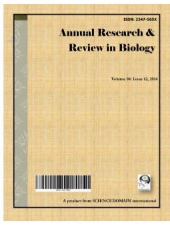

Annual Research & Review in Biology
11(3): 1-12, 2016, Article no.ARRB.28729
ISSN: 2347-565X, NLM ID: 101632869

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Investigation in Minerals Nutrients from Powders Deriving with Leaflets of *Moringa oleifera* L. and Beans of *Vigna unguiculata* W. for Fortification of the Flour Processed from New Shoots of *Borassus aethiopum* M.

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Authors' contributions

This study was carried out in collaboration between all authors. Author MMR wrote the protocol, performed the laboratory analysis and wrote the first draft of the manuscript. Author KNY performed the statistical analysis and achieved the manuscript revisions. Authors SD and CA managed the literature, took part in results interpretation and corrected the first draft of the manuscript. Author BGHM designed and supervised the study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARRB/2016/28729
Editor(s):
(1) George Perry, Dean and Professor of Biology, University of Texas at San Antonio, USA.
Reviewers:
(1) If Alex Amata, Delta State University, Asaba Campus, Delta State, Nigeria.
(2) Alessandra Durazzo, CREA-Alimenti e Nutrizione, Italy.
(3) Bharat Raj Singh, Technical Campus, Lucknow, India.
Complete Peer review History: http://www.sciencedomains.org/review-history/16625

Original Research Article

Received 2nd August 2016
Accepted 26th September 2016
Published 22nd October 2016

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ABSTRACT

This study aimed to evaluate mineral composition in the flour processed from new shoot tubers of Palmyra (*B. aethiopum*), and the powders of Moringa (*M. oleifera*) leaflets and Cowpea (*V. unguiculata*) beans for improving their valorization. Palmyra tubers and Cowpea beans were bought from sedentary saleswomen in the "*V Baoulé*" region in the Centre of Côte d'Ivoire, whereas Moringa leaflets were collected from fields in the same locations. Each vegetable was processed into meal, and then analyzed for mineral determination using energy dispersive spectrophotometry method. This technical revealed eight minerals in the samples assessed. With contents of 258.94 to 2012.35 mg/ 100 g DM, potassium was the major mineral element from overall samples. Furthermore, the Moringa powder was more provided (P‹.001) in calcium (1304.27 mg/ 100 g), potassium (2012.35 mg/ 100 g DM), phosphorous (557.92 mg/ 100 g), magnesium (481.24 mg/100 g), sodium (89.35 mg/100 g), iron (42.59 mg/ 100 g), copper (30.9 mg/ 100 g), and zinc (11.69 mg/ 100 g). Oppositely, the Palmyra flour was lower in minerals contents while the Cowpea powder recorded considerable amounts of minerals, especially for macroelements (15.95 to 1320.91 mg/ 100 d DM). Therefore, the Moringa leaflets and Cowpea beans are significant raw sources of mineral nutrients and could allow fortification of food recipes from Palmyra tubers for resulting in alternatives of food valorization and to address poverty and desert hazards in tropical countries.

Keywords: Palmyra new shoots tubers; Moringa; Cowpea; flour; minerals content.

