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Biochemical Characteristics and Nutritional Profile of the Stem Bark Extracts from the Red Variety of *Byttneria catalpifolia*, an Edible Wild Plant Growing in the Western Part of Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study evaluates the biochemical characteristics and nutritional profile of stem bark extracts of the red variety of *Byttneria catalpifolia*, an edible wild plant used as a stem vegetable in the western part of Côte d'Ivoire.
Study Design: Dried bark powder and mucilage extracted from the fresh bark of the red variety of *B. catalpifolia* were used to evaluate biochemical composition, minerals and nutritional profile.
Place and Duration of Study: Department of Food Science and Technology (UFR-STA), University Nangui Abrogoua, between January 2015 and December 2017.
Methodology: The study was carried out on the mucilage extracted from the fresh bark and the dried bark powder of *B. catalpifolia*. Then, the biochemical composition and the nutritional profile were determined.
Results: The proximate analysis revealed high rates of ashes (11.51%), crude fibre (50.33%), reducing sugar (26.37%), total sugar (44.88%), caloric energy (135.18 Kcal /100g dw) in Bark

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powder while the amount of protein (6.01%) and carbohydrate (30.95%) were moderate and that of fat was low. Mucilage showed a content of ashes (3.82%), total sugar (24.84%), carbohydrate (87.79%) and caloric energy (336.19 Kcal /100g dw) whereas the rate of crude fibre (0.5%), reducing sugar (1.80%) and fat (0.6%) found to be low and that protein (7.29%) was moderate. This study indicated that the both samples contained the amino acids and organic acids. The results also showed the both samples appeared to be good sources of minerals such as potassium, calcium and magnesium.

Conclusion: The bark extracts of the red variety of *B. catalpifolia* contain appreciable amounts of nutrients. Their nutritional profile by SAIN and LIM method showed that they belong to the group of foods recommended for health.

Keywords: Byttneria catalpifolia; mucilage; nutritional profile; vegetable; stem bark.

1. INTRODUCTION

Many plants are consumed as vegetables [1]. The term vegetable corresponds to whole or parts of edible plants consumed, cooked as a component of a dish or raw as a salad. Vegetables include leaves, fruits, seeds, stems, roots, flowers, bulbs, tubers and mushrooms [2,3]. The vegetables contribute significantly to the nutrition of populations by providing nutrients [4]. Thus, wild edible vegetables are beneficial for marginal populations, especially in developing countries where people have very few resources.

Some wild liana plants are edible. Lianas are woody climbing plants that have been extensively studied in the tropics [5,6]. They constitute an important component of tropical forests. With about 32% of stems and 35% of woody species diversity [7], they are generally more abundant and of great diversity in tropical than temperate forests [8,9]. Otherwise, the studies concerning the lianas were carried out on geographical, taxonomical and ecological aspects [10]. Among the liana species, *B. catalpifolia* is a perennial plant that is widely distributed in the tropics of Africa, Asia and America. It belongs to the Family Sterculiaceae and it is the most abundant of the genus *Byttneria*. Based on the colour of the bark, there are two varieties of *B. catalpifolia*. The white variety is characterized by the white colour of the bark when the skin is scraped while the red variety, by a purple colour of the bark. It is an edible wild plant whose bark is used to make a sticky sauce that is well appreciated by the populations of Western Côte d'Ivoire [11,12]. However, information on the nutritional composition of this plant species is scarce [12]. Note that, assessing the nutritional composition of wild edible plants is important for determining their nutritional significance [13]. The considerable consumption of wild plant species by local people motivated us to carry out the present proximate and nutrients analysis. Despite the use of *B. catapifolia* for several generations as a stem vegetable, to the best of our knowledge, there are no scientific data on the nutritional composition of the the stem bark and the mucilage extracted from the fresh bark of the red variety of *B. catalpifolia*. The mucilage of some plants has been studied by scientists and found to possess biologically active principles. Therefore, the present study was designed to evaluate the biochemical composition and nutritional profile of the dried stem bark powder and the mucilage extracted from fresh bark of the red variety of *B. catalpifolia* and provides consumers with the most appropriate mode of consumption which would give them health benefits.

