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[1]Chair of Botany, Faculty of Biology, Faculty of Science, Technische Universität Dresden, Dresden, Germany
[2]Chair of Food Chemistry, Faculty of Chemistry and Food Chemistry, Technische Universität Dresden, Dresden, Germany
[3]Max Rubner-Institut, Department of Safety and Quality of Fruit and Vegetables, Karlsruhe, Germany
[4]University of Kimpa Vita, Province of Uíge, Rua Henrique Freitas No. 1, Bairro Popular, Uíge, Angola

Potential and nutritional properties of local food plants from Angola to combat malnutrition – suitable alternatives to frequently cultivated crops

Christin Baumgärtel[1*], Anke Förster[2], Lara Frommherz[3], Thomas Henle[2], Guedes José Ramiro[4], Francisco Afonso[4], Thea Lautenschläger[1]

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Summary

The human diet of the local population in the province Uíge, Angola mainly consists of carbohydrate rich plants originating from America or Asia. Acidic soils lead to various deficiency syndromes and low livestock yield. The aim of this study is to evaluate the nutritional potential of 14 native plants from Africa (*Aframomum alboviolaceum*, *Aframomum angustifolium*, *Aframomum giganteum*, *Antidesma venosum*, *Clitandra cymulosa*, *Landolphia buchananii*, *Landolphia lanceolata*, *Landolphia owariensis*, *Oncoba welwitschii*, *Parinari capensis*, *Piper umbellatum*, *Pseudospondias microcarpa*, *Tristemma mauritianum*, *Vitex madiensis* subsp. *madiensis*). The amino acid composition, beta-carotene, vitamin B_1, B_2, C and E content was determined for the respective edible plant part. Fruits of *P. capensis* were found to be rich in beta-carotene. The pulp of *O. welwitschii* shows a high nutritional value (high in vitamin B_1, B_2, C, E and in indispensable amino acids). Leaves of *P. umbellatum* are determined as convenient substitutes for the human nutrition containing beta-carotene, vitamin B_1, B_2, C and E. The integration and cultivation of studied plants indicate positive health effects, supplying different amounts of frequently lacking vitamins and beneficial ratios of indispensable amino acids. Studies examining dependencies between site location, ripeness, storage or transportation are urgently needed as they directly influence the micronutrient content.

Keywords: vitamins; amino acids; Africa; traditional food; nutritional value

Introduction

Humans are incapable to synthesize vitamins in necessary amounts by themselves and are thus dependent on a manifold diet for the maintenance of their health. Vitamin deficiencies can lead, depending on the respective vitamin, to different syndromes. One of the best-known deficiencies is the lack of vitamin C. A vitamin C deficiency can cause scurvy which is invariably fatal if left untreated. (WHO and FAO, 2004). Vitamin B_1 (thiamin) and Vitamin B_2 (riboflavin) function as cofactors for various enzymes (Mangel et al., 2017; WHO and FAO, 2004). A deficiency of these vitamins affects the cardiovascular and neurological system and is further associated with ariboflavinosis, cancer, or anemia (Fitzpatrick et al., 2012; Mangel et al., 2017). Leading cause for those conditions are inadequate dietary intakes due to limited food supply or abnormal digestion (WHO and FAO, 2004).

Angola has one of the highest prevalence of vitamin A deficiency worldwide, presenting a severe public health problem (Wirth et al., 2017). The Angolan nutrition is low in animal products and consequently in retinol. It can be assumed that plant derived provitamin A in form of beta-carotene is the major source of vitamin A as in general for developing countries (Booth et al., 1992). The limited intake of animal products affects the protein supply and quality as well (Schönfeldt and Hall, 2012). The African nutrition is consequently low in proteins, resulting in persistent undernutrition, threatening the local population (Schönfeldt and Hall, 2012). A combination of different plant products, providing different amounts of indispensable amino acids, can thus increase the quality of incorporated protein.

The tropical fruit production in Africa is dominated by Asian and American species, although native species are better adapted to local soil conditions (Baumgärtel et al., 2022b). At the moment only a small proportion of the over 2000 native African food plants is utilized and even less plants are cultivated or sold (National Research Council, 2008). However, local food products are important for the households of the rural population and a sustainable utilization can protect vulnerable ecosystems (Shackleton and Shackleton, 2004). The remaining primary forests of the northern studied province Uíge, important biodiversity hotspots, are under high pressure with one of the highest tree cover losses of the country (World Resources Institute, 2016). Slash and burn farming and timber harvesting are major drivers affecting the natural vegetation. Reforestation and protection programs for this region lack completely. Acipa et al. (2013) recognize a decline of the harvest of wild foods in Uganda due to the disappearance of intact ecosystems, underlining the extensive anthropogenic effects. The cultivation of African plant species can increase the food supply, the nutrition and raise economic conditions (Baumgärtel et al., 2022b; National Research Council, 2008; Schönfeldt and Hall, 2012). Further, the utilization of local grown food plants can prevent destructive field creation, slash-and burn farming, expensive soil amelioration techniques or the application of pesticides/herbicides (Baumgärtel et al., 2022b; Göhre et al., 2016). Small scale cultivation, conservation of existing plant populations and reforestation can hold the fragile landscapes together and cushion the pressure of deforestation on last remaining forests (National Research Council, 2008). African food plants therefore present an alternative to conventional, introduced food crops as banana, mango or guava.

Natural foods are sparsely consumed as a snack besides the path and often considered as famine foods with low quality. However, these fruits need no preparation and are important to fulfil the requirements of a healthy, balanced diet, which is in Angola mainly based on high carbohydrate plants as cassava or rice. Additionally, wild fruits appear spontaneously and complex cultivation or soil amelioration techniques are not required as mandatory for most American or Asian species (Baumgärtel et al., 2022b). Previous studies of this region identified plant species and their different utilization patterns (Göhre et al., 2016; Heinze et al., 2017; Lautenschläger et al., 2018). Pharmacological analyses often follow, while nutritional studies

* Corresponding author

only build a minor part (Pompermaier et al., 2018). At the moment, only the edible leaves of *Piper umbellatum* L. were studied for their antinutritive action, revealing no toxicity effects (da Silva et al., 2014). The majority of studied plant species is additionally utilized in traditional medicine and several phytochemical publications analyze the cytotoxicity of specific plant parts (leaves, stem bark) (Ezike et al., 2016; Kuete et al., 2014; Mbatchi et al., 2006; Ondo et al., 2012; Uys et al., 2002). Data for the edible parts as fruits are missing, although health risks consuming the studied plant species are not expected.

Vitamin and amino acid profiles for plants consumed by the local population are widely lacking or incomplete and are urgently needed (National Research Council, 2008). In this study the vitamin, protein and amino acid content of 14 different plant species is examined. The aim is to identify potential future crops as alternative to conventional food crops with high nutritional quality, combating malnutrition in Angola.

A step towards Sustainable Development Goal 2 "Zero Hunger"

The studied plant species can help to combat malnutrition not only within the country of Angola. Alternative food crops are needed on global scale facing problems of climate change, food security and hunger. Local growing plants are best adapted to present growing conditions needing no expensive amelioration techniques or fertilizers. Wild edible plants are valuable sources of minerals, vitamins and proteins, enabling a sustainable utilization and agriculture by the local population.

Materials and methods

Study site

All analyzed plant parts were collected in Angola's northern province Uíge from October 2018 to March 2019. The province was once famous for its coffee plantations but after the long independence and subsequent civil war until 2002, the infrastructure and economy are still severely affected. Today subsistence farmers dominate the agricultural sector cultivating peanuts, corn, cassava or beans (Da Rocha, 2010). The climate is categorized as tropical savanna (Aw), with a rainy season from October to March (Briggs and Smithson, 1986; Peel et al., 2007). The analyzed plant species reflect the mosaic of different vegetation zones in this province: perennials growing on sandy soils in the savanna (*Parinari capensis* Harv.), high climbers in forests and transition zones (*Clitandra cymulosa* Benth.), herbs growing along riverine (*Tristemma mauritianum* J.F. Gmel.) or trees of the forest (*Oncoba welwitschii* Oliv.) (Fig. 1).

The plant selection was based on previous data and availability of a high amount of mature fruits for analyses (Lautenschläger et al., 2018) (Tab. 1). A team of students and lecturers from the University Kimpa Vita, Uíge, Angola and the Technische Universität Dresden, Germany, performed the transect walks together with local guides collecting the nutritive plant material and herbarium vouchers, stored at the Herbarium Dresdense and the Virtual Herbaria JACQ. Every participant was briefed about their rights and the aim of this study (prior informed consent). Working and collection permits were obtained from the Ministry of Environment Angola, the Province Government of Uíge, administrative heads and the Instituto Nacional da Biodiversidade e Conservação (INBC).

Sample preparation

The collected plant parts were prepared as indicated by the informants (e.g. removal of seeds, hard shell) (Tab. 1). The edible portion was freeze dried on-site in Uíge and transported in a freezer-bag to Germany. The moisture content was calculated from the difference in weight during freeze-drying. The plant material was homogenized with a ball mill (Retsch MM 400, Haan, Germany) and stored in a freezer (-80 °C) until the different analyses took part.

Protein and amino acid analyses

According to the method of Kjeldahl the protein content was determined for two portions of the dried plant material (weight: 0.2-0.8 g) and calculated using a conversion factor of F=6.25 (System of Büchi Labortechnik AG, Flawil, Switzerland) (Matissek et al., 2014). For the amino acid determination the plant powder (weight: 0.1-0.4 g) was hydrolyzed twice independently with 6N HCl for 23 hours at 110 °C and analyzed with an ion exchange chromatography with post-column ninhydrin-derivatization (Amino Acid Analyser S433, analytical cation exchanger LCA K07/Li, 7 µm, 4.6 mm × 150 mm, SYKAM Chromatographie Vertriebs GmbH, Fürstenfeldbruck, Germany) (Lautenschläger et al., 2017). All amino acids were detected at 570 nm, only Prolin (Pro) at 440 nm. As Tryptophan is labile to acidic conditions it could not be analyzed. Contents of the sulphureous amino acids cysteine and methionine present the minimum range as they are partially oxidized whilst hydrolysis. Asparagine (Asn) and glutamine (Gln) are converted to their respective acids, wherefore their contents are summarized under the contents of aspartic acid (Asp) and glutamic acid (Glu).

