Phytochemical Properties and Proximate Composition of Two Varieties of dried Okra (Abelmoschus caillei and Abelmoschus esculentus) During Maturation

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Abstract— The present work aims to study the variation of the biochemical parameters of two sun-dried varieties of Okra (Abelmoschus caillei and Abelmoschus esculentus) to determine the stage of maturity with the best nutritive profile after drying. The plant was harvested at 4 different stages of maturity, namely 5, 10, 15 and 20 days after flowering. The proximate composition, mineral element profile and phytochemical composition of two varieties of okra at four stages of maturity were investigated. The results showed a significant increase of phenolic compounds (Total phenolic, flavonoids) and minerals (Fe, Ca, P, K) until the 15th day of maturity before decreasing to the 20th day for the 2 varieties of okra. However, proximate analysis showed high level of proteins (18.27 %), total sugars (4.81%) and fat (16.25%) until the 15th day of maturity before declining to the 20th day except for soluble and insoluble fibres. At 15 days of maturity, the Koto variety provided the highest levels of flavonoids (17.20 mg (QE)/100 g DW) and antioxidant activity (1263.08 %). In contrast, the polyphenol (160.59 mg (GAE)/100 g DW) and oxalate (1652.78 mg TAE/ 100g DW) levels were the highest in the Tomi variety. Similarly, at the level of the minerals at 15 days of maturity, the Koto variety recorded the highest levels of 18.54 mg / 100g DW and 263 mg / 100g DW respectively in phosphorus and potassium while the Tomi variety obtained high values 1.37 mg / 100g DW and 224 mg / 100g DW respectively in iron and calcium. These data indicated that Koto variety recorded the highest levels at 15 days of maturity. Thus, high fibre, low fat, dried okra samples could be recommended in a diet for weight reduction because of their low energetic value and be recommended for lipid-lowering and hypoglycaemic diets.

Index Terms— Antioxidant activity, Drying, Okra, Phytochemical composition, Proximate composition, Dried, Stage of maturity.

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1 INTRODUCTION

Okra (Abelmoschus esculentus L. Moench) is a flowering plant native to Africa that has long been a part of the diet in several countries around the world [1]. It is one of the most important vegetable crops cultivated in tropical, sub-tropical and warm temperate regions. In Côte d'Ivoire, okra market gardening is much developed in pre-forest and forest areas [2]. Thus, are identified in this country, Abelmoschus esculentus koto variety and Abelmoschus caillei tomi variety [3] (Siemonsma, 1982), which are resistant to heavy rains and can produce fruit during the dry season [3, 4]. Côte d'Ivoire is the second largest African producer of okra after Nigeria ranked number 3 in the world with 105,597 tonnes [5]. The enormous nutritional and other biological activities in the pods and seeds of okra were reported by Agbo et al. [6] and Kumar et al. [7]. Okra is used daily in households in different forms (fresh fruits, grains, powder) due to its organoleptic qualities and it is a good wealth supplier. However, degradation of fresh okra is enhanced by its very high-water content [8]. To reduce post-

harvest losses, it necessary to harvested okra at a good stage of maturity. Vegetable fruits are generally harvested at juvenile stage of maturity and are mainly used in the preparation of sauces. These sauces are prepared either with freshor dried fruits, sliced or not and reduced to powder [9]. It undergoes several heat treatments before its consumption. These treatments could influence the bioavailability of micronutrients and cause the loss of minerals or the destruction of vitamins at too high temperature [10]. In Côte d'Ivoire, okra is eaten fresh or dried. A strategy to reduce losses was developed in the country; sun-drying is the first mean to preserve agricultural products because of its availability. Drying is the most common method to keep okra from wasting. Dried okra is more accessible and available in specialty markets and grocery stores. Drying increases the storage time of okra and extends its sale. The okras can therefore be exported and kept longer. The present work aims to study the variation of the biochemical parameters of dried okra at different stages of maturity to determine the stage of maturity with the best nutrient profile after drying

2 MATERIALS AND METHODS

2.1 Experimental site, plant material and cropping practice

The two varieties of Okra (Abelmoschus esculentus (Koto) and Abelmoschus caillei (Tomi)), used for this research work, have been brought from Malbaie, Abobo, Côte d'Ivoire. The experimental device used was done according to the model of Fisher with three repetitions in two blocks covering a surface of 11.25 m2 (1.50 m×7.50 m).

