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Vitamins Contents in Edible Parts of Some Mucilaginous Food Plants from Côte d'Ivoire

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Authors' contributions

The current study was achieved with the collaboration of all authors. Author OYA wrote the protocol, performed the laboratory analysis and wrote the first draft of the manuscript. Authors AC and YNK performed the statistical analysis, checked the first draft of the manuscript and achieved the submitted manuscript. Author PK took part in the interpretation of the results and corrected the first draft of the manuscript. Author OC managed the literature, assisted the experiments implementation and the statistical analysis. Author HGB designed the study and supervised author OYA in recovering the results. All authors read and approved the submitted manuscript.

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ABSTRACT

Aims: To assess the vitamin contents in different edible parts of nine mucilaginous food plants (MFPs) consumed by the Ivorian population.
Study Design: MFPs edible parts were dried and vitamin parameters analyzed.
Place and Duration of Study: The study was conducted in Laboratory of Biochemistry and Food

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Sciences, Bioscienes Unit, at Félix Houphouet-boigny University between January 2013 to December 2014.

Methodology: The acquirement of the plants has been done in 3 big regions (Tonkpi, Bélier and District of Abidjan) of Côte d'Ivoire. To achieve this study, 100 kg of fresh fruits and masts of the species *I. gabonensis, I. wombolu* and *B. mannii* have been bought to the farmer in the region of the Tonkpi. A same quantity of leaves, calyx and flowers of *B. buonopozense* has been harvested in the region of Bélier. As well as 100 kg of leaves of *C. olitorius*, *M. arboreus*, *A. digitata* and varieties tomi and koto of *A. esculentus* have been bought to the Gouro market in the District of Abidjan. HPLC techniques were used for the separation and quantification of β-carotene, α-tocopherol (vitamin E) and phylloquinone (vitamin k) and the water-soluble vitamins (thiamine, riboflavin, niacin, pyridoxine and folic acid. Also, estimated daily intake and contribution to dietary recommended intake have been evaluated for Ivorian adult of 70 kg.

Results: There was wide variation in the vitamin concentration depending on the plant source and the part of the plant ranging per 100 grams dry matter for α-tocopherol (5.15-70.83 mg), β-carotene (70-4340 RE) and phylloquinone (0.014-1.97 mg), thiamine (0.25-2.22 mg), riboflavin (0.01-1.61 mg), niacin (0.06-1.07 mg), pyridoxine (0.6×10^{-2}- 1.67 mg) and folic acid (0.3×10^{-2}- 0.66 mg). The kernels were rich sources of α-tocopherol, while the fruits were rich in fruits majority and thiamine, pyridoxine, folic acid, while the leaves and flowers were richest in β-carotene, vitamin E and K and contributed 0.60% to 3.79% of the daily requirement of fat-soluble vitamins. The estimated daily intake for each food ranged between 0.1 and 0.7 g/day with estimated total daily foods consumed of 1018.1 g.

Conclusion: MFPs valorisation could contribute to ensure the nutritional safety and bring more incomes to Ivorian populations.

Keywords: Vitamin analysis; mucilaginous food plants; Côte d'Ivoire.

1. INTRODUCTION

The mucilaginous food plants (MFPs) are consumed in general by African populations and by Ivorian in particular. They serve to the confection of very valued sauces [1]. The leaves of *Adansonia digitata* (baobab) and the fruits of *Abelmoschus esculentus* (okra) are used by numerous communities in the culinary preparations [2,3]. Indeed, the young leaves of baobab are rich in β-carotene and also have remarkable contents in C vitamin, thiamine, riboflavin and niacin [4]. Also, the immature fruits of okra showed presence several vitamins of which carotene, thiamine, and niacin [5] with the maximum nutritive elements at seven old days [6]. In the same way the leaves of *Bombax buonopozense* (kapok tree) and *Corchorus Olitorius* (jew's marrow) provided important quantity in protein, iron, calcium and vitamins.They also contain oxydase and chlorogenic acid [7,8]. These food plants are part of a big group designated under the name of non ligneous forest plants. In the tropical and subtropical forests of Africa, Asia and Latin America, the importance of the non ligneous forestry products is not anymore to demonstrate. These products complete the agricultural production of the households while bringing them some food stuff rich in essential nutritive constituent to the good functioning of the organism [9]. A big number of nutritive substances provided by forest food fill significant functions for health and development. Thus, their absence in the diet could mean important consequences on health and well-being [10].

The non ligneous forestry products also permit a real increase of the incomes. They can be also one of the elements on which a strategy of valorization of the products of a soil can lean and generate many jobs. One of the true characteristic to these products resides in their accessibility, even to people not having arable earth and/or sufficient incomes [11]. Indeed, the mucilaginous food plants are endowed with interesting properties bound to the presence of mucilages, substances of polysaccharide nature and/or protein, inflatable to the contact of water. Mucilage is a complex carbohydrate [12] with a highly branched structure that contains variable proportions of L-arabinose, D-Galactose, L-Rhamnose and D-xylose as well as in galacturonique acid [13]. The possibilities of use of the mucilaginous plants are numerous. Mucilages are used in the agroalimentary, pharmaceutical and cosmetic domains [14,15, 16,17].

