Advances in Biochemistry
2024, Vol. 12, No. 4, pp. 125-135
https://doi.org/10.11648/j.ab.20241204.12

Research Article

Quantitative Analysis of the Polyphenols Contained in the Mucilage Extracted from Barks and Baobab Leaves (*Adansonia digitata L*)

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Abstract

This work focuses on a phytochemical study of the mucilage contained in the leaves and barks of African baobab (*adansonia digitata L*). The objective of this phytochemical study is to determine the presence of polyphenols in the mucilage derived from baobab leaves and bark. These phenolic compounds are vital for maintaining optimal health, as they combat the presence of fats and cardiovascular disease. To achieve this, we used several samples. The leaves or barks samples were collected from three different sites: Boof Poupouye (Fatick region), Ngoh é(Diourbel region) and Tanime (Thi ès region). Ethanol and acetone were used as extraction solvents. To extract total polyphenols or each type of polyphenol contained in the mucilage, appropriate extraction methods was performed. Thus, to determine the rates of total polyphenols, flavonoids, condensed tannins and water-soluble tannins contained in the mucilage extracted from barks and leaves, we used respectively the method of Folin-Ciocalteu, Marinova and collaborators, and one based on the reaction with iron trichloride and the colorimetric method. The content of polyphenols depends to many factors such as the site, the extraction solvent and plant organs (barks or leaves). Indeed, in all the sites studied, the results showed that the concentration of total polyphenols and flavonoids were relatively higher in the leaves than in the barks. A similar result was obtained for tannins within the sites of Boof Poupouye and Tanime. On the other hand, in the Ngoh é site, the rates of condensed tannins and water-soluble tannins were higher in the barks. In all the cases studied, the highest rates were noted in the ethanolic extracts. The predominance of some factors (site, extraction solvent and plant organ) on variations of polyphenols and flavonoids was confirmed by statistical studies (ANOVA) while the tannins difference were more relatives to the chemical nature or operating methods.

Keywords

Phytochemical Study, Mucilage, Baobab (*Adansonia digitata L*), Extraction, Total Polyphenols, Flavonoids, Tannins

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Received: 29 September 2024; **Accepted:** 17 October 2024; **Published:** 11 November 2024

1. Introduction

Africa is abundant in a variety of plant species known to be rich in health-promoting compounds, but many of which remain undiscovered or unused by western societies [1]. The baobab tree, (*Adansonia digitata L*) has many uses in several applications such as in traditional medicine, food additives, or fruit juice for drinks [2]. In Senegal, the baobab (*Adansonia digitata L.*) is a mythic tree which grows in wild environment [3, 4]. It is also found in all semi-arid and sub-humid regions of intertropical Africa, as well as in the island of Madagascar [5, 6]. However, the African baobab (*adansonia digitata L*) widely present in Africa is an adequate source of mucilage. Mucilage is a water-soluble, sticky, gummy substance obtained from certain plants. Within plants, it acts as a membrane thickener and food reserve. The gums swell in water to form sticky aqueous colloidal dispersions. Mucilage is present in almost all parts of various categories of plants in relatively small proportions [7] and mainly consists of natural polymers used in different pharmaceutical formulations. They can easily be used as pharmaceutical excipients [8, 9] in so far as they are non-toxic, biodegradable and cost-effective.

In recent years, plant-derived polymers, such as mucilage have attracted great interest due to their various pharmaceutical applications such as diluent, binder, disintegrant in tablets, thickeners in oral fluids, protective colloids in suspensions, agents gelling in gels and bases in suppositories. They are also used in cosmetics, textiles, paints and papermaking. These natural hydrocolloid gums and mucilage are biocompatible, less expensive and easy to obtain. They are preferred over semi-synthetic and synthetic excipients due to their low toxicity, low cost, easy availability, soothing action and non-irritating nature. The demand for these substances is increasing and new sources are being developed [10].

In this present work, quantitative studies were carried out on some components of mucilage such as phenols, flavonoids and tannins. We first extracted each type of substances contained in the mucilage of bark and leaves of baobab using appropriate methods. These parts of the baobab are rich in vitamin C which contributes to its capacity as a total antioxidant [1, 11, 12], and constitute a good source of polyphenols, including certain flavonoids [1, 13, 14]. Then, three sites (Boof Poupouye, Ngoh é and Tanime) in two different regions of Senegal (Fatick and Diourbel) were visited and comparative studies were carried out on their influences on the quantities of phenols, flavonoids and tannins contained in the mucilage. The UV-visible spectrophotometer method allowed us to determine the corresponding rates after extraction. On the other hand, numerous studies carried out on baobab mucilage in different countries or regions have revealed disparities as to the nature and content of the constituents; comparison work will therefore be carried out at the end of this study.

