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[1]Chair of Botany, Faculty of Biology, Faculty of Science, Technische Universität Dresden, Dresden, Germany
[2]Chair of Inorganic Molecular Chemistry, Faculty of Chemistry and Food Chemistry, Technische Universität Dresden, Dresden, Germany
[3]University of Kimpa Vita, Province of Uíge, Bairro Popular, Uíge, Angola

Beneficial or hazardous? A comprehensive study of 24 elements from wild edible plants from Angola

Christin Baumgärtel[1*], Linda Götzke[2], Jan J. Weigand[2], Christoph Neinhuis[1], Mazecana H. G. Panzo[3], Francisco Afonso[3], Thea Lautenschläger[1]

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Summary

Angola suffers from a high child mortality rate and a prevalence of anemia due to malnutrition. The aim of this study is to provide a comprehensive overview of the mineral content of 43 wild edible plants. A total of 24 different elements (aluminum, antimony, arsenic, cadmium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, potassium, selenium, silicon, sodium, strontium, titanium, thallium, vanadium, zinc) were analyzed by inductively coupled plasma atomic emission spectroscopy to identify nutritional beneficial and hazardous plants. For the majority of studied species (31 of 43) data lack completely. For the remaining, only macronutrient contents are published yet, determining their (ultra)trace element and heavy metal contents for the first time. None of the examined plants pose a risk to human health due to low heavy metal contents, seasonality, and low amounts of consumed plant parts. Iron and zinc rich plant parts, such as fruits of *Canarium schweinfurthii*, or leaves of *Crassocephalum rubens*, *Solanum americanum,* and *Piper umbellatum* could help combating deficiency syndromes. The genus *Landolphia* shows to be an aluminum hyperaccumulator with aluminum contents >1000 mg/kg. Results of this study serve as a database for upcoming research. The nutritional value of edible plants is evaluated.

Keywords: wild edible plants; essential elements; nutritional value; heavy metals; recommended nutrient intake; minimal risk level; malnutrition; African traditions; rural population

Introduction

Although Angola has one of the highest per capita incomes, its economy vulnerability index is high, demonstrating wide disparities in the Angolan population, as confirmed by one of the highest child mortality rates worldwide (UNICEF et al., 2019; United Nations, 2018). Combating hunger, reducing mortality and improving maternal health are therefore parts of the Millennium development goals (Republic of Angola, Ministry of Planning, 2010). However, stunting is still a severe health problem for 33% of the rural Angolan population (McDonald et al., 2011). Inadequate dietary intakes, limited food security, poor care, and unhealthy living conditions are aspects leading to malnutrition and the resulting micronutrient deficiencies lead to different disease patterns. Thus, health problems in Angola are related to the unbalanced diet, which mainly consists of carbohydrate rich plants (McDonald et al., 2011). According to the World Health Organization (WHO), a healthy diet should contain at least 400 g of fresh fruits and vegetables per day, apart from potatoes, sweet potatoes and cassava (WHO, 2020).

Angola has a high diversity of wild edible fruits and legumes, but the relevance of these plants for the daily nutrition is low. The local population consumes these products irregularly and occasionally (for example when plants grow along the path). Indigenous African plant species are rarely cultivated, whereas species that originate from the Americas or Asia such as mango, banana, or peanut are commonly grown, although native plants are better adapted to local growing conditions (Baumgärtel et al., 2022b; McDonald et al., 2011).

The rich biodiversity of Angola could serve as a supplementary nutritional source to the few yet cultivated plant species (Figueiredo and Smith, 2008; Kier et al., 2005). The global trend to genetically uniform, high-yielding monocultures affect the plant diversity and in particular the variety of utilized wild edible plants. The Food and Agriculture Organization (FAO) observes a loss of crop varieties over the last decades (FAO, 2006). The documentation, examination, and cultivation of wild edible plants from Africa is thus of special value. Analyzed plants could serve as an alternative perpetual source of income and are a perspective for rural subsistence farmers (Baumgärtel et al., 2022a; Kissanga et al., 2021; McDonald et al., 2011).

Recently, a study from Southern Angola determined three wild leavy vegetables as valuable complementary food resources as they supply proteins, macronutrients, and micronutrients (Kissanga et al., 2021). Edible fruits of the northern province Uíge were further identified to be rich in vitamins (Baumgärtel et al., 2022a). However, comprehensive studies about food security, economic accessibility, food consumption and plant utilization are still lacking.

Only a small part of the plant kingdom has been investigated for their mineral contents and large knowledge gaps exist. Less than 10% of plant genera have been analyzed for their iron content (on species level only 0.52%) and for other micronutrients the data availability is even worse (Ancuceanu et al., 2015). Therefore, the aim of this study is to examine the mineral content and the associated nutritional potential of 43 plant species from Angola. In the Botanical Garden of the University Kimpa Vita in Uíge, we try to cultivate several of the analyzed local food plants for further studies and knowledge transfer. The mineral contents obtained are supposed to be monitored and compared in the course of the year, and on intraspecific level. The results presented are important specifications of a wide range of wild edible plants and serve as a baseline.

Materials and methods

Study area and data collection

The plant material was collected in October/November 2018 and February/March 2019 in nine municipalities of the province of Uíge. The province is located in the North of Angola, neighboring to the Democratic Republic of the Congo (DRC). Six different vegetation zones characterize the province, with forest formations and mosaics of savannah and forest predominating (Barbosa, 1970). The area, covered by a Kalahari sand sheet, is mountainous with planation levels up to 1200 m altitude (Beernaert, 1997). The chemical characteristics of the soil are determined primarily by the low pH,

* Corresponding author

and the related high plant-available amounts of Al and Mn, which are toxic for most crops (BAUMGÄRTEL et al., 2022b). The texture of the predominant ferralitic soils varies from fine sand with low storage capacity in the savanna to clay and loam which can be found in denser vegetation patterns and forests (BAUMGÄRTEL et al., 2022b; MISSÃO DE PEDOLOGIA DE ANGOLA E MOÇAMBIQUE & CENTRO DE ESTUDOS DE PEDOLOGIA TROPICAL, 1968).

The 20 villages where the field research was conducted were preselected according to the different vegetation zones and existing contacts with the relevant local authorities/field guides (Fig. 1). On-site students and lecturers from the University Kimpa Vita Uíge and the Technische Universität Dresden consulted the administrative heads and local authorities ('Soba') to receive a working and collection permission for every region. All participants of our study were informed about aims, methods and their rights (prior informed consent). Every informant was asked to indicate different edible plants occurring in the surroundings. We partially provided photographs of several food plants to support the informants and focus on indigenous, non-cultivated food-plants. Semi structured interviews were used to identify the vernacular name, the utilization and the utilized part of the plant species. Portuguese is the official language of Angola and was mainly used. If necessary, the accompanying student team translated into Kikongo and Kimbundu, languages of the main present ethnic groups Bakongo and Ovimbundu.

Transect walks were performed to identify plants of interest and collect the different edible plant parts. Herbarium vouchers were prepared for later scientific identification and are stored at the Herbarium Dresdense, Technische Universität Dresden, Germany. All vouchers are available in the Virtual Herbaria JACQ. Collection and export permits were issued by the Ministry of Environment Angola and the provincial government of Uíge. In addition, the Instituto Nacional de Biodiversidade e Conservação (INBC) of the Ministério da Cultura, Turismo e Ambiente da República de Angola and the Technische Universität Dresden, Germany signed a binding Memorandum of Understanding in 2014.

Examined Plants

We collected material of 43 plant species with nutritional importance for the local population (Tab. 1).

The majority of analyzed plant parts are fruits (30), followed by leaf samples (9), roots/rhizomes (2) and seeds (2). This distribution of consumed plant parts for nutrition is confirmed by previous studies in the northern provinces of Uíge and Cuanza Norte, where up to 76% of recorded edible plant parts belong to fruits, followed by leaves (19-36%) (GÖHRE et al., 2016; HEINZE et al., 2017; LAUTENSCHLÄGER et al., 2018). Data for species with restricted distribution areas are especially valuable as *Anisophyllea quangensis* (Angola, Cameroon, Zambia, DRC), *Landolphia camptoloba* (Angola, Gabon, Zambia, DRC), *Landolphia lanceolata* (Angola, DRC), *Sabicea gilletii* (Zambia; DRC) or *Raphionacme madiensis* (Angola, Burundi, Kenya, Rwanda, Tanzania, Uganda, Zambia, DRC) (Fig. 2). We even examined one species (*Landolphia villosa*), that was only recently listed for Angola (LAUTENSCHLÄGER et al., 2022). Nevertheless, three introduced species (*Pachira glabra, Passiflora foetida, Solanum americanum*) that are of importance for local diet were also analyzed.

Determination of mineral composition

All harvested plant parts were kept cool (~4 °C) for a maximum of 72 h until they were freeze-dried at the University Kimpa Vita in Uíge (Harvest Right, Medium Pharmaceutical Freeze Dryer). The samples were weighed, peeled if seeds or hard shell had to be removed, and vacuum-sealed for the transport to Germany. For ICP-OES analyzes on an Optima 2000 DV (Perkin Elmer Instruments), two portions of the plant samples (weight: 0.1-2.1 g) were digested with 10 mL of HNO_3 (69%, supraquality, Carl Roth GmbH + Co. KG) in sealed Teflon vessels in a MARS 6, Microwave Digestion System (CEM Corporation) for a double determination. The clear solutions were diluted with ultrapure water (to 50 mL) and analyzed three times in the ICP-OES. In general, microwave-assisted digestion using HNO_3 is efficient for samples with high organic content, but rather inefficient, for digestion of samples with high silicate content. Therefore, the solutions obtained were carefully checked for the formation of precipitates, which did not occur.

