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Plant material yield evaluation for hepatoprotective plant rational use in Burkina Faso, West Africa

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ABSTRACT

This study aims to contribute to the sustainable use of plant resources. Thus, 38 species with hepatoprotective potential were sampled in several locations of Burkina Faso between May and October 2021. These species were identified during previous surveys with traditional healers. These plants' leaves, roots, and trunk barks were collected and processed according to good harvesting practices guidelines of the World Health Organisation. After drying, the dried sample was weighed, and the dry matter and powder contents were determined. The results showed that *Khaya senegalensis* (Desr.) A.Juss (84%), *Combretum micranthum* G.Don (81.84%), and *Anogeissus leiocarpa* (DC.) Guill. & Perr. (53.85%), had the highest dry matter yields in leaves, trunk bark, and roots respectively. Powder yields were relatively low for all species. Indeed, only 7.67% of the species whose leaves were sampled had a powder yield of more than 50%. Powder yields of trunk and root bark were less than 50% for all plants, except *Khaya senegalensis*. The losses were so enormous that they could have been as high as 50%. Given these results, it is necessary to establish plant material requirements and master the collection, processing, and use techniques of suitable equipment to minimize plant material losses.

Keywords: Plant resources, hepatoprotective, exploitation, processing, conservation, sustainable use.

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INTRODUCTION

Plants are a reservoir for the world's pharmacopeias. Indeed, many modern medicines have been made from these medicinal plants, used directly in fresh, dried, processed form, stabilized, or as extracts or formulated with other plants or synthetic excipients (Ouedraogo et al., 2021). They are also used whole or in part (leaf, stem, root, bark, fruit...) in galenic preparations. The high cost of modern medicines, shortages in the supply of medicinal products, and people's perception of the ineffectiveness of modern drugs are all factors that could explain the high use of plants (Lara Reimers et al., 2018). In Africa, the use of plants is more of a cultural nature. In addition to their importance in the medicinal field, plants are also of socio-economic interest (Ganaba et al., 2005). They are the subject of transcontinental trade, the costs of which vary considerably depending on the country, climate, and chemical profile of the plant (Gänger, 2014; Lubbe and Verpoorte, 2011). Local populations use them to meet their basic needs, helping to reduce poverty rates. Ethnobotanical studies have also reported that several plants are strongly used in magico-religious and cultural fields (Savadogo et al., 2018).

Various players at different scales exploit natural areas rich in biodiversity without real compensation or concern for preserving plant resources. Unfortunately, after decades of uncontrolled overexploitation, the situation remains alarming. The area occupied by natural forests is shrinking considerably (Profizi et al., 2021). What's more, the desire to maximize profits, the multiplication of uses, and the importance of demand are leading to significant removals, the consequences of which are the drastic reduction or even disappearance of certain species. In Burkina Faso, 780,000 tons of dried shea kernels, 2,000 to 5,320 tons of gum arabic, 92,445 tons of baobab leaves, 4,853,868 tons of woody fodder, edible fruits and leaves, and medicinal plants and legumes are collected annually (SDR, 2015). Added to this is the uncontrolled exploitation and misuse of harvested plant resources. Indeed, parts of plants that can be used in the pharmacopeia are often displayed as merchandise in streets, homes, and markets. Herbalists and dryers alike store large quantities of irrationally harvested plant material. As the active plant ingredients of interest are generally present in tiny quantities in the plant (Sqalli et al., 2007), users tend to harvest a good quantity of raw material to obtain a sufficient quantity of biologically effective active ingredients. Also, for extraction purposes, students or researchers in universities or research centers, when harvesting plant material, are not too interested in the quantity of dry material but rather in the yield of the extract. For the most part, however, extraction is based on dry material. Several factors can influence the quantity and quality of material, from fresh to dry. These include losses associated with transporting the plant material and processing, drying, and grinding techniques.