Concerning the food habits of the populations of numerous regions, the mucilaginous plants act as agent of inflation in the local culinary preparations [1]. They are also used in the flocculation and the decanting of numerous local drinks [18]. The mucilaginous plants can be considered like functional food thanks to their properties of regulation of several parameters of health (blood sugar, blood-pressure, cholesterol, homeostasis of the nutriments) and they possess the organoleptic properties and cut hunger [17,19,20]. However, the various edible parts of all MFPs could contain variable nutritive potentialities being able to impact their nutritional interest. The aim of this present study is to contribute to the better valorisation by the comparative determination of the vitamin nutrients of some mucilaginous species resulting from Ivorian flora.

2. MATERIALS AND METHODS

2.1 Mucilaginous Non Ligneous Forestry Products

The study consisted of the following nine mucilaginous non ligneous forestry Ivorian flora presented in Table 1. The taxonomy of the plants have been authenticated by the Centre National de Floristique (CNF) of the University Felix HOUPHOUET-BOIGNY.

2.2 Collection and Preparation of Mucilaginous Food Plants Samples

The acquirement of the plants has been done in 3 big regions (Tonkpi, Bélier and District of Abidjan) of Côte d'Ivoire of January 2013 to December 2014. To achieve this study, 100 kg of fresh fruits and masts of the species *I. gabonensis, I. wombolu* and *B. mannii* have been bought to the farmer in the region of the Tonkpi. A same quantity of leaves, calyx and flowers of *B. buonopozense* has been harvested in the region of Bélier. As well as 100 kg of leaves of *C. olitorius*, *M. arboreus*, *A. digitata* and varieties tomi and koto of *A. esculentus* have been bought to the Gouro market in the District of Abidjan. In each of the regions, the different products have been collected from 3 farmers or sellers.

The fruits of *Irvingia spp* have been stocked several days then the seeds have been carving to isolate the kernels. The fruits of *B. mannii*, they have been cut in small pieces (less than 5 mm of thickness) before drying. In return, the fruits of *A. esculentus* (gumbo) have been cut in gill, whereas the leaves, the calyx and the flowers were sorted, cleaned, drained and dried in the shadow under ambient temperature until constant weight. The dry plants were milled with a Heavy Duty mark grinder followed by packing in a clean dry air-tight sample bottle for analysis.

Table 1. Mucilaginous vegetables sources from the Ivorian flora

Designation	Family	Local name	Edible parts	Estimated daily consumption (g per adult)
Irvingia gabonensis (Aubry-Lecomte ex O'Rorke) Baill.	Irvingaceae	Kaclou, Kple	Kernels	0.2
Irvingia wombolu (Vermoesen)	Irvingaceae	Kaclou, Kple	Kernels	0.2
Bombax buonopozense P.Beauv.	Bombacaceae	Kapokier	Calyx, leaves, flowers	0.7
Corchorus olitorius L.	Tiliaceae	Kplala	Leaves	0.7
Adansonia digitata L.	Bombacaceae	Baobab	Leaves	0.7
Myrianthus arboreus P. Beauv.	Cecropiaceae	Tikliti	Leaves	0.7
Beilschmiedia mannii (Meisn.) Benth & Hook. f. ex B.D. Jacks.	Lauraceae	sran	Fruits	0.2
Abelmoschus esculentus (L.) Moench variety tomi	Malvaceae	Gumbo baoule	Fruits	0.1
Abelmoschus esculentus (L.) Moench variety koto	Malvaceae	Gumbo dioula	Fruits	0.1

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. The dry matter (DM) content was deduced from the difference of 100 and percentage moisture [21].

2.3 Vitamin Analysis

The concentrations in water-soluble vitamins (WSV) and fat-soluble vitamins (FSV) were given using a high performance liquid chromatographic system (HPLC, mark Water Alliance). This system included a Waters pump, an automatic injector, a UV/PDA detector and a Servotrace recorder. The operating conditions were adapted to the type of required vitamins.

Preparation of the samples for HPLC separation One to two grams of the finely ground samples were extracted vigorously with five excess of n-hexane solvent followed by centrifugation in the cold for 5 min at 3000 rpm. The organic solvent was aspirated and saved. The residue was reextracted with the same solvent and the same steps were repeated until the extract was almost colorless. The total volume of the extract was recorded and an aliquot was injected in the HPLC system.

Fat soluble vitamins were separated on a column Kromasil C18 of 30 X 4 mm (CIL CLUZEAV) in stainless steel. The mobile phase was a mixture acetonitrile/methanol (80/20, v/v), of HPLC grade and well furnished by MERCK (Germany). The column temperature was 30°C, the elution length was 35 min and the flow rate was 1.2 mL/min.

Water soluble vitamins were separated on a Zorbax column to silica support post grafted in C18 (150 mm X4.6 mm) with particles of 3 mm. The mobile phase was a mixture of ammonium acetate and methanol, of grade HPLC and furnished by MERCK (Germany). The flow rate was programmed to 2 mL/min on a length of 20 min.

