Determination of the Nutrients, Anti-Nutrients and Functional Properties of Processed Cocoyam (Xanthosoma sagittifolium) Cultivars Grown in Southeast, Nigeria

A.N. Ukom* and C.F.L. Okerue

Department of Food Science and Technology, Michael Okpara University of Agriculture, Umudike, Nigeria.

tony2008gospel@gmail.com

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Abstract. This project determined the nutrients, anti-nutrients and functional properties of two cultivars of processed (boiled and fermented) Xanthosoma sagittifolium (ede ocha and ede uhie) flours grown in Southern, Nigeria. The proximate, minerals, chemical, anti-nutrients and functional properties of the cocoyam flours varied significantly (P<0.05). The results showed that the moisture content varied from 6.17% to 7.88%, with ede uhie exhibiting higher values. The same trend was observed in crude protein (4.33-5.92%), crude fiber (1.04-1.94%), crude fat (1.16-3.22%), ash (2.17-2.93%), with ede uhie exhibiting higher values than ede ocha. However, the carbohydrate and energy values were higher in ede ocha. For the mineral contents, the range values were: Ca (10.23-41.17mg/100g), Na (15.22-17.66mg/100g), Mg (5.82-8.38mg/100g), P (12.31-16.19mg/100g), K (2.78-3.62mg/100g), with ede uhie showing higher values. On pH, TTA, starch and total sugar, it was observed that fermented ede ocha had higher pH value (6.82), TTA was higher in fermented ede ocha (0.92%), starch (24.66%) and total sugar (3.29%) values were higher in raw ede ocha than others. Anti-nutrient factors were generously reduced by processing methods especially boiling by between 50-100%, and fermentation by between 5-77% in most of the parameters analyzed. Functional properties ranged from BD (0.60-0.81g/mL), WAC (2.19-2.71g/mL), OAC (1.45-2.92g/mL), FC (16.38-19.52g/mL), FS (1.96-2.48 min/sec) and GT (60.85-81.05 °C). While BD, WAC, OAC, FC were higher in the ede ocha flour, FS and GT were higher in ede uhie flour. Relating the physicochemical and functional properties, ede ocha has a potential for a quality food thickener. Overall, the results obtained in this study can be used to develop cocoyam food based products for enhanced nutrition with a potential to promote cocoyam commercial agriculture and composite utilization for confectionary industries in Nigeria.

Introduction

Cocoyam (Xanthosoma sagittifolium (L.) Schott) is one of the important specie of edible aroidis, grown as subsistence staple in tropical and sub-tropical countries. They are grown primarily for their edible starch laden corms and cornels, and their leaves are used as vegetable [1], and in wrapping of grated cocoyam (Xanthosoma spp.) or water yam (Dioscorea alata) for Ekpang nkukwo porridge, a local delicacy. According to Falade and Okafor [2], Nigeria is the largest producer of cocoyam in the world with an annual production of 3.450 million metric tonnes in 2012, representing 72.2 %, 57.7 % and 45.9 % of total production in West Africa, Africa and the World respectively. Cocoyam is a giant crop, which corms, cornels, leaves, stalks and inflorescence are utilized for food [3]. Odebunmi et al. [4] opined that Xanthosoma corms are rich sources of nutrients, namely, moisture (80.99 %), ash (1.03 %), crude protein (5.47 %), crude fat (0.20 %), crude fiber (1.28 %) and total carbohydrate of 11.03 %. The functional, pasting and granule size of cocoyam starches have been reported [2, 5, 6]. Cocoyam is a suitable food products, as a thickener and as food for people with gastro-intestinal disorders due to the starch digestibility (about 98 %), a quality attributed to its granule size which is ten times less than that of potato [7]. Cocoyam starches have great potential for industrial applications in textiles, pharmaceutical, paper
and food processing. However, cocoyam utilization has been limited due to a number of anti-nutritional and toxic factors, especially oxalates and phytates which impart an acrid taste, and causes sharp irritation and burning sensation in the throat and mouth on ingestion [8].

Among the local folks, *Xanthosoma sagittifolium* corms and cormels are boiled, roasted and eaten with palm oil and/or vegetable sauce. The corms can be pounded with cassava into fufu and served with soup. However, flour produced from *Xanthosoma sagittifolium* corms and cormels through adequate processing methods can be used for baked end products as a value addition to enhance the utilization of cocoyam. Processing of fresh *Xanthosoma sagittifolium* corms and cormels into flours has another advantage of reducing its losses due to high water content and storage inadequacy, reduce transportation cost, increase versatility and utilization in food formulations [2].