Unfortunately, due to poor estimation of needs and ignorance of good harvesting practices, the quantities of plant material harvested are always exaggerated and can often come from endangered plants. Furthermore, it has been established that plant storage conditions are generally factors in the degradation of medicinal plant quality (Kouame and Koné, 2017). Despite the WHO's adoption of guidelines on good practices for cultivating and harvesting medicinal plants, there are still considerable gaps between the state of knowledge and its implementation in practice (WHO, 2003). Undoubtedly, the situation is still far from ideal, and the practices observed in the harvesting field, in drying rooms, and on herbalists' shelves remain the antithesis of WHO standards (Compaore et al., 2020; Koudouvo et al., 2017; Dibong et al., 2011). Knowing the dry material yield of any plant you wish to harvest is prudent before going out into the field. However, to this day, there is a virtual absence of data on this subject. Thus, the present study is interested in providing data on sustainable plant exploitation following WHO guidelines. It aims to contribute to the rational use of plants of therapeutic interest in Burkina Faso. Specifically, the objective was to determine the yields in dry matter and powder of plant parts from hepatoprotective plants used in traditional medicine.

MATERIALS AND METHODS

Study site

The study was conducted in the departments of Manga, Pô, Boromo, Dedougou, and Bobo-Dioulasso in the Centre-sud, Boucle du Mouhoun, and Hauts-Bassins regions respectively (Figure 1). The departments of Manga and Dedougou are located in the Northern Sudanese phytogeographical sector, while those of Pô, Boromo, and Bobo-Dioulasso are in the Southern phytogeographical sector (Fontès and Guinko, 1995).

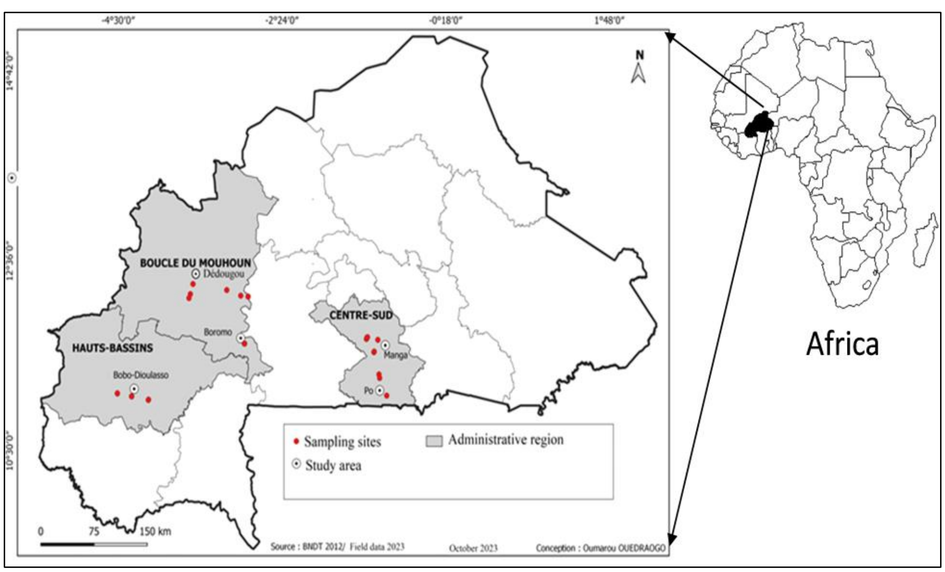

Figure 1. Location of Burkina Faso in Africa and study sites in Burkina Faso.

The North Sudanese phytogeographical sector lies between the 13th and 11th parallels. It is characterized by a Sudano-Sahelian climate, with rainfall ranging from 700 to 1000 mm and an average annual temperature of 24°C. It is a savannah zone characterized by the predominance of a woody flora based on Mimosaceae and Combretaceae (Sambaré et al., 2011; Bognounou et al., 2010). The South Sudanese phytogeographical sector lies south of 11°30 N, with average annual rainfall ranging from 900 to 1100 mm and an average temperature of 28.4°C. The rainy season lasts 6 to 7 months (Sambaré et al., 2011). Vegetation consists of grassy savannah, open forest, and wooded savannah with *Isoberlinia doka* Craib & Stapf. Soil types commonly encountered are poorly evolved erosion soils on gravelly materials, tropical ferruginous soils on sandy-clay-to-sandy-clay materials, and weakly to moderately denatured ferralitic soils. The main activity carried out by the population of this zone is agriculture (Sanou et al., 2022; Pallo et al., 2009).