For quantification, an external calibration using the Perkin Elmer multi-element standard Quality control 21 (100 mg/L; in 5% HNO_3) was employed for the later analyzed elements As, Cd, Co, Cr, Cu, Fe, Li, Mn, Mo, Ni, Pb, Sb, Se, Si, Sr, Ti, Tl, V and Zn. To quantify Al, Ca, Mg, K, and Na, single element standard solutions were used (1000 mg/L; in 0.5 mol/L HNO_3 (Al), 2% HNO_3 (K, Na); Perkin Elmer, Merck) and for Ca, Mg, K, and Na, an additional dilution step was performed prior to analysis to prevent the saturation of the detector. To monitor the instrument performance and exclude a potential overload, calibration check samples were analyzed after every tenth sample (a calibration standard and a blank measurement). At least two different characteristic emission wavelengths were analyzed for each element (Appendix, A.1). Mercury was excluded in the analyzes as this element is in general hard to determine with ICP-OES due to a "memory effect" (ZHU and ALEXANDRATOS, 2007). For each analyzed element, the limit of detection (LOD) was calculated as the triple standard deviation of the calibration blanks, the limit of quantification (LOQ) as the triple LOD. If the element

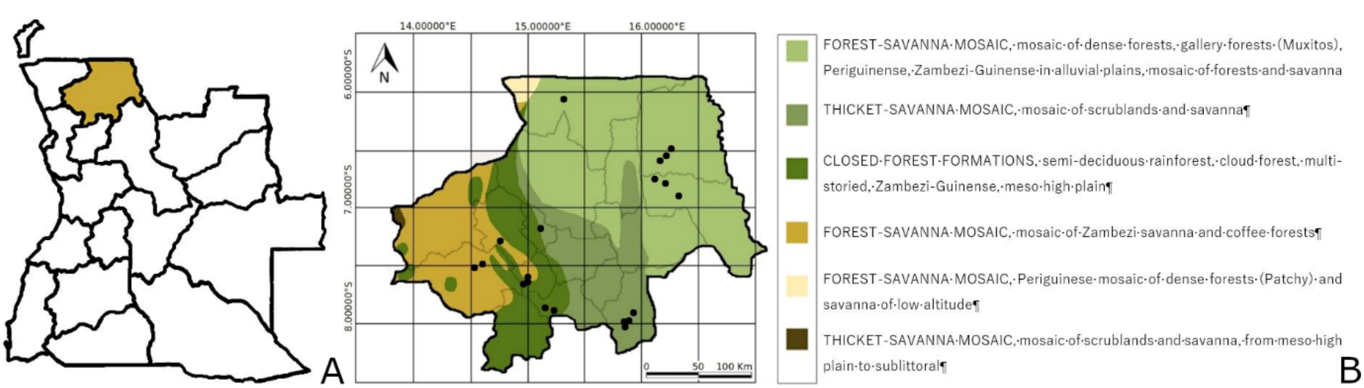

Fig. 1: Map of study area. A: Location of Uíge province in Angola; B: Vegetation zones of Uíge according to the phytogeographic chart of Angola by Barbosa (1970), black dots highlight visited locations

Tab. 1: Overview of the 43 collected and analyzed plants and their characteristics sorted alphabetically by plant family; plant species: scientific and vernacular name with specific voucher number according to Herbarium Dresdense (DR) or photo voucher (PH); Consumed plant part: Fr = fruit, L = leaf, R = root, S = seed; growth form; habitat and soil type according to Carta Generalizada dos Solos de Angola (Missão de Pedologia de Angola e Moçambique & Centro de Estudos de Pedologia Tropical, 1968)

Plant species	Plant part	Growth form	Habitat	Soil type
Achariaceae				
Caloncoba welwitschii (Oliv.) Gilg.; Mbamba, Mandanga; PH_4752	Fr	Tree	Forest, transition Zone	Yellow psammo ferralitic soils, loose sandy sediments
Anacardiaceae				
Pseudospondias microcarpa (A.Rich.) Engl.; Kisantu; DR 067254	Fr	Tree	Secondary forest, forest edge	Red psammo ferralitic soils, consolidated sedimentary rocks
Anisophylleaceae				
Anisophyllea quangensis Engl. ex Henriq.; Mfungu; DR 055143	Fr	Suffrutex	Open habitats	Red psammo ferralitic soils, consolidated sedimentary rocks
Annonaceae				
Annona stenophylla Engl. & Diels; Muloloa; DR 056627	Fr	(Sub)-Shrub	Burnt savanna, grassland	Yellow psammo ferralitic soils, consolidated sedimentary rocks
Apocynaceae				
Clitandra cymulosa Benth.; Menga menga; DR 056600, DR 056602	Fr	Liana	Forest (edge)	Yellow psammo ferralitic soils, loose sandy sediments
Landolphia buchananii (Hallier f.) Stapf; Makonge, Maboke; DR 056596, DR 056597	Fr	Liana	Forest	Chromic typo-paraferralitic soils, consolidated sedimentary rocks
Landolphia camptoloba (K. Schum.) Pichon; Mbungu mbungu; DR 056613, DR 056631	Fr	Shrub	Forest edge	Red psammo ferralitic soils, consolidated sedimentary rocks
Landolphia congolensis (Stapf) Pichon; Lieno Kikambo; DR 056595	Fr	Liana	Forest (edge)	Red psammo ferralitic soils, consolidated sedimentary rocks
Landolphia dewevrei Stapf; Mbungu Mbungu; DR 056612, DR 056632	Fr	Liana	Forest (edge)	Red psammo ferralitic soils, consolidated sedimentary rocks
Landolphia lanceolata (K. Schum.) Pichon; Mata; DR 056634	Fr	Shrub, Suffrutex	Sandy soil in savanna	Red psammo ferralitic soils, consolidated sedimentary rocks
Landolphia owariensis P. Beauv.; Makonge; DR 056599	Fr	Liana	Forest, Transition zone	Red psammo ferralitic soils, consolidated sedimentary rocks and yellow psammo ferralitic soils, loose sandy sediments
Landolphia robustior (K. Schum.) Pers.; Matendimba; DR 056601, DR 056607	Fr	Liana	Forest	Red psammo ferralitic soils, consolidated sedimentary rocks
Landolphia spec., Mbungu mbungu da mata; DR 056611	Fr	Liana	Forest	Red psammo ferralitic soils, consolidated sedimentary rocks
Raphionacme madiensis S. Moore; Sani; DR 056633	R	Herb	Open woodland	Yellow psammo ferralitic soils, consolidated sedimentary rocks
Arecaceae				
Raphia matombe De Wild.; Matombe, Giculo; PH_4959	Fr	Palm	Swampy forests	Red psammo ferralitic soils, consolidated sedimentary rocks
Asphodelaceae				
Aloe cf. *buettneri* A.Berger; Kikalango; PH_5939	L	Succulent	Savanna	Yellow psammo ferralitic soils, loose sandy sediments
Asteraceae				
Crassocephalum rubens (Jacq.) S. Moore; Bungudia; DR 055140	L	Herb	Open woodland, savanna	Yellow psammo ferralitic soils, loose sandy sediments
Crassocephalum vitellinum (Benth.) S.Moore; Bungudi; DR 055135	L	Herb	Open woodland, savanna	Red psammo ferralitic soils, consolidated sedimentary rocks
Vernonella subaphylla (Baker) H.Rob. & Skvarla; Tamba; PH_4543	R	Herb	Woodland	Yellow psammo ferralitic soils, consolidated sedimentary rocks
Burseraceae				
Canarium schweinfurthii Engl.; Mumbidi, M'bidi, Jimbidi; DR 055139	Fr	Tree	Forest (edge)	Yellow psammo ferralitic soils, loose sandy sediments
Chrysobalanaceae				
Parinari capensis Harv.; Kia, Salanka; DR 056615 consolidated sedimentary rocks	Fr	Shrub	Sandy soil, savanna, open woodland	Red psammo ferralitic soils,

Dennstaedtiaceae				
Pteridium centrali-africanum (Hieron.) Alston; Mitekua; DR 067337	L	Fern	Open forests, woodland	Red psammo ferralitic soils, consolidated sedimentary rocks
Fabaceae				
Dialium englerianum Henriq.; Kaboba, Mbota; PH_4092	Fr	Tree	Savanna	Red psammo ferralitic soils, consolidated sedimentary rocks
Loganiaceae				
Strychnos cocculoides Baker; Maboke; DR 055134	Fr	Tree	Savanna, woodland	Red psammo ferralitic soils, consolidated sedimentary rocks
Strychnos pungens Soler.; Madito; DR 055138	Fr	Tree	Savanna, woodland	Red psammo ferralitic soils, consolidated sedimentary rocks
Malvaceae				
Pachira glabra Pasq.; Castanheiro; DR 056617	Fr	Tree	Cultivated	Yellow psammo ferralitic soils, loose sandy sediments
Melastomataceae				
Calvoa aff. *monticola* A.Chev., Hutch. & Dalziel; Ixixi; DR 067260	L	Herb	Forest	Yellow psammo ferralitic soils, consolidated sedimentary rocks
Tristemma mauritianum J. F. Gmel.; Mankondo ma nfinda; DR 056628, DR 056629, DR 056630	Fr	Herb	Swampy forests	Chromic typo-paraferralitic soils, consolidated sedimentary rocks
Moraceae				
Treculia africana Decne.; Tsungi; DR 067249	Se	Tree	Forest, woodland	Red psammo ferralitic soils, consolidated sedimentary rocks
Myrtaceae				
Eugenia malangensis (O. Hoffm.) Nied.; Ndamba Dimi; DR 056619, DR 056620	Fr	Suffrutex	Grassland	Red psammo ferralitic soils, consolidated sedimentary rocks
Olacaceae				
Olax gambecola Baill.; Nkudi; DR 067250	L	Shrub	Forest	Yellow psammo ferralitic soils, consolidated sedimentary rocks
Passifloraceae				
Passiflora foetida L.; Diboke; DR 056616	Fr	Climber	Cultivated, transition zone	Yellow psammo ferralitic soils, loose sandy sediments
Phyllanthaceae				
Antidesma venosum E. Mey. ex Tul.; Muidu; DR 067335	Fr	Tree	Savanna	Yellow psammo ferralitic soils, loose sandy sediments
Hymenocardia ulmoides Oliv.; Tsangambala; DR 067251	L	Tree	Forest, transition zone	Yellow psammo ferralitic soils, consolidated sedimentary rocks
Piperaceae				
Piper umbellatum L.; Lemba kia mfinda; DR 063744	L	Climber	Forest	Yellow psammo ferralitic soils, loose sandy sediments
Polygonaceae				
Oxygonum fruticosum Dammer*;* Sengane; DR 060184, DR 062765	Fr	Herb	Forest, transition zone	Red psammo ferralitic soils, consolidated sedimentary rocks
Rubiaceae				
Colletoecema dewevrei (De Wild.) E. M. A. Petit; Ntseketseke, Mbendembende; DR 055145, DR 055144	Fr	Tree	Forest, transition zone	Red psammo ferralitic soils, consolidated sedimentary rocks
Sabicea gilletii De Wild.; Nzamune; DR 067255	Fr	Climber	Transition Zone	Red psammo ferralitic soils, consolidated sedimentary rocks
Solanaceae				
Solanum americanum Mill.; Gindemba; DR 067873, DR 067872	L	Herb	Forest, transition zone	Chromic typo-paraferralitic soils, consolidated sedimentary rocks
Vitaceae				
Vitex madiensis subsp. *madiensis;* Mfilo*;* DR 063748	Fr	Shrub, tree	Savanna	Yellow psammo ferralitic soil, loose sandy sediments
Zingiberaceae				
Aframomum alboviolaceum (Ridl.) K. Schum.; Gingenga da savanna, Matzunja; DR 063746	Fr	Herb	Savanna	Yellow psammo ferralitic soils, loose sandy sediments
Aframomum angustifolium (Sonn.) K.Schum.; Matsatsa, Mansasa, Imbutua; DR 063745	Fr	Herb	Wet places, forest, riverines	Yellow psammo ferralitic soils, loose sandy sediments
Aframomum giganteum (Oliv. & D.Hanb.) K.Schum.; Mapodia; DR 063747	Fr	Herb	Forest, transition zone	Yellow psammo ferralitic soils, loose sandy sediments

