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Geographic Variation in Nutritional Composition of Northern Nigerian Sweet Potato Varieties: Proximate, Vitamin (A, B_2), and Antinutrient Differences Among Zaria, Kano, and Minna Cultivars

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Abstract

The effects of some processing methods and environmental differences on the levels of nutrients and ant-nutrients in *Ipomoea batatas* were evaluated. From the findings, Fresh samples of *Ipomoea batatas* were obtained from Kano in Kano State, Minna in Niger State and Zaria in Kaduna state all in Nigeria. The samples were thoroughly washed separated with clean water, grated and divided into four portions for different processing; shade-drying, sun-drying, oven drying and 48-hour fermentation followed by shade-drying. The proximate, elemental and vitamin analysis were determined following the approved methods of AOAC. With the exception of the fermented sample which had significantly ($p<0.05$) lower crude protein in comparison to the shed-dried, there were no significant ($P>0.05$) changes in the proximate composition of *Ipomoea batatas* processed differently. Processing method did not significantly ($p>0.05$) affect the oxalate, tannins, nitrate, phytate and cyanide contents of *Ipomoea batatas*. However, oven-dried and fermented samples had significantly ($p<0.05$) lower trypsin contents when compared with shed-dried and sun-dried samples. The sun-dried sample of *Ipomoea batatas* had significantly ($p<0.05$) lower concentrations of Vitamin E compared to other samples. Levels of Vitamins A, B2, D, C and the studied minerals didn't significantly vary ($p>0.05$). Zaria specie had significantly ($p<0.05$) higher moisture, ash, lipid and Vitamin B2 compared with the Kano and Minna

species. There were no significant ($p>0.05$) differences in other proximate compositions between the Kano and Minna species of *Ipomoea batatas*. Kano specie had significantly ($p<0.05$) lower level of oxalate but higher trypsin compared with the other two species. On the other hand, tannins were significantly ($p<0.05$) lower in the Minna specie. Vitamins B6, D, C and E were not affected significantly ($p>0.05$) among the Zaria, Kano and Minna species. The levels of the studied minerals (Fe, Cu, Zn, Na, Mg, Ca, Ni, Co, and Pb) did not differ significantly ($p>0.05$) among the species. Shade-drying and oven-drying may be better in preserving the nutrients of *Ipomoea batatas than sun-drying and fermentation, and Zaria specie may be a better source of macronutrients and vitamins particularly of A and B 12*

Key Words: Sweet potato, Sun dried, Shed dried, Potato varieties, Cultivars, Nutritional.

Introduction

Sweet potato (*Ipomoea batatas*) is a highly nutritious food consumed globally. It is particularly rich in vitamin C and vitamin A (especially in orange-fleshed varieties), and serves as a valuable source of energy, fiber, vitamins B5 (pantothenic acid) and B6 (pyridoxine), and potassium.

Colored-fleshed sweet potatoes also contain bioactive compounds that promote health benefits (Sousa *et al*., 2019; Albuquerque *et al*., 2019).

A dicotyledonous plant from the bindweed or morning glory family (Convolvulaceae), the sweet potato is notable for its starchy, sweet-tasting tuberous roots, which are consumed as a root vegetable. It is unique as the only member of its family capable of producing such nutritious tuberous roots, making it the sixth most important food crop worldwide (Huaman *et al*., 1992; FAO, 2020).

The term "sweet potato" refers specifically to the tuberous roots of the plant. However, its name can sometimes cause confusion, leading to comparisons with the common potato (*Solanum tuberosum*). While the sweet potato is a tuberous root from the Convolvulaceae family, the potato is a tuber from the Solanaceae family. The word "potato" originates from the Arawak language, spoken by indigenous peoples of Central and South America, and was adopted by Spanish explorers to describe sweet potatoes. In South America, sweet potatoes are also called "camote," a term derived from the Nahuatl language of the Aztecs, while in Oceania, they are known as "kumara," a word from the Quechua language (Yen *et al*., 1963; Adelaar *et al*., 1996).

The origins and global spread of sweet potatoes remain topics of debate among researchers. The prevailing theory suggests that sweet potatoes originated in the Americas, particularly in Central and South America. Archaeological evidence from Peru indicates that sweet potatoes may have been consumed over 10,000 years ago (O'brien *et al*., 1972; Austin *et al*., 1988).

The spread of sweet potatoes from the Americas to other parts of the world is closely tied to historical maritime explorations. Christopher Columbus is credited with introducing sweet potatoes to Europe after collecting samples in Hispaniola (modern-day Santo Domingo) during his voyage to the New World. He presented them to the Spanish monarchs, Queen Isabella I of Castile and King Ferdinand II of Aragon, in 1493 (Kingsburry *et al*., 1992; Hawkes *et al*., 1993). Sweet potatoes thrive in marginal soils with minimal inputs and water, making them a resilient and productive crop. This adaptability has enabled their cultivation in over 100 countries (FAO, 2020; OECD, 2015). China is the leading producer, followed by several African and Asian nations, including Malawi, Minnaia, Ethiopia, India, Angola, and Uganda. In developing regions, particularly in Asia, Africa, and Latin America, sweet potatoes are a staple food. In Central and Sub-Saharan Africa, orange-fleshed sweet potatoes are especially important in combating hypovitaminosis A, a severe malnutrition issue (Denham *et al*., 2013).

In Brazil, sweet potato production faces challenges due to its low market value, with most harvests sold through basic food retail. However, Brazilian research institutions like EMBRAPA are investing in genetic improvement programs to develop cultivars suited to local soils, aiming to enhance productivity and nutritional quality (Rodrigues *et al*., 2016; Sousa *et al*., 2019).

Nutritionally, sweet potatoes are rich in fiber, vitamins, and minerals, and provide a significant energy source. Varieties with yellow, orange, and purple flesh contain bioactive compounds that offer additional health benefits (Albuquerque *et al*., 2019). Beyond direct consumption, sweet potatoes are used in various food products, including baked goods, sweets, starch, pasta, fermented preserves, nutritional and alcoholic beverages, soy sauce, and dairy products (Mu *et al*., 2017). They are also utilized in biofuel production (Lareo *et al*., 2019).

Sweet Potato Taxonomy and Morphology

The sweet potato (*Ipomoea batatas*) is a perennial plant from the Convolvulaceae family, widely recognized for its tuberous roots, which are utilized globally for various purposes. As a dicotyledonous angiosperm, it develops two cotyledons during germination and early growth, which help generate and store the energy required for the plant's development (Huaman *et al*., 1992).

The classification of plants has a long and extensive history, with numerous researchers contributing to various nomenclature systems. Examples include Species Plantarum (Linnaeus *et al*., 1753), the Hutchinson system (Hutchinson *et al*., 1973), the Takhtajan system (Takhtadzhian *et al*., 1997), the Angiosperm Phylogeny Group (APG) (2016), Wu Zhengyi (Zhou *et al*., 2016), and the Thorne system (Thorne *et al*., 1976). According to the APG system, which provides an updated classification of angiosperms, sweet potatoes belong to the Angiosperms clade, further branching into Eudicots, Superasterids, and Asterids. They are classified under the Lamiids class, Solanales order, and Convolvulaceae family (APG, 2016). The Convolvulaceae family, commonly known as the Morning Glory family due to its floral characteristics, is diverse and widespread. It primarily includes climbing plants, vines, or

shrubs, many of which produce roots, rhizomes, latex, and alkaloids. The flowers typically have a funnel shaped corolla with five fused petals and a calyx with five separate sepals. This family comprises approximately 59 genera and over 1,600 species (Buril *et al*., 2012).

Among the genera in the Convolvulaceae family, Ipomoea is the most prominent, encompassing more than 500 species (Singh, 2019). The sweet potato is the most significant representative of this genus, as it is the only species capable of producing nutritious and economically valuable tuberous roots, which are widely consumed and traded worldwide.

