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(RESEARCH ARTICLE)

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COMPARATIVE NUTRITIONAL AND PHYTOCHEMICAL CHARACTERIZATION OF THE CALYXES OF *BOMBAX BUONOPOZENSE* P. BEAUV. AND *BOMBAX COSTATUM* PELLEGR. & VUILLET CONSUMED IN IVORY COAST

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ABSTRACT

The species *Bombax buonopozense* and *Bombax costatum* are plants used in culinary and traditional practices in Ivory Coast. Although their flower calyxes are used in the preparation of sauces, data on their composition of primary and secondary metabolites remain limited. The objective of this study was to characterize and compare certain biochemical constituents of the calyxes of these two species in order to contribute to their utilization. The calyxes were dried, ground, and then subjected to various analyses. Proteins were quantified using the Kjeldahl method, lipids by Soxhlet extraction, and phenolic compounds by spectrophotometric methods. Polyphenols were determined using the Folin-Ciocalteu method, flavonoids by aluminum chloride complexation, and tannins using the vanillin method. The results show a predominance of carbohydrates, with contents of 80.59% in B. *buonopozense* and 79.67% in B. *costatum*. Protein contents are 7.72% and 11.08%, respectively, while lipids account for 3.01% and 2.51%. Ash contents are 8.68% in B. *buonopozense* and 6.76% in *B. costatum*. Both species also contain significant amounts of phenolic compounds. *B. buonopozense* stands out for having the highest levels of polyphenols, flavonoids, and tannins, 655.09, 62.21, and 93.25 mg/g of dry matter, respectively, compared to 414.19, 23.29, and 40.73 mg/g in *B. costatum*. These results highlight the nutritional and phytochemical potential of the calyxes of both species and support their value for further food and biological applications.

Keywords: *Bombax buonopozense*; *Bombax costatum*; Calyx; Valorisation

1 INTRODUCTION

Plants are an important source of food, medicinal, and socioeconomic resources for populations, particularly in tropical regions where many wild plant species contribute directly to diets and traditional health practices. In West Africa, several woody species provide food and medicinal products whose utilization still relies largely on local knowledge and practices. The plant parts that are consumed can serve as sources of macronutrients, minerals, and secondary metabolites that may be of biological interest [1]. Among these plant resources, species of the genus Bombax hold a special place. *Bombax buonopozense* and *Bombax costatum* are two species widely used in West Africa. Their calyxes are notably used in the preparation of sauces and thus constitute a traditional food resource. *B. costatum* is also recognized as a multifunctional species, with different parts used in food, traditional medicine, and other socioeconomic activities. However, the pressure exerted on this species by harvesting and resource exploitation underscores the importance of its sustainable management [2]. In Ivory Coast, the calyxes of *B. buonopozense* and *B. costatum* are consumed in certain regions, but their biochemical composition remains relatively poorly documented in the Ivorian context. This situation limits the scientific assessment of their nutritional and phytochemical value. However, studies conducted on *B. buonopozense* have shown that its calyxes contain, among other things, carbohydrates, proteins, lipids, fiber, and minerals, suggesting significant nutritional potential [3]. Recent research by Bamba *et al*. [4] has also confirmed that the calyxes of both species are rich in nutrients, minerals, and phenolic compounds, while highlighting the need to study the associated antinutritional factors. Secondary metabolites, particularly polyphenols, flavonoids, and tannins, are also of particular interest due to their potential biological properties. Polyphenols constitute an important class of plant compounds studied for their antioxidant properties and their potential role in protecting against processes related to oxidative stress [5]. Their quantification is therefore a key component in assessing the phytochemical potential of plant resources. In this context, characterizing the calyxes of *B. buonopozense* and *B. costatum* appears necessary to better understand their composition and contribute to their utilization. This study thus aims to determine several primary metabolites, notably proteins, carbohydrates, and lipids, as well as certain secondary metabolites, primarily polyphenols, flavonoids, and tannins, present in the calyxes of these two species. It also seeks to compare their composition in order to identify differences that may contribute to their nutritional and phytochemical value and to provide scientific data useful for their development in Ivory Coast.