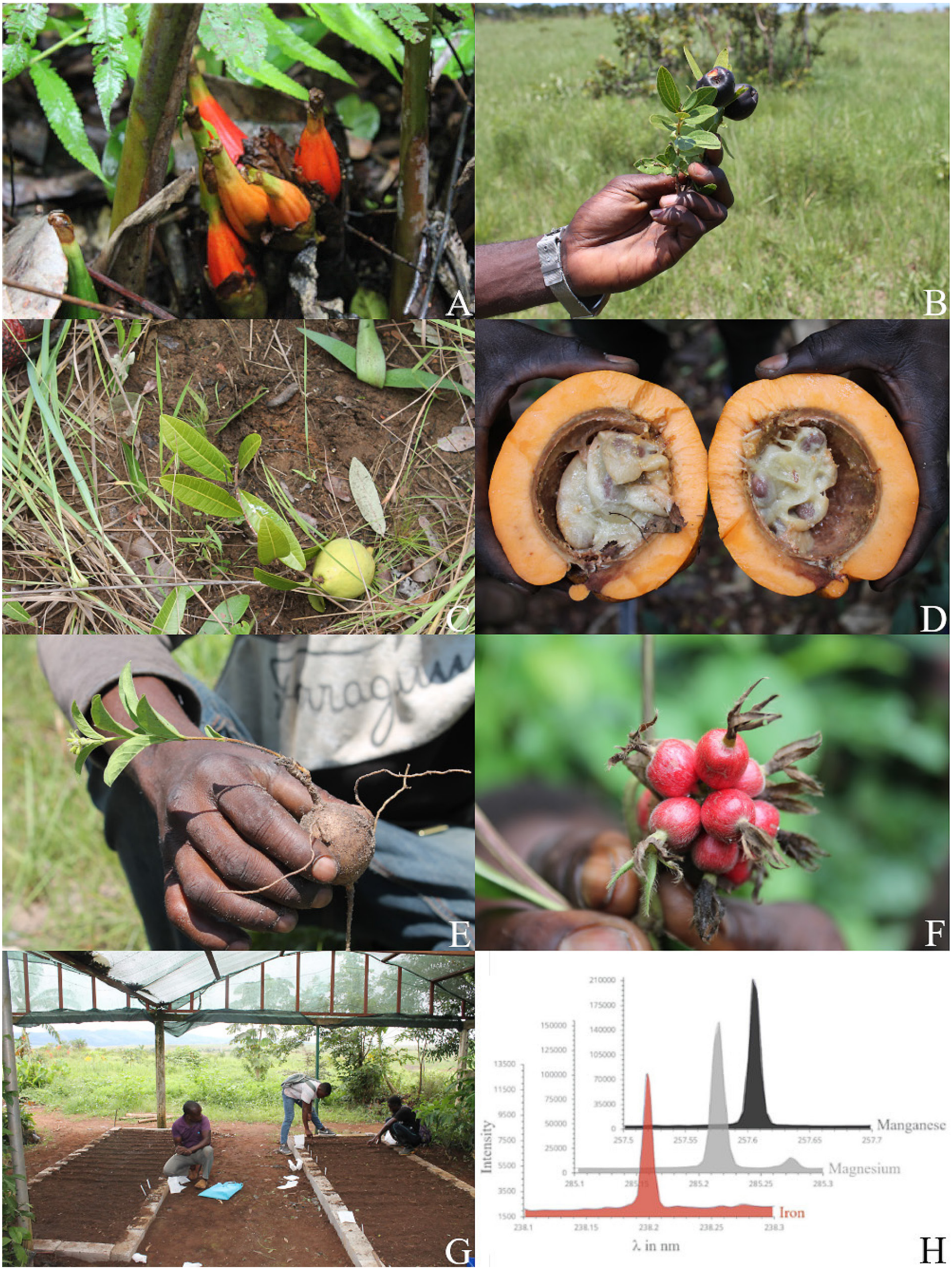

Fig. 2: Overview of analyzed plant species, cultivation trials and spectra of the ICP-OES; A: *Aframomum angustifolium*; B: *Anisophyllea quangensis*; C: *Landolphia lanceolata*; D: *Landolphia villosa*; E: *Raphionacme madiensis*; F: *Sabicea gilletii*; G: Cultivation areas in the Botanical Garden Uíge, Universidade Kimpa Vita; H: Examples of spectra taken by the ICP-OES analysis for Fe, Mg and Mn for seeds of *Treculia africana*.

concentration did not exceed the LOD, we quote the respective LOD in brackets behind. If the results exceed the LOD while going below the LOQ, the LOQ is quoted in brackets. If the element content was quantifiable, we calculated the average and quote it together with the standard error of the mean (SEM). Since the weights of the samples to be digested vary (0.1-2.1 g), the resulting LOD and LOQ values fluctuate.
In the beginning of the study, facilities to freeze-dry the plant material on site in Angola lacked and frozen material was transported to Germany. To compare all samples, we calculated the content of each element in mg/kg fresh weight of each analyzed plant part. The plant material of several specimens was collected in multiple areas in the province of Uíge. The number of locations included in this analysis is indicated in brackets after each plant species. The data sets of the respective plant species are aggregated. To evaluate and interpret the obtained results, an internet search using the platforms Scopus, Web of Science and Google Scholar was carried out for the search term of the respective plant species and often occurring synonyms or misspellings (i.e., *Landolfia* instead of *Landolphia*), taking into account publications with comparable data.

Results and discussion

The mineral contents of the 43 analyzed plant parts are summarized in Table 3 (Al, Ca, Cu, Fe, K, Mg, Mn, Na, Ni, Si, Sr, Ti, Zn), and in Appendix A.2 for elements, which could not be detected in the majority of analyzed plant parts (As, Cd, Co, Cr, Li, Mo, Pb, Sb, Se, Tl, V).
The following results and discussion briefly summarize the respective functions and possible toxicity effects of the elements analyzed, starting with major elements, followed by trace elements, and ultra-trace elements/others. For hazardous/toxic elements we indicate the Minimal Risk Level (MRL) for the oral intake published by the Agency for Toxic Substances and Disease Registry (ATSDR). Comparable data were only found for 12 of the 43 plants analyzed. However, most publications only deal with quantity elements such as Ca, Mg, K and Na, lacking the other 20 analyzed elements. Plant species with reference values are marked with an asterisk in Tab. 3. Detailed data and corresponding literature references are summarized in Appendix A.3.

Quantity elements (Ca, Mg, K, Na)

Quantity elements are important for the human nutrition and often interact as antagonists. The WHO/FAO recommends a daily Ca intake of 1000 mg (for pregnant and elderly people more), whereas the actual intake for the Angolan population is comparatively low (300 mg) and Ca suppliers are needed (Country Nutrition Profiles, 2020; WHO and FAO, 2004). High Ca contents were determined for leaves of *Aloe* cf. *buettneri* (8110 mg/kg), *Olax gambecola* (4429 mg/kg) and *Piper umbellatum* (2174 mg/kg) (Tab. 3). These contents are first reported for *O. gambecola* and verify previous results for *P. umbellatum* from Malaysia (2111 mg/kg) (Appendix, A.3) (Saupi et al., 2021). Higher Ca contents were already determined for commonly consumed *Hibiscus sabdariffa* and *Amaranthus* leaves, which are considered as valuable Ca sources for the West African Population (Boukari et al., 2001; Kissanga et al., 2021; Odhav et al., 2007). All fruit pulps from *Landolphia* and *Clitandra* show a low Ca content, which is confirmed by previous results for these genera (Bassey, 2012; Gueye et al., 2022; Herzog et al., 1994; Odoh and Agbachi, 2020; Opaleke et al., 2022). Mg is a physiological antagonist to Ca and associated with nerval and neuromuscular functions (WHO and FAO, 2004). The recommended Mg intake amounts 260 mg/day and the risk for Mg deficiency in Angola is low (estimated Mg intake 364 mg/day) (Joy et al., 2013; WHO and FAO, 2004). High Mg contents above 1000 mg/kg were measured for leaves of *O. gambecola* (2262 mg/kg, analyzed for the first time) and *P. umbellatum* (1203 mg/kg), confirming the results of Saupi et al. (2021) (Appendix A.3). Seeds of *Treculia africana* (1022 mg/kg) and the fruit pulp of *Caloncoba welwitschii* (1235 mg/kg) are rich in Mg as well (Tab. 3). For *T. africana* reference values vary widely (from 96 up to 1711 mg/kg) (Appendix A.3) (Ajayi, 2008; Appiah et al., 2016; Edet, 1985; James et al., 2020; Lawal, 1986; Osabor et al., 2009). The highest amount of Mg is found in seeds of *Pachira glabra* (2297 mg/kg). All examined species of *Apocynaceae* have a low Mg content (<300 mg/kg), as already published for the fruits of *Landolphia* spp. (Herzog et al., 1994). However, recent analyzes of *L. heudelotii* from Senegal identified the fruit as important source of Mg (Gueye et al., 2022).
The WHO recommends an increase in K intake up to 3510 mg/day to reduce the risk of cardiovascular disease, stroke and high blood pressure (Alves et al., 2018; WHO, 2012a). A beneficial ratio of one to one between Na and K is desired, revealing a K deficiency for the Angolan population where the ratio is 3:1 (Magalhães et al., 2015). Leaves of *Crassocephalum* (*C. rubens* 9403 mg/kg; *C. vitellinum* 7138 mg/kg), *Olax gambecola* (8429 mg/kg) and seeds of *Pachira glabra* (8987 mg/kg) are described as good K suppliers for the first time and thus are valuable wild edible plants (Tab. 3). All analyzed species of *Aframomum* show high K values and confirm previous results of this genus (Appendix A.3) (Herzog et al., 1994; Nsi Akoue et al., 2019). In contrast, leaves of *Calvoa* aff. *monticola* and *Hymenocardia ulmoides* are low in K (<800 mg/kg).
High Na intake is assumed to have negative health effects and the WHO recommends a reduction of Na to a level of less than 2000 mg/day (WHO, 2012b). Na is low in plant products proven by a low average Na content in all plant parts studied (35 mg/kg). Thus, the consumption of studied plants is recommended and expected to have positive health effects (Tab. 3).