Application of *Xanthosoma sagittifolium* flours in baking, soup and porridge is primarily governed by their functional and physicochemical properties. These are those properties that affect the physical and chemical attributes during food preparations [2]. Investigation of these properties was necessary to evaluate the requisite characteristics of *Xanthosoma sagittifolium* cultivars in order to enhance their food and industrial utilization. Several authors have reported on the functional, physicochemical, and pasting characteristics of cocoyam flours [2, 6, 7, 9, 10]. However, scarce information is available on the nutrients, anti-nutrients and functional properties and of processed cultivars of *Xanthosoma sagittifolium* flours. Therefore, the objective of this research was to evaluate the nutrients, anti-nutrients and functional properties of processed (boiled and fermented) *Xanthosoma sagittifolium* cultivars (*ede ocha* (white) and *ede uhie* (red)) grown in Southeastern, Nigeria.

**Material and Method**

**Raw materials**

Cultivars of *Xanthosoma sagittifolium* known as *ede ocha* (white) and *ede Uhie* (red) (Igbo language of Southeastern Nigeria) were procured from Umudike, Ikwuano Local Government Area, Abia State. There were identified by the University Herbarium, Michael Okpara University of Agriculture, Umudike, Nigeria. Umukike is situated between latitude 05°29N and longitude 07°33E and 122m altitude. The soil is classified as acidic and sandy loam and characterized as an ultisol [11].

**Sample preparation**

The samples was sorted, peeled, washed and cut into 2 cm slices and were divided into 3 equal parts of 500 grams for different processing treatments.

Fermented Flour: Five hundred grams of the sliced samples was soaked in 1500 mL of water and allowed to ferment for 72 h after which the water was drained off, washed in clean water and oven dried at 55°C for 72 h. The fermented cocoyam chips was milled and sieved through 0.42 mm mesh size (Fig. 1).

Boiled Flour: Five hundred grams of the sliced samples was boiled in 1L of water for 15 min. at 100°C after which it was oven dried at 55°C for 72 h. The boiled chips was milled and sieved through a 0.42 mm mesh size (Fig. 1).

Flour Raw: Five hundred grams of the sliced cocoyam samples was oven dried at 55°C for 72 h. The chips was milled and sieved through a 0.42 mm mesh size (Fig. 1).
**Determination of proximate composition**

The moisture, ash, crude fiber, fat and crude protein were determined as described by AOAC [12]. The total carbohydrate content was determined by difference.

**Determination of the mineral elements**

For the mineral elements: phosphorus was determined by the molybdate method using hydroquinone as reducing agent, and calcium and magnesium were determined by the compleximetric titration method described by Onwuka [13], sodium was determined by the method described by Onwuka [13], iron was determined by the spectrophotometric method, and potassium as described by James (1995), zinc was determined by the method of AOAC [12].

**Determination of the chemical properties**

For the chemical properties, pH was determined by the method described by Akpakpunam and Dedeh [14], titratable acidity was determined by the method described by AOAC [12], the starch content of the flours was determined by the method described by Noor et al. [15], total sugar was determined by method described by Pearson [16].

**Determination of the anti-nutrients**

The anti-nutritional factors determinations were: phenolic was determined using Folin-Ciocalteu reagent according to the method of Odabasoglu et al. [17], with garlic acid as the standard. Aluminium chloride complex assay was used to determine the flavonoid content.
according to Yong et al. [18] and quercetin was used as standard. Alkaloid was determined by
gravimetric method of Harbone [19]. The method described by Obadoni and Ochuko [20] was used
to determine the saponin content. Tannin was determined by the method of Pearson [16]. The
spectrophotometric method of Oberlease [21] was used to determine the phytate content. The
oxalate contents of flours were determined using the method of [9]. The acid titration method of
AOAC [12] was used for the determination of hydrocyanic acid.

Determination of the functional properties

The functional properties of flours include bulk density, oil absorption capacity, water
absorption capacities, and gelatinization temperatures were determined according to AOAC [12],
the foam capacity and stability were determined by the method of Coffman and Garcia [22].

Statistical analysis

The data are mean of two replications. One way ANOVA on a completely randomized design
using the SPSS version 22 was used to determine the mean values. Treatment means was separated
using Duncan multiple range test at 95% confidence level ($p<0.05$).

