AUCTORES
Globalize your Research

Journal of Nutrition and Food Processing
Hudson Nyambaka *

Open Access

Research Article

# Impact of Processing on Nutrients and anti-Nutrients in Tubers and Leaves of Cassava (Manihot Esculenta Crantz)

**Ogombe C. Ojiambo, Nawiri P. Mildred and Hudson Nyambaka ***

Department of Chemistry, Kenyatta University, P.O. BOX 43844-00100, Nairobi, Kenya

***Corresponding author:** Hudson Nyambaka, Department of Chemistry, Kenyatta University, P.O. BOX 43844-00100, Nairobi, Kenya.

**Received date: December 15, 2023; Accepted date: December 29, 2023; Published date: January 02, 2024**

**Citation:** Ogombe C. Ojiambo, Nawiri P. Mildred and Hudson Nyambaka (2024), Impact of Processing on Nutrients and Anti-Nutrients in Tubers and Leaves of Cassava (Manihot Esculenta Crantz), *J. Nutrition and Food Processing,* 7(1); **DOI:10.31579/2637-8914/185**

**Copyright:** © 2024, Hudson Nyambaka. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

**Abstract:**

**Purpose**

The study investigated the effect of boiling and deep-frying on the levels of selected nutrients and anti-nutrients in tubers and leaves of new Migyera and MM96/2480 varieties planted in Busia County. Although cassava contains high levels of nutrients (elements and vitamins) that meet nutrient requirements when consumed as the main diet, it requires thorough cooking to reduce high levels of phytochemicals, anti-nutrients affecting nutrient bio-accessibility, and carcinogenic compounds; procedures which also affect the nutrient levels.

**Methods**

Tubers and leaves from the tips of the plant were harvested after 8 months. A portion of the tubers was boiled in water (100 ºC, 20 minutes), while another deep-fried in vegetable cooking oil until it turned brown (5 minutes). Leaves were pounded until uniformly macerated and boiled in water (100 ºC, 45 minutes). Levels of nutrients and antinutrients were determined by standard methods.

**Results**

The levels of nutrients and anti-nutrients were significantly higher in leaves than in tubers, and also differed significantly in different cassava varieties. Boiling of tubers significantly reduced the nutrients and anti-nutrients levels more compared to frying ($P<0.001$), ranging from 13.7 to 97.7%. Deep frying of Migyera variety had higher nutrient reduction than in MM96/2480 variety. Essential elements and antinutrients molar ratios indicated that the elements were not bio-accessible.

**Conclusion**

Boiling and deep-frying of cassava tubers and leaves results in significant reduction of nutrient and anti-nutrient levels, implying that cassava cannot be used as the main diet; explaining the high level of child malnutrition in such communities.

**Key words:** cassava tubers; cassava leaves; boiling; deep frying; nutrients; anti-nutrients

## Introduction

Cassava is a semi-arid food crop that would address malnutrition, and is commonly grown and consumed in tropical and sub-tropical countries such as Kenya. Malnutrition remains prevalent in children under the age of 5 years and has been reported in Busia (stunting 26 %, 13 % underweight, and 10.1 % wasting) and Kilifi (22 % moderately stunted and 7 % severely stunted) counties of Kenya [1-3]. Among the common cassava varieties grown in Kenya are the newly improved Migyera and MM96/2480 varieties, which were developed by the Kenya Agricultural and Livestock Research Organization (KALRO). Cassava tubers and leaves are good sources of nutrients such as protein, vitamins (C, B1, B2, B3) and minerals (Ca, Zn, Fe, K), but also contain high levels of anti-nutrients (oxalate and phytate) [4,5]. However, the variation in the levels of nutrients and antinutrients depends on the age of the plant, cultivar, climatic conditions, and fertility of the soil [6]. In cassava roots, the levels reported are in the range of 0.3 – 3.5 mg/100 g (protein), 14.9 – 50 mg/100 g (vitamin C), 0.03 – 0.28 mg/100 g (vitamin B1), 0.03 – 0.06 mg/100 g (vitamin B2) and 1.3 – 2.8 mg/100 g, B3) [4]. These levels are sufficient to meet a good percentage of recommended dietary allowance (RDA) [7-10]. Wobeto et al. [11] and Waluchio [5] reported oxalate levels of between 1.35 g/100 g and 2.88 g/100 g and between 30.59 g/100 g and 154.7 g/100 g in cassava tubers and leaves respectively. Phytate level in tubers was reported in the range of 661.33 – 3040 mg/kg [12,13].

The bio accessibility of these nutrients is however affected by the presence of high levels of anti-nutrients such as oxalate, phytate and trypsin inhibitor in leaves. The presence of anti-nutrients in food affect bio accessibility of some nutrients; for example, by increasing elements

phytate molar ratio in food. The recommended molar ratios of phytate: zinc is < 15, that of phytate to iron is < 1 [14,15] and phytate: calcium > 0.24 [16].

Cassava tubers and leaves also contain other phytochemicals, mainly cyanogenic glycoside, which makes them poisonous and less popular [17]. On consumption, cyanogenic glycosides are broken down by the enzyme, linamarase into cyanohydrin and glucose. Cyanohydrin, being unstable, decomposes rapidly, producing hydrogen cyanide, which is poisonous [18]. Cassava tubers and leaves need therefore, to be processed by methods such as drying, fermentation, frying, pounding, and a long period of boiling to eliminate hydrogen cyanide (17,19,20].

The different processing methods have varied effects on nutrient and anti-nutrient levels. According to Ismaila et al. [21], the addition of palm oil during fermentation significantly increased the crude protein content of the bitter cassava product, yellow gari from 1.03±0.00 % to 1.22±0.01 % (P<0.05). Montagnac [3] observed that fermentation is the most efficient processing method to remove phytate (85.6 %) from cassava roots. During frying and boiling, there are high losses of phytate, which might be a result of thermal degradation and dissolution in water [22]. On the other hand, Omosuli [23] reported no significant difference in the ash, protein, crude fiber, sodium, magnesium, calcium, and phosphorus content in raw and boiled cassava tubers. According to Achidi [24], pounding or grinding cassava leaves before cooking both reduced ascorbic acid and thiamine content, with the loss being slightly higher with grinding (78.61% for ascorbic acid and 38.95% for thiamine) than pounding (76.87% for ascorbic acid and 35.14% for thiamine). The reduction was attributed to the leaching of the nutrients in boiling water. Ujong & Deede [25] reported a reduction of proteins by 4.40% on boiling cassava leaves.