Trace elements (Cr, Co, Cu, Fe, Mn, Mo, Zn)

The majority of analyzed plant samples has a Cr concentration below the LOD or LOQ (37) (Appendix, A.2). Five fruits and one leaf sample have a Cr content between 0.4 to 2.1 mg/kg and are analysed for the first time within this study (Tab. 2). The status of Cr as essential nutrient is discussed controversially as recognized deficiency diseases lack. Plants with a comparable high Cr amount are fruits of *Landolphia dewevrei* (2.1 mg/kg), *Oxygonum fruticosum* (1.3 mg/kg) or *Eugenia malangensis* (0.7 mg/kg) (Tab. 2).

Tab. 2: Chromium content of six plant species for fresh weight in mg/kg; Fr = fruit; L = leaf

Plant species	Plant part	Cr [mg/kg]
Anisophyllea quangensis Engl. ex Henriq.	Fr	0.4 ± 0.1
Crassocephalum vitellinum (Benth.) S. Moore	L	0.6 ± 0.3
Eugenia malangensis (O. Hoffm.) Nied.	Fr	0.7 ± 0.1
Landolphia spec.	Fr	0.4 ± 0.2
Landolphia dewevrei Stapf	Fr	2.1 ± 0.2
Oxygonum fruticosum Dammer	Fr	1.3 ± 0.2

Only in three plant samples the Co content is above the LOQ (Appendix, A.2): fruits of *Vitex madiensis* subsp. *madiensis* (0.4 mg/kg), seeds of *Pachira glabra* (0.6 mg/kg) and leaves of *Solanum americanum* (0.7 mg/kg). The ATSDR (Agency for Toxic Substances and Disease Registry) publishes an oral MRL for the intermediate-duration (15-364 days) of 0.01 mg Co/kg per day (ATSDR, 2004a). The consumption of the plant products mentioned has therefore to be studied in detail taking into account seasonality, uptake and consumed quantities.

Cu is known to cause harmful deficiency symptoms and toxic effects in plants and humans (Yruela, 2009). The main Cu source for humans is water and food. The ATDSR publishes an oral MRL for intermediate duration (15-364 days) of 0.01 mg/kg Cu per day (ATSDR, 2022). The Cu contents of the seeds of *Pachira glabra* and *Treculia africana* present the maximum within this study with 14.9 mg/kg and 7.4 mg/kg, respectively. Seeds of *T. africana* were intensively studied and reveal large fluctuations in the Cu content varying from 1 to 41 mg/kg (Appendix, A.3) (Ajayi, 2008; James et al., 2020; Osabor et al., 2009).The amount of consumed plant products with a high Cu content needs to be analyzed in detail to avoid toxicity effects.

Anemia is a disease which is prevalent in Angola and arises from Fe deficiency. Pregnant women are at particular high risk (57.1%) as well as preschool aged children (29.7%) (Micronutrient Initiative, 2009). The dietary Fe intake via food is accordingly inadequate. Around 6 mg Fe are required daily and the dietary integration of Fe rich plant sources such as *Solanum americanum* (74.8 mg/kg) or *Crassocephalum rubens* (60.7 mg/kg) is beneficial (Institute of Medicine, 2001). Previous published Fe contents of *S. americanum* (Booth et al., 1992) are significant lower (30 mg/kg) and more specific data about growing conditions of the individuals are needed (Appendix, A.3). The average Fe content is 14.0 mg/kg, placing the studied species of *Strychnos* at the minimum range (both analyzed species <3 mg/kg). However, previous studies identified the so-called monkey orange (*Strychnos* spp.) as a genus with high Fe contents and beneficial health effects (Appendix, A.3) (Ngadze et al., 2017).

Fruits of *Antidesma venosum* are rich in Mn (238 mg/kg) as well as fruits of the genus *Aframomum* (*A. angustifolium* 95.8 mg/kg; *A. giganteum* 63.8 mg/kg) (Tab. 3). In contrast, the fruit pulp of *Landolphia* spp. is low in Mn. Mn is rarely analyzed in its nutritional context and the data obtained present a first insight for a variety of edible plants. Comparable data were only found for *Hymenocardia ulmoides*, *Passiflora edulis* and *Piper umbellatum* (Appendix A.3).

The analysis of seeds from the tree *Pachira glabra* reveals a Mo content of 1.2 mg/kg. The oral MRL for intermediate exposure (15-364 days) is 0.06 mg/kg per day. Only a high daily intake of *Pachira glabra* would be harmful and could have negative effects (ATSDR, 2020). In all other examined plant parts Mo could not be detected (23 plant specimens below LOD; 19 plant specimens below LOQ) (Appendix, A.2).

Zn is an essential nutrient for plants and humans but high doses can result in toxic effects (ATSDR, 2005). A well-balanced Zn diet is therefore recommended. An estimate of 46% of the Angolan population is at risk of inadequate Zn supply (Micronutrient Initiative, 2009). The average Zn content of analyzed plant specimens is 7.7 mg/kg, with minimum contents occurring in fruits of the genus *Strychnos (S. cocculoides* 0.4 mg/kg; *S. pungens* 1.1 mg/kg) and *Parinari capensis* (1.1 mg/kg) (Tab. 3). The highest amounts of Zn were found in leaves of *Aloe* cf. *buettneri* (25.8 mg/kg*)*, seeds of *Pachira glabra* (27.1 mg/kg) and fruits of *Canarium schweinfurthii* (83.7 mg/kg). Consuming *C. schweinfurthii* fruits would therefore be beneficial for pregnant and lactating women, as they are in need of a large amount of Zn.

Ultratrace elements and others (Al, Li, Ni, Se, Si, Sr, Tl, Ti, V)

Al has no essential function in the human body and its consumption is rather hazardous for children or adults with chronic kidney disease (ATSDR, 2008). The estimated daily intake is 0.12 mg/kg and the oral MRL for intermediate duration (15-364 days) is 1 mg/kg per day (ATSDR, 2008). The Al content of the investigated plant tissues is relatively high with an average of 237 mg/kg. However, the median of 17.4 mg/kg demonstrates the huge effect of four plant species with high Al contents (*Landolphia congolensis* 1609 mg/kg, *Landolphia dewevrei* 1531 mg/kg*, Landolphia lanceolata* 723 mg/kg and *Anisophyllea quangensis* 713 mg/kg). These species can be considered as Al hyperaccumulators as recently demonstrated by Baumgärtel et al. (2022), which detected high plant-available Al amounts in the soil and dried leaf. The uptake of Al and accompanying health effects have to be investigated in detail. Data about the Al content of natural foods are sparse, especially for Africa.

Fruits of *Vitex madiensis* subsp. *madiensis* and leaves of *Solanum americanum* are the only sources of a detectable amount of Li (0.3 mg/kg for each plant part) (Appendix, A.2). Li is believed to have a positive effect on the human body as it is used as a mood stabilizer (Schrauzer, 2002). The average daily Li intake for adults varies over a large range from 348 µg/day (Austria) to 1560 µg/day (China), placing the fruit and leaf consumption of *V. madiensis* subsp. *madiensis* and *S. americanum* at the minimum range (300 µg Li provided by 1 kg *Vitex* fruits) (Schrauzer, 2002).

As a key component in the nitrogen metabolism of plants Ni can be found in higher amounts in the N-fixation plant family Fabaceae (Liu et al., 2020). In our study, the highest Ni contents are found in seeds of *Pachira glabra* (3 mg/kg), fruits of *Landolphia dewevrei* (1.7 mg/kg), *Landolphia owariensis* (1.6 mg/kg), *Oxygonum fruticosum* (1.2 mg/kg), and the only analyzed member of Fabaceae, fruits of *Dialium englerianum* with a Ni content of 1.1 mg/kg. So far no reference data for any of the species exist, necessitating more intensive research in this area. In total, the Ni content of 21 plants could be quantified (Tab. 3).

Se is an essential micronutrient for humans, but can be harmful when consumed over a long time in high quantities (ATSDR, 2003). Se is only quantified in fruits of the subshrub *Anisophyllea quangensis* (2.8 mg/kg) which can be considered as a non-accumulating plant posing no health risks according to published MRL (ATSDR, 2003).

Si is reported as a bioactive, beneficial element, whereas its essentiality is questioned at the moment (Farooq and Dietz, 2015). The highest Si content in this study is found in roots of *Vernonella subaphylla* (330 mg/kg), fruits of *Dialium englerianum* (312 mg/kg) and leaves of *Crassocephalum vitellinum* (302 mg/kg) (Tab. 3) exceeding those of Si rich bananas (62 mg/kg) (Robberecht et al., 2008). However, the absorbable Si content has to be determined in future studies to evaluate the nutritional importance of those plant products. Contaminations due to adhering soil residues are unlikely to occur in the fruits growing high up in the tree *D. englerianum*. However, as the deviations between the different samples of *V. subaphylla* and *C. vitellinum* are high, soil contaminations cannot be excluded completely and obtained values have to be verified.

Sr is chemically similar to Ca and thus taken up in the same manner by plants and animals. Thus, high Sr doses could affect the skeletal development, in particular by children during bone mineralization. A malnutrition with a lack of Ca could enhance the adverse effects of Sr. The Sr content of analyzed plant tissues ranges from 0.2 to 32.7 mg/kg and seems to have no negative effects (Tab. 3). Leaves of *Solanum americanum* (7.6 mg/kg), roots of *Vernonella subaphylla* (13.6 mg/kg) and leaves of *Aloe* cf. *buettneri* (32.7 mg/kg) show the highest amount. A potential hazardous daily consumption of 140 mg Sr is unlikely even considering the sum of several consumed plant parts (ATSDR, 2004b).