Sample collection

Sampling was carried out during May and October 2021. Thirty-eight (38) potentially hepatoprotective species were sampled in favorable habitats (Table 1). These species had been identified during previous surveys with traditional healers in the 13 regions of Burkina Faso (Tibiri et al., 2020). The plant parts harvested were mainly trunk bark, roots and leaves. Leaf harvesting involved 26 species, trunk bark harvesting involved 22 species, and root harvesting involved only 12 species, possibly affecting the same species in several cases. Surely, the trunk bark was harvested from the side of the tree that is sheltered from the sun's rays. Once the dead parts had been removed, the bark was cut and removed in a longitudinal strip using a pickaxe on one side (away from the sun) without stripping the trunk. The lateral roots were first located to collect the roots so as not to injure or damage the taproot, which is essential to the plant. After sampling, the holes were systematically closed.

Leaves were harvested using a clean pair of pruning shears positioned at the base of the plant in the case of shrubs or by climbing into the plant in the case of trees. Any plant material collected was placed in an unpolluted container. Harvesting was performed early in the morning on healthy individuals (not parasitized by insects, fungi or lichens) in habitats with no significant risk of chemical or microbial contamination. After each harvest, the plant material was weighed, and the weight of fresh material was noted.

Processing of plant material

Ensuring that the plant material and its derivatives were of the highest quality and purity was essential to get the most out of the medicinal plants. Once collected, the plant material was meticulously cleaned. Once the roots had been collected, they were immediately cleaned of any adhering soil and washed with tap water. The leaves were also thoroughly washed with tap water. After cleaning, the trunk and root barks were cut into small pieces to facilitate and accelerate drying (Ouldyerou and Righi, 2020).

Drying and grinding of plant material

Harvested plant material was shade-dried for an average of 15 days at room temperature in a well-ventilated room (Chabrier, 2010). The moisture content was determined using a halogen desiccator. The material was considered dry and suitable for grinding when the moisture content varied between 8% and 10%. This is the optimum moisture content for storage in good conditions while preserving quality (DEQM), 2008). The weighed dry matter was then ground using a blade mill (Gladiator Est. 1931 Type BN 1 Mach. 40461 1083), and the powder obtained was sieved using a 1mm sieve and then weighed. The powder, ready for use, was placed in airtight jars stored dry (at room temperature) and protected from humidity. Grinding the plant material increases the solvent-sample contact surface and improves solvent infiltration into the plant material, increasing extraction (solid-liquid).

Data analysis

Data were analyzed, and graphs were generated using Excel 2016. Calculating yields enables us to assess the total extracts that can be extracted from each species. These yields also make it possible to consider the quantity of plant parts to be harvested if needed for a similar study, which would make rational and sustainable use of the targeted species (Hoekou et al., 2016).

After drying, the mass of the dried sample was also recorded. The dry matter content or siccity was calculated using the formula:

$Ms = M_2 \times 100 / M_1$ (Bakayoko et al., 2012).

Let M_1 be the mass of the fresh sample (g) and M_2 its mass after drying (g).

RESULTS

Determination of dry matter and powder yields of hepatoprotective plant leaves

Among the species whose leaves were harvested,

Table 1. Hepatoprotective plants sampled.