2. MATERIALS AND METHODS

2.1 Sample Collection and Preparation

The stem samples of the red variety of *B. catalpifolia* were collected from the western part of Côte d'Ivoire (7°24'45" North latitude and 7°33'13" West longitude). These samples were immediately transported to the laboratory. After removing the epidermis with a kitchen knife, the barks were removed from the stems and chopped. The bark sample was divided into two parts. Part of sample was used for the extraction of mucilage. To do this, 20 g of fresh stem bark were ground in 200 mL of demineralized water using a crusher (Moulinex). The homogenate was centrifuged at 4000 rpm for 10 min. The pellet was ground again in 200 mL and centrifuged under the same conditions as those previously described [14]. The two viscous supernatants were mixed and kept in the freezer for physicochemical analysis. The other part was dried in an oven at 65°C for 72 h. The dried samples were ground using a crusher (Moulinex)

and the resulting sifted (Θ 2 mm) powder was stored in sealed plastic boxes for biochemical analysis.

2.2 Proximate Analysis

The AOAC's standard methods [15] were used to obtain the contents in moisture, ash, crude fibre, crude protein, fat and carbohydrate of bark extracts of *B. catalpifolia*. All these analyses were done in triplicates. A difference of weight before and after drying a sample of 10 g in an oven (Memmert, germany) at 105°C until constant weight allowed to quantify the moisture content. The ash fraction was expressed as the weight of the residue in percentage obtained from a dried sample (5 g) incinerated in a muffle furnace (Pyrolabo, France) at 550°C for 12 h while, the crude fibre content, was obtained from the loss in weight of dried residue after a digestion for fat-free samples with 1.25% each of sulfuric acid and sodium hydroxide solutions. Through a digestion apparatus applying the macrokjeldahl nitrogen assay method, the crude protein content (N × 6.25) was estimated. A Soxhlet extraction with hexane as a solvent was used for the fat content. Soluble sugars were extracted with 80% neutral aqueous ethanol. Using the ethanolic extract, the reducing sugar content was determined according to the Bernfeld method [16], while the total soluble sugar content was measured through the phenol-sulfuric acid method as described by Dubois et al. [17]. The following formulas allowed to calculate carbohydrate and calorific values [18]:

Carbohydrates (%) = 100 - (% moist. + % prot. + % lip. + % ash + % fib.)

Calorific value (kcal /100g) = (% prot. × 2.44) + (% carbo. × 3.57) + (% lip × 8.37)

moist. : moisture; prot. : proteins; carbo. : carbohydrates; lip. : lipids; fib. : fibres

The results of ash, crude fibre, crude protein, fat and carbohydrate contents were expressed based on dry weight of samples.

2.3 Mineral Analysis

According to AOAC principles [19], a scanning electron microscope (SEM) with different pressures (SEM FEG Zeiss Supra 40 VP) allowed to analyse the minerals after wet-ashing. An X-ray detector (Oxford Instruments) related to an energy diffusion spectrometry (EDS) microanalyzer platform (Inca Cool Dry, without liquid nitrogen) is associated to the SEM. Analysis was performed applying evenly to a primed platform with double-sided adhesive carbon, 10 mg of the sample ash residue. The measurement of the chemical elements content was done by measuring the transition energy of the electrons from electronic clouds of the K, L and M series of atoms of the sample.

2.4 Determination of Amino Acids

The amino acids of the bark extracts (powder and mucilage) of the red variety *B. catalpifolia* were determined by reversed-phase high performance liquid chromatography (PTC column RP-18, 220 mm long, 2.1 mm internal diameter) equipped with a pre-column (SHIMADZU SPD 20A) according to the method described by AOAC [20]. The samples were hydrolysed under vacuum at 150°C for 60 min in a Pico-Tag station (Waters, Milford, MA, USA) in the presence of 6% HCl at 1% phenol. They were then taken up in ultra-pure water and derived automatically thanks to a self-derivator-analyzer-420A (SHIMADZU SPD 20A). The amino acid derivatives obtained in the form of phenyl isothiocyanates (PITC) were separated under elution gradient (7-36%) using buffer A (45 M sodium acetate at pH 5.9) and buffer B (30% sodium acetate 105 mM, pH 4.6; 70% acetonitrile) at a flow rate of 1.5 mL /min. The detection was set at 254 nm and the runtime was 31 min. The acquisition and exploitation of the results was performed using the Model 600 Data Analysis System software (SHIMADZU SPD 20A).

