World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

Check for updates

Nutritional composition of Eight forage plants From the flora of Côte d'Ivoire

Yao Mesmin KOFFI [1,*], Anny Estelle N'GUESSAN [1], Amoin Gervaise KOUAME [2], Adama BAKAYOKO [2], Bi Fezan Honora TRA [2] and Mamidou Witabouna KONE [2]

[1] *Department of Natural Environments and Biodiversity Conservation, Faculty of Biosciences, Felix Houphouët-Boigny University, Côte d'Ivoire.*
[2] *Department of Botany and Plant Biodiversity Enhancement, Faculty of Natural Sciences, Nangui Abrogoua University, Côte d'Ivoire.*

World Journal of Advanced Research and Reviews, 2025, 27(01), 1138-1147

Publication history: Received on 01 June 2025; revised on 05 July 2025; accepted on 08 July 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.27.1.2618

Abstract

Gastrointestinal parasitism remains a major constraint in livestock farming. It impacts animal health and welfare, as well as farm profitability. The widespread use of conventional antiparasitic drugs in pastures has led to the development of worm resistance, reducing their effectiveness. As a result, there is growing interest in using plants with natural antiparasitic properties. These plants are particularly valuable when they are naturally consumed by livestock-meaning they also serve as good forage. This study aims to assess the nutritional potential of selected forage plants from the Ivorian flora. Eight species were examined: *Albizia adianthifolia*, *Albizia zygia*, *Afzelia africana*, and *Pterocarpus erinaceus* from the Leguminosae family, and *Morus mesozygia*, *Antiaris africana*, *Ficus exasperata*, and *Ficus lutea* from the Moraceae family. Leaves from these plants were harvested and analyzed to measure the levels of compounds such as crude protein, crude fiber, and essential minerals. The results revealed that all studied species are excellent sources of forage. They contained between 16% and 30% protein in dry matter-levels that exceed the maintenance requirements for livestock. In addition, they were rich in calcium, phosphorus, magnesium, sodium, and iron. However, the zinc concentrations were found to be below the minimum threshold needed for optimal livestock maintenance. These tree forages are therefore highly promising for improving both animal nutrition and livestock health.

Keywords: Animal health; Forage plants; Leguminosae; Moraceae; Nutritional composition

1. Introduction

Gastrointestinal parasitism is a complex and persistent challenge in domestic ruminant farming, necessitating continual adaptation of management strategies to reduce its economic impact and ensure animal welfare [1]. The systematic and, at times, inappropriate use of antiparasitic drugs (anthelmintics) by farmers has contributed to the emergence of parasite populations resistant to these compounds [2, 3]. This resistance has become a global concern, complicating chemical control and increasing associated costs. In addition, the efficacy of certain anthelmintic classes is declining, while novel compounds are scarce on the market. Moreover, research has shown that some of these drugs are excreted in their active form through the feces of treated animals, potentially harming the environment and biodiversity within pastures [4, 5].

Consequently, the pursuit of ecological and cost-effective solutions to gastrointestinal parasitism has become the focus of numerous scientific investigations. In recent decades, alternative methods such as phytotherapy and the use of nematophagous fungi have gained attention, although their effectiveness and scalability remain under evaluation [6, 7]. According to several authors, incorporating forage plants may offer a promising approach for the sustainable management of gastrointestinal nematodes in pastures. These plants are considered beneficial for two key reasons [8].

* Corresponding author: Yao Mesmin KOFFI

First, their consumption may bolster the animal's resistance and resilience against parasitic infections. Second, certain forage species may possess intrinsic anthelmintic properties, attributed to bioactive compounds they contain.

Globally, most forage species are classified within the Graminae and Leguminosae families, and Côte d'Ivoire reflects this distribution [9]. However, unlike dicotyledonous Leguminosae, Graminae generally contain fewer secondary metabolites (bioactive compounds). According to Aké-Assi [10], the Ivorian flora is predominantly composed of species from the Leguminosae family. Sarr et al. [11] highlight that natural vegetation is widely exploited for livestock feeding, as animals tend to graze on what is readily accessible in their immediate surroundings. In addition to Leguminosae, families such as Moraceae, Rubiaceae, and Combretaceae may also serve as valuable forage sources. These families, being dicotyledons, could similarly harbor bioactive compounds with anthelmintic properties.

The objective of this study is to support the development of ecological and sustainable strategies for controlling parasitism in domestic ruminants. Specifically, it aims to evaluate the nutrient composition of eight forage plant species selected from the Leguminosae and Moraceae families.