The experimental device has been sown on a plot of 1.5 m x 7.5 m. A plot of 1.5m x 7.5 m composed of twenty-two holes constitutes. The holes of the plot were separated to 0.5 m x 1 m. Before sowing, the ground was ploughed manually then enriched with 250 kg/ha by manure NPK 10-18-18. After the appearance of the first leaves of about five centimetres, guardians were assigned to each plant. Seedlings were rejected after the emergence of way to keep only the strongest plant.

Okra was harvested at four stages of maturity which are respectively 5, 10, 15 and 20 days after flowering for each variety.

2.2 Collection and sampling

The okras were harvested from a farm near Malbaie (Abobo), a village located at about 30 km north of Felix Houphouet Boigny Airport, Abidjan, Cote d'Ivoire. The fruit were transported directly to the Biocatalysis and Bioprocessing laboratory of Nangui Abrogoua University (Côte d'Ivoire). At each stage of maturity and for each species, (5) kg of fresh okra were collected and dried at the ambient temperature (35 - 38 °C). After drying, the samples were crushed and stored in airtight containers for analysis.

2.3 Proximate Composition Analysis

Dry matter were determined by drying in an oven at 105ºC during 24 h to constant weight [11]. Method described by Dubois et al. [12] was used to determine total sugars while reducing sugars were analysed according to the method of Bernfeld [13] using 3.5 dinitrosalycilic acids (DNS). Crude protein was calculated from nitrogen (N x 6.25) obtained using the Kjeldahl method by AOAC [14]. Crude fat was determined by continuous extraction in a Soxhlet apparatus for 8 h using hexane as solvent [15] according to standard NF V03-905. Vitamin C was determined according to the method of Tomohiro [16]. The crude fibre contents were determined according to the method of Van Soest [17]. Total carbohydrates were calculated by difference. Total ash was determined by incinerating in a furnace at 550 ºC [11].

2.4 Minerals Analysis

Minerals were determined employing AOAC [11].method. Powder was digested with a mixture of concentrated nitric acid (14.44 mol/L), sulfuric acid (18.01 mol/L) and perchloric acid (11.80 mol/L) and analysed using an atomic absorption spectrophotometer. The total phosphorus was determined as orthophosphate by the ascorbic acid method after acid digestion and neutralization using phenolphthalein indicator and combined reagent [18].

2.5 Phytochemical Composition

Extraction of phenolic compounds

Extraction of phenolic compounds were determined employing Singleton et al. [19] method. A sample (10 g) of okra powder was extracted by stirring with 50 ml of methanol 80 % (v/v) at 25°C for 24 hours and filtered through Whatman no 4 paper. The residue was then extracted with two additional 50 ml portions of methanol. The combined methanolic extracts were evaporated at 35°C (rotary evaporator HEILDOLPH Laborata 4003 Control, Schwabach, Germany) until 25 ml, prior to phenolic compound contents determination.

Determination of total phenolic compounds content

Contents of total phenolic compounds were estimated according Folin-Ciocalteu method [19]. A volume of 1 ml of methanolic extract of each sample was added to 1 ml of Folin-Ciocalteu's solution in a test tube. After 3 minutes, 1 ml of 20 % sodium carbonate solution was added to the mixture and adjusted to 10 ml with distilled water. The mixture could stand at room temperature in a dark environment for 30 min. Absorbance was measured against the blank reagent at 725 nm. Gallic acid was used for the calibration curve with a concentration range of 50-1000 µg/ml. Results were expressed as mg gallic acid equivalent (GAE)/100g DW (Dry Weight).

Determination of flavonoids

Total flavonoids content was determined according method used by Meda et al. [20], but slightly modified. A volume of 0.5 ml of methanolic extract of sample was diluted in 0.5 ml of distilled water. Then, 0.5 ml of aluminium chloride 10 % (P/V) and the same volume of sodium acetate 1M were added. Finally, 2 ml of distilled water was added and absorption reading at 415 nm was carried out after 30 min against a blank sample consisting of a 4 ml methanolic extract without aluminum chloride. Quercetin was used for the calibration curve with a concentration range of 0-100 µg/ml. Results were expressed as mg of quercetin equivalent (QE)/100g DW.

