Nutritional Potential and Microbiological Quality of the Taro Leaves (*Colocasia Esculenta*) Consumed in Abidjan City (Côte d’Ivoire)

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Authors’ contributions

This work was carried out in collaboration among all authors. Authors KKA and DKM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors BKMJ-P and DYF managed the analyses of the study. Author CK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

To fight malnutrition, which is a public health problem in the world, it is to use local foods as a cost-effective strategy to improve health. The aim of this study was to characterize taro (*Colocasia esculenta*) leaves for their valorization in human food. Sampling took place in the city of Abidjan (Côte d'Ivoire) and the collection of fresh taro (*Colocasia esculenta*) leaf samples was done in 10 fields in the commune of Abobo, 6 fields in Akeikoi and 4 fields in N'dotré, in October 2020. Three samples were taken in each field. To do so, physicochemical, nutritional and microbiological analyses of dried fresh leaves and dried cooked leaves were performed. The analysis of the biochemical composition allowed to characterize the taro leaves. Thus, the results showed that the crude protein and fat contents of the fresh dried taro leaves were respectively 4.95 ± 0.005% and 0.07 ± 0.001% against 3.75 ± 0.001% and 0.06 ± 0.001% for the boiled and dried taro leaves. The total carbohydrate content was 93.97± 0.02% for the dried cooked leaves and 91.24 ± 0.04% for the

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fresh dried leaves. The iron concentration for the dried fresh leaves (3.33 ± 0.57 mg) was higher than that for the boiled and dried leaves (1.33 ± 0.57 mg). Zinc content ranged from 385.66 ± 5.13 mg for fresh dried leaves to 196.66 ± 5.77 mg for boiled and dried taro leaves. Magnesium was present in taro leaves with higher contents in fresh dried leaves (45.66 ± 1.52 mg) than in cooked dried leaves (38.66 ± 1.52 mg). In addition, the presence of mesophilic aerobic germs, notably *Staphylococcus aureus* and *Bacillus* sporulates, was observed in the dried cooked leaves. It appears that the cooked taro leaves consumed in Abidjan have a good nutritional potential but could present a health hazard at the microbiological level for the consumer.

Keywords: Taro leaves; nutritional potential; microbiological quality.

1. INTRODUCTION

Sub-Saharan Africa is endowed with a rich biodiversity of food plants [1]. These plant genetic resources form the basis of global food security. Leafy vegetables are of vital importance, as they provide the majority of medicinal constituents and micronutrients essential for human health [2]. This biodiversity can improve the nutrition and health of the poorest rural and urban populations [3]. Tropical leafy vegetables are known to provide 10 to 100 times more minerals and vitamins than some exotic vegetables such as lettuce [4]. Daily consumption of leafy vegetables in sufficient quantity would ensure good health and prevent various chronic diseases. Their richness in trace elements, vitamins, and phytochemicals are a boon in developing countries such as Côte d'Ivoire where these traditional leafy vegetables can help solve many public health problems [5,6].

In the range of leafy vegetables listed in Côte d'Ivoire, we find taro leaves whose cultivation is increasingly abandoned and remains localized in a few regions of the country [7]. Indeed, these leaves contain significant levels of protein and are also an excellent source of carotene, potassium, calcium, phosphorus, iron, riboflavin, thiamine, niacin, vitamin A, vitamin C and dietary fiber [8]. The high level of dietary fiber found in the taro leaf is also beneficial for its active role in regulating intestinal transit, increasing food volume and fecal consistency due to its ability to absorb water [9]. In particular, it is a major vegetable and source of income for farm households.

However although taro leaf has not attracted enough research attention with respect to its nutritional, industrial and health potential. Previous research in Côte d'Ivoire has focused on taro tubers, but little research has been conducted on the taro leaf in human food. The aim of this study was to characterize taro (*Colocasia esculenta*) leaves for their valorization in human food.

