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Comparison of Nutritional Values of *Vernonia amygdalina*, *Crateva adansonii* and *Sesamum radiatum*: Three Main Vegetables Used in Traditional Medicine for the Treatment of Bacterial Diarrhoea in Southern Benin (West Africa)

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Abstract In Benin, as in many other sub-Saharan African countries, vegetables that serve in traditional medicine are highly used for human consumption. In order to establish the nutritional characteristics of such kinds of vegetables, the current study was carried out. Its objective was to compare the nutritional qualities of three local vegetables (*Vernonia amygdalina*, *Crateva adansonii* and *Sesamum radiatum*) commonly used in southern Benin for human consumption and in traditional medicine to treat bacterial diarrhoea. Therefore, the nutritional features of these vegetables were assessed through their nutrient and mineral contents using reference methods as per AOAC (Association of Official Analytical Chemists). Results showed that the three vegetables are nutritionally rich and contain calcium, sodium, magnesium, phosphorus, proteins, zinc, iron and copper. *V. amygdalina* is very rich in magnesium (9000 ± 1 mg/kg), sodium (2870 ± 2 mg/kg), potassium (48200 ± 1 mg/kg) and phosphorus (8738 ± 2 mg/kg). While *C. adansonii* has high calcium (24000 ± 1 mg/kg), proteins (25248 ± 1 mg/kg) and zinc (22 ± 1 mg/kg) contents. As for *S. radiatum,* it is rich in iron (1360 ± 1 mg/kg) and copper (38 ± 1 mg/kg). Furthermore, the analysis revealed that water and total ash contents, are respectively of 91.48% and 84.72% for *V. amygdalina*, 93.41% and 84.87% for *C. adansonii* and 91.51% and 88.30% for *S. radiatum*. Moreover, the Ca/P and Na/K ratios are respectively of 1.35 and 0.06 for *V. amygdalina*, 3.46 and 0.06 for *C. adansonii* and 2.34 and 0.01 for *S. radiatum*. With regards to the obtained values, *V. amygdalina*, *C. adansonii* and *S. radiatum* demonstrated each a satisfactory nutritional composition and can be valued for a balanced diet for populations. Thus, more efforts need to be devoted for the development of their production and the promotion of their consumption in Benin and the entire region at large.

Keywords Nutritional values, *V. amygdalina*, *C. adansonii*, *S. radiatum*

1. Introduction

The health of individuals depends on the quantity and quality of food that they consume [1]. In tropical countries in general and Sub-Saharan Africa in particular, the importance of vegetables in rural communities' deities paramount [2]. In the tropical world and West Africa in particular, there is a large diversity of local vegetable leaves that play important roles in food security in populations living in rural and urban areas [1, 3]. Vegetables are rich in vitamins (notably A, B and C), minerals, fibres, carbohydrates and proteins and some of them possess some medicinal properties [4-7]. They constitute an accessible food source for a large chunk of population and offer opportunities for the improvement of nutritional status of many households [5]. In many African countries, vegetables represent about 50 to 100% of rural house holds' income and contribute sustain ably to poverty reduction [8].

In Sub-Saharan Africa, about a thousand of plant species are consumed [1]. However, in Benin, an ethno-botanical survey recently conducted on vegetables throughout the

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country revealed 187 plant species with *Vernonia amygdalina*, *Crateva adansonii* and *Sesamum radiatum* being the most common ones [9, 10]. These three vegetables respectively named "Amanvivè ", "Hontonzuzoué" and "Agbô" in local language "Fon" in southern Benin are extensively consumed [10]. They are used by local communities as medicinal food in addition to their nutritive values [10]. Furthermore, they are believed to possess some antibiotic, anti-diarrheal, anti-diabetic and antimalarial properties. These vegetables are also known to play important roles in blood pressure regulation and the treatment of indigestion and liver problems, as well as, intestinal worms and pregnant woman delivery [10]. Despite the crucial role that they play in food security, these vegetables appear among the neglected and underused species in Benin [11]. With the recent economic crisis and its consequences on the purchasing power of populations in developing countries, it is obvious that food products that are neglected and underused would play an important role in the preservation of the nutritional and sanitary status of populations [12, 13].

Though *Vernonia amygdalina*, *Crateva adansonii* and *Sesamum radiatum* are used as food and have medicinal and economic importance in Benin, very little information are available on their nutritive values. Therefore, the present study aimed to determine the nutritional characteristics of these vegetables in order to stimulate interests for their use through populations' sensitization on their nutritional importance.

2. Material and Methods

2.1. Material

To carry out this study, powders were made from the leaves of *Vernonia amygdalina*, *Crateva adansonii* and *Sesamum radiatum*. These leaves were collected from Ouèdo, Abomey Calavi Municipality, Pahou, Ouidah Municipality and Savalou Municipality, respectively and thereafter identified at the National herbarium of Benin.

