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Original Research Article

Effect of Three Drying Modes on Nutritive and Antinutritive Properties of Leafy Vegetables Consumed in Northern Côte d'Ivoire

Coulibaly Tialafolo Alassane[1], Touré Abdoulaye[1, 2*], Zoro Armel Fabrice[1, 4], Kablan Ahmont Landry Claude[1, 5], Méité Souleymane[3], Coulibaly Adama[2]

[1]Biotechnology and Valorization of Agroresources and Natural Substances Laboratory, Peleforo GON COULIBALY University, BP 1328 Korhogo, Côte d'Ivoire
[2]Biochimical Parmacodynamy Laboratory, Félix Houphouet-Boigny University, 22 BP 582 Abidjan 22, Côte d'Ivoire
[3]Clinical Biochemistry Laboratory, Institut Pasteur of Côte d'Ivoire, 01 BP 490 Abidjan 01, Côte d'Ivoire
[4]Biotechnologie Laboratory, Félix Houphouet-Boigny University, 22 BP 582 Abidjan 22, Côte d'Ivoire
[5]Organic Chemistry and Natural Substances Laboratory, Félix Houphouet-Boigny University, 22 BP 582 Abidjan 22, Côte d'Ivoire

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Abstract: In tropical Africa, leafy vegetables are traditionally eaten as a relish together with a starchy staple food. Nevertheless, report on their nutritive potential is scanty. In order to contribute to their valorization, leafy vegetables consumed in the north of Côte d'Ivoire (*Cerathoteca sesamoides*, *Leptadenia hastata*, *Ocimum gratissimum* and *Portulaca oleracea*) were studied. The leafy vegetables were collected in the towns of Korhogo and Dabakala located respectively in the North and Center-North of Côte d'Ivoire. These sheets were subjected to three drying treatments before their characterization. To do this, the physico-chemical and nutritional properties of these leafy vegetables have been realized. The results revealed that oven and sun drying significantly reduced the moisture in our four leafy greens. After drying, *C. sesamoides* and *O. gratissimum* had the lowest moisture content of 8.25±0.15% and 8.07±0.06% respectively for oven drying, while sun drying reduced these moisture levels to 9.48±0.12% and 9.23±0.1% respectively for the leaves of *C. sesamoides* and *O. gratissimum*. Unlike humidity, these analyzes revealed a concentration of ashes, proteins, fibers and carbohydrates during the three drying modes. With regard to the ashes, drying in an oven allowed a better concentration in the leaves of *L. hastata* (13.40±0.04%) and *P. oleracea* (21.81±0.50%) while drying in the sun gave a content of 18.24±0.33% (*P. oleracea*) and that of shade drying recorded a content of 13.26±0.13% (*L. hastata*). Concerning the protein content, the results obtained showed that the leaves of *C. sesamoides*, *L. hastata* and *O. gratissimum* had a better concentration during drying in the oven and in the shade. Oven drying recorded a protein content of 22.01±0.08% (*L. hastata*) and 22.65±0.08% (*O. gratissimum*) while shade drying recorded a protein content of 22.67±0.10 % (*L. hastata*) and 23.62±0.46% (*C. sesamoides*). At the level of crude fibers, the results showed that the leaves of *C. sesamoides*, *L. hastata* and *O. gratissimum* had higher fiber contents during drying in the oven and in the sun. After drying in the oven, the crude fiber contents were respectively 39.36±0.21% (*C. sesamoides*) and 36.93±0.32% (*L. hastata*) while sun drying recorded a fiber content of 36.77±0.29% (*O. gratissimum*). The results also revealed that sun and oven drying resulted in increased carbohydrates in the leaves of *C. sesamoides* and *O. gratissimum*. After sun drying, total carbohydrate contents were 59.74±0.16% (*C. sesamoides*) and 54.17±0.04% (*O. gratissimum*) while oven drying recorded contents of 59.33±0.03% (*C. sesamoides*) and 52.74±0.03% (*O. gratissimum*). The energy value results were also determined. These results showed that compared to shade drying, sun and oven drying gave the leaves of *C. sesamoides*, *L. hastata* and *O. gratissimum* a higher energy value. Sun drying gave 285.24±0.77% (*C. sesamoides*); 277.08±1.05% (*L. hastata*) and 300.59±0.52% (*O. gratissimum*) while oven drying gave 276.08±0.63%, 269.06±0.40% and 299.79±0.39% for leaves of *C. sesamoides*, *L. hastata* and *O. gratissimum*. The results also revealed an increase in the content of mineral elements in all the leaves during the three drying modes. The mineral elements contents were high with remarkable amount of K (206.70±0.77-515.70±0.30 mg/100 g), Ca (132.50±0.96-255. 62±0.25 mg/100 g), Mg (106.00±0.97-263.60±0.71 mg/100

***Corresponding Author:** Touré Abdoulaye
Biotechnology and Valorization of Agroresources and Natural Substances Laboratory, Peleforo GON COULIBALY University, BP 1328 Korhogo, Côte d'Ivoire

g), P (178.50±1.29-325.50±0.52 mg/100 g) and Fe (34.20±0.92-63.60±0.89 mg/100 g). The Ca/P ratio was desirable and ranged from 0.60±0.00 to 0.87±0.00. These leafy vegetables also contained appreciable levels of Oxalates (251.90-914.30 mg/100 g) and phytates (20.28-35.29 mg/100 g). All these results suggest that the studied leafy vegetables if consume regularly would contribute to the nutritional requirement and to the food security of Ivorian population. Drying in the oven allows a better concentration of nutrients followed by sun and shade.