Results and Discussion

Proximate composition

The result of the proximate composition of the processed Xanthosoma sagittifolium cultivars
(ede ocha (white) and ede uhie (red)) flour is shown in Table 1. Processing methods significantly
affected analyzed proximate parameters. The moisture content of the flour ranged from 6.17% (raw
ede ocha) to 7.88% (raw ede uhie). Ede uhie flour showed higher moisture content than ede ocha
flour. The moisture content increased with boiling and fermentation processes irrespective of
cultivar. The moisture content obtained in this study is lower than the range (8.21% to 10.45%)
reported by Igbabul et al. [23] on wheat, sweet potato and hamburger bean flour blends. The
moisture content of the flour is low enough (less than 10%) to reduce the chance of microbial
spoilage to guarantee good storage stability.

The protein content of the flour varied significantly and ranged from 4.33 to 5.92%. The
protein content was higher in fermented flour (5.92%) but lower in boiled flour samples for both
cultivars. The increase in protein during fermentation could be attributed to the increase in
microbial mass during fermentation resulting into the synthesis of amino acids and other simple
peptides and/or the enzymatic hydrolysis of some protein inhibitors during fermentation [7]. Lower
protein values obtained in the boiling process can be attributed to the denaturation of proteins and
solubilization of amino acids into the cooking water. Comparatively, ede uhie (red) flour possessed
higher protein than ede ocha (white) flour. The range of the protein contents reported in this study
(4.33 to 5.92%) is lower than the values (5.83-6.98%) reported by Adane et al. [7]

Table 1. Proximate composition of X. sagittifolium cultivar (ede ocha and ede uhie) flours (%).

<table>
<thead>
<tr>
<th>Cultivar/Processing Methods</th>
<th>Moisture content</th>
<th>Crude protein</th>
<th>Crude fibre</th>
<th>Fat</th>
<th>Ash</th>
<th>Carbohydrate</th>
<th>Energy value (Kcal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw ede ocha</td>
<td>6.17±0.02</td>
<td>4.88e±0.01</td>
<td>1.16e±0.01</td>
<td>1.15f±0.01</td>
<td>2.81b±0.01</td>
<td>83.83a±0.01</td>
<td>365.19±0.16</td>
</tr>
<tr>
<td>Boiled ede ocha</td>
<td>7.06d±0.03</td>
<td>4.33f±0.01</td>
<td>1.67c±0.02</td>
<td>1.67d±0.01</td>
<td>2.17f±0.01</td>
<td>83.10c±0.00</td>
<td>364.75f±0.12</td>
</tr>
<tr>
<td>Fermented ede ocha</td>
<td>6.42e±0.01</td>
<td>5.06d±0.01</td>
<td>1.04f±0.01</td>
<td>1.48c±0.02</td>
<td>2.41d±0.01</td>
<td>83.59b±0.02</td>
<td>367.92a±0.06</td>
</tr>
<tr>
<td>Raw ede uhie</td>
<td>7.25c±0.02</td>
<td>5.65b±0.02</td>
<td>1.76b±0.01</td>
<td>3.04b±0.01</td>
<td>2.93a±0.01</td>
<td>79.37f±0.04</td>
<td>367.44d±1.12</td>
</tr>
<tr>
<td>Boiled ede uhie</td>
<td>7.88a±0.01</td>
<td>5.21c±0.01</td>
<td>1.94a±0.01</td>
<td>3.22a±0.01</td>
<td>2.32e±0.01</td>
<td>79.43de±0.01</td>
<td>367.54c±1.15</td>
</tr>
<tr>
<td>Fermented ede uhie</td>
<td>7.61b±0.01</td>
<td>5.92a±0.01</td>
<td>1.61d±0.01</td>
<td>2.92c±0.02</td>
<td>2.48c±0.01</td>
<td>79.46de±0.03</td>
<td>367.80b±0.50</td>
</tr>
</tbody>
</table>

a-f: Values are means ± standard deviation of duplicate determination. Mean values in the same column with different superscript are significantly different ($p<0.05$).
Crude fibre content ranged from 1.04 to 1.94%. Boiled ede uhie (1.94%) showed higher values, fermented ede ocha showed the lowest values (1.04%), and in both cultivars. Adane et al. [7] reported similar observation in processed taro flours, which they attributed to enzymatic degradation of the crude fibre during fermentation process. Fibre is an essential nutrient that facilitates bowel movement, bulk addition to food and prevents gastrointestinal diseases in man.