Vitamin analyses

Beta-carotene, vitamin C and E were determined and quantified using HPLC-UV. The dried plant material (0.5-2.7 g) was solubilized with methanol (MeOH) (5 ml), vortexed (5 min), centrifuged (15 min, 5000 rpm) and filtered (pore size 0.45 µm; regenerated cellulose). For quantification of beta-carotene and vitamin E a gradient elution with 0.01% TFA in H_2O and MeOH was applied using a RP-C18 250 mm × 4.6 mm column with 5 µm particle size and a diode array detector (Płonka et al., 2012). For the measurement of vitamin C the method from Hasimoglu and Ghodke (2018) was adopted (column: RP-C18 250 mm × 4.6 mm (5 µm); diode array detector; eluent A: 10.5 mM Pentane-1-sulfonic acid in distilled water, 15 mL acetic acid added; eluent B: mixture of methanol and eluent A (90:10 V/V). Standard solutions for retinol (Sigma-Aldrich R7632), ascorbic acid (Sigma-Aldrich 95209) and DL-Tocopherol (Sigma-Aldrich, T3251) were prepared in MeOH.

The vitamins B_1 and B_2 were analyzed using HPLC with fluorescence-detection, according to Bognar (1992) and Oguntoyinbo et al. (2016). For thiamine an additional post column in-line oxidation was applied.

The limit of detection (LOD) was determined for beta-carotene and the vitamins C and E as the lowest concentration, where the signal could be separated from the noise. The limit of quantification (LOQ) for vitamin B_1 and B_2 was calculated from the minimum calibration solution taking into account the specific sample weight. The vitamin contents of all plant materials were measured in at least a double determination.

All utilized reagents were of analytical quality. Results are given as the mean contents for dry weight with their respective standard deviation (SD).

Results

The obtained vitamin, protein and amino acid contents are presented based on 100 g dry matter (d.m.). If necessary, values were converted to fresh weight (f.w.) for comparison. Due to transport, storage, age and preparation of the plant material, all obtained contents present the minimum content. Unstable vitamins are of particular risk to get lost or diminish until analyses took part, so vitamin contents of

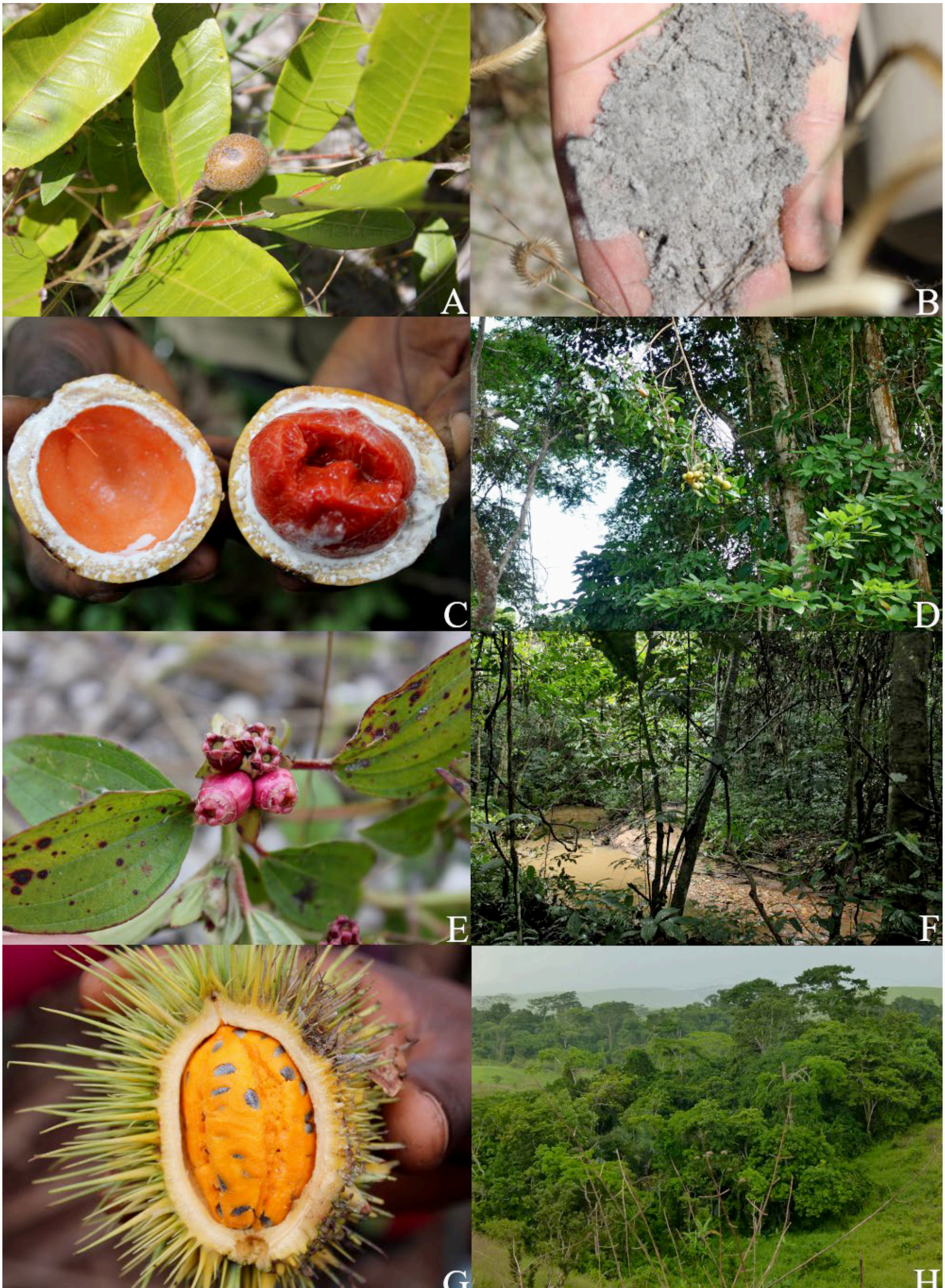

Fig. 1: Overview of some of the analyzed plant species and their typical habitats; A: *Parinari capensis*; B: Sandy soil in savanna; C: Fruit of *Clitandra cymulosa*; D: Climbing habit of *Landolphia owariensis*; E: *Tristemma mauritianum*; F: Swampy habitat near river; G: Fruit of *Oncoba welwitschii*; H: Forest-savanna mosaic.

Tab. 1: Analyzed plant species sorted by plant family, scientific and vernacular name in Bantu language Kikongo, voucher number according to the Herbarium Dresdense; consumed and analyzed plant part; growth form and habitat; Natural geographic distribution: CA = Central Africa; EA = East Africa; MAM = Middle America; NA =North Africa; SA = Southern Africa; SAM = South America; SEA = South East Asia; WA = Western Africa

Plant species	Plant part	Growth form	Habitat	Geographic distribution
Anacardiaceae				
Pseudospondias microcarpa (A.Rich.) Engl.; Kisantu; DR 067254	Fruit without seeds	Tree	Secondary forest, transition zone	CA, EA, NA, WA
Apocynaceae				
Clitandra cymulosa Benth.; Menga menga; DR 056600	Pulp without seeds	Liana	Forest, transition zone	CA, EA, WA
Landolphia buchananii (Hallier f.) Stapf; Makonge, Maboke; DR 056596, DR 056597	Pulp without seeds	Liana	Forest	CA, EA, NA, WA
Landolphia lanceolata (K. Schum.) Pichon; Mata; DR 056634	Pulp without seeds	Subshrub	Sandy soil in savanna	CA
Landolphia owariensis P. Beauv.; Makonge; DR 056602	Pulp without seeds	Liana	Forest, transition zone	CA, EA, NA, WA
Chrysobalanaceae				
Parinari capensis Harv.; Kia, Salanka; DR 056615	Fruit without seed	Shrub	Sandy soil in savanna	CA, EA, SA
Melastomataceae				
Tristemma mauritianum J. F. Gmel.; Mankondo ma mfinda; DR 056628, DR 056629, DR 056630	Whole fruit	Herb	Swampy forest	CA, EA, NA, WA
Piperaceae				
Piper umbellatum L.; Lemba kia mfinda; DR 063744	Leaves	Climber	Forest, Transition zone	MAM, SAM
Phyllanthaceae				
Antidesma venosum E. Mey. ex Tul.; Muidu; DR 067335	Whole fruit	Tree	Savanna	CA, EA, NA, SA, WA, SEA
Salicaceae				
Oncoba welwitschii Oliv.; Mbamba, Mandanga; PH_4752	Pulp without seeds	Tree	Forest, transition zone	CA, EA, WA
Vitaceae				
Vitex madiensis subsp. madiensis; Mfilo; DR 063748	Fruit without seeds	Shrub, tree	Savanna	CA, EA, NA, WA
Zingiberaceae				
Aframomum alboviolaceum (Ridl.) K. Schum.; Gingenga da savanna, Matzunja; DR 063746	Pulp without seeds	Herb	Savanna	CA, EA, NA, WA
Aframomum angustifolium (Sonn.) K. Schum.; Matsatsa, Mansasa, Imbutua; DR 063745	Pulp without seeds	Herb	Wet places, forest riverine	CA, EA, NA, WA
Aframomum giganteum (Oliv. & D.Hanb.) K.Schum.; Mapodia; DR 063747	Pulp without seeds	Herb	Forest, transition zone	CA

fresh material are most likely to be higher than the concentrations determined in the sampled material. In addition, the effects of freeze-drying must be considered when interpreting the obtained results. In general, the protein content of the studied leafy vegetable is higher than that of examined fruits (Tab. 2). Vitamin C was quantified in all analyzed plants, as it is abundant in fruits and leafy vegetables. Vitamin B_1 and B_2 were found in the majority of samples (10/14; 8/14), whereas Vitamin E was only detected in 7 samples. Beta carotene was rarely found (3/14), although it plays a pivotal role combating the predominant vitamin A deficiency within the country.