2 MATERIALS AND METHODS

2.1 Plant Material

The plant material consists of the calyxes of two Bombax species: *Bombax buonopozense* and *Bombax costatum*.

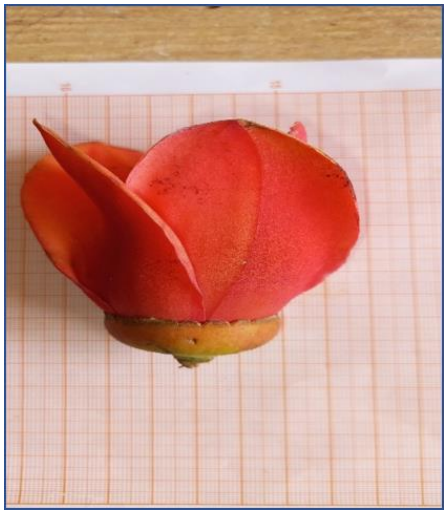


Figure 1: *Bombax buonopozense*



Figure 2: *Bombax costatum*

2.2 Methods

2.2.1 Primary Metabolites

2.2.1.1 Detection of Reducing Sugars

Reducing sugars were detected in the crude extracts using Fehling's reagent. To perform the Fehling test, 5 ml of Fehling's solution is added to 5 ml of calyx extract. After heating for 2 to 3 minutes at 70°C in a water bath, a red precipitate forms, indicating a positive reaction.

2.2.1.2 Detection of Aromatic Amino Acids

Aromatic amino acids are detected using the xanthoproteic reaction. To 3 mL of extract, 1 mL of concentrated nitric acid is added. The tube is then brought to a boil for 2 minutes. The appearance of a yellow color indicates a positive reaction, which confirms the presence of aromatic rings (benzene rings); amino acids in the aromatic series include tyrosine, tryptophan, and phenylalanine.

2.2.1.3 Protein Assay

Proteins were detected in the calyx residues using the biuret reaction. To an aliquot of Bombax calyces dissolved in 2 mL of 20% aqueous NaOH in a test tube, 2 to 3 drops of a 2% aqueous $CuSO_4$ solution were added. The appearance of a violet color, sometimes with a reddish tint, indicated a positive reaction.

2.2.1.4 Test for Gums and Mucilages

To test for gums and mucilages, 25 mL of absolute alcohol was added very slowly to 10 mL of aqueous calyx extract, all under constant stirring. The appearance of a flocculent precipitate indicated the presence of gums and mucilages.

2.2.1.5 Protein Assay

The crude protein content was determined using the Kjeldahl method [6]. A 0.5 g sample of powder from each sample was heated to 400 °C for 120 min in the presence of a pinch of the catalyst mixture (selenium + potassium sulfate (K_2SO_4)) and 20 mL of 95–97% sulfuric acid (H_2SO_4) in a digester (BUCHI, France).

The resulting mineral solution was made up to 60 mL with distilled water. At this volume, 50 mL of sodium hydroxide solution (40%, w/v) was added before the mixture was brought to a boil in a LEGALLAIS-type distiller. The ammonia released was collected in a measuring flask containing 10 mL of a mixed acid-base indicator solution (4%, w/v; methyl red + bromocresol green) at a pH of 4.4–5.8. The protein content was determined using the following formula:

$$\text{Total protein} = \frac{(V_1 - V_0) \times 14 \times 6{,}25 \times N}{m_e}$$

V_0: volume of sulfuric acid solution added for the blank test in (mL).
V_1: volume of sulfuric acid solution added for the test (sample) in (mL).
N: normality of the sulfuric acid solution (0.1 N).
me: mass (g) of the sample.
14: atomic mass of nitrogen.
6.25: conversion factor for nitrogen to protein.

