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Characterization of the Mucilages of Four Food Plants, *Abelmoschus esculentus*, *Beilschmiedia mannii*, *Corchorus olitorius*, and *Irvingia gabonensis*, 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 DS and PK performed the statistical analysis, checked the first draft of the manuscript and achieved the submitted manuscript. Authors VDM and YNK took part in the interpretation of the results and corrected the first draft of the manuscript. Author AC 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: The objective of this work is to characterize the mucilage of food plants from Côte d'Ivoire.
Study Design: Mucilage food plants edible parts were dried, mucilage were extracted and Physicochemical and nutritive constituent content have been evaluated.

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Place and Duration of Study: The study was conducted in Laboratory of Biochemistry and Food Sciences, Biosciences Unit, at Felix Houphouet-Boigny University between January and December 2014.

Methodology: The study was carried out on fruits of *A. esculentus* (okra), *B. mannii* (sran), *I. gabonensis* (kplé) and leaves of *C. olitorius* (kplala) collected. The mucilage of different plants has been extracted. Physicochemical and nutritive constituent content have been evaluated.

Results: The mucilage contents of *B. mannii*, *I. gabonensis*, *A. esculentus* and *C. olitorius* were respectively 63.00 ± 2.69%, 56.34 ± 5.44%, 34.86 ± 5.27% and 25.81 ± 4.13%. Scanning electron microscope (SEM) observations of the mucilages have showed varying forms. Ash, pH, total polyphenols, lipids, proteins and insoluble fibers differentiated the studied mucilages to $p<0.001$. The mucilages obtained are rich in minerals (ash content between 4.11 ± 0.19% and 10.71 ± 0.20%) and soluble fibers (72.86 ± 7.63% and 80.34 ± 5. 58%). These mucilages are very low in energy (36.66 ± 17.44 kcal/100 g at 50.71 ± 30.22 kcal/100 g).

Conclusion: Mucilages of selected plants are rich in ash and have low energy value.

Keywords: Mucilages; physicochemical characteristics; nutrients constituents; Côte d'Ivoire.

1. INTRODUCTION

The importance of non-wood food products in the diet of African populations is undeniable [1]. In many countries, food plants provide more than 80% of the population's food intake [2]. They are valuable sources of essential nutrients and contribute to satisfying the need for fiber and functional compounds necessary for good health [3].

In Africa, the foods habits of the populations have undergone changes related to lifestyles imposed by population sedentarization and the extraordinary development of African cities [4]. Therefore, it lands more and more health problems linked to the non balanced food diet. In addition to deficiency diseases, the metabolic diseases as obesity, diabetes, arterial high blood pressure and cancers become public health problems whose handling remains very heavy for the individuals and for our governments [5].

The promotion of certain non-woody forest plants (NWFPs) and their integration into diets becomes essential for good health and well-being; including mucilaginous food plants of which *Irvingia gabonensis* (kplé), *Abelmoschus esculentus* (gumbo), *Beilschmiedia mannii* (sran) and *Corchorus olitorius* (kplala). Indeed, okra is used by several communities in culinary preparations and young fruits reveal the presence of numerous vitamins including thiamine, β carotene and niacin [1,6,7]. Also, *C. olitorius* leaves provide significant amounts of protein, minerals and vitamins [8,9]. These plants, in addition to their richness in essential nutrients, are important sources of secondary metabolites essential for good health [10], thanks to their properties of hunger cutting, blood sugar regulation, tension, Cholesterol and certain homeostasis parameters [11,12]. The mucilages that they contain make them basic products in the diet of populations in several regions of Côte d'Ivoire [13]. This appreciation is mainly based on organoleptic properties. Indeed, mucilage is a complex carbohydrate with a highly branched structure containing variable proportions of L-Arabinose, D-Galactose, L-Rhamnose and D-xylose and galacturonic acid [14,15]. The possibilities of mucilages using are numerous. They are used in agro-food, pharmaceutical and cosmetic sectors [16,17,18,19]. In the fight against the pauperization of populations, mucilaginous plants can constitute a non-negligible source of income [20]. Therefore, the objective of our study was to characterize mucilages from selected non-wood forest plants (NWFPs).

