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Research Article

Comparative Study on the Effect Of Processing Methods on the Mineral Composition and Functional Properties of Two Varieties of Cocoyam (*Colocasia esculenta* and *Xanthosoma sagittifolium*) Flour

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Abstract

This study was carried out to comparatively evaluate the effect of different processing methods: oven drying and sun drying, on the mineral elements composition and functional properties of two varieties of cocoyam: *Colocasia esculenta* and *Xanthosoma sagittifolium*. Fresh cocoyam tubers from both *Colocasia esculenta* and *Xanthosoma sagittifolium* varieties were processed into flour, the mineral content and functional properties of flour samples were determined using standard laboratory procedures. Results obtained indicate that mineral composition of oven-dried *Colocasia esculenta* sample were 28.53mg/100g calcium, 615.97mg/100g potassium, 32.87mg/100g magnesium, 87.47mg/100g phosphorus and 1.35mg/100g iron. Oven-dried *Xanthosoma sagittifolium* sample had 23.03mg/100g calcium, 529.13mg/100g potassium, 24.03mg/100g magnesium, 79.31mg/100g phosphorus and 0.979mg/100g iron. Sun-dried *Colocasia esculenta* sample recorded 34.33mg/100g calcium, 691.00mg/100g potassium, 36.57mg/100g magnesium, 81.37mg/100g phosphorus and 1.70mg/100g iron. Sun-dried *Xanthosoma sagittifolium* sample had 28.49mg/100g calcium, 618.10mg/100g potassium, 32.97mg/100g magnesium, 84.70mg/100g phosphorus and 1.45mg/100g iron. Functional properties of oven-dried *Colocasia esculenta* were 2.300 g/ml water absorption capacity, 1.400 g/ml oil absorption capacity, 0.793 g/ml bulk density, 10.60% swelling power and 169.467 m^2/s. Oven-dried *Xanthosoma sagittifolium* had 1.933 g/ml water absorption capacity, 1.267 g/ml oil absorption capacity, 0.630 g/ml bulk density, 9.70% swelling power and 172.967 m^2/s viscosity. Sun-dried *Colocasia esculenta* sample recorded 2.577 g/ml water absorption capacity, 1.883 g/ml oil absorption capacity, 0.740 g/ml bulk density, 6.40% swelling power and 164.633 m^2/s viscosity. Sun-dried *Xanthosoma sagittifolium* had 2.370 g/ml water absorption capacity, 1.767 g/ml oil absorption capacity, 0.74 g/ml bulk density, 6.40% swelling power and 151.37 m^2/s viscosity. Statistical significance was adjudged at $p < 0.05$. Processing method significantly alters the final profile, indicating that value addition to cocoyam must be species- and application specific. There is no single best method; rather, the choice depends on whether the priority is maximizing mineral content (favouring sun drying) or achieving high viscosity/swelling (favouring oven drying for *Colocasia esculenta*).

Keywords: Processing Methods; Functional Properties; Mineral Composition; Cocoyam Flour; Oven Drying; Sun Drying

Introduction

Cocoyam is a tropical root crop that has gained increasing attention due to its nutritional value, functional applications, and potential role in food security and industrial uses. It belongs to the family *Araceae*, and the two most widely cultivated edible species are *Colocasia esculenta* (commonly known as taro) and *Xanthosoma sagittifolium* (tannia or new cocoyam). These crops are especially important in sub-Saharan Africa, Asia, and the Pacific Islands, where they serve as a major staple food and a source of income for rural households [1]. Cocoyam is highly valued for its digestibility, hypoallergenic properties, and richness in carbohydrates, dietary fibre, and essential minerals such as calcium, magnesium, phosphorus, potassium, and iron. The starch content of cocoyam is known to be fine-grained and easily digestible, making it suitable for infant foods, the elderly, and people with digestive disorders [2]. Furthermore, the mucilage present in cocoyam contributes to its unique textural and functional characteristics, such as thickening and binding, which are desirable in food formulations [3].

Cocoyam is a valuable source of essential minerals necessary for human health. It contains significant amounts of potassium, calcium, magnesium, phosphorus, iron, and zinc, which play critical roles in metabolic functions, bone health, oxygen transport, and enzyme activity [4]. Potassium, for instance, contributes to the regulation of blood pressure and nerve transmission, while magnesium and calcium are important for muscle function and skeletal strength. Among the two major species, *Xanthosoma sagittifolium* generally exhibits a slightly higher concentration of minerals, especially calcium and magnesium, making it more nutritionally advantageous in some diets [5].