Determination of oxalates

Oxalates content was determined using the method described

by Day and Underwood [21]. A sample (2 g) of dried okra powders was homogenized in 75 ml of H_2SO_4 (3M). The mixture obtained was put under magnetic agitation during 1 H at the ambient temperature (28 C). The whole was filtered on filter paper Whatman n4. Twenty-five (25) ml of filtrate were titrated hot by a permanganate solution of potassium (KMnO4) to 0.05 M until the turn with the pink persisting. The content oxalates were obtained by the equation:

$$\text{Oxalates (mg/100g)} = \frac{2{,}2 \times V_{eq} \times 100}{m_e}$$

Estimation of antioxidant activity by DPPH radical scavenging

The DPPH scavenging activity was determined using the method described by Shimada et al. [22]. Each sample of methanolic extract (2.5 ml) was mixed with 1 ml of a 3 mM DPPH methanol solution. After 30 min incubation at room temperature in the dark, the absorbance of the mixture was determined at 517 nm against a blank containing methanol without DPPH radical. A lower absorbance indicates a higher scavenging activity. Absorbance was converted to the DPPH radical-scavenging rate according to the equation:

DPPH radical scavenging rate (%) = [(Acontrol-Asample)/Acontrol] x100.

2.6 Statistical Analysis

The analysis of variance (ANOVA) was used to determine the differences between treatments. When a difference was observed, the multiple range test of Newman-Keuls at 5% was performed to separate treatment means. Statistical tests were performed using the STATISTICA software version 20.0.

3 RESULTS AND DISCUSSION

RESULTS

Phenolic compounds

Statistical analysis showed a significant difference for all levels of phenolic compounds in the two varieties of dried okra (Fig. 1, 2, 3 and 4). For the both varieties, there is a significant increase in levels until the 15th day before decreasing to the 20th day for all phenolic compounds. Also, it should be noted that the levels obtained with dried okra samples are higher than those of fresh okra for both varieties at each maturity stage.

Thus, the total polyphenol contents of the dried okra samples increased significantly from 127.05 mg / 100g DW (5th day of maturity) to 130.31 mg / 100 g DW (15th day of maturity) and 77.69 mg / 100g DW (5th day of maturity) at 160.59 mg / 100 DW (15th day of maturity) respectively for the variety Koto and Tomi. At 20 days of maturity, the values were 128.87 mg / 100g DW (Koto dried) and 133.71 mg / 100g DW (dried Tomi).

Dried Koto variety recorded a flavonoid content that increased significantly to 17.20 mg / 100g DW (15th day of maturity) before declining to the 20th day of maturity (16.07 mg / 100g DW). In the Tomi variety, the levels increased from 12.71 mg / 100g to 15.67 mg / 100g DW (15th day of maturity) before decreasing to 14.75 mg / 100g DM at 20 days of maturity.

The levels of oxalates increased significantly from 953.15 mg / 100g (5th day of maturity) to 1211, 73 mg / 100g DW (15th day of maturity) and 980.10 mg / 100g DW (5 days of maturity) at 1652, 78 mg / 100g (15th day of maturity) respectively for the dried variety Koto and Tomi. At 20 days of maturity, the values were 1144.67 mg / 100g DW (Koto dried) and 1310.24 mg / 100g DW (dried Tomi).

Finally, the Koto variety recorded a content of antioxidant activity which increased significantly to 1263.08 mg / 100g DW (15th day of maturity) before falling to day of maturity (1175.58 mg / 100g DW). In the Tomi variety, the levels increased from 982.25 mg / 100g DW to 1195.58 mg / 100g DW (15th day of maturity) before decreasing to 1110.24 mg / 100g DW at 20 days of maturity.

After 15 days of maturity, the Koto variety provided the highest levels of flavonoids and antioxidant activity. On the other hand, the polyphenol and oxalate contents were the highest in the Tomi variety.