It is expected that processing methods for should retains high levels of nutrients but minimizes levels of anti-nutrients and cyanogenic glycosides in different varieties of cassava to make consumable and provide required nutrients. The aim of the study was to investigated the impact of boiling and deep frying on the levels of nutrients [protein, minerals (K, Ca, Fe, Zn), and vitamins (C, B1, B2, B3)], and anti-nutrients (oxalate and phytate) in two new cassava varieties (Migyera and MM96/2480) grown in Busia County, Kenya.

## 2 Materials and methods

### 2.1 Equipment and chemicals

High Performance Liquid Chromatography, (HPLC) (Shimadzu 20A series), with a Hypsil C18 column was used for the measurement of vitamins and anti-nutrients. The Kjeldahl apparatus was used for measurement of protein, and an Atomic Absorption Spectrophotometer, (AAS) (Shimadzu AA-7000) was used for determination of minerals. Standards for minerals, vitamins, oxalate and phytate, and all other chemicals were obtained from Sigma-Aldrich, Germany.

### 2.2 Sampling and sample preparation

Migyera and MM96/2480 cassava varieties were planted in Busia County in June 2020 (rainy season). The county is located within the coordinates, 0˚ 28’ 0’’N/ 34˚ 6’ 0’’E. It covers an area of 1695 km2 and has a population of 893,681 [26]. It is covered mostly with sandy loam soils although the northern and central parts are covered with dark clay soils. The county receives an annual rainfall of between 750 mm and 2000 mm [27]. The mean temperature in the county is between 21 and 27 ℃ [28]. Busia County is the largest producer of cassava in Kenya, with a production of 16.4 tons per hectare [29].

A 19 by 19 m plot was tilled using a hoe, and planting of cuttings obtained from the Kenya Agricultural and Livestock Research Organization (KALRO) done the following day at intervals of 1 by 1 m. Neither fertilizer application nor irrigation were done. Weeding was done monthly, and the tubers and the first three leaves from the tips of the plant were harvested after 8 months. The preparation and processing of both cassava tubers and leaves were done according to home-based protocols. The tubers were washed to remove soil particles, peeled, split longitudinally into two halves, and cut into pieces of about 4 cm long. The pieces were washed using tap water and then divided into three portions. The first portion was packed raw in plastic containers. The second portion, consisting of 500 g was placed in 500 mL of water in a pan, then boiled at 100 ℃ until it became tender (approximately 20 minutes), cooled, and then packed in plastic containers. The third portion (500 g) was deep fried in 1 L of vegetable cooking oil until it turned brown (5 minutes), then cooled and packed in plastic containers.

The leaves from each variety were pounded in a mortar and pestle until uniformly macerated, then divided into two portions. The first portion was analyzed raw, while the second portion (500 g) was boiled in 1 L of water at 100 ℃ for 45 minutes and packed in plastic containers. Both tubers and leaf samples in plastic containers were placed in a cooler box kept at around 0 ℃. All the samples were then transported to Department of Food Science and Technology laboratories, Jomo Kenyatta University of Agriculture and Technology (JKUAT) within 8 hours where they were frozen at around -10 ℃ while awaiting the analysis.

### 2.3 Determination of crude protein

Protein was determined by the Kjeldahl method, according to Maehre et al. [30]. All the procedures were carried out in triplicate. One gram of the sample was digested using 15 mL concentrated H2SO4 and 0.5 g of CuSO4 catalyst. The mixture was heated until the digest color turned blue. It was cooled, transferred into a 100 mL volumetric flask, and topped up with distilled water. A blank digestion was also done. Ten (10) mL of digest was transferred into a distilling flask, which was connected to another flask that contained boric acid, and distillation was done to a volume of about 60 mL distillate. The distillate was titrated using 0.02 N-HCl to and an orange color of the mixed indicator. Total nitrogen was calculated using equation 1.

N (%) = ((mL 0.02 N sample-mL 0.02 N blank)×0.0014 ×N HCl ×100)/(Weight of sample) Equation 1.

Protein content was determined from total nitrogen by multiplying the concentration of nitrogen in food by a conversion factor of 6.25.

### 2.4 Determination of vitamins

Vitamins; C, B1, B2, and B3 were determined using a reversed phase (RP) HPLC procedure adopted from procedures described by Martin et al. [31], Tanmay et al. [32] and Sudipta et al. [33]. All procedures were done in triplicate. Exactly 20 cm3 of deionized water were added to a 5 g food sample. The mixture was homogenized for 1 min then centrifuged for 10 min at 14000 g. Then 10 mL of homogenized and centrifuged food sample was loaded on an activated stationary phase and eluted with 10 mL methanol and 10 mL water whose pH had been adjusted to 4.2 at a flow rate of 1 mL min-1. The eluent was collected in a bottle and evaporated to dryness. The residue was dissolved in the mobile phase, filtered with a 0.45 μm Millipore filter and 20 μL of the filtrate was infused into the HPLC system. The separation was achieved by a C18 column (internal diameter 4.6 mm; pore size 3.5 μm) using a mobile phase of 0.1 M KH2PO4 (pH 7): methanol (9:1) at a flow-rate of 0.7 mL min-1 and 25 ℃. The column elute was monitored with a photodiode-array detector at 265 nm, 234 nm, 266 nm and 261 nm for vitamin C, thiamine, riboflavin, and niacin, respectively. Identification and quantification of compounds were achieved by comparing their peak areas with those of standards of known concentrations using the calibration curves.