2.2.1.6 Lipid Analysis

Total lipids were extracted with hexane (an organic solvent) according to the method described by [6] using the Soxhlet apparatus. Five (5) grams of dried and ground sample were placed in a pre-tared Whatman filter paper. Next, 200 mL of hexane was poured into a pre-weighed extraction flask. The flask containing the hexane (m0) was placed on the condenser and heated under reflux at 110 °C for 8 hours. After this extraction period, the flask was removed from the Soxhlet apparatus and placed in an oven at 130 °C for 1 hour to completely evaporate the solvent using a rotary evaporator. The flask was weighed after evaporation, and this weight was recorded as m1. The lipid content was determined using the following equation:

$$\text{Lipids (\%)} = \frac{(m_1 - m_0) \times 100}{m_e}$$

m_0: mass (g) of the empty flask.

m_e: mass (g) of the sample.

m_1: mass (g) of the total (flask + lipids) after evaporation of the hexane

2.2.2 Secondary metabolites

2.2.2.1 Extraction of Phenolic Compounds

Phenolic compounds were extracted with 70% (v/v) methanol. To 10mL of 70% (v/v) methanol, 1 g of the dried and ground sample was added. The resulting mixture was centrifuged at 1,000 rpm for 10 min. Next, the residue was transferred to 10 mL of 70% methanol and centrifuged again. The supernatants were combined in a 50-mL flask and diluted with distilled water to the mark. The resulting extract served as the phenolic extract for the determination of phenolic compounds.

2.2.2.2 Polyphenol Assay

The method described by Singleton *et al*. [7] was used for the polyphenol assay. A 1 mL volume of methanolic extract was added to 1 mL of Folin-Ciocalteu reagent in a test tube. The mixture was thoroughly homogenized by manual shaking. After 3 minutes, 1 mL of an aqueous sodium carbonate solution (20%, w/v) was added, and the volume was adjusted to 10 mL with distilled water. The tube was then placed in the dark for 30 minutes. Absorbance was measured using a spectrophotometer (PG Instruments, England) at 725 nm against a blank. Finally, a calibration curve was prepared using a series of gallic acid concentrations ranging from 0 to 1 mg/mL. The results were expressed in mg gallic acid equivalent (GAE)/100 g of dry matter (DM).

$$\text{Polyphenols (mg/100g)} = \frac{DO_{725} \times 5 \times 10^3}{5{,}04 \times m_e}$$

Calibration curve: $DO_{725} = 5.04$.

Mass (mg) of gallic acid

where: mass (g) of the sample.

2.2.2.3 Flavonoid Assay

The total flavonoid assay was performed according to the method described by Zhishen *et al*. [8]. To a 0.5 mL volume of methanolic extract, the following quantities were added in sequence: 0.5 mL of distilled water, 0.5 mL of aluminum chloride (10% w/v), 0.5 mL of sodium acetate (1 M), and 2 mL of distilled water. The tube was then allowed to stand for 20 minutes in the dark, and the absorbance was measured using a spectrophotometer (PG Instruments, 39 England) at 415 nm against a blank. Finally, a calibration curve was prepared using a range of quercetin concentrations from 0 to 0.1 mg/mL. The results were reported in mg quercetin equivalent per 100 g of dry matter.

$$\text{Flavonoids(mg/100g)} = \frac{DO_{415} \times 2 \times 10^3}{18{,}12 \times m_e}$$

Calibration line: $DO_{415} = 18.12$

m_e: mass (g) of the sample.