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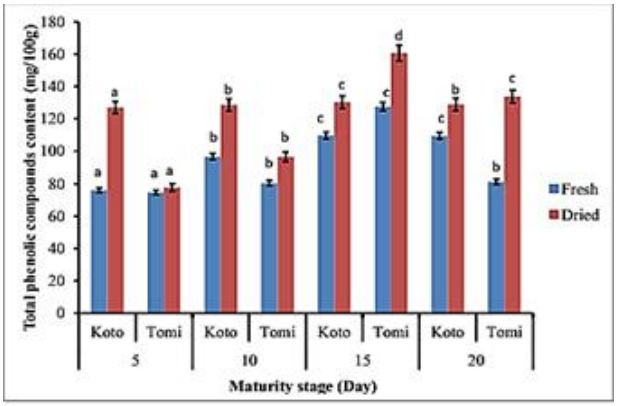

Fig. 1. Total polyphenol content at different stages of maturity of 2 varieties of dried Okra

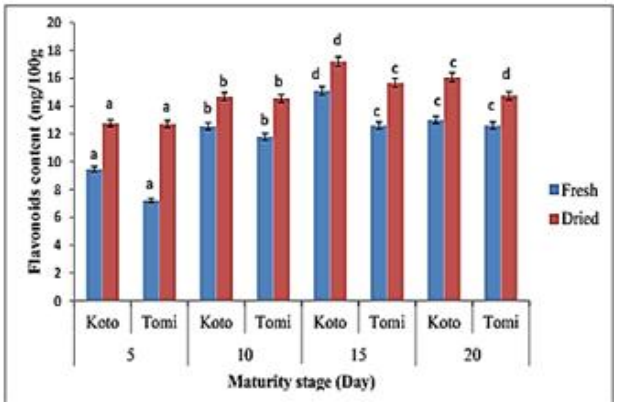

Fig. 2. Flavonoids content at different stages of maturity of 2 varieties of dried Okra

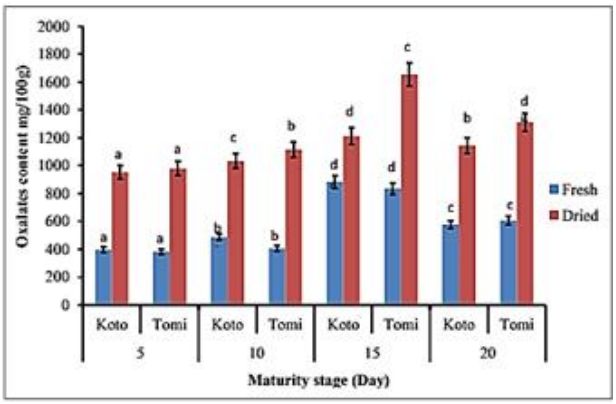

Fig. 3. Oxalates content at different stages of maturity of 2 varieties of dried Okra

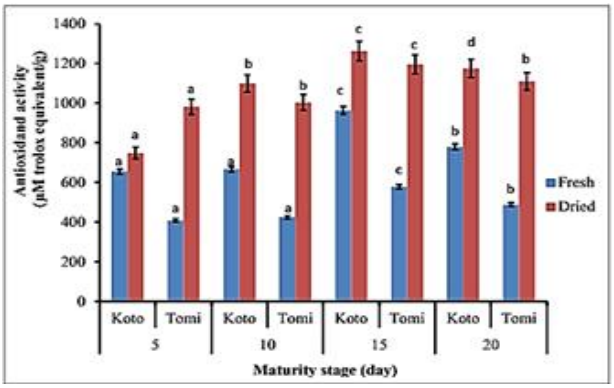

Fig. 4. Antioxidant activity at different stages of maturity of 2 varieties of dried Okra

Proximate Composition

The results of the proximate composition analysis of fresh and dried okra varieties (Tables 1, 2 and 3). Statistical analysis of the results showed a significant difference for all levels of chemical compounds for both varieties. There is a significant increase in levels up to the 15th day before decreasing to the 20th day for all biochemical compounds except soluble and insoluble fibre for two varieties of okra.

The protein content of dried okra samples increased significantly from 11.59 mg / 100g DW (5th day of maturity) to 18.27 mg / 100g DW (15th day of maturity) and 10.34 mg / 100g DW (5th day of maturity) at 13.69 mg / 100g DW (15th day of maturity) respectively for the variety Koto and Tomi. At 20 days of maturity, the values were 17.25 mg / 100g DW (Koto dried) and 11.31 mg / 100g DW (dried Tomi).