The mineral composition of cocoyam further enhances its nutritional value. Cocoyam is a good source of potassium, which plays a vital role in maintaining normal blood pressure and cardiovascular health. It also contains calcium and phosphorus, which are essential for bone and teeth development, and magnesium, which is involved in energy metabolism, nerve transmission, and muscle function. Additionally, trace elements such as iron and zinc are present in measurable quantities and contribute to blood formation and immune system function [6].

Traditional processing methods such as boiling, roasting, drying, fermentation, and pounding are known to significantly influence the physicochemical characteristics and mineral bioavailability of root and tuber crops [5]. Processing, for instance, can reduce anti-nutritional factors such as oxalates and phytates in cocoyam, which are known to interfere with mineral absorption [5]. However, it may also lead to the leaching of water-soluble nutrients and thermal degradation of sensitive minerals during cooking or drying [7]. Moreover, the method of processing directly impacts the functional properties of cocoyam flour such as water absorption capacity, swelling index, bulk density, and gelatinization behaviour which determine its suitability for different food products [8].

Drying techniques (sun, oven, or freeze-drying) reduce moisture content, enhance storability, and allow for flour production. However, high drying temperatures can affect functional properties like swelling capacity and water absorption [4]. According to Umoh and Iwe [9], processing reduces the level of mineral elements in the processed false yam samples.

Several studies have suggested that the functional and nutritional qualities of tubers can be optimized by selecting appropriate processing techniques [4]. However, there is a paucity of comprehensive comparative data on the effects of different processing methods on the functional properties and mineral composition of the two cocoyam species. This knowledge gap hinders effective value addition and utilization of cocoyam as a functional food ingredient or an industrial starch source.

However, there is insufficient data comparing how these processing methods affect the two cocoyam varieties. This knowledge gap hinders optimal utilization and value addition.

The aim of this study is to comparatively evaluate the effects of different processing methods, namely; oven drying and sun drying, on the mineral composition and functional properties of two cocoyam varieties (*Colocasia esculenta* and *Xanthosoma sagittifolium*).

Materials and Methods

Sample collection and preparation

Fresh cocoyam tubers from both *Colocasia esculenta* and *Xanthosoma sagittifolium* varieties were obtained from Ukam market in Mkpat Enin Local Government Area, Akwa Ibom State, Nigeria. The tubers were chosen for consistent size and ripeness levels and were carefully rinsed to eliminate any soil or contaminants. The tubers were subjected to manual peeling to strip away the outer layers, resulting in the consumable parts prepared for subsequent handling.

The peeled cocoyam tubers were processed into flour using two drying methods: oven drying and sun drying.

Portions of the peeled tubers were dried in an electric oven set at 60°C for 12 hours until a constant weight was achieved.

Other portions of the peeled tubers were spread in a single layer on clean trays and allowed to dry naturally under direct sunlight until moisture equilibrium was reached.

The dried cocoyam products from both methods were ground into fine flour using a mechanical grinder. The resulting flour from each treatment was sieved using a mesh (0.55mm) to ensure uniformity before storage in airtight containers pending analysis.

Analysis of mineral composition

The mineral elements content of the processed cocoyam flours was determined using standard laboratory procedures, as described by Umoh and Iwe [9].

- **Sample digestion**: The dried and ground sample was subjected to wet digestion using a mixture of concentrated nitric acid (HNO_3) and hydrochloric acid (HCl) in a digestion chamber. The mixture was heated progressively until a clear, colourless solution was obtained, indicating complete sample dissolution. The resulting digest was filtered and diluted to a fixed volume with de-ionized water for analysis.
- **Mineral quantification:** The prepared digests were analyzed for their content of calcium (Ca), magnesium (Mg), potassium (K), and iron (Fe) using an Atomic Absorption Spectrophotometer (AAS). Standard curves were prepared to facilitate accurate quantification of the minerals in both Colocasia esculenta and Xanthosoma sagittifolium samples.

Determination of functional properties

The functional properties of the prepared cocoyam flours were evaluated using the methods described by Onwuka [10] as follows:

- **Bulk density:** Bulk density was determined by tapping a known weight of flour into a graduated cylinder until a constant volume was achieved. The bulk density was calculated as the mass of the flour divided by its occupied volume (g/ml).
- **Water absorption capacity (WAC):** WAC was measured by mixing 1g of flour with a known volume of distilled water. After allowing the mixture to stand for 30 minutes, the supernatant was centrifuged, and the water retained by the flour was determined by calculating the difference in weight.
- **Oil absorption capacity (OAC):** OAC was determined by mixing 1g of flour with a known volume of edible oil. After settling for 30 minutes, the excess, unabsorbed oil was decanted after centrifugation, and the absorbed oil was calculated by weight difference.
- **Swelling power and solubility:** Swelling power and solubility were determined by dispersing a known weight of flour in distilled water, heating the slurry, and then cooling it. The final volume occupied by the swollen paste was measured to determine swelling power, while the supernatant after centrifugation was dried to measure solubility.
- **Viscosity:** The viscosity of standard slurry of the cocoyam flour was measured using a viscometer under controlled temperature and shear rate conditions to assess its flow behaviour.