Proteins and their composition

The highest protein content (14.9% d.m.) was found for leaves of *Piper umbellatum* (Tab. 2). In comparison to other leafy vegetables from South Africa this content is one of the lower values (Schönfeldt and Pretorius, 2011). Rich in proteins are the fruit pulps of *Oncoba welwitschii* (9.1% d.m.) and *Pseudospondias microcarpa* (6.8% d.m.). The protein content of the fresh pulps from those fruits (4.7% f.w. and 3.9% f.w.) is higher than those of commonly consumed fruits (banana: 1.3% f.w.; baobab 1.4% f.w.; mango: 0.4% f.w..) (FAO, 2020).

To examine the nutritional value of the proteins the amino acid concentrations were quantified and classified according to their physiological role (indispensable amino acids Tab. 2, dispensable amino acids Annex, Tab. 5). The largest share of amino acids accounts for the sum of Glu/Gln and Asp/Asn (Annex, Tab. 5). Natural fruits and vegetables from Tropical Africa are seldom analyzed for their amino acid composition, obtained results were therefore compared to recommended amino acid intakes for the human nutrition (World Health Organization, 2007). Food proteins (e.g. animal proteins, legumes, root crops) are often lacking the indispensable amino acids of lysine and branched-chain amino acids (Leu, Ile, Val) (World Health Organization, 2007). For leucine all examined plant

Tab. 2: Major nutrients of analyzed plant species: moisture and protein content on 100 g dry matter basis; indispensable amino acids: Thr = threonine; Val = valine; Ile = isoleucine; Leu = leucine; His = histidine; Tyr = tyrosine; Phe = phenylalanine; Lys = lysine in g/100 g protein and amino acid requirements according to the (World Health Organization, 2007), amino acid contents not covering the recommendations of the WHO are highlighted in bold.

	Major nutrients [g/100 g]		Indispensable amino acids [g/100 g protein]								
Plant species	**Moisture**	**Protein**	**Thr**	**Val**	**Ile**	**Leu**	**His**	**Tyr**	**Phe**	**Phe+ Tyr**	**Lys**
Aframomum alboviolaceum	63.5	3.1	3.5	5.2	4.2	7.1	3.2	3.5	4.6	8.0	5.7
Aframomum angustifolium	48.5	2.6	3.5	4.4	3.6	6.4	4.8	4.7	3.8	8.4	**3.8**
Aframomum giganteum	55.7	3.2	3.8	5.2	4.0	7.5	3.6	3.2	4.3	7.5	4.6
Antidesma venosum	45.8	1.7	4.6	5.7	5.2	8.6	2.7	2.7	5.4	8.1	7.1
Clitandra cymulosa	37.2	4.3	3.5	4.5	3.8	6.5	2.1	2.8	4.1	6.8	5.7
Landolphia buchananii	52.9	2.8	3.4	4.6	4.0	6.7	2.5	2.8	4.1	6.9	5.7
Landolphia lanceolata	56.9	1.8	3.4	4.3	4.0	6.6	2.6	1.9	4.1	5.9	6.0
Landolphia owariensis	22.4	1.1	3.9	5.2	4.4	7.5	3.1	1.1	4.4	5.5	6.8
Oncoba welwitschii	47.7	9.1	4.5	5.9	4.8	8.3	2.7	6.8	5.1	12.0	5.4
Parinari capensis	62.3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Piper umbellatum	74.0	14.9	4.2	4.9	4.1	7.2	2.2	3.8	5.3	9.1	5.7
Pseudospondias microcarpa	42.5	6.8	3.4	4.0	3.2	**5.2**	2.3	1.9	3.5	5.4	5.2
Tristemma mauritianum	47.4	2.1	3.1	4.3	3.7	6.7	2.2	2.1	5.1	7.2	**3.5**
Vitex madiensis subsp. *madiensis*	62.1	1.2	4.6	6.0	4.9	7.6	2.2	2.8	5.2	8.0	**4.1**
Amino acid requirement per 100 g protein (World Health Organization, 2007)			2.3	3.9	3.0	5.9	1.5			3.8	4.5

species meet the recommendations of the WHO, except the fruit pulp of *Pseudospondias microcarpa* which only covers 89% of the recommended intake per 100 g protein. As the amount of all other indispensable amino acids per 100 g protein of *P. microcarpa* fruit fulfill the recommended amounts, leucine can be categorized as limited amino acid for this protein (Tab. 2).

Fruits from *Antidesma venosum* and *Oncoba welwitschii* are convenient leucine suppliers, covering 146% or respectively 141% of the recommendation. Those two species are further convenient sources for the often-lacking amino acids isoleucine and valine (Tab. 2). Fruits of *Vitex madiensis* subsp. *madiensis* can further help to enhance the sum of incorporated leucine, isoleucine and valine exceeding the recommended amounts of these acids per 100 g/protein (covering 130%, 164%, 155% respectively). Although the majority of analyzed food proteins from Angolan plants meet the human demand for indispensable amino acids, lysine was found to be the limited amino acid in the fruit pulp of *Aframomum angustifolium* (covering 84% of the requirement), in fruits of *Tristemma mauritianum* (covering 77%) and *Vitex madiensis* subsp. *madiensis* (covering 90%). The contents of cysteine, methionine and tryptophan were due to the analytical method not discussed in detail.

Water-soluble vitamins: B_1, B_2 and C

The water-soluble vitamin B_1 could be quantified in ten of the 14 analyzed plants (Tab. 3). In fruits from *Tristemma mauritianum* vitamin B_1 could not be determined. Rich in thiamine are the fruit pulp of *Aframomum angustifolium* (0.75 ± 0.01 mg/100g d.m.), *Oncoba welwitschii* (0.55 ± 0.01 mg/100 g d.m.) and *Clitandra cymulosa* (0.41 ± 0.2 mg/100 g d.m.) (Tab. 3). Compared to introduced fruit crops (0.03 mg/100 g f.w. B_1 in mango and banana) their high contents seem to be of outstanding nutritional value (*A. angustifolium* 0.39 mg/100 g f.w.; *O. welwitschii* 0.30 mg/100 g f.w.; *C. cymulosa* 0.26 mg/100 g f.w.) (FAO, 2020). However, the obtained contents have to be confirmed on fresh plant material to specify their nutritional value. Leaves of *Piper umbellatum* (0.36 ± 0.1 mg/100 g d.m.) are further high in vitamin B_1 compared to other leafy vegetables of this region (Lautenschläger et al., 2021). The contribution of leaves from this species to the human thiamine requirement needs to be studied in the processed, cooked form due to the heat sensitive and water-soluble characteristics of vitamin B_1.

As the WHO recommends a daily intake of 1.2 mg vitamin B_1/day the consumption of plant products from *Aframomum alboviolaceum*, *Aframomum angustifolium*, *Antidesma venosum*, *Clitandra cymu-*

losa, *Landolphia buchananii*, *Landolphia lanceolata*, *Landolphia owariensis*, *Oncoba welwitschii*, *Piper umbellatum* or *Pseudospondias microcarpa* can help to cover the human thiamine requirement and prevent deficiency (Tab. 3).

Vitamin B_2 could be quantified in eight plants. A high content exhibits the analyzed fruit pulp of *Oncoba welwitschii* (6.12 ± 0.01 mg/100 g d.m.). Comparing to frequent ingested fruits from Asia their content is up to 100-times higher, presenting a promising vitamin B_2 supplier (FAO, 2020). However, the incorporated amount of riboflavin has to be studied in detail as only teeny portions of *O. welwitschii* are consumed when seasoning (fruit in Fig. 1G). The recommended intake of vitamin B_2 (1.3 mg/day) can be met by fruits from *Landolphia owariensis* (0.7 mg/100 g f.w.) or *Clitandra cymulosa* (0.14 mg/100 g f.w.) regularly in to the diet (WHO and FAO, 2004).

All examined plant species had a detectable vitamin C content, whereby the content in fruits of *Antidesma venosum* was not quantifiable. Tab. 3 therefore quotes the vitamin C content of *A. venosum* exceeding 150 mg/100 g d.m., presenting together with *Tristemma mauritianum* (176.7 ± 34.3 mg/100 g d.m.), *Piper umbellatum* (167.2 ± 21.3 mg/100 g d.m.) and *Pseudospondias microcarpa* (155.7 ± 14.3 mg/100 g d.m.) the maximum contents of ascorbic acid determined. Their values are higher compared to commonly consumed ripe mangos (35 mg/100 g f.w.), but still lower than those contents of commercial utilized baobab and guava, some of the richest vitamin C sources cultivated in Africa (251 and 268 mg/100 g f.w.) (FAO, 2020).

Tab. 3: Content of water soluble vitamins B_1, B_2 and C of analyzed plant species; means calculated for 100 g dry matter ± SD; ~ B_1 and B_2 values analyzed according to Hasimoglu and Ghodke, 2018; rest according to Bognar, 1992 and Oguntoyinbo et al., 2016; * content of one analysis due to limited sample weight; n.d. = not determinable.