Keywords: Leafy vegetables, nutritional value, sun drying, shade drying, oven drying, Côte d'Ivoire.

INTRODUCTION

In order to solve the problem of undernourishment and malnutrition, man has recourse to plants. Plants involved in human nutrition could be subdivided into cultivated plants and those called spontaneous or wild which have the advantage of being better adapted to eco-climatic conditions (Liengola, 2001).

In Africa, spontaneous food plants are among the species of great diversity and multipurpose. During lean periods or in exceptional circumstances, for example in times of drought or war, they are essential to the survival of populations (Bioversity International, 2006). These include leafy vegetables (Almekinders, 2000).

Traditional leafy vegetables are increasingly known for their importance in the food security of millions of Africans in rural and urban areas (Kpevi, 2008). They are generally an important source of micronutrients (FAO/WHO, 2007). Indeed, these leafy vegetables are generally richer in mineral elements, vitamins, dietary fiber and nutritional factors, with no prohibitive antinutritional factors compared to exotic vegetables temperate (Bailey, 2003). The high concentrations of assimilable minerals combined with low levels of anti-nutritional substances (phytic or tannic acids, oxalates) make them recommendable dietary supplements (Akindahunsi and Salawu, 2005). Their richness in iron, vitamins A and C correspond to particularly significant health issues in countries with high levels of anemia and stunted children caused by malnutrition (UNICEF, 2012). To this end, Salami (2011) reported that traditional African type vegetables can play a great role in reducing malnutrition problems by providing the required amounts of proteins, minerals and vitamins to the human body.

In Ivory Coast, a total of 26 plant species have been inventoried as traditional vegetables grown for their leaves. These species are divided into 15 botanical families, 19 local names and 20 common names (Fondio *et al*., 2007). The consumption of leafy vegetables in Ivory Coast is mainly related to the region (CNRA, 2011). Thus, populations in Western, Southern and Northern Ivory Coast consume the leaves *Manihot esculenta* (cassava), *Myrianthus arboreus* (tikliti), *Talinum triangulare* (Mamichou), *Basella alba* (Spinach), *Amaranthus hybridus* (boronbrou) and *Andasonia digitata* (baobab) (Zoro *et al*., 2013; Acho *et al*., 2014; Oulaï *et al*., 2014).

Unfortunately, many species of spontaneous food plants are very poorly known and therefore considered as local curiosities and traditional recipes (Kahane *et al*., 2005).

Despite some research on the biochemical and nutritional characterization of some traditional leafy vegetables consumed in Côte d'Ivoire (Agbo *et al*., 2009; Soro *et al*., 2012; Zoro *et al*., 2013), it must be recognized that the nutritional potential of many species of spontaneous food plants consumed in Ivory Coast remains insufficiently explored, which could therefore limit the prospect of their valorization.

The objective of this study is to evaluate the biochemical and nutritional profile of 4 moderately known leafy vegetables (*Cerathoteca sesamoides*, *Leptadenia hastata*, *Ocimum gratissimum* and *Portulaca oleracea*) consumed in the Northern of Ivory Coast with a view to their valorization in the field of dietetics.

MATERIAL AND METHODS

1- MATERIAL

1.1- Biological material

Leafy vegetables (*Cerathoteca sesamoïdes*, *Leptadenia hastata*, *Ocimum gratissimum* et *Portulaca oleracea*) (Figure 1) were collected fresh at Dabakala (latitude: 08°23' North; longitude: 04°26'West) (Abidjan District) and Korhogo (Latitude North: 09°27'41''; longitude west : 05°38'19''). These plants were previously authenticated by the National Floristic Center (University Felix Houphouët-Boigny, Abidjan-Côte d'Ivoire).

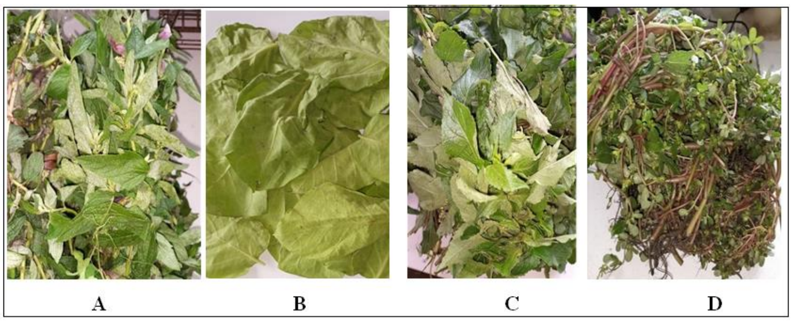

Figure 1: Traditional leafy vegetables. A: *Cerathoteca sesamoïdes*; B : *Leptadenia hastata*; C: *Ocimum gratissimum*; D: *Portulaca oleracea*

1.2- Chemicals

All solvents (n-hexane, petroleum ether, acetone, methanol) were purchased from Merck. All chemicals used in the study were of analytical grade.