The crude fat values of the sample flours showed significant (P<0.05) differences. Higher value (3.22%) was observed in boiled ede uhie, lower value (1.15%) was seen in raw ede ocha. This result was higher than the range values reported by Nip et al. [24], Aboubakar et al. [10]. The fat content of ede uhie (red) flour was double the values of ede ocha flour. The reason could be attributed to the carotenoid lipophilic property of ede uhie (red) than ede ocha (white).

The ash content of the flour samples ranged from 2.17 to 2.93% with significant differences (P<0.05) between them. Lower value was observed in boiled ede ocha, while raw ede uhie showed highest value (2.93%). This result is lower than the range of ash values reported by Njoku and Ohia [25] on taro varieties. This difference may be attributed to variety. In both cultivars, boiled flour had reduced ash values which are attributed to possible leaching of soluble mineral elements into the boiling medium. This agrees with the report of Okaka et al. [26] that most nutrients leach out during processing. Cocoyam is a rich source of mineral elements and this could account for the appreciable quantity of ash in the flour samples.

With the exception of boiled and fermented ede uhie flours, carbohydrate content varied significantly. The highest carbohydrate value was obtained in raw ede ocha (83.83%). It was also noted that the range of values obtained for carbohydrate was lower than that reported by Adane et al. [7], and higher than the values reported by Igbabul et al. [23] on wheat, sweet potato and hamburger bean flour blends. The energy value ranged from 364.75 to 367.92 kcal/100g. The values compares to the energy content of maize, higher than the energy content of cassava, and less than the energy content of rice and sorghum reported by Serge [27]. High energy value of flour is of great importance to human health, especially in alleviating protein-energy malnutrition. The range of energy value obtained in this study conformed to the recommended minimum energy content of food (1674KJ/100g) by FAO/WHO/UNU [28]. The general observation was that ede uhie cultivar is a richer source of basic nutrients than ede ocha.

Mineral composition

The mineral composition of the processed Xanthosoma sagittifolium (ede ocha and ede uhie) flours are presented in Table 2. The results of the mineral contents showed that they were significant variations in the following ranges: calcium (10.23-41.17mg/100g), sodium (15.22 to 17.66 mg/100g), magnesium (5.81 to 8.38 mg/100g), phosphorus (12.31-16.19), potassium (2.28-3.62), iron (4.14 to 6.48 mg/100g) and zinc (0.66 to 2.25 mg/100g) respectively.

This study revealed that raw ede uhie cultivar had the higher values of calcium, sodium, magnesium, potassium, and zinc contents than the processed flours respectively. The values for Fe, Mg, Na and P were within the values reported by Adane et al. [7], but less than the values reported by Njoku and Ohia [25]. In this study, the concentrations of the minerals were less in the fermented process as a result of minerals utilization by microorganisms during fermentation. Compared to other roots and tuber crops, cocoyam varieties are known to be richer sources of mineral elements.
Table 2. Mineral contents of X. sagittifolium cultivar (ede ocha and ede uhie) flours (mg/100g).

<table>
<thead>
<tr>
<th>Cultivar/Processing Methods</th>
<th>Calcium</th>
<th>Sodium</th>
<th>Magnesium</th>
<th>Phosphorus</th>
<th>Potassium</th>
<th>Iron</th>
<th>Zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw ede ocha</td>
<td>30.13±0.01</td>
<td>16.43±0.01</td>
<td>7.12±0.02</td>
<td>12.31±0.01</td>
<td>3.46±0.01</td>
<td>5.11±0.01</td>
<td>2.18±0.01</td>
</tr>
<tr>
<td>Boiled ede ocha</td>
<td>12.61±0.01</td>
<td>17.38±0.01</td>
<td>7.94±0.01</td>
<td>13.43±0.01</td>
<td>3.04±0.01</td>
<td>5.86±0.01</td>
<td>1.08±0.01</td>
</tr>
<tr>
<td>Fermented ede ocha</td>
<td>10.23±0.01</td>
<td>15.22±0.01</td>
<td>8.14±0.00</td>
<td>16.19±2.84</td>
<td>2.78±0.01</td>
<td>4.14±0.02</td>
<td>0.66±0.01</td>
</tr>
<tr>
<td>Raw ede uhie</td>
<td>41.17±0.01</td>
<td>17.56±0.03</td>
<td>8.38±0.01</td>
<td>16.18±0.01</td>
<td>3.62±0.02</td>
<td>6.28±0.01</td>
<td>2.25±0.02</td>
</tr>
<tr>
<td>Boiled ede uhie</td>
<td>16.36±0.02</td>
<td>17.66±0.01</td>
<td>5.82±0.01</td>
<td>14.78±0.01</td>
<td>3.23±0.03</td>
<td>6.48±0.01</td>
<td>1.19±0.00</td>
</tr>
<tr>
<td>Fermented ede uhie</td>
<td>12.08±0.01</td>
<td>15.36±0.02</td>
<td>6.23±0.01</td>
<td>15.08±0.01</td>
<td>3.05±0.01</td>
<td>5.36±0.01</td>
<td>0.84±0.01</td>
</tr>
</tbody>
</table>

