

Quality Evaluation, Storage Stability, and Sensory Acceptability of Cocoyam (*Xanthosoma sagittifolium*) Flour Enriched with *Moringa oleifera* Seed Powder for the Production of Swallowable Dough

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ABSTRACT

Background: Cocoyam flour is rich in carbohydrates and provides a good source of dietary fiber, but it is generally low in essential vitamins and minerals such as calcium, iron, and zinc. *Moringa oleifera*, commonly known as the drumstick tree, is renowned for its high nutritional content, vitamins, and minerals.

Objective: This study aims to determine the proximate and mineral composition, functional and sensory properties, and storage stability of cocoyam flour enriched with *Moringa oleifera* seed powder.

Methods: Cocoyam flour was blended with *Moringa oleifera* seed powder in various proportions and compared with 100% cocoyam flour. The proximate composition, mineral, functional, sensory, and microbial analyses were determined.

Results: Proximate composition showed a decrease in moisture (9.64% to 8.07%), an increase in protein (4.07% to 5.64%), an increase in fiber (1.42% to 3.80%), an increase in fat (1.35% to 10.14%), and a decrease in carbohydrates (80.38% to 69.24%). Functional properties showed a decrease in bulk density (0.71 g/cm³ to 0.56 g/cm³), an increase in water absorption (1.44 g/g to 1.48 g/g), and an increase in swelling capacity (5.95 g/g to 6.38 g/g). Inclusion of moringa in cocoyam flour increased the texture (6.83), appearance (6.80), aroma (7.00), taste (6.60), and overall acceptability (6.86) of the dough. Bacterial count decreased from 190×10⁻¹ cfu/g to 16×10⁻¹ cfu/g while fungi count decreased from 101×10⁻¹ cfu/g to 14×10⁻¹ cfu/g during storage. There was a significant increase ($p < 0.05$) in sodium, magnesium, calcium, and potassium.

Conclusion: The enhanced samples are safe, stable, and dough made from 15% moringa inclusion was most acceptable and recommended.

Keywords: Cocoyam, Moringa, Enrichment, Evaluation, Storage stability

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INTRODUCTION

The issue of micronutrient deficiencies, or "hidden hunger," which impacts millions of people globally, particularly in poor nations, may be effectively and sustainably addressed by food fortification. Food enrichment involves increasing

the concentration of one or more essential nutrients to higher-than-normal levels and adding them to the diet to prevent and treat nutritional deficiencies in the general public or in certain demographic groups. Food products enriched with organic materials (fruits, grains, etc.) are

among the best ways to increase overall nutritious consumption with minimal side effects, according to nutritionists. However, it seems that compliance notes regarding the production of fortified foods are essential for safeguarding consumer health and guaranteeing that the substance is not harmful [1]. The necessity of high-quality and safe food has led to a greater focus on consumer health. However, the acceptability, importation, and usage of fortified foods are increasing due to vitamin deficits in human societies, particularly throughout critical phases of development [2].

Cocoyam belongs to the group of monocotyledonous plants called *Araceae*, or *Aroids*, which are grown and eaten in tropical and subtropical regions. *Xanthosoma sagittifolium* (L.) Schott and *Colocasia esculenta* (L.) Schott are the two most significant genera for food production. These are annual crops, although they are perennial herbaceous plants. Cocoyam offers nutritional advantages over other tuber crops, and the root is superior to cassava and yams in terms of nutrition [3]. Compared to other roots and tubers, cocoyam has higher crude protein content, and its starch is more digestible. Though less prestigious than yams, cocoyam is utilized in the same ways. Certain cultivars are used to make fufu by boiling, frying, or pounding them, while other cultivars are used to thicken soups. Post-harvest use of cocoyam is still restricted despite its clear benefits over roots and other tubers, since not much study or work has been done to increase its utility to humans [4]. More than 60% of the continent's total output originates from the west and central regions, mainly Nigeria, Ghana, and Cameroon. Africa is the world's top producer [5]. Therefore, it is impossible to overestimate the importance of cocoyam to regional food security. *Xanthosoma sagittifolium* has been overlooked in agricultural research and policy projects on root and tuber crops, despite having superior storability and greater output levels compared with other tropical root and tuber crops. Falade and Okafor [6], production levels are dropping in Ghana and Cameroon, making it an underused food resource.