Species	Family	Local name (mooré)	Biological type
Adansonia digitata L.	Malvaceae	Toèga	Ligneous
Annona senegalensis Pers.	Annonaceae	Badkoudga	Ligneous
Anogeissus leiocarpa (DC.) Guill. & Perr.	Combretaceae	Siiga	Ligneous
Balanites aegyptiaca (L.) Delile	Zygophyllaceae	Kièglga	Ligneous
Cassia occidentalis L.	Fabaceae	Kinkeliba	Herbaceous
Cassia sieberiana DC.	Fabaceae	Koubressaka	Ligneous
Cochlospermum planchonii Hook.f.	Bixaceae	Sons-yânga	Sub-ligneous
Cochlospermum tinctorium Perr. ex A.Rich.	Bixaceae	Sons-raaga	Sub-ligneous
Combretum micranthum G.Don	Combretaceae	Ranega	Ligneous
Dichrostachys cinerea (L.) Wight & Arn.	Fabaceae	Soulsoutga	Ligneous
Diospyros mespiliformis Hochst. ex A.DC.	Ebenaceae	Gâanka	Ligneous
Entada africana Guill. & Perr.	Fabaceae	Sêonego	Ligneous
Eucalyptus camaldulensis Dehnh.	Myrtaceae	Ti-woaka	Ligneous
Faidherbia albida (Delile) A.Chev.	Fabaceae	Zaanga	Ligneous
Ficus sycomorus L.	Moraceae	Kankanga	Ligneous
Gardenia sokotensis Hutch.	Rubiaceae	Tang-rakoènga	Ligneous
Guiera senegalensis J.F.Gmel.	Combretaceae	Wilinwiiga	Ligneous
Gymnosporia senegalensis (Lam.) Loes.	Celastraceae	Tokvougri	Ligneous
Khaya senegalensis (Desr.) A.Juss.	Meliaceae	Kouka	Ligneous
Lannea microcarpa Engl. & K.Krause	Anacardiaceae	Sâbga	Ligneous
Lippia chevalieri Moldenke	Verbenaceae	Wiisaodo	Herbaceous
Mitragyna inermis (Willd.) Kuntze	Rubiaceae	Yiilga	Ligneous
Opilia amentacea Roxb.	Opiliaceae	Wag-salgo	Ligneous
Parkia biglobosa (Jacq.) R.Br. ex G.Don	Fabaceae	Roanga	Ligneous
Pseudocedrela kotschyi (Schweinf.) Harms	Meliaceae	Siguedré	Ligneous
Psidium guajava L.	Myrtaceae	Goyaka	Ligneous
Pteleopsis suberosa Engl. & Diels	Combretaceae	Guirga	Ligneous
Sarcocephalus latifolius (Sm.) E.A.Bruce	Rubiaceae	Gouiinga	Ligneous
Sclerocarya birrea (A.Rich.) Hochst.	Anacardiaceae	Noabga	Ligneous
Securidaca longipedunculata Fresen.	Polygalaceae	Pèlga	Ligneous
Sterculia setigera Delile	Malvaceae	Ponsenponrgo	Ligneous
Strychnos spinosa Lam.	Loganiaceae	Katr-poenga	Ligneous
Tamarindus indica L.	Fabaceae	Pousga	Ligneous
Terminalia avicennioides Guill. & Perr.	Combretaceae	Kondpoko raaga	Ligneous
Terminalia macroptera Guill. & Perr.	Combretaceae	Kondpoko yâanga	Ligneous
Trichilia emetica Vahl	Meliaceae	Kikir-taanga	Ligneous
Ximenia americana L.	Ximeniaceae	Lèenga	Ligneous
Zanthoxylum zanthoxyloides (Lam.) Zepern. & Timler	Rutaceae	Rapeeko	Ligneous

Combretum micranthum had the highest yields in dry matter (81.48%) and powder (59.26%). The lowest yields were obtained with *Cassia occidentalis*, at 18.42% and 15.79% respectively. Powder losses (PL) range from 2.62% for *Cassia occidentalis* to 22.22% for *Combretum micranthum*. Only 38.46% of species had dry matter yields of over 50%. These include *Combretum micranthum* (81.48%), *Lannea microcarpa* (76.11%), *Guiera senegalensis* (65.63%), *Diospyros mespiliformis* (56.25%), *Pseudocedrela kotschyi* (56.25%), *Eucalyptus camaldulensis* (52.94%), *Cassia sieberiana* (50%), *Dichrostachys cinerea* (50%), *Opilia amentacea* (50%) and *Ximenia americana* (50%). Only two species (7.69%), *namely L. microcarpa* (64.29%), and *C. micranthum* (59.26%) had powder yields of over 50% (Table 2).

Determination of dry matter and powder yields of hepatoprotective plant trunk bark

According to the results indicated in Table 3, 36.36% of the species from which bark was collected had dry matter yields of over 50%. The highest yield was obtained with

Table 2. Dry matter and powder yields from plant leaves.