2. Experiments

2.1. Plant Products and Solvents Used

To carry out this study, we collected two types of plant organs from three different sites: baobab leaves and bark, which we dried for 15 days in the shade. Three solvents were used in this study including ethanol (96%, m/m), acetone (99%, m/m) and distilled water. Ethanol and acetone were used as extraction solvents while water was used to wash the plant organs.

2.2. Apparatus

In this work, we used a desiccator to preserve the powder obtained and a grinder to grind the different plant samples. An UV-visible spectrophotometer was used to measure the absorbance of the extracted solutions. We also used a pH meter and a conductivity meter to monitor the pH and conductivity of the samples respectively, as well as a stirrer for homogenization of the mixture.

3. Procedures and Measurements

3.1. Determination of Soil Grain Size in Harvesting Areas

In this study, soil samples were collected from the three harvest sites (Boof Poupouye, Ngoh é and Tanime), in the hope that their analysis could lead to an explanation of the difference in content of the collected mucilage. Hence, we set out to determine the soil particle size using the sieving method which consists of separating the different types of sand using an electromagnetic sieve, equipped with separation sieves. From each sample, 100 g of soil are taken which are poured onto a rotating magnetic stirrer equipped with a separation sieve whose mesh is well defined. Sands retained by the mesh with a diameter less than 0.002 mm are considered clays. Silt, fine sand, medium sand, coarse sand and very coarse sand are respectively retained by meshes with diameters between 0.05 and 0.02 mm, 0.25-0.1 mm, 0.5 -0.25mm, 1-0.5mm and 2-1mm. After 15 min of stirring at 80 rpm, the contents of the sieves are weighed using a precision scale.

3.2. pH and Ionic Conductivity Measurements of the Soil

The measurements were carried out in accordance with the AFNOR standard [15]. Thus, 10 g of "fine earth" dried then sieved were taken and mixed with 25 mL or 50 mL of distilled water, for pH and conductivity measurements, respectively. Afterwards, the mixture was boiled and cooled, before using a pH meter and a conductivity meter for analytical measurements.

3.3. The Mucilage Extraction Method

10 g of each powder (barks or leaves) soaked in 100 mL of distilled water was put into a muslin bag divided by eight to remove the pomace from the solution. The resulting filtrate was collected separately in two small beakers. Acetone and ethanol were added separately to these two beakers in an amount corresponding to three times the volume of the total filtrate. The precipitated mucilage from both beakers was removed by rolling it gently with a glass rod and collected separately in two different Petri dishes. The mucilage was then dried by keeping the dishes in an oven at 50 ℃. The dried mucilage powder was scraped, ground using a mortar and pestle and weighed. The powder obtained was therefore stored in a desiccator [16].

3.4. Dosage of Total Polyphenols of the Mucilage

The dosage of total polyphenols was carried out through the Folin-Ciocalteu method [17]. In an alkaline medium, the Folin-Ciocalteu reagent was reduced to blue-colored tungsten and molybdenum oxide by polyphenols. The intensity of this blue color would provide information on the content of total polyphenols in the mixture [17]. The polyphenols exhibited an absorption maximum at 760 nm with intensity proportional to the quantity of polyphenols present in the sample.

A sample of 125 µL of suitably diluted extract was placed in a tube in the presence of 500 µL of distilled water and 125 µL of Folin-Ciocalteu's reagent. After vigorous stirring and resting the mixture for 3 min, 1250 µL of a 7% Na_2CO_3 solution were added, and the mixture is adjusted to 3 mL with distilled water. The tube was placed at rest for 90 min at room temperature and then kept away from light. A standard range was prepared with gallic acid at concentrations of 50, 100, 200, 300, 400 and 500 µg mL^{-1}. The corresponding absorbances were determined at a wavelength of 760 nm. From the value of these absorbances, we deduced the contents of phenolic compounds which were expressed in mg of gallic acid equivalent per gram of dry matter (mg EAG/g MS).

The content of total polyphenols (TPT) was calculated from the curve gallic acid calibration test and the results were expressed in milligram-equivalent of gallic acid per gram of dry matter.

$$TPT = \frac{C \times V}{M} \quad (1)$$

Where C was concentration extracted in µg/mL, V the volume in mL and M the weight in mg.