The reducing sugar content increased significantly to 0.69 mg / 100g DW (15th day of maturity) before declining to the 20th day of maturity (0.64 mg / 100g DW) for Koto variety. In the Tomi variety, the levels increased from 0.13 mg / 100g to 0.7mg / 100g DW (15th day of maturity) before decreasing to 0.56 mg / 100g DW at 20 days of maturity. Similarly, the total sugar contents of dried okra samples increased significantly from 2.49 mg / 100g DW (5th day of maturity) to 4.21 mg / 100g DW (15th day of maturity) and 2.06 mg / 100g DW (5th day of maturity) to 5.86 mg / 100g DW (15th day of maturity) respectively for the variety Koto and Tomi. At 20 days of maturity, the values were 3.79 mg / 100g DW (Koto dried) and 3.19 mg / 100g DW (Tomi dried).

Similarly, vitamin C levels in dried okra samples increased significantly until the 15th day of maturity before declining to the 20th of maturity at the 2 varieties of okra. These levels ranged from 1.40 mg / 100g DW (5th day of maturity) to 3.10 mg / 100g DW (15th day of maturity) and from 0.49 mg / 100g DW (5th day of maturity) to 1, 19 mg / 100g DW (15th day of maturity) respectively for dried Koto and Tomi.

The lipid contents of dried okra samples increased significantly for both varieties depending on the stage of maturity. The Koto variety recorded a lipid content which increases to 16.25 mg / 100g DW (15th day of maturity) before falling to 11.54 mg / 100g DW (20th day of maturity). In the Tomi variety, this lipid content increased significantly to 11.16 mg / 100g DW (15th day of maturity) before decreasing to 9.12 mg / 100g DW (20th day of maturity). In contrast to other chemical compounds, the soluble and insoluble fibre contents of dried okra samples increased with fruit maturity and peaked at the 20th day of maturity. The soluble fibres content was 34.04 mg / 100g DW (20th day of maturity) and 27.67 mg / 100g DW (20th day of maturity) respectively for Koto and Tomi varieties. The Koto and Tomi varieties recorded respectively 38.75 mg / 100g DW (20th day of maturity) and 29.03 mg / 100g DW (20th day of maturity) of insoluble fibre. The pH values increased according to the stage of maturity to reach the value of 6.45 and 6.35 respectively for Koto and Tomi dried at 20 days of maturity.

The mineral content of the vegetables fruits of okra during drying in the sun was shown in Table 4. In general, these levels increase significantly with drying compared to grades in fresh okra fruit. The iron values were included from 0.91 mg / 100g DW (5th day of maturity) to 1.25 mg / 100g DW (15th day of maturity) and 0.97 mg / 100 mg DW (5th day of maturity) at 1.37 mg / 100g DW (15th day of maturity) respectively for the Koto and Tomi varieties before decreasing (20th day of maturity) for both varieties. The Tomi variety recorded the highest values in Iron.

Phosphorus content of Koto variety recorded a grade that increased significantly to 18.54 mg / 100g DW (15th day of maturity) before declining to 20 days of maturity (17.08 mg / 100g DW). In the Tomi variety, phosphorus content increased from 14.66 mg / 100g to 17 67 mg / 100g DW (15th day of maturity) before decreasing to 16.56 mg / 100g DW at 20 days of maturity. Calcium content of dried Koto variety increased significantly to 57. 68 mg / 100g DW (15th day of maturity) before declining to the 20th day of maturity (55. 88 mg / 100g DW). In the Tomi variety, the levels increased from 217.01 mg / 100g to 224 mg / 100g DW (15th day of maturity) before declining to 223 mg / 100g DW at 20 days of maturity. Similarly, potassium levels in dried okra samples increased signifycantly.