Plant species	Vitamin B1 [mg/100g]	Vitamin B2 [mg/100g]	Vitamin C [mg/100g]
Aframomum alboviolaceum	0.25 ± 0.01	0.10 ± 0.01	85.9 ± 7.2
Aframomum angustifolium	0.75 ± 0.01	0.18 ± 0.01	64.3 ± 11.3
Aframomum giganteum	~LOD (< 0.04)	~LOD (< 0.06)	71.2 ± 8.8
Antidesma venosum	0.07 ± 0.01	*0.07	> 150
Clitandra cymulosa	0.41 ± 0.02	0.22 ± 0.3	29.0 ± 3.7
Landolphia buchananii	0.20 ± 0.01	0.08 ± 0.01	106.8 ± 16.8
Landolphia lanceolata	0.08 ± 0.01	LOQ (< 0.08)	34.9 ± 10.5
Landolphia owariensis	~0.38 ± 0.04	~0.83 ± 0.07	31.2 ± 17.0
Oncoba welwitschii	0.55 ± 0.01	6.12 ± 0.01	119.8 ± 15.5
Parinari capensis	~LOD (< 0.1)	~LOD (< 0.16)	16.7 ± 2.6
Piper umbellatum	0.36 ± 0.01	0.77 ± 0.07	167.2 ± 21.3
Pseudospondias microcarpa	0.26 ± 0.01	LOQ (< 0.08)	155.7 ± 14.3
Tristemma mauritianum	n.d.	n.d.	176.7 ± 34.3
Vitex madiensis subsp. *madiensis*	LOQ (< 0.06)	LOQ (< 0.08)	63.1 ± 1.7

Fat soluble (pro)vitamins: beta-carotene and vitamin E

Beta-carotene could be quantified in three out of the 14 analyzed plant species (*Parinari capensis* 3.8 ± 0.37 mg/100 g d.m.; *Piper umbellatum* 1.68 ± 0.32 mg/100 g d.m.; *Antidesma venosum* 0.07 ± 0.02 mg/100 g d.m.). The retinol activity equivalent (RAE), calculated by conversion of 12 µg/g trans-beta-carotene to 1 RAE, of the mature yellow fruits from *P. capensis* (0.12 mg RAE/100 g f.w.) are higher than those of most known edible fruits (Yeum and Russell, 2002). Only ripe banana and mango have similar contents (0.12 mg RAE/100 g f.w.; 0.36 mg RAE/100 g f.w.) (FAO, 2020). The intense yellow fruits of *P. capensis* and the in course of ripening red colored fruits of *A. venosum* are consumed raw, leaves of *P. umbellatum* cooked. The content of beta-carotene has to be analyzed in the processed leaves as food preparation in general can diminish the provitamin A content (Booth et al., 1992). All other examined species have a beta-carotene content below the LOD, Annex Tab. 6. As freeze-drying, storage and handling affect the beta-carotene content, additional fresh plant material, even of those plants where no beta-carotene could be found, have to be analyzed. The maturity of fruits also has a direct influence on the retinol activity equivalent, so more detailed data are needed.

For seven plant species vitamin E could be calculated and contents ranging from 0.51 mg/100 g d.m. (*Landolphia buchananii*) up to 17.9 mg/100 g d.m. (*Piper umbellatum*) were determined (Tab. 4). Commonly consumed plant products as banana, mango or leaves of cassava are low in vitamin E (0.28 mg/100 g f.w.; 0.99 mg/100 g f.w.; 0.42 mg/100 g f.w.) (FAO, 2020). Only dried leaves of *Vigna unguiculata* (cowpea) (21 mg/100 g d.m.) show contents in a similar range of those obtained for *P. umbellatum* (FAO, 2020). Thus, all of the studied plants with determinable vitamin E contents appear to be promising food crops for diversification and fortification of the local human diet (Tab. 4). Species where no Vitamin E was found are listed with their specific LOD.

Tab. 4: Content of vitamin E of analyzed plant species, means calculated for 100 g dry matter ± SD.

Plant species	Vitamin E [mg/100 g]
Aframomum alboviolaceum	LOD (< 0.05)
Aframomum angustifolium	LOD (< 0.04)
Aframomum giganteum	LOD (< 0.04)
Antidesma venosum	3.22 ± 0.42
Clitandra cymulosa	1.05 ± 0.02
Landolphia buchananii	0.51 ± 0.22
Landolphia lanceolata	0.63 ± 0.08
Landolphia owariensis	LOD (< 0.09)
Oncoba welwitschii	LOD (< 0.04)
Parinari capensis	3.34 ± 0.50
Piper umbellatum	17.89 ± 2.70
Pseudospondias microcarpa	LOD (< 0.09)
Tristemma mauritianum	LOD (< 0.09)
Vitex madiensis subsp. *madiensis*	LOD (< 0.03)

Discussion

As each analyzed plant species is adopted to their respective growing conditions and the nutritional value of the examined plant parts are diverse, the results in the upcoming discussion are arranged according to the particular plant families. The obtained contents of macro-and micronutrients are set into context to the specific plant characteristics and compared to previous references, obtaining a comprehensive plant profile.

Although more data, especially concerning the vitamin analyses, are needed to accurately determine the nutritional value of the examined plants, this study identifies the fruit pulp of *Oncoba welwitschii* as of particular interest. The intense orange pulp (Fig. 1G) is rich in proteins and covers the WHO-requirements of all indispensable amino acids (except Cys, Met and Trp which were excluded in this study). The consumption of *O. welwitschii* is further beneficial as it contains high amounts of vitamin B_1 and B_2. The red-colored fruits of *Antidesma venosum* contain the highly required provitamin A. They seem to have an additional high content of Vitamin C, necessitating a verification by the utilization of other methods and/or the separation of interfering signals. As *Parinari capensis* exhibits a high beta-carotene content, fruits of this species should be incorporated into the human nutrition combating the prevalent vitamin A deficiency. Leaves of *Piper umbellatum* are higher in vitamin B_1 than commonly consumed fruits, requiring a comprehensive analysis of food preparation methods. Vitamins are vulnerable to external influences and concentrations depend on the maturity of fruits. As all plant material was collected in Angola, freeze-dried on-site and transported for analysis to Germany, vitamins were at particular risk to be affected. Additional collections and analyses are therefore needed to confirm the obtained results of this study. Even during maturity, the vitamin content of fruits can vary and the obtained data therefore only present a first insight into the nutritive potential of the specific plant species from Africa, guiding towards a more specific analysis in future.

Anacardiaceae: Pseudospondias microcarpa

Pseudospondias microcarpa is a tree of the forest and transition zones, bearing sweet, plum-like fruits (voucher and image). Various phytochemical studies of the leaves, fruit and bark are already done as for example focusing on phenolic compounds, anticonvulsant activity, or essential oils (Adongo et al., 2017; Babouongolo et al., 2021; Guetchueng et al., 2020). The pulp is rich in proteins (6.8% d.m.) but yet leucine is the limiting amino acid for nutrition. The fruits of *P. microcarpa* are rich in vitamin C (90 mg/100 g f.w.), exceeding contents of common cultivated fruits as mango or banana (FAO, 2020). Comparative analyses of *P. microcarpa* from the Ivory Coast (12.5 mg/100 g f.w.) and *P. longifolia* (36.3 mg/100 g f.w.) from Gabon determined lower vitamin C contents, directly depending on the ripeness of the analyzed fruits (Fungo et al., 2019; Herzog et al., 1994). The determined vitamin B_1 content is confirmed by previous studies (0.15 mg/100 g f.w.) (Herzog et al., 1994). First cultivation trials are implemented in Gabon, needing extensive continuation and adaption to other African regions (Ndoutoumou et al., 2013).

Apocynaceae:* Genera *Clitandra* and *Landolphia

The distribution of the genus *Landolphia* with its 63 accepted species and the relative *Clitandra cymulosa* is restricted to Africa and Madagascar (Persoon et al., 1992). Unarmed, large lianas form the majority of phenotypes for these genera with a useful latex. Fruits are harvested for their almost sweet, edible pulp. *L. owariensis* is the most widespread of the genus having diverse utilization patterns and various studies focusing on the ingredients of its different plant parts (Nwaogu et al,. 2007; Odoh and Agbachi, 2020; Okonkwo and Osadebe, 2013; Persoon et al., 1992). Nutritive analyses are the minority and comprehensive data about the pulp are lacking. Herzog et al. (1994) studied mineral and vitamin contents of the fruits of *L. owariensis*. However, analyses were conducted for the whole fruit according to their use by locals of the Ivory Coast (Herzog et al., 1994). The informants of this study solely consume the pulp, which led to the analysis of only this part. The protein content of *L. owariensis* is similar to already published values (0.9 mg/100 g f.w.) and exceeds previous contents of riboflavin and vitamin C (0.7 mg/100g f.w.; 24 mg/100g f.w.) (Favier et al., 1993; Herzog et al., 1994).

Another climbing liana with difficult reachable fruits (up to 40 m height) is *L. buchananii*. Although it has a similar wide distribution as *L. owariensis,* nutritional and pharmaceutical studies of the pulp are lacking (only stem bark analyzed) (Nthiga et al., 2016). The pulp is a suitable supplement covering the vitamin C and E requirement (50 mg/100 g f.w.; 0.24 mg/100 g f.w.).

L. lanceolata grows as a rhizomatous shrub on sandy, acidic soils in open terrain (Baumgärtel et al., 2022b). Fruits are easily obtained and often found on local markets (Mawunu et al., 2020; Persoon et al., 1992). The fruits are particularly sweet and delicious, containing vitamin B_1, C and E (0.03 mg/100 g f.w.; 15 mg/100 g f.w.; 0.27 mg/100 g f.w.). The species has a narrow distribution area, occurring only in Angola and the D.R. Congo. It is a valuable crop for the Angolan population utilizing barren, open vegetation sites (Baumgärtel et al., 2022b).