3.5. Dosage of Flavonoids of the mucilage

To carry out the dosage of flavonoids in the extracts of baobab leaves or barks, we first used the method of Marinova and collaborators [18] to detect their presence in these various extracts. Then, we used the method of Zhishen and collaborators [19] to quantify them. The principle of such methods was based on the oxidation of flavonoids using aluminum trichloride ($AlCl_3$) and sodium nitrite ($NaNO_2$) as reagents. Aluminum trichloride have formed a yellow complex with flavonoids and sodium nitrite have formed a pink complex which absorbs at 510 nm.

Thus, to carry out this work, we proceeded as follows:

To 0.75 mL of 5% (m/v) $NaNO_2$, we added 0.75 mL of 10% (m/v) $AlCl_3$ and 2.5 mL of extract (barks or leaves) samples of baobab. After 6 min of reaction in the dark at room temperature (30 ± 1 ℃), 5 mL of NaOH (1 M) was added to the mixture. Then, the volume of the mixture was adjusted to 25 mL with distilled water. The whole mixture was shaken vigorously. Finally, the absorbance of the solution obtained was measured with a spectrophotometer at the wavelength λ=510 nm. The content of total flavonoids measured was expressed in mg EQ (Quercetin Equivalent) per g of dry matter.

3.6. Dosage of Water-soluble Tannins of the Mucilage

This method was based on a reaction with iron trichloride. The mixture of tannic extract added to the ferric trichloride reagent ($FeCl_3$) causes a purple red color of the complex, hence the formation of (Fe^{3+}) ions [20, 21].

For the dosage of hydrolysable tannins, 0.2 g of each crushed organ of our plant was macerated for 18 hours in 10 mL of 80% methanol. After maceration, the mixture was filtered. 1 mL of the filtrate was added to 3.5 ml of a solution prepared based on ferric trichloride ($FeCl_3$) at 0.01 M in hydrochloric acid (HCl) at 0.001 M. After 15 seconds of addition of the reagent, the absorbance of the mixture was read at a wavelength λ = 660 nm using an UV-visible spectrophotometer.

The hydrolysable tannin contents were expressed through the following formula:

$$HT(\%) = \frac{A \times M \times V}{Emole \times P} \quad (2)$$

Where HT was the content of hydrolysable tannins, A the absorbance, E mole was the constant expressed in moles (= 2169 of gallic acid), M was the mass, V is the volume of the extract used and P the weight of the sample.

3.7. Dosage of Condensed Tannins of the Mucilage

The dosage of condensed tannins is carried out through colorimetric method based on the depolymerization of condensed tannins in the presence of sulfuric acid. Under the effect of vanillin, these tannins are transformed into anthocyanidins in a specific red color [22].

To carry out this work, we proceeded as follows:

A 0.05 mL aliquot of the aqueous extract is added to 3 mL

of vanillin (4%) and 1.5 mL of concentrated H_2SO_4. After 15 min of incubation at room temperature, the absorbance is measured at 500 nm.

Next, a standard range of catechin was prepared, under the same conditions as the samples, for concentrations ranging from 0 to 100 mg L^{-1}. The condensed tannin contents of the extracts were expressed in mg of catechin equivalent per gram of dry matter (mg EC /g dry matter). Condensed tannin contents were expressed using the formula:

$$CT\ (\%) = \frac{(5{,}2 \text{ x } 10^{-2} \text{x Abs x V})}{\text{P}} \quad (3)$$

Where CT was the content of condensed tannins, 5.2 x 10^{-2}: constant expressed in equivalent of cyanidins, Abs: absorbance, V: volume of the extract used, P: weight of the sample.

4. Results and Discussions

4.1. Soil Study in Harvest Areas

In this part, we have determined some factors relative to the soils that can affect the development of plants. These factors can be the nature of the soil, the pH and the ionic conductivity of the soils.

4.1.1. Soil Granulometry Determination

The analysis of the soil of the three sites studied (Boof Poupouye, Ngohé and Tanime) on the basis of the method described in section 3-1, enabled us to determine the contents of the various components (clay, silt, fine sand, medium sand, coarse sand and very coarse sand). At each site, eight samples were studied, and the results of this analysis were summarized in Table 1.

