Oil Determination

2 g of the sample was weighed, placed in a filter paper, and then into an extraction thimble. The weight of the receiver flask was recorded, and 200 ml of petroleum ether was added. The apparatus was assembled and heated for 8 hours. After extraction, the solvent was evaporated from the flask. The flask containing the fat was dried at 100°C for 1 hour, cooled in a desiccator, and weighed.

Calculation

% DM = (W2-W1)/W X 100

where W2 = Weight of the crucible and dry sample, W1 = Weight of the empty crucible, and W = Weight of the sample

Crude Fiber Determination

2 g of the fat/oil-free sample was weighed. The sample was boiled with 100 ml of sulfuric acid solution for 30 minutes, rinsed with boiling water, and then boiled with 100 ml of sodium hydroxide solution for another 30 minutes. After rinsing, the residue was dried at 100°C for 24 hours, cooled, and weighed. The residue was then incinerated at 550°C for 3 hours, cooled, and reweighed.

Calculation

% Crude Fiber = (W2-W1)/W X 100

where W2 = Weight of the crucible and sample before ashing, W1 = Weight of the crucible and ash, and W = Weight of the sample.

Nitrogen and Crude Protein Determination

0.5-2 g of the sample was weighed and placed in a digestion flask. Copper sulfate (10 g) and sodium sulfate (50 ml) were added, followed by 25 ml of concentrated sulfuric acid. The flask was heated until the mixture turned clear and light blue-green. After cooling, the mixture was diluted to 250 ml. A 10 ml aliquot was used for distillation. Sodium hydroxide (10 ml, 40%) was added, and the ammonia was distilled into 20 ml of 2% boric acid. The ammonia absorbed was titrated with 0.02 M hydrochloric acid.

Calculation

% N2 = (14.02 ×Concentration of acid ×Volume made ×Titre ×100)/(10 ×1000 ×Sample weight)

where Crude protein = N2 x 6.25 (General factor), N2 x 6.30 (milk), N2 x 5.70 (Flour), and N2 x 5.55 (Gelatin).

Carbohydrate

The carbohydrate content was calculated by subtracting the percentages of crude protein, fat/oil, ash, moisture, and crude fiber from 100%.

Calculation

% Carbohydrate = 100 - (Crude protein + Fat/Oil + Ash + Moisture + Crude fiber)

Table 1: Proximate composition of flours on dry weight bases (g/100g)

Foods	Components					
	Protein (%)	**Fat/Oil (%)**	**Ash (%)**	**Moisture (%)**	**Crude Fiber (%)**	**Carbohydrate (%)**
Millet	7.00	3.80	1.28	9.71	1.82	76.39
Cassava	2.63	0.56	1.84	9.88	1.33	83.76
Yam	7.00	0.36	2.35	12.37	1.53	76.39

The food samples were mixed in a 70:30 ratio (carbohydrate to soybeans), and proximate analysis was performed to determine the moisture, protein, fat, fiber, ash, and carbohydrate content in all three flour samples, as shown in Table 2.

Table 2: Proximate composition of flours mixed with Soya beans in the ratio of 70:30 on dry weight bases (g/100g)

Foods	Components					
	Protein (%)	**Fat/Oil (%)**	**Ash (%)**	**Moisture (%)**	**Crude Fiber (%)**	**Carbohydrate (%)**
Millet 70% + Soybean 30%	29.81	7.99	2.43	12.98	8.66	38.13
Cassava 70% + Soybean 30%	19.38	7.87	1.75	12.72	5.96	52.32
Yam 70% + Soybean 30%	21.13	6.20	2.89	13.00	4.06	52.72

Functional Properties

Functional Analysis was also performed to determine Bulk density, Gelation capacity, Swelling Index, Oil and Water absorption capacity.