2. Materials and methods

2.1. Plant selection criteria

The plant material consisted exclusively of leaves from eight forage species. These species were collected from two distinct ecological zones: the Agboville Department and the Pacobo Sub-prefecture. The Agboville Department, situated in the forested region of southern Côte d'Ivoire, lies between latitudes 5°30′ and 6°00′ North and longitudes 3°30′ and 4°20′ West. In contrast, the Pacobo Sub-prefecture is located in a savannah zone, between latitudes 6°00′ and 6°40′ North and longitudes 4°80′ and 5°00′ West. Accordingly, four plant species were collected from the forest zone and four from the savannah zone. In Côte d'Ivoire, livestock farming is predominantly practiced in the central and northern savannah regions. However, animals raised in the southern forest zone are often destined for market, highlighting the relevance of selecting forage species from both ecological zones. The eight plant species studied were: *Ficus exasperata* (Moraceae), *Morus mesozygia* (Moraceae), *Antiaris africana* (Moraceae), and *Albizia adianthifolia* (Leguminosae) for forest zone species, and, *Albizia zygia* (Leguminosae), *Pterocarpus erinaceus* (Leguminosae), *Afzelia africana* (Leguminosae), and *Ficus lutea* (Moraceae) for savannah zone species:

2.2. Determination of the chemical composition of the plants studied

The chemical composition was determined by analyzing several components: dry matter, moisture content, mineral and organic matter, crude protein, crude fiber, and various micronutrients, including calcium, phosphorus, magnesium, and sodium (classified as major minerals or macroelements), as well as iron and zinc (considered trace elements).

2.2.1. Dry Matter and Water Content

Dry matter (DM) content was measured using the AOAC standard method [12]. For this, 1 g of powdered plant material was placed in a glass dish and dried in an oven at 105 °C for 24 hours. The dish was then removed, cooled in a desiccator, and weighed. The dry matter content (g/100 g of sample) was calculated using the formula provided below. Each test was performed in triplicate.

Dry Matter (g/100 g) = 100 – Water Content (%) (1)

$$\text{Water Content (g/100 g)} = \frac{(m_1 - m_2)}{m_0} \times 100 \quad (2)$$

m_0 : mass of sample before drying

m_1 : mass of glass capsule + sample

m_2 : mass of glass capsule + sample after drying

2.2.2. Determination of mineral matter (inorganic matter) and organic matter

The ash content (representing mineral matter) was also determined following the AOAC method [12]. One gram of powdered sample was incinerated in a porcelain crucible of known mass in a muffle furnace at 550 °C for two hours. After incineration, the crucible was cooled in a desiccator and then weighed. The ash content (g/100 g of dry sample) was calculated using the standard formula. Each measurement was repeated three times for accuracy.

$$\text{Ash (g/100 g)} = \frac{(m_2 - m_0)}{m_1} \times 100 \quad (3)$$

m_0 : Empty capsule mass

m_1 : Sample mass before incineration

m_2 : Mass of capsule + sample after incineration

The organic matter value is simply deduced from this relationship by the following calculation:

$$\text{Organic matter (g/100 g)} = 100 - \text{Ash (\%)} \quad (4)$$

2.2.3. Determination of crude protein content

Total protein content was determined using the Kjeldahl method [12]. A 500 mg sample of powdered plant material (Me) was mineralized in a Kjeldahl flask at 400 °C for 2 hours using 10 mL of 96% sulfuric acid and 500 mg of a mineralization catalyst, TKN (total Kjeldahl nitrogen), composed of K_2SO_4 and selenium. Following mineralization, 50 mL of distilled water and a few drops of 1% phenolphthalein were added to the mixture. Next, a 40% sodium hydroxide solution (400 g/L) was introduced until the solution turned pink. To the resulting solution, 10 mL of boric acid and a few drops of Tashiro indicator (a mixture of methyl red and bromocresol green) were added. The solution was distilled using a Kjeldahl distiller, and 200 mL of the distillate was collected and titrated with a 0.0225 M hydrochloric acid (HCl) solution until the color changed from green to blue (V_1). A blank test (without sample) was also conducted (V_0). All analyses were performed in triplicate. The protein content was calculated based on the total nitrogen content using the standard Kjeldahl formula.

$$\text{Total nitrogen (\%)} = \frac{(V_1 - V_0)}{M_e} \times 14 \times N \quad (5)$$

Total protein (g/100 g) = 6.25 x Total nitrogen (%) (6)