Moringa oleifera is sometimes referred to as the tree of life or the miraculous plant. The therapeutic and nutritional qualities of the moringa plant give rise to its name. This plant is indigenous to the sub-Himalayan areas of Afghanistan, Pakistan, Bangladesh, and India. Out of the 13 species in the *Moringaceae* family, *Moringa oleifera* is mostly grown because it is

highly nutritious and has a variety of uses [7]. This wonder tree has nearly every aspect that is highly beneficial. Forage is made from leaves, gum is made from tree trunks, honey is made from flower nectar, and water is purified using powdered seeds. *Moringa oleifera* leaf is a substitute food item that has been utilized in the battle against malnutrition, especially in young children and babies. There is a claim that *Moringa oleifera* leaves are rich in vitamins A, C, and E. Significant levels of proteins, calcium, potassium, magnesium, iron, manganese, and copper are also present in *M. oleifera* leaves. Phytonutrients such as carotenoids, tocopherols, and ascorbic acid are also abundant in the leaves [8, 9]. In the context of a well-balanced diet, these nutrients have the potential to suppress immunity and scavenge free radicals. However, cocoyam is low in protein and other essential nutrients, and its consumption alone cannot meet the daily nutritional requirements of individuals. This makes it imperative to enrich cocoyam with *Moringa oleifera* seed powder, a functional ingredient that can enhance its nutritional value. The aim of this work is to evaluate the quality and sensory acceptability of cocoyam (*Xanthosoma sagittifolium*) flour enriched with *Moringa oleifera* seed powder.

MATERIALS AND METHODS

Materials

Raw cocoyam corms (*Xanthosoma sagittifolium*) were purchased from Ota Main Market, situated in Ota, Ogun State, Nigeria, and *Moringa oleifera* seeds were purchased from Supermart E-commerce, Lagos State, Nigeria. They were taken to the food processing laboratory, Bell University of Technology, Ota, Nigeria, for further processing. The cocoyam was washed, peeled, and washed again. It was carefully cut into 3 to 4 cm-thick discs and dried in a hot air oven at a temperature of 65°C for 9 hours. It was then milled into flour using a double-disc attrition milling machine and sieved. *Moringa oleifera* seeds were manually extracted from the seed kernels and dried in a cabinet dryer at 60°C for 5 days. The dried seeds were milled to obtain fine powder using a clean Marlex blender and then sieved with a mesh size of 0.8 mm.

Preparation of flour blends

Four different blends of cocoyam flour and *Moringa oleifera* seed powder were formulated as described by Aruna et al. [10]. The formulations are as follows: 95:5, 90:10, 85:15, and 80:20, respectively, while 100% cocoyam flour was used as a control experiment.

Determination of proximate composition

Proximate composition: moisture content, total ash, crude protein content, crude fat, crude fiber, and carbohydrate content of the samples were evaluated using the standard method by AOAC [11].

Determination of mineral composition

Mineral composition of the samples in terms of sodium, calcium, magnesium, potassium, iron, and zinc was determined using an atomic absorption spectrophotometer described by Nilusha et al. [12]. Each of the samples was digested with concentrated nitric acid and perchloric acid before being analyzed with an atomic absorption spectrophotometer and flame photometer. The mineral content was expressed as milligrams per 100 grams of the sample.

Determination of functional properties

Bulk density: The bulk density was determined using the method described by Makinde and Eytayo [13]. A known weight of the sample (50 g) was poured into a 100 ml measuring cylinder, and the volume occupied by the sample was recorded. The bulk density was then calculated as the weight of the sample divided by its volume.

Water absorption capacity: The water absorption capacity was determined using the method described by Makinde and Eytayo [13]. A known weight of the sample (2 g) was added to 20 ml of distilled water in a centrifuge tube and allowed to stand for 30 minutes. The mixture was then centrifuged at 2000 rpm for 15 minutes, and the supernatant was decanted. The water absorption capacity was calculated as the weight of the water absorbed by the sample divided by the weight of the sample.

Swelling capacity: The swelling capacity was determined using the method described by Millar et al. [14]. A known weight of the sample (2 g) was added to 20 ml of distilled water in a centrifuge tube and allowed to stand for 30 minutes. The mixture was centrifuged at 2000 rpm for 15 minutes, and the volume of the swollen sample was recorded. The swelling capacity was calculated as the volume of the swollen sample divided by the weight of the sample.