Species	FM	DM	Pd	DMY	PY	PL
Adansonia digitata	1250	400	300	32.00	24.00	8.00
Annona senegalensis	1500	600	400	40.00	26.67	13.33
Anogeissus leiocarpa	2200	600	500	27.27	22.73	4.54
Cassia sieberiana	2800	1400	1250	50.00	44.64	5.36
Cassia occidentalis	1900	350	300	18.42	15.79	2.63
Combretum micranthum	1350	1100	800	81.48	59.26	22.22
Dichrostachys cinerea	500	250	200	50.00	40.00	10.00
Diospiros mespiliformis	1600	900	600	56.25	37.50	18.75
Eucalyptus camaldulensis	1700	900	700	52.94	41.18	11.76
Gardenia sokotensis	1450	700	500	48.28	34.48	13.80
Guiera senegalensis	1600	1050	700	65.63	43.75	21.88
Lannea microcarpa	2100	1600	1350	76.19	64.29	11.90
Lippia chevalieri	4500	1500	1250	33.33	27.78	5.55
Mitragyna inermis	2000	650	400	32.50	20.00	12.50
Opilia amentacea	1400	700	500	50.00	35.71	14.29
Parkia biglobosa	1080	450	400	41.67	37.04	4.63
Pseudocedrela kotschyi	2400	1350	1000	56.25	41.67	14.58
Psidium guajava	2100	1000	800	47.62	38.10	9.52
Sarcocephalus latifolius	2700	1200	950	44.44	35.19	9.25
Sclerocarya birrea	2500	1000	900	40.00	36.00	4.00
Securidaca longipedunculata	1100	400	200	36.36	18.18	18.18
Tamarindus indica	1800	700	600	38.89	33.33	5.56
Terminalia avicennioides	1300	500	350	38.46	26.92	11.54
Terminalia macroptera	1800	550	450	30.56	25.00	5.56
Trichilia emetica	1300	500	400	38.46	30.77	7.69
Ximenia americana	1400	700	600	50.00	42.86	7.14

FM : Fresh Material; **DM** : Dry Material; **Pd**: Powder; **DMY**: Dry Material Yield; **PY**: Powder Yield; **PL**: Powder Loss.

Table 3. Dry matter and powder yields from plant trunk bark.

Species	FM	DM	Pd	DMY	PY	PL
Anogeissus leiocarpa	900	500	400	55.56	44.44	11.12
Balanites aegyptiaca	3500	250	150	7.14	4.29	2.85
Cassia sieberiana	700	400	300	57.14	42.86	14.28
Dichrostachys cinerea	350	200	100	57.14	28.57	28.57
Diospyros mespiliformis	700	300	200	42.86	28.57	14.29
Entada africana	330	100	50	30.30	15.15	15.15
Faidherbia albida	600	300	200	50.00	33.33	16.67
Ficus sycomorus	1300	600	550	46.15	42.31	3.84
Khaya senegalensis	1250	1050	900	84.00	72.00	12.00
Gymnosporia senegalensis	500	200	150	40.00	30.00	10.00
Mitragyna inermis	450	200	100	44.44	22.22	22.22
Parkia biglobosa	500	300	200	60.00	40.00	20.00
Pseudocedrela kotschyi	1250	500	350	40.00	28.00	12.00
Pteleopsis suberosa	950	200	200	21.05	18.95	2.11
Sarcocephalus latifolius	1000	500	400	50.00	40.00	10.00
Sclerocarya birrea	1250	600	400	48.00	32.00	16.00
Securidaca longipedunculata	600	250	170	41.67	28.33	13.34
Sterculia setigera	500	200	150	40.00	30.00	10.00
Strychnos spinosa	500	200	100	40.00	20.00	20.00
Terminalia avicennioides	500	300	200	60.00	40.00	20.00
Terminalia macroptera	1400	550	400	39.29	28.57	10.72
Trichilia emetica	700	250	200	35.71	28.57	7.14

FM : Fresh Material; **DM** : Dry Material; **Pd**: Powder; **DMY**: Dry Material Yield; **PY**: Powder Yield; **PL**: Powder Loss.