During growth, the sweet potato plant develops a creeping stem that lies prostrate on the ground, often rooting at the nodes where it contacts the soil. The stem is tender, flexible, and cylindrical, with a slightly flattened shape. It is primarily green but may also exhibit purple, violet, or reddish hues depending on the cultivar (Edmond *et al*., 1971). The stem's epidermis may be smooth or slightly hairy, featuring stomata for transpiration and gas exchange. The cortex contains chlorophyll-rich cells and latex-producing ducts, while a thin endodermis separates it from the vascular bundles, which include phloem and xylem for nutrient transport. The central pith consists of parenchyma cells (Ma *et al*., 2015).

Stem length can range from 1 to 5 meters, with a thickness of 3 to 10 mm. Internodes may be spaced 2 to 20 cm apart along the stem (Barrera *et al*., 1989; Daros *et al*., 2002). The petioles, which support the leaves, can grow up to 30 cm long and may be smooth or slightly hairy. Both stems and petioles contain nutrients and are often used as animal feed, particularly for pigs and cattle, either fresh or as silage (Miranda *et al*., 2007).

The leaves are simple, smooth, or slightly hairy, with shapes ranging from ovate to orbicular, sagittal, cordate, or elliptical. They grow on petioles with entire margins and a cordate base, arranged spirally in a pentamerous phyllotaxis pattern (2/5). This means that the genetic spiral completes two turns, grouping five leaves, with the sixth leaf positioned directly above the first (Edmond *et al*., 1971).

Figure 1: Sweet potato main stem, petioles and leaves in spiral configuration of 2/5 phyllotaxis. Source: Miranda *et al.* (2007)

The sweet potato plant develops a root system that is pivotal, branched, and diffuse, comprising a main root along with secondary and tertiary roots that can extend up to 90 cm deep. This root structure is typical of dicotyledonous plants, featuring an axial root, also known as a storage root, which takes on a tuberous form. These tuberous roots are thick and can be elongated, round, or fusiform in shape. Additionally, the plant produces absorbent roots, including pencil and fibrous roots, which are numerous and highly branched. These absorbent roots play a crucial role in extracting and transporting water and nutrients from the soil to the plant (Huaman *et al*., 1992)

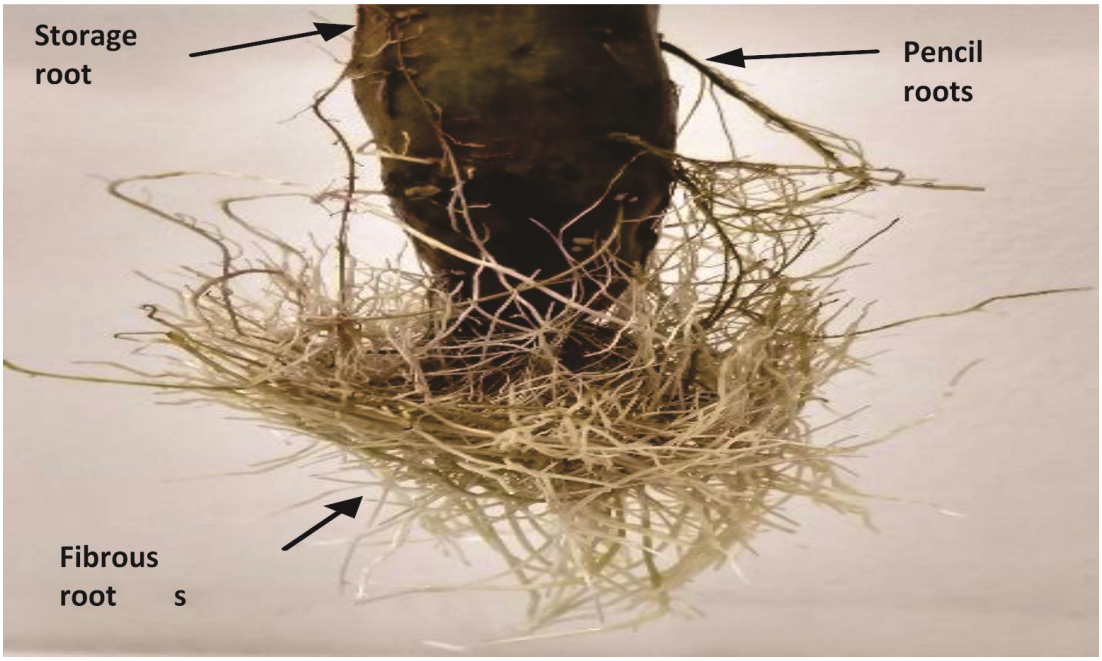

Figure 2: Sweet potato pivoting root system
Source: Silva *et al*. (2008)

The sweet potato plant's absorbent roots are formed from tissues containing meristematic cells, with the exchange rate meristem responsible for their development. The axial root, or tuberous root, arises from the activity of primary, secondary, and tertiary meristematic cells, supported by the xylem and phloem tissues that facilitate nutrient and water transport (Huaman *et al*., 1992). Tuberous roots vary in length, diameter, skin color, and pulp color depending on the cultivar. Adventitious roots, which develop from internodes, are thicker than basal roots due to the active growth of lateral meristem cells. Even within the same cultivar, variations in root morphology and quantity can occur between plants, including those grown from clones (Huaman *et al*., 1992; Silva *et al*., 2008).

The thickening of tuberous roots is driven by the activity of secondary meristem cells, including the cork cambium, vascular cambium, and anomalous cambium. The cork cambium generates outer cork layers, forming the periderm that protects the root. The vascular cambium creates a circular structure, producing secondary phloem externally and parenchyma cells

internally. The anomalous cambium refers to secondary meristem cells with atypical growth patterns (Lebot *et al*., 2019; Wilson *et al*., 1973). Tuberous roots consist of primary tissues such as the periderm, vascular bundles, tracheid, sieve cells (particularly sieve tube members in the phloem), and laticifers. Their structure is heterogeneous, including xylem, phloem, reserve parenchyma, protective epidermis, and secondary periderm (Lebot *et al*., 2019; Wilson *et al*., 1973).

The sweet potato's peel is approximately two millimeters thick, composed of a few cell layers. The outer skin is easily detachable, but separating it from the pulp can be challenging due to the indistinct boundary between the two. The root's surface is generally smooth but may exhibit horizontal or vertical constrictions depending on the cultivar and cultivation practices. Skin colors range from purple, white, cream, yellow, orange, brown, to reddish, while the pulp can be white, cream, yellow, orange, or purple. These color variations are due to bioactive pigments like anthocyanins and carotenoids (Huaman *et al*., 1992; Silva *et al*., 2008).

Antioxidant Activities of *Ipomoea batata*

Sweet potato leaves (SPL) are a valuable source of dietary antioxidants, with their antioxidant activity varying across cultivars and regions. SPL with high antioxidant content can be processed into nutraceutical products, offering health benefits such as improved nutrition and enhanced antioxidant defense. SPL contain various antioxidants, including polyphenols like caffeoylquinic acid derivatives, which exhibit strong antioxidant properties (Ji *et al*., 2015; Kwak *et al*., 2013). These compounds help combat oxidative stress, reduce LDL oxidation, and prevent DNA damage in human lymphocytes (Nagai *et al*., 2011; Chen *et al*., 2005).

In vivo studies have shown that consuming high-polyphenol diets, such as purple SPL, can enhance plasma antioxidant levels, reduce oxidative stress markers, and improve overall antioxidant status (Chang *et al*., 2013). Purple SPL consumption has also been linked to increased glutathione levels, plasma antioxidant capacity, and reduced lipid and DNA oxidation (Ameho *et al*., 2008; Myhrstad *et al*., 2002). Polyphenols in SPL boost glutathione production by promoting the expression of γ-glutamylcysteine synthetase and inhibiting glutathione reductase (Moskaug *et al*., 2005; Zhang *et al*., 2016).