Standard β-carotene, α-tocopherol and phylloquinone were purchased from Fluka Chemie (Switzerland), while standard water soluble vitamins were purchased from Sigma-type Aldrich (UK). Table 2 present the concentrations of the standard vitamins used for injection in the HPLC system.

2.4 Validation of the Vitamin Analysis

The validation of vitamins dosage by HPLC has been achieved by the application of the NFV03-110 norm [22]. This process consists in the study of the linearity of the standardization range, the determination of the limits of detection and quantification, the calculation of the variation coefficient on tests of repeatability and reproducibility, as well as the calculation of the percentage of addition recovery measured.

Table 2. Concentration for injection and wavelengths

Vitamins	Concentration range (µg/ml)	Wavelengths (nm)
α Tocopherol	0.2 to 5.5	295
Phylloquinone	0.3 to 5	245
β-carotene	0.2 to 4.5	445
Thiamine	0.1 to 3.5	270
Riboflavin	0.1 to 7	265
Niacin	0.2 to 4.5	256
Pyridoxine	0.5 to 12	257
Folic acid	0.5 to 5	280

2.4.1 Test of linearity

The linearity was tested between 0 and 125 µg/ml using 5 points of calibration: 0, 25, 50, 75 and 125 µg/ml, five distinct tests were carried out.

2.4.2 Limits of detection and quantification

The limits of detection (LOD) and quantification (LOQ) were calculated with the standards of the various required vitamins. Ten (10) distinct tests were carried out and the values were obtained with the following formulas:

LD = Average (MX) + 3 standard deviation
LQ = Average (MX) + 10 standard deviation

2.4.3 Test of repeatability and reproducibility

To test the repeatability, 10 trials of extract from a reference sample were analysed by HPLC. For reproducibility, 5 separate tests samples from a reference sample were analyzed by HPLC at intervals of several days. The standard concentrations are 1 mg/ml.

2.4.4 Test of accuracy

Ten separate trials from reference samples were analyzed to assess the recovery rate by the method used for the determination of vitamins. The standard concentrations are 5 mg/ml.

2.5 Estimate of Nutritive Supply at the Consumer

Vitamins supply have been estimated according to the method of the Codex Alimentarius that takes into account the concentrations in vitamins recovered in the food and the daily consumption of an adult individual of 70 kg (Table 1) of this food. These quantities of foods are given by World Health organization studies [23]. The contribution of this food in daily requirement has been calculated also from the values of daily recommended intakes [24].

$$\text{Estimated Daily Intake (EDI)} = C \times Q$$
$$\text{Contribution (\%)} = (\text{EDI} \times 100)/\text{DRI}$$

With: C, mineral concentration measured; Q, food daily consumption; DRI, daily recommended intake.

The main daily consumption of edible parts from mucilaginous vegetables is provided in Table 1.

2.6 Statistical Analysis

All the analyses were performed in triplicate the samples analyzed consisted of a variance analysis (ANOVA) to a criterion of classification (parts of the plants), using software SPSS (SPSS 16.0 for Windows, SPSS Inc). The averages were compared by the test of Newman Keuls and statistical significant difference was stated at $p < 0.001$. The software STATISTICA (STATISTICA version 7.1) used for an analysis in principal components (ACP) and an Ascending hierarchical clustering (CAH) in order to structure variability between the samples and the contents of vitamins.

3. RESULTS

3.1 Results of the Validation

The results of validation are presented in Table 3. The coefficients of determination obtained for the study of linearity are between 0.996 and 0.999 for the various required vitamins. The limits of detection (LOD) lie between 25 µg/L and 135 µg/L, whereas the limits of quantification (LOQ) vary from 83 µg/L with 449 µg/L. The coefficients of variation determined for the repeatability oscillate between 1.0±0.05% and 1.7±0.04% and those of the tests of reproducibility lie between 2.5±0.47% and 4.4±0.60%. As for the outputs of extraction of the proportioned additions, the rates are consisted between 96.8±0.14% and 100.5±0.07%.

3.2 Samples Vitamins Contents

3.2.1 Fat-soluble vitamins

The contents of fat-soluble vitamins (FSV) statistically differentiate ($P<0.001$) the samples of mucilaginous plants analyzed (Table 4). Thus, the α- tocopherol is found with average contents from 65.17 to 70.8 mg/100 g in kernels, whereas it hardly exceeds 30 mg/100 g in the leaves and is more little concentrated in the fruits with less than 8 mg/100 g. phylloquinone contents varies between 0.014 and 1.97±0.32 mg/100 g, the fruits of *B. mannii* (1.97 mg/100 g), the leaves of *A. digitata* (1.20 mg/100 g) and leaves of *B. Buonopozense* (0.92 mg/100 g) and with a less degree the leaves of *M. arboreus* and the flowers of *B. buonopozense* (respectively 0.67 and 0.65 mg/100 g) contain the greatest contents of phylloquinone. As for β- carotene, the greatest contents are recorded in the flowers and the leaves (750 to 4340 RE/100 g). In return, they rarely reach 300 RE/100 g in the fruits and are only discerned to an average of 70 RE/100 g in the kernels (Table 4).