1.3- Technical Materials

These materials used were blender (Nasco, South Korea), oven (Memmert, Germany), muffle furnace (Pyrolabo, France), Kjeldhal apparatus, spectrophotometer (PG Instruments, England), flame emission photometer (Sherwood Flame Photometer 410), atomic absorption spectrophotometer (AAS model, SP9).

2- METHODS

2.1- Leafy vegetables processing

The fresh leafy vegetables were destalked, washed with deionized water and edible portions were separated from the inedible portion. The edible portions were allowed to drain at ambient temperature and separated into 4 portions of 250 g each.

2.1.1- Oven drying

Oven drying was carried out according to the method of Chinma and Igyor (2007). 250 g of leaves were dried in an oven (MEMMERT) at 60°C for 3 days. The dried leafy vegetables were ground with a laboratory crusher (Culatti, France) equipped with a 10 µm mesh sieve and stored in air-tight containers for further analysis.

2.1.2- Sun drying

The fresh leafy vegetables (250 g) was spread on black polythene sheet and dried under the sun (35-38°C) for 5 days during 10 hours per day (Mepba *et al*., 2007). The leaves were constantly turned to avert fungal growth. After drying period, the dried leaves were ground with a laboratory crusher (Culatti, France) equipped with a 10 µm mesh sieve and stored in air-tight containers for further analysis.

2.1.3- Shade drying

250 g was spread on clean filter paper and kept in a well-ventilated room of the laboratory at 25°C for 15 days. Natural current of air was used for shadow drying and the leaves were constantly turned to avert fungal growth (Vanderhulst *et al*., 1990). After drying period, the dried leaves were ground with a laboratory crusher (Culatti,France) equipped with a 10 µm mesh sieve and stored in air-tight containers for further analysis.

2.2- Physicochemical analysis

Proximate analysis was performed using official methods (AOAC, 1990). The moisture content was determined by the difference of weight before and after drying fresh sample (10 g) in an oven (Memmert, Germany) at 105°C until constant weight. Ash fraction was determined by the incineration of dry matter sample (5 g) in a muffle furnace (Pyrolabo, France) at 550°C for 12 h. The percentage residue weight was expressed as ash content. For crude fibres, 2 g of dry matter sample were weighed into separate 500 mL round bottom flasks and 100 mL of 0.25 M sulphuric acid solution was added. The mixture obtained was boiled under reflux for 30 min. Thereafter, 100 mL of 0.3 M sodium hydroxide solution was added and the mixture were boiled again under reflux for 30 min and filtered through Whatman paper. The insoluble residue was then incinerated, and weighed for the determination of crude fibres content. Proteins were determined through the Kjeldhal method and the lipid content was determined by Soxhlet extraction using hexane as solvent. Carbohydrates content and calorific value were calculated and expressed on dry matter basis using the following formulas (FAO, 2002).

Carbohydrates: 100 – (% moisture + % proteins + % lipids + % ash + % fibres)

Calorific value: (% proteins x 2.44) + (% carbohydrates x 3.57) + (% lipids x 8.37)

2.3- Mineral analysis

The dried powdered samples (5 g) were burned to ashes in a muffle furnace (Pyrolabo, France). The ashes obtained were dissolved in 10 mL of HCl/HNO3 and transferred into 100 mL flasks and the volume was made up using deionized water. The mineral composition of each sample was determined using an Agilent 7500c inductively coupled argon plasma mass spectrometer (ICP-MS) method (CEAEQ, 2013). Calibrations were performed using external standards prepared from a 1000 ppm single stock solution made up with 2% nitric acid.

2.4- Oxalates and phytates quantification

Oxalates content was performed using a titration method (Day and Underwood, 1986). One (1) g of dried powdered sample was weighed into 100 mL conical flask. A quantity of 75 mL of sulphuric acid (3 M) was added and stirred for 1 h with a magnetic stirrer. The mixture was filtered and 25 mL of the filtrate was titrated while hot against KMnO4 solution (0.05 M) to the end point. Phytates contents were determined using the Wade's reagent colorimetric method (Latta and Eskin, 1980). A quantity (1g) of dried powdered sample was mixed with 20 mL of hydrochloric acid (0.65 N) and stirred for 12 h with a magnetic. The mixture was centrifuged at 12000 rpm for 40 min. An aliquot (0.5 mL) of supernatant was added with 3 mL of Wade's reagent. The reaction mixture was incubated for 15 min and absorbance was measured at 490 nm by using a spectrophotometer (PG Instruments, England). Phytates content was estimated using a calibration curve of sodium phytate (10 mg/mL) as standard.

2.5- Statistical analysis

All the analyses were performed in triplicate and data were expressed as mean ± standard deviation (SD). Data were analyzed using EXCELL and STATISTICA 7.1 (StatSoft). Differences between means were evaluated by Duncan's test. Statistical significant difference was stated at $p < 0.05$.