a-f: Values are means ± standard deviation of duplicate determination. Mean values in the same column with different superscript are significantly different (p<0.05).

Chemical properties

The chemical properties of processed ede ocha and ede uhie flours are presented Table 3. The parameters analyzed are pH, total acidity, starch and total sugar. The pH values showed that boiled ede ocha and ede uhie showed higher values (6.82 and 6.79), while fermented ede ocha and ede uhie showed lower values (6.40 and 6.41) respectively. These values are within the range of low acid to neutral (6.40-6.82). These ranges of pH values can encourage the growth and multiplication of microorganisms in flour-water mixtures [2]. The decrease in pH during fermentation was due to the utilization of fermentable sugar by microorganisms. The acids produced lead to decreased pH and increased total titratable acidity. That is, the total titratable acidity increased in fermented ede ocha flour (0.92%) and fermented ede uhie flour (0.90%), but lower in boiled ede ocha and ede uhie flours (0.64% and 0.66%). This inverse relationship between pH and acidity values demonstrates microbial behavior on substrate fermentation.

For starch, raw ede ocha flour showed higher value (24.66%), while fermented ede uhie flour showed the least value (16.02%). The sugar content also followed the same pattern as raw ede ocha flour showed higher value (3.29%) and fermented ede uhie showed least value (1.06%).

Table 3. Chemical properties of X. sagittifolium (ede ocha and ede uhie) flour.

<table>
<thead>
<tr>
<th>Cultivar/processing methods</th>
<th>pH</th>
<th>Total titratable acidity (%)</th>
<th>Starch (%)</th>
<th>Total sugar (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw ede ocha</td>
<td>6.75±0.00</td>
<td>0.75±0.01</td>
<td>24.66±0.02</td>
<td>3.29±0.01</td>
</tr>
<tr>
<td>Boiled ede ocha</td>
<td>6.82±0.01</td>
<td>0.64±0.01</td>
<td>20.15±0.02</td>
<td>2.83±0.01</td>
</tr>
<tr>
<td>Fermented ede ocha</td>
<td>6.40±0.00</td>
<td>0.92±0.01</td>
<td>17.33±0.01</td>
<td>2.17±0.01</td>
</tr>
<tr>
<td>Raw ede uhie</td>
<td>6.68±0.01</td>
<td>0.80±0.01</td>
<td>19.33±0.01</td>
<td>2.31±0.01</td>
</tr>
<tr>
<td>Boiled ede uhie</td>
<td>6.79±0.01</td>
<td>0.66±0.01</td>
<td>18.94±0.01</td>
<td>1.64±0.01</td>
</tr>
<tr>
<td>Fermented ede uhie</td>
<td>6.41±0.01</td>
<td>0.90±0.01</td>
<td>16.02±0.03</td>
<td>1.06±0.01</td>
</tr>
</tbody>
</table>

a-f: Values are means ± standard deviation of duplicate determination. Mean values in the same column with different superscript are significantly different (p<0.05).