Determination of microbial analysis

Microbial analysis was done to determine microbial stability of cocoyam and *Moringa oleifera* flour blends over a period of 4 weeks using the method described by Oladeji et al. [15].

Total bacterial count: To determine bacterial count, 100 ml of distilled water was used to homogenize one (1) g of the sample. To get the 10⁻¹ dilution, 1 ml of food homogenate was combined with 9 ml of sterile diluents in a test tube. The diluent's composition was 10-2 and 10-3. The total viable count of bacteria was ascertained by counting these forming units (cfu) by pouring plating on nutrient agar and cultivating at 37 °C for 48 hours. Using a colony counter, the number of colony-forming units on each plate was determined and expressed as cfu/g.

Total fungal count: By pour-plating potato dextrose agar plates supplemented with 1% tetracycline to suppress the growth of bacteria, the total number of fungi was counted. The plates were incubated at room temperature (30°C) for two days, and the number of colonies was indicated as cfu/g.

Preparation of swallowable dough

Production of swallowable dough made from the flour blends began by filling a large pot with 300 cl of water and placing it over medium heat. Water was allowed to come to a rolling boil, which typically means large bubbles consistently breaking the surface. A separate bowl was made with 2 kg of composite flour and cold water to form a homogenous mixture. The flour mixture was carefully added to the boiling water in the pot. It's important to do this gradually while continuously stirring with a wooden spatula or a whisk to prevent any lumps from forming. During this process, the heat was reduced as the stirring continued vigorously. The dough cooks and thickens significantly, and this process usually takes about seven to ten minutes. The dough was folding and tossing until it achieved a smooth, cohesive consistency that pulls away from the edges of the pot. Once the dough was prepared, it was allowed to cool, wrapped in transparent polytene material, and presented for sensory evaluation.

Evaluation of sensory attributes

A panel of untrained assessors rated the samples using a 9-point hedonic scaling, where point "9" indicated extreme likeness and point "1" indicated extreme dislike, to examine sensory acceptance of the swallowable dough. A panel of 20 judges, comprised of males and females between the age bracket of 20 to 60 years from Bells University of Technology, Ota, Nigeria, was used. Each coded sample was presented to panelists in random order to taste and thereafter

rinsing their mouths. The following attributes were considered: texture, appearance, aroma, taste, and overall acceptability.

Statistics analysis

Analysis of variance (ANOVA) was used for the data obtained, and means were separated using Duncan's multiple range test. SPSS design software version 24 was employed at a significant level of $P < 0.05$.

RESULTS

Proximate composition

The result of proximate composition of the samples presented in Table 1 showed decrease in moisture content (9.64% to 8.07%), increase in protein (4.07% to 5.64%), increase in crude fiber (1.45% to 3.80%), increase in crude fat (1.35% to 10.14%), and decrease in carbohydrate content

(80.38% to 69.24%) as moringa powder inclusion increased. However, ash content was significantly increased ($p < 0.05$). The control sample showed low moisture (7.20%), low ash (0.50%), low protein (3.28%), low fiber (1.42%), low fat (1.00%), and high carbohydrate content (86.60%).

Functional property

The functional properties of cocoyam flour enriched with moringa seed powder as shown in Table 2, revealed that bulk density decreased (0.71 g/cm^3 to 0.56 g/cm^3), water absorption capacity increased (1.44 g/g to 1.48 g/g), and swelling capacity increased (5.95 g/g to 6.38 g/g) as moringa powder increased. The control sample showed low bulk density (0.41 g/cm^3), high water absorption (2.00 g/g), and low swelling capacity 2.95 g/g).

Table 1: Proximate composition of cocoyam flour enriched with moringa seed powder blends

Samples	Moisture content (%)	Ash content (%)	Protein content (%)	Crude fiber content (%)	Crude fat content (%)	Carbohydrate content (%)
CC-A	7.20 ^a ±0.40	0.50 ^c ±0.04	3.28 ^c ±0.02	1.42 ^d ±0.06	1.00 ^a ±0.10	86.60 ^{bc} ±0.09
CMC-B	9.64 ^b ±0.25	3.11 ^a ±0.13	4.07 ^a ±0.10	1.45 ^e ±0.10	1.35 ^a ±0.05	80.38 ^a ±0.03
CMC-C	8.75 ^b ±0.20	3.18 ^{ab} ±0.13	4.54 ^b ±0.08	1.63 ^b ±0.03	3.86 ^{bc} ±0.25	78.04 ^c ±0.04
CMC-D	8.18 ^b ±0.10	3.06 ^{bc} ±0.30	5.08 ^{bc} ±0.05	2.08 ^c ±0.04	6.25 ^{ab} ±0.61	75.35 ^b ±0.09
CMC-E	8.07 ^b ±0.07	3.11 ^{bc} ±0.13	5.64 ^{ab} ±0.04	3.80 ^{ab} ±0.08	10.14 ^c ±0.10	69.24 ^{ab} ±0.05

Values are the means \pm of the SD of duplicate readings. Values with different superscripts within the same column are statistically different. ($p < 0.05$).