SPL are also rich in flavonoid antioxidants, with quercetin showing particularly high antioxidant capacity (Chu *et al*., 2000). Anthocyanins in purple SPL are among the most potent antioxidants, with 15 identified anthocyanins demonstrating both antioxidant and anti-mutagenic activities (Islam *et al*., 2002). Other phytochemicals in SPL, such as triterpenes, alkaloids, saponins, and tannins, also contribute to their antioxidant properties (Fu *et al*., 2016).

The antioxidant capacity of SPL varies with leaf color, with purple SPL exhibiting higher activity than other leafy vegetables like celosia, gynura, and amaranth (Tang *et al*., 2013). Among sweet potato varieties, 'Biru-Putih' and 'Indon' showed the lowest and highest scavenging activities, respectively (Hue *et al*., 2012). Additionally, leaves generally have higher radical scavenging activity compared to other plant parts (Troung *et al*., 2014).

Given their antioxidant properties, SPL hold promise for dietary applications aimed at disease prevention and treatment. Further research is needed to optimize processing techniques, such as drying and extraction, to preserve the maximum antioxidant content in SPL-based products.

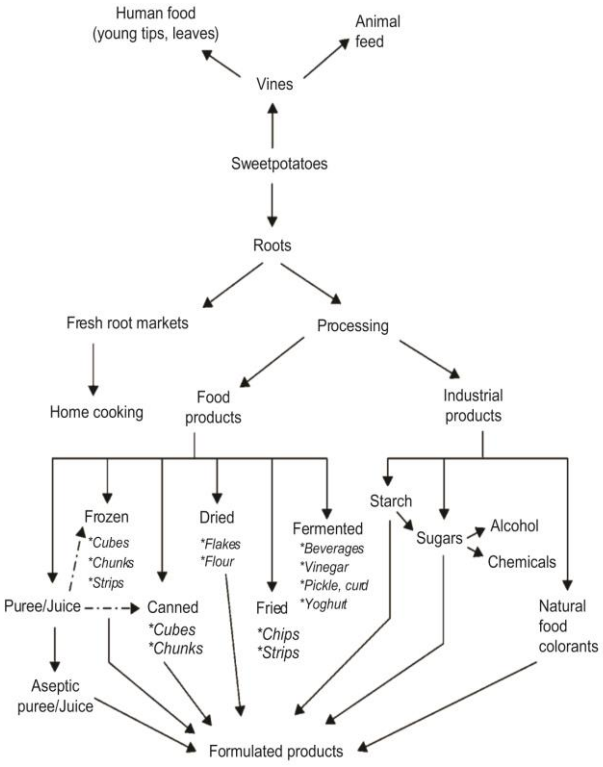

Figure 3: Different processing and utilizing methods of *Ipomoea batata.* Source: Padmaja, (2009)

The primary objective of this research is to identify the most effective processing method to enhance the nutritional value of sweet potatoes. By addressing the presence of anti-nutrients and toxins, such as nitrates, this study aims to improve the overall nutrient availability and safety of sweet potatoes for consumption.

MATERIALS AND METHOD

Materials

All materials and chemicals used in the research work were pure and of high grate purity. The list of instrument and reagent are presented in appendix I

SAMPLES STUDIED

The sweet potatoes (*Ipomoea batatas*) samples studied were obtained from Gulu LGA in Kano, Patigi LGA in Minna, and Zaria LGA in Kaduna State.

METHODOLOGY

Sample collection and identification

Sweet potatoes were all purchased from the various locations and taken to Department of biological science federal university Dutsin-Ma, which were identified with the sample I. D. voucher number FUDMA/PSB/00116, and the fresh samples were randomly selected, placed in polythenene bags, properly labelled and transported to the lab for analysis.

Sample Preparation

The sample collected were thoroughly washed with clean water and divided into four portions for different processing. The first part was dried under the shade, the second part was dried under the sun, the third part was fermented for 48hours then dried under the sun while last part was dried in an oven after cutting into pieces with grater.

PROXIMATE ANALYSIS PROCEDURE

Determination of moisture content

A clean, dried aluminum dish was weighed (W_1). Sweet potato (5g) was weighed into each of the dish (W_2). The dish was shaken gently to ensure uniform distribution of sample. The dish containing sample was placed in the oven at 100^{o}C for 2 hours. The dish was kept in a desiccator and allowed to cool. The dish was dried and weighed (W_3). All experiments were conducted in triplicates.

Calculation:

The percentage moisture was calculated as

% of moisture = W_2-W_3 / W_2-W_1

Where;

W1= initial weight of empty aluminum dish

W2= weight of aluminum + sample before drying

W3= final weight of dish + samples after drying

Determination of ash content

A clean crucible was dried for at least 2 hours at 100^{o}C in an oven and was cooled in a dessicator. The weight of the crucible was recorded as W_1 sweet potatoes (5g) was weighed into the crucible (W_2). The samples were ashed in a furnace at 600^{o}C for 2hours. The crucible was allowed to cool in a dessicator and the weight recorded (W_3). All experiments were conducted in triplicates.

Calculation:

% of ash (dry basis) = W_3-W_1 / W_2-W_1

Where;

W1= initial weight of empty crucible

W2= weight of crucible + sample before ashing

W3= final weight of crucible + samples after ashing

Crude fiber Determination

Sweet potatoes were weighed (W_1) and transferred into a filter paper, supported on a filter cone in a funnel. It was then extracted with three 25cm^3 portions of ether and vacuum was applied until the sample was dried. The extracted sample was transferred quantitatively by brushing into a 600cm^3 beaker of the fiber digestion apparatus. 200cm^3 of 1.25% sulfuric acid (H_2SO_4) solution was added. A beaker was placed on the digestion apparatus with a pre-adjusted heater and boiled for exactly 30minutes. The beaker was rotated periodically to keep solids from adhering to the sides. The beaker was removed and the content was filtered through a California Buckner funnel. The beaker was rinsed with 50-75cm^3 of boiling water and washed through a funnel. This was repeated with three 50cm^3 portions of water and sucked dry. The residue was returned to the beaker by blowing through the funnel. 200cm^3 of boiling 1.25% sodium hydroxide (NaOH) solution was added. It was boiled for 30minutes. The beaker

was removed and filtered as above. It was then washed with 25cm^3 of boiling 1.25% sulfuric acid solution which was followed by 50cm^3 portion of water and 25cm^3 of alcohol respectively. The fiber residue was dried at 130^oC for two (2) hours. It was then ignited at 600^oC to constant weight for about 30minutes. It was cooled in a desiccator and weighed (W_3). All experiments were conducted in triplicates.

Calculation:

% of crude fiber = W_2-W_3 / W_1

Where;

W1= initial weight of empty crucible

W2= weight of crucible + sample before ashing

W3= final weight of crucible + samples after ashing

Crude fiber Determination

Sweet potatoes (0.2g) was weighed into a digestion tube. Sulphuric acid (15cm^3) was added. The tube was swirled gently until the sample and the acid were thoroughly mixed. Kjeldahl catalyst (0.5g) was added. The solution was heated continuously until it was clear. The temperature was raised and the solution was heated to boil for two (2) hours until the solution was cleared. The solution was allowed to cool and it was transferred into 100cm^3 volumetric flask and diluted with distilled water and mixed thoroughly.

For the distillation, 2% boric acid (10cm^3) was measured into a 100cm^3 Erlenmeyer flask then 1-2 drops of mixed indicator was added. Aliquot (10cm^3) of the digest was transferred into a distillation apparatus. 40% NaOH (15cm^3) was added into the mixture. The nitrogen distilled into boric acid/indicator flask for at least 10-15minutes. The condenser tip was then rinsed with distilled water. The distillate was then titrated with sulfuric acid (0.025N) to a pink end point and the burette reading was taken. All experiments were conducted in triplicates.