1. INTRODUCTION

The wild plants used by populations in food account numerous interests over the world [1]. In Africa, thousands farmers use various food plants by days for nutritional and medicinal reasons or for additional livelihoods. *Borassus aethiopum*, commonly known as Palmyra tree, is one of these raw food resources. Palmyra is a wild palm tree met in Africa and Asia within the plants family of Arecaceae, [2]. It belongs to the non-ligneous forest products (NLFP) with low using for long time in the tropical areas of sub-Saharan Africa. In the central region of Côte d'Ivoire, this palm tree which height can reach 20 m to 30 m [3] represents a sentry for the savannah and records quite utility for local populations. It is used in food [4,5], technology [6] and in traditional medicine [7,8]. It also provides trade stuffs like source of incomes for smallholder farmers from rural regions. Palmyra is recommended in the reforestation to curb the wilderness projection [9]. From their growing belt in Côte d'Ivoire, the Palmyra adult trees are often used for producing palm wine, a fermented drink resulting from the sap [10]. However, the common palm wine extraction methods implemented unfortunately involve in the rapid death of the Palmyra plants [11]. Yet, the palm wine production is successfully worked from some palm trees (*Cocos nucifera*, *Elaeis guineensis*) using other plant organs like the unopened inflorescences and accounting advantages in the plant's survival [12]. This technology is not yet practiced from the Palmyra plants and their devastation is a serious ecological concern for the biodiversity. Moreover, many populations use the new shoots deriving with the germinating Palmyra seeds for food purposes. This valorization seems to be a quite alternative in the plant's uses, and could be popularized for adding significant nutritional, economic and therapeutic values to the Palmyra. Indeed, Palmyra trees provide numerous fruits over the year, large proportion of which is unused and goes rotten [13]. Several research tasks have been achieved on these fruits. Thus, from the raw fruit pulp, Ezoua et al. [10] produced a juice richer in soluble sugars, especially sucrose, glucose and fructose. Diby et al. [14] also obtained fruit pulp nectar which could possibly undergo alcoholic fermentation.

Each Palmyra fruit encloses two or three embryos generating potentially new growths after germination. The Palmyra new shoots are tuberous and edible foods highly valued by the local populations as caloric food resource [15]. They are often processed into flour for making porridge or local *fufu* [5]. Other attempts reveal the preventive effect provided by the consumption of the new growths of Palmyra against the gastro duodenal ulcers and the sickly fever [16]. However, this caloric raw food resource is with lower proteins, minerals and vitamins contents like most of the starchy foods. Their abusive consumption without any improvement results in obvious nutritional troubles. In fact, more than 852 million people are suffering from the malnutrition over the world, accounting above 95% from the developing countries where at least 250 million children are concerned [17]. In this case, for resulting in successful food recipes, the meals prepared on the Palmyra tubers basis should be improved with other local edible vegetable sources, particularly with Cowpea (*Vigna unguiculata* Walp) and Moringa (*Moringa oleifera* Lam). Such vegetables have the ability in correcting the nutritional deficiency, referring to the recommendations of the *Codex alimentarius* [18], and could release populations from the malnutrition caused by the intake of caloric foods poor in micronutrients [19].

From cowpea beans, previous attempts reported high quality proteins in significant contents of about 25% [20]. Regarding moringa, the nutritional interest is related to the leaflets which have good minerals and vitamins properties [21]. The main minerals from moringa leaflets are calcium, potassium, magnesium, phosphorus, sodium, copper, iron, zinc, and manganese. Concerning vitamins components, carotene-like, tocopherol, ascorbic acid, and B-group vitamins (B_1, B_2, B_3, B_6, and B_9) are usually reported. Moreover, they contain the 8 or 9 human essential amino acids [22], namely leucine, isoleucine, lysine, methionine, phenylalanine, threonine, tryptophane, valine, and histidine, accounting moringa as an exceptional species in the plant kingdom. So, the moringa vegetable is promoted by the World Health Organization (WHO) as essential food alternatives against malnutrition [23]. Regarding their food interests, the development of composite dishes with Palmyra new shoot tubers fortified with moringa leaflets and cowpea beans, could be beneficial for populations. Nevertheless, such formulations would be optimal only with sounded knowledge of these three raw food materials. The current work aims to assess the mineral composition from Palmyra new shoots tubers, Moringa leaflets, and cowpea beans for better valorization.

2. MATERIALS AND METHODS

2.1 Plant Material

The plant material was the flour processed from Palmyra new shoots tubers, and powders of Moringa leaflets and Cowpea beans.