Tl has not been detected in the majority of examined plant species or its concentration is beneath the LOQ (26 plants below LOD; 15 below LOQ) (Appendix, A.2). Leaves of *Crassocephalum rubens* (1.3 mg/kg) and *Solanum americanum* (0.8 mg/kg) are first reported to contain Tl. However, obtained contents have to be verified as the pure emission lines of Tl were overlapping and result in high measurement uncertainties. Studies about health effects by low

Tab. 3: Content of aluminum (Al), calcium (Ca), copper (Cu), iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), sodium (Na), nickel (Ni), silicon (Si), strontium (Sr), titanium (Ti) and zinc (Zn) of the 43 analyzed plant species for fresh weight in mg/kg; number of collection sites in brackets behind plant species; * = comparable data were found, see Appendix (A.3); Fr = fruit; L = leaf; Se = seed; n. a. = not analyzed; LOD = below limit of detection; LOQ = below limit of quantification

Plant species	Plant part	Al [mg/kg]	Ca [mg/kg]	Cu [mg/kg]	Fe [mg/kg]	K [mg/kg]	Mg [mg/kg]	Mn [mg/kg]	Na [mg/kg]	Ni [mg/kg]	Si [mg/kg]	Sr [mg/kg]	Ti [mg/kg]	Zn [mg/kg]
**Afromomum alboviolaceum* (Ridl.) K. Schum. (1)	Fr	2.8 ± 0.1	*169 ± 2	2.1 ± 0.1	*7.6 ± 0.1	*4539 ± 43	*324 ± 2	45.6 ± 0.5	12.4 ± 0.3	LOQ (<0.4)	31.3 ± 2.3	1.2 ± 0.1	LOQ (<0.2)	7.5 ± 0.1
Aframomum angustifolium (Sonn.) K.Schum. (2)	Fr	n. a.	275 ± 3	3.5 ± 0.1	9.7 ± 0.1	4647 ± 34	595 ± 6	95.8 ± 1.0	10.1 ± 0.2	0.9 ± 0.1	n. a.	2.3 ± 0.1	LOD (<0.3)	12.5 ± 0.1
Aframomum giganteum (Oliv. & D.Hanb.) K.Schum. (1)	Fr	n. a.	194 ± 2	3.4 ± 0.1	14.4 ± 0.1	4553 ± 28	539 ± 3	63.8 ± 0.3	13.7 ± 0.3	0.4 ± 0.1	n. a.	1.5 ± 0.1	LOQ (<0.3)	12.5 ± 0.1
Aloe cf. *buettneri* A.Berger (1)	L	n. a.	8110 ± 2	3.6 ± 0.1	34.2 ± 0.1	1089 ± 28	264 ± 3	5.3 ± 0.3	30.0 ± 0.3	LOD (<0.2)	n. a.	32.7 ± 0.1	2.0 ± 1.0	25.8 ± 0.1
Anisophyllea quangensis Engl. ex Henriq. (1)	Fr	713 ± 6	116 ± 6	1.7 ± 0.1	4.3 ± 0.1	n. a.	107 ± 4	12.8 ± 0.2	n. a.	0.6 ± 0.1	26.5 ± 0.5	0.7 ± 0.1	0.3 ± 0.1	2.2 ± 0.1
Annona stenophylla Engl. & Diels (1)	Fr	6.5 ± 0.1	590 ± 11	1.5 ± 0.1	6.0 ± 0.2	4354 ± 95	288 ± 2	4.2 ± 0.1	38.5 ± 0.3	LOQ (<0.4)	43.7 ± 1.2	3.3 ± 0.1	0.6 ± 0.1	2.1 ± 0.1
Antidesma venosum E. Mey. (1) ex Tul.	Fr	10.5 ± 0.1	1420 ± 7	1.8 ± 0.1	9.0 ± 0.1	3782 ± 28	466 ± 4	238 ± 3	36.5 ± 0.5	0.7 ± 0.1	126 ± 2	3.6 ± 0.1	LOQ (<2.5)	6.6 ± 0.1
Caloncoba welwitschii (Oliv.) Gilg. (1)	Fr	n. a.	761 ± 5	3.1 ± 0.1	8.0 ± 0.1	4513 ± 27	12535 ± 8	17.5 ± 0.2	144 ± 2	LOD (<0.7)	n. a.	4.3 ± 0.1	LOQ (<1.3)	5.6 ± 0.1
Calvoa aff. *monticola* A.Chev., Hutch. & Dalziel (1)	L	n. a.	580 ± 11	1.2 ± 0.1	24 ± 0.3	766 ± 5	795 ± 6	23.9 ± 0.8	55.0 ± 1.0	LOQ (<0.5)	n. a.	1.7 ± 0.1	LOQ (<2.5)	3.1 ± 0.1
**Canarium schweinfurthii* Engl. (1)	Fr	4.4 ± 0.1	*114 ± 2	1.7 ± 0.1	*6.8 ± 0.2	*n. a.	*75.2 ± 2.5	2.6 ± 0.1	*n. a.	LOQ (<0.4)	129 ± 2	0.6 ± 0.1	1.0 ± 0.1	83.7 ± 1.4
Clitandra cymulosa Benth. (2)	Fr	n. a.	52.5 ± 0.5	1.6 ± 0.1	6.3 ± 0.1	3016 ± 26	118 ± 1	5.0 ± 0.1	13.3 ± 0.3	0.9 ± 0.1	n. a.	0.4 ± 0.1	LOD (<0.2)	4.1 ± 0.1
Colletoecema dewevrei (De Wild.) E. M. A. Petit (1)	Fr	470 ± 17	532 ± 11	1.7 ± 0.1	4.0 ± 0.1	4451 ± 76	379 ± 5	39.9 ± 0.6	n. a.	LOQ (<0.5)	77.3 ± 0.9	3.5 ± 0.1	0.8 ± 0.1	2.6 ± 0.1
Crassocephalum rubens (Jacq.) S. Moore (1)	L	117 ± 1	1040 ± 34	4.9 ± 0.1	60.7 ± 1.4	9403 ± 150	254 ± 5	36.4 ± 1.3	22.0 ± 1.0	0.3 ± 0.1	166 ± 4	3.6 ± 0.2	1.4 ± 0.1	5.2 ± 0.2
Crassocephalum vitellinum (Benth.) S. Moore (1)	L	17.4 ± 0.8	820 ± 13	2.0 ± 0.1	15.5 ± 0.2	7138 ± 169	189 ± 2	8.9 ± 0.1	n. a.	0.6 ± 0.1	302 ± 16	3.7 ± 0.1	0.9 ± 0.1	3.2 ± 0.1
Dialium englerianum Henriq. (1)	Fr	15.6 ± 1.0	362 ± 6	4.9 ± 0.2	15.2 ± 0.3	n. a.	347 ± 15	28.4 ± 1.0	n. a.	1.1 ± 0.8	312 ± 3	0.8 ± 0.1	1.8 ± 0.1	5.2 ± 0.3
Eugenia malangensis (O. Hoffm.) Nied. (1)	Fr	103 ± 3	333 ± 12	1.4 ± 0.1	35.7 ± 0.9	n. a.	179 ± 3	12.0 ± 0.3	n. a.	0.9 ± 0.3	211 ± 14	1.9 ± 0.1	3.7 ± 0.2	3.5 ± 0.3
**Hymenocardia ulmoides* Oliv. (1)	L	*n. a.	*293 ± 3	0.9 ± 0.1	*14.3 ± 0.1	*708 ± 9	*414 ± 4	*22.2 ± 0.2	*26.5 ± 0.6	LOD (<0.2)	n. a.	0.6 ± 0.1	0.6 ± 0.1	3.2 ± 0.1
Landolphia spec. (1)	Fr	22.6 ± 0.4	5.0 ± 0.8	2.8 ± 0.1	7.5 ± 0.1	885 ± 36	71.4 ± 6.0	1.9 ± 0.1	n. a.	0.6 ± 0.1	47.0 ± 1.1	0.2 ± 0.1	0.6 ± 0.1	2.9 ± 0.1
Landolphia buchananii (Hallier f.) Stapf (2)	Fr	16.6 ± 0.1	104 ± 1	1.9 ± 0.1	4.7 ± 0.1	2818 ± 11	166 ± 1	9.5 ± 0.1	36.1 ± 0.5	0.8 ± 0.1	5.6 ± 0.3	0.3 ± 0.1	0.9 ± 0.1	2.6 ± 0.1
Landolphia camptoloba (K. Schum.) Pichon (1)	Fr	12.7 ± 0.5	159 ± 2	1.9 ± 0.1	7.2 ± 0.1	2748 ± 188	255 ± 3	26.7 ± 0.3	n. a.	0.9 ± 0.1	95.8 ± 3.0	0.8 ± 0.1	1.1 ± 0.2	3.9 ± 0.1
Landolphia congolensis (Stapf) Pichon (1)	Fr	1609 ± 24	53.5 ± 0.8	2.8 ± 0.1	12.4 ± 0.1	3404 ± 78	108 ± 1	3.3 ± 0.1	93.0 ± 2.8	0.4 ± 0.3	23.0 ± 0.4	0.3 ± 0.1	0.9 ± 0.1	4.6 ± 0.1
Landolphia dewevrei Stapf (1)	Fr	1531 ± 7	65.6 ± 0.5	1.7 ± 0.1	13.6 ± 0.2	4489 ± 40	118 ± 1	4.1 ± 0.1	n. a.	1.7 ± 0.4	98.1 ± 0.7	0.4 ± 0.1	1.3 ± 0.1	2.3 ± 0.1
Landolphia lanceolata (K. Schum.) Pichon (1)	Fr	723 ± 38	42.1 ± 0.4	2.3 ± 0.1	5.0 ± 0.1	2974 ± 16	113 ± 1	2.7 ± 0.1	14.8 ± 0.3	LOQ (<0.4)	30.1 ± 1.7	0.3 ± 0.1	0.4 ± 0.1	1.6 ± 0.1
**Landolphia owariensis* P. Beauv. (2)	Fr	n. a.	*57.1 ± 0.5	1.7 ± 0.1	*4.9 ± 0.1	*1647 ± 13	*140 ± 1	2.7 ± 0.1	44.5 ± 0.6	1.6 ± 0.1	n. a.	0.3 ± 0.1	LOD (<0.3)	3.5 ± 0.1
Landolphia robustior (K. Schum.) Pers. (2)	Fr	n. a.	107 ± 1	2.5 ± 0.1	7.7 ± 0.1	2104 ± 22	160 ± 2	12.1 ± 0.1	34.4 ± 0.5	LOQ (<0.3)	n. a.	0.4 ± 0.1	LOD (<0.3)	3.0 ± 0.1
Olax gambecola Baill. (2)	L	n. a.	4429 ± 34	5.1 ± 0.1	24.2 ± 0.1	8429 ± 74	2262 ± 15	53.9 ± 0.9	38.5 ± 1.0	1.0 ± 0.1	n. a.	1.0 ± 0.1	LOQ (<2.4)	8.2 ± 0.1
Oxygonum fruticosum Dammer (1)	Fr	5.3 ± 0.2	171 ± 2	0.4 ± 0.1	9.7 ± 0.1	1406 ± 27	208 ± 2	5.1 ± 0.1	n. a.	1.2 ± 0.1	44.1 ± 1.6	0.4 ± 0.1	0.5 ± 0.1	2.8 ± 0.1
Pachira glabra Pasq. (1)	Se	n. a.	1268 ± 9	15 ± 0.2	23.6 ± 0.2	8987 ± 128	2297 ± 33	23.5 ± 0.1	33.7 ± 0.6	3.0 ± 0.1	n. a.	5.3 ± 0.1	LOD (<0.6)	27.1 ± 0.2
Parinari capensis Harv. (1)	Fr	n. a.	807 ± 9	LOQ (<1.3)	2.6 ± 0.1	2233 ± 30	267 ± 2	2.1 ± 0.1	21.5 ± 0.6	LOD (<0.2)	n. a.	2.6 ± 0.1	LOQ (<0.2)	1.1 ± 0.1
**Passiflora foetida* L. (1)	Fr	n. a.	*866 ± 12	*2.6 ± 0.1	*8.4 ± 0.3	*4842 ± 37	*552 ± 7	*5.3 ± 0.1	*18.1 ± 0.4	LOQ (<0.3)	n. a.	1.6 ± 0.1	LOQ (<0.8)	*8.7 ± 0.1
**Piper umbellatum* L. (2)	L	10.4 ± 0.2	*2174 ± 15	*2.5 ± 0.1	*24.9 ± 0.1	*4503 ± 25	*1203 ± 8	*18.1 ± 0.1	*37.8 ± 0.5	LOQ (<0.8)	167 ± 2	6.2 ± 0.1	3.0 ± 0.1	*8.8 ± 0.1
**Pseudospondias microcarpa* (A.Rich.) Engl. (1)	Fr	n. a.	*181 ± 3	0.7 ± 0.1	*12.8 ± 0.1	*4256 ± 62	*248 ± 3	6.0 ± 0.1	10.5 ± 0.6	LOD (<0.1)	n. a.	0.7 ± 0.1	0.7 ± 0.1	2.8 ± 0.1
**Pteridium centrali-africanum* (Hieron.) Alston (1)	L	n. a.	*81 ± 1	1.6 ± 0.1	*5.7 ± 0.1	2947 ± 47	197 ± 3	2.4 ± 0.1	24.0 ± 1.2	LOQ (<0.7)	n. a.	LOQ (<0.3)	LOD (<0.7)	3.6 ± 0.1
Raphia matombe De Wild. (1)	Fr	n. a.	2516 ± 6	0.8 ± 0.2	4.3 ± 0.1	2429 ± 22	560 ± 9	49.5 ± 1.2	57.2 ± 0.3	LOD (<0.2)	n. a.	7.1 ± 0.2	LOD (<0.4)	5.7 ± 0.1
Raphionacme madiensis S. Moore (1)	R	4.6 ± 0.3	545 ± 7	0.3 ± 0.1	2.1 ± 0.1	n. a.	683 ± 16	2.5 ± 0.1	n. a.	LOD (<0.1)	44.0 ± 1.4	4.1 ± 0.1	0.7 ± 0.1	1.7 ± 0.1
Sabicea gilletii De Wild. (1)	Fr	n. a.	639 ± 4	2.3 ± 0.1	10.3 ± 0.1	1431 ± 20	302 ± 1	56.7 ± 0.6	21.0 ± 0.6	LOD (<0.2)	n. a.	3.6 ± 0.2	0.5 ± 0.1	2.4 ± 0.1
**Solanum americanum* Mill. (1)	L	154 ± 10	*n. a.	1.8 ± 0.1	*74.8 ± 1.0	*n. a.	*n. a.	59.6 ± 0.6	n. a.	LOQ (<0.2)	192 ± 7	7.6 ± 0.3	6.9 ± 0.1	10.0 ± 0.1
**Strychnos cocculoides* Baker (1)	Fr	1.6 ± 0.2	*171 ± 1	*0.3 ± 0.1	*1.6 ± 0.1	*2062 ± 37	*281 ± 8	11.7 ± 0.2	*n. a.	0.5 ± 0.2	25.7 ± 0.9	0.7 ± 0.1	0.3 ± 0.1	*0.4 ± 0.1
**Strychnos pungens* Soler. (1)	Fr	7.9 ± 0.3	*219 ± 2	*1.6 ± 0.1	*2.6 ± 0.1	*5630 ± 132	*368 ± 3	13.4 ± 0.2	*n. a.	LOQ (<0.5)	46.0 ± 0.6	1.3 ± 0.1	0.4 ± 0.1	*1.1 ± 0.1
**Treculia africana* Decne. (1)	Se	n. a.	*867 ± 12	*7.4 ± 0.2	*17.6 ± 0.2	*3616 ± 36	*1022 ± 9	*34.7 ± 0.4	*38.2 ± 0.6	LOQ (<0.7)	n. a.	1.1 ± 0.1	LOD (<0.7)	*11.0 ± 0.1
Tristemma mauritianum J. F. Gmel. (2)	Fr	316 ± 15	1370 ± 14	1.9 ± 0.1	14.2 ± 0.1	1622 ± 13	372 ± 3	26.5 ± 0.3	18.5 ± 1.0	0.5 ± 0.1	116 ± 6	6.2 ± 0.1	LOD (<0.2)	4.4 ± 0.1
Vernonella subaphylla (Baker) H.Rob. & Skvarla (1)	R	38.0 ± 2.2	806 ± 27	1.6 ± 0.4	20.8 ± 0.6	n. a.	580 ± 1	19.8 ± 0.6	n. a.	LOQ (<3.5)	330 ± 6	13.6 ± 0.7	3.1 ± 0.7	14.6 ± 0.4
Vitex madiensis subsp. *Madiensis* (1)	Fr	22.2 ± 0.2	264 ± 2	1.0 ± 0.1	3.6 ± 0.1	5040 ± 52	256 ± 1	47.0 ± 0.4	30.7 ± 0.6	0.8 ± 0.1	17.2 ± 0.6	1.0 ± 0.1	1.0 ± 0.7	3.1 ± 0.1