TABLE 1. EVOLUTION OF SOME BIOCHEMICAL PARAMETERS DURING MATURITY STAGES OF 2 VARIETIES OF DRIED OKRA

Biochemical Parameters (mg/100g DW)	Maturity Stage	varieties			
		Koto		Tomi	
		fresh	dried	fresh	dried
Proteins	5	4.79 ± 0.61^{b}	11.59 ±0.30a	2.57 ± 0.6^{b}	10.34±0.30^{a}
	10	4.97 ± 0.30^{c}	16.78 ±0.30^{b}	2.98 ± 0.31^{c}	12.21±0.30^{c}
	15	5.78 ± 0.38^{d}	18.27±0.67^{d}	3.01 ± 0.30^{d}	13.69 ± 0.6^{d}
	20	4.67 ± 0.51^{a}	17.25 ±0.38^{c}	2.4 ± 0.60^{a}	11.31±0.68^{b}
Reducing Sugar	5	0.17±0.00^{a}	0.29±0.00^{a}	0.12±0.00^{a}	0.23±0.00^{b}
	10	0.19±0.00^{b}	0.62±0.00^{b}	0.15±0.00^{b}	0.54±0.00^{b}
	15	0.48±0.00^{d}	0.69±0.00^{d}	0.49±0.00^{d}	0.7±0.00^{a}
	20	0.21±0.00^{c}	0.64±0.00^{c}	0.27±0.00^{c}	0.56±0.00^{c}
Total sugar	5	0.99±0.00^{a}	2.49±0.00^{a}	1.04±0.00^{a}	2.06±0.00^{a}
	10	1.19±0.00^{b}	3.17±0.00^{b}	1.20±0.00b	3.12±0.00^{b}
	15	4.21±0.00^{d}	4.81±0.00d	3.64±0.00^{d}	5.86±0.00^{c}
	20	1.35±0.00^{c}	3.79±0.00^{c}	2.26±0.00^{c}	3.19±0.00^{b}
Fat	5	5.04±0.01^{a}	8.77±0.01^{a}	2.71±0.00^{a}	5.82±0.02^{a}
	10	6.13±0.03^{b}	9.70±0.01^{b}	3.7±0.02^{b}	7.21±0.01^{b}
	15	10.26±0.01^{d}	16.25±0.02^{d}	6.78±0.00^{d}	11.16±0.01^{d}
	20	9.18±0.01^{c}	11.54±0.01^{c}	5.88±0.02^{c}	9.12±0.02^{c}
Soluble fibre	5	15.98±0.00^{a}	19.33±0.02^{a}	9.32±0.01^{a}	14.32±0.01^{a}
	10	20.67±0.02^{b}	27.34±0.02^{b}	11.66±0.01^{b}	19.67±0.01^{b}
	15	25.02±0.01^{c}	32.83±0.01^{c}	13.25±0.01^{c}	24.70±0.01^{c}
	20	31.7±0.01^{d}	34.04±0.02^{d}	17.1±0.01^{d}	27.67±0.01^{d}
Insoluble fibre	5	18.72±0.01^{a}	22.02±0.01^{a}	11.77±0.01^{c}	16.70±0.01^{c}
	10	24.32±0.01^{b}	28.23±0.01^{b}	13.66±0.01^{d}	21.70±0.01^{d}
	15	29.32±0.01^{c}	33.04±0.01^{c}	15.47±0.01^{a}	25.66±0.02^{a}
	20	34.02±0.01^{d}	38.75±0.01^{d}	19.16±0.01^{b}	29.03±0.01^{b}

Assigned different letters on the same column are significantly different at p <0.05 according to the Newman and Keuls test

TABLE 2: EVOLUTION OF THE PH AND VITAMIN C ACCORDING TO THE MATURITY STAGES OF 2 VARIETIES OF DRIED OKRA

Biochemical Parameters (mg/100g DW	Maturity Stage	Varieties			
		Koto		Tomi	
		fresh	dried	fresh	dried
pH	5	4.84±0^{a}	5.30±0^{b}	4.98±0.02^{a}	5.60±0^{a}
	10	5.84±0^{b}	5.96±0^{a}	6.15±0^{b}	5.85±0^{b}
	15	6.3±0^{d}	6.04±0^{b}	6.3±0^{d}	6.04±0^{c}
	20	6.25±0.00^{c}	6.45±0.00^{c}	6.26±0.01^{c}	6.35±0.00^{d}
Vitamin C	5	4.93±1.12^{a}	1.40±0.50^{b}	2.13±0.97^{a}	0.49±0.32^{a}
	10	11.27±3.80^{b}	1.81±0^{a}	2.17±0^{a}	0.77±0.51
	15	13.85±0.49^{c}	4.50±0.48	3.66±0.49^{c}	1.19±0.49^{c}
	20	13.59±0^{c}	3.10±1.01d	2.42±3.60^{b}	0.81±0.09^{b}

Assigned different letters on the same column are significantly different at p <0.05 according to the Newman and Keuls test