Bulk Density

Was measured using the method described by Onwuka (2005). A 10 ml graduated cylinder was filled with the flour sample, tapped until no further settling occurred, and then weighed to determine the bulk density. Bulk density was expressed as:

Bulkdensity (g/ml)=(weight of sample (g))/(volume of sample (ml))

Water and Oil Absorption Capacities

Were assessed following the procedure outlined by Onwuka (2005). For water absorption, 1 g of flour was mixed with 10 ml of distilled water, allowed to stand for 30 minutes, and then centrifuged to measure the volume of water absorbed. Oil absorption was determined using a similar method with olive oil.

Swelling Index

was determined according to Alobo (2003) and Onwuka (2005). One gram of flour was added to a 10 ml measuring cylinder, filled with water, and the volume change after 45 minutes was recorded to calculate the swelling index. The ratio of the initial volume to the final volume gave the swelling index.

Least Gelation Capacity

was evaluated using the method described by Onwuka (2005). Flour suspensions at concentrations from 2% to 15% (W/V) were heated, cooled, and assessed for gelation by observing the lowest concentration at which the gel remained intact upon inversion of the test tube.

Table 3: Functional analysis of the various food samples

Foods	Components				
	Swelling Index	**Bulk Density (g/mL)**	**Oil Absorption Capacity (mL)**	**Water Absorption Capacity (mL)**	**Gelation Capacity (%)**
Millet	1.33	0.65	1.70	2.3	10%
Cassava	1.25	0.53	1.70	2.5	6%
Yam	1.24	0.61	1.20	3.5	8%

RESULTS AND DISCUSSION

The proximate composition and functional properties of the food samples reveal important insights into their nutritional content and potential applications in food processing.

Proximate Composition

From Figure 1, it is evident that the carbohydrate content is highest in Cassava (83.76%), followed by Millet and Yam, both with 76.39%. The inclusion of Soya beans significantly alters the nutritional profile. For instance, the crude protein content increases drastically in all samples with the inclusion of Soya beans, with Millet-Soya mixture showing the highest protein content (29.81%), followed by Yam-Soya (21.13%) and Cassava-Soya (19.38%). This indicates that Soya beans are an excellent source of protein and can significantly enhance the protein content of carbohydrate-rich foods. Additionally, the reduction in carbohydrate content when mixed with Soya beans can be beneficial in creating more balanced nutrient profiles in these foods.

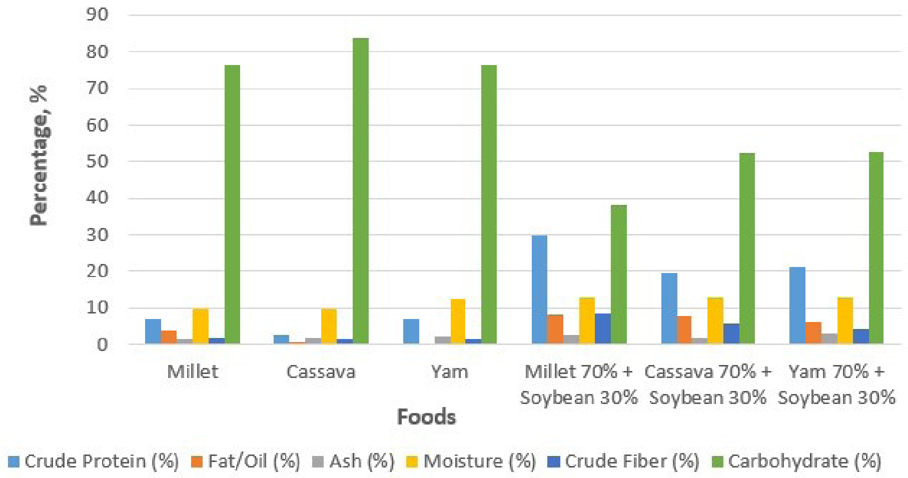

Figure 1: Proximate composition of flours on dry weight basis (g/100g) compared with proximate composition of flours mixed with Soya beans in the ratio of 70:30 on dry weight basis (g/100g)