exposure over a long period are lacking and upcoming studies have to be taken into account to protect the health of the local population (ATSDR, 1992).

Ti is a non-essential but beneficial nutrient for plants (Bacilieri et al., 2017). It interacts with other nutrients, especially Fe for which a synergistic/antagonistic relationship is hypothesized (Lyu et al., 2017). Ti is part of several plant fertilizers. The plant uptake of this element is directly dependent upon the soil acidity, which is limiting the effects of the fertilizer in alkaline soils. Acidic soils, as the studied ones, increase the Ti solubility and result in higher Ti uptakes (Baumgärtel et al., 2022b; Lyu et al., 2017). The Ti content of 26 plants studied ranges from 0.3 to 6.9 mg/kg (Tab. 3). The highest contents were found in plants growing on fine sand, which are extremely acidic (fruits of *Eugenia malangensis* 3.7 mg/kg; leaves of *Solanum americanum* 6.9 mg/kg) (Baumgärtel et al., 2022b). The Ti contents of the other 17 plant samples are not quantifiable. At the moment, no MRL exists for Ti, but the adverse health effects of titanium oxide (TiO_2, also declared as E171) in food industry are still under discussion.

The V content of almost all plant specimens was not detectable (11 species below LOD; 29 below LOQ) (Appendix, A.2). One plant genus, *Crassocephalum*, has a measurable V uptake. The analysis of the leaves of *Crassocephalum rubens* reveals a V content of 0.2 mg/kg and for *Crassocephalum vitellinum* 0.1 mg/kg. The highest amount of V was found in leaves of *Solanum americanum* (0.5 mg/kg). Leaves of *C. rubens* and *S. americanum* are prepared in a similar manner as spinach and a daily intake of about 500 g is estimated, which falls far below the oral MRL (ATSDR, 2012).

Other heavy metals (As, Cd, Pb, Sb)

The concentration of the hazardous heavy metals arsenic (As), cadmium (Cd), lead (Pb) and antimony (Sb) were below the LOD for all examined plant samples (Appendix, A.2). No toxic effects for the consumption of analyzed plants can be expected.

Conclusion

No health risk was found for any of the 43 different edible wild plants examined. Only the consumption of *Pachira glabra* seeds needs to be investigated in detail, taking into account the frequency and number of seeds consumed (high content of Co, Cu, Mo, Zn). For this species, no comparable data exist and obtained values have to be verified. The consumption of Fe rich plants helps to combat anemia. Instead of cost-and transport-intensive supplements for Fe and Zn, consumption of locally available leaves and fruits is preferable. Leaves, used similarly to spinach are rich in Fe (*Solanum americanum, Crassocephalum rubens, Piper umbellatum, Olax gambecola, Calvoa* aff. *monticola)* and recommended to supplement the diet of the Angolan rural population. Except *P. umbellatum*, for which a high Fe content was already published, obtained results are first descriptions and underline their importance as food plants (Saupi et al., 2021). Pregnant and lactating women have an especially high demand for Fe and Zn, which may be further covered by fruits of *Canarium schweinfurthii*, leaves of *Aloe* cf. *buettneri* or fruits of *Aframomum* spp.. *C. schweinfurthii* is widely known and several investigations of its edible pulp were already carried out. The results of this study are within the range of published values (Appendix A.3) (Georges et al., 1992; Malaisse and Parent, 1985; Nyam et al., 2014). Contents of (ultra)trace elements and heavy metals are first published for these species. The dietary integration of Mg and Ca rich plants like *Olax gambecola* or *Caloncoba welwitschii,* analyzed for the first time in this study, can further encourage the health status of the rural population and raises the interest for those wild edible plants. The lianas *Landolphia congolensis, L. dewevrei* and the subshrub *L. lanceolata* accumulate Al in their fruits. The last one is additionally known to accumulate Al in leaves, extracted from its extremely acidic soil (Baumgärtel et al., 2022b). Correlations of soil parameters and plant-uptake are only found in certain species and depend primary on specific adaptations of the plant metabolism (Goolsby and Mason, 2015).

Elevated mineral contents due to soil contaminations seem to play only a minor role in this study, as the majority of analyzed plant parts are fruits or seeds, which are often consumed peeled (*Landolphia* spp.) or grow in distance to the ground (tree species). However, impacts of dust cannot completely be excluded, especially in the analysis of roots or leaves. Elevated standard errors are an indication of such discrepancies and have to be analyzed in detail, especially for Si and Tl.

The obtained data are a rough outline concerning the mineral content and more data about different individuals, location effects and the content of different plant tissues are needed. This is underlined by varying contents previously described for the seeds of *Treculia africana*. Wide ranges are found for Ca (48-4200 mg/kg, this study: 867 mg/kg) or Cu (0.7-41.3 mg/kg, this study: 7.4 mg/kg), questioning whether these results are natural or methodological deviations (Ajayi, 2008; Appiah et al., 2016; Edet, 1985; James et al., 2020; Lawal, 1986; Osabor et al., 2009).