2.2 Sampling

The raw material samples were collected between August and December 2015 from three localities, especially Toumodi, Dimbokro, and Didiévi, located in the Centre Region, which are the natural habitat accommodating with Palmyra in Côte d'Ivoire and where large quantities of Cowpea and Moringa are also produced. Three retailers of Palmyra shoot tubers and Cowpea beans were considered per town, and then 30 kg tubers and 10 kg beans were perceived from each retailer, giving total amount of 270 kg Palmyra tubers and 90 kg Cowpea beans. In addition, 50 kg fresh leaflets of Moringa were collected from two sites in each town, 25 kg/site, leading to 150 kg leaflets. Once acquired, the samples have been conveyed to the laboratory for analyses. Thus, a pool was constituted by mixing samples by plant species. Finally, 250 kg, 75 kg and 75 kg of respective samples from Palmyra new shoots tubers, Cowpea beans, and Moringa leaflets were deducted, sorted, washed with distilled water and processed into different meals.

2.3 Processing for Palmyra Flour and Powders from Cowpea and Moringa

Palmyra flour and powders from Cowpea beans and Moringa leaflets were processed according to previous reports of Mahan et al. [20]. The Palmyra new shoots tubers were washed, boiled, peeled, carved, rinsed, and then submitted to fermentation into a tank container for 24 h [24]. The resulted fermented tubers pieces were dried at 65°C into a ventilated oven (Minergy Atie Process, France) for 6 h, and ground using a hammer mill (Forplex).

The moringa leaflets were disinfected for 5 min with chlorinated water (50 mL of 8% sodium hypochlorite in 30 L of water), rinsed, and fermented into a tank for 24 h. Then, fermented leaflets were dried at 30°C for 10-14 days with shade ambient temperature and powdered. Regarding Cowpea, beans were washed, soaked, drained, and submitted to sprouting at 30°C during 48 h. The seeds were dried at 40°C using the previous oven for 96 h, and the resulted malt was sprout out, heated for 15 min in boiling water and submitted to 24 h fermentation into tank. The fermented Cowpea beans were strained, roasted, dried at 50°C in the oven for 24 h, and ground.

Finally, flour and powders were filtered using sieves with 250 µm diameter and the resulting products were put in polyethylene hermetic bags and kept into dry place till analyses.

2.4 Samples Mineralization

Samples were mineralized in ashes by incineration at 550°C using electric muffle furnace. The ashes were obtained after incineration of 5 g flour beforehand carbonized on a Bunsen burner, for 12 h, leading to a white residue [25] (AOAC).

2.5 Mineral Elements Evaluation

The minerals contents of the studied flours were recovered from ashes using an Energy Dispersive Spectrometer device.

2.5.1 Operating conditions of the energy dispersion spectrometer (EDS)

The energy dispersive spectrophotometer apparatus used for the minerals determination was coupled with a scanning electronic microscope, operating at variable pressure (SEM-FEG Supra 40 Vp Zeiss), and equipped with an X-ray detector (Oxford instruments) bound to a flat shape of the EDS microanalyser (Inca cool dry, without liquid nitrogen). The operative conditions of the EDS-SEM device are:

- Zoom: 10x to 1000000x;
- Resolution: 2 nm;
- Variable voltage: 0.1 KeV à 30 KeV.

The chemical elements were acquired with following parameters: zoom, 50 x; probe diameter, 30 nm to 120 nm; probe energy, 20 KeV and 25 KeV; work distance (WD), 8.5 mm.

The chemical composition was explored from 3 different zones, and then the data was transferred to MS Word and Excel softwares for treatment.

2.5.2 Validation test of the minerals determination method

The mineral analysis method has been validated according to standard procedure [26,27], consisting in determination of the linearity, repeatability, reproducibility, extraction yields, and detection and quantification limits. The linearity of 10 mineral elements was valued using 5 standard points between 25% and 125% (25%, 50%, 75%, 100%, and 125%). The repeatability and reproducibility tests were achieved with standard of the different minerals at the content of 25%. A percentage of 5% was added on each mineral's standard content for determining the yield of mineral extraction. Ten separate tests were performed for the proportions added.