Statistical/data analysis

The data obtained from the oven-dried and sun-dried samples were subjected to statistical analyses using ANOVA followed by Tukey's HSD test ($p < 0.05$).

Results and Discussions

The experimental data consisted of mineral content (calcium, potassium, magnesium, phosphorus, iron) and functional properties (water absorption capacity, oil absorption capacity, bulk density, swelling power, viscosity) for the two species of cocoyam processed by two methods (oven-dried and sun-dried), as presented in Table 1, 2 and Table 3, 4, respectively.

Effect of drying method on mineral content

The data presented in Tables 1 and 2 show that the drying technique employed had a substantial effect on mineral preservation, which in turn influences the ultimate nutritional quality of the cocoyam flour.

Mineral (mg/100g)	Oven-Dried (Mean ± SD)	Sun-Dried (Mean ± SD)	P-Value	Significant Finding
Calcium (Ca)	28.53 ±0.57	34.33±0.91	0.001	Sun-dried > Oven-dried
Potassium (K)	615.97 ± 4.08	691.00 ± 1.84	0.000	Sun-dried > Oven-dried
Magnesium (Mg)	32.87±0.25	36.57±0.61	0.001	Sun-dried > Oven-dried
Phosphorus (P)	87.47±0.65	81.37 ± 1.38	0.002	Oven-dried > Sun-dried
Iron (Fe)	1.35±0.15	1.70±0.06	0.020	Sun-dried > Oven-dried

Table 1: Mineral Content (mg/100g) for *Colocasia esculenta* based on Drying method.

Mineral (mg/100g)	Oven-Dried (Mean ± SD)	Sun-Dried (Mean ± SD)	P-Value	Significant Finding
Calcium (Ca)	23.03 ± 0.38	28.49 ± 0.57	0.415	Not Significant
Potassium (K)	529.13 ± 9.10	618.10 ± 4.48	0.000	Sun-dried > Oven-dried
Magnesium (Mg)	24.03 ± 0.20	32.97 ± 0.21	0.000	Sun-dried > Oven-dried
Phosphorus (P)	79.31 ± 1.16	84.70 ± 0.76	0.003	Sun-dried > Oven-dried
Iron (Fe)	0.977 ± 0.125	1.45 ± 0.132	0.011	Sun-dried > Oven-dried

Table 2: Mineral Content (mg/100g) for *Xanthosoma sagittifolium* based on Drying method.

Functional Property	Oven-Dried (Mean ± SD)	Sun-Dried (Mean ± SD)	P-Value	Significant Finding
WAC (g/ml)	2.300 ± 0.100	2.517 ± 0.076	0.041	Sun-dried > Oven-dried
OAC (g/ml)	1.400 ± 0.100	1.883 ± 0.076	0.003	Sun-dried > Oven-dried
Bulk density (g/ml)	0.793 ± 0.015	0.740 ± 0.027	0.039	Oven-dried > Sun-dried
Swelling power (%)	10.600 ± 0.100	6.400 ± 0.100	0.000	Oven-dried > Sun-dried
Viscosity (m^2/s)	169.467 ± 0.702	164.633 ± 0.666	0.001	Oven-dried > Sun-dried

Table 3: Functional properties for *Colocasia esculenta* based on Drying method.

Functional Property	Oven-Dried (Mean ± SD)	Sun-Dried (Mean ± SD)	P-Value	Significant Finding
WAC (g/ml)	1.933 ± 0.153	2.370 ± 0.036	0.009	Sun-dried > Oven-dried
OAC (g/ml)	1.267 ± 0.252	1.767 ± 0.042	0.027	Sun-dried > Oven-dried
Bulk Density (g/ml)	0.630 ± 0.010	0.740 ± 0.027	0.003	Sun-dried > Oven-dried
Swelling power (%)	9.700 ± 0.100	6.400 ± 0.100	0.000	Oven-dried > Sun-dried
Viscosity (m^2/s)	172.967 ± 0.208	151.37 ± 3.67	0.001	Oven-dried > Sun-dried

Table 4: Functional properties for *Xanthosoma sagittifolium* based on Drying method.

Overall patterns for macro-minerals (potassium and magnesium) revealed that, across both varieties (*Colocasia esculenta* and *Xanthosoma sagittifolium*), sun drying preserved considerably greater amounts of potassium (K) and magnesium (Mg) compared to oven drying, with statistical significance at $p < 0.001$ in most cases. However, high amount of calcium, potassium and magnesium have been reported to reduce blood pressure [9].