Table 1. *Granulometry of the soil from the three sites of harvest.*

Sites	Samples number	Clay (%)	Silt (%)	Fine sand (%)	Medium sand (%)	Coarse sand (%)	Very coarse sand (%)	Total sand (%)
BOOF POUPPOUYE	B1	0	0.11	1.16	93.49	5.04	0.2	99.89
	B2	0	0.44	1.01	92.95	4.97	0.63	99.56
	B3	0	0.99	2.65	92.14	3.67	0.55	99.01
	B4	0	0.53	2.10	93.31	3.82	0.24	99.47
	B5	0	0.15	1.60	94.04	4.02	0.19	99.85
	B6	0	1.25	1.56	92.79	4.05	0.35	98.75
	B7	0	0.21	1.20	94.73	3.69	0.17	99.79
	B8	0	1.89	2.35	92.07	3.33	0.36	98.11
NGOHE	N1	0	0	4.67	77.12	15.96	2.25	100
	N2	0	0	4.49	81.46	10.79	3.26	100
	N3	0	0.11	1.12	67.86	27.11	3.8	99.89
	N4	0	0.34	0.92	72.09	23.37	3.28	99.66
	N5	0	0	2.69	85.04	11.44	0.83	100
	N6	0	0	1.40	87.90	10.12	0.58	100
	N7	0	0	1.35	84.69	12.87	1.09	100
	N8	0	0.93	0.84	90.67	7.23	0.33	99.07
TANIME	T1	0	0.06	1.47	95.81	2.53	0.13	99.94
	T2	0	0.85	1.02	94.07	3.95	0.11	99.15
	T3	0	0.17	1.07	95.23	3.32	0.21	99.83
	T4	0	0.34	0.85	95.46	3.06	0.29	99.66
	T5	0	0.84	2.1	93.4	3.64	0.02	99.16
	T6	0	0.91	1.61	94.11	3.36	0.01	99.09

Sites	Samples number	Clay (%)	Silt (%)	Fine sand (%)	Medium sand (%)	Coarse sand (%)	Very coarse sand (%)	Total sand (%)
	T7	0	1.12	1.28	91.9	5.69	0.01	98.88
	T8	0	0.6	0.37	95.88	3.14	0.01	99.4

We noted for these three sites an absence of clay and a very significant quantity of total sand. The amount of silt being very low compared to the total sand, these soils were of the sandy type. These types of soil were therefore porous and unable to retain any mineral salts.

4.1.2. Measurement of the pH and Ionic Conductivity of the Soils

This study was carried out for the three different sites, and for each of them, eight samples were studied. The measurements were taken in compliance with the AFNOR standard [15] described in section 3-2. Using a pH-meter and a conductivity meter, we determined for each sample, the pH and the ionic conductivity of the soil. All the results were mentioned in Table 2.

This table shows that the pH varies according to the sites studied. Indeed, it was between 7.62 and 8.25 for Boof Poupouye, 5.92 and 7.8 for Ngoh éthen between 5.08 and 6.96 for the Tanime site. These pH values noted at the three sites respectively indicated slightly alkaline to alkaline, moderately acidic to slightly alkaline and slightly acidic to neutral soils [23]. These results could therefore indicate the existence of different nutrients in these types of soils because the pH determines the form in which the molecule exists.

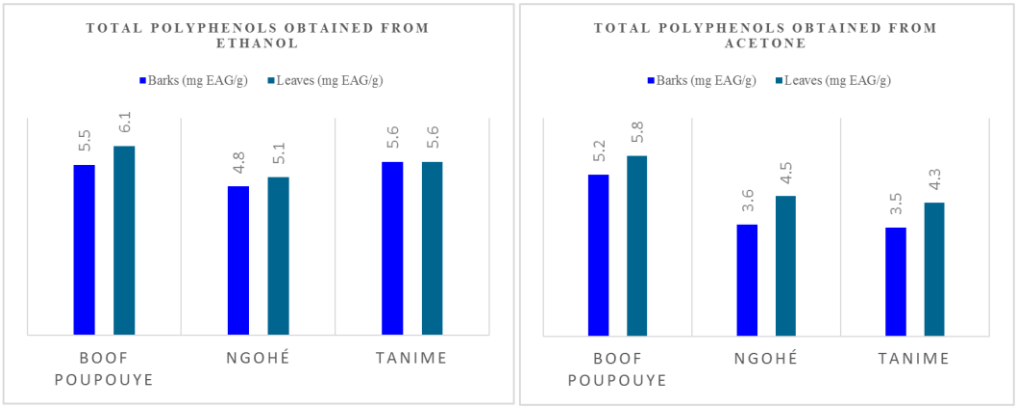
Table 2. *Analytical values of the pH and the ionic conductivity of the three sites.*