TABLE 3: EVOLUTION OF PH AND VITAMIN C ACCORDING TO THE MATURITY STAGES OF 2 VARIETIES OF DRIED OKRA

Biochemical Parameters (mg/100g DW	Maturity Stage	Varieties			
		Koto		Tomi	
		fresh	dried	fresh	dried
pH	5	4.84±0^{a}	5.30±0^{b}	4.98±0.02^{a}	5.60±0^{a}
	10	5.84±0^{b}	5.96±0^{a}	6.15±0^{b}	5.85±0^{b}
	15	6.3±0^{d}	6.04±0^{b}	6.3±0^{d}	6.04±0^{c}
	20	6.25±0.00^{c}	6.45±0.00^{c}	6.26±0.01^{c}	6.35±0.00^{d}
Vitamin C	5	4.93±1.12^{a}	1.40±0.50^{b}	2.13±0.97^{a}	0.49±0.32^{a}
	10	11.27±3.80^{b}	1.81±0^{a}	2.17±0^{a}	0.77±0.51
	15	13.85±0.49^{c}	4.50±0.48	3.66±0.49^{c}	1.19±0.49^{c}
	20	13.59±0^{c}	3.10±1.01d	2.42±3.60^{b}	0.81±0.09^{b}

Assigned different letters on the same column are significantly different at p <0.05 according to the Newman and Keuls test

4 DISCUSSION

The high levels of phenolic compounds in the two varieties of dried okra can be explained by the bioconcentration of elements after removal of water by the drying phenomenon. Also, this high content of total phenolic compounds could be attributed in part to the nature of the extraction solvent used. Indeed, Ng et al. [23] reports have indicated that methanol is one of the best solvents for extraction of total phenolic compounds of vegetable. These high percentages of phenolic compounds of the two varieties of dried okra can provide data interesting for the human nutrition, because it is well-known that these bioactive compounds present in the food act like antioxidants and play a role in the stabilization of the lipidic peroxidation [24, 25].

The drying in the sun resulted in the concentration of the macro and micro constituent elements following the water loss of the okra fruits. These results are similar with the values found by Lakshmi and Vimla [26] on okra leaves would contain a good amount of protein, fibre, and ash after sun drying.

The increasing of phenolic compounds of dried Koto and Tomi varieties would be responsible for the high level of antioxidant activity observed. This high antioxidant activity observed in dried okra can be explained by their exposure to the sun and their storage conditions [27, 28, 29]. According to Kim et al. [30], there is a positive correlation between antioxidant activity and the amount of the phenolic compounds in plants. This phenomenon has been observed in edible fungi [31, 32]. Indeed, phenolic compounds play an important role in certain sensory properties of foods. Previous studies have shown that some of them exhibit biological activities related to their antioxidant and antiradical properties [33]. Similarly, phenolic compounds are capable of trapping peroxide radicals (ROO), alkoxyls (RO), superoxide (O2-) and hydroxyls (OH) [34]. This role of natural antioxidant allows the body to fight against the attacks of oxygen which are at the origin of many diseases [35, 36].

High oxalate content in foods can have deleterious effects on digestibility [37]. Indeed, oxalate forms complexes with essential minerals, making minerals unavailable to the body. Thus, the consumption of our samples of dried okra with a low oxalate content would be without major risk because the lethal dose of oxalate in a food is between 2000 and 5000 mg of oxalate / 100 g of food [38]

Regarding the proximate composition of okra, the high levels of chemical compounds observed of dried okra could be ex-