Determination of crude fat

Filter paper was folded into a thimble shape and weighed and its weight was zeroed. Sweet potatoes (2g) was placed into thimble. The thimble was slipped into a thimble holder. Petroleum ether (250cm^3) was added using glass funnel from the top of the condenser. The heater switch, main power switch and the condenser water were turned on and extraction began for a minimum of 4 hours on a high setting (condensation rate of 5-6 drops per second). After the extraction, the heater and water tap were turned off and the ether (with the fat extract) was transferred into a beaker of known weight (W_1). The thimble was rinsed with more petroleum ether. The beaker was taken into an oven at 70^oC for about 30minutes. It was then allowed to cool and the ether was drained out. The weight of the beaker and the fat it contains was weighed (W_2). All experiments were conducted in triplicates.

Calculation:

% of crude fat = W_2-W_1

Where;

W1= initial weight of beaker
W2= weight of beaker (g) + fat extract (g)

Determination of carbohydrate

Carbohydrate as nitrogen free extract (NFE) was calculated by difference as: NFE = 100 - (Crude protein + Crude fiber + Moisture + Ash + Crude fat.

ANTINUTRIENT DETERMINATION PROCEDURE

QUANTITATIVE EVALUATION OF ANTI-NUTRITIONAL FACTORS PROCEDURE FOR ANALYSIS:

Oxalate Determination by Titration Method: This determination involved three major steps: digestion, oxalate precipitation and permanganate titration. Digestion

i) 2g of sample was suspended in 190ml of distilled water in a 250ml volumetric flask.

ii) 10ml of 6MHCl was added and the suspension digested at 100^0C for 1 hour.

iii) The solution was cooled, and then made up to 250ml mark before filtration.

Oxalate Precipitation: Duplicate Portions of the filtrate were measured into breakers and four drops of methyl red indicator added. Then NH_4OH solution was added (drop wise) until the test solution changed from pink to faints yellow colour (pH4.0 - 4.5). Each portion was then heated to 90^0C, cooled and filtered to remove precipitate containing ferrous ion. The filtrate was again heated to 90^0C and 10ml of 5% $CaCl_2$ solution was added while being stirred constantly. The solution was then heated and left overnight at 25 ^{0}C; it was then centrifuged at 2500rpm for 5minutes. The supernatant was decanted and the precipitate completely dissolved in 10ml of 20% (v/v) H_2SO_4 solution. Permanganate Titration At this point, the total filtrate resulting from digestion of 2g of sample was made up to 300ml. Aliquots of 125ml of the filtrate was heated until near boiling and then titrated against 0.05M standardized KMnO4 solution to a faint pink colour which persisted for 30 seconds. The calcium oxalate content was calculated using the formula:

$$\frac{T \times (Vme)\ (Df)}{(ME) \times M_F)} \times (Mg/100g) \qquad (1)$$

Where T is titre of $KMnO_4$ (ml),
Vme is the volume-mass equivalent
Df is the Dilution factor= Vt/A
Where Vt is the total volume of fitrate (300ml) and A is the aliquot used i.e. 250ml,
ME is the molar equivalent of $KMnO_4$ in oxalate and
Mf is the mass of sample used

Phytate Determination: The method used was the Young and Greaves method (1940) as adopted by Lucas Markakes (1975). 0.2g of the sample was weighed into 250ml conical flask. It was soaked in 100ml of 20% concentrated HCl for 3 hours, the sample was then filtered 50ml of the filtrate was placed in a 250ml beaker and 100ml distilled water added to the sample. Then 10ml of 0.3% ammonium thiocyanate solution was added as indicator and titrated with standard iron (III) chloride solution which contained 0.00195g iron per 1 ml.
Calculation:

$$\text{Phytic acid} = \frac{\text{Titre value} \times 0.001\ 95 \times 1.19 \times 100}{2}$$

Estimation of tannin content:

Prior the quantitative estimation of the tannin content in the samples, the presence of tannins was identified using the classic $FeCl_3$ and Gelatin tests. The quantitative tannin content in samples was estimated by the method of Price and Butler (Price and Butler, 1977), with some modifications. In short, 0.1 g of a dry gall or plant sample was transferred to 100 ml flask; 50 ml water was added, and boiled for 30 min. After filtration with cotton filter the solution was further transferred to a 500 ml flask and water was added ad 500 ml mark. 0.5 ml aliquots were finally transferred to vials, 1 ml 1% $K_3Fe(CN)_6$ and 1 ml 1% $FeCl_3$ were added, and water was added ad 10 ml volume. After five min time period, the solutions were measured spectrophotometrically at 720 nm. The actual tannin concentrations were calculated on the basis of the optical absorbance values obtained for the standard solutions in range 5 - 25 µg /10 ml.

Determination of total nitrate:

Estimated of total nitrate content was determined by the method described by Makkar *et al*. based on vanillin sulphuric acid colorimetric reaction with some modifications (Makkar *et al*., 2007). About 50 µL of the extract was added with 250 µL of vanillin reagent (800 mg of vanillin in 10 mL of 99.5 % ethanol) was added. Then 2.5 mL of 72% sulphuric acid was added and it was mixed well. This solution was kept in a water bath at 60^{o}C for 10 min. After 10 min, it was cooled in ice cold water and the absorbance was read at 544 nm. The values were expressed as diosgenin equivalents (mg DE/g extract) derived from a standard curve.

ELEMENTAL ANALYSIS

Sample Digestion

1.0g of the grounded plant sample was placed in 100cm^1 volumetric flask. 10cm^3 of HNO, was added and kept overnight for pre-digestion. 8cm^3 of HCIO, was added and swirled gently the flask was then place on low heat (at about 100 ^{0}C) on hot plate. Then heated at higher temperature (at about 260 ^{0}C) until the production of red fumes ceases, the content was then further evaporated until the volume is reduced to about 3cm^3 The completion of the digestion was confirmed when the liquid became colourless. Deionised water was added up to mark after cooling and filtered through Whatman number I filter paper (Vijay *et al*, 2017).

Calculation of Mineral Contents:

Concentration (mg/kg) = $\frac{C+V+DF}{W}$ - - - - - Eqn 3.2

Where:
C=Concentration of metal in sample (mg / l)
V = Final volume of sample in (cm^3)
DF = Dilution factor
W = Weight of sample in (g)
Estimation of minerals

Minerals such as (Ca, Mg, Na, Cu, Fe, Co, Ni, Zn, Pb) were determined by Agilent Atomic Absorption spectrophotometer (AAS) after appropriate digestion of samples.

Preparation of Reagent Solutions

All the reagents used were of analytical grade. Glass wares were washed with liquid detergent solution, rinsed with deionized water and oven dried at 50^0C

Calcium Stock Solution (1000mg/l)

The Calcium stock solution was prepared by dissolving (2.7693g Calcium Chloride ($CaCl_2$) into 250cm^3 beaker and 20cm^3 of deionised water was added to the solution. This solution was then transferred into 1000cm^3 volumetric flask and made up to the mark with deionised water.

Calcium Solution (100mg/l)

About 10cm^3 of the stock solution was pipetted and transferred into 100cm^3 volumetric flask. more deionised water was added to make it to the mark.

Calcium Solution (10mg/1)

About 5cm^3 of the 100 mg/l solution was pipetted and transferred into 50cm^3 volumetric flask; more deionised water was added to make it to the mark.

Calcium Solution (1mg/l)

About 5cm^3 of the 10 mg/l solution was pipetted and transferred into 50cm^3 volumetric flask, more deionised water was added to make it to the mark. Serial dilution was carried out for 0.8, 0.6, 0.4, 0.2 and 0.1 mg/l.

Magnesium Stock Solution (1000mg/l)

About 4.951g of magnesium sulphate ($MgSO_4$) was weighted into 250cm^3 beaker and 20ml of deionised water was added to the solution. This solution was then transferred into 1000 cm^3 volumetric flask and made up to the mark with deionised water.