CC-A, Control experiment (100% cocoyam flour); CMC-B (95% Cocoyam flour and 5% moringa seed powder); CMC-C (90% Cocoyam flour and 10% moringa seed powder); CMC-D (85% Cocoyam flour and 15% moringa seed powder); CMC-E (80% Cocoyam flour and 20% moringa seed powder).

Table 2: Functional properties of cocoyam flour enriched with moringa seed powder blends

Samples	Bulk density (g/cm^3)	Water absorption capacity (g/g)	Swelling capacity (g/g)
CC-A	0.41 ^a ±0.09	2.00 ^{bc} ±0.17	2.95 ^a ±0.13
CMC-B	0.71 ^{ab} ±0.20	1.44 ^c ±0.07	5.95 ^c ±0.10
CMC-C	0.66 ^{bc} ±0.23	1.45 ^a ±0.04	6.15 ^{ab} ±0.03
CMC-D	0.67 ^b ±0.12	1.47 ^b ±0.04	6.34 ^c ±0.11
CMC-E	0.56 ^c ±0.14	1.48 ^{ab} ±0.12	6.38 ^{bc} ±0.08

Values are the means \pm of the SD of duplicate readings. Values with different superscripts within the same column are statistically different. ($p < 0.05$).

CC-A, Control experiment (100% cocoyam flour); CMC-B (95% Cocoyam flour and 5% moringa seed powder); CMC-C (90% Cocoyam flour and 10% moringa seed powder); CMC-D (85% Cocoyam flour and 15% moringa seed powder); CMC-E (80% Cocoyam flour and 20% moringa seed powder).

Mineral composition

The mineral composition of cocoyam-moringa seed composite flour presented in Table 3 showed that as moringa increased, sodium significantly decreased (3.65 mg/100g to 0.42 mg/100g), magnesium increased (2.06 mg/100g to 3.29 mg/100g), calcium decreased (5.11 mg/100g to 4.81 mg/100g), iron decreased (0.94 mg/100g

to 0.89 mg/100g), potassium decreased (39.2 mg/100g to 28.8 mg/100g), and zinc decreased (0.66 mg/100g to 0.53 mg/100g). The control sample showed 1.85 mg/100g sodium, 1.31 mg/100g magnesium, 2.85 mg/100g calcium, 1.15 mg/100g iron, 15 mg/100g potassium, and 0.75 mg/100g zinc.

Table 3: Mineral composition of cocoyam flour enriched with moringa seed powder blends

Samples	Sodium (mg/100g)	Magnesium (mg/100g)	Calcium (mg/100g)	Iron (mg/100g)	Potassium (mg/100g)	Zinc (mg/100g)
CC-A	1.85 ^{ac} ±0.04	1.31 ^{ab} ±0.11	2.85 ^b ±0.22	1.15 ^a ±0.10	15 ^{bc} ±0.22	0.75 ^c ±0.08
CMC-B	3.65 ^c ±0.12	2.06 ^a ±0.15	5.11 ^c ±0.18	0.94 ^{ab} ±0.05	39.2 ^b ±0.38	0.66 ^b ±0.07
CMC-C	0.24 ^a ±0.06	2.01 ^d ±0.20	3.29 ^a ±0.20	0.71 ^c ±0.07	26.5 ^a ±0.28	0.36 ^a ±0.06
CMC-D	0.36 ^b ±0.08	2.99 ^b ±0.19	4.64 ^d ±0.17	0.84 ^b ±0.09	28.2 ^d ±0.30	0.48 ^{ab} ±0.06
CMC-E	0.42 ^{bc} ±0.02	3.29 ^c ±0.16	4.81 ^{ab} ±0.20	0.89 ^d ±0.09	28.8 ^c ±0.32	0.53 ^{bc} ±0.07

Values are the means \pm of the SD of duplicate readings. Values with different superscripts within the same column are statistically different. ($p < 0.05$).