V_1: Volume of HCl used to titrate the sample

V_0: Volume of HCl used to titrate the blank

N: HCl concentration

M_e: Mass of the sample used

6.25: Nitrogen to protein conversion factor

2.2.4. Determination of crude fiber content

Crude fiber content was determined using the AOAC method [12]. Two grams of powdered plant material were homogenized with 50 mL of 0.25 N sulfuric acid in a flask and boiled under reflux for 30 minutes. The mixture was then treated with 50 mL of 0.31 N sodium hydroxide and boiled again under reflux for 30 minutes. The extract was filtered through Whatman No. 1 filter paper, and the residue was rinsed repeatedly with hot water until all alkali was removed. The residue was dried in an oven at 105 °C for 8 hours, cooled in a desiccator, and weighed. It was then incinerated in a muffle furnace at 550 °C for 3 hours. After cooling in the desiccator, the ash residue was weighed again. This procedure was carried out three times for each sample. The crude fiber content was expressed in grams per 100 g of dry sample matter according to the standard formula:

$$\text{Crude fiber (g/100 g)} = \frac{(m_1 - m_2)}{m_0} \times 100 \quad (7)$$

m_0: mass of the sample used

m_1: mass of the residue after drying in an oven

m_2: mass of the residue after incineration

2.2.5. Determination of macroelements and trace elements

The macroelements and trace elements measured in this study were calcium, phosphorus, magnesium, sodium, iron, and zinc. The content of these elements was determined using the method described by [12] for the analysis of plant samples. Initially, a mass of 300 mg of ground sample was weighed into a porcelain crucible and placed in a furnace (PROLABO) at 650°C for 5 hours. After cooling, 5 mL of 1 mol nitric acid was added to the resulting ash and allowed to evaporate completely in a sand bath. Subsequently, 5 mL of 0.1 mol hydrochloric acid was added to the residue, which

was then returned to the furnace at 400°C for 30 minutes. The final residue was recovered with 10 mL of 1 mol hydrochloric acid and transferred to a 50 mL flask. The crucible was rinsed twice with 10 mL of hydrochloric acid, and the flask was filled to the 50 mL mark with hydrochloric acid. A blank test was conducted under identical conditions.

Dilution ranges were prepared for the minerals to be determined (Ca, P, Na, Mg, Fe, and Zn) to establish calibration lines. The concentrations were 0, 0.5, 1, 1.5, and 2 mg/L in concentrated hydrochloric acid. For calibration, a stock solution of each mineral at a concentration of 100 µg/mL was used. Depending on the element tested, five to seven increasing volumes of solution were added to different 100-mL volumetric flasks. A 2-mL volume of concentrated hydrochloric acid was added to each flask, and the contents were made up to the mark with deionized water. For calcium solutions, 10 mL of 3% lanthanum solution was added to the flasks before the addition of deionized water.

The assays were performed using an air-acetylene flame atomic absorption spectrophotometer. The wavelengths for the elements analyzed were defined on the instrument as follows: 422.7 nm for calcium, 430 nm for phosphorus, 589 nm for sodium, 285.2 nm for magnesium, 213.9 nm for iron, and 213.5 nm for zinc. Measurements of the calibration ranges were used to establish calibration curves, representing absorbance as a function of concentration. Finally, the solutions containing the ash were presented to the instrument to determine absorbance. Before each absorbance measurement, the blank was systematically presented to the device. The values were expressed in mg/L and converted to mg/100 g using the standard calculation formula:

$$\text{Content} = \frac{(C_e - C_b)}{m} \times V \quad (9)$$

C_e: Sample concentration in mg/L
C_b: Blank concentration in mg/L
V: Volume of the solution obtained in mL (50 mL)
m: Test sample (0.3 g)

2.3. Statistical analysis

The nutrient contents of the different forage plants were presented as means, and a one-way analysis of variance (ANOVA) was used to compare the means. When the ANOVA concluded that the means differed significantly at the 5% level ($\alpha < 0.05$), Tukey's post-ANOVA test was used to determine the level of difference between the means and to rank them. All these statistical analyses were performed using XLSTAT 2017.02 software integrated with EXCEL 16.4393.

3. Results

Table 1 presents the average nutrient contents of the selected plants. These contents were expressed as a percentage of dry matter (% DM). The average composition of the various chemical compounds differs from one species to another.