Magnesium Solution (100mg/l)
About 10cm^3 of the stock solution was pipetted and transferred into 100cm^3 volumetric flask, more deionised water was added to make it to the mark.

Magnesium Solution (10mg/l)
About 5cm^3 of the 100 mg/l solution was pipetted and transferred into 50cm^3 volumetric flask, more deionised water was added to make it to the mark.

Magnesium Solution (1mg/l)
About 5cm^3 of the 10 mg/l solution was pipetted and transferred into 50cm^3 volumetric flask, more deionised water was added to make it to the mark. Serial dilution was carried out for 0.8, 0.6, 0.4, 0.2 and 0.1 mg/l.

Cobalt Stock Solution (1000mg/l)
About 2.5862g of Cobalt nitrate ($CoNO_3$) was weighted into 250cm^3 beaker and 20cm^3 of deionised water was added to the solution. This solution was then transferred into 1000cm^3 volumetric flask and made up to the mark with deionised water.

Cobalt Solution (100mg/l)
About 10cm^3 of the stock solution was pipetted and transferred into 100cm^3 volumetric flask, more deionised water was added to make it to the mark.

Cobalt Solution (10mg/l)
About 5cm^3 of the 100 mg/l solution was pipetted and transferred into 50cm^3 volumetric flask, more deionised water was added to make it to the mark.

Cobalt Solution (1mg / l)
About 5cm^3 of the 10 mg/l solution was pipetted and transferred into 50cm^3 volumetric flask, more deionised water was added to make it to the mark. Serial dilution was carried out for 0.8, 0.6, 0.4, 0.2 and 0.1 mg/l.

Sodium Stock Solution (1000mg / l)
About 2.542g of Sodium Chloride (NaCl) nitrate was weighted into 250cm^3 beaker and 20cm^3 of deionised water was added to the solution. This solution was then transferred into 1000cm^3 volumetric flask and made up to the mark with deionised water.

Sodium Solution (100mg / l)
About 10cm^3 of the stock solution was pipetted and transferred into 100cm^3 volumetric flask, more deionised water was added to make it to the mark.

Sodium Solution (10mg / l)
About 5cm^3 of the 100 mg/l solution was pipetted and transferred into 50cm^3 volumetric flask, more deionised water was added to make it to the mark.

Sodium Solution (1mg / l)
About 5cm^3 of the 10 mg/l solution was pipetted and transferred into 50cm^3 volumetric flask, more deionised water was added to make it to the mark. Serial dilution was carried out for 0.8, 0.6, 0.4, 0.2 and 0.1 mg/l.

Iron Stock Solution (1000mg / l)
Iron Sulphate Fe (SO_4) (2.7143g) was weighted into 250cm^3 beaker and 20cm^3 of deionised water was added to the solution. This solution was then transferred into 1000cm^3 volumetric flask and made up to the mark with deionised water.

Iron Solution (100mg / l)
About 10cm^3 of the stock solution was pipetted and transferred into 100cm^3 volumetric flask, more deionised water was added to make it to the mark.

Iron Solution (10mg / l)
About 5cm^3 of the 100 mg/l solution was pipetted and transferred into 50cm^3 volumetric flask, more deionised water was added to make it to the mark.

Iron Solution (1mg / l)
About 5cm^3 of the 10 mg/l solution was pipetted and transferred into 50cm^3 volumetric flask, more deionised water was added to make it to the mark. Serial dilution was carried out for 0.8, 0.6, 0.4, 0.2 and 0.1 mg/l.

Zinc Stock Solution (1000mg / l)
About 4.5902g of hydrated Zinc nitrate Zn $(NO_3)_2$ $6H_2O$, was weighted into 250cm^3 beaker and 20cm^3 of deionised water was added to the solution. This solution was then transferred into 1000cm^3 volumetric flask and made up to the mark with deionised water.

Zinc Solution (100mg / l)
About 10cm^3 of the stock solution was pipetted and transferred into 100cm^3 volumetric flask. more deionised water was added to make it to the mark.

Zinc Solution (10mg / l)
About 5cm^3 of the 100 mg/l solution was pipetted and transferred into 50cm^3 volumetric flask, more deionised water was added to make it to the mark.

Zinc Solution (1mg / l)
About 5cm^3 of the 10 mg/l solution was pipetted and transferred into 50cm^3 volumetric flask, more deionised water was added to make it to the mark. Serial dilution was carried out for 0.8, 0.6, 0.4, 0.2 and 0.1 mg/l.

Copper Stock Solution (1000mg / l)
About 4.057g of copper sulphate ($CuSO_4$,$4H_2O$) was weighted into 250cm^3 beaker and 20cm^3 of deionised water was added to the solution. This solution was then transferred into 1000cm^3 volumetric flask and made up to the mark with deionised water.

Copper Solution (100mg / l)
About 10cm^3 of the stock solution was pipetted and transferred into 100cm^3 volumetric flask, more deionised water was added to make it to the mark.

Copper Solution (10mg / l)
About 5cm^3 of the 100 mg/l solution was pipetted and transferred into 50cm^3volumetric flask, more deionised water was added to make it to the mark.

Copper Solution (1 mg/l)
About 5cm^3 of the 10 mg/l solution was pipetted and transferred into 50cm^3volumetric flask, more deionised water was added to make it to the mark. Serial dilution was carried out for 0.8, 0.6, 0.4, 0.2 and 0.1 mg/l.

Nickel Stock Solution (1000mg / l)
About 7.696g of hydrated Nickel nitrate [Ni(NO_3), $9H_2O$] was weighted into 250cm^3 beaker and 20cm^3 of deionised water was added to the solution. This solution was then transferred into 1000cm^3 volumetric flask and made up to the mark with deionised water.

Nickel Solution (100mg / l)
About 10 cm^3 of the stock solution was pipetted and transferred into 100cm^3 volumetric flask, more deionised water was added to make it to the mark.

Nickel Solution (10mg / l)
About 5cm^3 of the 100 mg/l solution was pipetted and transferred into 50cm^3 volumetric flask, more deionised water was added to make it to the mark.

Nickel Solution (1mg / l)
About 5cm^3 of the 10 mg/l solution was pipetted and transferred into 50cm^3 volumetric flask. more deionised water was added to make it to the mark. Serial dilution was carried out for 0.8, 0.6, 0.4, 0.2 and 0.1 mg/l.

Lead Stock Solution (1000mg / l)
About 1.598 Of lead (ii) nitrate Pb $(NO_5)_2$ was dissolved in 250cm^3 beaker and dissolved with 20cm^3 of deionized water. This solution was then transferred into 1000cm^3 volumetric flask and made up to the mark with deionized water.

Lead Solution (100mg / l)
About 10 cm^3 of the stock solution was pipetted and transferred into 100cm^3 volumetric flask. more deionised water was added to make it to the mark.

Lead Solution (10mg / l)
About 5cm^3 of the 100 mg/l solution was pipetted and transferred into 50cm^3 volumetric flask, more deionised water was added to make it to the mark.

Lead Solution (1mg / l)
About 5cm^3 of the 10 mg/l solution was pipetted and transferred into 50cm^3 volumetric flask, more deionised water was added to make it to the mark. Serial dilution was carried out for 0.8, 0.6, 0.4, 0.2 and 0.1 mg/l.

RESULTS PRESENTATION

Effect of Processing on the Proximate Components of *Ipomoea Batatas*

There were no significant ($P>0.05$) changes in the moisture, ash, crude lipid, crude fibre and carbohydrate content of *Ipomoea batatas* (sweet potato) processed differently. However, protein was significantly ($p<0.05$) lower in fermented sample when compared with shed dried (Table 4.1).

Effect of Processing on the Anti-Nutrient Components of *Ipomoea Batatas*

Processing method did not significantly ($p>0.05$) affect the oxalate, tannins, nitrate, phytate and cyanide contents of *Ipomoea batatas*. However, oven-dried and fermented samples had significantly ($p<0.05$) lower trypsin contents when compared with shed-dried and sun-dried samples (Table 2).