2.2. Methods

2.2.1. Preparation of Leave Powders

Leaves from the three vegetables were thoroughly washed with distilled water containing Bleach (1/100) and dried at laboratory temperature (16°C) for20 days. The dried leaves were ground using a mechanical grinder. The obtained powders were sifted with a 0.2 mm stitch sieve and stored in sterile containers at laboratory temperature until use.

2.2.2. Dosage of Nutritional Elements

The first step consisted of mineralizing the powders of each of the three vegetables following the procedure of [14]. Once the mineralization is done, sodium, potassium, calcium and magnesium were measured by Atomic absorption Spectrophotometry (Atomic Absorption Spectrophotometer VARIAN SPECTRA 110 with flame). For the measurement of phosphorus, proteins, iron, copper and zinc, Molecular absorption Spectrophotometry (Spectrophotometer DR 2800) was used. Thereafter, water and total ash contents were measured. All the measurements were repeated thrice.

2.2.3. Determination of Sodium, Potassium, Calcium and Magnesium

The leave powders were scorched in a muffle oven at 550°C for24 hours. The obtained ashes were dissolved in 2 ml of 6N hydrochloric acid (HCl), and then evaporated using a hot plate at125°C. The viscous remainder was again dissolved and recovered using nitric acid at 0.1 M in a 100 ml flask. The obtained solution was used, after dilution, to measure the elements in accordance with the EN 14082 standards [14].

2.2.4. Determination of Iron, Copper, Zinc and Phosphorus

A known volume was neutralized (pH between 4 and 5) by addition of 5N sodium hydroxide (NaOH). The final volume was adjusted with distilled water in a certain proportion. Reagents used for the assay were those recommended by [14]. Methods of FERROZINE (Method 8147) for iron, BICINCHONINATE (Method 8026) for copper, ZINCOVER (Method 8009) for zinc and ASCORBIC ACID (Method 8048) for phosphorus were used in accordance with instructions of [14]. The following formulae were used to obtain the various results:

$$\text{Fe, Cu, P (mg/kg)} = A \times 2500/B \times C$$
$$\text{Zn (mg/kg)} = A \times 2500/B \times C$$

With A = value read on the machine in mg/l;
B = weight use during mineralization and
C = Volume collected for analyses

2.2.5. Protein Test

The amount of proteins was determined according to KJELDAHL method, which consisted of taking10 mL of the mineralized solution to which 1/10 of 12N potassium hydroxide (KOH) was added. Respectively 3 drops of mineral stabilizer and polyvinyl alcohol were added to the mixture. After increasing the mixture volume to 25 ml in a reading tub with distilled water, 1 ml of NESSLER reagent was added before reading and comparing with the distilled water treated the same way. This method yielded Kjeldahl nitrogen (TKN) by the following formula:

$$\text{TKN (mg/kg)} = 75 \times A/B \times C$$

With A = value read in mg/l, B = weight used during mineralization and C = Volume collected for analysis.

The detection limit of the machine is 1 mg/l and the protein level was obtained by multiplying the previous results by a factor of 6.25 [14].

2.2.6. Water and Total Ash Contents

The water content of the powders of each vegetable was determined following the methodology of [15]. Total ashes were measured according to the methods of the Association of Official Analytical Chemists, section 923.03 [16].

2.2.7. Statistical Analyses

For the nutritional shutter of the studied vegetables, Student t test was used to compare means. The measurements of each parameter were repeated thrice. Results were presented as Mean ± Standard Deviation (SD) for nutritive elements. A significance level of 5% was defined and Stata 11.0 and Microsoft Excel 2010 software were used.

3. Results

Analyses revealed that the leaves of *V. amygdalina* contain more magnesium, potassium, sodium and the phosphorus than those of *C. adansonii* and *S. radiatum* ($p < 0.05$) (Table 1). However, the leaves of *C. adansonii* are significantly richer in calcium, proteins and zinc than those of *V. amygdalina* and *S. radiatum*. On the other hand, the leaves of *S. radiatum* contain significantly higher concentrations of iron and copper than the leaves of *V. amygdalina* and *C. adansonii* (Table 1). Nevertheless, the leaves of *V. amygdalina*, *C. adansonii* and *S. radiatum* are all very rich in water (91.48%, 93.41% and 91.51%, respectively). Concentrations in total ash were 84.72% for *V. amygdalina*, 84.87% for *C. adansonii* and 88.30% for *S. radiatum*.