2.6 Contribution in Essential Minerals from Consumption of the Studied Food Resources

The minerals intake was evaluated using the mean consumption of each food assessed (Table 1) and its mineral concentration. The mineral estimated intake from the human adult individual was calculated according to the following formula [28]:

$$DI = C \times Q$$

With: DI, daily intake; C, mean concentration; Q, daily food consumption.

Table 1. Main daily consumption of the studied food resources

Meal sources	Main consumption (g/day)
Tubers of Borassus aethiopum	<6.02
Beans of Vigna unguiculata	15.07
Leaflets of Moringa oleifera	0.7
Total consumption	21.79

Thus, the contributions deriving from the daily intake on the daily recommended intake basis was determined as below:

$$\text{Contribution (\%)} = (DI \times 100)/DRI$$

With: DI, daily intake; DRI, daily recommended intake

2.7 Statistical Analysis

The data were recorded with Excel file and statistically treated with Statistical Program for Social Sciences (SPSS 22.0 for Windows). The statistical test consisted in a one-way analysis of variance (ANOVA) with the type of meal assessed basis. From each parameter, means were compared using Student Newman Keuls post-hoc test at 5% significance level. In addition, Multivariate Statistical Analysis (MSA) was performed through Principal Components Analysis (PCA) and Hierarchical Ascending Clustering using STATISTICA software (version 7.1) for structuring correlation between the samples studied and their minerals traits.

3. RESULTS AND DISCUSSION

3.1 Validation Parameters for Quantification of Minerals Using EDS

The data from validation assays are reported in Table 2. The determination coefficient (R^2) recovered from the standard lines are included between 0.99 and 1. The minerals limits of detection vary from 104 µg/kg to 581 µg/kg and their minimal values quantified are between 146 µg/kg and 796 µg/kg. The coefficients of variation (CV) from 10 repeatability tests oscillate between 1.0% and 1.8%; while 15 reproducibility tests result in CV from 2.3% to 4.7%. About the minerals added, the extraction yields run from 97.3% to 99.5%, revealing minerals extraction defaults between 0.5% and 2.7% (Table 2).

3.2 Mineral Composition of the Meals

The overall flours studied account eight mineral elements: five macroelements (Ca, P, K, Na, and Mg) and three oligoelements (Fe, Cu, and Zn). Table 3 reveals high divergence ($P<.001$) between the samples regarding each mineral. Thus, potassium is the major mineral element, with lower content from Palmyra flour (258.94 mg/ 100 g DM) while Moringa provides the greatest potassium content of 2012.35 mg/ 100 g DM. Statistically, the Moringa powder is also with most contents ($P<.001$) in calcium, phosphorous, magnesium, and sodium ranging between 89.35 mg/100 g DM and 1304.27 mg/ 100 g DM. These minerals are found in lower contents of 3.92 mg/ 100 g DM to 88.33 mg/ 100 g from the Palmyra shoots tubers, whereas Cowpea beans record 15.95 to 442 mg/ 100 g.

Regarding oligoelements, the contents vary statistically ($P<.001$) from few traces to 42.59 mg/100 g. Thus, iron is found in contents of 1.52 mg/100 g DM to 42.52 mg/100g DM and Moringa is more provided. Moreover, both copper and zinc have also more contents from Moringa leaflets (30.9 mg/100 g DM and 11.69 mg/100 g DM, respectively) while their amounts in meals of Palmyra and Cowpea are often below the LOD values (Table 3).