2. MATERIAL AND METHODS

2.1 Materials

The study material consisted of fresh taro (*Colocasia esculenta*) leaves collected from different fields in Akeikoi and N'dotré in Abobo municipality.

2.2 Methods

2.2.1 Sampling

Sampling took place in the city of Abidjan (Côte d'Ivoire) and the collection of fresh taro (*Colocasia esculenta*) leaf samples was done in 10 fields in the commune of Abobo, 6 fields in Akeikoi and 4 fields in N'dotré, in October 2020. Three samples were taken in each field. The choice of these sites is justified by the availability of taro leaves in these fields and the willingness of the field owners to participate in this study. Three thousand grams (3000 g) of fresh *Colocasia esculenta* leaves were collected from the fields and brought to the Central Laboratory of Nangui Abrogoua University for analysis.

2.2.2 Taro leaf powder production (*Colocasia esculenta*)

In the laboratory, taro (Colocasia esculenta) leaves were removed from their petioles, washed and drained. Two (2) batches of fresh leaf samples of 900 g each were formed. The first batch of fresh leaves was boiled in sterile distilled
water at 100°C for 15 minutes and drained, then
the second batch of raw fresh leaves was
formed. These two batches were oven dried at
45°C for 72 hours and ground using a
microgrinder equipped with 500 µm mesh
screens to obtain the dried leaf powder (Fig. 2). These powders were then used
for all analyses.

Fig. 1. Taro leaf (Colocasia esculenta)

Fig. 2. Powder of fresh (A) and cooked (B) taro leaves
2.2.3 Biochemical analysis

Titratable acidity and pH were determined according to the method described by [13]. The percentage of moisture was determined using the Official Methods of Analysis [14]. The total soluble solids, expressed as °Brix value were determined in using a hand refractometer (Atago N-20E, Japan).

The ash content was determined according to the method [15] which consists of incinerating 5 g of the sample in an oven at 550°C for 4 hours. Total sugars were determined according to the method of [16] using sulfuric acid and phenol. It consists in determining the concentrations of total sugars of 0.5 g of sample, on a standard curve plotted against the concentration and optical density of glucose solutions of known concentrations. The THERMO SCIENTIFIC spectrometer, type Hélios Oméga UV-VIS (USA) was used for the determination of the optical densities of sugar solutions of unknown concentrations. These optical densities, reported on the standard curve, allow to determine the total sugar concentration of the samples. The assay is repeated three times. The total lipid content was determined according to the Soxhlet method described by [17]. The determination of total protein was performed according to the [17] method using Kjeldahl. The Weende method described by Wolf (1968) was used for the determination of crude fiber. Total carbohydrates (Glu) and energy value (EV) were determined by difference following the calculation method recommended by [2]. This method takes into account on the one hand the contents of moisture, fat, protein, ash, and fiber and on the other hand the energy coefficients. The determination of minerals was performed according to the method of [18]. A quantity of 0.25 g of powder was weighed into a crucible and calcined in a furnace until a white ash was obtained. After cooling in a desiccator, the ash was dissolved in a solution containing 5 mL of chloridric acid (20%) and 1 mL of concentrated nitric acid. The whole was put in a water bath for 1 h and the mixture was brought to the mark with distilled water in a 50 mL flask. The elements contained in the solution were then determined by Atomic Absorption Spectrophotometer (AAS). To avoid interferences of the elements Ca and K, lantana chloride was added (5 mL of lantana)

The determination of the minerals was done by atomic absorption spectrophotometer with air-acetylene flame (SAA 20 type VARIAN). The wavelength of the minerals K, Zn, Fe, Mg, Mn, Ca and P are 767.6 nm; 214.6 nm; 249 nm; 286 nm; 280.6 nm; 422.71 nm and 885 nm respectively. The assay is repeated three (3) times for each mineral.