3.2.2 Water-soluble vitamins

The concentrations in water-soluble vitamins (WSV) are consigned in Table 5 and significantly differentiate ($P<0.001$) the studied samples.

The contents of thiamine vary from 0.25 to 2.22 mg/100 g. This vitamin is concentrated in the fruits of *A. esculentus* (1.73 to 2.22 mg/100 g), the flowers of *B. buonopozense* (1.05 mg/100 g) and the leaves of *M. arboreus* (1.71 mg/100 g). But it's slightly found in the kernels (0.25 to 0.78 mg/100 g), the fruits of *B. mannii* (0.31 mg/100 g) and in the majority of the leaves (0.55 to 0.91 mg/100 g). With riboflavin, averages from 0.01 to 1.67 mg/100 g are observed, with a more significant presence in the fruits of *A. esculentus* (1.15 to 1.61 mg/100 g) and the leaves of *A. digitata* (1.14 mg/100 g) and *B. buonopozense* (1.01 mg/100 g). Concerning niacin, the contents fluctuate between 0.06 and 1.07 mg/100 g, the leaves and flowers of *B. buonopozense* (1.01 and 1.06 mg/100 g, respectively). The fruits of *A. esculentus* (0.78 to 1.07 mg/100 g) provided contents higher than the other samples.

Table 3. Tests results of analytic validation of the HPLC vitamins dosage

Vitamins	Linarity		CV repeat. (%, n=10)	CV reprod. (%, n=5)	Rend Ext (%,n=10)	LOD (ng/ml)	LOQ (ng/ml)
	Standard	CD (R^2)					
β carotene	Y=326.6x+152.9	0.999	1.5±0.12	4.4±0.60	98.7±0.88	125±0.69	416±0.25
α- tocopherol	Y=836.2x-5800	0.997	1.7±0.04	3.1±0.51	100.5±0.07	98±0.23	326±0.41
Phylloquinone	Y=139.4x+55,5	0.998	1.2±0.68	3.3±0.02	98.1±0.33	135±0.08	444±0.03
Thiamine	Y=723.4x+1346	0.998	1.3±0.10	3.2±0.98	97.3±0.55	62±0.17	206±1.09
Riboflavin	Y=4787x+7107	0.998	1.6±0.94	3.6±0.22	96.8±0.14	54±0.29	179±0.76
Niacin	Y=462.5x-331.5	0.999	1.4±0.73	3.4±0.63	99.1±0.18	64±0.01	213±1.62
Pyridoxine	Y=550.9x+627.1	0.996	1.0±0.05	2.8±0.41	97.7±0.59	25±0.38	83±0.47
Folic acid	Y=942.4x-1615	0.999	1.2±0.21	2.5±0.47	98.6±0.44	33±0.75	109±0.15

CD, coefficient of determination; CV repeat, coefficient of variation of repeatability; CV Reprod, coefficient of variation of the reproducibility; Ext yield, extraction yield; LOD, limit of detection; LOQ, limit of quantification

Table 4. Average (± SD) fat-soluble vitamins of Ivorian mucilaginous food plants

Edible parts		α tocopherol (mg/100g DM)	phylloquinone (mg/100g DM)	β carotene (RE/100g DM)
Kernels	IG	70.83±9.73^{A}	0.14±1.58^{E}	70±0.69^{J}
	IW	65.17±1.53^{B}	0.08±0.22^{F}	70±0.69^{J}
Fruits	AE-*koto*	7.51±3.44^{I}	0.014±0.08^{G}	330±2.67^{G}
	AE-*tomi*	6.45±3.92^{J}	0.014±0.08^{G}	260±0.94^{H}
	BM	5.15±2.27^{K}	1.97±0.32^{A}	90±4.11^{I}
Leaves	AD	25.43±4.95^{D}	1.20±0.68^{B}	4340±0.17^{A}
	CO	23.5±6.90^{E}	0.014±0.08^{G}	1620±1.66^{D}
	MA	17.55±2.42^{F}	0.67±1.72^{D}	1070±0.24^{E}
	BB	31.05±1.64^{C}	0.92±1.12^{C}	2620±4.72^{C}
Flowers	BB-*calyx*	10.43±0.11^{H}	0.014±0.08^{G}	740±0.54^{F}
	BB-*flowers*	17.31±7.55^{G}	0.65±0.36^{D}	3110±1.15^{B}
F		118116.09	261283.86	1171.15
P-value		<0.001	<0.001	<0.001

Data are represented as Means ± SD (n = 3). Means in the column with no common letter differ significantly (p<0.001) for each edible parts; DM, dry matter

The averages of pyridoxine contents strongly vary less 0.6×10^{-2} with more than 1.67 mg/100 g. The samples most provided in this vitamin are the fruits of *A. esculentus* (1.35 and 1.67 mg/100 g) and the leaves of *A. digitata* (1.06 mg/100 g) and *C. olitorius* (1.21 mg/100 g). Folic acid is more slightly concentrated in the studied samples (0.3×10^{-2} to 0.66 mg/100 g). Nevertheless, the fruits of *A. esculentus* (0.38 to 0.54 mg/100 g) and especially the leaves of *A. digitata* (0.66 mg/100 g) provide the greatest values (Table 5).