2.2.2.4 Tannin Assay

Tannin determination was performed according to the method described by (Bainbridge *et al*. [9]. A 1 mL volume of methanolic extract was taken, and 5 mL of vanillin reagent (50 g of vanillin + 4 mL of hydrochloric acid in 100 mL of distilled water) was added to this volume. The tube was then allowed to stand for 20 minutes in the dark, and the absorbance was measured using a spectrophotometer (PG Instruments, England) at 500 nm against a blank. Finally, a calibration curve was prepared using a series of tannic acid solutions ranging in concentration from 0 to 2 mg/mL. The results were expressed in mg of tannic acid equivalent (TAE)/100 g of dry matter (DM).

$$\text{Tannins} = \frac{DO_{500} \times 10^3}{3{,}11 \times m_e}$$

Calibration line: $DO_{500} = 3.11$

m_e: mass (g) of the sample.

3 RESULTS

3.1 Primary Metabolites

The results of the analysis of several primary metabolites in aqueous extracts of the calyxes of *Bombax buonopozense* and *Bombax costatum* reveal varying levels of carbohydrates, proteins, and ash. The carbohydrate content is higher, at 80% and 79%, in the aqueous extracts of the calyxes of *Bombax buonopozense* and *Bombax costatum*, respectively. The other primary metabolites are present in the following proportions: 7% protein and 4% lipids in the aqueous extract of *Bombax buonopozense*. In the aqueous extract of *Bombax costatum*, the proportions of proteins and lipids are 11% and 0.4%, respectively. The ash content in the calyx powder is 8.68% for *Bombax buonopozense* and 6.76% for *Bombax costatum* (Figure 3).

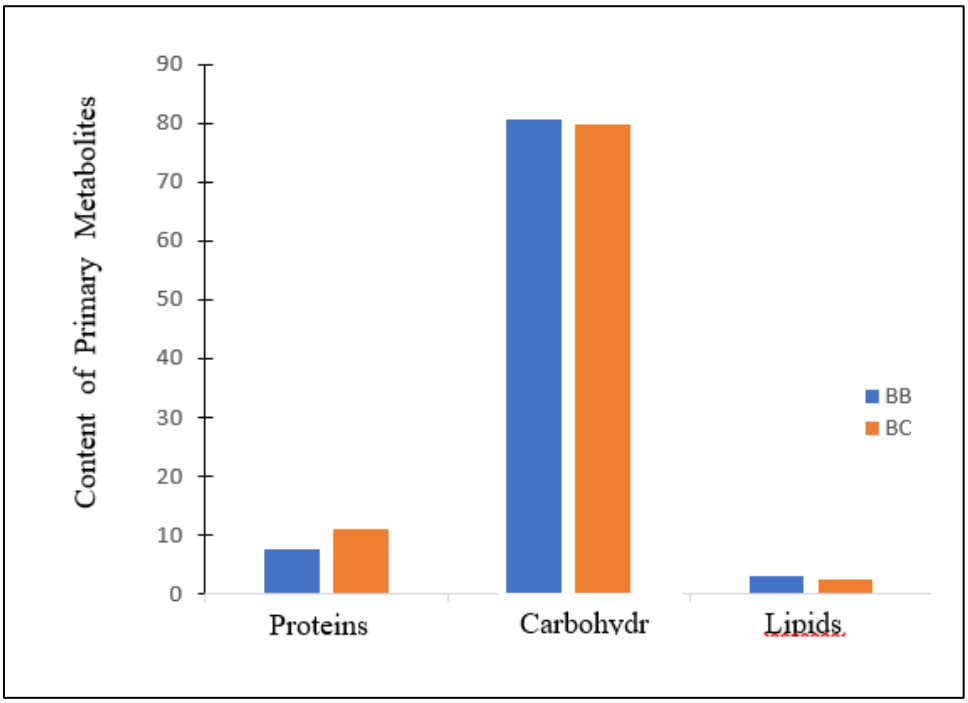


Figure 3: Composition of Primary Metabolites in the Calyxes of *B. buonopozense* and *B. custatum*