2.2.4 Isolation and enumeration of bacteria

The stock solution and decimal dilutions were performed according to the methods of [19]. For the analyses, (10 g) of samples were crushed and taken under sterile conditions created by the flame of a bunsen burner and mixed in a "stomacher" bag with 90 mL of buffered peptone water (AES Laboratoire, COMBOURG France) previously sterilized and used as diluent. Mesophilic aerobic germs (MAG) were counted on PCA (Plate count Agar) agar (Oxoid LTD, Basingstore, Hampshire, England) after two (2) days of incubation at 30°C according to AFNOR Standard NF V08-051, 1999. Yeasts and moulds were enumerated on plates of Sabouraud chloramphenicol agar (Fluka, Bochemica 89579, Sigma-Aldrich Chemie GmbH, Inda) incubated at 30 °C for 4 days. The research and counting of Staphylococcus aureus were done on Baird Parker agar after one (1) day of incubation at 30°C using [20] method. The quantitative estimation of spores of Bacillus cereus was performed by a standard plate-counting method. Isolations were achieved from heat-treated dilutions by plating on mannitol egg yolk polymyxin B agar [13]. Presumptive colonies of Bacillus cereus were randomly selected based on characteristic colony feature, purified on the same medium, and identified by morphological, cultural, and biochemical characteristics according to the documented procedures [21]. Violet crystal and neutral red biliated lactose agar (VRBL agar) was used for coliform count, after one day of incubation according to AFNOR Standard, NF ISO 4832 July 1991. The isolation and enumeration of Salmonella were carried out using [22] method in several steps. This was achieved by pre-enrichment in a non-selective medium, followed by enrichment in a selective medium and culture on selective agar. For enrichment in non-selective or pre-enrichment media, a quantity of Twenty-five grams (25) g of samples was homogenized with 225 mL of peptonned water in a sterile jar, incubated at 37°C for 24 h. For selective recording-(1 mL) of the pre-enriched culture was transferred using a sterile pipette into 10 mL of previously prepared sterile Rappaport Vassiliadis. The tryptone sulphite neomycine (TSN) agar (Bio-Rad, Marnes-La Coquette, France) was used for the
detection of *Clostridium perfringens* after a thermal shock of the dilutions (80°C for 15 min and immediately cooled). One millilitre of each appropriate treated dilution was used to inoculate the TSN agar (Bio-Rad) stored in surfusion at 45°C in assay tubes. After the agar had solidified, all inoculated media were incubated in an upright position for 24 h at 46°C [13]. Tubes containing between 30 and 300 colonies were counted, and five colonies were picked for confirmation in motility-nitrate medium. The medium used for the research and enumeration of *Escherichia coli* was RAPID'E.coli agar (Standard NF ISO 16140, 2003). Inoculation was done by spreading 0.1 ml of the mother suspension or decimal dilutions on the surface of the agar previously poured and cooled in Petri dish. Incubation was done at 37°C for 24 hours. Presumptive *Escherichia coli* colonies were purple to pink. Presumptive *Escherichia coli* colonies present in plates containing 15 to 150 colonies were counted.

### 2.3 Statistical Analysis

The software R. 3-01, ANOVA method with Duncan's post-hoc test, significance level 5% was used. This software was used to calculate the averages, the deviations of the microbiological and physico-chemical parameters. It was also used to compare the means of the microbiological and physico-chemical parameters of the samples and to determine if the differences observed in the means of these parameters were significant at the 5% level, with P<0.05.