Results of this study present a first insight and identify plant species of special interest for human nutrition and as future crops. The actual human uptake of micronutrients via the consumption of plant parts has to be taken into account separately.

Some of the plants studied are found only in limited areas, so their use must be sustainable in order to safeguard them for future generations. The conservation and cultivation of these plants has to be stimulated. At the moment, only the Brazilian tree *Pachira glabra* and rare specimens of *Aframomum* are cultivated. The fruits of *Aframomum* spp., *Strychnos* spp., *Landolphia* spp., *Canarium schweinfurthii*, *Raphia matombe* or leaves of *Crassocephalum rubens* and *Piper umbellatum* are offered seasonally at local markets, even in the far-away capital Luanda, indicating their local importance and their potential as alternative source of income.

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Conflict of interest

No potential conflict of interest was reported by the authors.

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ORCID
Christin Baumgärtel https://orcid.org/0000-0001-5169-0599
Linda Götzke https://orcid.org/0000-0002-6472-3713
Jan J. Weigand https://orcid.org/0000-0001-7323-7816
Christoph Neinhuis https://orcid.org/0000-0001-9965-4394
Mazecana H. G. Panzo – not registered
Francisco Afonso – not registered
Thea Lautenschläger https://orcid.org/0000-0003-4013-9456

Address of the corresponding author:
Christin Baumgärtel, Department of Biology, Chair of Botany, Technische Universität Dresden, Zellescher Weg 20b; 01062 Dresden, Germany
E-mail: christin.baumgaertel@tu-dresden.de

Appendix

A.1: Analyzed emission wavelengths for each examined element for ICP-OES analysis

Element	Wavelength [nm]		
Aluminum (Al)	237.313	394.401	396.153
Antimony (Sb)	206.836	217.582	
Arsenic (As)	188.979	193.696	
Cadmium (Cd)	214.440	228.802	
Calcium (Ca)	317.933	396.847	
Chromium (Cr)	205.560	267.716	
Cobalt (Co)	228.616	230.786	
Copper (Cu)	324.752	327.393	
Iron (Fe)	238.204	259.939	
Lead (Pb)	217.000	220.353	
Lithium (Li)	610.362	670.784	
Magnesium (Mg)	280.271	285.213	
Manganese (Mn)	257.610	259.372	
Molybdenum (Mo)	202.031	204.597	
Nickel (Ni)	221.648	231.604	
Potassium (K)	766.490	769.896	
Selenium (Se)	196.026	206.279	
Silicon (Si)	212.412	251.611	
Sodium (Na)	588.995	589.592	
Strontium (Sr)	407.771	421.552	
Thallium (Tl)	276.787	351.924	
Titanium (Ti)	336.121	337.279	
Vanadium (V)	292.464	309.310	
Zinc (Zn)	202.548	213.857	

A.2: Content of arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), lithium (Li), molybdenum (Mo), lead (Pb), antimony (Sb), selenium (Se), thallium (Tl) and vanadium (V) of the 43 analyzed plant species for fresh weight in mg/kg; number of collection sites in brackets behind plant species; Fr = fruit; L = leaf; Se = seed; n. a. = not analyzed; LOD = below limit of detection; LOQ = below limit of quantification

Plant species	**Plant part**	**As [mg/kg]**	**Cd [mg/kg]**	**Co [mg/kg]**	**Cr [mg/kg]**	**Li [mg/kg]**	**Mo [mg/kg]**	**Pb [mg/kg]**	**Sb [mg/kg]**	**Se [mg/kg]**	**Tl [mg/kg]**	**V [mg/kg]**
Aframomum alboviolaceum (Ridl.) K. Schum. (1)	Fr	LOD (<0.7)	LOD (<0.1)	LOD (<0.1)	LOD (<0.2)	LOD (<0.1)	LOD (<0.2)	LOD (<0.8)	LOD (<0.2)	LOQ (<3.7)	LOQ (<0.7)	LOQ (<0.5)
Aframomum angustifolium (Sonn.) K.Schum. (2)	Fr	LOD (<0.8)	LOD (<0.1)	LOD (<0.1)	LOD (<0.2)	LOD (<0.1)	LOQ (<0.5)	LOD (<0.9)	LOD (<0.3)	LOD (<2.0)	LOQ (<1.2)	LOQ (<0.6)
Aframomum giganteum (Oliv. & D.Hanb.) K.Schum. (1)	Fr	LOD (<0.9)	LOD (<0.1)	LOD (<0.1)	LOD (<0.3)	LOD (<0.1)	LOQ (<0.7)	LOD (<1.1)	LOD (<0.3)	LOQ (<1.8)	LOD (<0.8)	LOQ (<0.7)
Aloe cf. *buettneri* A.Berger (1)	L	LOD (<1.2)	LOD (<0.4)	LOD (<0.4)	LOD (<0.9)	LOD (<0.4)	LOD (<0.4)	LOD (<2.7)	LOD (<1.6)	LOD (<3.1)	LOD (<0.7)	LOQ (<0.9)
Anisophyllea quangensis Engl. ex Henriq. (1)	Fr	LOD (<0.5)	LOD (<0.1)	LOD (<0.1)	**0.4 ± 0.1**	n. a.	LOQ (<0.5)	LOD (<0.3)	LOD (<0.3)	**2.8 ± 0.1**	LOD (<0.3)	LOQ (<0.2)
Annona stenophylla Engl. & Diels (1)	Fr	LOD (<1.0)	LOD (<0.1)	LOD (<0.1)	LOQ (<0.3)	LOD (<0.1)	LOD (<0.5)	LOD (<0.7)	LOD (<0.4)	LOD (<1.9)	LOD (<0.6)	LOD (<0.3)
Antidesma venosum E. Mey. (1) ex Tul.	Fr	LOD (<1.7)	LOD (<0.2)	LOQ (<0.3)	LOQ (<0.8)	LOD (<0.1)	LOQ (<1.3)	LOD (<1.0)	LOD (<0.6)	LOD (<2.3)	LOD (<1.5)	LOQ (<0.7)
Caloncoba welwitschii (Oliv.) Gilg (1)	Fr	LOD (<2.2)	LOD (<0.2)	LOD (<0.2)	LOD (<0.6)	LOD (<0.2)	LOQ (<0.7)	LOD (<1.3)	LOD (<0.8)	LOD (<5.9)	LOD (<1.2)	LOQ (<1.8)
Calvoa aff. *monticola* A.Chev., Hutch. & Dalziel (1)	L	LOD (<1.7)	LOD (<0.1)	LOD (<0.3)	LOD (<0.3)	LOD (<0.1)	LOD (<0.4)	LOD (<0.8)	LOD (<0.6)	LOD (<2.4)	LOD (<1.6)	LOD (<0.6)
Canarium schweinfurthii Engl. (1)	Fr	LOD (<0.7)	LOD (<0.1)	LOD (<0.1)	LOQ (<0.3)	n. a.	LOD (<0.2)	LOD (<0.3)	LOD (<0.4)	LOQ (<1.9)	LOQ (<1.1)	LOD (<0.1)
Clitandra cymulosa Benth. (2)	Fr	LOD (<1.4)	LOD (<0.1)	LOD (<0.1)	LOD (<0.3)	LOD (<0.1)	LOD (<0.3)	LOD (<1.1)	LOD (<0.3)	LOD (<2.5)	LOD (<0.5)	LOQ (<0.4)
Colletoecema dewevrei (De Wild.) E. M. A. Petit (1)	Fr	LOD (<1.0)	LOD (<0.1)	LOD (<0.1)	LOQ (<0.3)	n. a.	LOQ (<0.7)	LOD (<0.8)	LOD (<0.4)	LOQ (<2.3)	LOQ (<1.3)	LOQ (<0.3)
Crassocephalum rubens (Jacq.) S. Moore (1)	L	LOD (<0.3)	LOD (<0.1)	LOD (<0.1)	LOD (<0.1)	LOD (<0.1)	LOD (<0.1)	LOD (<0.4)	LOD (<0.3)	LOD (<0.6)	**1.3 ± 0.5**	**0.2 ± 0.1**
Crassocephalum vitellinum (Benth.) S. Moore (1)	L	LOD (<0.6)	LOD (<0.1)	LOD (<0.1)	**0.6 ± 0.3**	n. a.	LOQ (<0.6)	LOD (<0.6)	LOD (<0.4)	LOQ (<1.9)	LOQ (<1.1)	**0.1 ± 0.1**