BOOF POUPPOUYE			NGOHE			TANIME		
Samples number	pH	Conductivity (µS/cm)	Samples number	pH	Conductivity (µS/cm)	Samples number	pH	Conductivity (µS/cm)
B1	8.25	84	N1	7.80	227	T1	5.15	19
B2	7.68	88	N2	7.22	181	T2	5.08	10
B3	7.62	159	N3	7.44	268	T3	6.22	13
B4	7.78	110	N4	7.23	164	T4	5.24	11
B5	7.73	104	N5	6.87	58	T5	6.42	15
B6	7.64	102	N6	7.74	75	T6	5.63	10
B7	7.63	55	N7	5.92	48	T7	6.96	27
B8	7.49	58	N8	6.54	26	T8	5.67	20

We also noted in this Table 2 that the values of the ionic conductivity varied according to the sites. However, in all the cases studied, these values were relatively low and remain below 250 µS/cm, with the exception of that obtained in sample N3 from the Ngoh é site. This indicated that the soil types studied were generally non-saline, and therefore with low salt content [23].

4.2. Total Polyphenols Content of Mucilage

Using the Folin-Ciocalteu method [17], we determined the content of phenolic compounds in each extract. The results obtained were mentioned in Figure 1. This figure shows that the total polyphenols levels depend on three factors including the plant organ, the extraction solvent and the sampling site. Indeed, we found for a given site, that these contents are higher on the leaves regardless of the solvent used. However, the highest levels obtained in the two organs studied are noted at Boof Poupouye, except in the barks where the highest amounts were noted at the Tanime site using ethanol. In all cases, we found that the contents of total polyphenols were higher in the ethanolic extracts. This difference could derive from the fact that ethanol has a more dissociating character than acetone.



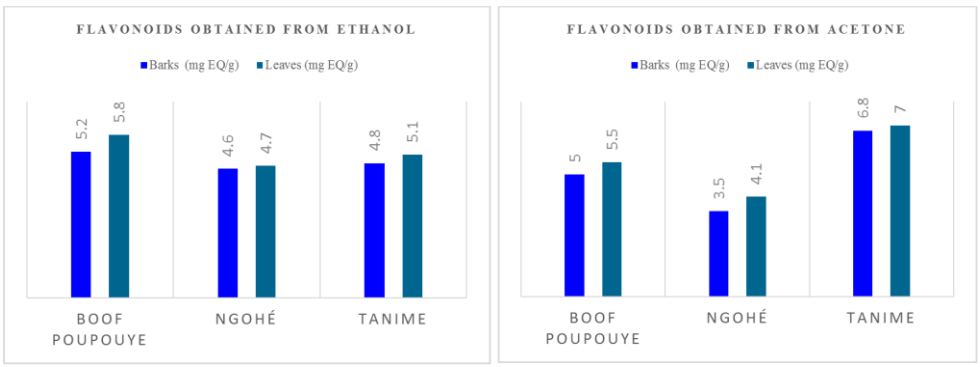
(a) (b)

Figure 1. *Average concentrations of total polyphenols of the ethanolic (a) and acetone (b) extracts (in mg EAG/g of dry matter) of the two organs (barks and leaves) from the three sites (Boof Poupouye, Ngoh é and Tanime).*

On the basis of our results and those of the literature, it was difficult to determine the origin of these disparities. Indeed, they may be due to differences in the plant organ tested (barks and leaves), in the physiological state at harvest, in the analysis methods, as well as the genotypic and geographical differences of the herbs [24]. Moreover, the low specificity of the Folin-Ciocalteu reagent was the main drawback of the colorimetric method. The reagent was extremely sensitive to the reduction of all hydroxyl groups not only those of phenolic compounds but also some sugars and proteins. Indeed, in plants, the levels of phenolic compounds and their nature were greatly modified under the action, on the one hand of external or exogenous factors, whether they were of a biotic or abiotic nature, and on the other hand, of internal factors or endogenous such as genetic factors leading to differences between species of the same genus [25]. Therefore, genetic factors were considered among the criteria of qualitative and quantitative variability of phenolic compound contents. As a result, we can proceed to the decreasing classification of the two organs of the plant according to their concentrations in total phenols: *(i)* leaves > barks and, *(ii)* ethanolic extracts > acetonic extracts.