### 2.5 Determination of minerals

In the determination of the levels of minerals, standard calibration curves were developed from the calcium, zinc, iron, and potassium standards

series (0-2 µg/mL). All the procedures were done in triplicate. A clean dry crucible was weighed, and about 5 grams of sample were weighed into it. The crucibles were placed on a hot plate under a fume hood, and the temperature was slowly increased until smoking ceased and the samples were thoroughly charred. They were then placed in a muffle furnace and heated for 1 hour as temperature increased gradually to 250 ℃. The temperature was increased to 600 ℃ and incinerated for about 5 hours. The temperature was then decreased to 300 ℃, the crucibles were removed and they were cooled to room temperature. The ash was transferred quantitatively to 100 mL beaker using 20 mL of 0.5 N HNO3, then stirred and allowed to settle. This was then transferred to a 100 mL volumetric flask and filled to the mark using 0.5 N HNO3. Insoluble matter was filtered, and absorbance of the solutions was read by an Atomic Absorption Spectrophotometer (AAS) at 422.7 nm, 213.9 nm and 248.3 nm for calcium, zinc, and iron respectively. Emission was read by an Atomic Emission Spectrophotometer (AES) for potassium at 766 nm and concentrations of all the minerals were obtained from their respective calibration curves developed from their standards.

### 2.6 Determination of Oxalate

The sample procedure followed for the determination of oxalate was done according to Karanja et al. [34]. Standard calibration curves were developed from the oxalate standard series (0-200 µg/mL). All the procedures were done in triplicate. Exactly 0.5 g fresh weight of the sample from the freezer was homogenized with 4 mL of 0.5 N HCl, heated at 80 ℃ for 10 minutes with intermittent shaking, and then distilled water was added to a volume of 25 mL. An aliquot of 3 mL of the solution was withdrawn and centrifuged at 24149 g for 10 minutes to get 1 mL of supernatant that was filtered through a 0.45µm microfilter for injection into the HPLC column. HPLC detection was done using a Shimadzu UV-VIS detector, and a Hypsil C18 column (5µ M, 4.6 mm *250 mm) equipped with waters 550 was used as the static phase. Mobile phase was 0.25 % dehydrogenate phosphate and 0.0025 M, Tetrabutyl Ammonium hydrogen sulphate buffered at pH 2.0 with orthophosphoric acid. Flow rate of 0.6 mL min-1, pressure of 62 kgf and a detection wavelength of 314 nm.

### 2.7 Determination of phytate

Phytates were analyzed by the HPLC method according to Camire & Clydesdale [35]. Standard calibration curves were developed from the phytate standards (0-200 µg/mL range). All the procedures were done in triplicate. Approximately 0.5 g of sample was extracted with 10 mL of 3 % H2SO4. The contents were filtered, and the filtrate was transferred to a boiling water bath for 5 minutes, followed by the addition of 3 mL of FeCl3 solution (6 mg ferric iron per mL in 3 % H2SO4). The contents were heated for 45 minutes to complete precipitation of the ferric phytate complex. They were then centrifuged at 1048 g for 10 minutes, and the supernatant was discarded. The precipitate was washed with 30 mL distilled water, centrifuged again at the same speed and time, and the supernatant was discarded. A 3 mL of 1.5 N NaOH was added to the residues, and the volume was brought to 30 mL with distilled water. The contents were heated for 30 minutes in a boiling water bath to precipitate the ferric hydroxide. Cooled samples were centrifuged, and the supernatant was transferred into a 50 mL volumetric flask. The precipitate was rinsed with 10 mL distilled water, centrifuged (1048 g for 10 minutes) and the supernatant was added to the contents of the volumetric flask. This was microfiltered, and HPLC analysis was carried out. The mobile phase was 0.005 N sodium acetate in distilled water, and detection was done at 500 nm.

### 2.8 Determination of molar ratio of phytate/mineral

The molar ratio of phytate to minerals was determined as described by Norhaizan & Faizadatul [36]. The mole of phytate and minerals was determined by dividing the weight of phytate and minerals by their atomic weights (phytate: 660 g/mol; Fe: 56 g/mol; Zn: 65 g/mol; Ca: 40 g/mol. The molar ratio between phytate and minerals was obtained by dividing the mole of phytate with the mole of minerals.

Molar ratio of phytate/ mineral = (moles of phytate)/(moles of mineral) Equation 2.

### 2.9 Method validation procedures

The linearity of standard calibration curves was checked by calculating the correlation coefficient R2. The accuracy of the methods was verified by determining the percentage recovery after spiking the samples. Precision was determined by calculating the coefficient of variation (CV) of repeated measurements of the test samples.

### 2.10 Data analysis

The levels of nutrients and anti-nutrients in cassava tubers and leaves under different processing as well as in different varieties were compared using one way ANOVA, using the SPSS program (version 28) to determine a significant difference at $P < 0.001$. The calculation of the mean separations was done by standard error [37].

## 3 Results and discussion

### 3.1. Method validation

The method validation results are shown in **Table 1**. The percentage recoveries ranged from 98.000 % to 100.002 % which confirms that the methods of analysis used were accurate and suitable for the analysis of each parameter [38]. The coefficient of variations (CV) ranged from 0.6897 to 2.9851, which was within the sufficiently precise range [39]. The degree of linear relation between the signal and concentration shown by the correlation coefficient R2 ranged from 0.9921 to 1.0000, which indicates a 99.21-100 % instrumental response, and that established that the calibration curves used were linear over the respective range of the concentration of the standards [40].

| Analyte | Equation | $R^2$ | % Recovery | % CV |
|---|---|---|---|---|
| Vitamin C | y= 42299x | 0.9999 | 99.996 | 2.686 |
| Vitamin $B_1$ | y= 33361x | 0.9936 | 99.940 | 2.838 |
| Vitamin $B_2$ | y= 128202x | 0.9999 | 100.002 | 0.690 |
| Vitamin $B_3$ | y= 211142x | 1.0000 | 99.940 | 1.859 |
| Calcium | y= 0.06x+0.0104 | 0.9921 | 98.000 | 2.728 |
| Zinc | y= 1.065x-0.0109 | 0.9966 | 99.800 | 2.985 |
| Iron | y=0.1136x+0.0024 | 0.9975 | 99.200 | 2.687 |
| Potassium | y= 8572x+0.0399 | 0.9939 | 99.400 | 1.361 |
| Phytate | y= 12745x | 0.9991 | 99.998 | 1.019 |
| Oxalate | y= 43493x | 0.9992 | 99.994 | 2.871 |