Khaya senegalensis (84%), followed by *Parkia biglobosa* (60%), *Terminalia avicennioides* (60%), *Cassia sieberiana* (57.14%), *Dichrostachys cinerea* (57.14%), *Anogeissus leiocarpa* (55.56%), *Faidherbia albida* (50%), *Sarcocephalus latifolius* (50%). Concerning powder, only *Khaya senegalensis* yields over 50%. Powder losses (PL) range from 2.11% for *Pteleopsis suberosa* to 28.57% for *Dichrostachys cinerea*.

The lowest yields in dry matter (7.14%) and powder (4.29%) were obtained with *Balanites aegyptiaca*. Fifteen species, i.e., 68.18% of all species, lost 2/3 of their mass after grinding. These species namely *Faidherbia albida* (33.33%), *Sclerocarya birrea* (32%), *Gymnosporia senegalensis* (30%), *Sterculia setigera* (30%), *Terminalia macroptera* (28.57%), *Trichilia emetica* (28.57%), *Diospyros mespiliformis* (28.57%), *Dichrostachys cinerea* (28,57%), *Securidaca longipedunculata* (28.33%), *Pseudocedrela kotschyi* (28%), *Mitragyna inermis* (22.22%), *Strychnos spinosa* (20%), *Pteleopsis suberosa* (18.95%), *Entada africana* (15.15%) and *Balanites aegyptiaca* (4.29%).

Determination of dry matter and powder yields of hepatoprotective plant root bark

During sampling, 12 species were subjected to root sampling (Table 4). After drying and grinding, only three species (25%) which were *A. leiocarpa* (53.85%), *T. avicennioides* (53.33%) and *D. cinerea* (50%) had dry matter yields of over 50%. The highest powder yield, below 50%, was obtained with *Opilia amentacea* (44.12%). Powder losses (PL) vary between 2.94% and 35% for *O. amentacea* and *D. cinerea* respectively.

Table 4. Dry matter and powder yields from plant root bark.

Species	FM	DM	Pd	DMY	PY	PL
Annona senegalensis	1200	350	250	29.17	20.83	8.34
Anogeissus leiocarpa	1300	700	500	53.85	38.46	15.39
Balanites aegyptiaca	1100	500	400	45.45	36.36	9.09
Dichrostachys cinerea	200	100	30	50.00	15.00	35.00
Entada africana	450	100	30	22.22	6.67	15.55
Opilia amentacea	1700	800	750	47.06	44.12	2.94
Sarcocephalus latifolius	2200	600	500	27.27	22.73	4.54
Terminalia avicennioides	1500	800	650	53.33	43.33	10.00
Terminalia macroptera	1100	250	200	22.73	18.18	4.55
Zanthoxylum zanthoxyloides	1600	550	450	34.38	28.13	6.25
Cochlospermum planchonii	1750	450	350	25.71	20.00	5.71
Cochlospermum tinctorium	700	200	100	28.57	14.29	14.28

FM : Fresh Material; **DM** : Dry Material; **Pd**: Powder; **DMY**: Dry Material Yield; **PY**: Powder Yield; **PL**: Powder Loss.

Determination of dry matter and powder yields from leaves, trunk bark, and roots within a single plant

Among the thirty-eight species sampled, seventeen were harvested for trunk bark, leaves, and roots (Table 5). For most species where at least two plant parts were harvested, the dry matter yields of trunk bark are higher than those of the other plant parts. Indeed, the best yields are obtained with *Anogeissus leiocarpa* (55.56%), *Cassia sieberiana* (57.14%), *Dichrostachys cinerea* (57.14%), *Parkia biglobosa* (60%) and *Terminalia avicennioides* (60%). None of their powder yields reached 50%. The highest trunk bark powder yield was achieved with *Anogeissus leiocarpa* (44.44%).