CC-A, Control experiment (100% cocoyam flour); CMC-B (95% Cocoyam flour and 5% moringa seed powder); CMC-C (90% Cocoyam flour and 10% moringa seed powder); CMC-D (85% Cocoyam flour and 15% moringa seed powder); CMC-E (80% Cocoyam flour and 20% moringa seed powder).

Storage stability

As indicated in Table 4, no growth was detected in agar plates for aerobic mesophilic bacteria count and potato dextrose agar plates for fungi count during week 0. Week 1 of the microbial analysis during storage revealed that the total viable count of the flour blends under ambient storage conditions, the counts of bacteria decreased from 190 cfu/g in CC-B to 80 cfu/g in

CMC-E, while the fungi count decreased from 101 cfu/g in CMC-C to 70 cfu/g in CMC-E. As moringa seed powder increased, bacterial and fungal counts decreased from 125 cfu/g to 50 cfu/g and 70 cfu/g to 50 cfu/g, respectively in Week 2; from 80 cfu/g to 32 cfu/g and 42 cfu/g to 30 cfu/g, respectively in Week 3; and from 42 cfu/g to 16 cfu/g and 24 cfu/g to 14 cfu/g, respectively in Week 4.

Table 4: Microbial count of cocoyam flour enriched with moringa seed powder blends under ambient conditions

Week	(cfu/g) $\times 10^{-1}$	Samples				
		CC-A	CMC-B	CMC-C	CMC-D	CMC-E
0	Bacteria	Nil	Nil	Nil	Nil	Nil
	Fungi	Nil	Nil	Nil	Nil	Nil
1	Bacteria	140 ^c ±0.10	190 ^{bc} ±0.10	180 ^{ab} ±0.25	134 ^b ±0.08	80 ^a ±0.04
	Fungi	60 ^b ±0.10	101 ^a ±0.20	91 ^{ac} ±0.30	90 ^{ab} ±0.20	70 ^c ±0.20
2	Bacteria	90 ^c ±0.10	125 ^{ab} ±0.21	105 ^{bc} ±0.10	88 ^a ±0.10	50 ^b ±0.20
	Fungi	40 ^{ac} ±0.10	70 ^a ±0.20	60 ^c ±0.30	70 ^{ab} ±0.20	50 ^b ±0.20
3	Bacteria	50 ^a ±0.10	80 ^{bc} ±0.20	66 ^{ab} ±0.15	54 ^b ±0.08	32 ^c ±0.30
	Fungi	25 ^{bc} ±0.10	42 ^{ab} ±0.30	32 ^b ±0.25	50 ^c ±0.15	30 ^a ±0.55
4	Bacteria	24 ^{bc} ±0.10	42 ^b ±0.50	24 ^{ab} ±0.25	24 ^c ±0.07	16 ^a ±0.04
	Fungi	15 ^c ±0.10	24 ^{ab} ±0.30	14 ^b ±0.25	30 ^{bc} ±0.15	14 ^a ±0.55

Values are the means \pm of the SD of duplicate readings. Values with different superscripts within the same column are statistically different. ($p < 0.05$).

CC-A, Control experiment (100% cocoyam flour); CMC-B (95% Cocoyam flour and 5% moringa seed powder); CMC-C (90% Cocoyam flour and 10% moringa seed powder); CMC-D (85% Cocoyam flour and 15% moringa seed powder); CMC-E (80% Cocoyam flour and 20% moringa seed powder).

Sensory evaluation

Figure 1 shows the sensory attributes of cocoyam-moringa seed swallowable dough. Sample CMC-B showed 6.2 texture, 6.4 appearance, 6.5 aroma, 6.6 taste, and 6.43 overall acceptability; sample CMC-C showed 6.4 texture, 6.6 appearance, 6.93 aroma, 6.6 taste, and 6.63 overall acceptability; CMC-D showed 7.03 texture, 6.8 appearance, 7 aroma, 6.6 taste, and 6.86 overall acceptability; CMC-E showed 6.83 texture, 6.57 appearance, 6.83 aroma, 6.4 taste, and 6.66 overall acceptability. However, the control sample showed 6.0 texture, 6.03

appearance, 6.4 aroma, 5.8 taste, and 6.06 overall acceptability. Product made from cocoyam flour alone (control experiment), as shown in CC-A sample, showed the lowest rating of all attributes by the panelists. This is characterized by dark color with a rough surface, as shown in Figure 2. The product surface became smoother with the addition of moringa seed, as shown in CMC-B, CMC-C, CMC-D, and CMC-E doughs. This suggests that the sensory appeal of the products was positively influenced by the inclusion of *Moringa oleifera* seed, thus enhancing overall consumers' preference.