Table 1. Nutritional values of the studied vegetables

	Quantity in mg/kg		
Parameters	***V. amygdalina***	***C. adansonii***	***S. radiatum***
Calcium (Ca)	11800±1[a]	24000±1[b]	15200±1[c]
Magnesium	9000±1[a]	6700±1[b]	5100±1[c]
Potassium (K)	48200±1[a]	28100±1[b]	16300±1[c]
Sodium (Na)	2870±2[a]	1690±2[b]	210±2[c]
Proteins	17476±1[a]	25248±1[b]	16500±1[c]
Phosphorus (P)	8738±2[a]	6931±1[b]	6500±2[c]
Iron	497±1[a]	541±1[b]	1360±1[c]
Copper	17±1[a]	16±1[b]	38±1[c]
Zinc	7±1[a]	22±1[b]	7±1[a]
Water content	91.48%	93.41%	91.51%
Total ashes	84.72%	84.87%	88.30%
Ca/P	1.35	3.46	2.34
Na/K	0.06	0.06	0.01

Means followed by the same letters in different columns are not significantly different at the significance level of $\alpha = 0.05$

4. Discussion

Various essential elements have effects on functions of organisms [17]. This study showed that leaves of *V. amygdalina* are richer in magnesium, potassium, sodium and phosphorus thanthe leaves of *C. adansonii* that are highly concentrated in calcium, proteins and zinc, as well as those of *S. radiatum* having high iron and copper contents ($p < 0.05$). Magnesium content was 9000 ± 1 mg/kg in *V. amygdalina*, 6700 ± 1 mg/kg in *C. adansonii* and 5100 ± 1 mg/kg in *S. radiatum*. The nutritional recommended need in magnesium is 3500 mg/kg for adults and 1700 mg/kg for children. Considering the differences that exist between the varieties [18] it can be concluded that the three vegetables have the minimal required level of magnesium to satisfy the daily needs of adults and children. According to [18] magnesium plays an essential role in the metabolism of calcium and bones formation and is also implicated in prevention of illnesses related to the circulatory system. It helps in blood pressure regulation and insulin secretion as well. Sodium is an important mineral that contributes to the regulation of blood fluidity and maintenance of electrons power in different tissues of the body [18]. Sodium contents in *V. amygdalina*, *C. adansonii* and *S. radiatum* are 2870 ± 2 mg/kg, 1690 ± 2 mg/kg and 210 ± 2 mg/kg respectively. These vegetables are therefore non negligible sources of sodium and could be recommended to pregnant women and those suffering from high blood pressure and renal illnesses in which the direct consumption of salt should be reduced [19]. Phosphorus content in dried leaves of *V. amygdalina* is 8738 ± 2 mg/kg, 6931 ± 1 mg/kg for *C. adansonii* and 6500 ± 2mg/kg for *S. radiatum*. The daily recommended phosphorus intake in adults and children is 8000 mg/kg [20]. Phosphorus in association with calcium, contributes to bones and teeth reinforcement especially in children and nursing mothers [2]. The phosphorus content obtained in the leaves of *V. amygdalina* is beyond the recommended level. Therefore, *V. amygdalina* offers the nutritional needs in phosphorus if it is consumed reasonably. Potassium content of *V. amygdalina* (48200 ± 1 mg/kg) is significantly higher ($p < 0.05$) than those of *C. adansonii* (28100 ± 1 mg/kg) and *S. radiatum* (16300 ± 1 mg/kg). Likewise, with respect to the leaves of *Solanum macrocarpon* (45960 mg/kg) [21] and *Crassocephalum rubens* (44699 mg/kg) [22]. *V. amygdalina* is the best vegetable for potassium contribution.

V. amygdalina, *C. adansonii* and *S. radiatum* samples have calcium contents of 11800 ± 1 mg/kg, 24000 ± 1 mg/kg and 15200 ± 1 mg/kg respectively. Each of these vegetables has higher calcium content than the leaves of *Crassocephalum crepidioides* and *Crassocephalum rubens* [22]. However, only the leaves of *C. adansonii* contain higher level of calcium than those of *Solanum macrocarpon* [21]. The daily calcium intake recommended by WHO (World Health Organization) is 8000 mg/kg for adults and children. This study showed that the calcium content of the three studied vegetables is above the WHO recommended