Dry matter (DM) contents range from 94.36% (highest value) to 88.51% (lowest value). *Albizia adianthifolia* has the highest dry matter content, while *Ficus exasperata* has the lowest. Water content is inversely correlated with dry matter content: *Albizia adianthifolia* has a water content of 5.64% and *Ficus exasperata* approximately 11.49%. Within the dry matter, organic matter represents a proportion of between approximately 85.71% and 96.39% depending on the plant species, which translates into a mineral content of between 14.29% and 3.61% of the dry matter. The organic compounds sought in the organic matter were crude protein and crude fiber. Crude protein represents between 16.62% and 30.68% of the dry matter. The plants richest in crude protein are *Albizia adianthifolia*, *Afzelia africana*, *Albizia zygia* and *Ficus exasperata*. The measured contents for this nutrient in these plants are 30.68%, 26.19%, 25.55% and 25.08% of the dry matter. Of these four plants cited, the first three belong to the botanical family of Leguminosae. However, the eight plants studied had crude protein contents above the minimum value (7 to 8%) that should be contained in a forage for better animal maintenance. For crude fiber, the recommended values for better digestibility of a forage are between 30% and 40% fiber in dry matter. Among the eight plants, only *Ficus lutea* (45.08%), *Ficus exasperata* (42.44%), and *Morus mesozygia* (41.86%) had high crude fiber contents. These three plants all belong to the Moraceae family. Regarding ash or mineral matter, with the exception of *Afzelia africana*, *Ficus exasperata*, and *Morus mesozygia*, all the remaining plants had crude ash contents below 10% of dry matter, as recommended for better animal maintenance. In summary, we can conclude that the forage plants studied have a good nutritional composition, especially those belonging to the Leguminosae family.

Table 1 Nutritional composition of the plants studied

Plant species	Dosed nutrient compounds (% DM)				
	DM (%)	OM	Crude protein	Crude fiber	MM
Ficus exasperata	88.51±0.02^{h}	86.36±0.02^{g}	25.08±0.60^{c}	42.44±0.58^{b}	13.64±0.02^{b}
Morus mesozygia	88.78±0.09^{g}	89.33±0.01^{f}	19.19±0.44^{f}	41.86±1.41^{b}	10.67±0.01^{c}
Antiaris africana	89.55±0.05^{f}	90.47±0.03^{d}	21.41±0.58^{e}	39.36±0.69^{c}	9.53±0.03^{e}
Ficus lutea	93.53±0.01^{b}	90.13±0.01^{e}	16.62±0.15^{g}	45.08±0.96^{a}	4.30±0.00^{g}
Afzelia africana	90.67±0.09^{d}	85.71±0.02^{h}	26.19±0.27^{b}	39.36±0.79^{c}	14.29±0.02^{a}
Albizia adianthifolia	94.36±0.07^{a}	96.39±0.02^{a}	30.68±0.30^{a}	35.08±2.18^{d}	3.61±0.02^{h}
Pterocarpus erinaceus	92.70±0.00^{c}	91.2±0.04^{c}	22.34±0.40^{d}	35.5±0.00^{d}	8.80±0.04^{f}
Albizia zygia	89.85±0.05^{e}	95.7±0.00^{b}	25.55±0.17^{bc}	37.47±0.57^{cd}	9.87±0.01^{d}
Animal maintenance needs	-	-	7 à 8 %	30 à 40 %	≤ 10 %

DM = dry matter; OM = organic matter; MM = mineral matter; The average contents or percentages of nutrient compounds with distinct letters in the same column are statistically different from each other (P<0.05).

The macroelement contents measured in plants are presented in Table 2. Four major minerals (calcium, magnesium, phosphorus, and sodium) were analyzed in the plant samples. The calcium contents in all plants ranged from 1.62 to 6.2 g/100 g DM, exceeding the minimum requirement for animals in forage, which is 0.2 g/100 g DM. This indicates that all plants are rich in calcium. The phosphorus contents of all plants ranged from 0.12 to 0.18 g/100 g DM, while magnesium contents ranged from 0.31 to 1.31 g/100 g DM. Both minerals surpass the minimum maintenance requirements for animals, which are 0.12 g/100 g DM for phosphorus and 0.13 g/100 g DM for magnesium. With the exception of *Ficus exasperata*, all plants had sodium contents above the minimum recommended level for animal maintenance, which is 130 µg/g DM. The sodium content in *Ficus exasperata* was measured at 114.29 µg/g DM. The Ca/P ratio in all plants was significantly higher than the recommended optimum of 1:1 to 2:1. The lowest ratio was observed in *Albizia adianthifolia* (11.92:1), which is approximately six times higher than the upper limit of the optimum value. From this analysis, it can be concluded that the forage of the trees studied is rich in calcium, phosphorus, magnesium, and sodium.