4.3. Flavonoids Content of Mucilage

For each extract (ethanolic or acetonic), we determined the flavonoid content using the aluminum trichloride ($AlCl_3$) method [19]. The results are shown in Figure 2. This figure shows that the flavonoids content in the ethanolic extracts is higher than that of the acetone extracts except the results of Tanime study area. It is also noted that these flavonoids contents are higher on the leaves than the barks regardless of the solvent used and the site. However, in the two organs studied, the flavonoids contents of the different ethanolic extracts are higher in the Boof Poupouye site, while the largest quantities are noted in Tanime for the acetone extracts. As a result, we can proceed to the decreasing classification of the different organs of the plant according to their concentrations of flavonoids: *(i)* leaves > barks, and *(ii)* for ethanolic extracts: Boof Poupouye > Tanime > Ngoh é, and *(iii)* for acetone extracts: Tanime > Boof Poupouye > Ngoh é



(a) (b)

Figure 2. *Average flavonoids concentrations of the ethanolic (a) and acetone (b) extracts (in mg EAG/g of dry matter) of the two organs (barks and leaves) from the three sites (Boof Poupouye, Ngoh é and Tanime).*

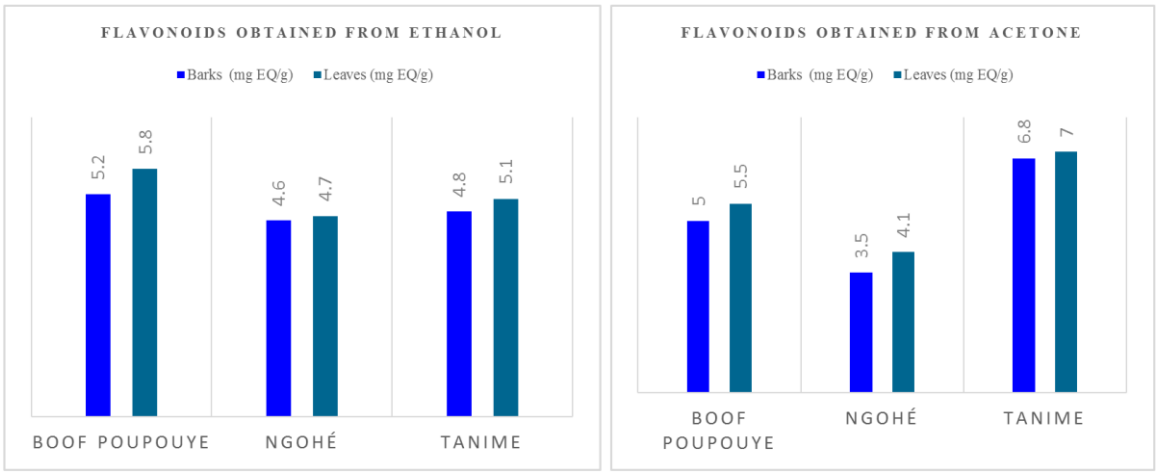
Our results are therefore in accordance with those obtained by J. G. Marco [26]. Indeed, by using different solvents in the extraction of flavonoids, this author has shown that the concentration of flavonoids in plant extracts depends on the polarity of the solvents and the parts of the plant used in the preparation of the extracts.

4.4. Content of Water-soluble Tannins and Condensed Tannins in Mucilage

4.4.1. Content of Water-soluble Tannins

In each plant organ studied, the water-soluble tannin contents of the different extracts were determined using the equation 2. The results obtained in the three sites were presented in figure 3. This figure also shows that the water-soluble tannin contents vary depending on the solvent, the location of the site and the plant organ studied.

We note that tannin concentrations are generally higher at Boof Poupouye and Tanime. However, in all the cases studied, the ethanolic extracts presented higher values than that of the acetonic one. The variations noted on the concentrations of tannins according to the sites, could be due to the experimental conditions. This result is in accordance with the results obtained by F. Deba and collaborators [27]. These authors have shown that the variations noted in the tannin concentrations can be explained by the fact that the extraction of tannins depends on their chemical nature, the solvent used and even the operating conditions. Figure 3 could confirm that these variations in the case of our study could be due either to the chemical nature of the tannin or to the experimental conditions. However, in the three sites studied, these contents follow the order below: *(i)* ethanolic extracts > acetonic extracts; *(ii)* for Boof Poupouye and Tanime, leaves > barks, and *(iii)* for Ngoh é barks > leaves.