**Table 1:** Methods validation parameters

Where x is concentration, and y is absorbance

### 3.2 Levels of proteins and vitamins

The mean levels of proteins and vitamins in raw and processed cassava tubers and leaves are shown in Table 2. The levels in raw tubers and leaves, which ranged from 0.056±0.001 to 0.219±0.001 mg/100 g for protein, 2.137±0.037 to 23.863±0.491 mg/100 g for vitamin C, 1.163±0.033 to 13.353±0.146 mg/100 g for vitamin B1, 0.145±0.001 to 0.485±0.008 mg/100 g for vitamin B2, and 0.767±0.011 to 8.875±0.079 mg/100 g for vitamin B3 agree with those reported by USDA (2008). Leaves had levels within the ranges reported in kale and spinach [41], which are common green leafy vegetables consumed in Kenya. Cassava leaves had significantly higher (P< 0.001) levels of protein and vitamins than tubers, which agrees with the findings of the USDA (2008). This may be attributed to the fact that nutrients are synthesized in leaves, and tubers only act as storage sites. The roots are the main part of cassava that is consumed because the leaves contain higher levels of anti-nutrients and cyanogenic glucosides that are not easily removed by boiling, which is the main method of processing green vegetables [42]. This explains why a cassava tuber diet does not provide necessary nutrients.

| P<0.001 | | | | | |
|---|---|---|---|---|---|
| Vitamin $B_1$ (mg/100 g) | *Migyera* tuber | 1.163±0.033$^{cA}$ | 0.319±0.009$^{aA}$ (72.6%) | 0.688±0.015$^{bA}$ (40.8%) | P<0.001 |
| | *Migyera* leaves | 13.353±0.146$^{bD}$ | 0.924±0.016$^{aD}$ (93.1%) | | |
| | *MM96/2480* tubers | 1.190±0.020$^{cB}$ | 0.335±0.006$^{aB}$ (71.8%) | 0.993±0.028$^{bB}$ (16.6%) | |
| | *MM96/2480* leaves | 4.212±0.030$^{bC}$ | 0.392±0.010$^{aC}$ (90.7%) | | |
| P<0.001 | | | | | |
| Vitamin $B_2$ (mg/100 g) | *Migyera* tuber | 0.145±0.001$^{bA}$ | 0.031±0.001$^{aC}$ (78.6%) | 0.067±0.0018$^{aA}$ (53.8%) | P<0.001 |
| | *Migyera* leaves | 0.485±0.008$^{bD}$ | 0.020±0.005$^{aB}$ (95.9%) | | |
| | *MM96/2480* tubers | 0.403±0.004$^{cC}$ | 0.049±0.001$^{aD}$ (87.8%) | 0.085±0.0009$^{bB}$ (78.9%) | |
| | *MM96/2480* leaves | 0.394±0.005$^{bB}$ | 0.009±0.001$^{aA}$ (97.7%) | | |
| P<0.001 | | | | | |
| Vitamin $B_3$ (mg/100 g) | *Migyera* tuber | 1.399±0.026$^{cB}$ | 0.358±0.004$^{aA}$ (74.4%) | 0.575±0.012$^{bA}$ (58.9%) | P<0.001 |
| | *Migyera* leaves | 8.875±0.079$^{bD}$ | 2.775±0.032$^{aD}$ (68.7%) | | |
| | *MM96/2480* tubers | 0.767±0.011$^{cA}$ | 0.585±0.009$^{aB}$ (23.7%) | 0.610±0.011$^{bB}$ (20.5%) | |
| | *MM96/2480* leaves | 6.021±0.118$^{bC}$ | 1.377±0.014$^{aC}$ (77.1%) | | |
| P<0.001 | | | | | |

**Table 2:** Mean levels (DM) of protein and vitamins in raw and processed tubers and leaves of cassava varieties

Mean values followed by a different small letter within the same row differ significantly from one another. Mean values followed by a different capital letter within the same column differ significantly from one another (One - Way ANOVA, P < 0.001, SNK - test, α = 0.05).

Although the cassava varieties were grown under similar conditions, the levels of protein and vitamins varied significantly (P<0.001) between the Migyera and MM96/2480 varieties. For instance, protein in tubers of the Migyera variety was 0.114±0.003 mg/100 g while it was 0.056±0.001 mg/100 g in tubers of the MM96/2480 variety. Tubers of the Migyera variety were also higher in vitamins; C, and B3, minerals (Zn and K) and anti-nutrients (oxalate and phytate) than the MM96/2480 variety. The leaves of Migyera had higher levels of vitamins (C, B1, B2 and B3), minerals (calcium, zinc, and potassium), and anti-nutrients (phytate). This may be attributed to the genetic differences of the different cassava varieties [43].

The levels of proteins and vitamins were reduced significantly (P<0.001) with boiling and deep frying. Boiling reduced nutrients in the ranges of 80.4 % - 92.1 % (protein), 46.0 % - 92.4 % (vitamin C), 71.8 % - 72.6 % (vitamin B1), 78.6 % - 87.8 % (vitamin B2), 23.7 % - 74.4 % (vitamin B3), which agrees with the results reported by Alamu et al. [44] and Zipporah et al. [45] for vitamin C and B1. Frying reduced nutrient levels in tubers by 51.8 % - 88.6 % (protein), 39.6 % - 43.1 % (vitamin C), 16.6 % - 40.8 % (vitamin B1), 53.8 % - 78.9 % (vitamin B2), 20.5 % - 58.9 % (vitamin B3). Boiling significantly reduced the levels of proteins more than deep frying, mainly due to leaching [23,46]. Frying is a better processing method for tubers than boiling, as it retains relatively higher levels of water-soluble nutrients. Both processing methods significantly reduced nutrient levels (P<0.001) hence, a small fraction of the total nutrients in raw cassava will be available in processed cassava products, resulting in lower bioavailability. This may explain why there are cases of malnutrition in communities that rely on a cassava-based diet.