2. MATERIALS AND METHODS

2.1 Plant Material

The biological material consisted of the kernels of *Irvingia gabonensis* (kplé), the fruits of *Beilschmiedia mannii* (sran), the leaves of *Corchorus olitorius* (kplala) and the variety koto of *Abelmoschus esculentus* (gumbo). The plants have been authenticated by the Centre National de Floristique (CNF) of the University Felix HOUPHOUET-BOIGNY. Mucilaginous food plants have been collected in several regions of Côte d'Ivoire.

2.1.1 Samples processing to obtain dry matter

The plant material was collected between January and December 2014 in different regions of Côte d'Ivoire. The fruits of *Irvingia* have been stocked several days then the seeds have been ground to isolate the kernels. As for 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 of *C. olitorius* were sorted, cleaned and drained before being dried. After drying, plants parts collected have been reduced in powder with a grinder of Heavy Duty mark [21].

2.1.2 Extraction and PAMu mucilage content

The powder of *I. gabonensis* kernels was delipidated with hexane and then macerated for 24 h in distilled water with a ratio of 1/50 (vegetable / water). The whole is filtered on a muslin cloth. The mucilage is collected, dried and ground and then stored in desiccators.

As for *B. mannii*, *C. olitorius*, *A. esculentus*, the powders are macerated in distilled water for 24 h with a ratio 1/50 (vegetable / water). The mixture is then boiled for 1 hour and filtered on a muslin cloth. The mucilage is collected, dried and ground and then stored in desiccators [21].

2.1.3 Mucilage preliminary tests of confirmation

Preliminary tests to know, the red ruthenium test, the Molisch test and the iodine test have been done to confirm the mucilaginous nature of substances obtained [22,23,24].

2.1.3.1 Red ruthenium test

This test is used to confirm the presence of mucilage. A small amount of dried mucilage powder has been mounted on a slide with a solution of ruthenium red and the whole has been observed under a microscope [22,23,24].

2.1.3.2 Molisch test

This test is used to confirm the presence of carbohydrate in the mucilage. 0.1 g of dried mucilage powder has been placed in a clean test tube. Then, two drops of the freshly prepared Molisch reagent were also introduced. Finally, concentrated sulfuric acid has been added gradually to the side of the tube to form a layer above the aqueous solution. The observations have been done [22,23,24].

2.1.3.3 Iodine test

This test is used to confirm the presence or absence of starch in the mucilage. 0.1 g of dried mucilage powder has been added to 1 ml of iodine solution at 0.2% dye in a test tube and the mixture has been observed [22,23,24].

2.1.4 PH

The pH has been determined according to AOAC [25] method. Test samples of 10 g have been diluted in 100 ml of distilled water. The resulting solution was filtered on Whatman paper. The pH was measured using a HANNA pH-meter, previously calibrated in the filtrate obtained.

2.1.5 Nutritive compounds determination

Ash content is the one described by AOAC [25] that consists to incinerate in a muffle furnace at 550℃ during 24 h a sample until the obtaining of white ashes.

Polyphenols content was determined using the method reported by Singleton and other [26].

The contents in fat matters have been determined according to the method described by AFNOR [27] and using the Soxhlet as extractor.

The raw proteins have been determined according to the method of Kjeldhal [25] from the dosage of the total nitrogen.

Soluble and insoluble fiber fractions were analyzed according to AOAC [28] Method, an enzymatic-gravimetric procedure [29].

Carbohydrates content has been determined by difference according to the following formula [30].

$$\% \text{ Carbohydrates} = 100 - (\% \text{ Lipids} + \% \text{ proteins} + \% \text{ Ash} + \% \text{ fibers})$$

Energy value of the samples has been calculated from the specific coefficients for proteins, lipids and carbohydrates [30].

$$\text{Energy (kcal/100 g)} = (\% \text{ Proteins} \times 2.44) + (\% \text{ carbohydrates} \times 3.57) + (\% \text{ Lipids} \times 8.37)$$

The results of ash, fibers, proteins, lipids and carbohydrates contents were expressed on dry matter basis.