Anti-nutritional properties

The anti-nutrient factor of the processed flours of Xanthosoma sagittifolium cultivars is presented in Table 4. The anti-nutrient factors of the flours: oxalate, alkaloid, tannin, flavonoid, saponin, phenol, phytate, and cyanogenic glycoside varied significantly between the processing methods and exhibited decreased values from the raw to the processed flours. Raw ede ocha flour
showed higher value (95.5 mg/100g) of oxalate and boiled *ede uhie* flour showed lower (10.2 mg/100g) value. Boiling greatly reduced the oxalate contents of the flour samples to about 89%. Other authors [9, 29] have reported different percentages of reduction of oxalates upon boiling due to the solubility in the boiling water. The oxalate content in this study was lower than that of other authors [30, 31], although on taro flours. Fermentation reduced the oxalate contents of the *Xanthosoma sagittifolium* flours significantly. Oxalates constitute a major anti-nutrient factor in cocoyam which limits its food applications. Oxalates forms insoluble complex with calcium ions, and interfere with calcium metabolism and absorption. Thus the reduced oxalates content in this study will enhance calcium bioavailability in nutrition.

Phytate content was higher in the raw *ede uhie* flour (3.74mg/100g), and lower in boiled *ede ocha* flour (0.82mg/100g). In this study, *ede uhie* flour contained more phytate than *ede ocha*. Boiling appreciably reduced the phytate content to about 46% in *ede ocha* and 77% in *ede uhie* respectively. A lower degree of reduction (about 15.27%) was reported by Bhandari and Kawabata [32] on wild yams and (about 20%) was reported by Adane et al. [7] on taro cultivars upon boiling. The reduction of phytate during boiling may be attributed to insoluble complexes of phytate with protein and minerals. Fermentation also decreased the phytate content of the flour samples. Phytate form complexes with phosphorus, iron and zinc and lowers their nutritional bioavailability [33]. With the low values of phytate obtained in this study, we anticipate increased utilization of protein, phosphorus, iron and zinc from the cocoyam flours.

**Table 4.** Antinutritional factors of *X. sagittifolium* cultivar (*ede ocha* and *ede uhie*) flours (mg/100g).

<table>
<thead>
<tr>
<th>Cultivar/Processing methods</th>
<th>Oxalate</th>
<th>Alkaloid (%)</th>
<th>Tannin</th>
<th>Flavonoids</th>
<th>Saponin</th>
<th>Phenol</th>
<th>Phytate</th>
<th>Cyanogenic glucoside</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw <em>ede ocha</em></td>
<td>95.5±0.01</td>
<td>1.71±0.01</td>
<td>0.29±0.01</td>
<td>6.31±0.01</td>
<td>0.51±0.01</td>
<td>0.02ab±0.00</td>
<td>15.17c±0.01</td>
<td>3.41b±0.01</td>
</tr>
<tr>
<td>Fermented <em>ede ocha</em></td>
<td>21.5c±0.01</td>
<td>1.61±0.01</td>
<td>0.15±0.01</td>
<td>4.88±0.01</td>
<td>0.14±0.01</td>
<td>0.00cdef±0.00</td>
<td>13.11d±0.01</td>
<td>2.31d±0.01</td>
</tr>
<tr>
<td>Boiled <em>ede ocha</em></td>
<td>10.4ef±0.01</td>
<td>1.51±0.01</td>
<td>0.00ef±0.00</td>
<td>2.2f±0.01</td>
<td>0.00f±0.00</td>
<td>0.00cdef±0.00</td>
<td>8.26f±0.01</td>
<td>0.82f±0.01</td>
</tr>
<tr>
<td>Raw <em>ede uhie</em></td>
<td>43.6b±0.01</td>
<td>2.31±0.01</td>
<td>0.42±0.01</td>
<td>6.46a±0.01</td>
<td>0.58a±0.01</td>
<td>0.02ab±0.01</td>
<td>37.43a±0.01</td>
<td>3.74a±0.01</td>
</tr>
<tr>
<td>Fermented <em>ede uhie</em></td>
<td>20.5d±0.07</td>
<td>2.08b±0.01</td>
<td>0.23c±0.01</td>
<td>5.03c±0.01</td>
<td>0.21c±0.01</td>
<td>0.00cdef±0.00</td>
<td>25.80b±0.01</td>
<td>2.58c±0.01</td>
</tr>
<tr>
<td>Boiled <em>ede uhie</em></td>
<td>10.2ef±0.01</td>
<td>1.69d±0.01</td>
<td>0.00ef±0.00</td>
<td>2.86f±0.01</td>
<td>0.07e±0.01</td>
<td>0.00cdef±0.00</td>
<td>8.71e±0.01</td>
<td>0.87e±0.01</td>
</tr>
</tbody>
</table>

a-f: Values are means ±standard deviation of duplicate determination. Mean values in the same column with different superscript are significantly different (p<0.05).