Effect of Processing on the Vitamin Components of *Ipomoea Batatas*

The sun-dried sample of *Ipomoea batatas* had significantly ($p<0.05$) lower concentrations of Vitamin E compared to other samples (shed-dried, oven-dried and fermented samples), while the shed-dried and oven-dried samples didn't significantly ($p>0.05$) differ in their Vitamin E concentrations. There were no significant changes in the concentrations of Vitamins A, B2, D and C among the differently processed *Ipomoea batatas* (Table 4.3).

Effect of Processing on the Mineral Contents of *Ipomoea Batatas*

The levels of the studied minerals (Fe, Cu, Zn, Na, Mg, Ca, Ni, Co and Pb) in *Ipomoea batatas* is presented in Table 4.4. The levels of the studied minerals (Fe, Cu, Zn, Na, Mg, Ca, Ni, Co, and Pb) did not differ significantly ($p>0.05$) among the different processing methods (shed-drying, oven-drying, sun-drying, and fermentation) used in the research.

Effect of Environment on the Proximate Content of *Ipomoea Batatas*

Zaria specie had significantly ($p<0.05$) higher moisture, ash and lipid compared with the Kano and Minna species. Zaria and Minna species had significantly ($p<0.05$) higher crude fibre in

comparison with the Kano species. There were no significant ($p>0.05$) differences in other proximate compositions between the Kano and Minna species of *Ipomoea batatas* (Table 4.5).

Effect of Environment on the Anti-Nutrient of *Ipomoea Batatas*

Table 4.6 shows the result of the environmental effects on the studied antinutrients. Phytate, nitrate and cyanide didn't vary significantly ($p>0.05$) among the Zaria, Kano and Minna species. Kano specie had significantly ($p<0.05$) lower level of oxalate but higher trypsin compared with the other two species. On the other hand, tannins were significantly ($p<0.05$) lower in the Minna specie.

Effect of Environment on the Vitamin Contents of *Ipomoea Batatas*

The environmental effects on the vitamin levels of *Ipomoea batatas* is presented in Table 4.7. Vitamins B6, D, C and E were not affected significantly ($p>0.05$) among the Zaria, Kano and Minna species. Zaria specie had significantly higher Vitamin B2 concentration compared to Kano and Minna species, while Kano specie had significantly lower Vitamin A compared to the Minna and Zaria species.

Effect of Environment on the Elemental Analysis of *Ipomoea Batatas*

The levels of minerals studied (Fe, Cu, Zn, Na, Mg, Ca, Ni, Co and Pb) in *Ipomoea batatas* species are presented in Table 4.8. The levels of the studied minerals (Fe, Cu, Zn, Na, Mg, Ca, Ni, Co, and Pb) did not differ significantly ($p>0.05$) among the species.

Table 1: Proximate Composition of Differently Prepared *Ipomoea batatas*

	Moisture	Ash	Crude protein	Crude lipid	Crude fibre	Carbohydrate
Shed dried	7.6±2.0^{a}	5.2±1.3^{a}	8.2±0.5^{b}	4.4±0.7^{a}	4.9±0.7^{a}	69.8±4.1^{a}
Oven dried	8.5±0.8^{a}	4.5±0.1^{a}	7.4±0.4^{ab}	4.8±0.2^{a}	4.8±0.3^{a}	68.6±0.4^{a}
Fermented	8.5±0.2^{a}	^{A}5.0±0.0^{a}	7.2±0.1^{a}	4.2±0.0^{a}	5.0±0.8^{a}	69.8±0.8^{a}
Sun dried	6.0±1.7^{a}	4.3±0.8^{a}	7.5±0.6^{ab}	4.3±0.0^{a}	4.8±0.3^{a}	72.4±3.0^{a}

Values are presented as mean ± SM, N=3. Values in the same column bearing different superscript are significantly different

Table 2: EFFECT OF PROCESSING ON THE ANTI-NUTRIENT COMPONENTS OF *Ipomoea batatas*

	Oxalate	Phytate	Trypsin	Tannins	Nitrate	Cyanide
Shed dried	3.8±0.2^{a}	1.8±0.1^{b}	0.8±0.2^{a}	4.2±1.7^{a}	0.5±0.11^{a}	0.2±0.0^{a}
Oven dried	3.6±0.3^{a}	1.5±0.0^{a}	0.6±0.0^{b}	2.3±0.3^{a}	0.5±0.1^{a}	0.2±0.1^{a}
Fermented	3.2±0.2^{a}	1.8±0.1^{ab}	0.6±0.0^{b}	3.5±2.3^{a}	0.4±0.1^{a}	0.1±0.0^{a}
Sun dried	3.4±1.1^{a}	1.7±0.2^{ab}	0.8±0.1^{a}	4.0±2.0^{a}	0.4±0.0^{a}	0.2±0.0^{a}

Values are presented as mean ± SM, N=3. Values in the same column bearing different superscript are significantly different

Table 3: VITAMIN CONTENTS OF DIFFERENTLY PROCESSED *Ipomoea batatas*

	VIT A	VIT B6	VIT B2	VIT D	VIT C	VIT E
Shed Dried	1.70 ±0.88[a]	0.05±0.04[a]	3.30±1.51[a]	2.4±0.49[a]	0.06±0.02[a]	0.09±0.00[c]
Oven Dried	1.97±0.16[a]	0.16±0.05[a]	4.70±0.51[a]	1.9±0.25[a]	0.05±0.01[a]	0.09±0.00[c]
Fermented	1.63±0.55[a]	0.03±0.00[a]	3.80±1.08[a]	2.6±0.43[a]	0.04±0.01[a]	0.08±0.00[b]
Sun Dried	1.50±0.55[a]	0.11±0.08[a]	4.0±1.36[a]	2.2±0.01[a]	0.08±0.01[a]	0.07±0.00[a]

Values are presented as mean ± SM, N=3. Values in the same column bearing different superscripts are significantly different

Table 4: ELEMENTAL CONTENTS OF DIFFERENTLY PROCESSED *Ipomoea batatas*

	Fe	Cu	Zn	Na	Mg	Ca	Ni	Co	Pb
Shed Dried	0.26±0.13[a]	0.06±0.03	0.06±0.03	0.33±0.18	0.073±0.07	0.13±0.00	0.08±0.05	0.30±0.17	0.05±0.04
Oven Dried	0.24±0.04[a]	0.11±0.10	0.12±0.00	0.33±0.04	0.13±0.01	0.15±0.05	0.04±0.02	0.17±0.01	0.03±0.01
Fermented	0.24±0.08[a]	0.09±0.02	0.15±0.13	0.34±0.13	0.11±0.01	0.13±0.06	0.08±0.03	0.18±0.03	0.02±0.00
Sun Dried	0.25±0.04[a]	0.05±0.04	0.18±0.49	0.36±0.11	0.05±0.02	0.13±0.04	0.07±0.03	0.25±0.06	0.03±0.00

Values are presented as mean ± SM, N=3. Values in the same column bearing different superscript are significantly different

Table 5: Effect of environment on Proximate Content of *Ipomoea batatas*

	M	Ash	Pro	Lipid	Fibre	CHO
Zaria	10.0± 0.6[b]	6.7±0.2[b]	8.8±0.3[a]	5.3±0.7[b]	5.7±0.3[b]	65.1±2.8[a]
Kano	6.3±0.3[a]	5.0±1.0[a]	8.3±0.7[a]	4.4±1.2[a]	4.3±0.1[a]	71.5±2.7[a]
Minna	6.7±0.3[a]	4.1±0.3[a]	7.7±0.8[a]	3.8±0.6[a]	4.8±0.8[b]	72.8±2.8[a]

Values are presented as mean ± SM, N=3. Values in the same column bearing different superscripts are significantly different