3.3 Estimated Daily Intakes and Contributions of Ivoirian Adult

3.3.1 Fat-soluble vitamins

The estimated of FSV daily intakes are presented in Table 6. By considering all the studied samples, the daily intakes in α-tocopherol are estimated between 6 µg/day and 217 µg/day. On the level of the phylloquinone, the daily intakes are of 0.04 µg with 8.40 µg. As for β- carotene, quantities estimated between 0.14 RE and 30.38 RE are brought per day. The contributions are presented in Table 7.

3.3.2 Water-soluble vitamins

The WSV daily intakes are presented in Table 6. The studied mucilaginous resources provide quantities of thiamine between 0.5 µg/day and 11.9 µg/day. The contributions in riboflavin are estimated between 0.02 µg/day and 7.98 µg/day. Concerning niacin, pyridoxine and folic acid, daily intakes oscillating respectively between 0.12 µg and 7.42 µg, $1.6.10^{-2}$ µg and 8.47 µg and 0.02 µg and 4.62 µg are estimated. The contributions are presented in Table 7.

3.4 Variability of Vitamin Contents

An ascending hierarchical clustering distinguishes all kernels by the greatest content of α- tocopherol, whereas the majority of the fruits are correlated with the most significant contents of thiamine, pyridoxine, folic acid and phylloquinone. Concerning the samples resulting from the flowers and leaves, some generate the best contents of vitamins β- carotene, riboflavin and niacin; whereas others are provided in vitamins (Fig. 1).

4. DISCUSSION

The low coefficients of variation obtained from the tests of repeatability and reproducibility (1 to 4.4%) are indication of stability and satisfactory precise details for technique HPLC used. Moreover, the extraction of the near total of the proportioned additions and the linearity of proportioning are evidence of the reliability and exactitude of this technique of analysis. Moreover, the low values of the limits of detection and quantification are pledges of effectiveness of the proportioning of the vitamins contained in the samples studied by HPLC system.

The analysis showed a heterogeneous distribution of the FSV in the samples. The α-tocopherol is concentrated in the kernels (65.17 to 70.8 mg/100 g). The greatest contents of this vitamin in kernels could be justified by the significant quantity of fat content, between 60% and 75%, that they contain [25]. Much less than the results of these work, brought back 19.6 mg of α-tocopherol in dry matter 100g of leaves of *B buonopozense* [7]. These authors also indicated 6.8 mg/100 g dry matter of this vitamin in the fruits of *A. esculentus*, comparable with our results. The α-tocopherol is an antioxidant implied in the protection of fabrics and the skin against oxidation and the infections. It also protects the cells against the carcinogenesis [26].

β-carotene is more present in the flowers and leaves, especially the leaves of *A. digitata* (4340±0.17 RE) and the flowers of *B buonopozense* (3110±1.15 RE). Work also underlined the wealth of this vitamin in the leaves of *A. digitata* [4]. Several leaves, whose *C olitorius*, also have considerable contents of α-tocopherol and WSV, justifying their strong consumption in many countries [27]. However, the leaves of *C olitorius* are associated a weak presence of β-carotene, in agreement with the estimates [28]. This vitamin has an essential role in the reproduction, the growth, the development of the foetal vision, like in the safeguarding of ocular health and the night vision of the mother. She reinforces immunizing defences against infections [29,30]. Its prolonged deficiency can cause the paediatric blindness and of the severe infections often mortals in the children [31]. The deficiency in β-carotene remains a problem of public health which touches 19 million pregnant women in Africa [32].

Table 5. Average (± SD) water-soluble vitamins of Ivorian mucilaginous food plants

Edible parts		**Content (mg/100 g DM)**				
		Thiamine	**Riboflavin**	**Niacin**	**Pyridoxine**	**Folic acid**
Kernels	IG	0.78 ± 0.03^{F}	0.05 ± 0.00^{H}	0.06 ± 0.23^{I}	0.85 ± 0.10^{E}	$0.3\times10^{-2}\pm0.75^{G}$
	IW	0.25 ± 0.03^{I}	0.01 ± 0.00^{I}	0.09 ± 0.08^{H}	0.12 ± 0.08^{I}	$0.3\times10^{-2}\pm0.75^{G}$
Fruits	AE-koto	1.73 ± 0.07^{B}	1.15 ± 0.16^{B}	0.78 ± 0.10^{C}	1.67 ± 0.17^{A}	0.54 ± 0.11^{B}
	AE-*tomi*	2.22 ± 0.12^{A}	1.61 ± 0.08^{A}	1.07 ± 0.31^{A}	1.35 ± 0.07^{B}	0.38 ± 0.22^{C}
	BM	0.31 ± 0.03^{H}	0.43 ± 0.04^{G}	0.21 ± 0.04^{G}	$0.6\times10^{-2}\pm0.38^{J}$	$0.3\times10^{-2}\pm0.75^{G}$
Leaves	AD	0.91 ± 0.07^{D}	1.14 ± 0.07^{B}	0.59 ± 0.66^{E}	1.06 ± 0.50^{D}	0.66 ± 0.89^{A}
	CO	0.79 ± 0.08^{F}	0.83 ± 0.06^{D}	0.71 ± 0.21^{D}	1.21 ± 0.26^{C}	0.07 ± 0.31^{F}
	MA	1.71 ± 0.07^{B}	0.62 ± 0.03^{E}	0.06 ± 0.15^{I}	0.79 ± 0.04^{F}	0.15 ± 0.77^{D}
	BB	0.55 ± 0.23^{G}	1.01 ± 0.16^{C}	1.01 ± 0.07^{B}	0.61 ± 0.69^{G}	0.08 ± 0.02^{E}
Flowers	BB-*calyx*	0.82 ± 0.08^{E}	0.52 ± 0.05^{F}	0.32 ± 0.11^{F}	$0.6\times10^{-2}\pm0.38^{J}$	$0.3\times10^{-2}\pm0.75^{G}$
	BB-*flower*	1.05 ± 0.06^{C}	0.63 ± 0.20^{E}	1.06 ± 0.66^{A}	0.54 ± 0.02^{H}	$0.3\times10^{-2}\pm0.75^{G}$
F		1267.52	1289.41	1376.82	163.7	1644.07
P-value		<0.001	<0.001	<0.001	<0.001	<0.001