TABLE 4: EVOLUTION OF SOME MINERALS ACCORDING TO THE MATURITY STAGES OF 2 VARIETIES OF DRIED OKRA

minerals	Maturity stage	Varieties			
		Koto		Tomi	
		fresh	Dried	fresh	dried
Fe	5	0.88±0.06^{a}	0.91±0.01^{a}	0.93±0.02^{a}	0.97±0.01^{a}
	10	0.92 ±0.07^{b}	0.96±0.02^{b}	0.97±0.01^{d}	1.01±0.02^{d}
	15	1.15±0.04^{c}	1.25±0.03^{c}	1.22±0.04^{b}	1.37±0.03^{b}
	20	1.11±0.03^{c}	1.21±0.03^{d}	1.17±0.03^{c}	1.28±0.04^{c}
P	5	15.21±0.01^{a}	17.67±0.05^{a}	12.68±0.4^{a}	14.66±0.3^{a}
	10	15.67±0.01^{b}	16.21±0.05^{b}	12.98±0.4^{b}	15.04±0.7^{b}
	15	16.07±0.02^{c}	18.54±0.03^{c}	14.68±0.3^{c}	17.67±0.6^{c}
	20	15.89±0.01^{d}	17.08±0.04^{d}	13.37±0.3^{d}	16.56±0.5^{d}
Ca	5	51.40±0.02^{a}	53.7±0.02^{a}	214±13^{a}	217.01±14^{a}
	10	52.06±0.02^{a}	54.9±0.02^{a}	216±12^{b}	220.6±12^{b}
	15	54.73±0.04^{b}	57.68±0.03^{b}	219.36±15^{c}	224±15^{c}
	20	53.35±0.03^{b}	55.88±0.04c	217±16^{d}	223.01±17^{d}
K	5	250.01±20^{a}	253.04±23^{a}	2.42±0.01^{a}	3.97±0.03^{a}
	10	252.2±20^{a}	255.4±24^{a}	2.78±0.02^{b}	5.45±0.07^{b}
	15	257.02±22^{b}	263.88±26^{b}	4.03±0.04^{c}	7.08±0.09^{c}
	20	256.15±21^{c}	259.68±25^{c}	3.59±0.03^{d}	6.56±0.06^{d}

Assigned different letters on the same column are significantly different at p <0.05 according to the Newman and Keuls test

plained by the elimination of water. Morris et al. [39] have shown that the decrease of moisture in food leads to the concentration of constituent elements. This would explain the increase in the various chemical parameters studied including protein, sugar, fat and carotenoid content. Similarly, the work of Elegbede [40] has shown that the increase in the protein content of dried vegetables is due to the decrease in moisture. Our results corroborate those of Lakshmi and Vimla [26] who showed that dried leafy vegetables contained a good amount of protein between (15 and 20 %).

Thus, fibre-rich dried okra samples may be recommended in a diet for weight reduction because of their low energetic value. A high fibre diet is also very beneficial because it helps to prevent constipation and diseases of the gut such as appendicitis and colon cancer [41]. Indeed, the fibres have a high hydrophilic power. This great ability to retain water along their path in the stomach and intestine facilitates the reduction of food intake and increases stool volume [42]. In addition, the fibres form a viscous gel lining the lining of the intestine, which slows the intestinal absorption of carbohydrates and cholesterol [43].

The result shows a low amount of lipids in dried okra. The consumption of okra could be recommended for lipid-lowering and hypoglycaemic diets. In addition, this implies that these okra fruits provide very little energy after consumption [44].

In fact, lipids give a food its energy value, which is why the low energy values found would make these okra fruits foods of choice to remedy the problems of overweight and obesity [45]. Vitamin C levels decreased considerably in samples during sun drying. This decrease is due to their oxidation by certain factors such as heat, light and oxygen [46]. Previous studies have shown that traditional vegetable drying methods have led to excessive losses of β-carotene due to photo oxidation in addition to other factors [47]. In addition, the work of Diplock et al. [48] and Gil et al. [49] also showed losses of vitamin C in spinach leaves after 3 days of sun drying.

Concerning minerals, the rate increase during drying. This result is like that determined by Pallavi and Dipika [50] in dried leaves of M. oleifira. Minerals are inorganic elements, some of which are essential nutrients. The major minerals (Ca, K, Na and Mg) and essential trace elements (Fe, Cu, Zn and Mn) play very important roles in human metabolism [51]. Deficiencies of these minerals can lead to metabolic disorders and organ damage, leading to acute and chronic disease and ultimately death [51]. Thus, they must be obtained from food. The ash content represents all the mineral elements contained in the samples. The high ash content of Okra (Abelmoschus esculentus (Koto) and Abelmoschus caillei (Tomi)) would be an indicator of their mineral wealth [52]. The mineral content of sun-dried okra fruits is significantly higher compared to fresh okra fruits. These two varieties would have considerable contributions in various minerals (Ca, K, P and Fe) that can fully or partially cover the daily requirements recommended for different sections of the population including pregnant or breastfeeding women, the elderly and children.

5 CONCLUSION

The objective of this study was to contribute to the food Security of the Ivorian populations through the valuation of dried okra fruits. The okra's sun-dried fruits allowed an increase of most of the biochemical compounds of the 2 varieties (Koto and Tomi) harvested at the 15th day of maturity. Thus, high fibre, low fat, dried okra samples may be recommended in a diet for weight reduction because of their low energetic value and may also be recommended for Fat-lowering and hypoglycaemic diets.

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