This study presents the first nutritional data for the liana *C. cymulosa* (Fig. 1C*)*, containing a pulp which is rich in proteins, vitamin B_1 and C (2.7 g/100 g f.w.; 0.26 mg/100 g f.w.; 0.66 mg/100 g f.w.) (Fig. 1C).

Although fruits and rubber of the genera *Landolphia* and *Clitandra* are sold on local markets, cultivation data are sparse, in part because of complex growing conditions. Plants with up to 200 fruits, its multiple utilization properties and growth on local conditions make them an extremely suitable genera as a food crop for the Angolan population (National Research Council, 2008). It is assumed that a well-organized cultivation of plants and the in-situ conservation of existing populations can contribute to a nutritional and economic well-being of the rural population (National Research Council, 2008).

Chrysobalanaceae: Parinari capensis

Many species of the family Chrysobalanaceae bear sweet, edible drupes as the studied geoxylic shrub *Parinari capensis* (Fig. 1A). Six species of the genus *Parinari* are known for Africa, several with high local economic and nutritional importance (Prance and White, 1988). Nevertheless, data about the fleshy pulp of the whole genus are missing, available are only selected nutritive properties for *P. curatellifolia* (Benhura et al., 2012; Muchuweti et al., 2013). *P. capensis,* known for its delicious fruits, were already examined for antimalarial effects, flavonoids and diterpene lactones (Coradin et al., 1985; Garo et al., 1997; National Research Council, 2008; Uys et al,. 2002). The fruit is of special nutritional value due to its high beta-carotene content (121 μg RAE/100 g f.w.), comparable to those of conventional banana (119 μg RAE/100 g f.w.) (FAO, 2020). As vitamin A deficiency is still a serious problem and fruits are the main provitamin A source in Africa, the integration of *P. capensis* into the nutrition seem to have positive effects (Codjia, 2001). Especially children and pregnant/lactating women can profit from the consumption of those fruits (WHO and FAO, 2004). In South Africa fruits of *P. capensis* are already utilized for the production of syrup and further preservation methods as sun-drying have to be analyzed in detail, in regards of their effects on the vitamin content (Shai et al., 2020). A commercialization of the species is not known, or at the most done on regional level. However, the sale seems to be lucrative due to its high nutritional value and convenient sales increase to the capital Luanda (Heinze et al., 2019).

Euphorbiaceae: Antidesma venosum

The reddish, dark purple fruits of *Antidesma venosum* are widespread around Africa. Extensive phytochemical studies of the root and bark were already performed (Fawole et al., 2009; Mwangomo et al., 2012; Steenkamp et al., 2009). To our knowledge only one study analyzed the nutritional composition of the fruits, focusing on macronutrients (Wilson and Downs, 2012). Fruits of *A. venosum* contain all studied vitamins and provitamins and are thus of special nutritional value. Their vitamin C content was not quantifiable, needing additional methods and analyses. However, their high vitamin E content is convenient (1.74 mg/100 g f.w.) and fruits further supply highly needed beta carotene. The amino acid composition is advantageously, exceeding the recommendations of the WHO for the respective amounts of indispensable amino acids per 100 g protein (World Health Organization, 2007). The consumption of fruits from *A. venosum* seem to have diverse positive health effects and juice or jam are valuable plant products derived from this genus

(Hardinasinta et al., 2020). Further, the tree is known to produce fruits during drought, being a promising crop for these periods of food shortage (Shackleton et al., 2000).

Lamiaceae: Vitex madiensis* subsp. *madiensis
Many species of the large genus *Vitex* (> 250 species) are used in traditional medicine, around 70 species bear edible fruits (Moke et al., 2018). The studied species *Vitex madiensis* subsp. *madiensis* grows on sandy soil in the savanna as a shrub with a massive subterranean woody rootstock (Baumgärtel et al., 2022b). The purplish black drupes are in general low in vitamins, containing solely vitamin C (24 mg/100 g f.w.). Previous nutritional analyses lack for *V. madiensis*, wherefor a comparison is made to *V. doniana*. According to different publications the ascorbic acid of *V. doniana* fruits varies from 1-20 mg/100 g f.w., ranking the obtained content of *V. madiensis* on the upper range (FAO, 2020). Vitamins B_1 and B_2 were determined in *V. doniana*, necessitating more data for *V. madiensis* subsp. *madiensis* (FAO, 2020; Herzog et al., 1994). As salesmen of *Vitex* spp. from Cameroon generate a high income (up to 1800 US$ in 7 months) selling "chocolate berries" this genus is a suitable crop for alternative income (Mapongmetsem et al., 2012). Preservation methods have to be analyzed in detail as syrup or marmalade is made out of the fruits of *Vitex* spp. in some regions (Moke et al., 2018). Cultivation trials of *V. madiensis* are also promising, as the species is fruiting every year and is easily propagated, thus recommended for agroforestry programs (Mapongmetsem, 2006).

Melastomataceae: Tristemma mauritianum
Tristemma mauritianum is an abundant perennial herb in Africa, inhabiting humid habitats (Fig. 1E). The fruits of this species are a well-known snack among the different African populations with a high iron content (Baumgärtel et al., 2022a; Nabatanzi and Nakalembe, 2016; Nsengimana et al., 2020). The determined vitamin C content is lower than previously published results from Ethiopia (94-137 mg/100 g f.w.) (Aragaw et al., 2021). As the species is known to accumulate aluminum in leaves, it can be used for cultivation on acidic, shady locations with high plant-available Al and Mn (Baumgärtel et al., 2022b). The specific signals of vitamins B_1 and B_2 could not clearly be separated, needing more analyses of fresh material precising the obtained results.

Piperaceae: Piper umbellatum
Piper umbellatum is a perennial climber, introduced from Tropical America and utilized in over 24 countries across three continents (Roersch, 2010). Among the different occurrences 94 different medical applications are reported and various pharmacological studies were performed (Roersch, 2010). The vitamin C content of the examined leaves, used similar to spinach, are in the same range as samples from Nigeria (167 mg/100 g d.m.; Nigeria: 181 mg/100 g d.m.) (Mensah et al., 2008). The ascorbic acid content is further comparable to those of *Gnetum africanum*, exceeding those of other common leafy vegetables as *Dracaena camerooniana* or cassava (FAO, 2020; Lautenschläger et al., 2021). Leaves of *P. umbellatum* further contain beta-carotene, vitamin B_1, B_2, E and can therefore be regarded as a nutritional source with high quality, although prepared leaves have to be analyzed in detail due to the sensitivity of selected vitamins. Leaves of *P. umbellatum* are rich in vitamin E and can thus serve as an alternative for the main vitamin E supplier peanuts (Schneider, 2005). The determined protein content is in the same range to previous studies and other commonly consumed leafy vegetables (3.9 mg/100 g f.w.) (Mensah et al., 2008; Schönfeldt and Pretorius, 2011).

Salicaceae: Oncoba welwitschii
Oncoba welwitschii is a small tree/shrub of the forest and adjacent transition zones, characterized by its ornamental white flowers and fruits with slender spines (Fig. 1G). The tree is very common in secondary forests and appreciated by the local population as a host tree for caterpillars, a source of fuel wood and charcoal, for the consumption of the fruit pulp, the gathering of honey and diverse pharmaceutical applications (Latham and Konda ku Mbuta, 2014; Peltier et al., 2014). Nearly all parts of the species are utilized and yet screenings of alkaloids, cyanides, phytochemicals and anti-inflammatory properties were performed, lacking nutritional analysis completely (Bondjengo et al., 2017; Lautenschläger et al., 2018; Pompermaier et al., 2018; Rick-Léonid et al., 2007). The pulp is high in vitamin B_1, B_2 and E (0.3 mg/100 g f.w.; 3.2 mg/100 g f.w., 2.1 mg/100 g f.w.) exceeding contents of commonly consumed fruits (FAO, 2020). As a high Vitamin E uptake lowers the risk for cardiovascular diseases, the consumption of the pulp seems to have positive health effects (WHO and FAO, 2004). In Africa, especially Angola, peanuts and products made of them serve as main vitamin E supplier (8.5 mg/100 g d.m.), which can be supplemented by the consumption of *O. welwitschii* (FAO, 2020; Schneider, 2005). The pulp further contains high quality protein with convenient proportions of Thr, Val, Ile and Leu. An assisted natural regeneration trial from the D.R. Congo identified *O. welwitschii* as fast growing and suitable crop for the regeneration of disturbed areas, especially due to its manifold utilization patterns (Peltier et al., 2014).

Zingiberaceae: Genus Aframomum
Perennial herbs with extensive rhizome systems and medicinal as well as nutritional valuable fruits are the main characteristics for plants of the genus *Aframomum*. Over 60 species are accepted, occurring in Africa from Senegal over Sudan up to Mozambique (Harris and Wortley, 2018). For Angola only ten species are known (Figueiredo and Smith, 2008; Harris and Wortley, 2018). The seeds of the genus are utilized in a similar manner as pepper, whereas the pulp is of nutritional value. The fruits of *Aframomum* spp. are sold on national and international scale, contributing to the household income in rural areas of Angola and adjacent regions (Knippers et al., 2021; Kyayesimira et al., 2019). Among the species analyzed in this study *A. alboviolaceum* is the most studied plant. Diverse phytochemical, anthelmintic and antimicrobial studies are already conducted for the roots and fruits of this plant as well as for *A. angustifolium* (Acipa et al., 2013; Asemave and Ode, 2018; Bongo et al., 2017; Kyayesimira et al., 2019; Merveille et al., 2021; Tsiba et al., 2020). Nutritional analyses are the minority, examining mostly the mineral content of the fruit in general (Acipa et al., 2013; Baumgärtel et al., 2022a; Josiane et al., 2019). According to the consumer habits of the informants only the nutritional relevant pulp of the fruit was analyzed, whereas the whole fruit of *A. alboviolaceum* from the Ivory Coast was already studied for their vitamin content (Herzog et al., 1994). The protein, vitamin B_1 and B_2 content of the extracted pulp is lower than of the whole fruit (Herzog et al., 1994; Josiane et al., 2019). However, the Vitamin C content of analyzed *A. alboviolaceum* (31.8 mg/100g f.w.) is higher than those of the Ivory Coast (2.5 mg/100g f.w.), explainable by the difference of analyzed plant part (pulp vs. whole fruit), time until analysis, studied part, preparation or storage (Herzog et al., 1994). Further, endogenous and exogenous factors as ripeness, location and growth conditions influence the vitamin content of each analyzed fruit.