### 3. RESULTS

#### 3.1 Physico-Chemical Characteristics

Table 1 shows the variability in the physicochemical characteristics of taro leaves. The results showed a significant difference in dry matter content between cooked and fresh taro leaves (P < 5%) thus the dry matter content of the water-cooked leaves was higher (97.35 ± 0.04%) than that of the fresh leaves (93.70 ± 0.01%). The pH of both samples was below the threshold of neutrality. The fresh leaves had a higher pH (5.55 ± 0.03) than the cooked leaves (4.95 ± 0.05). Titratable acidity was lower in fresh leaves (3.04±0.05 meq/g) than in cooked leaves (4.01 ± 0.01 meq/g). Cooking did not significantly impact the soluble dry extract of taro leaves. It ranged from 1.13 ± 0.15% for fresh leaves to 1.6 ± 0.26% for cooked leaves. The ash content of fresh and cooked leaves differed significantly. It decreased with cooking from 1.53 ± 0.02% for fresh leaves to 1.10 ± 0.01% for cooked leaves.

#### 3.2 Biochemical Composition and Energy Value of Taro Leaves

Table 2 shows the variability in biochemical characteristics as well as energy value of fresh and cooked taro leaves. The results showed a significant difference in lipid content between fresh and cooked taro leaves. In addition, the lipid content of fresh leaves was higher (0.07 ± 0.001%) than that of cooked leaves (0.06 ± 0.001%). As for protein, fresh leaves had a higher protein content (4.95 ± 0.005%) than cooked leaves (3.75 ± 0.001%). Then the total sugar contents varied from 3.01 ± 0.002% for fresh leaves to 2.08 ± 0.01% for cooked leaves. The fiber content was 2.19 ± 0.02%; 1.10 ± 0.01% for fresh and cooked leaves respectively, while the carbohydrate content was 91.24 ± 0.04% (fresh leaves); 93.97 ± 0.02% (cooked leaves). The same is true for the energy value which was 338.45 ± 0.16 Kcal for fresh leaves; 345.21 ± 0.07 Kcal for cooked leaves.

#### 3.3 Mineral Content in Taro Leaves (*Colocasia esculenta*)

Table 3 presents the contents of calcium, zinc, iron, phosphorus and magnesium. The cooking of taro leaves in water resulted in a significant reduction of calcium, zinc, iron, and magnesium contents. Phosphorus content did not change significantly. The highest calcium content was found in the fresh leaves (1063.66 ± 1.52 mg) compared to 987.66 ± 2.51 mg in the cooked leaves.

#### 3.4 Microbial Load in Cooked Taro Leaves

Table 4 shows the microbial load in cooked taro leaves. The cooked taro leaves analyzed did not contain spoilage and pathogenic germs. However, they did not contain *Salmonella* and *Clostridium perfringens*. Aerobic mesophilic germs were the most abundant with a microbial load of 5.3 ± 0.3 × 10⁷ CFU/g. Total and fecal coliform loads were 2.8 ± 0.2 × 10⁴ CFU/g and 2.4 ± 0.1 × 10² CFU/g, respectively. These loads were lower than the 2019/229/EC standard. On the other hand, the loads of mesophilic aerobic germs, yeasts/molds and *Staphylococcus aureus* were higher than this same standard.
Table 1. Physico-chemical characteristics of taro leaves

| Parameters                  | Fresh taro leaves     | Cooked taro leaves |
|----------------------------|-----------------------|--------------------|
| Dry matter (%)             | 93.70 ± 0.01 a        | 97.35 ± 0.04 a     |
| Humidity (%)               | 6.30 ± 0.01 a         | 2.65 ± 0.04 b      |
| pH                         | 5.55 ± 0.03 a         | 4.95 ± 0.05 b      |
| Titratable acidity (meq/g) | 3.04 ± 0.05 b         | 4.01 ± 0.01 a      |
| Soluble dry extract (%)    | 1.13 ± 0.15 a         | 1.6 ± 0.26 a       |
| Ash (%)                    | 1.53 ± 0.02 a         | 1.10 ± 0.01 b      |

*Within a row, mean values followed by different alphabetical letters are statistically different (P<0.05).*