Functional Properties

The data in Table 3 provides a comprehensive overview of the functional properties of Millet, Cassava, and Yam, which are further illustrated in Figures 2, 3, 4, 5, and 6 through bar charts. These functional properties are crucial for determining the usability of these food samples in various food applications. The swelling index, bulk density, oil absorption capacity, and water absorption capacity are critical parameters that influence the texture, shelf-life, and consumer acceptability of food products. Millet has the highest gelation capacity (10%), making it suitable for products requiring thickening. The food samples exhibit high water absorption capacity, indicating their potential use in products where moisture retention is important. The close range in swelling index and bulk density among the samples suggests they can be used interchangeably in various food applications depending on the desired texture and consistency.

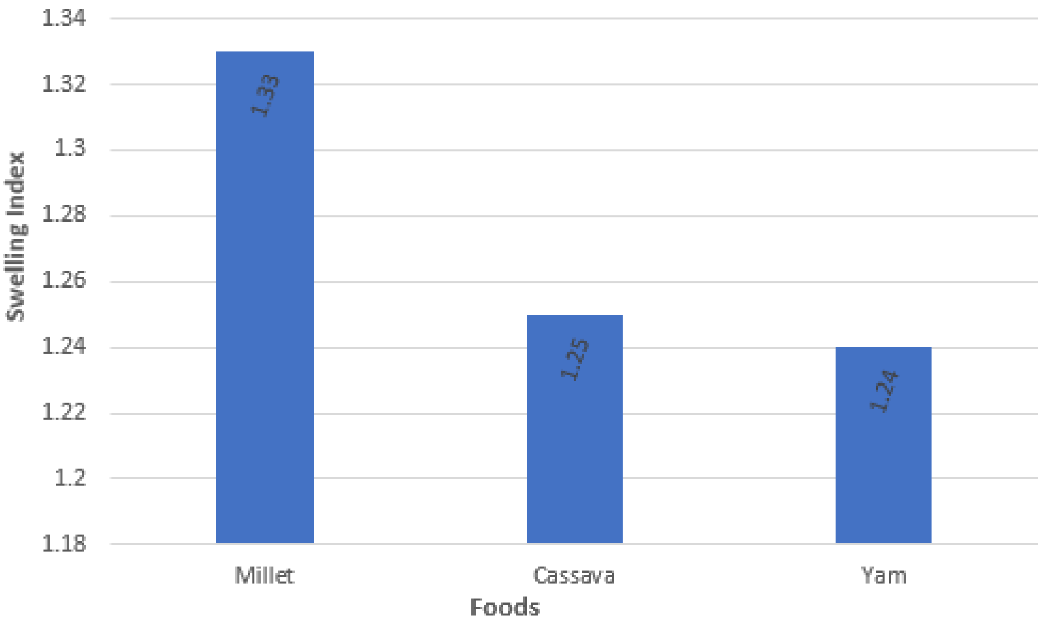

Figure 2: Swelling Index for various food samples.