2.5 Determination of Organic Acids

About 1 g of sample served to extract organic acids using 50 mL of 80% methanol saturated with NaCl. The organic acids contained in the methanolic extract were determined according to the method of Karadeniz [21] using a HPLC system (Shimadzu Corporation, Japan) equipped with a pump (Shimadzu LC-6A Liquid Chromatograph), a UV detector (Shimadzu SPD-6A UV Spectrophotometric detector) and an integrator (Shimadzu CR 6A Chromatopac). The analysis was performed in isocratic mode using ion exclusion column (ICSep ICE ORH-801, 40 cm x 5 µm, Interchrom, France) that was maintained at 35 °C thanks to a Meta ThermTM furnace (Interchrom, France). Standard solutions were prepared at different concentrations with bidistilled water. Sample (20 µL) was injected

and the elution flow rate was maintained at 0.6 mL / min using a mobile phase consisting of sulphuric acid (0.004 N). The detection was set at 210 nm and the runtime was 35 min. The levels of the organic acids in the samples were obtained by comparing the retention times of the eluted compounds with the retention times of the reference solutions. The analysis was carried out in triplicate.

2.6 Determination of B Vitamins

The determination of B vitamins was performed by the method of Morales et al. [22]. About 5 g of sample (mucilage / powder) served to extract B vitamins using 20 mL of methanol (80%). The standards were prepared by dissolving 0.01 g of each standard in methanol (80%). The methanolic extract was analysed using a HPLC system (SHIMADZU SPD 20A) equipped with a UV detector (PAD) and a C18 ODS column (250 x 4.6 from Cluzeau France) in isocratic mode. A 10 µL of extract or standard was injected. The analysis was carried out at a flow rate of 1.5 mL / min using a mobile phase consisting of a mixture of acetonitrile (55 mL), tetrahydrofuran (37 mL) and water (8 mL) monitored at room temperature. The compounds were detected at a wavelength of 325 nm.

2.7 Nutritional Profile of Extracts of the Red Variety of *B. catalpifolia* according to the SAIN and LIM Method

The nutritional profile of dried bark powder and mucilage extracted from the fresh bark of *B. catalpifolia* was calculated using the nutrient profiling system proposed by AFSSA and based on two scores, the SAIN score (score of nutritional adequacy of individual foods) and the LIM score (score of nutrients to be limited) [23,24]. The number of nutrients taken into account to calculate the SAIN score is variable and generally based on the RDA (recommended dietary allowance) of 5, 16 or 23 qualifying nutrients per 100 kcal of food. The LIM score is based on the average percentage of excess of sodium, saturated fatty acids (SFA) and added sugars per 100 g of food [25,26]. The choice of nutrients to be taken into account is based on the most prevalent nutritional problems of the target population. Thus, the nutritional profile of *B. catalpifolia* extracts was calculated using proteins, crude fibre, calcium, vitamin C and iron. Regarding the LIM score, only sodium was used, because *B. catalpifolia* extracts do not contain saturated fatty acids or added sugars. Nutrient contents were expressed on the basis of 100 g of dry matter [24]. The SAIN and LIM results obtained were projected on a four-quadrant graph that positions food according to their composition in qualifying and disqualifying nutrients [23].

$$SAIN = \frac{\frac{\frac{Prot}{65} + \frac{Fib}{30} + \frac{Ca}{900} + \frac{Vit.C}{110} + \frac{Fe}{12.5}}{5} \times 100}{Energy} \times 100$$

$$LIM = \frac{\frac{Na}{3153} + \frac{SFA}{22} + \frac{Added\ sugar}{50}}{3} \times 100$$

Prot : proteins, Fib : fiber, Ca : calcium, Vit. C : vitamin C, Fe : iron, Na : sodium, SFA : saturated fatty acids.

2.8 Statistical Analysis

All analyses were performed in triplicates. Results were reported as means ± SD. Means of proximate composition, amino acid and organic acid contents of the dried bark powder and mucilage of *B. catalpifolia* were separated according to the Student's t-test ($P \leq 0.05$) while means of mineral values were analysed according to the Duncan test ($P \leq 0.05$) post ANOVA one way, with the help of JMP® Pro software (version 12, SAS Institute Inc., Cary, NC, 2007).

3. RESULTS

3.1 Proximate Composition

Results of the composition of dried stem bark powder and mucilage extracted from the fresh bark of the red variety of *B. catalpifolia* are presented in Table 1. The pH value of dried stem bark powder (5.95 ± 0.02) and mucilage (5.95 ± 0.01) was similar. The dry matter content observed in fresh bark (45.03 ± 0.34%) was significantly ($p \leq 0.05$) higher than that obtained in the mucilage (6.21 ± 1.15%). The ash contents obtained in dried stem bark powder and mucilage were 11.51 ± 0.45% and 3.82 ± 0.62% of dry weight (dw), respectively. There was meaningful difference ($p \leq 0.05$) between ash contents of dried stem bark powder and mucilage. Our results showed that protein content (7.29 ± 1.01% dw) and caloric energy (336.19 ± 1.18 kcal /100 g dw) were significantly ($p \leq 0.05$) higher in mucilage than those observed in dried stem bark powder, with values of 6.01 ± 0.20%

dw and 135.18 ± 2.26 kcal /100 g dw, respectively. Crude fibres observed in the dried stem bark (50.33 ± 0.22% dw) was largely higher than that obtained in the mucilage (0.50 ± 0.01% dw). Furthermore, this study revealed the presence of parameters such as fat, reducing sugar, total soluble sugar, vitamin B9 and vitamin B2 in the both samples.