2.2 Statistical Analysis

The statistical processing of the data consisted of an analysis of variance (ANOVA) with a classification criterion using the SPSS software (SPSS 16.0 for Windows, SPSS Inc.). Means were compared by the Newman Keuls test at the 5% significance level. A principal component analysis (PCA) was also carried out using STATISTICA software (STATISTICA version 7.1) in order to structure the variability between mucilages and nutritive content

3. RESULTS

3.1 Characterization of Mucilages

The yields of mucilage differentiate (p <0.001) the mucilaginous food plants retained. The various mucilages extracted are shown in Fig. 1. Preliminary mucilage confirmation tests (Molisch test, ruthenium red test and iodine test) were all positive with the various mucilages (Table 1).

The highest levels of mucilage were found in *B. mannii* (63.00 ± 2.69%) and *I. gabonensis* (56.34 ± 5.44%), contrary to *A. esculentus* (34.86 ± 5.27%) and *C. olitorius* (25.81 ± 4.13%) (Table 2).

The pH differentiated the extracted mucilages to p<0.001; it varied respectively from 5.17 ± 0.09 to 6.51 ± 0.12 (Table 2).

Scanning electron microscopy (SEM) photographs revealed that *A. esculentus* (A) mucilage exhibited an irregular planar structure with particles when *B. mannii* (B) showed an ovoid-shaped structure. The mucilage of *C. olitorius* (C) consists of concretions with fine particles. In parallel *I. gabonensis* (D) is composed of smooth microplates with regular contours (Fig. 1).

Table 1. Preliminary confirmation tests of mucilages

Plants	Molisch test	Ruthenium red test	Iodine test
I. gabonensis	+	+	+
B. mannii	+	+	+
A. esculentus (koto)	+	+	+
C. olitorius	+	+	+

Table 2. pH and mucilage yields

Plants	Mucilage yields (%)	pH
I. gabonensis	56.34±5.44[b]	6.16±0.13[b]
B. mannii	63.00±2.69[a]	5.33±0.09[c]
A. esculentus koto	34.86±5.27[c]	6.51±0.12[a]
C. olitorius	25.81±4.13[d]	5.17±0.09[c]
F	113.70	100.1
p-value	<0.001	<0.001

On the same line, the averages (n=3) ± SD carrying the same letter is statistically identical at (p≤0.05) F, Fischer statistical value to the ANOVA; p-value, probability value of the ANOVA

3.2 Nutritive Compounds Determination

The ash, total polyphenols, lipids, proteins and insoluble fibers differentiated the studied mucilages to p< 0.001. The total ash and total polyphenols contents varied from 4.11 ± 0.19 to 10.71 ± 0.20% and 0.60 ± 0.09 mg/100g at 104.32 ± 6.50 mg/100g. Lipids are obtained in *C. olitorius* (0.45 ± 0.10%) and *A. esculentus* (0.17 ± 0.04%). Protein contents range from 1.81 ± 0.17% to 2.73 ± 0.08%. The insoluble fibers varied respectively from 1.89 ± 0.13% to 3.22 ± 0.04%. There was no significant difference between mucilages in soluble fiber (p = 0.559), total carbohydrate (p = 0.814) and energy (p = 0.885). Energy values generated varied between 36.66 ± 17.44 kcal/100 g and 50.71 ± 30.22 kcal/100 g (Table 3).

3.3 Variability of the Mucilage Nutritive Compounds

The principal analysis components has been done while considering the first two factors (F1 and F2) that accumulate the most important proportion of the variability (88.13%). The projection of the nutritive content of the studied mucilages is presented on the Fig. 2. This representation distinguishes the mucilages of *I. gabonensis* by the biggest content in soluble fibers, whereas the mucilages of *B. mannii* are correlated to the most important contents in polyphénols, energy and in carbohydrates. Concerning the mucilages from the variety koto of *A. esculentus*, they generate the best contents in insoluble fibers and ash; whereas those of *C. olitorius* are provided well in proteins and lipids.