**Key:** C.GLY= Cyanogenic glucoside.

Processing methods had a significant effect on the tannin content of the cocoyam flours. Boiling had 100% reduction in both flours while fermentation had about 45 to 48% reduction. The observed decrease in tannin content upon boiling might be attributed to the leaching out of hydrolysable tannin in the boiling water. Tannins form complexes with proteins and some minerals, particularly iron and render them unavailable for human nutrition. According to Tinko and Uyano [34] and Adane et al. [7], foods rich in tannins are considered to be of low nutritional value because they precipitate proteins, inhibit digestive enzymes, iron absorption and affect the utilization of vitamins and minerals from meals. The tannin contents of the cocoyam flour samples are so negligible that they cannot pose any adverse effect to consumers.

The results showed that raw *ede uhie* flour had higher alkaloids value (2.31%), while boiled *ede ocha* flour (1.51%) was least. The decrease in the processed flours may be due to the dissolution of alkaloids in boiling water.
Similarly, flavonoids, saponin, and cyanogenic glucoside values of raw ede uhie (6.46mg/100g, 0.58% and 3.74mg/100g) showed higher values than others. Contrarily, the flavonoids, saponin and cyanogenic glucoside of boiled ede ocha flour (2.2mg/100g, 0.0 % and 0.82mg/100g) showed lower values respectively. Phenol content was only observed in the raw cocoyam flour cultivars. The non detection of phenol in both boiled and fermented flour samples may be due to leaching out of hydrolyzable phenol or the action of enzymes as reported by Adane et al. [7]. Xanthosoma maffa scotch cultivar, a variant of Xanthosoma spp. has shown strong antioxidant activity, high total phenolics and flavnoids contents than Dioscorea spp. [35], indicating that cocoyam cultivars are good sources of phyto-nutrient other than anti-nutrient factors.

Processing methods greatly reduced the anti-nutrient factors in both cultivars. Boiling reduced the anti-nutrients between 50-100%, while fermentation reduction was between 5-77% respectively. Although oxalates and phytates were the major anti-nutrient factors identified in both cultivars of Xanthosoma sagittifolium (ede ocha and ede uhie), their presence cannot pose any harm to consumers.

Functional properties

The results of the functional properties of the samples are presented in Table 5. The bulk density ranged from 0.06 to 0.81 g/mL between the flour samples. The bulk density of raw ede ocha (0.81 g/mL) was significantly higher than others while fermented ede uhie was least (0.60g/mL). Bulk density values obtained in this study were generally higher than the values reported by Igbabul et al. [23] (0.58 to 0.65 g/mL) on wheat, sweet potato and hamburger bean flour blends and 0.57-0.71 g/mL reported for taro flours by Njintang et al. [36]. Bulk density is a measure of the heaviness of solid samples, which is important in determining packaging requirements, material handling and application in food industry [2]. The bulk density >0.7g/mL in raw, boiled and fermented ede ocha, and raw ede uhie makes for good thickening quality [37]. The lower bulk density of fermented ede uhie suggests that it could be suitable for production of complementary foods.

The water absorption capacity (WAC) of the flour samples ranged from 2.19 to 2.71g/mL. Fermented ede ocha flour (2.71g/mL) showed higher water absorption capacity, the least was seen in raw ede uhie (2.19g/mL). WAC enables processors to add more water to flours during food preparation, and this ultimately improve handling characteristic. According to Falade and Okafor [2], WAC shows the water absorbed by flour after filtration and use of mild pressure of the centrifuge. The oil absorption capacity (OAC) of the flours showed that raw ede ocha and raw ede uhie cultivars had higher values (2.92 g/mL and 2.71 g/mL), and the least was from fermented ede uhie flour (1.45 g/mL). OAC is a property of emulsification and the volume of oil absorbed by flour during frying operation. Oil in food products improves mouth feel and retains flavour.