Table 2. Biochemical composition and energy value of taro leaves

| Parameters                  | Fresh taro leaves     | Cooked taro leaves |
|----------------------------|-----------------------|--------------------|
| Lipids (%)                 | 0.07 ± 0.001 a        | 0.06 ± 0.001 b     |
| Proteins (%)               | 4.95 ± 0.005 a        | 3.75 ± 0.001 b     |
| Carbohydrate (%)           | 91.24 ± 0.04 b        | 93.97 ± 0.02 a     |
| Total sugars (%)           | 3.01 ± 0.002 a        | 2.08 ± 0.01 b      |
| Fibers (%)                 | 2.19 ± 0.02 a         | 1.10 ± 0.01 b      |
| Energy value (Kcal/100g)   | 338.45 ± 0.16 b       | 345.21 ± 0.07 a    |

*Within a row, mean values followed by different alphabetical letters are statistically different (P<0.05).*

Table 3. Mineral content in taro (Colocasia esculenta) leaves in mg/100g dry matter

| Parameters       | Fresh taro leaves     | Cooked taro leaves |
|------------------|-----------------------|--------------------|
| Calcium          | 1063.66 ± 1.52 a      | 987.66 ± 2.51 b    |
| Zinc             | 385.66 ± 5.13 a       | 196.66 ± 5.77 b    |
| Iron             | 3.33 ± 0.57 a         | 1.33 ± 0.57 b      |
| Phosphorus       | 60 ± 1 a              | 59 ± 1 a           |
| Magnesium        | 45.66 ± 1.52 a        | 38.66 ± 1.52 b     |

*Within a row, mean values followed by different alphabetical letters are statistically different (P<0.05).*

Table 4. Microbial load in cooked taro leaves in CFU/g

| Microbiological parameters | Cooked taro leaves | 2019/229/EC standard |
|----------------------------|--------------------|----------------------|
| Mesophilic aerobic germs   | 5.3 ± 0.3.10 c     | 10^c                 |
| Echerichia Coli           | 2 ± 0.1.10 c       | -                    |
| Yeast/mold                | 5 ± 0.7.10 d       | 10^d                 |
| Staphylococcus aureus     | 5 ± 0.7.10 d       | 10^d                 |
| Bacillus (spore)          | 4.2 ± 0.4.10 c     | -                    |
| Total coliforms           | 2.8 ± 0.2.10 e     | 10^e                 |
| Faecal coliforms          | 2.4 ± 0.1.10 e     | 10^e                 |
| Clostridium perfringens   | <1                 | -                    |
| Salmonella                | Absent             | -                    |

4. DISCUSSION

Taro leaves as well as other edible leaves are highly valued by consumers. The aim of this study was to characterize taro (*Colocasia esculenta*) leaves for their valorization in human food. Physicochemical analyses revealed that the moisture content of the different samples ranged from 6.30 ± 0.01 % to 2.65 ± 0.04 %. The water content of dried fresh taro leaves was the highest (6.30 ± 0.01 %) than that of dried cooked taro leaves. The water content of the food sample is an index of stability and determines the appearance, keeping quality and yield of the product [23]. This low moisture content could be due to drying at adequate temperature and time of the samples to ensure the lowest moisture that keeps longer [24]. On the other hand, the leaf water content of cooked leaves could be explained by the cooking process. Indeed, during cooking, the temperature allows the bursting of the vacuoles of the cells and facilitates the release of water in these vacuoles during drying. The decrease
of the protein content of the dried cooked taro leaves is due to two phenomena. Indeed during cooking by the phenomenon of dialysis proteins will be found in the cooking water, but also during drying proteins can coagulate under the effect of dry heat [7]. The crude fat content of the taro leaves in percentage differed significantly (P <0.05). The dried fresh taro leaf sample had the highest fat content (0.07 ± 0.001%) than the dried cooked taro leaf sample (0.06 ± 0.00 %). A small reduction in fat content was observed in the dried cooked leaf sample. Indeed, this may have occurred probably because the crude fat diffused into the process water [25]. These results are in agreement with those of [26] who worked on the leaves and tubers of three cultivars of the yam Dioscorea dumetorum pa.