3- RESULTS AND DISCUSSION

Table 1 presents the biochemical parameters of the leafy vegetables studied according to the mode of drying. Statistical analysis of the moisture showed a significant difference ($p \leq 0.05$) in the 4 leafy vegetables studied. Moisture ranges from 8.07±0.06 to 16.27±0.11%. Oven drying records low values (8.07±0.06 to 13.62±0.25%) followed by sun drying (9.23±0.10 to 15.40±0.30%) and shade drying (11.92±0.11 to 16.27±0.11%). Our results are different from those of Oulai *et al*., (2016) which ranged from 15.19 ± 0.38% to 20.36 ± 2.77% after 15 days of drying in the shade of the leaves of *A. hybridus*, *A. digitata*, *C. patendra*, *H. sabdariffa* and *V. unguiculata* and Zoro *et al.*, (2016) in leaves of *A. esculentus*, *C. argentea*, *I. batatas*, *M. esculenta* and *M. arboreus* after 3 days of sun drying (3.81 to 7.94%). This difference could be due to the nature of the plant species. Decreased water activity in food significantly slows degradation by blocking the action of microorganisms (mould, yeasts, bacteria) and decreasing the rate of internal biochemical degradation of food (enzymatic reactions) (Ferenzi, 1985). Moreover, according to Morris *et al*., (2004), the decline moisture leads to the concentration of the constituent elements. Oven drying allows a better concentration of biochemical compounds. Ash results showed a significant difference ($p \leq 0.05$) in dried leafy vegetables. They oscillate between (6.68±0.35 and 21.81±0.50%). Highest levels are recorded during drying oven drying (9.60±0.28 and 21.81±0.50%) then in the shade (8.58±0.35 and 17.75± 0.42%) and finally in the sun (6.68±0.35 and 18.24±0.33%). Our results are consistent with Koua *et al.*, (2015) which obtained ash contents varying from 11.80±0.28 to 18.77±0.29% in the leaves of *C. gynandra*, *S. nigrum* and *V. amygdalina* after drying at 60°C for 72H but similar from those of Zoro *et al.*, (2016) who recorded values ranging from 5.85±0.25 and 10.90±0.37% in the leaves of *A. esculentus*, *C. argentea*, *I. batatas*, *M. esculenta* and *M. arboreus* after 15 days of drying in the shade. This concentration of ashes would be due to the reduced moisture. The high ash content of *P. oleracea* (21.81%) would be an indicator of its mineral richness. Drying in the oven allows a better concentration of the ash. Nevertheless, the 4 leafy vegetables studied could be considered a good source of minerals compared to cereals and tubers (2 – 10%) FAO (1986). As regards protein content, the statistical analysis shows a significant difference ($p \leq 0.05$). However, sun-drying has statistically identical contents for leafy vegetables *L. hastata* and *O. gratissimum*. Protein contents varied significantly from 19.31 ± 0.00% (*P. oleracea*) to 23.62 ± 0.46% (*C. sesamoides*). After 5 days of sun drying, they are between 20.13±0.08 and 21.88±0.36% compared to shade (19.31±0.00 and 23.62±0, 46%) and oven (20.42±0.015 and 22.65±0.08). Our recorded contents are much higher than those of Iniaghé *et al*., (2009) which recorded in leaves of the Acalypha genus dried in the shade for 2 weeks values between 13.78 ± 0.11 and 18.15 ± 0.03%. On the other hand, the contents (13.25±0.13 and 21.96±0.30) reported by Oulai *et al.*, (2014), are within the range of our contents after 3 days of drying in the oven of the leaves of *A. hybridus*, *A. digitata*, *C. patendra*, *H. sabdariffa* and *V. unguiculata* This increase in proteins could occur following the reduction of moisture leading to a concentration effect of dry matter (Hassan *et al*., 2007). These leafy vegetables could be important sources of protein for poor populations in developing countries in order to fight against protein deficiencies. For fiber contents, the statistical analysis shows a significant difference ($p \leq 0.05$) in the 4 leafy vegetables. However, statistically identical levels were observed between *C. sesamoides* and *O. gratissimum* for sun and shade treatments, respectively. Oven treatment (32.82±0.06 (*P. oleracea*) to 39.36±0.21% (*C. sesamoides*)) has the highest levels followed by the sun (30.77±0. 06 (*P. oleracea*) at 36.74±0.10% (*O. gratissimum*)) and shade (29.63±0.17 (*P. oleracea*) at 35.89±0.04% (*O. gratissimum*)). The work of Oulai *et al*., (2016), obtained contents ranging from 11.04 ± 2.40 to 27.40 ± 1.73% after 15 days of shade drying. The work of Zoro *et al*., (2016) after 3 days of sun drying recorded fiber contents ranging from 26.70 (*I. batatas*) to 48.44% (*M. arboreus*). For oven treatment, our results are different from those of Ehilé *et al*., (2018) which obtained contents of between 14.6 ± 0.00 (*S. radiatum*) and 19.5 ± 0.00% (*M. arboreus*) after 3 days of drying in an oven at 45°C for 72 hours. This difference could be related to the drying temperature and the species of our leafy vegetables. Consumption of the leafy vegetables studied could be beneficial for digestion, prevention of colon cancer, treatment of diabetes and gastrointestinal disorders (Saldanha, 1995; UICC/WHO, 2005). Statistical analyzes of lipid, carbohydrate and energy value show a significant difference ($p \leq 0.05$) in the 4 leafy vegetables. Levels ranged from 1.45±0.10 (*C. sesamoides*) to 7.66±0.13% (*O. gratissimum*) and from 39.20±0.10 (*P. oleracea*) to 59.74±0 .16% (*O. gratissimum*) for lipids and carbohydrates, respectively. These low values have been highlighted by many authors who have shown that leafy vegetables are not good sources of lipids and carbohydrates (Ejoh *et al*., 1996; Emebu and Anyika, 2011). This would explain the low energetic value (230.62±1.12 (*P. oleracea*) to 300.59±0.52 Kcal/100g (*O. gratissimum*) of the leafy vegetables studied. These values are comparable to those of Antia *et al*., (2006) which recorded values 248.8-307.1 kcal/100 g in some leafy vegetables in Nigeria Consumption of these leafy vegetables would be beneficial in the prevention of cardiovascular diseases, cancer and cellular aging (Kris-Etherton *et al*., 2002).