3.3 Estimated Daily Intakes of Minerals

Among the studied meals, Cowpea powder records the highest macroelements intakes. The total potassium intake is 228.73 mg/day, with more contribution from Cowpea (199.06 mg/day). Moringa and Palmyra record respective contribution of 14.09 mg/day and 15.59 mg/day. The total phosphorous intake is 75.83 mg/day, and also more provided by Cowpea (66.61 mg/day) whereas Palmyra and Moringa are scarcely with 5 mg/day. Magnesium, calcium, and sodium have respective daily intakes of 36.88 mg, 33.21 mg and 3.26 mg and record contribution of 30.99 mg, 22.41 mg, and 2.40 mg from the Cowpea powder (Table 4).

From oligoelements, the total daily intakes are estimated at 1.58 mg (iron), 0.31 mg (copper), and 0.09 mg (zinc). The iron daily intake is more originated from the Cowpea beans powder (1.20 mg). But, copper and zinc record more intakes from powder of Moringa leaflets (Table 4).

From each mineral's daily intake, Palmyra always displays the least contribution.

On the daily recommended intakes basis, the powder deriving from Cowpea beans record more contributions in fitting needs of mineral elements, from 1% to 9.95%. Moringa and Palmyra are with percentages between 0.01% and 1.14% for covering needs of minerals macronutrients. Besides from oligoelements, Cowpea is more fitted with only needs of iron, whereas copper and zinc have higher needs fitting contributions from Moringa powder (22% and 0.8%, respectively), as shown in Table 5.

3.4 Multivariate Parameters

The Principal Components Analysis (PCA) was achieved with the F1 and F2 factors which support 99.99% of the total variability. F1 component records eigenvalue of 7.35 and expresses 91.96% variance, and F2 accounts eigenvalue of 0.64 and only 8.03% of variance. Figs. 1 and 2 show the gatherings of the studied samples. Thus, the powder samples of Moringa leaflets are correlated to the top mineral contents. The powder of Cowpea beans displays often intermediate mineral values. The data resulting from Palmyra flour are lower in mineral traits.

4. DISCUSSION

4.1 Validation Parameters

The R^2 determination coefficients got from the calibrations tests were close to 1, forecasting a quasi-linear estimation of the mineral nutrients according to their concentration from in the meals. Also, the lower coefficients of variation

(<5%) resulting from reproducibility and repeatability translate quite stability of the EDS method used, which is as fitted as the full amount of each mineral nutrient is revealed, as shown by the weak extraction defaults below 2.7% from the added minerals. Thus, these characteristics highlight the reliability and precision of the outcomes in the minerals contents determination using the EDS method.

4.2 Minerals Nutriments

The minerals are more provided in the powder of Moringa leaflets than from Cowpea beans and Palmyra flour. Such observations are involved from the minerals accumulation in the top parts of the plants, especially in leaves where they take part in various physiological processes such as photosynthesis and respiration [12]. Thus, Atchibri et al. [29] reported great mineral contents in leafy vegetables, contributing to ensure food safety for populations. The good mineral characteristics of Moringa leaflets were also found by Sodamade et al. [30], attesting the use of this plant in dietetic dietary in developing countries.

Besides, the food interests of Cowpea beans and Palmyra tubers result from their higher amounts of macronutrients, namely proteins and glucides as shown by Mahan et al. [20]. Meals processed from both food resources enclose lower minerals contents than Moringa. Nevertheless, the Cowpea powder displays rather significant minerals amount. Unlike the current study, Ayssiwede et al. [31] revealed lower minerals contents in Cowpea beans powder. Various cultural conditions as climate, soil quality, and agronomical practices often consisting in application of natural or artificial manure could result in heterogeneous mineral traits of the plants edible crops. In fact, minerals are with straight soil absorption by the plants roots prior to be drained towards other organs through the xylem [12].

Oppositely, the flour resulting from Palmyra tubers does not contain rather minerals, as stated by Niamké et al. [3], and accordingly to the numerous tuberous crops as yam, cassava, potato, etc. Therefore, foods processed from Palmyra new shoot tubers should be fortified with other minerals sources, especially vegetables, for mitigating the mineral default.