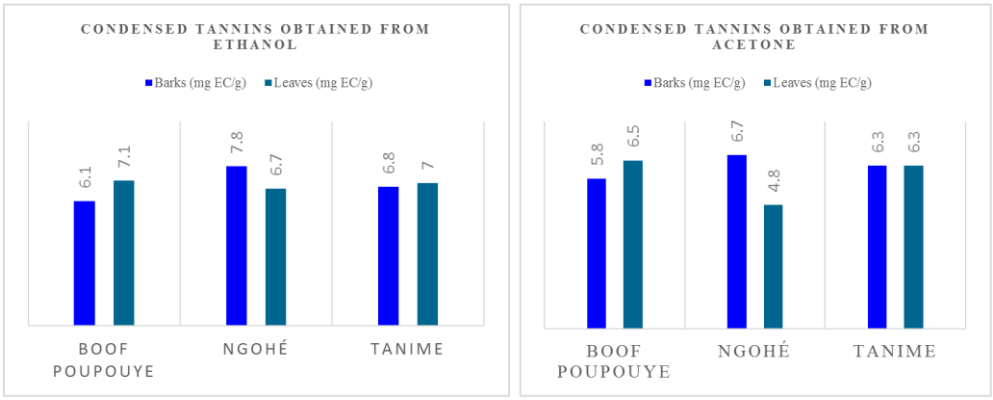
(a) (b)

Figure 3. *Average concentrations of water-soluble tannins in the ethanolic (a) and acetone (b) extracts (in mg EC/g of dry matter) of the two organs (barks and leaves) from the three sites (Boof Poupouye, Ngoh é and Tanime).*

4.4.2. Content of Condensed Tannins

Using equation 3, we determined for each extract, the level of condensed tannins. The results are mentioned in Figure 4. This figure also shows for each site that the condensed tannin contents are higher in the ethanolic extracts, regardless of the plant organ studied. However, in the different sites studied, these contents follow the following decreasing order: *(i)* ethanolic extracts > acetonic extracts; *(ii)* for Boof Poupouye and Tanime, leaves ≥ barks, and *(iii)* for Ngoh é barks > leaves. These rates therefore vary according to the solvent, but also according to the site and the plant organ studied. As in the previous case, the plot processing showed no predominant factor. This also shows that these results could depend on the chemical nature of the tannins, but also on the experimental conditions.

The presence of these tannins in the plants studied show that they could have important therapeutic effects. Indeed, B. Tepe and collaborators [28] have shown in their study that the presence of tannins in a plant indicates its capacity to play a major role as an antimicrobial and antioxidant agent.



(a) (b)

Figure 4. *Average concentrations of condensed tannins of ethanolic (a) and acetone (b) extracts (in mg EC/g of dry matter) of the two organs (barks and leaves) from the three sites (Boof Poupouye, Ngoh é and Tanime).*

5. Statistical Processing of Results

The dosage results of the founded mucilage contents are expressed as the average of three measurements ± the standard deviation, thus they are submitted to the analysis of variance with a single classification criterion (ANOVA 1), at the 5% threshold, to highlight the effect of the factors which are in our case the extracts of the organs of the studied plant, the harvesting area and the extraction solvent. This analysis is carried out for the comparison between the average values corresponding to the different concentrations and to the different contents of the organic compounds in mixture on the extracts of leaves and barks.

Table 3 shows that only the solvent and region (site) factors have a more or less significant effect on the polyphenol's concentration. In the three sites studied, no noticeable variation was seen between the textures of the soil, nor of the ionic conductivity. The results indicate saline and sandy soils regardless of the site studied. However, the pH of the soils of Tanime was acidic (very acidic; moderately acidic and slightly acidic) while the site of Boof Poupouye had soils that slightly alkaline and that of Ngoh é possessed lightly alkaline and neutral soils. pH and solvent factors could be the cause of this observed disparity.

As for the concentration of flavonoids, analysis of variance (Table 4) on the three factors (species, solvent and sites) showed significant effect. However, solvent and site factors played a more determining role. In the three sites, we noted that the soils are generally saline and sandy. Therefore, the disparity observed in the flavonoid contents could be essentially linked to soil pH, which varies from one site to another, and to the solvent.

One can see that, the ANOVA statistical analysis carried out on the species, the solvent and the site, ended up showing that these factors were indeed decisive on the composition of the mucilage. It can be noted that the extraction solvent has more impact on the quantification of polyphenols and flavonoids even if the characteristics of the sites are not to be neglected. However, for water-soluble tannins, these factors had no effects on their quantification (Tables 5 and 6).