3.2 Amino Acid Contents

The amino acid compositions of the dried stem bark powder and mucilage from the fresh bark of the red variety of *B. catalpifolia* are illustrated in Table 2. These results indicated that proline, valine, methionine, arginine, glycine, glutamic acid, tyrosine, threonine, lysine and cysteine were found in the both analysed samples. The amino acid contents of died stem bark powder ranged from 0.11 ± 0.02 mg /100 g dw (threonine) to 3.70 ± 0.01 mg /100 g dw (arginine), while those of mucilage varied from 0.02 ± 0.01 mg /100 g dw (arginine) to 7.57 ± 0.31 mg /100 g dw (cysteine). This study revealed the presence of essential amino acids such as valine, methionine, threonine and lysine in both samples. Their levels ranged from 0.11 ± 0.02 mg /100 g dw (threonine) to 1.64 ± 0.01 mg /100 g dw (methionine) for dried stem bark powder, whereas those of mucilage varied from 1.09 ± 0.01 mg /100 g dw (lysine) to 4.77 ± 0.03 mg /100 g dw (methionine). The statistical analysis showed that the essential amino acids contents of dried stem bark powder were lower meaningfully ($p \leq 0.05$) than those observed in mucilage. Besides, proline, arginine, glutamic acid and glycine (non-essential amino acids) contents in dried bark powder were found also to be lower significantly ($p \leq 0.05$) than those obtained in mucilage, excepted for tyrosine and cysteine contents.

3.3 Mineral Composition

The mineral composition of the dried bark powder and the mucilage extracted from the fresh bark of *B. catalpifolia* are shown in Table 3. The minerals detected were magnesium (Mg), phosphorus (P), potassium (K), calcium (Ca), sodium (Na), iron (Fe), copper (Cu), Zinc (Zn) and iodine (I). The amounts of these minerals in dried stem bark powder appeared significantly higher ($P \leq 0.05$) than those of mucilage. Ca (414.17 ± 27.97 - 1104.36 ± 223.30 mg /100 g dw) and K (440.00 ± 20.93- 990.69 ± 227.31 mg /100 g dw) were the abundant minerals. The least concentrated macro-elements in the mucilage and stem bark powder was Na (8.02 ± 1.27 - 28.72 ± 17.92 mg / 100 g dw, respectively). The micro-elements observed in the dried stem bark powder were Fe, Cu, Zn and I. Cu and Zn were not detected in mucilage. Iodine (I) content of the mucilage (6.99 ± 1.10 µg /100 g dw) was meaningfully lower ($p \leq 0.05$) than that obtained in dried stem bark powder (14.61 ± 1.10 µg /100 g dw).

Table 1. Proximate composition of the dried stem bark and mucilage from the fresh bark of the red variety of *B. catalpifolia*

Parameters	Dried bark powder	Mucilage
pH	5.95 ± 0.02[a]	5.95 ± 0.01[a]
Dry matter* (%)	45.03 ± 0.34[b]	6.21 ± 1.15[a]
Ashes (% dw)	11.51 ± 0.45[b]	3.82 ± 0.62[a]
Fat (% dw)	1.20 ± 0.01[b]	0.60 ± 0.01[a]
Proteins (% dw)	6.01 ± 0.20[a]	7.29 ± 1.01[a]
Carbohydrates (% dw)	30.95 ± 0.51[a]	87.79 ± 1.01[b]
Crude fibres (% dw)	50.33 ± 0.22[b]	0.50 ± 0.01[a]
Reducing sugar (mg /100 g dw)	26.37 ± 0.05[b]	1.80 ± 0.08[a]
Total sugar (mg /100 g dw)	44.88 ± 0.16[b]	24.84 ± 0.16[a]
Vitamin B2 (mg /100 g dw)	694.83 ± 32.23[b]	102.18 ± 0.61[a]
Vitamin B9 (mg /100 g dw)	31.97 ± 1.37[b]	2.09 ± 0.01[a]
Caloric Energy (Kcal /100 g dw)	135.18 ± 2.26[a]	336.19 ± 1.18[b]