BB : *Bombax buonopozense*; **BC** : Bombax custatum

3.2 Secondary metabolites

3.2.1 Quantitative analysis of phenolic compounds

Analysis of secondary metabolites in the calyxes of *B. buonopozense* and *B. costatum* reveals that they are rich in polyphenols, flavonoids, and tannins in varying proportions. The results show that the polyphenolic content in extracts from the calyxes of *Bombax buonopozense* is higher than that of *Bombax costatum*. This content is approximately 655.09 mg, or 325 mg/g of dry matter (DM), for *B. buonopozense*, and 414.19 mg, or 200 mg/g of dry matter, for *B. costatum*. The flavonoid and tannin content is distributed as follows: 95 mg, or 47.5 mg/g of DM, for *B. buonopozense*; 45 mg, or 22.5 mg/g of DM, for *B. costatum*; 95 mg, or 47.5 mg/g of dry matter, for *B. buonopozense*, and 50 mg, or 25 mg/g of dry matter, for *B. costatum* in the extracts (Figure 4).

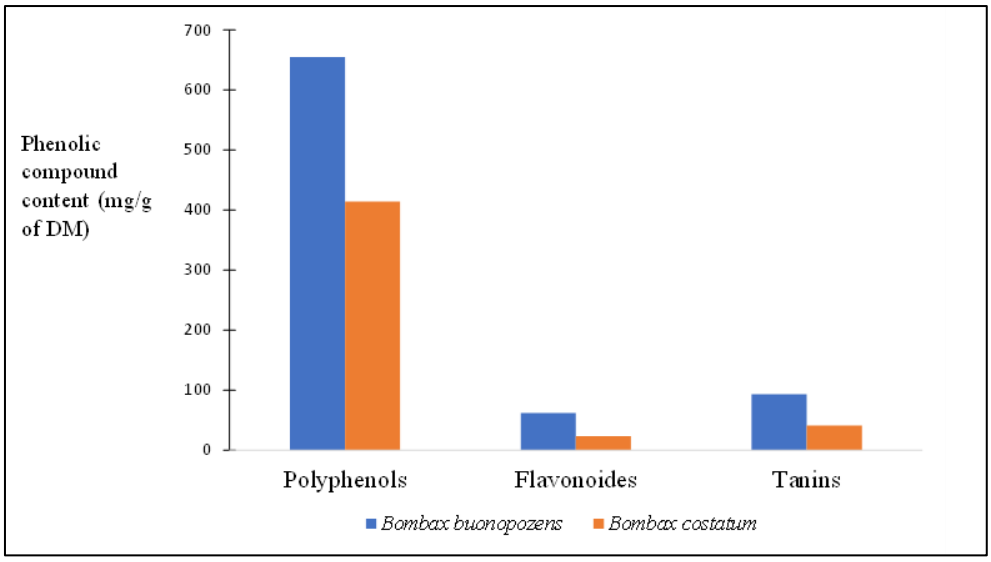


Figure 4: Phenolic Compound Content of the Calyxes of *B. buonpozense* and *B.custatum*

4 DISCUSSION

The results show that the calyxes of *Bombax buonopozense* and *Bombax costatum* have a biochemical composition dominated by carbohydrates. The recorded carbohydrate contents are 80.59% for *B. buonopozense* and 79.67% for *B. costatum*, while proteins account for 7.72% and 11.08%, and lipids for 3.01% and 2.51%, respectively. These results indicate that both species are primarily sources of carbohydrates, though proteins and lipids also make a significant contribution. The high proportion of carbohydrates observed in both species is consistent with previous studies on the calyxes of *Bombax buonopozense*. Musah *et al*. [3] reported a carbohydrate content of 66.20%, along with 7.20% protein, 3.10% lipids, and 5.50% ash in the calyxes of this species.