Except from sodium, the minerals contents obtained from Moringa leaflets are higher than the values recommended for the flours. The potassium and magnesium contents in the Cowpea powder are also higher than the recommendations [32]. Potassium and phosphorus are the most abundant minerals in foods. The potassium is the overriding mineral in the studied flours. It has contribution in the heart's physiological functions and is a regulation factor for the osmotic pressure through the Na^+/K^+ pump. It is also effective in maintenance of the acid-base balance for the organism [33]. The main physiological function of phosphorus is related to the phosphorylation reactions involved in energy production [34].

Calcium is agent of the bone fortification, especially needed during the growth years. It has a major role in the muscular contraction, the absorption of vitamin B_{12}, and the blood coagulation [35]. Magnesium is effective for prevention against muscles degeneration, development delay and congenital malformations [36]. It is a great cohesive agent for proteins which it activates many enzymatic functions. The 19 mg/ 100 kcal recommended in the food dietary [32] could be fitted from the consumption of cowpea beans and Moringa leaflets. Sodium is important for the hydric balance, the nervous and muscular systems, and in the dropping of blood pressure [37]. However, the sodium contribution from the studied flours could remain below the recommendations.

Regarding oligoelements (Fe, Zn, Cu), the Moringa also provides the greatest contents. Thus, our results agree with the amount of iron found in Moringa by El-Massry et al. [21]. Iron is significant component of blood hemoglobin and myoglobin. It supports the blood oxygenation, prevents anemia and fits resistance to organism against infections. From the overall samples studied, only Moringa powder is significantly provided in zinc, with higher content than the value below 3 mg/ 100g found by Ndong et al. [38]. Zinc is cofactor for the metabolism of vitamins A and E. It is useful for the fœtal development during the pregnancy [37]. For the copper, the current study indicates higher content than the 2.14 mg/100 g reported by Tété-Bénissan et al. [39] from Moringa samples. Copper has significant role in the synthesis and maintenance of myelin. It's also a cofactor in the anti-radicalizing processes [37].

Table 2. Data from validation parameters for evaluation of minerals contents using energy diffusion spectrometer (EDS)

Validation parameters		K	Mg	P	Ca	Na	Fe	Cu	Zn
Linearity	**ESL**	Y=3821x+3838	Y=1452x+237	Y=2667x+1742	Y=6581x+5287	Y=2083x+147	Y=2285x-88	Y=1953x+6951	Y=4365x-523
	CD (R^2)	1	0.99	0.99	1	0.99	0.99	0.99	0.99
CV repeat (%)		1.3±0.04	1.1±0.21	1.4±0.11	1.5±0.43	1.2±0.05	1.4±0.07	1.8±0.95	1.3±0.51
CV reprod (%)		4.7±0.32	3.1±1.44	3.7±1.22	2.3±0.93	3.4±0.48	3.6±0.01	2.5±0.3	3.2±0.96
EYAM (%)		98.4±1.51	97.9±0.68	99.4±0.66	97.3±0.84	98.8±0.33	99.5±0.17	98.8±0.43	98.3±0.03
LOD (µg/kg)		581±0.04	426±0.11	334±0.21	514±0.15	261±0.74	107±0.32	104±0.05	281±0.58
LOQ (µg/kg)		796±0.09	635±0.19	467±0.88	704±0.47	365±0.07	149±0.55	146±0.63	396±0.29

ESL, equation of standard lines; CD, coefficient of determination; CV repeat, coefficient of variation from repeatability test; CV reprod, coefficient of variation from reproducibility test; EYAM, extraction yield from added minerals; LOD, limit of detection; LOQ, limit of quantification; Ca, calcium, P, phosphorous; K, potassium ; Na, sodium; Cu, copper; Fe, iron; Mg, magnesium; Zn, zinc.

Table 3. Minerals composition* in samples of meals deriving from new shoots tubers of *Borassus aethiopum* Mart., leaflets of *Moringa oleifera* Lam., and beans of *Vigna unguiculata* Walp.