Table 3. *Statistical study on the factors that can influence Total Polyphenols (mg EAG/g) contents.*

> P= lm(Polyph énols -ESPECES+SOLVANT+REGION, data=Poly)

> anova (P)

Analysis of variance Table

Reponse: Polyphenols

	Df	Sum Sq	Mean Sq	F value	Pr (> F)	Meaning
ESPECES	1	0.85333	0.85333	4.7282	0.066181	.
SOLVANTS	1	2.80333	2.80333	15.5330	0.005595	**
REGION	2	2.92667	1.46333	8.1082	0.015051	*

> P= lm(Polyphénols -ESPECES+SOLVANT+REGION, data=Poly)

> anova (P)

Analysis of variance Table

Reponse: Polyphenols

	Df	Sum Sq	Mean Sq	F value	Pr (> F)	Meaning
Residuals	7	1.26333	0.18048			

meaning codes: 0 ' *** ' 0.001 ' ** ' 0.01 ' * ' 0.05 '. ' 0.1 ' ' 1

Table 4. *Statistical study on the factors that can influence Flavonoids (mg EQ/g) contents.*

> P= lm(Flavonoides - ESPECES+SOLVANT+REGION, data=Flavo)

> anova (P)

Analysis of variance Table

Reponse: Flavonoides

	Df	Sum Sq	Mean Sq	F value	Pr (> F)	meaning
ESPECES	1	0.7008	0.70083	6.448	0.038704	*
SOLVANTS	1	2.0008	2.00083	18.409	0.003608	**
REGION	2	3.3800	1.69000	15.549	0.022659	**
Residuals	7	0.7608	0.10869			

meaning codes: 0 ' *** ' 0.001 ' ** ' 0.01 ' * ' 0.05 '. ' 0.1 ' ' 1

Table 5. *Statistical study on the factors that can influence Water-soluble Tannins (mg EC/g) contents.*

> P= lm(Tanins_hydrosolubles - ESPECES+SOLVANT+REGION, data= Tahydro)

> anova (P)

Analysis of variance Table

Reponse: Tanins_hydrosolubles

	Df	Sum Sq	Mean Sq	F value	Pr (> F)	meaning
ESPECES	1	0.44083	0.44083	1.6363	0.2416	
SOLVANTS	1	0.80083	0.80083	2.9726	0.1283	
REGION	2	1.29500	0.64750	2.4034	0.1605	
Residuals	7	1.88583	0.26940			

meaning codes: 0 ' *** ' 0.001 ' ** ' 0.01 ' * ' 0.05 '. ' 0.1 ' ' 1

Table 6. *Statistical study on the factors that can influence Condensed Tannins (mg EC/g) contents.*

> P= lm(Tanins_condenses - ESPECES+SOLVANT+REGION, data= Tacon)

> anova (P)

Analysis of variance Table

Reponse: Tnains_condenses

	Df	Sum Sq	Mean Sq	F value	Pr (> F)	Meaning
ESPECES	1	0.1008	0.10083	0.1898	0.67622	
SOLVANTS	1	2.1675	2.16750	4.0795	0.08316	.
REGION	2	0.1017	0.05083	0.0957	0.90993	
Residuals	7	3.7192	0.53131			

meaning codes: 0 ' *** ' 0.001 ' ** ' 0.01 ' * ' 0.05 '. ' 0.1 ' ' 1

6. Conclusion

The results of our study showed that the amount of extracted polyphenols was greater in the leaves regardless of the extraction solvent used. Therefore, this shows that the leaves are richer in phenolic compounds. Thus, we can say that baobab mucilage was practically concentrated in the leaves. Solvent and site factors played a determining role in the extraction of total polyphenols and flavonoids as shown the ANOVA test. Indeed, the largest quantities were noted in the most polar solvent and varied depending on the site. On the other hand, the factors (species, solvent and sites) have no significant effect on the concentrations of condensed and water-soluble tannins. However, their presence provided the studied plant with a therapeutic effect, which justifies its massive use in traditional medicine. In our future works, we intend to carry out other in-depth tests as well as the characterization of all the compounds present in the baobab mucilage.

Abbreviations

Abs	Absorbance
C	Concentration Extracted
CT	Content of Condensed Tannins
Df	Degrees of Freedom
EQ	Quercetin Equivalent
HT	Content of Hydrolysable Tannins
M	Weight
Mean sq	Average Squares
Sum sq	Sum of Squares
P	Weight of the Sample
pH	Hydrogen Potential
TPT	Total Polyphenols
V	Volume

Author Contributions

Babacar Sadikh Yatte: Data curation, Investigation, Methodology, Writing – original draft

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Mohamed Sakho: Visualization

Fran çois Delattre: Conceptualization, Methodology, Writing – review & editing

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Conflicts of Interest

The authors declare no conflicts of interest.

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