Data are represented as Means ± SD (n = 3). Means in the column with no common letter differ significantly (p<0.001) for each edible parts; DM, dry matter

Table 6. Estimated daily intake (µg/day) in vitamins resulting from the consumption of MFPs by an Ivorian adult

Vitamins	IG	IW	AE-*koto*	AE-*tomi*	BM	AD	CO	MA	BB	BB-*calyx*	BB-*flower*
α Tocopherol	142	130	8	6	10	178	164	123	217	73	121
Phylloquinone	0.28	0.16	0.04	0.04	3.94	8.40	0.31	4.69	6.44	0.31	4.55
β-carotène (RE/day)	0.14	0.14	0.33	0.26	0.18	30.38	11.34	7.49	18.34	5.18	21.77
Thiamine	1.56	0.5	1.73	2.22	0.62	6.37	5.53	11.9	3.85	5.74	7.35
Riboflavin	0.1	0.02	1.15	1.61	0.86	7.98	5.81	4.34	7.07	3.64	4.41
Niacin	0.12	0.18	0.78	1.07	0.42	4.13	4.97	0.42	7.07	2.24	7.42
Pyridoxine	1.7	0.24	1.67	1.35	0.016	7.42	8.47	5.53	4.27	0.056	3.78
Ac. folique	0.02	0.02	0.54	0.38	0.02	4.62	0.49	1.05	0.56	0.07	0.07

Table 7. Recommendations and contribution (%) of vitamins of food to the satisfaction of the advisable contributions

Vitamins		IG	IW	AE-*koto*	AE-*tomi*	BM	AD	CO	MA	BB	BB-*calyx*	BB-*flower*
α Tocopherol	DRI						12					
	Contr	1.18	1.08	0.06	0.05	0.08	1.48	1.36	1.02	1.80	0.60	1.00
Phylloquinone	DRI						45					
	Contr	0.62	0.35	0.008	0.08	8.75	18.66	0.68	10.42	14.31	0.68	10.11
β-carotene	DRI						800					
	Contr	0.02	0.02	0.04	0.03	0.02	3.79	1.42	0.93	2.29	0.65	2.72
Thiamine	DRI						1.1					
	Contr	0.14	0.04	0.16	0.20	0.05	0.58	0.50	0.11	0.35	0.52	0.67
Riboflavin	DRI						1.4					
	Contr	0.01	0.001	0.08	0.12	0.06	0.57	0.42	0.31	0.51	0.26	0.32
Niacin	DRI						16					
	Contr	0.0007	0.001	0.005	0.007	0.003	0.03	0.03	0.003	0.04	0.01	0.05
Pyridoxine	DRI						1.4					
	Contr	0.12	0.02	0.12	0.09	0.001	0.53	0.51	0.39	0.31	0.004	0.27
Folic acid	DRI						200					
	Contr	0.01	0.01	0.27	0.19	0.01	2.31	0.25	0.53	0.28	0.04	0.04