Table 2 Contents of macroelements sought in the total mineral matter of plants

Plant species	Dosed macroelements and trace elements				
	[Ca] (g/100g DM)	[Mg] (g/100g DM)	[P] (g/100g DM)	[Na] (µg/g DM)	Ca/P ratio
Ficus exasperata	6.20±0.00^{a}	0.54±0.00^{d}	0.14±0.00^{b}	114.29±0.36^{g}	44.29
Morus mesozygia	4.68±0.00^{b}	0.32±0.00^{g}	0.14±0.00^{b}	287.62±0.91^{d}	33.43
Antiaris africana	4.15±0.00^{c}	0.58±0.00^{c}	0.12±0.00^{d}	724.51±0.76^{c}	34.58
Ficus lutea	1.98±0.00^{f}	0.40±0.00^{f}	0.13±0.00^{c}	193.87±0.13^{e}	15.23
Afzelia africana	3.93±0.00^{d}	1.17±0.00^{b}	0.18±0.00^{a}	190.03±0.05^{f}	21.83
Albizia adianthifolia	1.55±0.00^{h}	0.31±0.00^{h}	0.13±0.00^{c}	764.65±0.74^{b}	11.92
Pterocarpus erinaceus	2.38±0.00^{e}	1.31±0.00^{a}	0.14±0.00^{b}	190.06±0.06^{f}	17
Albizia zygia	1.62±0.00^{g}	0.52±0.00^{e}	0.13±0.00^{c}	940.51±0.45^{a}	12.46
Animal maintenance needs	0.2	0.13	0.12	130	1 à 2

Ca = Calcium ; Mg = Magnesium ; P= Phosphorus ; Na = Sodium; The average contents or percentages of nutrient compounds with distinct letters in the same column are statistically different from each other (P<0.05).

Concerning the trace elements analyzed in the mineral matter, it was observed that all plants had iron levels at least ten times higher than the minimum required for adequate livestock maintenance. The measured iron levels ranged from

86.7 µg/g to 314.97 µg/g of DM, compared to the minimum requirement of 8 µg/g of DM. As for zinc, the second trace element analyzed, it was found that not all plants could meet the zinc requirements of animals. The minimum maintenance requirement for zinc is 50 µg/g of DM, whereas the zinc levels in all plants ranged from 26.83 µg/g to 42.55 µg/g of DM (Table 3). In summary, the forage plants studied were found to be rich in iron but deficient in zinc.

Table 3 Trace element contents sought in the total mineral matter of plants

Plant species	**Dosed trace elements**	
	[Fe] (µg/g DM)	[Zn] (µg/g DM)
Ficus exasperata	185.47±0.61^{e}	31.12±0.33^{c}
Morus mesozygia	255.62±0.87^{b}	26.83±0.29^{f}
Antiaris africana	230.26±0.05^{d}	28.17±0.18^{e}
Ficus lutea	139.53±0.09^{g}	29.5±0.17^{d}
Afzelia africana	248.06±0.09^{c}	27.27±0.26^{f}
Albizia adianthifolia	314.97±0.19^{a}	32.05±0.04^{b}
Pterocarpus erinaceus	148.62±0.18^{f}	29.32±0.11^{d}
Albizia zygia	86.7±0.05^{h}	42.55±0.45^{a}
Animal maintenance needs	8	50

Fe = Iron ; Zn = Zinc ; The average contents or percentages of nutrient compounds with distinct letters in the same column are statistically different from each other ($P<0.05$)

The following figure illustrates the distribution of major minerals (Ca, P, Mg, and Na) and trace elements (Fe and Zn) within the total mineral matter of the plant samples. Major minerals clearly account for a larger proportion across all species compared to trace elements. Calcium is particularly dominant in all plants, representing between 16.37% and 46.01% of their dry matter. For phosphorus, *Albizia adianthifolia* showed the highest proportion (3.68%), while *Ficus exasperata* had the lowest (1.03%). Magnesium content ranged from 3.01% in *Morus mesozygia* to 14.88% in *Pterocarpus erinaceus*. Sodium levels also varied, with *Albizia adianthifolia* showing the highest concentration (2.12%) and *Ficus exasperata* the lowest (0.08%). Among trace elements, iron ranged from 0.09% in *Albizia zygia* to 0.87% in *Albizia adianthifolia*. Zinc was less abundant, with the highest proportion of 0.09% in *Albizia adianthifolia*, and the lowest (0.02%) found in *Morus mesozygia*, *Afzelia africana*, and *Ficus exasperata*. Minerals not quantified in this study accounted for proportions ranging from 40.68% in *Ficus lutea* to 78.98% in *Albizia zygia*. In conclusion, the analysis confirms that calcium is the most prevalent mineral in the selected tree forages.