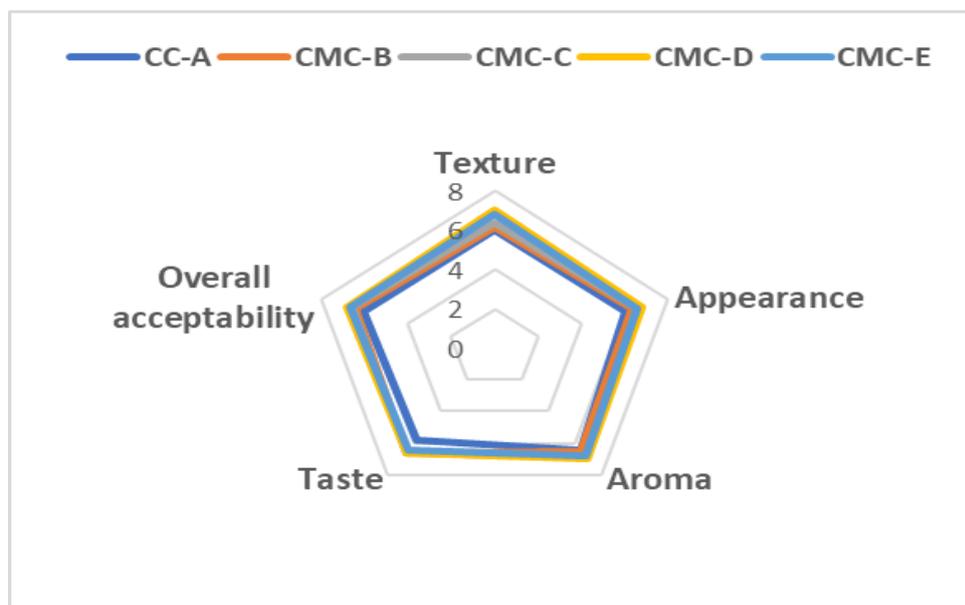


Figure 1: Sensory attributes of swallowable dough made from cocoyam-moringa composite flour

CC-A, Control experiment (100% cocoyam flour); CMC-B (95% Cocoyam flour and 5% moringa seed powder); CMC-C (90% Cocoyam flour and 10% moringa seed powder); CMC-D (85% Cocoyam flour and 15% moringa seed powder); CMC-E (80% Cocoyam flour and 20% moringa seed powder).

DISCUSSION

Moisture content decreased as moringa seed powder increased. Moringa seeds are hydrophilic and have the potential to absorb and retain water. When utilized in culinary items, it enhances the stability and texture of the product [16]. Ash is an inorganic residue and an indication of minerals present in food. Moringa seed powder increased the ash content of the samples significantly ($p < 0.05$), showing a tendency for minerals that are essential for a variety of physiological activities in the human body, such as bone health, muscular function, and metabolic processes. Besides, at 5% inclusion of moringa, the geometric increase in potassium (39.2 mg/100g) was not replicated in other samples with higher substitutions. At 5% level of significance, protein content, crude fiber, and crude fat increased significantly as moringa seed powder increased. However, the protein content of the samples is in variance with the protein content (6.44% to 7.61%) reported by Jimoh and Akinkurolere [17] from wheat-tiger nut composite flour blends. Moringa seeds contain soluble and insoluble fiber, which helps in digestion, encourages regular bowel movement, and reduces constipation [18]. High fiber consumption has been linked to a variety of health advantages, including improved blood sugar management, lower cholesterol levels, and lower risk of

cardiovascular disease [19]. This makes enriched flour samples especially useful for individuals at risk of a dietary fiber deficit. Increase in crude fat content with increasing moringa seed powder could be a result of high lipid content of moringa seeds, which are abundant in antioxidants, vitamins A and C, and unsaturated fatty acids, especially oleic acid [20]. Cocoyam is predominantly composed of carbohydrates and sugars. Apparently, as the percentage of cocoyam reduces, the carbohydrate content decreases. This drop in carbohydrate content may have an impact on energy density, especially in people who rely largely on cocoyam as a predominant meal.