Meal sources	Macroelements					Oligoelements		
	Ca	**P**	**K**	**Na**	**Mg**	**Fe**	**Cu**	**Zn**
BAMF	27.85±0.2^{c}	88.33±0.3^{c}	258.94±0.74^{c}	3.92±0.17^{c}	42.06±0.47^{c}	1.52±0.07^{c}	1.61±0.10^{b}	<2.81.10^{-2}
VUW	148.71±0.21^{b}	442±0.19^{b}	1320.91±0.69^{b}	15.95±0.24^{b}	205.66±0.51^{b}	7.94±0.1^{b}	<1.04.10^{-2c}	<2.81.10^{-2}
MOL	1304.27±0.84^{a}	557.92±0.64^{a}	2012.35±0.83^{a}	89.35±0.17^{a}	481.24±0.48^{a}	42.59±0.17^{a}	30.9±0.25^{a}	11.69±0.04^{a}
F	5716843.14	1013205.04	4096950.92	171255.25	626848.05	104449.56	37337.64	232408.33
p_{-value}	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**

** Values are expressed in mg of mineral for 100 g of dry matter. From the same column, values differ statistically at P=5% according to the lowercase letter. BAMF, fermented tuber of B. aethiopum Mart; MOL, M. oleifera Lam; VUW, V. unguiculata Walp; F, value of the Ficher statistical test of ANOVA; P_{-value}, value of the ANOVA probability test*

Table 4. Estimated daily intakes of minerals provided by consumption of meals deriving with *Borassus aethiopum* Mart., leaflets of *Moringa oleifera* Lam., and beans of *Vigna unguiculata* Walp.

Meal sources	Estimated intakes (mg/day) from an adult individual of 70 kg weight							
	Macroelements					Oligoelements		
	Ca	P	K	Na	Mg	Fe	Cu	Zn
BAMF	< 1.68	< 5.32	< 15.59	< 0.24	< 2.53	< 0.09	< 0.1	$2.38.10^{-3}$
VUW	22.41	66.61	199.06	2.4	30.99	1.2	2.2.10-3	$5.97.10^{-3}$
MOL	9.13	3.91	14.09	0.63	3.37	0.3	0.22	0.08
Total ≈	**33.21**	**75.83**	**228.73**	**3.26**	**36.88**	**1.58**	**0.31**	**0.09**

BAMF, fermented tuber of B. aethiopum Mart; MOL, M. oleifera Lam; VUW, V. unguiculata Walp

Table 5. Daily minerals recommended intakes and contribution of the food resources in their fitting

Meal sources	Macroelements										Oligoelements					
	Ca		P		K		Mg		Na		Fe		Cu		Zn	
	DRI	Contr	DRI	Contr	DRI	Contr	DRI	Contr	DRI	Contr	DRI	Contr	DRI	Contr	DRI	Contr
BAMF	**800**	<0.21	**700**	<0.76	**2000**	<0.78	**375**	<0.67	**2500**	<0.01	**14**	<0.64	**1**	<10	**10**	0.02
VUW		2.8		9.52		9.95		8.26		1		8.57		0.22		0.06
MOL		1.14		0.56		0.7		0.9		0.03		2.14		22		0.8

Dri, daily recommended intake (mg/day), contr, contribution (%)