Data about the amino acid composition lack for all examined species of *Aframomum*. In particular nutritional data lack for the rare species *A. giganteum*. As the pulp of this species supplies over 130% of the daily requirements for Ile and Leu, its integration in the diet could have positive effects (FAO, 2020). Cultivation of *Aframomum* spp.

seems to be lucrative for the local population as the plant is fast yielding, bear piquant seeds, a sweet pulp and fruits are demanded on national and international scale (Heinze et al., 2019; Knippers et al., 2021; Kyayesimira et al., 2019).

The obtained vitamin and amino acid profiles are a landmark addressing further investigations and dietary recommendations. The dietary protein uptake of developing countries is still low, resulting in persistent undernutrition (Schönfeldt and Hall, 2012). *Parinari capensis* was found to be rich in beta-carotene and can help to combat vitamin A deficiency. As cost and logistic intensive vitamin supplements are far from being effective, alternative sources for micronutrients are needed (UNICEF, 2019). The orange fruit pulp of the spiny fruits from *Oncoba welwitschii* are of particular nutritional value. However, the respective vitamin contents have to be set into the context to the manner of consumption as storage, food preparation and transport have direct effects on the vitamin contents. The treatment (freeze-drying, transport, storage) of the analyzed plant material hence influenced the vitamin contents and additional analyses verifying the obtained results are needed. Vitamin uptake also varies within the course of the year due to the seasonality of many fruits. Several vitamin C rich fruits as baobab or mango mainly fruit at the beginning of the rainy season, necessitating supplementary food products for the rest of the year. Although health benefits consuming the analyzed plants are expected, antinutrient factors and toxicity trials have to be conducted in the future.

Cultivation trials, reforestation and sustainable utilization methods have to be intensified, integrating participants of the local population and government. They have an extensive knowledge handling the examined species and know the specific growing conditions. The examined fruits have a beneficial nutritional profile and constitute suitable alternatives to common cultivated crops as banana or mango. Monocropping can be prevented cultivating a mixture of the plants investigated in this study. Trees as *Oncoba welwitschii* or *Antidesma venosum* with nutritious fruits are suitable for disturbed transition zones, whereas *Parinari capensis* or *Landolphia lanceolata* can be grown as undergrowth on sandy soils. The importance of the selected plant species as nutritional source or alternative income opportunity have to be clearly communicated.

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Conflict of interest

No potential conflict of interest was reported by the authors.

References

Acipa, A., Kamatenesi-Mugisha, M., Oryem-Origa, H., 2013: Nutritional profile of some selected food plants of Otwal and Ngai Sub Counties, Oyam District, Northern Uganda. Afr. J. Agric. Nutr. Dev. 13 (2).

Adongo, D.W., Mante, P.K., Kukuia, K.K.E., Biney, R.P., Boakye-Gyasi, E., Benneh, C.K., Ameyaw, E.O., Woode, E., 2017: Anticonvulsant activity of *Pseudospondias microcarpa* (A. Rich) Engl. hydroethanolic leaf extract in mice: The role of excitatory/inhibitory neurotransmission and nitric oxide pathway. J. Ethnopharmacol. 206, 78-91. DOI: 10.1016/j.jep.2017.05.017

Aragaw, H.S., Nohr, D., Callo-Concha, D., 2021: Nutritional potential of underutilized edible plant species in coffee agroforestry systems of Yayu, southwestern Ethiopia. Agrofor. Syst. 95 (6), 1047-1059. DOI: 10.1007/s10457-021-00626-6

Asemave, K., Ode, S.S., 2018: Proximate and antinutritional analyses of seed, pulp and peel of *Aframomum angustifolium* (Sonn) K.Schum. Org. Med. Chem. Int. J., 5.

Babouongolo, S.-G., Loumpangou, C.N., Dao, E., Simon, V., Ndinga, A.M., Ouamba, J.-M., 2021: Variability in aromatic composition of different fruit parts of *Pseudospondias microcarpa* (A. Rich). J. Essent. Oil Bear. Plants 24, 11.

Baumgärtel, C., Götzke, L., Weigand, J.J., Neinhuis, C., Panzo, M.H.G., Afonso, F., Lautenschläger, T., 2022a: Comprehensive study of beneficial and hazardous minerals of 43 traditionally consumed fruits and vegetables of the province Uíge, Angola. Under Review, Food Sci. Nutr.

Baumgärtel, C., Lautenschläger, T., Panzo, M.H.G., Afonso, F., Neinhuis, C., Feger, K.-H., 2022b: Metal accumulation properties of eight traditionally utilized nutritional plants and their potential as suitable crops for cultivation on acidic soils of the Northern Province Uíge, Angola. Appl. Sci. 12 (2), 792. DOI: 10.3390/app12020792

Benhura, C., Benhura, M.A.N., Muchuweti, M., Nyagura, S.F., Gombiro, P.E., 2012: Proximate analysis of *Parinari curatellifolia* fruit pulp of fruit from parts of Harare and a rural area in Zimbabwe. Pak. J. Nutr. 11 (7), 639-642. DOI: 10.3923/pjn.2012.639.642

Bognar, A., 1992: 096 Determination of vitamin B1 in food by high-performance liquid chromatography and post-column derivatization. Fresenius J. Anal. Chem. 343 (1), 155-156. DOI: 10.1007/BF00332090

Bondjengo, N., Kitengie, G., Musibono, D., Lubini, C., Hohmann, G., Fruth, B., 2017: Presence of alkaloids and cyanogenic glycosides in fruits consumed by sympatric bonobos and the Nkundo People at LuiKotale/Salonga National Park, Democratic Republic of Congo and its relationship to food choice. Afr. Primates, 14.

Bongo, G., Inkoto, C., Masengo, C., Tshiama, C., Lengbiye, E., Djolu, R., Kapepula, M., Ngombe, K., Mbemba, T., Tshilanda, D., Mpiana, P., Ngbolua, K.-N., 2017: Antisickling, Antioxidant and Antibacterial Activities of *Afromomum alboviolaceum* (Ridley) K. Schum, *Annona senegalensis* Pers. and *Mondia whitei* (Hook. f.) Skeels. Am. J. Lab. Med. 2 (4), 52-59. DOI: 10.11648/j.ajlm.20170204.13

Booth, S.L., Johns, T., Kuhnlein, H.V., 1992: Natural food sources of Vitamin A and Provitamin A. Food Nutr. Bull. 14 (1), 1-15. DOI: 10.1177/156482659201400115

Briggs, D.J., Smithson, P., 1986: Fundamentals of physical geography. London.

Codjia, G., 2001: Food Sources of Vitamin A and Provitamin a Specific to Africa: An FAO Perspective. Food Nutr. Bull. 22 (4), 357-360. DOI: 10.1177/156482650102200403

Coradin, L., Giannasi, D.E., Prance, G.T., 1985: Chemosystematic Studies in the Chrysobalanaceae. I. Flavonoids in *Parinari*. Brittonia 37 (2), 169. DOI: 10.2307/2806097

Da Rocha, M.J., 2010: Desigualidades e assimetrias regionais em Angola - Os factores de competitividade terriorial.

FAO, 2020: FAO/INFOODS Food Composition Table for Western Africa (2019). User Guide & Condensed Food Composition Table. Rom. Retrieved 3rd of February 2022, from https://www.fao.org/3/ca7779b/CA7779B.

Favier, J.-C., Ireland-Ripert, J., Laussucq, C., Feinberg, M., 1993: Répertoire général des aliments : 3. Table de composition des fruits exotiques, fruits de cueillette d'Afrique. Paris.

Fawole, O.A., Ndhlala, A.R., Amoo, S.O., Finnie, J.F., Van Staden, J., 2009: Anti-inflammatory and phytochemical properties of twelve medicinal plants used for treating gastro-intestinal ailments in South Africa. J. Ethnopharmacol. 123 (2), 237-243. DOI: 10.1016/j.jep.2009.03.012

Figueiredo, E., Smith, G.F., 2008: Plants of Angola/Plantas de Angola. Strelitzia. Pretoria.