### 3.3 Levels of minerals and anti-nutrients

The mean levels of minerals and anti-nutrients in raw and processed tubers and leaves are shown in Table 3. The ranges were in 32.075±0.875 - 50.134±0.204 mg/100 g for calcium, 0.544±0.003 - 1.160±0.009 mg/100 g for zinc, 0.707±0.019 - 3.141±0.028 mg/100 g for iron, 298.397±3.107 - 485.778±6.609 mg/100 g for potassium, 284.274±6.296 - 613.456±17.611 mg/100 g for oxalate, and 452.774±13.922 - 561.281±5.720 mg/100 g phytate. The levels are in the same range as reported by Tagesse & Tesfaye [47] and the USDA [48]. Similar levels were reported in kale for calcium ]49], iron [41] and zinc [50], while the USDA [48] reported results in the same range in spinach for calcium (99

mg/100 g), zinc (0.53 mg/100 g), iron (2.71 mg/100 g) and potassium (558 mg/100 g). In other studies, oxalate levels ranged between 1.35 and 2.88 g/100 g and between 30.59 and 154.7 g/100 g in cassava tubers and leaves, respectively [5,11], while phytate levels in tubers were reported in the range of 661.33 – 3040 mg/kg [12,13,51. The levels of the nutrients are high and meet a percentage of the RDA. The leaves of MM96/2480 variety had significantly (P<0.001) higher levels of Ca, Fe, and K than the Migyera variety. The tubers of MM96/2480 had significantly (P<0.001) higher levels of Ca and Fe than the Migyera. This may be attributed to the genetic differences of the different cassava varieties [43] as both varieties were planted in the same soil under the same environmental conditions. The leaves of Migyera variety had significantly higher levels of Ca, Zn and Fe than tubers.

The elements and anti-nutrients were significantly reduced (P<0.001) by the processing methods of boiling and deep frying for tubers and leaves. Boiling reduced calcium by 77.7 % - 79.3 %, zinc 17.5 % - 22.8 %, iron 13.7 % - 43.9 %, potassium 22.0 % - 32.4 %, oxalate 31.8 % - 74.3 %, and phytate 58.6 % - 73.9 %. On the other hand, deep frying reduced calcium by 32.5 % - 36.8 %, zinc 2.6 % - 16.4 %, iron 6.6 % - 13.3 %, potassium 0.02 % - 8.6 %, oxalate 12.6 % - 58.9 %) and phytate 47.3 % - 51.7 %. The percentage reductions were lower than for protein and vitamins under the same processing conditions. The leaves experienced a significantly higher reduction in the elements and anti-nutrients as a result of leaching and evaporation, especially when the leaves were pounded before boiling [23,46]. The losses of phytate due to frying and boiling might be a result of thermal degradation and dissolution in water [22]. Phytate is soluble in water and relatively heat stable during normal household boiling, but experiences higher losses in industrial processing such as canning or extrusion cooking where high temperatures are used [52].

| **Nutrients and Anti-nutrients (mg/ 100 g)** | **Cassava variety/part** | **Raw Mean ± SD** | **Process** | | **P-Value** |
|---|---|---|---|---|---|
| | | | **Boiled Mean ± SD (% reduction)** | **Fried Mean ± SD (% reduction)** | |
| Calcium | *Migyera* tuber | $32.075\pm0.875^{cA}$ | $6.644\pm0.146^{aA}$ (79.3%) | $21.646\pm0.534^{bA}$ (32.5%) | **P<0.001** |
| | *Migyera* leaves | $50.134\pm0.204^{bD}$ | $20.288\pm0.221^{aC}$ (59.5%) | | |
| | *MM96/2480* tubers | $47.461\pm0.634^{cC}$ | $10.571\pm0.124^{aB}$ (77.7%) | $29.986\pm0.214^{bB}$ (36.8%) | |
| | *MM96/2480* leaves | $39.149\pm0.381^{bB}$ | $33.021\pm0.240^{aD}$ (15.7%) | | |
| **P<0.001** | | | | | |
| Zinc | *Migyera* tuber | $0.737\pm0.022^{bB}$ | $0.608\pm0.0151^{aD}$ (17.5%) | $0.618\pm0.016^{aB}$ (16.4%) | **P<0.001** |
| | *Migyera* leaves | $1.160\pm0.009^{bD}$ | $0.350\pm0.005^{aA}$ (69.8%) | | |
| | *MM96/2480* tubers | $0.544\pm0.003^{bA}$ | $0.420\pm0.011^{aB}$ (22.8%) | $0.530\pm0.006^{bA}$ (2.6%) | |
| | *MM96/2480* leaves | $1.014\pm0.021^{bC}$ | $0.466\pm0.012^{aC}$ (54.0%) | | |
| **P<0.001** | | | | | |
| Iron | *Migyera* tuber | $0.707\pm0.019^{bA}$ | $0.610\pm0.018^{aB}$ (13.7%) | $0.613\pm0.015^{aA}$ (13.3%) | **P<0.001** |
| | *Migyera* leaves | $2.381\pm0.034^{bC}$ | $1.476\pm0.017^{aC}$ (38.0%) | | |
| | *MM96/2480* tubers | $0.715\pm0.020^{bB}$ | $0.401\pm0.009^{aA}$ (43.9%) | $0.668\pm0.013^{bB}$ (6.6%) | |
| | *MM96/2480* leaves | $3.141\pm0.028^{bD}$ | $1.779\pm0.011^{aD}$ (43.4%) | | |
| **P<0.001** | | | | | |
| Potassium | *Migyera* tuber | $485.778\pm6.609^{cD}$ | $328.570\pm3.754^{aD}$ (32.4%) | $375.798\pm3.777^{bB}$ (22.64%) | **P<0.001** |
| | *Migyera* leaves | $375.798\pm3.777^{bC}$ | $185.454\pm2.092^{aB}$ (50.7%) | | |
| | *MM96/2480* tubers | $326.43\pm5.037^{cB}$ | $254.473\pm3.280^{aC}$ (22.0%) | $298.212\pm1.281^{bA}$ (8.6%) | |
| | *MM96/2480* leaves | $298.397\pm3.107^{bA}$ | $163.301\pm2.542^{aA}$ (45.3%) | | |
| **P<0.001** | | | | | |
| Oxalate | *Migyera* tuber | $613.456\pm17.611^{cD}$ | $157.406\pm2.307^{aB}$ (74.3%) | $252.267\pm5.497^{bA}$ (58.9%) | **P<0.001** |
| | *Migyera* leaves | $284.274\pm6.296^{bA}$ | $115.562\pm3.478^{aA}$ (59.3%) | | |
| | *MM96/2480* tubers | $413.863\pm8.087^{cB}$ | $282.252\pm2.855^{aC}$ (31.8%) | $361.529\pm7.187^{bB}$ (12.6%) | |
| | *MM96/2480* leaves | $526.982\pm0.177^{bC}$ | $294.280\pm4.121^{aD}$ (44.2%) | | |
| **P<0.001** | | | | | |
| Phytate | *Migyera* tuber | $561.281\pm5.720^{cD}$ | $146.343\pm0.942^{aC}$ (73.9%) | $271.163\pm2.486^{bB}$ (51.7%) | **P<0.001** |
| | *Migyera* leaves | $555.994\pm5.718^{bC}$ | $61.520\pm0.787^{aB}$ (88.9%) | | |
| | *MM96/2480* tubers | $463.774\pm5.750^{cB}$ | $192.229\pm3.641^{aD}$ (58.6%) | $244.508\pm2.787^{bA}$ (47.3%) | |
| | *MM96/2480* leaves | $452.774\pm13.922^{bA}$ | $32.089\pm0.338^{aA}$ (92.9%) | | |
| **P<0.001** | | | | | |