DISCUSSION

From drug to powder, plant material goes through several processing stages, the most decisive of which are drying and grinding. One of the benefits of drying is that it reduces the moisture content of the plant material to a level that prolongs its shelf life and prevents degradation. It can be used not only as an effective preservation method but also as a process for improving the quality and availability of plant material (Dadda, 2020; Mechlouch et al., 2013). This operation is carried out by several methods, including exposure to the sun, storage in a dry place, and using air heated by solar radiation as a heat source. The process is carried out in a well-insulated chamber to ensure the continuity of the drying operation (Houhou, 2012). Except for *Lannea microcarpa* and *Combretum micranthum*, the leaves of most plants have a low dry matter content. Indeed, according to an earlier study by Tolman (1989), the dry matter content is between 30 and 40%. Dry matter and powder yields vary from one method to another. These variations in plant material yields depend on the nature of the taxa studied, its morphological characteristics, harvesting periods, drying and preservation methods (Mahboub et al., 2022;

Table 5. Dry matter and powder yields of leaves, trunk bark and roots from a single plant.

Species	Dry Material Yield (g)			Powder Yield (g)		
	Leaves	TB	RB	Leaves	TB	RB
Annona senegalensis	40.00	-	29.17	26.67	-	20.83
Anogeissus leiocarpa	27.27	55.56	53.85	22.73	44.44	38.46
Balanites aegyptiaca	-	7.14	45.45	-	4.29	36.36
Cassia sieberiana	50.00	57.14	-	44.64	42.86	-
Dichrostachys cinerea	50.00	57.14	50.00	40.00	28.57	15.00
Diospyros mespiliformis	56.25	42.86	-	37.50	28.57	-
Entada africana	-	30.30	22.22	-	15.15	6.67
Mitragyna inermis	32.50	44.44	-	20.00	22.22	-
Opilia amentacea	50.00	-	47.06	35.71	-	44.12
Parkia biglobosa	41.67	60.00	-	37.04	40.00	-
Pseudocedrela kotschyi	56.25	40.00	-	41.67	28.00	-
Sarcocephalus latifolius	44.44	50.00	27.27	35.19	40.00	22.73
Sclerocarya birrea	40.00	48.00	-	36.00	32.00	-
Securidaca longipedunculata	36.36	41.67	-	18.18	28.33	-
Terminalia avicennioides	38.46	60.00	53.33	26.92	40.00	43.33
Terminalia macroptera	30.56	39.29	22.73	25.00	28.57	18.18
Trichilia emetica	38.46	35.71	-	30.77	28.57	-

TB : Trunk Bark; **RB** : Root Bark.

Papierowska et al., 2018).

In addition, leaf dry matter and powder content indicate the amount of structural material in the leaf, which can be influenced by a number of factors, both internal and external to the plant. In fact, the leaf of *C. micranthum* has a rigid, brittle, and relatively thick blade (Arbonnier, 2002), which gives it a certain rigidity. It is a species characteristic of skeletal Sahelian soils and degraded, virtually impermeable termite mounds (Thiombiano, 2005). This may reflect the plant's low capacity to accumulate large quantities of water in its leaves and, consequently, to supply large quantities of dry biomass.

L. microcarpa is a deciduous tree species that shed leaves at the end of each growing season (Sanogo et al., 2023). Imparipinnate compound leaves have a waxy appearance covered with a cuticle to prevent water loss. Plant waxes are so impenetrable that if the stomata are closed, losses relative to the amount of water contained in the plant are minuscule (Durand, 2007). Previous studies have reported that plant species with rough leaves caused by epicuticle wax crystals and epidermal cells retained fewer water droplets (Wang et al., 2014; Massinon and Lebeau, 2012).

C. micranthum's high yield in dry matter and powder is all the more favorable for sustainable use of this resource, as local populations widely use it. Surely, *C. micranthum* is widely used in West Africa in traditional medicine (Faye et al., 2022; Tine et al., 2019), called *Kinkeliba* in several countries, this plant grows in most Sub-Sahelian African countries and is used to treat several human (Kpemissi et al., 2023; Bernice et al., 2020) and veterinary (Tianhoun et al., 2023; Hama et al., 2019) pathologies.