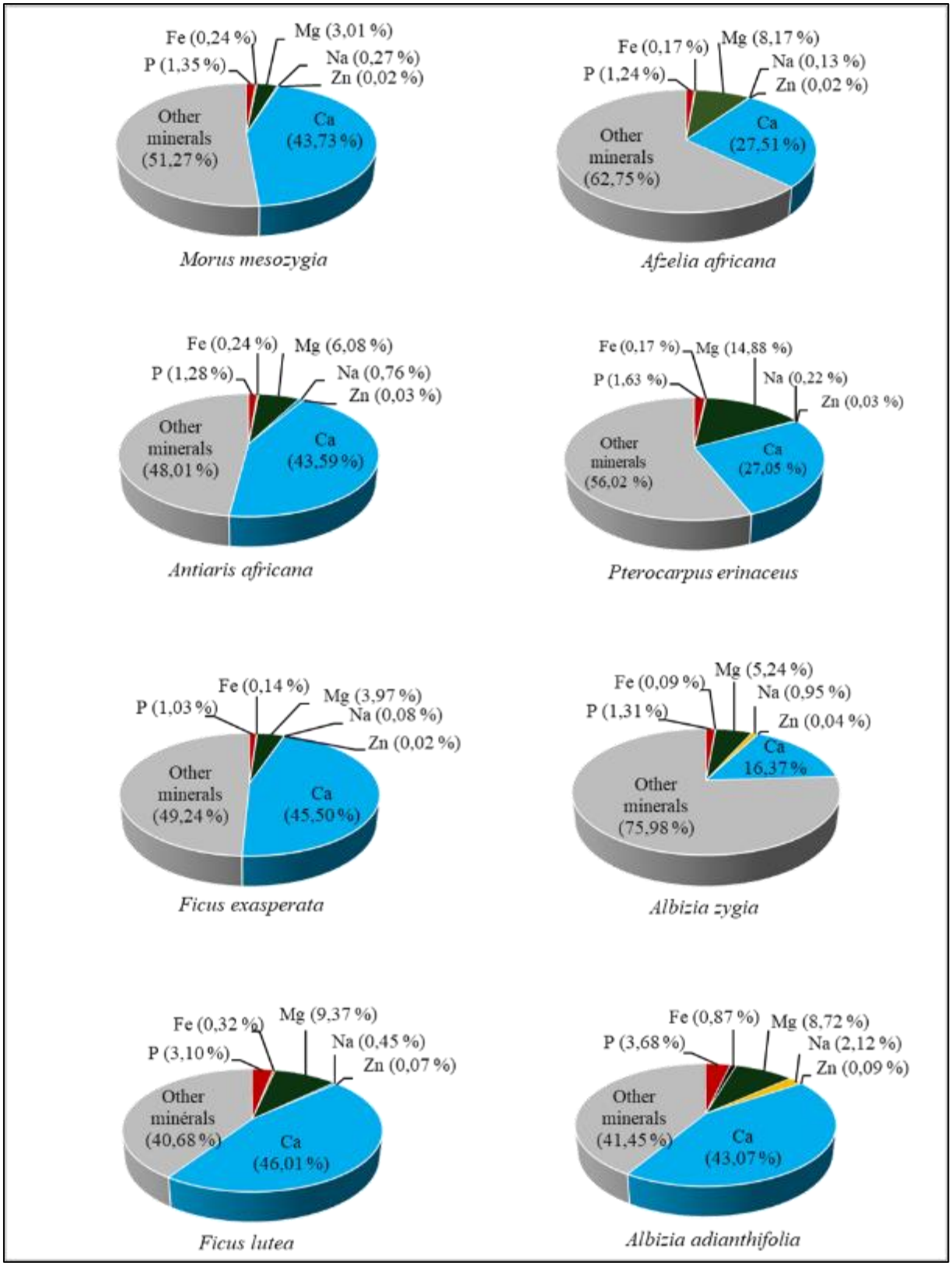

Figure 1 Spectrum of macroelements and trace elements in the mineral matter of the eight plants studied

4. Discussion

This study focused on species from the Leguminosae and Moraceae families, including *Afzelia africana*, *Albizia adianthifolia*, *Albizia zygia*, *Pterocarpus erinaceus*, *Morus mesozygia*, *Antiaris africana*, *Ficus exasperata*, and *Ficus lutea*.

These eight plants were analyzed to assess their nutritional potential. Organic matter content ranged from 85.71% in *Afzelia africana* to 96.39% in *Albizia adianthifolia*.