**Table 3:** Mean levels (DM) of minerals and anti-nutrients in raw and processed tubers and leaves of cassava varieties

Mean values followed by a different small letter within the same row differ significantly from one another. Mean values followed by a different capital letter within the same column differ significantly from one another (One - Way ANOVA, P < 0.001, SNK - test, α = 0.05). (% reduction levels on processing)

Even though boiling and frying lead to significant reductions in oxalate and phytate, the levels that remain are higher than the recommended molar ratios (Table 4). The ratios for phytate to elements were: zinc < 15, iron < 1 and Calcium < 0.24 [14-16]. The results show that although raw cassava tubers and leaves contain high levels of proteins, vitamins, and

minerals, a higher percentage of nutrients is lost during boiling and deep frying. Boiling and deep frying are the main methods used to prepare cassava for consumption. The processed cassava tubers and leaves therefore contribute very little towards meeting the RDAs, which are, 0.83 g/kg (protein), 40 mg – 120 mg/day (vitamin C), 0.2 mg – 1.4 mg/day (vitamin B1), 0.3 mg – 1.6 mg/day (vitamin B2), 2 mg – 18 mg/day (vitamin B3), 200 mg – 1300 mg/day (Ca), 8 mg – 11 mg/day (Zn), 1.8 mg/day (Fe) and 4700 – 5100 mg/day (K) [7-10]. Both boiled and fried cassava tubers and leaves cannot therefore be relied on to alleviate malnutrition.

| **Mineral** | **Cassava variety/part** | **Phytate:Mineral Molar ratio** | | | **Recommended molar ratios** (Hurrell and Egli, 2010; Magallanes-Lopez *et al.,* 2017; Morris & Ellis, 1985) |
|---|---|---|---|---|---|
| | | **Raw** | **Boiled** | **Deep fried** | |
| Calcium | *Migyera* tubers | 1.061 | 1.335 | 0.759 | **<0.24** |
| | *Migyera* leaves | 0.672 | 0.184 | | |
| | *MM96/2480* tubers | 0.592 | 1.102 | 0.494 | |
| | *MM96/2480* leaves | 0.701 | 0.059 | | |
| Zinc | *Migyera* tubers | 75.003 | 23.705 | 43.213 | **<15** |
| | *Migyera* leaves | 47.204 | 17.311 | | |
| | *MM96/2480* tubers | 83.961 | 45.075 | 45.435 | |
| | *MM96/2480* leaves | 43.976 | 6.782 | | |
| Iron | *Migyera* tubers | 67.360 | 20.356 | 37.533 | **<1** |
| | *Migyera* leaves | 19.813 | 3.537 | | |
| | *MM96/2480* tubers | 55.036 | 40.674 | 31.057 | |
| | *MM96/2480* leaves | 12.231 | 1.530 | | |

**Table 4:** Phytate to minerals molar ratios in raw and processed cassava products

## 4 Conclusions

The levels of nutrients and anti-nutrients are not only significantly higher in leaves than in tubers but also significantly different among cassava varieties. The leaves of the MM96/2480 variety are more nutritious than those of the Migyera variety, while the tubers of the Migyera variety are more nutritious than those of MM96/2480 variety. The levels of nutrients in both tubers and leaves are significantly affected by boiling and deep frying, reducing the levels by up to 97 %. Hence, boiled and deep-fried cassava products cannot be relied on to reduce malnutrition in communities. However, deep-frying is a better processing method for tubers than boiling, as it retains relatively higher levels of water-soluble nutrients. Both boiling and frying significantly reduce the anti-nutrients (oxalate and phytate) in both tubers and leaves, although levels that remain still affect the bio-accessibility of the nutrients due to high molar ratios. This may explain why there is a high level of child malnutrition in communities that rely on cassava food.

## Statements and Declarations

## Ethical approval

The study followed national guidelines and legislation, as appropriate permission for the study was received from the National Council of Science Technology and Innovation, Kenya (NACOSTI).

## Consent for publication

The manuscript does not have details, images, or videos relating to an individual person and thus requires no consent to publish.

## Availability of data and materials

The data obtained and analyzed during the current study is available from the corresponding author on reasonable request.

## Competing interest

The authors declare that they have no competing interests.

## Funding

The authors declare that there was no funding given to support the current study.

## Authors contribution

All authors contributed to the study conception and design. Data collection and analysis, and the drafting of the manuscript was by Ogombe, Charles Ojiambo. The other authors read, commented on previous versions and approved the final manuscript. The authors have agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work.

## Acknowledgements

The authors acknowledge the chairman of the Department of Chemistry, Kenyatta University and the chief Technician in the Department of Food Science at Jomo Kenyatta University of Agriculture and Technology for the support in carrying the study.