Table 1: Biochemical parameters of leafy vegetables according to the three (03) drying methods (sun, oven and shade)

Leafy vegetables	Biochemical parameters							
	Drying modes	Moisture (%)	Ash (%)	Proteins (%)	Fibers (%)	Lipids (%)	Carbohydrates (%)	Value energetic (Kcal/100g)
C. sesamoïdes	Raw	**89.43±0.01^{b}**	0.38±0.07^{l}	**2.57±0.02^{g}**	**4.37±0.13^{i}**	0.25±0.01^{l}	**7.37±0.02^{l}**	34.67±0.28^{j}
	Sun	9.48±0.12^{k}	6.68±0.35^{h}	21.88±0.36^{bc}	36.74±0.10^{b}	2.22±0.06^{h}	59.74±0.16^{a}	285.24±0.77^{c}
	Oven	8.25±0.15^{l}	9.60±0.28^{f}	21.37±0.61^{c}	39.36±0.21^{a}	1.45±0.10^{i}	59.33±0.03^{a}	276.08±0.63^{d}
	Shade	12.02±0.11^{h}	8.58±0.35^{g}	23.62±0.46^{a}	35.73±0.06^{c}	2.28±0.06^{h}	53.50±0.11^{c}	267.71±1.27^{f}
L. hastata	Raw	**89.42±0.42^{b}**	**1.05±0.00^{j}**	**2.64±0.10^{g}**	**4.26±0.07^{i}**	0.60±0.02^{j}	6.29±0.05^{m}	33.91±0.33^{j}
	Sun	10.68±0.17^{i}	11.54±0.39^{d}	21.63±0.21^{c}	35.77±0.11^{c}	4.97±0.06^{f}	51.18±0.00^{e}	277.08±1.05^{d}
	Oven	10.02±0.08^{j}	13.40±0.04^{c}	22.01±0.08^{bc}	36.93±0.32^{b}	4.28±0.14^{g}	50.29±0.50^{f}	269.06±0.40^{e}
	Shade	12.79±0.04^{g}	13.26±0.13^{c}	22.67±0.10^{b}	35.09±0.25^{d}	5.37±0.28^{e}	45.91±0.08^{h}	264.16±1.86^{f}
O. gratissimum	Raw	83.55±0.56^{c}	**1.51±0.27^{i}**	**3.90±0.13^{f}**	**5.56±0.19^{h}**	**1.40±0.06^{i}**	**9.64±0.05^{k}**	**55.64±2.10^{i}**
	Sun	9.23±0.10^{k}	9.53±0.31^{f}	20.13±0.08^{d}	36.77±0.29^{b}	6.94±0.11^{b}	54.17±0.04^{b}	300.59±0.52^{a}
	Oven	8.07±0.06^{l}	9.82±0.03^{f}	22.65±0.08^{b}	35.47±0.04^{d}	6.72±0.06^{c}	52.74±0.03^{d}	299.79±0.39^{a}
	Shade	11.92±0.11^{h}	10.49±0.03^{e}	20.75±0.50^{d}	35.89±0.04^{c}	7.66 ± 0.13^{a}	49.18±0.54^{f}	290.31±1.22^{b}
P. oleracea	Raw	**94.86±0.35^{a}**	0.85±0.02^{k}	1.36±0.08^{h}	1.87±0.07^{j}	0.34±0.02^{k}	2.59±0.04^{n}	15.41±0.64^{k}
	Sun	15.40±0.30^{e}	18.24±0.33^{b}	21.61±0.38^{c}	30.77±0.06^{f}	5.55±0.11^{e}	39.20±0.10^{j}	239.12±1.52^{g}
	Oven	13.62±0.25^{f}	21.81±0.50^{a}	20.42±0.15^{d}	32.82±0.06^{e}	4.83±0.13^{f}	39.32±0.73^{j}	230.62±1.12^{h}
	Shade	16.27±0.11^{d}	17.75±0.42^{b}	19.31±0.00^{e}	29.63±0.17^{g}	5.95±0.10^{d}	40.72±0.16^{i}	242.28±1.38^{g}