The crude protein levels of forage species from both families were significantly higher than the minimum required for proper rumen function and adequate feeding of ruminants, which is estimated at 7–8% of dry matter [13]. Below this threshold, ration utilization decreases due to reduced activity of ruminal microflora in domestic ruminants. The high crude protein values obtained (16.62–30.68% DM) highlight the richness of these forage plants in protein. Le Houérou [14] describes tree forages from West Africa as excellent sources of protein. Among the two botanical families studied, Leguminosae exhibited the highest crude protein levels, with *Albizia adianthifolia* (Leguminosae) being the richest species at 30.68% DM. The high protein content of Leguminosae supports Klein et al. [15], who noted that plants in this family are characterized by remarkable protein richness in leaves, fruits, and seeds compared to other plants. According to INRA [16], the nutritional value of forage is primarily determined by crude protein content and digestibility. The protein richness of these plants enhances their nutritional value for livestock.

Digestibility depends on the content and digestibility of crude fibers [17]. Rüegsegger and Emmenegger [18] explain that crude fibers, or plant cell walls, are mainly composed of cellulose and hemicellulose, which constitute 30–70% of dry matter depending on the plant's developmental stage. Higher crude fiber levels reduce voluntary dry matter intake. In this study, crude fiber content ranged from 35.08% DM to 45.08% DM. These fibers can serve as an important energy source for livestock if they are sufficiently digestible. Crude fiber digestibility varies from 40–90%, depending on lignin encrustation [16]. Less mature leaves are recommended for feeding, as lignin encrustation increases with organ age, limiting digestibility [18]. Overall, Leguminosae showed lower crude fiber values than Moraceae.

While nitrogen content and digestibility are key factors in forage nutritional value, mineral composition is also crucial. Major minerals and trace elements are vital for ruminants (sheep, goats, cattle) for growth, milk production, and skeletal development during gestation [16]. Winslow [19] states that the natural mineral content of plants is generally below 10% of dry matter. With the exception of *Afzelia africana*, *Ficus exasperata*, and *Morus mesozygia*, all plants had total mineral content below this threshold. Higher values in these three plants may result from contamination during harvesting or drying. In all forage plants studied, except for zinc, major minerals and trace elements exceeded the minimum levels required for animal growth. Assessing forage mineral value requires knowledge of phosphorus and calcium content, the two most essential minerals for animals [14]. Deficiencies in these minerals lead to reduced appetite, fertility, coat quality, and growth. Calcium content in the studied plants ranged from 1.55 to 6.2 g/100 g DM, far exceeding the minimum requirement of 0.2 g/100 g DM [20]. This high calcium presence may be attributed to the deep root systems of forage trees, which access minerals in deeper soil layers. Phosphorus levels ranged from 0.12 to 0.18 g/100 g DM, meeting animal requirements. However, the Ca/P ratio was very high (11.92–44.29) compared to the optimal range of 1–2. Le Houérou [14] attributes this unfavorable ratio to the phosphorus-poor soils of West Africa. To mitigate calcium interference during phosphorus absorption, phosphorus supplements should be added to animal rations. The plants also contained trace elements such as iron and zinc. Le Houérou [14] notes that livestock iron requirements are generally met by tree forage, unlike zinc requirements. This study confirmed that all plants had iron levels above the minimum and zinc levels below the minimum required. Le Houérou [14] suggests that African tree forage can compensate for deficiencies in dry herbaceous forage, which is poor in phosphorus, copper, zinc, sodium, and carotene.

Given their nutritional composition, these forage plants provide essential elements for livestock well-being.

Additionally, three of the studied plants demonstrated antiparasitic activity against intestinal worms in goats and sheep during in vitro experiments. *Albizia adianthifolia*, *Ficus lutea*, and *Morus mesozygia* showed activity against eggs and L1 and L2 larvae of the nematode *Haemonchus contortus* [21]. *Morus mesozygia* inhibited egg hatching, while *Albizia adianthifolia* and *Ficus lutea* were active against L1 and L2 larvae and adult worms. These findings indicate that tree forage plants not only provide nutrients but also address livestock health issues, particularly gastrointestinal parasitism.

5. Conclusion

This study aimed to identify high-quality forage plants containing bioactive compounds with antiparasitic properties. Nutritional analysis of the eight forage species examined revealed that those belonging to the Leguminosae and Moraceae families are excellent forage candidates due to their high levels of crude protein, fiber, and minerals. The assays conducted highlighted nutritional components that largely meet the maintenance requirements of livestock, with the exception of zinc. The species *Albizia adianthifolia*, *Morus mesozygia*, and *Ficus lutea*, which demonstrated antiparasitic potential in our previous research, further underscore the value of tree-based forage plants for both animal

nutrition and livestock health. Consequently, these plants represent an ecological and sustainable approach to combating gastrointestinal parasitism in livestock.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that there are no conflicts of interest.