Table 6: Effect of Environment on Anti-nutrients of *Ipomoea batatas*

	Oxalate	Phytate	Trypsin	Tannins	Nitrate	Cyanide
Zaria	4.1±0.0[b]	1.8±0.0[a]	0.5±0.0[c]	5.7±0.3[c]	0.6±0.0[a]	0.3±0.0[a]
Kano	3.5±0.2[a]	2.0±0.0[a]	0.9±0.0[b]	4.8±0.5[b]	0.4±0.0[a]	0.2±0.0[a]
Minna	3.8±0.1[b]	1.7±0.2[a]	1.0±0.0[a]	2.3±0.1[a]	0.5±0.0[a]	0.2±0.0[a]

Values are presented as mean ± SM, N=3. Values in the same column bearing different superscripts are significantly different

Table 7: Effect of Environment on Vitamin content Of *Ipomoea batatas*

	Vit A	Vit B6	Vit B2	Vit D	Vit C	Vit E
Zaria	2.6±0.0[b]	0.1±0.0 [a]	5.0±0.1 [b]	3.0±0.0 [a]	0.09±0.0 [a]	0.1±0.0[a]
Kano	0.8±0.1 [a]	0.03±0.0 [a]	2.1±0.0 [a]	2.2±0.0 [a]	0.04±0.0 [a]	0.09±0.0 [a]
Minna	1.6±0.0 [b]	0.03±0.0 [a]	2.8±0.0 [a]	2.1±0.0 [a]	0.06±0.0 [a]	0 .1±0.0[a]

Values are presented as mean ± SM, N=3. Values in the same column bearing different superscripts are significantly different

Table 8: Effect of Environmemt on Elemental Analysis of *Ipomoea batatas*

	Fe	Co	Cu	Ni	Pb	Zn	Mg	Ca	Na
Zaria	0.4	0.5	0.03	0.1	0.04	0.2	0.01	0.13	0.2
Kano	0.2	0.1	0.09	0.04	0.01	0.08	0.06	0.13	0.5
Minna	0.1	0.2	0.06	0.08	0.1	0.08	0.15	0.13	0.1

Values are presented as mean ± SM, N=3. Values in the same column bearing different superscripts are significantly different

DISCUSSION

Proximate Compositions of Differently Processed *Ipomoea Batatas*

P**roximate analysis** of samples is essential in that it provides information on the fundamental nutritional values and economic importance of a feed (Francis *et al*., 2024; Rijal, 2023). The component of the analysis includes moisture, crude protein, ash, lipid, crude fibre and carbohydrates (Pesti, 2024; McDonald *et al*., 2024). **The** results of the proximate analysis shows that the different processing methods applied did not affect the components of the proximate analysis except protein which was higher in the shed dried in comparison to the fermented sample. The stability of the m**oisture content among the samples implies that the processing methods used in this research have similar effect on the shelf life and tenderness of potato. Moisture content is mostly responsible for the spoilage,** crispness, juiciness and mouth-feel of foods (Monteiro, 2024; Zhang & Li, 2024). **In nutritional research, ash content is of essence as it** represents the total mineral composition of the sample. The four processing methods used in this research seem to have same effects on the ash contents of the samples as indicated by the absence of significant changes among the samples. The ash content is usually affected by **temperature as** high temperatures can volatilize some minerals including sodium and potassium (Al Mamun *et al*., 2023). The drying methods applied here may not have reached the threshold that could volatilize or degrade the minerals as such happen only at very high temperatures. S**un-drying and shed-drying** are relatively low-temperature processes and not expected to cause any significant impact on mineral content. Further, boiling may cause leaching of minerals into water thereby reducing the mineral contents, while drying may concentrate the minerals by reducing water content and this can give false rise in the mineral content (Kumar *et al*., 2023). During fermentation, microorganisms may **solubilize minerals** and make them more bioavailable. However that doesn't change the overall ash content. Leaching may also occur during fermentation (Oboh & Akinyemi, 2023) but that may not have happened appreciably in the case of fermenting *Ipomoea batatas*.

Lipid contents of sweet potato appears to be resistant to the fermentation and drying methods used in the preservation as shown by the non-significant difference among the samples. Although lipids are generally liable to oxidative degradation at high temperatures

(Qian *et al*., 2023), this may however only affect the nature of the lipid and not the content particularly at moderate temperatures.

The stability observed in fibre content suggests that the structural carbohydrates (cellulose, hemicellulose, lignin) were largely unaffected by the processing methods. Although fermentation can degrade fibre, that depends on the available microorganisms and duration of the fermentation process (Adebo & Medina-Meza, 2023).

The significantly lower protein content in the fermented sample compared to the shed-dried could be because the shed-dried sample had the highest protein content among the drying methods though the difference among the drying methods was not significant. This decrease in the fermented sample may be due to microbial metabolism during which microorganisms do utilize amino acids and small peptides as nitrogen sources for their own growth and reproduction (Sah *et al*., 2023). Since there were mostly no significant changes in the other components of the proximate analysis, carbohydrate was as expected stable. Carbohydrate content is usually determined by difference which implies subtracting from 100 the combined values of other components of the proximate analysis.

From the results, *Ipomoea batatas* could be preserved using different drying methods without fear of nutritional losses. Fermentation before drying may however not be desirable as it tends to cause loss of protein.

Antinutrient Contents of Differently Processed *Ipomoea Batatas*

The knowledge of the presence of compounds in plant-based foods that can **interfere with the absorption and/or utilization of nutrients** in the human body otherwise known as a**ntinutrients is key factor in determining the nutritional quality of such foods (**Igwe & Ujowundu, 2024**). It is also important ascertaining the effects processing could have on the antinutrients.** The 3.8 **mg/100g**, 4.2 **mg/100g and 1.8 mg/100g** of oxalate, tannin and phytate respectively in the *Ipomoea batatas* are very safe since **any value below 50 mg/100g for oxalate, 100 mg/100mg for both tannin and phytate** are generally considered safe (Gupta *et al*., 2023). Therefore consumption of *Ipomoea batatas* may not contribute to the risk of kidney stone and may not affect protein and mineral metabolisms. Oxalates form calcium oxalate crystals when it comes in contact with calcium. These crystals are responsible for kidney stone formation (Holmes & Assimos, 2023). In addition, oxalates do interfere with **calcium and magnesium absorption**, a situation that can cause mineral deficiencies (Guo & Liu, 2023; Weaver & Plawecki, 2022). Tannin form complexes not only with minerals such as zinc and iron, it also complexes with proteins thereby making the complexed proteins and minerals less available for absorption (Khokhar & Owusu-Apenten, 2023). Phytate also make minerals such as zinc, iron and calcium unavailable for absorption once it binds to them (Hurrell & Egli, 2022).

The *Ipomoea batatas* also contains far below what is considered intolerable levels for trypsin inhibitor (**20 TIU/mg protein**) and cyanide (**10 mg/kg**) in food (Oduro *et al*., 2022; CAC, 2021). Intake of trypsin inhibitor beyond safe limit does hinder digestion and then absorption

protein, and also interferes with pancreatic function (Friedman, 2024), while cyanide can lead to acute poisoning and chronic neurological disorder (Howlett & Hill, 2023).

The non-significant effects of the processing methods (shed-drying, sun-drying, oven-drying and fermentation) on oxalate, phytate, nitrate, tannin and cyanide, and the reduction in trypsin inhibitor by fermentation and oven drying may therefore be of no effects since *Ipomoea batatas* inherently contains low levels of these antinutrients. Previous research had reported these drying methods don't always have serious effects on the levels of these antinutrients. For instances, oxalates and phytates are relatively heat-stable and can be degraded only at high temperatures (Chai & Abdullah, 2023). Further, phytate and cyanide respectively exist as phytin and cyanogenic glycosides both of which are known to resist degradation during drying except at very high temperatures (Marolt & Kolar, 2021).