Bulk density measures the heaviness of flour relative to its volume and influences its packaging, transportation, and handling properties. The light and airy texture of cocoyam flour is characterized by its lower value. Sample CMC-B exhibited the highest bulk density, showing 5% moringa seed powder inclusion with optimum interaction for heavy composite flour. Beyond 5% inclusion, bulk density decreases. Cocoyam flour absorbs more water, as shown in the control sample, and this may be due to its high fiber and carbohydrate content, forming a gel when mixed with water. Water absorption capacity of the samples is closely related to the

result of water absorption index (1.94 to 2.72) reported by Obadina et al. [21] on quality changes in cocoyam flours during storage. However, there was a significant difference in bulk density and water absorption capacity among samples ($p < 0.05$). Research findings showed that cocoyam flour has lower swelling capacity because its starch gelatinizes in water [22]. The swelling capacity of the enriched composite flour

increased significantly as moringa seed powder increased. Investigation by Ikuemonisan et al. [23] suggested that when protein in moringa seed flour is heated with starch-based flour, the protein in moringa seed holds water within the starch mixture, thereby increasing swelling capacity. Besides, fiber in the seed serves as a supporting tool to retain more water to facilitate swelling.



Figure 2: Swallowable dough made from cocoyam-moringa composite flour

CC-A, Control experiment (100% cocoyam flour); CMC-B (95% Cocoyam flour and 5% moringa seed powder); CMC-C (90% Cocoyam flour and 10% moringa seed powder); CMC-D (85% Cocoyam flour and 15% moringa seed powder); CMC-E (80% Cocoyam flour and 20% moringa seed powder).

Sample CMC-B showed the highest concentration of sodium, calcium, iron, potassium, and zinc, while sample CMC-C showed the lowest concentration of sodium, magnesium, calcium, iron, potassium, and zinc. This further confirms 5% moringa seed inclusion in cocoyam-moringa seed composite flour for its quality characteristic behavior for optimum performance. There was a significant difference in mineral composition of the samples ($p < 0.05$). This result is closely related to the findings for zinc and iron (0.40 mg/100g to 1.92 mg/100g and 0.70 mg/100g to 1.30 mg/g, respectively) reported by Olayiwola et al. [22] from cocoyam-enriched food products.

The significant decrease at 5% level of significance in bacterial and fungal counts during

ambient storage conditions of the samples, as moringa seed powder inclusion increases, follows the same trend, and this depicts anti-microbial attributes of the seed. It is also important to note that microbial counts also decreased as the storage period increased, indicating that the storage condition did not cause substantial growth and did not affect microbial stability of the enriched samples. This could be a result of low moisture content in the samples achieved during drying. However, the bacterial and fungal count obtained in this work were within the acceptable aerobic count in the food product guideline. microbial growth recommended globally in ready-to-eat food products is $< 10^6$ cfu/g [17].

Swallowable dough made from cocoyam flour fortified with moringa seed powder showed that the values for the texture, appearance, aroma, and overall acceptability increased significantly as moringa seed inclusion increased up to 15% as shown in CMC-B, CMC-C, and CMC-D samples. However, the taste of these samples remains the same, showing that the characteristic changes that occurred do not affect the product's taste. This could be a result of the effectiveness of the mixer during blends. Thus, the perceptible scent of the flour blends was likely achieved by enhancement with moringa seed. At 20% inclusion, sensory attributes decreased significantly, showing consumers' dislike.

CONCLUSION

Enrichment of cocoyam flour with *Moringa oleifera* seed powder improves its nutritional value, functional properties, boosts food security, alleviates micronutrient shortage, and palatability of the product. Bacterial and fungal counts significantly decreased in all samples over the storage period under ambient conditions. This suggests that the nutrient profile of *Moringa oleifera* seed powder creates an unfavorable environment for microbial proliferation. However, the microbiological growth was within internationally acceptable microbial limits for ready-to-eat flour products. From the assessors' point of view, swallowable dough made from cocoyam fortified with 15% moringa (CMC-D) was most preferred by the panelists and therefore, recommended. Future collaboration with local farmers and research institutes to encourage the development of viable varieties of cocoyam and *Moringa oleifera*, providing a sustainable supply chain and boosting local economies.

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