The crude fiber content decreased in the dried cooked taro leaves. In addition the present study indicated that the reduction in fiber content may be due to the effect of heat treatment which breaks down the fiber components into smaller, soluble forms [27]. The results of this study revealed that the carbohydrate content was high in cooked taro leaves compared to fresh taro leaves. This increase in carbohydrate content in the dried cooked leaves would be explained by the effect of cooking. Total carbohydrates are the most important biochemical components in taro leaves Colocasia esculenta. This result confirms those reported by [28] who worked on tuber flours of six taro varieties in Cameroon. Mineral salts are part of the large family of micronutrients. Although they do not provide calories, they play an important role in the metabolic processes of the human body. Increased consumption of leafy vegetables can improve mineral regulation and reduce the risk of cardiovascular disease and some cancers [29]. Globally, it is estimated that two (2) billion people suffer from micronutrient malnutrition [30]. Pregnant and lactating women and young children are the first victims of deficiencies, as their needs for vitamins and minerals are greater. They therefore suffer more from the harmful consequences of these deficiencies [31-32]. The majority of mineral and vitamin intake is therefore provided by fruits and vegetables [33-34]. Taro leaves (Colocasia esculenta) seem to be an important source of minerals in this study. Most of the highlighted minerals play an important role in the body. Analyses showed that the Ca/P ratio of taro leaves is greater than 1 (result not shown). However, according to [35] a good food menu should have a Ca/P ratio greater than 1. Foods high in phosphorus and low in calcium tend to make the body more acidic, deplete calcium and other minerals, and lead to inflammation [36]. To avoid this problem, cooked taro leaves can be used as calcium supplements to prevent mineral and osmotic imbalance. Iron concentration ranged from 3.33±0.57 mg to 1.33±0.57 mg. There is a large reduction of iron in the dried cooked leaves, this iron loss is believed to be due to the iron diffusing into the processing water [37]. The iron content of taro leaves remains significant although low, as iron is essential for a large number of metabolic reactions. It is involved in the formation of hemoglobin, myoglobin and many enzymes [38]. Iron can also act as an antioxidant and can help prevent cardiomyopathy and stunting [39]. Magnesium is necessary for biochemical reactions in the body, maintaining muscle, improving nerve function, maintaining regular heartbeat and regulating blood sugar levels [40]. Magnesium is present in taro leaves with higher levels in dried fresh leaves (45.66 ± 1.52 mg/100g) than in dried cooked leaves (38.66 ± 1.52 mg/100g).

Microorganisms such as Bacillus, E.coli, Staphylococcus, and GAM were found in the sample except Salmonella and Clostridium perfringens. The presence of these germs in the taro leaf powder would be due to the hygienic conditions of preparation of the powder. The presence of Staphylococcus exceeding the 2019/229/EC standards could be due to contamination of the powder by the production environment, utensils and personnel. Consumption of cooked and dried taro leaves under these conditions could present a health risk to the consumer. In addition, these microorganisms are producers of heat-resistant toxins and once ingested by humans, they could cause gastroenteritis, vomiting, and often death [41].

5. CONCLUSION

The aim of this study was to characterize the leaves of taro (Colocasia esculenta) for their valorization in human food. Boiling time had a significant effect on the physicochemical and biochemical composition of taro leaves (Colocasia esculenta) except for soluble dry extract and phosphorus. Taro leaves in this study contained carbohydrate, crude fiber, calcium, zinc, magnesium, iron and protein and therefore should be valued as a crop for food security.
Based on these results, taro leaves have good nutritional potential to be used in the food industry and develop new products. These new products could be used in the fight against micronutrient deficiency such as iron. On the microbiological level, the analyses revealed the existence of microorganisms of alteration and pathogens. However, the product passing through the cooking process could preserve the health of the consumer.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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