*All analyses were performed in triplicates and the values in the table are the mean ± standard deviation. On the same line, the means followed by a similar letter are not significantly different ($p \leq 0.05$) according to the Student's test; dry weight: dw; *Dry matter of the fresh bark of the red variety of B. catalpifolia*

Table 2. Amino acid contents of the dried stem bark powder and mucilage from the fresh bark of the red variety of *B. catalpifolia*

Amino acids (mg /100 g dw)	Dried stem bark powder	Mucilage
Proline	0.34 ± 0.11[a]	2.33 ± 0.04[b]
Valine	0.81 ± 0.28[a]	1.11 ± 0.06[a]
Methionine	1.64 ± 0.01[a]	4.77 ± 0.03[b]
Arginine	3.70 ± 0.01[a]	7.57 ± 0.31[b]
Glycine	0.60 ± 0.01[a]	0.81 ± 0.06[b]
Glutamic acid	0.43 ± 0.03[a]	1.06 ± 0.29[b]
Threonine	0.11 ± 0.02[a]	2.28 ± 0.07[b]
Tyrosine	0.15 ± 0.02[b]	0.07 ± 0.00[a]
Cysteine	0.43 ± 0.13[b]	0.02 ± 0.01[a]
Lysine	0.17 ± 0.02[a]	1.09 ± 0.01[b]

All analyses were performed in triplicates and the values in the table are the mean ± standard deviation. On the same line, the means followed by a similar letter are not significantly different ($p \leq 0.05$) according to the Student's test; dry weight: dw

Table 3. Mineral and mineral ratios of the dried stem bark and mucilage from the bark of the red variety of *B. catalpifolia*

Minerals (*mg /100 g dw)	Dried bark powder	Mucilage	Pellet
Mg	381.56 ± 162.27[c]	198.47 ± 16.88[b]	129.24 ± 18.18[a]
P	38.50 ± 9.46[c]	35.09 ± 7.36[b]	8.01 ± 1.57[a]
K	990.69 ± 227.31[c]	440.00 ± 20.93[b]	368.40 ± 3.78[a]
Ca	1104.36 ± 223.30[c]	414.17 ± 27.97[a]	543.79 ± 85.62[b]
Na	28.72 ± 17.92[c]	8,02 ± 1.27[a]	15.24 ± 0.62[b]
Fe	11.05 ± 5.07[c]	5.42 ± 2.92[a]	6.85 ± 0.1[b]
Cu	0.49 ± 0.02[b]	ND	0.21 ± 0.01[a]
Zn	0.46 ± 0.01[b]	ND	0.14 ± 0.00[a]
I (µg /100 g dw)	14.61 ± 1.10[b]	6.99 ± 1.10[a]	13.55 ± 0.37[b]
[Ca]/[P]	28.68	11.80	67.89
[Ca]/[Mg]	2.89	2.09	4.21

All analyses were performed in triplicates and the values in the table are the mean ± standard deviation. On the same line, the means followed by a similar letter are not significantly different ($p \leq 0.05$) according to the test of Duncan; dry weight: dw. Not detected: ND
** the unit does not apply to ratios*

3.4 Organic Acid Contents

The organic acids were extracted from the powder of dried stem bark and mucilage of *B. catalpifolia*. They were identified and measured using HPLC system. Tannic, oxalic, citric, tartaric, sulfanilic, salicylic, adipic, fumaric and benzoic acids were observed. All of these organic acids were present in both samples. Table 4 clearly indicates that content organic acids contents of the dried bark powder was found to be lower ($p \leq 0.05$) than those observed in the mucilage except tannic acid and citric acid. In both samples, levels of fumaric and benzoic acids did not vary significantly ($p > 0.05$). In addition, organic acids varied from 0.09 ± 0.02 mg /100 g dw to 51.35 ± 0.75 mg /100 g dw and from 0.11 ± 0.02 mg /100 g dw to 55.45 ± 0.12 mg /100 g dw for dry bark powder and mucilage, respectively.

3.5 Nutritional Profile

The Fig. 1 shows the SAIN and LIM scores of *B. catalpifolia* extracts (Dried bark and mucilage). The SAIN score for the dried bark was 57.42 and its LIM score was 0.30. As for mucilage, the SAIN score was 13.75 and its LIM score recorded was 0.08. The extracts of this stem vegetable had a high SAIN (SAIN > 5) and a low LIM (LIM < 7.5).