<table>
<thead>
<tr>
<th>Cultivar/Processing Methods</th>
<th>BD (g/mL)</th>
<th>WAC (g/mL)</th>
<th>OAC (g/mL)</th>
<th>FC (g/mL)</th>
<th>FS (min/sec)</th>
<th>GT (ºC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw ede ocha</td>
<td>0.81±0.01</td>
<td>2.21±0.01</td>
<td>2.92±0.00</td>
<td>18.22±0.01</td>
<td>1.96±0.01</td>
<td>72.05±0.07</td>
</tr>
<tr>
<td>Boiled ede ocha</td>
<td>0.77±0.00</td>
<td>2.45±0.01</td>
<td>1.83±0.01</td>
<td>19.05±0.01</td>
<td>2.06±0.01</td>
<td>70.85±0.07</td>
</tr>
<tr>
<td>Fermented ede ocha</td>
<td>0.70±0.01</td>
<td>2.71±0.01</td>
<td>1.51±0.01</td>
<td>19.52±0.01</td>
<td>2.21±0.01</td>
<td>60.45±0.07</td>
</tr>
<tr>
<td>Raw ede uhie</td>
<td>0.71±0.01</td>
<td>2.19±0.01</td>
<td>2.71±0.01</td>
<td>16.38±0.01</td>
<td>2.14±0.01</td>
<td>81.05±0.07</td>
</tr>
<tr>
<td>Boiled ede uhie</td>
<td>0.62±0.01</td>
<td>2.33±0.01</td>
<td>1.81±0.01</td>
<td>16.94±0.01</td>
<td>2.31±0.01</td>
<td>74.70±0.00</td>
</tr>
<tr>
<td>Fermented ede uhie</td>
<td>0.60±0.00</td>
<td>2.69±0.00</td>
<td>1.45±0.01</td>
<td>17.38±0.01</td>
<td>2.48±0.01</td>
<td>66.85±0.07</td>
</tr>
</tbody>
</table>

a-f: Values are means ± standard deviation of duplicate determination. Mean values in the same column with different superscript are significantly different (p<0.05)

BD=Bulk density, WAC=Water absorption capacity, OAC=Oil absorption capacity, FC=Form capacity, FS=Foam stability and GT=Gelattion temperature
The foam capacity of the flours was lower in raw *ede uhie* (16.3%) and higher in fermented *de ocha* (19.52%). The foam stability of raw *ede ocha* flour was lower (1.96%), while fermented *ede uhie* (2.48%) was highest. Foam capacity and foam stability are indications of the level of absorbed air on the air-liquid interface during whipping or bubbling and by it a cohesive viscoelastic film is formed through molecular interactions [38]. While foam capacity can be affected by temperature, pH, salt concentration, protein type and preparation method, foam stability can indicate the amount of foams retained after 1h standing contributed by the flour protein.

The gelation temperature varied from 60.45-81.05°C. Raw *ede uhie* exhibited higher gelation temperature (81.05 °C), followed by boiled *ede uhie* (74.70 °C), while fermented *ede ocha* flour exhibited the least value (60.45 °C). Gelation temperature is a temperature at which a food solution forms an observable thicker consistency when heat is applied to it [39]. This also means that the gel structures when heated can provide a matrix that holds water, oil, flavor and other food additives. The high gelling temperature of the flours could be influenced by protein and fat components of the cocoyam flours which hindered the starch granules from active swelling and thus, increasing the amount of heat application to obtain the final swelling. This observation was also made by Falade and Okafor [2] on cocoyam cultivars. The results of the functional properties showed that these flours can be put into domestic and industrial uses for weaning food blends and confectionary formulations.

**Conclusion**

This study has shown that the proximate and mineral nutrient of *Xanthosoma spp.* of *ede uhie* cultivar was higher in crude protein, crude fibre, fat, ash, Ca, P, Fe and Zn than *ede ocha* cultivar irrespective of processing method. On the other hand, *ede ocha* cultivar was higher in starch, total sugar, BD, WAC, OAC, FC especially in the raw and fermented flours than *ede uhie* cultivar. The results also showed that anti-nutrient factors were highly reduced to safe levels by the processing methods. Irrespective of cultivar, it was observed that fermentation and boiling methods increased the moisture, protein, fibre, fat, Fe, pH, titratable acidity properties of the cocoyam flours than the flour from the raw method. Conversely, the raw treatment had higher anti-nutrient content, Zn, Ca, starch, sugar, BD, OAC and GT cocoyam flour than the flours obtained from fermented and boiled methods. These results have established the relationship between the physicochemical and functional properties of the two *X. sagittifolium* cultivars. It showed that *ede ocha* has better functional potentials in food systems as thickener than *ede uhie* cultivar, while *ede uhie* showed higher nutrient density than *ede ocha* cultivar.

**References**