4. DISCUSSION

The interest in the industrial world for mucilages explains itself by several reasons to know the

Table 3. Physicochemical content of mucilages

Parameters	*I. gabonensis*	*B. mannii*	*A. esculentus* (koto)	*C. olitorius*	F	p-*value*
Ash (%)	4.11±0.19[d]	5.32±0.19[c]	10.71±0.20[a]	6.89±0.17[b]	677.60	<0.001
Polyphenols (mg/100 g)	0.60±0.09[d]	104.32±6.50[a]	13.09±1.14[c]	22.74±0.86[b]	586.27	<0.001
Lipids (%)	ND	ND	0.17±0.04[b]	0.45±0.10[a]	24.83	<0.001
Proteins (%)	2.44±0.28[b]	1.81±0.17[c]	3.29±0.16[a]	2.73±0.08[b]	31.21	<0.001
Insolubles fibers (%)	1.89±0.13[c]	2.73±0.09[b]	3.22±0.04[a]	2.90±0.22[b]	50.20	<0.001
Solubles fibers (%)	80.34±5.58[a]	77.17±8.30[a]	72.86±7.63[a]	79.53±5.03[a]	0.736	0.559
Carbohydrates (%)	8.77±6.59[a]	12.97±8.58[a]	9.75±7.69[a]	7.61±5.01[a]	0.315	0.814
Energy (Kcal/100 g)	37.29±23.24[a]	50.71±30.22[a]	44.29±26.79[a]	36.66±17.44[a]	0.212	0.885

On the same line, the averages (n=3) ± SD carrying the same letter is statistically identical at (p≤0.05) F Fischer statistical value to the ANOVA; p-value, probability value of the ANOVA

availability, the low production costs, and the beneficial effects on the health of the consumers [31,32,33]. Today, numerous prospecting are carried out in order to discover hydrocolloids more suited to the needs of industrial. This need has more or less guided our work, the results of which have shown two trends. Edible parts of plants with high mucilage contents represented by *B. mannii* (63.00%) and *I. gabonensis* (56.34%) followed by *A. esculentus* (34.86%) and *C. olitorius* (25.81%). Similar results have been obtained on *Bombax costatum* (45%) and *Grewia venusta* (20%) [34] as well as on *B. costatum* (46,5%) and *Cissus populnea* (29,8%) [35]. Much work has been done on *A. esculentus*, including [36], which reported a very high yield of 57%, when Rajendra and other [37] were able to extract only 9.5% of mucilage. At the same time, our results on *C. olitorius* are close to the 29.18% revealed by Muazu [38]. According to Estevez [39], this variability observed in the levels of mucilage could be explained by the extraction methods, the variety, the stage of maturity of the parts analyzed, as well as the environmental conditions.

Mucilaginous food plants are known in many parts of the world for their nutritional values [40, 41] and the possibilities of mucilages using extracted are numerous [42,43]. These plants occupy a place of choice in the diet of the populations of several regions of Cote d'Ivoire. The studies of characterization done on the mucilages of *B. mannii*, *C. olitorius*, *I. gabonensis* and *A. esculentus* revealed quite high concentrations of ash. Several studies, including Capitani [44] and Muñoz [45] on mucilages of *Salvia hispanica* have given high yields of 10.27% and 8.07% respectively. This abundance of ashes and consequently of minerals appears to be due to the role played by the minerals in the viscosity of the mucilages. Indeed, calcium would be implicated in the reduction of viscosity [46], and also according to Sagou [47], sodium, at the origin of the saltiness, would increase the viscosity and would generate the tolerance of some halophytes to the concentrations raised in salt [48]. What appears to be expressed by Zahrau and other [49] by claiming that the viscosity of the mucilages is the result of the interactions between carbohydrates, proteins and minerals? This characteristic of mucilages to concentrate minerals could be used in the fight against the deficits of certain minerals such as Fe, Mg, Ca and Zn whose deficiency causes anemia and threatens the vital prognosis of the mother and the child [50]. However, apart from the ashes, overall concentrations of the other parameters were lower compared to the values of the parts of plants used [51]. To the origin, the MFPs investigated showed weak contents in fat matters, but *Irvingia* kernels whose strong contents required previous a délipidation before the extraction of mucilages [52,53]. Our results are supported by those of Oladipo and Nwokocha [54] and Thanatcha and Pranee [55] with respective grades of 1.02% and 0.12%. This quasi-absence of fat in mucilages is an asset in the fight against obesity and certain metabolic diseases [56,57]. Unlike the mucilage of animals whose main component is protein origin, that of the plants is based on the polysaccharides [58, 59], which explains the protein weakness observed in the mucilages.