## References

1. Azikoyo, N., Wandayi, O., Kuria, M. (2012). Nutrition status of children under five years in cassava consuming communities in Nambale, Busia of Western Kenya. Food and nutrition science, 3, 796 – 801
2. Nginya, W. (2015). Contribution of Cassava to Nutrition of Children 2-5 Years and their Primary Care Givers in Coastal Kenya. Master's thesis, University of Nairobi.
3. Montagnac, A., Davis, R., Tanumihardjo, A. (2009). Nutritional value of cassava for use as a staple food and recent advances for improvement. Comprehensive Reviews in Food Science and Food Safety, 8, 181 – 194.
4. United States Department of Agriculture, USDA. (2008). National Nutrient Database for Standard Reference, Release, 21. Nutrient Data Laboratory Home page.
5. Waluchio, N. (2016). Nutrient and anti-nutrient content in leaves of selected coastal Kenya cassava varieties as affected by maturity stage, leafage and preparation method. Erespository.uonbi.ac.ke/handle/11295/97238. https://www.hdl.handle.net/11295/97238.
6. Temesgen, Z & Bakalo, B. (2019). Medicinal, Nutritional and Anti-Nutritional Properties of Cassava (Manihot esculenta): A Review

7. Aly, N., El-Gendy, K., Mahmoud, F., & El-Sebae, K. (2010). Protective effect of vitamin C against chlorpyrifos oxidative stress in male mice. Pesticide Biochemistry and Physiology, 97, 7–12.
8. Constán-Aguilar, C., Leyva, R., Blasco, B., Sánchez-Rodríguez, E., Soriano, T., Ruiz, M. (2014). Biofortification with potassium: Antioxidant responses during postharvest of cherry tomato fruits in cold storage. Acta Physiologiae Plantarum, 36, 283–293.
9. Endrias, D., Negussie, R., Gulelat, D. (2016). Comparison of three sweet potato (Ipomoea Batatas (L.) Lam) varieties on nutritional and anti-nutritional factors. Global Journal of Science Frontier Research, 16, 1920–1931.
10. Nicanuru, C., Laswai, S., Sila, N. (2015). Effect of sun- drying on nutrient content of orange fleshed sweet potato tubers in Tanzania. Sky Journal of Food Science, 4(7), 91–101.
11. Wobeto, C., Correa, D., De Abreu, P., Dos Santos, D., Pereira, V. (2007). Anti – nutrients in the cassava (Manihot esculenta Crantz) leaf powder at three ages of the plant. Food Science and Technology 27, 108 – 112.
12. Manano, J., Ogwok, P., Byarugaba-Bazirake, W. (2018). Chemical composition of major cassava varieties in Uganda, targeted for industrialization. Journal of food research 7,
13. Sarkiyayi, & Agar, T (2010). Comparative analysis on the nutritional and ant-nutritional contents of the sweet and bitter cassava varieties. Advanced Journal of Food Science and Technology 2, 328-334.
14. Hurrell, R & Egli, I. (2010). Iron bioavailability and dietary reference values. American journal of clinical nutrition, 91, 1461 – 1467.
15. Magallanes-Lopez, A., Hernandez-Espinosa, N., Velu, G., Posadas-Romano, G., Ordonez-Villegas, V., Crossa, J., Guzman, C. (2017). Variability in iron, zinc and phytic acid content in a worldwide collection of commercial durum wheat cultivars and the effect of reduced irrigation on these traits. Food Chemistry 237: 499-505.
16. Morrris, R & Ellis, R. (1985). Bioavailability of dietary calcium effect of phytate on adult men consuming non-vegetarian diets. In: ACS symposium series 75: Nutritional bioavailability of calcium. Kies C (eds), p. 63. American chemical society: Washington, DC, USA.
17. Islamiyat, B., Olaniyan, A., Olatunde, J., Ayandokun, T., Olaifa, A. (2016). Effect of processing amygdalin and cyanide contents of some Nigerian Foods. Journal of Chemical and Pharmaceutical Research, 8(2), 106-13.
18. Centre for Food Safety CFC). (2007). Natural toxins in food plants. Risk assessment studies. Food and Environment Hygiene department, the Government of the Hong Kong Special Administrative Region. Report No.27. 2007.
19. Bradbury, H & Denton, C. (2011). Mild methods of processing cassava leaves to remove cyanogens and conserve key nutrients. Food Chemistry 127: 1755-1759.
20. Ojiambo, O., Nawiri, M., Masika, E. (2017). Reduction of cyanide levels in sweet cassavas leaves grown in Busia County, Kenya based on different processing methods. Food research; 1: 97-102.
21. Ismaila, R., Alakali, S., Atume, G. (2018). Effect of Local Processing Techniques on the Nutrients and Anti-Nutrients Content of Bitter Cassava (Manihot Esculenta Crantz). American Journal of Food Science and Technology; 6: 92-97.
22. Joseph, I., Onyango, A., Makokha, A., Kanenski, O., Okoth, J. (2020). Effect of boiling and wet frying on nutritional and antinutrient content of traditional vegetables commonly consumed in Malawi. Journal of Food Research, 9 (1): 19-33.
23. Omosuli, V. (2014). Effects of processing on the chemical anti-nutritional properties of cassava roots. Research and Reviews. Journal of Botanical Sciences, 3, 27-31.
24. Achidi, U., Olufunmike, A., Bussie, M., and Mpokp, B. (2008). The effect of processing on the nutrient content of cassava (manihot esculenta crantz) leaves. Journal of Food Processing and Preservation 32: 486-502.
25. Ujong, E & Deede, B. (2020). Effect of processing on the chemical and anti-nutritional properties of cassava leaves (sweet and bitter varieties). ARC Journal of Nutrition and Growth 6, 6-12. DOI: https:// doi.org/10.20431/2455-2550.0602002
26. Kenya National Bureau of Statistics. (2019). 2019 Kenya Population and House Census: Population by County and Sub-County. Volume 1. Kenya National Bureau of Statistics. Pp.9-19.
27. GOK (2014). Soil suitability evaluation for maize production in Kenya. Ministry of Agriculture, Livestock and Fisheries, State Department of Agriculture. Government of Kenya, Nairobi
28. Jaetzold, R., Schmidt, H., Hometz, B., Shisanya, C. (2011). Farm management Handbook of Kenya, Vol. II- Natural Conditions and Farm Management Information- 2nd edition.
29. GOK (2015). Economic Review of Agriculture. Government of Kenya, Nairobi.
30. Maehre, K., Dalheim, L., Edvinsen, K., Elvevoll, O., Jensen, I. (2018). Protein determination—Methods Matter. Foods. 1:5.
31. Martin, F., Giménez, C., Konings, E. (2016). New Methods for the Analysis of Water-Soluble Vitamins in Infant Formula and Adult/Pediatric Nutritionals. Journal of AOAC International. 99:19-25.
32. Tanmay S., Molla S., Sudipta, K H., Sudipta K., Hazra, Runu C. (2020). The impact of raw and differently dried pineapple (Ananas comosus) fortification on the vitamins, organic acid and carotene profile of dairy rasgulla (sweetened cheese ball). Heliyon, 6, 1-10.
33. Sudipta, K H, Tanmay S, Molla S, Hassan I. S, Siddhartha P., Runu C., 920200. Characterization of phytochemicals, minerals and in vitro medicinal activities of bael (Aegle marmelos L.) pulp and differently dried edible leathers. Heliyon, 6, 1-13.
34. Karanja, N., Kenji, M., Njoroge, M., Sila, N., Onyango, A., Koaze, H., Baba, N. (2015). Compositional Characteristics of Young Shoots of Selected Bamboo Species Growing in Kenya and Their Potential as Food Source. Journal of Food and Nutrition Research. 2015, 3 (9), 607-612.
35. Camire, L & Clydesdale, M. (2006). Analysis of phytic acid in foods by HPLC. Journal of food science; 47: 575-578.
36. Norhaizan, M & Nor Faizadatul, A. (2009). Determination of Phytate, Iron, Zinc, Calcium Contents and Their Molar Ratios in Commonly Consumed Raw and Prepared Food in Malaysia. Malaysian Journal of Nutrition; 15: 213 - 222
37. Sawyer, W & Beebe, A. (2007). Chemistry experiment for instrumental methods. Wisley, New York Pp 43-51.
38. Gonzalez, A & Herrador, M. (2007). A practical guide to analytical method validation, including measurement uncertainty and accuracy profiles. Trends in Analytical Chemistry, 26: 227 – 238.
39. Lu, N., Li, N., An, Q., Dong, Y. (2016). A rapid micellar HPLC method for simultaneous separation of olanzapine and its related compound A in tablets. Journal of Lanzhou University (Medical Sciences), 42(3), 12-21.
40. Meghanathan, N. (2016). Assortativity Analysis of Real-World Network Graphs based on Centrality Metrics. Computer and Information Science. 9. 7.