level, especially for the leaves of *C. adansonii*. Therefore, a sauce prepared with these vegetables can be considered as a great source of calcium. Furthermore, Calcium is the most abundant mineral in the body and intervenes in blood coagulation, muscular contraction, neurological function, formation of bones and teeth [1]. It also constitutes an important factor in the enzymatic metabolic processes [23]. Moreover, the study revealed that leaves of *V. amygdalina*, *C. adansonii* and *S. radiatum* contain a non-negligible level of proteins (17476 ± 1 mg/kg; 25248 ± 1 mg/kg and 16500 ± 1 mg/kg respectively). These results are similar to those reported in many other vegetable leaves by [24]. Nevertheless, these values are lower than the protein contents of *Moringa oleifera* leaves (27200 mg/kg) [25]. *Afzelia africana* leaves (165200 mg/kg) [26] and *Solanum macrocarpon* leaves (271600 mg/kg) [21]. However, the protein contents of the three studied vegetables are above the one contained in *Manihot esculenta* leaves [27]. As observed for cabbages [19], *V. amygdalina*, *S. radiatum* and especially *C. adansonii* are great sources of plant proteins and could be used as alternative protein sources in the diet of developing countries like Benin where food of majority of populations is essentially composed of starchy foods and cereals. Besides, thanks to its protein content and according to [2], *C. adansonii* could present many advantages to human body. It can provide vital constituents of the organism; participate in the maintenance of blood fluids balance, and the synthesis of hormones and enzymes as well as contributing in the immune functions. Furthermore, there was no significant difference between the zinc content of the leaves of *V. amygdalina* and *S. radiatum*. However, the zinc level of *C. adansonii* leaves was significantly higher than those of the two others. Zinc is very useful in the synthesis of proteins, cellular division, cellular maturation, immunity and sexual functions [28]. Copper is necessary for enzymes production and electrons transportation in the body [18]. Out of this study, only the copper content of *S. radiatum* (38 ± 1 mg/kg) was higher than there commended daily copper intake that is 30 mg/kg and 20 mg/kg for adults and children respectively. Therefore the leaves of *S. radiatum* can be regarded as an acceptable source of copper for children and adults. The iron contents of the leaves of *V. amygdalina*, *C. adansonii* and *S. radiatum* are extremely higher than the daily WHO recommended one that is 100-150 mg/kg [1]. Additionally, they are above those obtained in *Crassocephalum crepidioides*, *Crassocephalum rubens* and *Solanum macrocarpon* leaves [22, 21]. According to [2], iron as a trace element, plays many biochemical roles and constitutes a fundamental element in the metabolism of almost all living organisms. Inhuman, iron is an essential element of several types of proteins and enzymes [2].

Water contents of *V. amygdalina*, *C. adansonii* and *S. radiatum* are 91.48%, 93.41% and 91.51% respectively. These values are higher than those reported by [25] for *Moringa oleifera* (73.90%), [19] for *Brassica oleracea* (81.36%) and *Solanum nodiflorum* (85.12%), as well as, [5] for *Senecio biafrae* (89.38%). However, they are similar to those of *Talinum triangulare* (89.00%) and *Basella oleifera* (93.40%) [29, 30] reported that high water content increases the activity of water soluble enzymes and co-enzymes that are necessary for the metabolic activities of these leaves. On the other hand, the ash contents of *V. amygdalina, C. adansonii* and *S. radiatum* were 84.72%, 84.87% and 88.30%, respectively. These values are higher than those of *Moringa oleifera* (11.10%) and *Dicellandroides ochthocharis* (4.19%) reported by [25, 2], respectively. Likewise, they are greater than those of other vegetables consumed in Benin including *Talinum triangulare*, *Telferia occidentalis* [2], *Solanum macrocarpon* and *Amaranthus cruentus* [4].

Results also showed that the Ca/P ratios were 1.35; 3.46 and 2.34 for *V. amygdalina, C. adansonii* and *S. radiatum* respectively. According to [31, 18] a Ca/P ratio greater than 2 enhances calcium absorption in the small intestine. Besides, a diet is considered as good when the Ca/P ratio is greater than1 and poor when it is lower than 0.5. Therefore, these three vegetables appear as good and nutritive food sources since their Ca/P ratios were all above 0.5. Moreover, the Na/K ratios of *V. amygdalina*, *C. adansonii* and *S. radiatum* were 0.06; 0.06 and 0.01 respectively. [18] demonstrated that the Na/K ratio plays an important role in blood pressure regulation where by a diet having a Na/K ratios smaller than1 may lower blood pressure. All the three studied vegetables present a Na/K ratios lower than1. They and can therefore be used not only for nutritional purposes but also to curb blood pressure problems.

5. Conclusions

The present study demonstrated the nutritional qualities of *V. amygdalina*, *C. adansonii* and *S. radiatum* in Benin. It revealed that *V. amygdalina* is rich in magnesium, sodium, potassium and in phosphorus. While, *C. adansonii* contains high concentrations of calcium, zinc and proteins. On the other hand, high iron and copper contents are recorded in the leaves of *S. radiatum.* With regards to the obtained results, it is concluded that the studied vegetables constitute highly nutritive food sources for human. Their regular use may help to cope with the daily recommendations inessential nutrients and improve the nutritional status of rural and urban populations.

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