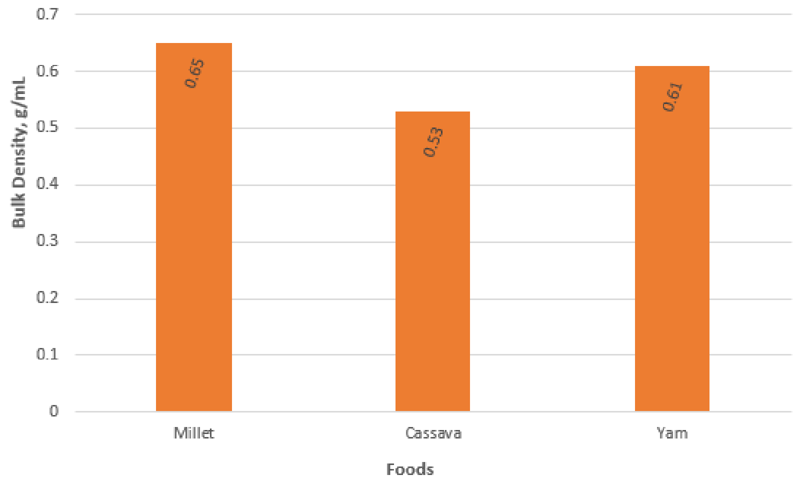

Figure 3: Bulk Density for various food samples

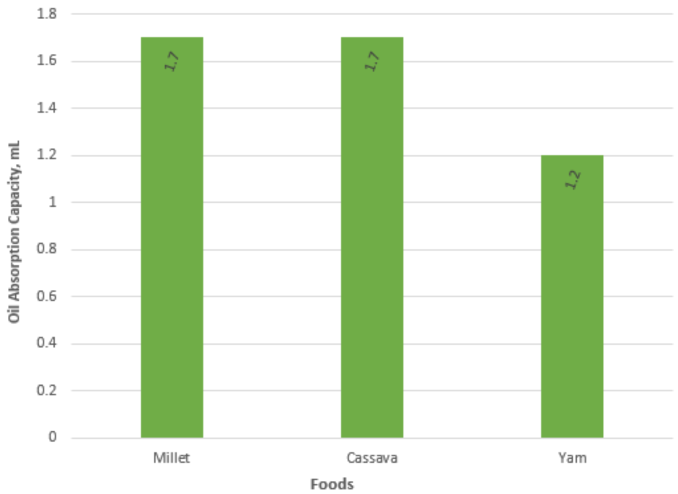

Figure 4: Oil Absorption Capacity for various food samples.

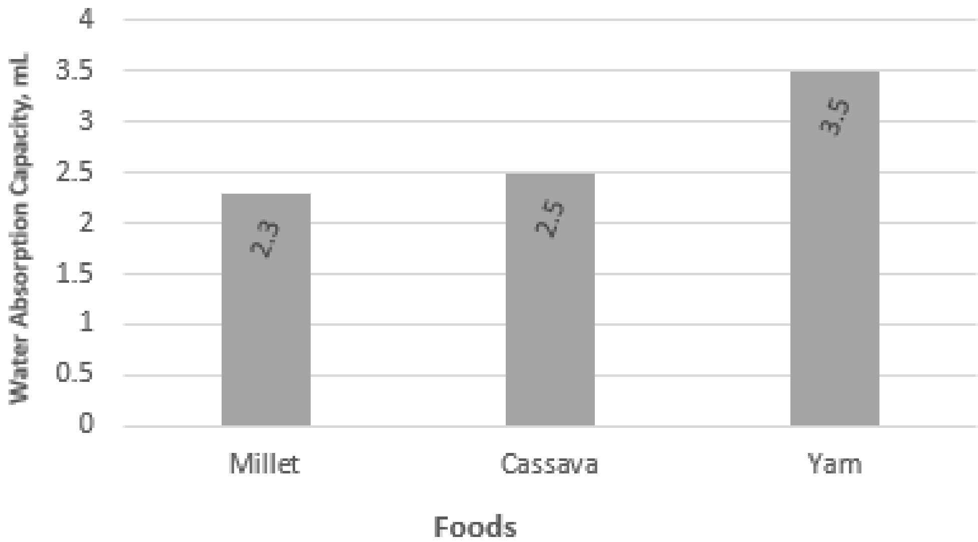

Figure 5: Water Absorption Capacity for various food samples.