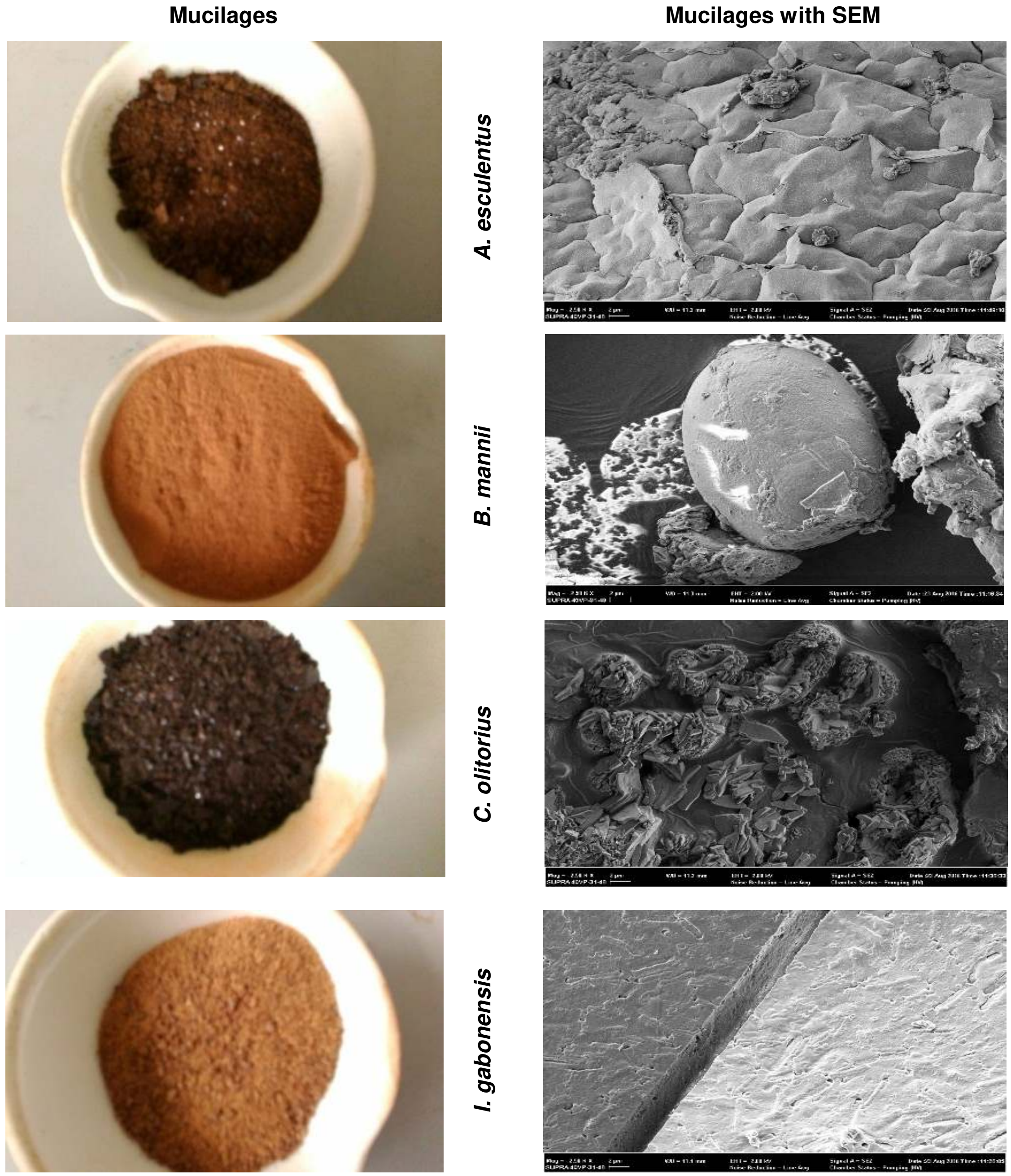

Fig. 1. Mucilages with SEM

The analysis of the fibers showed that mucilages are composed mainly of soluble fibers to more than 72%, which is also confirmed by the work of Thanatcha and Pranee [55]. Nowadays, the extracts of mucilages are conditioned in capsules and are sold in slimming diets due to the low energy value. Nazni and Vigneshwar [60] obtained low calorific values (74.5 kcal/100 g) comparable to ours on okra mucilages. The energizing contributions of mucilages proved to be very weak to the look of the caloric contributions of the plants parts (*I. gabonensis*, 707.68 kcal and *B. mannii*, 379.61 kcal) from which they originated [61]. The absence of significant difference between the mucilages in soluble fiber and in energy values would be an advantage to be exploited.