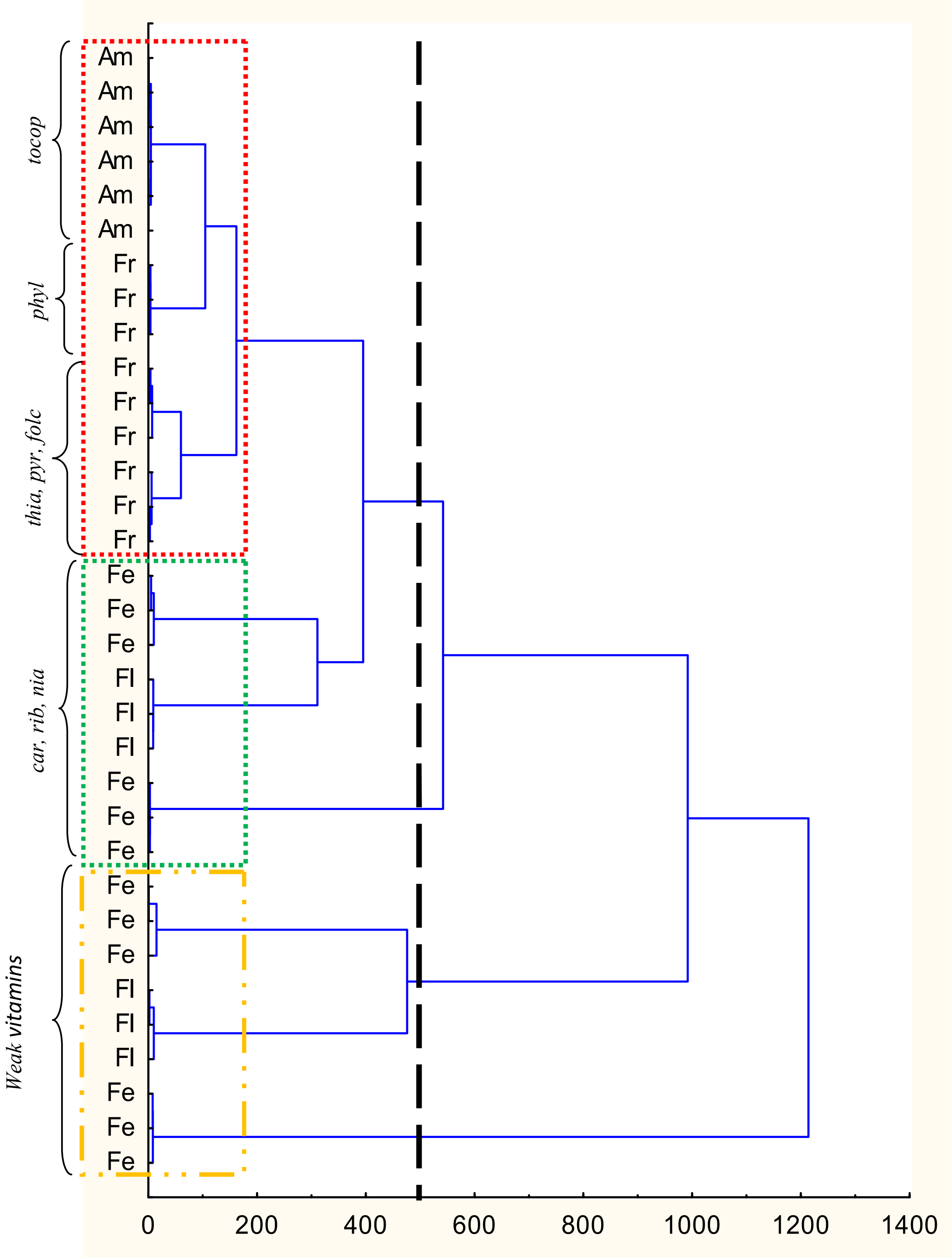

Fig. 1. Dendrogram representing ascending hierarchical classification of the parts of the mucilaginous plants according to vitamin contents

Fr, fruit; Fe, leaves; Fl, flowers; Am, kernels; car, β-carotene; rib, riboflavin; nia, niacin; thia, thiamin; pyr; pyridoxine; folc, folic acid; phyl, phylloquinone; tocop, α-tocopherol

On the level of the phylloquinone, the contents are much weaker. It misses almost in the fruits of *A. esculentus,* the leaves of *C olitorius* and the flowers of *B buonopozense.* Nevertheless, the fruits of *B mannii* and the leaves of *A. digitata* respectively express of them 1.97 and 1.20 mg/100 g, comparable with the 1 mg/100 g brought back by this work [33]. The needs are reduced because its mechanism of recycling is very effective [34]. In this case, the deficiencies in phylloquinone are truly not observed, except in the event of lipid malabsorption or following ingestion of products containing of the antagonistic compounds to this vitamin. It intervenes in the mechanism of coagulation of blood [35].

The WSV are represented in the majority of MFPs studied, with greater concentrations in the fruits, the leaves and the flowers. The fruits of *A. esculentus* (1.73 to 2.22 mg/100 g), the leaves of *A. digitata* (1.71 mg/100 g) and the flowers of *B buonopozense* (1.05 mg/100 g) are richer in thiamine. Thanks to their good thiamine content, the seed powder of gumbo was used to strengthen certain cereal flours, especially the cornstarch in Egypt [36]. The thiamin contents of ours work are higher than the values deriving from other authors who indicated 0.04 mg/100 g in *C. olitorius* [37]. In the body, thiamine intervenes in the reactions of oxidative decarboxylation of the cetoacides and of transcetolisation [38] and its lack can cause the asthenia, the anorexia, of the vomiting and especially beriberi [39]. The concentrations in riboflavin are more significant in the fruits of *A. esculentus* (1.15 to 1.61 mg/100 g) and the leaves of *A. digitata* (1.14 mg/100 g) and *B. buonopozense* (1.01 mg/100 g). The strong contents riboflavin in the young leaves of baobab has been detected by certain works [4]. The rare deficiencies in riboflavin are in general the consequence of the needs increase in the (case of the sportsmen) or of a defect for intestinal absorption [40]. The fruits of *A. esculentus*, the leaves and flowers of *B. buonopozense*, as well as the leaves of *C. olitorius* present the strongest contents in niacin.