41. Emebu, K & Anyika, U. (2011). Proximate and Mineral Composition of Kale (Brassica oleracea) Grown in Delta State, Nigeria. Pakistan Journal of Nutrition, 10: 190-194.
42. Latif, S & Muller, J. (2015). Potential of cassava leaves in human nutrition: A review. Trends in Food Science and Technology; 44: 147-158.
43. Oresegun, A., Fagbenro, P., Edah, B. (2016). Nutritional and anti-nutritional composition of cassava leaf protein concentrate from six cassava varieties for use in aqua feed. Cogent Food and Agriculture; 2.
44. Alamu, E., Chileshe, P., Bukola, O., Omalola, O., Adegunwa, O., Chikoye, D., Busie, M. (2021). Evaluation of nutritional properties and consumer preferences of legume fortified cassava leaves for low-income house-holds in Zambia. Cogent Food and Agriculture, 7.
45. Zipporah, O., Mildred, N., Hudson, N., Naumih, N. (2021). In Vitro Bioaccessibility of the Vitamin B Series from Thermally Processed Leafy African Indigenous Vegetables Journal of Food Quality, 1-8,
46. Okibe, G., Jubril, B., Paul, A., Dallatu, A. (2016). Effect of cooking methods on proximate and mineral composition of fluted pumpkin (Telfairia accidentalis) leaves. International Journal of Biochemistry, 9:1-7.
47. Tagesse, L & Tesfaye, D. (2022). Evaluation of nutritional potential and effect of processing on improving nutrient content of cassava (Manihot esculenta Crantz) Roots and Leaves.
48. USDA (2018). USDA food compositional database. Retrieved from https://ndb.nal.usda.gov/ndb/foods/show/11601?fgcd=&manu=&format=&count=&max=25&offset=&sort=default&order=asc&qlookup=yam&ds=&qt=&qp=&qa=&qn=&q=&ing=
49. Manchali, S., Chidambara, N., Patil, S. (2012). Crucial facts about health benefits of popular cruciferous vegetables. Journal of Functional Foods, 4: 94–106.
50. Sikora, E & Bodziarczyk, I. (2012). Composition and antioxidant activity of kale (Brassica oleracea L. var. acephala) raw and cooked. Acta scientiarum polonorum. Technologia Alimentaria; 11(3), 239-248.
51. Charles, L., Sriroth, K., Huang, C. (2005). Proximate composition, mineral contents, Hydrogen cyanide and phytic acid of 5 cassava genotypes. Food Chemistry, 92 (4), 615-620.
52. Schlemmer, U., Frolich, W., Prieto, R., Grases, F. (2009). Phytate in foods and significance for humans: Food sources, intake, processing, bioavailability, protective role and analysis. Molecular Nutrition and Food Research 53: 330-375.

This work is licensed under Creative Commons Attribution 4.0 License

To Submit Your Article Click Here: **Submit Manuscript**

**DOI:** 10.31579/2637-8914/185

**Ready to submit your research? Choose Auctores and benefit from:**

- fast, convenient online submission
- rigorous peer review by experienced research in your field
- rapid publication on acceptance
- authors retain copyrights
- unique DOI for all articles
- immediate, unrestricted online access

At Auctores, research is always in progress.

Learn more https://auctoresonline.org/journals/nutrition-and-food-processing