Table 4. Organics acid contents of the dried stem bark and mucilage extracted from the fresh bark of red variety of *B. catalpifolia*

Organic acids (*mg /100 g dw)	Dried bark powder	Mucilage
Tannic acid	6.57 ±0.03^{b}	4.64 ± 0.31^{a}
Oxalic acid	1.39 ±0.36^{a}	5.28 ± 0.11^{b}
Citric acid	15.63 ±0.22^{b}	13.39 ± 0.30^{a}
Tartric acid	51.35 ±0.75^{a}	55.45 ± 0.12^{b}
Sulfanilic acid	0.15 ±0.03^{a}	0.31 ± 0.01^{b}
Salycilic acid	0.32 ±0.03^{a}	2.86 ± 0.23^{b}
Adipic acid	0.31 ±0.02^{a}	0.50 ± 0.06^{b}
Fumaric acid	0.23 ± 0.07^{a}	0.25 ± 0.02^{a}
Benzoïc acid	0.09 ± 0.02^{a}	0.11± 0.02^{a}
[oxalic acid] / [Ca]	0.001	0.061

All analyses were performed in triplicates and the values in the table are the mean ± standard deviation. On the same line, the means followed by a similar letter are not significantly different ($p \leq 0.05$) according to the Student's test; dry weight: dw.
** the unit does not apply to ratios*

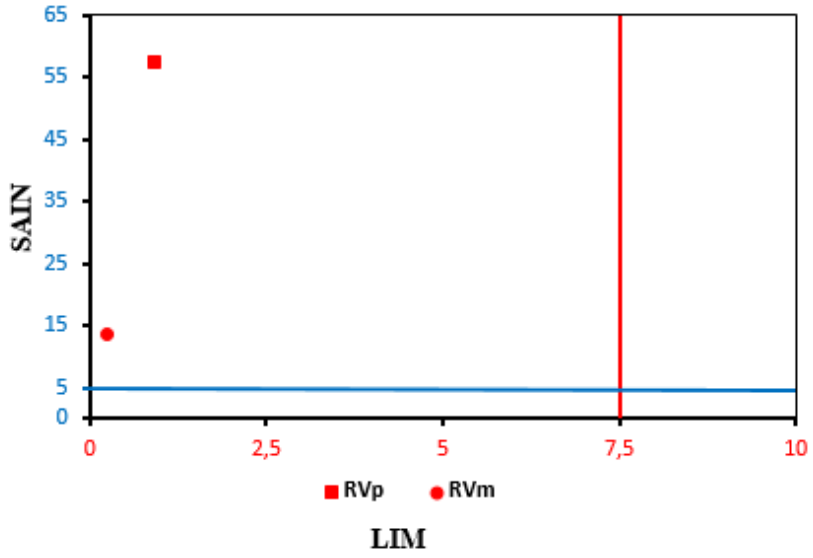

Fig. 1. SAIN and LIM profile of powder and mucilage extracted from the bark of *B. catalpifolia*
(RVp: Red Variety powder; RVm: Red Variety mucilage)

4. DISCUSSION

4.1 Proximate Composition

This work revealed that ash contents of the dried stem bark and mucilage from the red variety of *B. catalpifolia* differed meaningfully ($p \leq 0.05$). Note that, ash content is useful in assessing the quality grading of food materials and also gives an idea of the amount of their mineral composition [27]. This suggested that a significant part of the minerals was not extracted with the mucilage. The recorded values of ash were lower than that of the bark from *Bridelia thermifolia* (12.14 ± 0.63%) and *Corchorus olitorius* (18.2%) [28,29]. By contrast, they were higher than that found by Ndouyang et al. [30] in tubers of *Tacca leontopetaloides* (0.80 ± 0.01%).

The fat contents of samples testified that the red variety of *B. catalpifolia* is poor in lipids. Indeed, fat contents of dried stem bark and mucilage of this plant species were low compared with those of the seeds of *Daniella oliveri* (7.09%) and *Olax subscorpoidea* (3.66%) [31]. Our results were also found to be slightly higher than those reported by Oderinde et al. [32] for the seed of *Parkia filicoidea* (0.43%).

Dietary fibre is an important component of food in human nutrition because it promotes intestinal mobility and reduces serum cholesterol, breast cancer and hypertension [33,34]. In fact, there is evidence that dietary fibre is likely to reduce the absorption rate of glucose and fat [35], leading to health benefit. Our results revealed that the crude fibre of stem bark was high while it was low in mucilage. Moreover, the crude fibre of the dried bark powder of *B. catalpifolia* was higher than that of *Melochia corchorifolia* (23.33 ± 2.89%), a leafy vegetable [36]. According to Dietary Guidelines for Americans [37], the recommend limit for fibre intake is from 1.4% to 3.5%. Based on this report, only the dried stem bark powder was good source of dietary fibre.