The niacin content thus provided by the leaves of *C olitorius* is close to the value found by another author [41]. This compound has a co-enzymatic action in the reactions of oxido-reductions where it is used as conveyor of electrons. It is necessary to biosyntheses of the fatty acids and cholesterol. The niacin is can be product from food tryptophan [42]. The vitamin deficiency in niacin causes the pellagra, a frequent disease in the countries with strong corn consumption, a food rather low in tryptophan [43]. The fruits of *A. esculentus* also provide the most significant contents of pyridoxine (1.35 to 1.67 mg/100 g), followed by the leaves. The pyridoxine is a coenzyme implied in the metabolism of proteins, the amino acids, glycogen, and the synthesis of the neurotransmitters. It also contributes to the formation of antibody and the red globules. Its deficiency, although rare, can however be related to certain medicament us catches for inhibiting purpose on its biological activity [44]. The concentrations in folic acid are very weak, below 1 mg/100 g, even if the fruit samples of *A. esculentus* (0.38 to 0.54 mg/100 g) and the leaves of *A. digitata* (0.66 mg/100 g) express the most significant contents of them. However, in Benin certain works have showed very high content in baobab fresh leaves (104 mg/100 g) and dried leaves (486 mg/100 g) [45]. This vitamin is a basic component of the coenzymes of the synthesis of certain amino acids. It is essential with the formation of the globules red and necessary to the correct operation of the central nervous system [41]. The folic acid makes it possible to correct maternal anaemia [46]. Certain factors like hormonal contraception, the repeated pregnancies, the excessive consumption of alcohol and tobacco can worsen the consequences of its deficiency [47].

The estimated daily intakes of MFPs lie between 0.1g and 0.7 g. This consumption is low in comparison with 1018.1 g of food consumed per day [23]. Effectively, African doesn’t eat enough vegetables. In the world, they have the weakest consumption (77 g/day) compared to European (371.6 g/day) and Middle Eastern populations (233 g/day) [23]. Indeed, their food practices based on starchy foods and cereals that represents in fact nearly 60% of the daily contributions in nutrients. Such a report is all the more real as the milled rice remains the cereal most consumed in Côte d’Ivoire by 89.8% of the households [48,49]. Taking into account the vitamin poverty of this food, it would be advisable to associate them with greater quantities of vitamin resources.

Among the studied plants, the consumption of vegetables leaves and flowers ensure the best estimated daily intake of FSV for an Ivorian adult with 73 to 217 µg/day of α-tocoperol, 0.31 to 8.40 µg/day of phylloquinone, 5.18 to 30.38 RE of β-carotene. The kernels provide also raised contributions α-tocoperol of them.

The consumption of MFPs studied ensure 0.02% to 18% of the daily recommended intake (DRI) in α-tocoperol, phylloquinone and β-carotene, which are respectively of 12 µg/day, 45 µg/day and 800 RE/day [24]. The importance of vitamins brought the European authorities to fortification the diets by supplementing them from 25% to 50% of β-carotene [50].

On the level of the WSV, the estimated contributions are weak as a whole. They contribute below 0.67% to body needs except folic acid for which the leaves of *A. digitata* satisfy 2.31% of the DRI. Work brought back a similar contribution for the folic acid [51].

Although presenting multiple largely tested nutritional properties, the contributions of MFPs in the estimated daily intake are relatively weak bus their consumption remains limited. However, a food containing this food could reduce the cases of malnutrition causes many death and often irreversible effects. It could also improve the physiological conditions of people have AIDS, which the requirements in micronutrients are unceasingly increasing [52]. In this direction, a consumption of MFPs between 1 g and 7 g per day could cover at least 40% of the requirements in vitamins for the populations. However, of the factors of bioavailability are to be taken into account, such as the effect of the intestinal parasites which negatively influence the bio-efficacy of the food precursors of vitamin A [53]. Nevertheless, of real policies of valorisation of MFPs could improve public health and ensure of significant economic incomes.

5. CONCLUSION

Mucilaginous food plants found in the food of the Ivorian populations present very varied vitamin compositions. Some are richer in β-carotene, riboflavin, and niacin, others contain more thiamine, pyridoxine, folic acid, phylloquinone and α-tocopherol, whereas some present less vitamin. As a whole, the leaves and the fruits are particularly rich in these nutrients. Unfortunately, the daily consumption of these plants in the of the Ivorian adult remains low in comparison with the total quantity of introduced food. Consequently, the estimated daily intake and the deduced contributions are weak as a whole. But relative to 0.4% of presence of MFPs, the contributions obtained are considerable. Among these resources, the leaves and the flowers provided the greatest contributions of vitamins. In a preoccupation with an optimization of the contributions, it would be judicious to promote the consumption of the parts with strong content. The availability and the low cost of MFPs can support their valorisation near the populations. They could be the subject of formulation additional food and be advised with the people living with immunizing problems and significant requirements in micronutrients.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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