Dialium englerianum Henriq. (1)	Fr	LOD (<1.3)	LOD (<0.3)	LOD (<0.1)	LOQ (<0.6)	n. a.	LOQ (<1.1)	LOD (<0.7)	LOD (<0.8)	LOQ (<3.2)	LOQ (<2.3)	LOQ (<0.6)
Eugenia malangensis (O. Hoffm.) Nied. (1)	Fr	LOD (<0.8)	LOD (<0.2)	LOD (<0.2)	**0.7 ± 0.1**	n. a.	LOQ (<0.6)	LOD (<0.4)	LOD (<0.4)	LOQ (<2.3)	LOD (<0.4)	LOQ (<0.3)
Hymenocardia ulmoides Oliv. (1)	L	LOD (<0.8)	LOD (<0.1)	LOD (<0.1)	LOD (<0.3)	LOD (<0.1)	LOD (<0.4)	LOD (<1.5)	LOD (<0.4)	LOD (<2.4)	LOD (<0.9)	LOQ (<0.9)
Landolphia spec. (1)	Fr	LOD (<1.1)	LOD (<0.2)	LOD (<0.1)	**0.4 ± 0.2**	n. a.	LOD (<0.2)	LOD (<0.7)	LOD (<0.4)	LOQ (<2.2)	LOQ (<1.3)	LOQ (<0.3)
Landolphia buchananii (Hallier f.) Stapf (2)	Fr	LOD (<1.8)	LOD (<0.1)	LOD (<0.1)	LOD (<0.4)	LOD (<0.1)	LOD (<0.6)	LOD (<1.9)	LOD (<0.7)	LOD (<4.2)	LOD (<0.9)	LOQ (<0.4)
Landolphia camptoloba (K. Schum.) Pichon (1)	Fr	LOD (<1.0)	LOD (<0.2)	LOD (<0.1)	LOQ (<0.3)	n. a.	LOQ (<0.7)	LOD (<0.7)	LOD (<0.4)	LOQ (<2.3)	LOQ (<1.3)	LOQ (<0.3)
Landolphia congolensis (Stapf) Pichon (1)	Fr	LOD (<2.3)	LOD (<0.1)	LOD (<0.1)	LOD (<0.3)	LOD (<0.1)	LOD (<0.3)	LOD (<2.3)	LOD (<0.3)	LOQ (<7.0)	LOD (<0.5)	LOQ (<0.7)
Landolphia dewevrei Stapf (1)	Fr	LOD (<1.9)	LOD (<0.3)	LOD (<0.2)	**2.1 ± 0.2**	LOD (<0.1)	LOQ (<1.0)	LOD (<1.5)	LOD (<0.8)	LOQ (<3.4)	LOD (<1.1)	LOQ (<0.5)
Landolphia lanceolata (K. Schum.) Pichon (1)	Fr	LOD (<0.8)	LOD (<0.1)	LOD (<0.1)	LOQ (<0.3)	LOD (<0.1)	LOQ (<0.3)	LOD (<1.9)	LOD (<0.3)	LOQ (<2.0)	LOQ (<1.0)	LOQ (<0.6)
Landolphia owariensis P. Beauv. (2)	Fr	LOD (<0.9)	LOD (<0.1)	LOD (<0.1)	LOD (<0.2)	LOD (<0.1)	LOQ (<0.5)	LOD (<1.0)	LOD (<0.3)	LOD (<2.3)	LOD (<0.5)	LOQ (<0.7)
Landolphia robustior (K. Schum.) Pers. (2)	Fr	LOD (<1.1)	LOD (<0.1)	LOD (<0.1)	LOD (<0.3)	LOD (<0.1)	LOQ (<0.4)	LOD (<1.3)	LOD (<0.4)	LOD (<2.8)	LOD (<0.6)	LOD (<0.3)
Olax gambecola Baill . (2)	L	LOD (<1.7)	LOD (<0.1)	LOQ (<0.9)	LOQ (<0.9)	LOD (<0.1)	LOD (<0.4)	LOD (<0.9)	LOD (<0.6)	LOD (<2.4)	LOD (<1.6)	LOD (<0.6)
Oxygonum fruticosum Dammer (1)	Fr	LOD (<0.9)	LOD (<0.1)	LOD (<0.1)	**1.3 ± 0.2**	LOD (<0.1)	LOD (<0.2)	LOD (<0.6)	LOD (<0.4)	LOQ (<1.9)	LOD (<0.6)	LOQ (<0.3)
Pachira glabra Pasq. (1)	Se	LOD (<0.9)	LOD (<0.1)	**0.6 ± 0.1**	LOD (<0.2)	LOD (<0.1)	**1.2 ± 0.1**	LOD (<0.6)	LOD (<0.4)	LOD (<1.5)	LOQ (<2.1)	LOD (<0.4)
Parinari capensis Harv. (1)	Fr	LOD (<1.2)	LOD (<0.1)	LOD (<0.1)	LOD (<0.3)	LOD (<0.1)	LOD (<0.4)	LOD (<1.4)	LOD (<0.4)	LOD (<3.1)	LOD (<0.6)	LOQ (<0.6)
Passiflora foetida L. (1)	Fr	LOD (<0.5)	LOD (<0.1)	LOD (<0.1)	LOD (<0.1)	LOD (<0.1)	LOQ (<0.4)	LOD (<0.3)	LOD (<0.2)	LOD (<0.7)	LOD (<0.5)	LOD (<0.2)
Piper umbellatum L. (2)	L	LOD (<2.1)	LOD (<0.1)	LOD (<0.3)	LOQ (<0.5)	LOD (<0.3)	LOQ (<1.2)	LOD (<1.4)	LOD (<0.6)	LOD (<2.3)	LOQ (<0.8)	LOQ (<1.3)
Pseudospondias microcarpa (A.Rich.) Engl. (1)	Fr	LOD (<0.8)	LOD (<0.1)	LOD (<0.1)	LOD (<0.2)	LOD (<0.1)	LOD (<0.3)	LOD (<0.9)	LOD (<0.3)	LOD (<2.0)	LOD (<0.4)	LOQ (<0.6)

Pteridium centrali-africanum (Hieron.) Alston (1)	L	LOD (<1.3)	LOD (<0.1)	LOD (<0.2)	LOD (<0.2)	LOD (<0.1)	LOD (<0.3)	LOD (<0.7)	LOD (<0.4)	LOD (<1.9)	LOD (<1.2)	LOD (<0.4)
Raphia matombe De Wild. (1)	Fr	LOD (<0.8)	LOD (<0.1)	LOD (<0.2)	LOD (<0.2)	LOD (<0.1)	LOD (<0.2)	LOD (<0.4)	LOD (<0.3)	LOD (<1.1)	LOQ (<2.2)	LOD (<0.3)
Raphionacme madiensis S. Moore (1)	R	LOD (<0.4)	LOD (<0.1)	LOD (<0.1)	LOD (<0.1)	LOD (<0.1)	LOD (<0.1)	LOD (<0.2)	LOD (<0.3)	LOQ (<1.3)	LOD (<0.3)	LOQ (<0.2)
Sabicea gilletii De Wild. (1)	Fr	LOD (<3.8)	LOD (<0.1)	LOD (<0.1)	LOD (<0.3)	LOD (<0.1)	LOD (<0.3)	LOD (<2.3)	LOD (<0.3)	LOD (<2.5)	LOD (<0.5)	LOQ (<0.8)
Solanum americanum Mill. (1)	L	LOD (<1.3)	LOD (<0.1)	**0.7 ± 0.1**	LOQ (<0.2)	**0.3 ± 0.1**	LOQ (<0.4)	LOD (<0.8)	LOD (<0.1)	LOD (<1.0)	**0.8 ± 0.3**	**0.5 ± 0.1**
Strychnos cocculoides Baker (1)	Fr	LOD (<0.9)	LOD (<0.1)	LOD (<0.1)	LOD (<0.1)	n. a.	LOD (<0.2)	LOD (<0.6)	LOD (<0.4)	LOQ (<1.9)	LOQ (<1.1)	LOQ (<0.3)
Strychnos pungens Soler. (1)	Fr	LOD (<1.0)	LOD (<0.2)	LOD (<0.1)	LOQ (<0.3)	LOD (<0.1)	LOD (<0.2)	LOD (<0.7)	LOD (<0.4)	LOQ (<2.2)	LOQ (<1.3)	LOQ (<0.1)
Treculia africana Decne. (1)	Se	LOD (<1.5)	LOD (<0.2)	LOD (<0.2)	LOD (<0.2)	LOD (<0.2)	LOQ (<1.1)	LOD (<0.7)	LOD (<0.5)	LOD (<2.0)	LOD (<1.3)	LOD (<0.5)
Tristemma mauritianum J. F. Gmel. (2)	Fr	LOD (<0.9)	LOD (<0.1)	LOD (<0.3)	LOD (<0.5)	LOD (<0.1)	LOD (<0.5)	LOD (<2.4)	LOD (<0.3)	LOQ (<1.7)	LOD (<0.5)	LOQ (<0.7)
Vernonella subaphylla (Baker) H.Rob. & Skvarla (1)	R	LOD (<5.4)	LOD (<0.4)	LOD (<0.4)	LOD (<0.8)	n. a.	LOD (<1.6)	LOD (<2.7)	LOD (<1.3)	LOD (<5.4)	LOD (<3.1)	LOD (<0.8)
Vitex madiensis subsp. *Madiensis* (1)	Fr	LOD (<1.5)	LOD (<0.1)	**0.4 ± 0.1**	LOD (<0.3)	**0.3 ± 0.1**	LOQ (<0.4)	LOD (<1.3)	LOD (<0.4)	LOD (<3.0)	LOQ (<0.5)	LOQ (<0.9)

A.3: Reference values for the following plant specimens, results of this paper in brackets behind, values calculated for fresh weight in mg/kg and the respective literature references

	Al [mg/kg]	**Ca [mg/kg]**	**Cu [mg/kg]**	**Fe [mg/kg]**	**K [mg/kg]**	**Mg [mg/kg]**	**Mn [mg/kg]**	**Na [mg/kg]**	**Zn [mg/kg]**	**References**
Aframomum alboviolaceum (Ridl.) K. Schum.		72 (169)		7.5 (7.6)	10210 (4539)	255 (324)				Herzog et al. 1994
Canarium schweinfurthii Engl.		3.5-187 (114)		1.9-28 (6.8)	1.5-10.8 (n. a.)	2.7 (75.2)		0.2-14.4 (n. a.)		Georges et al. 1992; Malaisse and Parent 1985; Nyam et al. 2014
Hymenocardia ulmoides Oliv.	0.1 (n. a.)	2.5 (293)		0.1 (14.3)	4.4 (708)	1.1 (414)	0.1 (22.2)	0.1 (26.5)		Andzouana and Mombouli 2011
Landolphia owariensis P. Beauv.		88.5 (57.1)		3.5 (4.9)	2745 (1647)	85.5 (140)				Herzog et al. 1994
Passiflora foetida L.		63 (866)	2.1 (2.6)	8.9 (8.4)	4510 (4842)	400 (552)	3.2 (5.3)	100 (18.1)	10.3 (8.7)	Song et al. 2018
Piper umbellatum L.		2111 (2174)	8.1 (2.5)	60.5 (24.9)	4737 (4503)	1195 (1203)	44.8 (18.1)	14.8 (37.8)	11.7 (8.8)	Saupi et al. 2021
Pseudospondias microcarpa (A.Rich.) Engl.		377 (181)		10.8 (12.8)	5295 (4256)	207 (248)				Herzog et al. 1994
Pteridium centrali-africanum (Hieron.) Alston (1)		6.6 (81)	31.2 (5.7)							Malaisse and Parent 1985
Solanum americanum Mill.		2200 (n. a.)		30 (74.8)	3220 (n. a.)	540 (n. a.)				Booth et al. 1992
Strychnos cocculoides Baker		108-115 (171)	8.6 (0.1)	2.2-336 (1.6)	2303 (2062)	330 (281)		10.8 (n. a.)	1.0 (0.4)	Arnold et al. 1985; Malaisse and Parent 1985
Strychnos pungens Soler.		107-376 (219)	4.6 (1.6)	7.8-35.7 (2.6)	6133 (5630)	488 (368)		25.7 (n. a.)	4.4 (1.1)	Arnold et al. 1985; Malaisse and Parent 1985
Treculia africana Decne.		48-4200 (867)	0.7-41.3 (7.4)	5.2-112 (17.6)	1616-5400 (3616)	96-1711 (1022)		64.5-1566 (38.2)	5-78 (11.0)	Ajayi 2008; Appiah et al. 2016; Edet 1985; James et al. 2020; Lawal 1986; Osabor et al. 2009