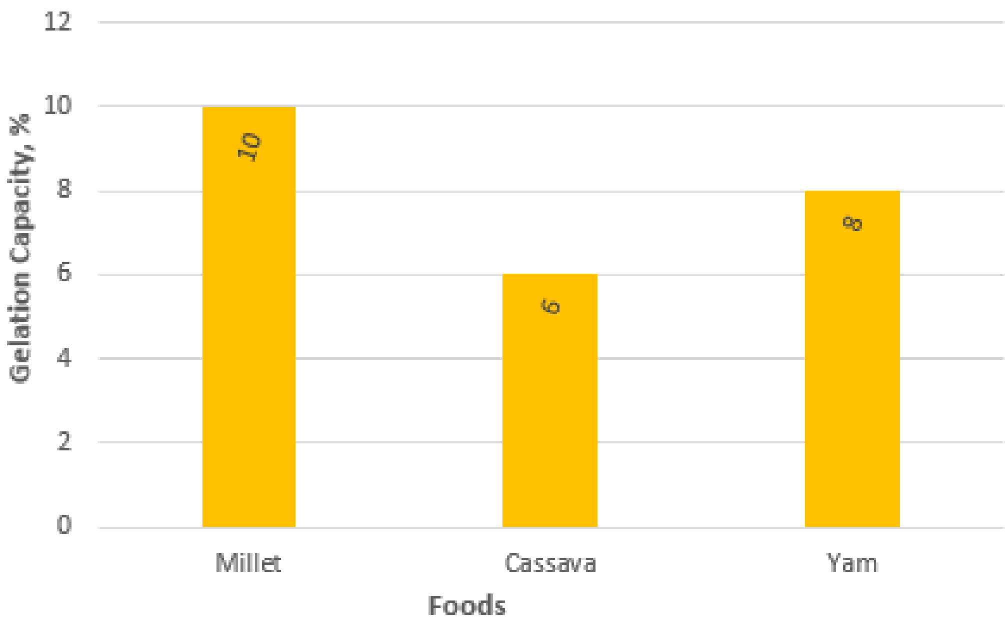

Figure 6: Gelation Capacity for various food samples

Plant foods are generally processed before consumption, involving methods such as cooking (boiling, roasting, frying, steaming, baking, autoclaving), drying, mashing, grinding into flour, and fermentation. In this study, the test foods were primarily obtained from North Bank Market, Makurdi, Benue State, and processed by drying, milling into flour, sieving, and reconstituting to paste with hot water. These processes reduce particle sizes and retrograde starch to varying extents, potentially influencing their functional properties and nutritional benefits.

The nutritional responses in human subjects and animals for different foods and among the same group of food may vary due to factors such as chemical composition, nature of the carbohydrates, dietary fiber, method of food processing, and the presence of substances acting as inhibitors of enzymatic digestion (Tovar *et al.*, 1992; Bjorck *et al.*, 1994; Behall *et al.*, 1999; Darabi *et al.*, 2000; Thannoun and Al-Kubati, 2005a and 2005b).

CONCLUSION

The proximate composition and functional properties assessment showed significant differences in the carbohydrate, protein, fat, and other nutrient contents when the food samples were mixed with Soya beans. These differences highlight the nutritional benefits of incorporating Soya beans into carbohydrate-rich foods, thereby enhancing their protein content and other nutritional qualities. The functional properties also indicate potential applications of these food mixtures in various food products. Understanding these properties can guide food processing techniques and dietary planning, promoting healthier food choices.

Further research into the proximate composition and functional properties of locally consumed foods is recommended to generate comprehensive data that can aid in dietary planning and food processing. Additional studies could help food manufacturers develop a broader range of processed foods from African farm produce, utilizing the nutritional benefits of Soya beans. The findings have significant implications in formulating rational dietary and therapeutic goals for diabetic patients and others with clinical conditions necessitating carbohydrate restriction. Moreover, such research can assist food manufacturers and processors in developing a greater range of low-GI processed foods, enhancing the health profiles of traditional diets and supporting public health objectives.

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The Food Science and Technology Laboratory at the University of Agriculture Makurdi, Benue State, Nigeria for their expertise in milling the samples using the Brook Crompton Hammer mill.

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