The higher quantities of dry matter and powder from the bark are linked to the species and the nature of the bark itself. Most of the woody species sampled are mainly arborescent. As a result, many of their individuals are old. *K. senegalensis* has smooth grey bark that becomes more or less ferruginous and scaly. *Parkia biglobosa* has cracked, scaly, grey bark with orange to rusty and fibrous edges. *Terminalia avicennioides* has deeply fissured, corky, dark grey to thick black bark with a yellowish edge, rapidly turning brown. *D. cinerea* has a rigid, crevassed, braided-looking, Îibreuse bark, peeling off in strips, with a yellowish-white edge (Arbonnier, 2002). Bark thickness also varies between species and is directly correlated with trunk diameter, probably for metabolic reasons (Rosell, 2016; Nefabas and Gambiza, 2007). According to Louppe et al. (2016), the rates of *A. leiocarpa* bark generally vary according to the individual and the trunk's diameter. Gérardin et al. (2020) reported that bark taken from the same height did not show significant differences in yield from one tree to another. The difference is more between the base and the top of the trunk, linked to the maturity of the bark. Bark taken from the top of the trunk has a higher yield than bark taken from the base of the trunk.

The thickness of a plant's bark also depends on the environment and the stresses to which the plant is exposed. As the cambium's protective layer, the bark is a mechanical barrier against external stresses such as blows, scratches, falling branches, rocks, and insects. A consistent bark thickness protects the cambium from bushfires and high and low temperatures that could permanently damage it (De Antonio et al., 2020). In addition, the thickness of the bark increases more rapidly the higher the altitude of the tree. This influence is thought to be due to the need to protect the cambium from frost, given the high cold temperatures at altitude (Bauer, 2021). The bark is thicker in drier, warmer environments (Rosell, 2016).

Like the trunk, the root is influenced by the environment in which it is located (Comas et al., 2012). Its functioning depends directly on the local environment (Weemstra et al., 2021). Plants in unfavorable environments have a high density of root tissue and root characteristics that reduce the loss of water and scarce nutrients (Chen et al*.,* 2016). *Terminalia avicennioides* generally grow on ferruginous soils where litter is often absent due to the mineralization of organic matter caused by the tropical-type climatic regime (Lebrun et al., 1991). In addition, root diameter is strongly influenced by cortical thickness. According to a 50 tropical and temperate species study, thicker roots had greater cortical thickness and more cortical cell layers than thinner roots (Gu et al., 2014). Depression of soil water content is accompanied by a sharp reduction in diameter, mainly explained by a decrease in the dimensions of the cortical parenchyma cells (Adda et al., 2013). The low powder yields were probably due to material losses during grinding. Insofar as large quantities of rejects or losses were recorded, this could be attributable to the grinding technique and equipment. According to Djantou (2006), improved grinding is characterized by an increase in grinding efficiency, a reduction in the energy required for grinding, and a reduction in the final size of the particles produced. Regarding particle size, constraints are linked to the efficiency of grinding operations and processes downstream of grinding (Melcion, 2000). For example, using an ultracentrifugal grinder with a fineness of 1 mm impacted the physicochemical properties, active ingredient composition, antioxidant capacity, and functional properties of Chinese green tea (Gunpowder) (Céleste et al., 2015). To obtain optimum results when grinding a solid material, it is necessary to take into account parameters such as the choice of grinder, optimal sample preparation, material properties, the size of the initial sample pieces, the grinding time, and the desired final fineness (Laib, 2023).

CONCLUSION

The sustainable use of plants for their multifaceted benefits raises several issues that need to be resolved. From harvesting to obtaining the powder via the drying and grinding stages, several factors influence the yield of plant matter. Dry matter and powder yields can also vary depending on the nature of the plant or its parts being used. The quality of the plant material also depends on controlling the drying conditions to preserve its initial properties. Generally speaking, the yields of dry matter and powder from the plant parts studied were relatively low compared with the quantities of plant parts harvested. For extraction, a much lower yield would probably be expected.

Consequently, low dry matter yields will require large quantities of plant material to be harvested. Therefore, the results of this study suggest the need for a clear assessment of requirements before harvesting plant resources. It is also important to master harvesting and processing techniques and to use appropriate equipment to minimize losses of plant matter.

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