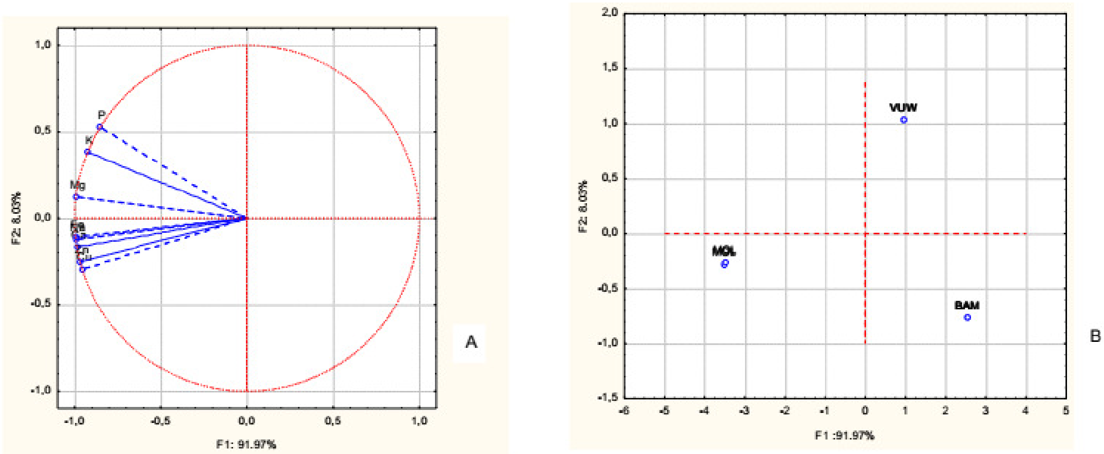

Fig. 1. Correlations drawn between the F1-F2 factorial design of the PCA and the mineral parameters (A) and samples (B) deriving from meals of *B. aethiopum* M. (BAM), *V. unguiculata* W. (VUW) and *M. oleifera* L. (MOL)

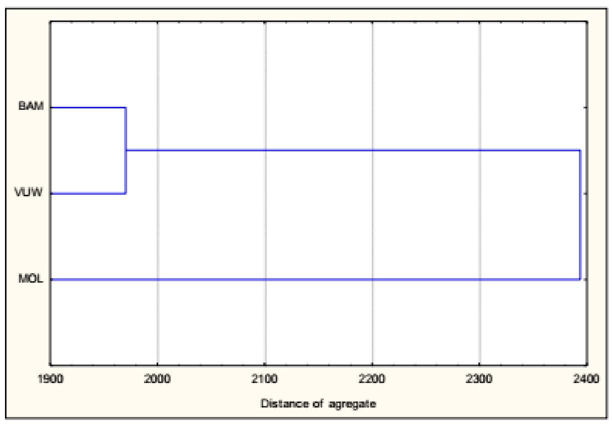

Fig. 2. Dendrogramme of clustering of samples drawn with the unweighted Pair Group Method with Arithmetic means

The daily food consumption from adult individuals in Africa is about 1018.1 g [32]. With such a consumption basis, the main daily intakes of Cowpea beans (15.07 g), Moringa leaflets (0.7 g) and Palmyra tubers (< 6.02 g) remain lower, being in respective contribution of 1.48%, 0.07% and below 0.6% of the daily food consumption. Moringa and Cowpea which are considerable sources of minerals cumulate 1.55% daily consumption. The total intakes of Ca, P, K, Na, Mg, Fe, Cu, and Zn from Moringa and Cowpea record relative lower contribution (from 0.86% to 22.22%) in the daily recommendations [40], due to their slight consumption. Nevertheless, except for Na, Moringa and Cowpea reveal so exceptional amounts of minerals that the contributions are beyond 1.55% of the daily recommendations. The increase in the consumption of these foods could provide more nutrients for populations.

5. CONCLUSION

The study showed more minerals from powder of Moringa leaflets. The Cowpea beans powder has also considerable mineral quality for fitting the minerals daily recommended intakes. Besides, the flour processed from Palmyra new shoots tubers is less provided in mineral elements. The Moringa leaflets and Cowpea beans could be significantly used to address the recurring food safety concerns for the harshen populations. Such uses are able to promote the cultivation of these vegetable species, to protect the biodiversity, and to provide significant incomes. Results from this work would sustain formulation of composite floor containing Palmyra new shoot tubers and vegetables for their better valorization.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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