It is worthy of note that the *Ipomoea batatas* is not entirely free of the studied antinutrients. This is good since some of these antinutrients play significant physiological and/or therapeutic roles if consumed in moderations (Egounlety & Aworh, 2023). For instances, tannins have antimicrobial and antoxidant properties (Villanueva *et al*., 2023), while phytates are credited with having antioxidant properties, and can regulate blood sugar and cholesterol (Reddy *et al*., 2023). Trypsin inhibitor slows down certain protease-dependent pathways, conferring on it anticancer properties (Zhao *et al*., 2023). Nitrate at low concentrations is reported to improve cardiovascular health by stimulating vasodilation (Kapil *et al*., 2023). The result of the antinutritional analysis illustrates that *Ipomoea batatas* may not affect nutrient digestion and/or absorption since it contains low levels of the studied antinutritional factors which are unlikely to cause harm but instead can offer health benefits.

Vitamin Contents of Differently Processed *Ipomoea Batatas*

The lowering effect of sun-drying on the concentration of Vitamin E in *Ipomoea batatas* in comparison to the other processing methods applied in the research may be due to thermal degradation by sun light. Being fat soluble, Vitamin E is very sensitive to oxidative degradation once exposed to sun light for a prolonged period (**Karaca *et al*., 2023**). This, because sun-drying exposes the sample to direct ultraviolet (UV) radiation and to fluctuating humidity over a long period, factors that can accelerate degradation of Vitamin E (Kim, 2024; Marconi *et al*., 2015). Vitamin E remaining high in the shed-dried and oven-dried indicates that controlled drying environments are better options in processing *Ipomoea batatas if preservation of Vitamin E is required. Decrease in* exposure to UV radiation as provided by shed-drying, and uniform heating as provided by oven-drying limit exposure to oxygen and minimize oxidative losses (Mohammed *et al*., 2020). It had been similarly reported that lipophilic vitamins like Vitamin E are more prone to degradation and loss during sun-drying than shed and oven-drying (Boonprasert *et al*., 2019). Vitamins A, B_2, D and C levels in *Ipomoea batatas* remained unaffected by the processing methods which may be due to the mild nature of the treatments. Vitamin D is present in low amounts in plant-based foods (Chan *et al*., 2009), and the stability in the content may be due to this inherent low level. The non-variation in the concentration of Vitamin A is not surprising since it is relatively heat-stable

(Tian *et al*., 2023) and the drying conditions were not severe. It is however not clear why the concentration of vitamin C was not affected. Vitamin C is water-soluble and sensitive to heat (Yang *et al*., 2024), and is expected to undergo oxidative damage upon exposure to heat. It is seen from the result that processing of *Ipomoea batatas* by various mild drying methods may not affect the studied vitamins except *for Vitamin E which appears to be sensitive to sun-drying.*

Effect of Processing on the Mineral Contents of *Ipomoea Batatas*

Minerals are inorganic and as such are generally stable to heat. By their nature, they are not readily degraded or volatilized under moderate thermal or fermentation treatments (Samtiya *et al*., 2021). This could be responsible for the non-effects of the sun-drying, oven-drying, sun—drying and fermentation observed on the levels of iron (Fe), copper (Cu), zinc (Zn), sodium (Na), magnesium (Mg), calcium (Ca), nickel (Ni), cobalt (Co), and lead (Pb) in *Ipomoea batatas*. The finding implies that the mineral components of *Ipomoea batatas* is unaffected by heat and microbial activities respectively encountered during drying and fermentation. Apart from being stable to heat drying methods such as oven-drying and sun-drying, drying removes moisture and since no solvent is involved losses of minerals due to leaching may not have taken place. Mineral concentrations of tuber crops including *Ipomoea batatas* had been reported not to be sensitive to common drying methods such as shed, sun and oven-drying methods (Nainggolan *et al*., 2024).

It is also worthy of note that both the drying and fermentation may not contribute to heavy metal contamination and increased load of other potentially toxic elements such as Pb as depicted by the non-changes in their concentrations. Minerals are of high nutritional importance and the result shows that preserved *Ipomoea batatas* may remain a source of these minerals irrespective of the drying method and fermentation used in the preservation. It is more so as the *Ipomoea batatas* is low in antinutrients such as oxalates and phytates as earlier presented which are known to decrease the bioavailability of the minerals.

Environmental Effects on the Nutrient and Antinutrient Components of *Ipomoea Batatas*

Zaria, Kano and Minna are all in the Northern part of Nigeria. However, they have geographical differences that could affect both the nutritional and anti-nutritional components of tuber plants including *Ipomoea batatas* due to an interplay between environmental conditions and plant metabolism. Zaria has a tropical savanna climate with rainfall between 800-1200, moderately fertile soil and temperature that ranges between 24-33 ^{0}C (Awwal & Fatihu, 2024). The climate of Kano is semi-arid. It has a sandy and loamy souls, annual rainfall of 600-800 mm and a temperature of 25-35 ^{0}C (Zakka *et al*., 2022). Minna on the other hand is tropically wet and dry with annual rain fall of 1000-1300 mm, a temperature between 23-32 0C and fertile but erosion-prone soil (Ako *et al*., 2014).

The higher moisture, ash, lipid, and fibre contents observed in Zaria sample of sweet potato could be due to more availability of water in the Zaria soil and higher soil fertility as moisture in particular is influenced by soil moisture (Li *et al*., 2023). The zaria soil may also be more

rich in micronutrients which made uptake by *Ipomoea batatas* more efficient. The higher fiber content in Zaria and Minna species of *Ipomoea batatas* may be connected with higher availability of water and nutrients in their soils. As explained earlier, Zaria and Minna have more rainfalls and their soils are more fertile than that of the Kano. It had been reported that the nutrient compositions like fibre content is influenced by factors that include soil type and water availability (Yonghua *et al*., 2024). Although, some of the anti-nutrients varied significantly, this may be of no effects since all the values fall far below the levels that are considered unsafe as earlier discussed.

The higher levels of Vitamin B 12 in Zaria specie and Vitamins B12 and A in Zaria and Minna species of *Ipomoea batatas* may still be due to better soil fertility in Zaria and Minna as earlier explained. The Zaria specie may therefore be a better source of energy as Vitamin B 12 an essential component of coenzymes involved in energy metabolism (Mucha *et al*., 2024). The higher Vitamin A in Zaria and Minna species makes the two species better in preserving vision and the immune system (Schmieder *et al*., 2025).

Like the various processing methods, the different environmental conditions didn't have any significant effects on the studied elemental compositions of *Ipomoea batatas. This may be due to similar mineral profiles of the soils from the locations. Ipomoea batatas may also have a homeostatic mechanism that regulate/maintain the levels of these elements irrespective of the climatic and other environmental conditions. On the whole, the Zaria variety may be a better source of macronutrients and vitamins particularly of A and B 12.*

CONCLUSION

The effects of some processing methods and environmental differences on the levels of nutrients and ant-nutrients in *Ipomoea batatas* were evaluated. From the findings, it is concluded that;

Ipomoea batatas could be preserved using different drying methods without fear of nutritional losses. Fermentation before drying may however not be desirable as it tends to cause loss of protein.

Ipomoea batatas may not affect nutrient digestion and/or absorption since it contains low levels of the studied antinutritional factors which are unlikely to cause harm but instead can offer health benefits.

Processing of *Ipomoea batatas* by various mild drying methods may not affect the studied vitamins except *for Vitamin E which appears to be sensitive to sun-drying*

Ipomoea batatas may remain a source of minerals irrespective of the drying method and fermentation used in the preservation

Zaria variety may be a better source of macronutrients and vitamins particularly of A and B 12

RECOMMENDATION

Similar study should be carried out to evaluate the antioxidant potential of other sweet potatoes samples available in Kano, Katsina and Kaduna and in vivo studies of these samples may be

needed in order to ascertain the antioxidant activities inside the living system. Investigation of individual compounds (i. e. isolation of bioactive compounds), responsible for their biological activities may also be conducted.

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