References

[1] Roeber F, Jex AR, Gasser RB. Impact of gastrointestinal parasitic nematodes of sheep, and the role of advanced molecular tools for exploring epidemiology and drug resistance an Australian perspective. Parasites & Vectors. (2013); 6(153): 1-13.

[2] Moreno-Romieux C, Sallé G, Jacquiet P, Blanchard A, Chylinski C, Cabaret J, Francois D, Saccareau M, Astruc JM, Bambou JC, Mandonnet N. La résistance génétique aux infections par les nématodes gastro-intestinaux chez les petits ruminants : un enjeu de durabilité pour les productions à l'herbe. INRA Productions Animales. 2017; 30: 47-56.

[3] Ravinet N, Chartier C, Hoste H, Mahieu M, Duvauchelle-Wache A, Merlin A, Bareille N, Jacquiet P, Chauvin A. Enjeux et outils du traitement raisonné contre les strongles gastro-intestinaux chez les bovins et les petits ruminants. INRA Productions Animales. 2017; 30(1): 57-76.

[4] Kaplan RM. Drug resistance in nematodes of veterinary importance: a status report. Trends Parasitology. 2004; 20: 477-81.

[5] Erzen NK, Kolar NK, Flajs VC, Kuzner J, Irena M, Pogacnik M. Degradation of Abamectin and Doramectin on sheep grazed pasture. Ecotoxicology. 2005; 14(6): 627-35.

[6] Ketzis JK, Vercruysse J, Stromberg BE, Larsen M, Athanasiadou S, Houdijk JG. Evaluation of efficacy expectations for novel and non-chemical helminth control strategies in ruminants. Veterinary Parasitology. 2006; 139(4): 321-35.

[7] Waller PJ. From discovery to development: current industry perspectives for the development of novel methods of helminth control in livestock. Veterinary Parasitology. 2006; 139(1-3): 1-14.

[8] Hoste H, Jackson F, Athanasiadou S, Thamsborg SM, Hoskin SO. The effects of tannin-rich plants on parasitic nematodes in ruminants. Trends Parasitology. 2006; 22: 253-61.

[9] Mello JPF, Devendra C. Tropical legumes in animal nutrition. Edition JPF Mello and C Devendra. Wallingford: CABI; 1995.

[10] Aké-Assi L. Flore de la Côte d'Ivoire : catalogue systématique, biogéographique et écologie. Boissiera. 2001; 57(1): 1-396.

[11] Sarr O, Diatta S, Gueye M, Ndiaye PM, Guisse A, Akpo LE. Importance des ligneux fourragers dans un système agropastoral au Sénégal (Afrique de l'Ouest). Revue de Médecine Vétérinaire. 2013; 164(1): 2-8.

[12] AOAC. Official methods of Analysis of the AOAC. Volume 2. Arlington, Helrich KC; 1990.

[13] Van Soest PJ. Nutritional Ecology of the Ruminant. 2nd edition. New York: Cornell University Press; 1994.

[14] Le Houérou HN. Les fourrages ligneux en Afrique : Etat actuel des connaissances. Addis Abéba: Centre International pour l'Elevage en Afrique (CIPEA); 1980.

[15] Klein H-D, Rippstein G, Huguenin J, Toutain B, Guerin H, Louppe D. Les cultures fourragères. Agricultures tropicales en poche. Versailles: Editions Quae; 2014.

[16] INRA. Alimentation des bovins, ovins et caprins. Besoins des animaux, Valeur des aliments. Versailles: Editions Quae; 2007

[17] INRA. Alimentation des bovins, ovins et caprins. Paris: Jarrige R. ed; 1988.

[18] Rüegsegger H, Emmenegger J. Composants des parois cellulaires. Production animale. Revue UFA. 2012; 7-8: 70-71.

[19] Winslow. Colloque sur les plantes fourragères 2013 du Centre de Reference en Agriculture et Agroalimentaire du Québec (CRAAQ). Québec: CRAAQ; 2013.

[20] Meschy F. Alimentation minérale et vitaminique des ruminants : actualisation des connaissances. INRA Production Animale. 2007; 20(2): 119-28.

[21] Koffi YM, Kossonou YK, Kouamé AG, Kouadio NJ, Bakayoko A, Tra BFH, Koné MW. Activité anthelminthique in vitro et teneurs en tanins et flavonoïdes de huit plantes fourragères utilisées en élevage des petits ruminants en Côte d'Ivoire. European Scientific Journal. 2018; 14(15): 434-49.