The protein content obtained in our study for *B. buonopozense* (7.72%) is therefore relatively close to that reported by these authors, while the lipid content (3.01%) is also comparable. In contrast, the carbohydrate content appears higher in the present study. This difference may be related to several factors, including the geographic origin of the samples, the stage of maturity, drying conditions, the extraction method, the nature of the material analyzed, and whether the results are expressed on a dry matter or extract basis. The nutritional composition of plant organs can indeed vary considerably depending on environmental conditions and preparation methods. The available data on *B. buonopozense* also show significant variations depending on whether the calyxes are analyzed fresh or after drying. The dried calyxes reported in the PROTA data, in particular, have a high proportion of carbohydrates, confirming the nutritional importance of this fraction. The protein content of *B. costatum* (11.08%) is higher than that of *B. buonopozense* (7.72%). This difference may reflect species-specific variability in the accumulation of nitrogenous compounds. From a nutritional standpoint, this characteristic makes *B. costatum* particularly valuable, especially for food applications. However, protein content alone is not sufficient to determine the nutritional quality of these proteins. Further studies on the amino acid profile and digestibility would be necessary. Fat content is relatively low in both species, at 3.01% for *B. buonopozense* and 2.51% for *B. costatum*. This low proportion confirms that the calyxes of these two species are not primarily a source of lipids. Comparable values have been reported for the calyxes of *B. buonopozense*, notably 3.10% in the study by Musah *et al*. [3].

Analysis of secondary metabolites reveals that the calyxes of both species are rich in polyphenols, flavonoids, and tannins. The values presented in the figure indicate a polyphenol content of approximately 655.09 mg/g of dry matter in *B. buonopozense* compared to 414.19 mg/g in *B. costatum*. Flavonoids amount to approximately 62.21 mg/g and 23.29 mg/g, while tannins amount to 93.25 mg/g and 40.73 mg/g, respectively. The predominance of phenolic compounds in *B. buonopozense* is one of the major findings of this study. This species exhibits a concentration significantly higher than that of *B. costatum*, suggesting a greater capacity to accumulate these secondary metabolites. The results obtained are particularly interesting since phenolic compounds constitute an important class of plant metabolites involved in plant defense mechanisms and possess reducing and chelating properties that may contribute to the antioxidant activity of plant matrices [5]. The results are also consistent with observations made on other organs of *B. buonopozense*. Studies focusing on the leaves of this species have notably demonstrated the presence of phenolic compounds and flavonoids, as well as measurable antioxidant activity. The presence of these classes of molecules in the calyxes may therefore contribute to the biological properties traditionally attributed to this plant. The flavonoid content is also higher in *B. buonopozense* than in *B. costatum*. This difference could contribute to potential differences in antioxidant activity between the two species. Flavonoids are, in fact, a major family of dietary polyphenols whose biological properties are

highly dependent on their chemical structure, concentration, and bioavailability [10]. Tannins are also present in higher concentrations in *B. buonopozense*. These compounds are known for their ability to interact with proteins and certain metal ions. Their presence may contribute to the antioxidant and astringent properties of plants, but high concentrations may also limit the bioavailability of certain nutrients [9].

5 CONCLUSION

This study characterized several primary and secondary metabolites in the calyxes of *Bombax buonopozense* and *Bombax costatum*, two species used in Ivorian pharmacopoeia and cuisine. The results show that both species are characterized by a high proportion of carbohydrates, combined with significant levels of protein, lipids, and minerals. *B. costatum* is notably distinguished by a higher protein content, while *B. buonopozense* has a higher ash content. Analysis of secondary metabolites reveals, above all, a high concentration of phenolic compounds, flavonoids, and tannins. *Bombax buonopozense* has the highest levels of all these compounds, making it of particular interest as a potential source of bioactive molecules. Thus, the calyxes of both species could be valuable plant resources for food, nutritional, and phytochemical applications, particularly in the Ivorian context. Further research should also focus on the identification of individual phenolic compounds using HPLC or LC-MS, the experimental evaluation of antioxidant activity, the study of nutrient bioavailability, and the determination of protein nutritional quality. These investigations would enable a transition from simple biochemical characterization to a genuine demonstration of the functional and technological potential of the calyxes of *B. buonopozense* and *B. costatum*.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

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