**Means not sharing any letter are significanly different for each parameter*

The effect of drying on the mineral composition of the leafy vegetables studied is presented in Table 2. Like other biochemical parameters, the statistical analysis shows a significant difference ($p \leq 0.05$) in mineral. However, statistically identical levels are observed in some leafy vegetables. A concentration of minerals is observed during the different drying modes. The most abundant macroelement is K (206.70 ± 0.77 (*P. oleracea*) at 515.70 ± 0.30 mg/100g (*L. hastata*)) followed by P (178.50 ± 1.29 (*P. oleracea*) at 325.50 ± 0.52 mg/ 100g (*L. hastata*)), Ca (132.50 ± 0.96 (*P. oleracea*) at 255.62 ± 0.25 mg/ 100g (*L. hastata*), Mg (106.00 ± 0.97 (*P. oleracea*) to 263.60 ± 0.71 mg/ 100g (*O. gratissimum*)) and finally Na (11.19 ± 0.11 (*C. sesamoides*) at 25.80 ± 1.04 mg/ 100g (*L. hastata*). The concentration of these elements is higher during drying in the sun followed by the oven and finally in the shade. Our results obtained coincide with those reported by Oulai *et al*., (2015) whose work focused on the impact of solar drying on the nutritional and antioxidant properties of five leafy vegetables consumed in northern Ivory Coast. In view of the results obtained, our leafy vegetables could cover at least 25% of the recommended daily intakes (RDA) and thus contribute to the improved human nutrition (FND, 2005). Indeed, calcium (1000 mg/day) and phosphorus (800 mg/day) play a major role in ossification and dentition (Turan *et al*., 2003) and have a preventive effect on hypertension in the elderly. (McCarron *et al*., 1999). Magnesium (400 mg/day) is a cofactor in over 300 enzymatic reactions that regulate various biochemical reactions in the body, including protein synthesis, muscle contraction, blood sugar, blood pressure and heart rate (Rude *et al*., 2009). Sodium and potassium are two important extracellular and intracellular cations, respectively, which are involved in plasma volume regulation, acid-base balance and muscle contraction (Akpanyung, 2005). The Ca/P and Na/K ratios vary from 0.60 to 0.87 and 0.03 to 0.08, respectively. Leafy vegetables could be considered good because the Ca/p ratios are greater than 0.5 (Adeyeye and Aye, 2005). In addition, consumption of the studied leaves would probably reduce hypertension diseases because the Na/K ratios are less than one (FND, 2005). Iron (34.20 ± 0.92 (*O. gratissimum*) at 63.60 ± 0.89 mg/100g (*C. sesamoides*) was more abundant than Zinc (12.90 ± 1 .06 (*P. oleracea*) to 24.90 ± 1.10 mg/100g (*C. sesamoides*). Drying in the oven allows a better concentration of the microelements unlike the macroelements where this concentration is important during sun drying. These high concentrations during oven drying were also observed by Koua *et al*., (2015) in leaves of *C. gynandra*, *S. nigrum* and *V. amygdalina* for Fe (31.30 to 55.25 mg/100g) and Zn (24.21 to 42.30 mg/100g). Our studied leaves could cover the daily needs in Fe and Zn requirements of 8 mg/day and 6 mg/day, respecetively (FAO, 2004). Iron (Fe) plays an important role in preventing anemia while zinc (Zn) is important in neurological function (Yamada *et al*., 2014). Therefore, the leafy vegetables studied could be recommended to breastfeeding women, the elderly and especially children to fill iron deficiencies.

Table 2: Mineral composition (mg/100 g of Dry Matter) of leafy vegetables according to the three (03) drying methods (sun, oven and shade)