As concern reducing and total soluble sugars, their levels in the stem bark powder were higher than those observed in mucilage, whereas the carbohydrates content of mucilage was higher than that observed in dried bark powder. This showed that the mucilage could contain most complex sugars. The level of carbohydrates of the mucilage from the fresh bark of the red variety of *B. catalpifolia* was high compared with the values of 52.6% in mucilage of *Ziziphus mauritiana* [38].

As for vitamin B2 and B9, the result showed that the both samples were a good source of the vitamin B9. This work revealed that the calculated caloric energy of the both samples was low compared with the respective values of 1476.7 KJ / 100 g dw and 1513.5 KJ /100 g dw in mushroom flours from *Ganoderma spp and Hebeloma mesophaeum* [39]. Therefore, the consumption of bark and mucilage of the red variety of *B. catalpifolia* could be recommended to people suffering from obesity.

4.2 Amino Acid Content

Amino acids are among the main functionally essential compounds in a food. As a result, the amino acid composition is a reliable indicator of the nutritional value of foods. The amino acid contents found in the mucilage was higher than those of the bark. These low levels of amino acids could be due to the effects of the processing (drying, grinding, sieving) undergone by the bark to obtain the powder. [40] in their work, showed that the quality of a dried product is often lower than the original food with an important impact on nutritional value. Otherwise, amino acids contents of bark powder or mucilage of *B. catalpifolia* were found to be very lower than those of 11 wild edible mushrooms (from 153.09 mg/100 g dw in *F. hepatia* to 2267.32 mg /100 g dw in *B. edulis*) from northeastern Portugal [41]. Besides, the essential amino acids contents of both samples studied were very low compared with the respective values of 154.3 mg /100 g in *B. craspedius* and 5232.5 mg /100 g in *T. microcarpus* [42]. This suggested that both samples were poor in essential and non-essential amino acids. Moreover, levels of some of them were very lower than that recommended by Adeyeye [43]. In addition to that, protein contents were relatively low in the mucilage as well as in the dried bark powder and were not sufficient to meet protein requirements or the balance of the amino acids. Thus, we recommend that consumers eat *B. catalpifolia* with meat or fish to balance the diet in protein.

4.3 Mineral Composition

The mineral composition indicated that the macro-elements such as Mg, P, K, and Ca had relatively high contents in *B. catalpifolia* samples. These results showed a close agreement with those of Oke [44] Omale and Ugwu [45], who reported that Ca and K levels were highest in vegetables. Ca is an essential nutrient needed for many functions in human body. Ca content of the dried bark of *B. catalpifolia* was higher than that of the leaves of *Urtica urens* (830 mg /100 g dw) [46], *Melochia corchorifolia* (750.37 mg /100 g dw) [36] and that of mucilaginous vegetables such as *Irvingia gabonensis* (452 mg /100 g dw) and *Beilschmedia manii* (104 mg /100 g dw) [47]. As the recommended daily allowance of Ca is 1200 mg, one serving of the dried bark powder of *B. catalpifolia* per day would help to meet daily Ca requirements [48].

The level of K in the dried bark of the red variety of *B. catalpifolia* was higher than that of mucilage and both had high contents in K as well as leaves of *Urera trinervis* (1.25%) and *Hippocratea myriantha* (1.29%) [49]. K is involved in the acid-base balance and osmotic regulation of body fluids. It also contributes to nerve and muscle excitability and carbohydrate metabolism [50].

Ca and Mg are essential elements of human physiology and are particularly important in the biological functions which are characteristics of the cardiovascular system [51]. The absorption of Mg is closely related to Ca level and P level also influence Ca absorption. Mg levels obtained in the bark and mucilage were greater than those reported by Appiah et al. [52] and

Nassar et al. [53] in *Artocarpus altilis* flours (90.63 - 92.7 mg /100 g) and cassava (36.58 - 37.71 mg /100 g), respectively. Moreover, in the extracts of the bark of *B. catalpifolia*, the [Ca] / [Mg] ratio was greater than 2. Note that, the absorption of Ca and Mg are interdependent, depending on their ratio. Diet is considered good if the ratio between these two minerals in the diet is from 2 to 1 in favour of Ca [54].