This aligns closely with prior research mentioned in the literature review, such as studies by Ukom., *et al.* [5] and Enwezor., *et al.* [7], which indicate that intense heat treatments like oven drying can cause the loss of water-soluble elements such as K through leaching or thermal breakdown. The gentler, lower-heat approach of sun drying proves more effective in maintaining these vital macro-minerals, recommending its use to enhance the nutritional advantages of cocoyam flour.

In line with the macro-minerals, sun drying typically resulted in markedly better preservation of calcium (Ca) and iron (Fe) in *Colocasia esculenta* (as shown in Table 1). For iron across both varieties, sun drying offered enhanced retention, probably by reducing oxidation or reactions triggered by excessive heat. However, for calcium in *Xanthosoma sagittifolium* (Table 2), the variation between the drying techniques was not statistically meaningful ($p = 0.415$). This might indicate that calcium within the *Xanthosoma* structure is less prone to heat-induced loss or leaching under the tested conditions, or that the variability among the three replicates was sufficient to obscure a difference, even with a mean gap of 2.46 mg/100g.

The result for Phosphorus is the most notable deviation. In *Colocasia esculenta* (Table 1), oven drying significantly increased the measured phosphorus content ($p = 0.002$). This contradicts the general trend for other minerals. This could be explained by the concentration effect during oven drying if the overall moisture loss was more pronounced than any actual loss of phosphorus, or perhaps due to the breakdown of phytate-P complexes during heating, making the phosphorus more extractable/measurable by the subsequent digestion method. In *Xanthosoma sagittifolium* (Table 2), the trend reversed with sun drying showing significantly higher level of phosphorus ($p = 0.003$), highlighting a potential species-specific response to thermal processing, as alluded to by Azeez and Madukwe [6].

Effect of drying method on functional properties

The impact of drying method on the functional properties, which determine the suitability of the flour for specific food applications, was pronounced (Tables 3 and 4).

- **Water and Oil Absorption capacity (WAC/OAC):** Sun drying consistently resulted in significantly higher WAC and OAC for both *Colocasia esculenta* and *Xanthosoma sagittifolium* ($p < 0.05$). This is crucial, as higher absorption capacities indicate superior quality for use in products like doughs, batters, and structured foods, allowing for greater moisture/fat retention and a desirable texture (Okafor and Ugwu, 2015). The less intense drying likely preserved the porous structure of the starch granules better than the more aggressive oven drying.
- **Swelling Power and Viscosity:** Conversely, oven drying yielded significantly higher swelling power and viscosity for *Colocasia esculenta* (Table 3), $p = 0.000$ for swelling power. This is a classic indication that severe heat treatment has caused extensive gelatinization or damage to the starch crystallites, leading to increased hydration potential (swelling) and intermolecular forces (viscosity). However, for *Xanthosoma sagittifolium*, the trend was mixed. Oven drying yielded significantly higher swelling power, but the viscosity difference was also significant in favour of oven drying (Table 4). This implies that while the starch structure of *Colocasia esculenta* is more easily disrupted by heat, leading to better swelling, both species react to oven drying in a way that increases viscosity, possibly due to the formation of more stable paste structures under rapid drying/high heat.
- **Bulk Density:** For *Colocasia esculenta* (Table 3), oven drying produced significantly denser flour, suggesting the heat caused greater compaction. However, for *Xanthosoma sagittifolium* (Table 4), sun drying resulted in significantly denser flour. This stark difference between species highlights the species-specific nature of cell wall structure and compaction behavior, directly impacting packaging and transportation costs. Low bulk density is desirable in infant feeding, while flours with high bulk density are used as thickeners in food products [11-13].

Conclusions

Based on the results/findings obtained, the following conclusions are drawn: The sun drying method is superior for mineral preservation in cocoyam flour, particularly for potassium, magnesium, calcium, and iron, making it the recommended technique for enhancing the nutritional profile of the processed products.

The functional properties are strongly dependent on the thermal intensity of the drying method. Sun-dried flour is better suited for applications requiring high water/oil binding (e.g., baked goods where moisture retention is key), whereas oven-dried flour (especially *Colocasia esculenta*) exhibits characteristics (higher swelling/viscosity) suitable for thickening agents in soups and porridges.

Colocasia esculenta is inherently richer in most essential minerals (Ca, K, Mg, Fe) and exhibits better water-holding and swelling characteristics than *Xanthosoma sagittifolium* across both drying methods studied.

Processing method significantly alters the final profile, indicating that value addition to cocoyam must be species- and application specific. There is no single best method; rather, the choice depends on whether the priority is maximizing mineral content (favouring sun drying) or achieving high viscosity/swelling (favouring oven drying for *Colocasia esculenta*).

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