Leafy veget-ables	Drying modes	Macroéléments					Oligoéléments		Ratios	
		Ca	P	Mg	K	Na	Fe	Zn	Ca/P	Na/K
C. sesamoïdes	Raw	19.13±0.00[n]	31.84±0.00[n]	25.29±0.00[l]	46.51±0.00[k]	7.38±0.00[i]	20.31±0.00[h]	6.43±0.00[g]	0.60±0.00	0.16±0.00
	Sun	182.66±0.05[g]	304.00±0.59[c]	241.50±0.74[b]	444.10±0.21[b]	13.20±1.08[d]	61.60±0.84[b]	23.20±0.85[a]	0.60±0.00	0.03±0.00
	Oven	177.65±0.70[h]	272.30±0.71[d]	196.40±0.48[e]	412.60±0.76[c]	13.40±0.60[d]	63.60±0.89[a]	24.90±1.10[d]	0.65±0.00	0.03±0.00
	Shade	152.50±0.79[i]	235.00±0.91[i]	106.00±0.97[j]	357.15±0.65[d]	11.19±0.11[e]	56.30±0.90[c]	17.60±0.88[c]	0.65±0.00	0.03±0.00
L. hastata	Raw	24.52±0.00[m]	36.26±0.00[m]	24.02±0.00[m]	**61.66±0.00[j]**	**17.08±0.00[f]**	**21.07±0.00[i]**	4.38±0.00[h]	0.67±0.00	0.28±0.00
	Sun	205.10±0,90[b]	303.30±0.74[e]	200.90±1.34[d]	515.70±0.30[a]	25.80±1.04[a]	50.09±0.75[d]	19.90±0.79[b]	0.67±0.00	0.05±0.00
	Oven	193.70±0.79[d]	325.50±0.52[b]	194.55±0.61[e]	315.70±0.72[f]	21.20±0.90[bc]	52.20±0.82[d]	19.40±0.90[b]	0.60±0.00	0.07±0.00
	Shade	181.00±0.99[e]	279.80±1.14[f]	121.40±1.04[h]	412.60±0.64[c]	19.70±1.12[c]	48.60±0.90[d]	18.60±0.71[bc]	0.65±0.00	0.05±0.00
O. gratissimum	Raw	25.99±0.00[l]	30.82±0.00[o]	**26.80±0.00[k]**	32.08±0.00[m]	12.32±0.00[h]	14.75±0.00[j]	**8.45±0.00[g]**	**0.84±0.00**	**0.38±0.00**
	Sun	255.62±0.25[a]	303.10±1.05[e]	263.60±0.71[a]	315.50±0.61[f]	22.78±0.82[b]	37.20±0.97[ef]	24.10±0.89[a]	0.84±0.00	0.07±0.00
	Oven	227.20±1.22[b]	266.40±0.60[g]	205.72±1.05[c]	301.20±1.11[g]	23.40±0.91[ab]	42.60±0.58[f]	23.90±1.04[a]	0.85±0.00	0.08±0.00
	Shade	206.50±0.65[c]	237.70±0.75[h]	199.10±0.93[d]	352.80±1.24[e]	22.70±0.58[b]	34.20±0.92[f]	18.60±0.87[bc]	0.87±0.00	0.06±0.00
P. oleracea	Raw	**28.61±0.00[n]**	**44.02±0.00[l]**	20.22±0.00[n]	37.62±0.00[l]	8.64±0.00[g]	14.91±0.00[g]	5.42±0.00[g]	0.65±0.00	0.23±0.00
	Sun	157.20±0.79[j]	258.80±0.92[a]	111.10±0.93[i]	206.70±0.77[i]	14.50±0.87[d]	41.50±0.83[d]	14.30±0.83[de]	0.61±0.00	0.07±0.00
	Oven	176.30±0.62[f]	205.20±1.19[j]	131.60±0.97[g]	316.30±0.81[f]	12.10±0.90[d]	45.20±0.89[cd]	15.60±0.95[f]	0.86±0.00	0.04±0.00
	Shade	132.50±0.96[k]	178.50±1.29[k]	181.50±0.90[f]	244.70±0.84[h]	11.50±0.85[d]	37.50±0.92[e]	12.90±1.06[f]	0.74±0.00	0.05±0.00

**Means not sharing any letter are significanly different for each parameter*

The figure 1 presents the results of the effect of drying on the levels of anti-nutrient factors of the leafy vegetables studied. Statistical analyzes of anti-nutrient factors (oxalate and phytate) show a significant difference ($p \leq 0.05$) in the 4 dried leafy vegetables. However, statistically identical levels are observed for some leafy vegetables such as *C. sesamoides* and *L. hastata*. Compared with the initial contents of oxalates (37.04±0.00 – 93.48±0.12 mg/100g) and phytates (3.63±0.20 – 11.41±0.00 mg/100g), a concentration of oxalates (163.40±0.83 – 914,3±0.72 mg/100g) and phytates (22.18±0.20-35.29±0.09 mg/100g). This is less important during shade drying. The toxicity of oxalates for humans is 2-5 g/day and consumption of a diet rich in oxalates can lead to kidney stones (Hassan and Umar, 2004; Hassan *et al*., 2007). Our studied leaves with contents lower than 1 g could be consumed without risk. Phytates are the major form of phosphorus storage and are particularly abundant in cereals and legumes (Champ, 2002). These chelate divalent cations such as calcium, magnesium, zinc and iron, reducing their bioavailability (Sandberg, 2002). In order to reduce the negative impact of these leafy vegetables on health, it would be desirable to soak and blanch them to reduce the levels in the leaves.

To predict the bioavailability of iron and calcium, the phytates/calcium, phytates/iron and oxalate/calcium ratios were calculated and the results are presented in Table 3. With the exception of *L. hastata* and *O. gratissimum* leaves, [Oxalate]/Ca ratios are below the standard (2.5). For [Phytates]/Fe whose iron could be available after consumption of the leaves of *L. hastata* and *C. sesamoides* since these ratios are less than 0.5. On the other hand, the [phytates]/[Ca] ratios are all less than 2.5. In order to reduce the negative impact of these leafy vegetables on health, it would be desirable to soak and blanch them to reduce the contents in the leaves.