Fitzpatrick, T.B., Basset, G.J.C., Borel, P., Carrari, F., DellaPenna, D., Fraser, P.D., Hellmann, H., Osorio, S., Rothan, C., Valpuesta, V., Caris-Veyrat, C., Fernie, A.R., 2012: Vitamin Deficiencies in Humans: Can Plant Science Help? Plant Cell 24 (2), 395-414. DOI: 10.1105/tpc.111.093120

Fungo, R., Muyonga, J.H., Ngondi, J.L., Mikolo-Yobo, C., Iponga, D.M., Ngoye, A., Nchuaji Tang, E., Chupezi Tieguhong, J., 2019: Nutrient and Bioactive Composition of Five Gabonese Forest Fruits and Their Potential Contribution to Dietary Reference Intakes of Children Aged 1-3 Years and Women Aged 19-60 Years. Forests 10 (2), 86. DOI: 10.3390/f10020086

Garo, E., Maillard, M., Hostettmann, K., Stdeckti-Evans, H., Mavi, S., 1997: Absolute Configuration of a Diterpene Lactone from *Parinari capensis*. Helv. Chim. Acta 80 (2), 538-544. DOI: 10.1002/hlca.19970800218

Göhre, A., Toto-Nienguesse, Á.B., Futuro, M., Neinhuis, C., Lautenschläger, T., 2016: Plants from disturbed savannah vegetation and their usage by Bakongo tribes in Uíge, Northern Angola. J. Ethnobiol. Ethnomedicine 12. DOI: 10.1186/s13002-016-0116-9

Guetchueng, S.T., Nahar, L., Ritchie, K.J., Daud Ismail, F.M., Dempster, N.M., Nnanga, E.N., Sarker, S.D., 2020: Phenolic compounds from the leaves and stem bark of *Pseudospondias microcarpa* (A. Rich.) Engl. (Anacardiaceae). Biochem. Syst. Ecol. 91, 104078. DOI: 10.1016/j.bse.2020.104078

Hardinasinta, G., Mursalim, M., Muhidong, J., Salengke, S., 2020: Determination of some chemical compounds of bignay (*Antidesma bunius*) fruit juice. Food Sci. Technol. DOI: 10.1590/fst.27720

Harris, D.J., Wortley, A.H., 2018: Monograph of *Aframomum* (Zingiberaceae). Systematic Botany Monographs. Laramie WY 82071, USA.

Hasimoglu, A., Ghodke, S.B., 2018: A novel RP-HPLC method for simultaneous determination of vitamins B1, B2, B3, B6 and C in oral powder for veterinary consumption. J. Res. Pharm. 22 (1), 153-161. DOI: 10.12991/jrp.2018.89

Heinze, C., Ditsch, B.,Congo, M.F., Lautenschläger, T., Neinhuis, C., 2017: First ethnobotanical analysis of useful plants in Cuanza Norte, North Angola. Res. Rev. J. Bot. Sci. 6 (2), 44-53.

Heinze, C., Dundão, M.D.F., Neinhuis, C., Lautenschläger, T., 2019: Economic potential of selected native plants from Cuanza Norte, Northern Angola. Econ. Bot. 73 (1), 96-111. DOI: 10.1007/s12231-018-9439-x

Herzog, F., Farah, Z., Amadò, R., 1994: Composition and consumption of gathered wild fruits in the V-Baoulé, Côte d'Ivoire. Ecol. Food Nutr. 32 (3-4), 181-196. DOI: 10.1080/03670244.1994.9991399

Josiane, E., Jean, P.L.O., Yves, O., Arielle, M.-K., Mvoula, T., 2019: Biochemical characterization of four less exploited edible fruits in Congo-Brazzaville: *Passiflora edulis* f. *flavicarpa*, *Aframomum alboviolaceum*, *Saba comorensis* and *Clitandra cymulosa*. Afr. J. Agric. Res. 14 (34), 1913-1920. DOI: 10.5897/AJAR2019.14421

Knippers, R.H.M., Gallois, S., van Andel, T., 2021: Commercialization of *Aframomum* spp. in Africa: a systematic review of literature and supporting botanical vouchers. Econ. Bot. 75 (1), 76-91. DOI: 10.1007/s12231-021-09517-4

Kyayesimira, J., Mawanda, I., Andama, M., Safari, D., 2019: Studies on the utilization and proximate composition of wild *Aframomum anguistifolium* (sonn.) K. Schum fruits in Nakaseke district, Uganda. Afr. J. Food Agric. Nutr. Dev. 19 (04), 14790-14804. DOI: 10.18697/ajfand.87.1760

Latham, P., Konda ku Mbuta, A., 2014: Useful plants of Bas-Congo province, Democratic Republic of Congo.

Lautenschläger, T., Frommherz, L., Monizi, M., Neinhuis, C., Henle, T., Förster, A., 2021: Anatomy and nutritional value of *Dracaena camerooniana* Baker - an African wild vegetable. South Afr. J. Bot. DOI: 10.1016/j.sajb.2021.08.046

Lautenschläger, T., Monizi, M., Pedro, M., Mandombe, J.L., Bránquima, M.F., Heinze, C., Neinhuis, C., 2018: First large-scale ethnobotanical survey in the province of Uíge, northern Angola. J. Ethnobiol. Ethnomedicine 14 (1). DOI: 10.1186/s13002-018-0238-3

Lautenschläger, T., Neinhuis, C., Kikongo, E., Henle, T., Förster, A., 2017: Impact of different preparations on the nutritional value of the edible caterpillar *Imbrasia epimethea* from northern Angola. Eur. Food Res. Technol. 243 (5), 769-778. DOI: 10.1007/s00217-016-2791-0

Mangel, N., Fudge, J.B., Fitzpatrick, T.B., Gruissem, W., Vanderschuren, H., 2017: Vitamin B1 diversity and characterization of biosynthesis genes in C*assava*. J. Exp. Bot. 68 (13), 3351-3363. DOI: 10.1093/jxb/erx196

Mapongmetsem, P.M., 2006: Domestication of *Vitex madiensis* in the Adamawa Highlands of Cameroon: Phenology and Propagation, 10.

Mapongmetsem, P.M., Kapchie, V.N., Tefempa, B.H., 2012: Diversity of local fruit trees and their contribution in sustaining the rural livelihood in the Northern Cameroon. Ethiop. J. Environ. Stud. Manag. 5 (1), 32-36. DOI: 10.4314/ejesm.v5i1.5

Matissek, R., Steiner, G., Fischer, M., 2014: Lebensmittelanalytik. Springer-Lehrbuch. DOI: 10.1007/978-3-642-34829-7

Mawunu, M., Makuntima, P., Masidivinga, L., Lautenschläger, T., Luyindula, N., Ngbolua, K.N., Lukoki, L., 2020: First Survey on the Edible Non-Wood Forest Products Sold in Uíge Province, Northern Angola. Eur. J. Agric. Food Sci. 2 (6). DOI: 10.24018/ejfood.2020.2.6.135

Mensah, J.K., Okoli, R.I., Ohaju-Obodo, J.O., Eifediyi, K., 2008: Phytochemical, nutritional and medical properties of some leafy vegetables consumed by Edo people of Nigeria. Afr. J. Biotechnol. 7 (14).

Merveille, M.G.R., Célestine, N.L., Brice, K.A., Akhanovna, M.-B.J., Yves-Alain, B., Jean-Maurille, O., 2021: Phytochemical Study and Anthelmintic Activity of Nine Congolese Medicinal Plants. J. Pharm. Res. Int., 63-76. DOI: 10.9734/jpri/2021/v33i1431278

Moke, L.E., Ngbolua, K.-N., Bongo, G.N., Messi, M., Noté, O.P., Mbing, J.N., Pegnyemb, E., Mpiana, P.T., 2018: *Vitex madiensis* Oliv. (Lamiaceae): phytochemistry, pharmacology and future directions, a mini-review. J. Pharmacog. Phytochem., 9.

Muchuweti, M., Matongo, N., Benhura, M.A.N., Bhebhe, M., Kasiyamhuru, A., Chipurura, B., 2013: Nutritional Composition of *Parinari curatellifolia* Fruit and a Jam made from the Pulp of the Fruit: an Untapped Resource. Acta Hortic. (979), 621-624. DOI: 10.17660/ActaHortic.2013.979.67

Mwangomo, D.T., Moshi, M.J., Magadula, J.J., 2012: Antimicrobial activity and phytochemical screening of *Antidesma venosum* root and stem bark ethanolic extracts. Int. J. Res. Phytochem. Pharmacol. 2 (2), 90-95.

Nabatanzi, A., Nakalembe, I., 2016: Wild food plants used by people living with HIV/AIDS in Nakisunga sub-county, Uganda. Afr. J. Food, Agric., Nutr. Dev. 16 (4), 11310-11330. DOI: 10.18697/ajfand.76.15720

National Research Council, 2008: Lost Crops of Africa: Volume III: Fruits. Washington, D.C..

Ndoutoumou, P.N., Ovono, P.O., Ondo-Azi, A.S., Ignanga, W.I., Beyeme, A.M.M., 2013: Tests of propagation of *Pseudospondias microcarpa* A. Rich. under the climatic conditions of Franceville in the southeastern of Gabon. Int. J. Agron. Agric. Res. 11.

Nsengimana, T., Nsengimana, V., Nsanganiwimana, F., 2020: Local Knowledge and Use of Wild Edible Plants in Eastern Part of Nyungwe National Park in Rwanda: Prospects for Forest Biodiversity Conservation. J. Res. For. Wildl. Environ. 12 (4).

Nthiga, P., Kamau, J., Safari, V.Z., Mwonjoria, J.K., Mburu, D.N., Ngugi, M.P., 2016: Antipyretic Potential of Methanolic Stem Bark Extracts of *Harrisonia abyssinica* Oliv and *Landolphia buchananii* (Hallier F.) Stapf in Wistar Rats. J. Appl. Pharm. 8. DOI: 10.21065/1920-4159.1000227

Nwaogu, L.A., Alisi, C.S., Ibegbulem, C.O., Igwe, C.U., 2007: Phytochemical and antimicrobial activity of ethanolic extract of *Landolphia owariensis* leaf. Afr. J. of Biotechnol. 6 (7), 890-893.

Odoh, E.U., Agbachi, B.C., 2020: Phytochemical, Proximate and Nutritive Composition Analyses of the Seed of *Landolphia owariensis* P. Beauv. (Apocynaceae). World J. of Innov. Res. 8 (5), 6.