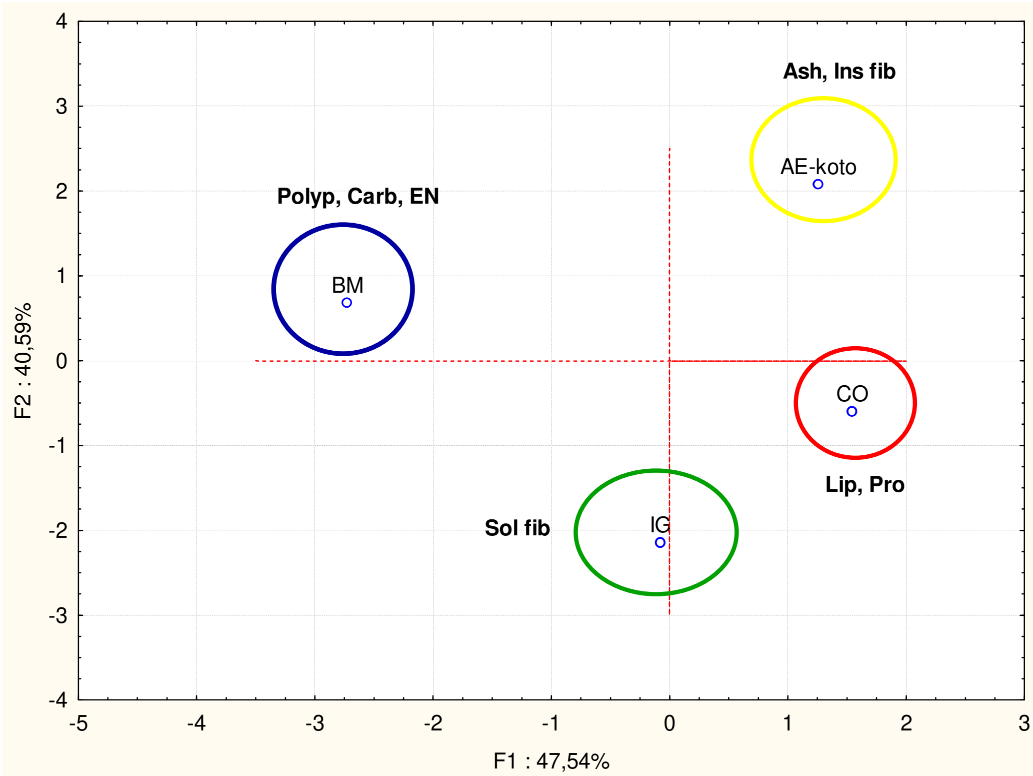

Fig. 2. Principal analysis components of nutritive compounds

Polyp, polyphenols; Carb, carbohydrate; EN, energy; Ins fib, insoluble fiber; Sol fib, soluble fibre; Lip, lipids; Pro, proteines

The comparison of mucilages composition extracted in relation to previous works on the MFPs reveals three tendencies: to the level of the concentrations in polyphenols, in lipids and in energizing value, we observed a drastic decrease going from 76.28 to 96.32%, of 92.22 to 100% and of 79.55 to 93.43% respectively. For proteins, the decreases were less strong and included between 53.52 and 78.46%. Contrary to the general decrease observed the concentrations in ashes and therefore in minerals increased of 3.98 to 54.81%. The observations made to the level of the proteins and minerals could confirm their importance in the mucilages working mechanism.

5. CONCLUSION

The study of the physicochemical characterization and the determination of the mucilage content of *I. gabonensis*, *B. mannii*, *A. esculentus* and *C. olitorius* showed a non-negligible source of ash and soluble fiber. Mucilages are low in energy. Of the different plants studied, *B. mannii* is the richest in mucilage with an ovoid-shaped structure. The interesting properties of the mucilages studied could be used in the fight against certain metabolic pathologies as well as diseases related to essential mineral deficiencies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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