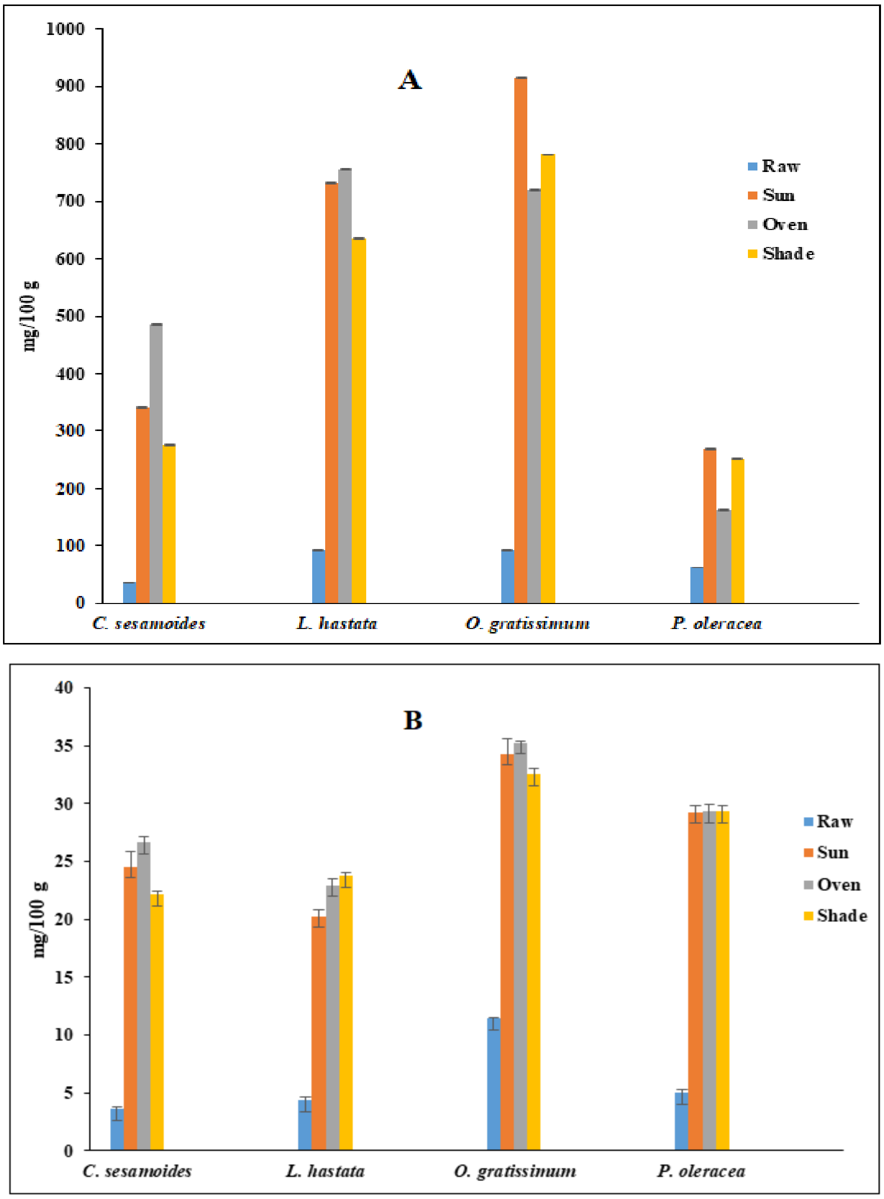

Figure 1: Oxalate (A) and Phytate (B) contents of leafy vegetables at different drying methods

Table 3: Antinutritional factor/mineral ratios of the 4 leafy vegetables according to the three (03) drying methods (sun, oven and shade)

Leafy vegetables	Drying modes	[Phytates]/Fe	[Phytates]/Ca	[Oxalates]/Ca
C. sesamoïdes	Raw	0.18	0.19	1.94
	Sun	0.40	0.13	1.86
	Oven	0.42	0.15	2.73
	Shade	0.40	0.14	1.81
L. hastata	Raw	0.21	0.18	3.80
	Sun	0.40	0.10	3.56
	Oven	0.44	0.12	3.90
	Shade	0.49	0.13	3.50
O. gratissimum	Raw	0.77	0.44	3.59
	Sun	0.92	0.13	3.58
	Oven	0.83	0.15	3.17
	Shade	0.95	0.16	3.78
P. oleracea	Raw	0.33	0.17	2.39
	Sun	0.70	0.19	1.71
	Oven	0.65	0.17	0.93
	Shade	0.78	0.22	1.90

**Means not sharing any letter are significanly different for each parameter*

CONCLUSION

The results showed that the various treatments that dried resulted in a concentration of nutrients. Oven drying allows for a better concentration of nutrients followed by sun drying and finally shade drying. The leaves of *Cerathoteca sesamoides*, *Leptadenia hastata*, *Ocimum gratissimum* and *Portulaca oleracea* could serve as a dietary supplement for the Ivorian population by providing the body with nutrients such as fibers, proteins and minerals. These species also contain certain anti-nutritional factors such as oxalates and phytates that need to be eliminated to improve their nutritional quality. Thus, the leafy vegetables studied could contribute to reducing protein-energy malnutrition and micronutrient deficiencies if consumed in sufficient quantities. However, it is necessary to evaluate secondary metabolites in order to appreciate their medicinal value.

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