P has more functions than any other mineral element in the body. It forms a complex with Ca that gives stiffness to bones, teeth and muscles [55]. It acts as a cofactor for many enzymes and activates several of the B complex vitamins. It also affects the production of the adenosine triphosphate molecule, which is crucial for energy storage [56]. The P contents of powder and mucilage of *B. catalpifolia* were higher than that of *O. gratissimum, T. occidentalis,* and *V. amygdalina* (13.8, 13.1 and 15.08 mg /100 g dw, respectively) which are leafy vegetables eaten in South West of Nigeria [57]. It should be noted that, food is also considered "good" if the [Ca] / [P] ratio is greater than 1 and "mediocre" if less than 0.5 [54]. The [Ca] / [P] ratio of dried bark powder and mucilage was 28.68 and 11.80, respectively. Thus, the levels of these minerals showed that the dried stem bark and mucilage of this plant may be used to complement the required macro-element needed for proper growth and development in human beings and other domesticated animals.

The high content of iodine (I) and other minerals in the pellet compared to the mucilage showed that the use of mucilage to prepare sauce does not allow access to all the minerals contained in this stem vegetable. The relative high concentration of iodine in dried stem bark powder compared with other vegetables such as eggplant leaves (7.6 µg /100 g dw) and melon leaves (6.13 µg /100 g dw) [58] indicated that the bark could be a good source of Iodine. Thus, its regular consumption would supply appreciable amount of iodine and would benefit consumers, particularly those in the western of Côte d'Ivoire, where endemic goitre is high (38.3%) [59]. Indeed, Iodine is essential to produce thyroid hormones, triiodothyronine and thyroxine, so that its deficiency can lead to hypothyroidism, goitre, poor physical development and mental disabilities [60].

4.4 Organic Acid Contents

Several organic acids were observed in *B. catalpifolia* extracts with relative important level. Citric and tartaric acids had the highest levels in both samples. Citric acid contents of samples were higher than that observed for *moringa* leaf (1.56 ± 0.45 mg /100 g dw) [61]. However, they were lower than that observed in kale (*Brassica oleraceae* L.var. acpehala DC.) leaf (2213 mg /100 g dw) [62]. As for tartaric acid contents of both samples, they were found to be lower than that obtained by Muangthai and Nookaew [61] in Ceylon Spinach (1200 ± 11.56 mg /100 g dw). In contrast, tartaric acid levels were higher than that found in moringa leaf by Muangthai and Nookaew [61], who recorded the value of 0.45 ± 0.02 mg /100 g dw. Note that, the organic acid contents of foods influence their flavour. In addition, they influence the pH of the stomach and the stability and acceptability of foods [63]. The [oxalic acid] / [Ca] ratios of dried bark (0.001) and mucilage (0.061) were less than 2.25, which is the threshold value not to be exceeded. Indeed, oxalic acid interferes with Ca uptake. Thus, the [oxalic acid] / [Ca] ratios below 2.25 indicated that the amount of oxalic acid in both samples will not interfere with Ca [64].

4.5 Nutritional Profile

The nutritional profile of extracts of the red variety of *B. catalpifolia,* following the SAIN and LIM method showed that they belong to the group of foods recommended for health. These results corroborate those of Koné et al. [65] in their work on the assessment of the nutritional profile of foods for children under-five in Abidjan, Côte d'Ivoire. According to these authors, the different vegetable-based soups such as okra, tomato and eggplant have a good nutritional value because their SAIN > 5 and LIM < 7.5. [66] also showed that 80% of vegetables belong to the food group with a strong SAIN and a low LIM and therefore recommended for health. According to Pem and Jeewon [67], non-starchy vegetables such as *B. catalpifolia* are rich in fibres that improve intestinal transit by forming a mass, which leads to a more gradual absorption of nutrients, thus avoiding constipation. They are also very poor in energy and therefore can be consumed in relatively larger amounts to maintain a normal weight [68].

5. CONCLUSION

On the basis of the above results it can be concluded that the dried bark and the mucilage extracted from the fresh bark of the red variety of *B. catalpifolia* contain appreciable amounts of nutrients such as carbohydrates, Proteins,

essential amino acids, vitamins and minerals. Our findings indicated that the both samples were nutritionally important, since their nutritional profile by SAIN and LIM method showed that they belong to the group of foods recommended for health. The powder of the dried bark was very rich in iodine and other nutrients, therefore the consumption of this powder would be more beneficial to nutritional balance than the mucilage.

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COMPETING INTERESTS

The authors declared that they have no conflict of interests.

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