Oguntoyinbo, F.A., Cho, G.-S., Trierweiler, B., Kabisch, J., Rösch, N., Neve, H., Bockelmann, W., Frommherz, L., Nielsen, D.S., Krych, L., Franz, C.M.A.P., 2016: Fermentation of African kale (*Brassica carinata*) using *L. plantarum* BFE 5092 and *L. fermentum* BFE 6620 starter strains. Int. J. Food Microbiol. 238, 103-112. DOI: 10.1016/j.ijfoodmicro.2016.08.030

Okonkwo, T., Osadebe, P., 2013: Isolation and Characterization of Potential Bioactive Compounds from *Landolphia owariensis* P. Beauv Stringy Seed Pulp. Int. J. Appl. Res. Nat. Prod. 6 (3), 28-38.

Peel, M.C., Finlayson, B.L., McMahon, T.A., 2007: Updated world map of the Köppen-Geiger climate classification. Hydrol. Earth Sys. Sci. 11 (5), 1633-1644. DOI: 10.5194/hess-11-1633-2007

Peltier, R., Dubiez, É., Diowo, S., Gigaud, M., Marien, J.-N., Marquant, B., Peroches, A., Proces, P., Vermeulen, C., 2014: Assisted Natural Regeneration in slash-and-burn agriculture: Results in the Democratic Republic of the Congo. Bois et Forets Trop. 321 (3), 67. DOI: 10.19182/bft2014.321.a31220

Persoon, J.G.M., van Dilst, F.J.H., Kuijpers, R.P., Leeuwenberg, A.J.M., Vonk, G.J.A., 1992: The African species of *Landolphia* P.Beauv. Series of revisions of Apocynaceae XXXIV. Wagening. Agric. Univ. Pap. 92 (2).

Płonka, J., Toczek, A., Tomczyk, V., 2012: Multivitamin Analysis of Fruits, Fruit–Vegetable Juices, and Diet Supplements. Food Anal. Methods 5 (5), 1167-1176. DOI: 10.1007/s12161-011-9349-3

Pompermaier, L., Marzocco, S., Adesso, S., Monizi, M., Schwaiger, S., Neinhuis, C., Stuppner, H., Lautenschläger, T., 2018: Medicinal plants of northern Angola and their anti-inflammatory properties. J. Ethnopharmacol. 216, 26-36. DOI: 10.1016/j.jep.2018.01.019

Prance, G.T. White, F., 1988: The Genera of Chrysobalanaceae: A Study in Practical and Theoretical Taxonomy and Its Relevance to Evolutionary Biology. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 320 (1197), 1-184.

Rick-Léonid, N.M.M., Joseph-Privat, O., Norbert, A.E.J., Bourdette, O., Cédric, S.O., 2007: Phytochemical screening, Antioxidant and Antiangiogenic Properties of *Oncoba welwitschii* (Oliv.) Gilgn. and *Tetrorchidium oppositifolium*(Pax. and Khoffm.). Medicinal Plants from Gabon. 6 (1), 11.

Roersch, C.M.F.B., 2010: *Piper umbellatum* L.: A comparative cross-cultural analysis of its medicinal uses and an ethnopharmacological evaluation. J. Ethnopharmacol. 131 (3), 522-537. DOI: 10.1016/j.jep.2010.07.045

Schneider, C., 2005: Chemistry and biology of vitamin E. Mol. Nutr. Food Res. 49 (1), 7-30. DOI: 10.1002/mnfr.200400049

Schönfeldt, H.C., Hall, N.G., 2012: Dietary protein quality and malnutrition in Africa. Br. J. Nutr. 108 (S2), 69-76. DOI: 10.1017/S0007114512002553

Schönfeldt, H.C., Pretorius, B., 2011: The nutrient content of five traditional South African dark green leafy vegetables—A preliminary study. J. Food Compos. Anal. 24 (8), 1141-1146. DOI: 10.1016/j.jfca.2011.04.004

Shackleton, C.M., Dzerefos, C.M., Shackleton, S.E., Mathabela, F.R., 2000: The use of and trade in indigenous edible fruits in the Bushbuckridge savanna region, South Africa. Ecol. Food Nutr. 39 (3), 225-245. DOI: 10.1080/03670244.2000.9991616

Shackleton, C., Shackleton, S., 2004: The importance of non-timber forest products in rural livelihood security and as safety nets: a review of evidence from South Africa. South Afr. J. Sci. 100 (11-12), 658-664.

Shai, K.N., Ncama, K., Ndhlovu, P.T., Struwig, M., Aremu, A.O., 2020: An Exploratory Study on the Diverse Uses and Benefits of Locally-Sourced Fruit Species in Three Villages of Mpumalanga Province, South Africa. Foods 9 (11), 1581. DOI: 10.3390/foods9111581

Steenkamp, V., Mokoele, T.L., Rensburg, C.E.J.V., 2009: Toxicity Testing of Two Medicinal Plants, *Bridelia micrantha* and *Antidesma venosum*. Open Toxicol. J. 3 (1), 35-38. DOI: 10.2174/1874340400903010035

Tsiba, G., Yoca, J.E., Blondy, M.-B., Thimoleon, A.-B., Ongoka, P., 2020: Chemical Characterization and Anti-Radical Activity of Fruits and Vegetables Commonly Consumed in Brazzaville. Food Nutr. Sci. 11 (08), 773. DOI: 10.4236/fns.2020.118055

UNICEF, 2019: Vitamin A Deficiency in Children. UNICEF Data. Retrieved 10th of May 2021 from https://data.unicef.org/topic/nutrition/vitamin-a-deficiency/.

Uys, A.C.U., Malan, S.F., van Dyk, S., van Zyl, R.L., 2002: Antimalarial compounds from *Parinari capensis*. Bioorg. Med. Chem. Lett. 12 (16), 2167-2169. DOI: 10.1016/S0960-894X(02)00350-5

WHO, FAO, 2004: Vitamin and mineral requirements in human nutrition. Geneva.

Wilson, A.-L., Downs, C.T., 2012: Fruit nutritional composition and non-nutritive traits of indigenous South African tree species. South Afr. J. Bot. 78, 30-36. DOI: 10.1016/j.sajb.2011.04.008

Wirth, J.P., Petry, N., Tanumihardjo, S.A., Rogers, L.M., McLean, E., Greig, A., Garrett, G.S., Klemm, R.D.W., Rohner, F., 2017: Vitamin A Supplementation Programs and Country-Level Evidence of Vitamin A Deficiency. Nutrients 9 (3). DOI: 10.3390/nu9030190

World Health Organization, 2007: Protein and amino acid requirements in human nutrition: report of a joint WHO/FAO/UNU Expert Consultation. WHO technical report series. Geneva.

World Resources Institute, 2022: Interactive World Forest Map & Tree Cover Change Data | GFW. Retrieved 1st March 2022, from https://www.globalforestwatch.org/

Yeum, K.-J., Russell, R.M., 2002: Carotenoid Bioavailability and Bioconversion. Annu. Rev. Nutr. 22 (1), 483-504. DOI: 10.1146/annurev.nutr.22.010402.102834

ORCID
Christin Baumgärtel https://orcid.org/0000-0001-5169-0599
Anke Förster – not registered
Lara Frommherz https://orcid.org/0000-0001-6178-3430
Thomas Henle https://orcid.org/0000-0001-6220-7267
Guedes José Ramiro – 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

Annex

Tab. 5: Dispensable amino acids of analyzed plant species: Asp = aspartic acid; Ser = serine; Glu = glutamic acid; Gly = glycine; Ala = alanine; Arg = arginine; Pro = proline and Cys = cysteine; Met = methionine in g/100 g protein.

Plant species	Dispensable amino acids [g/100 g protein]								
	Asp	Ser	Glu	Gly	Ala	Cys	Met	Arg	Pro
Aframomum alboviolaceum	9.0	2.5	12.8	4.1	5.5	0.5	0.8	5.7	3.9
Aframomum angustifolium.	9.9	2.9	12.7	4.0	4.9	0.4	0.7	6.5	3.6
Aframomum giganteum	10.6	2.8	15.9	4.3	5.1	0.5	1.1	5.9	3.7
Antidesma venosum	10.7	4.2	16.5	5.1	5.7	0.4	1.0	7.0	6.3
Clitandra cymulosa	14.2	3.0	10.4	4.7	5.2	0.5	0.6	5.3	3.8
Landolphia buchananii	11.1	2.3	14.2	3.8	4.7	0.4	1.0	4.2	3.9
Landolphia lanceolata	10.0	3.8	16.0	4.6	4.6	0.2	1.0	4.2	3.6
Landolphia owariensis	11.2	3.1	10.8	4.3	4.7	0.1	1.3	4.4	4.2
Oncoba welwitschii	7.3	4.1	9.3	3.9	4.4	0.3	0.6	11.3	4.9
Parinari capensis	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Piper umbellatum	8.5	3.6	10.0	4.1	4.6	0.4	0.7	5.5	4.6
Pseudospondias microcarpa	12.0	3.3	17.8	3.3	14.3	0.6	0.9	4.0	4.0
Tristemma mauritianum	8.9	3.1	16.2	4.9	3.5	0.5	1.2	10.4	3.3
Vitex madiensis subsp. *madiensis*	11.1	4.5	10.3	5.3	5.3	0.2	1.1	5.1	5.2

Tab. 6: Content of beta-carotene for the analyzed plant species, means calculated for 100 g dry matter ± SD.

Plant species	Beta-carotene [mg/100g]
Aframomum alboviolaceum	LOD (< 0.08)
Aframomum angustifolium	LOD (< 0.05)
Aframomum giganteum	LOD (< 0.06)
Antidesma venosum	0.07 ± 0.02
Clitandra cymulosa	LOD (< 0.13)
Landolphia buchananii	LOD (< 0.07)
Landolphia lanceolata	LOD (< 0.09)
Landolphia owariensis	LOD (< 0.18)
Oncoba welwitschii	LOD (< 0.07)
Parinari capensis	3.81 ± 0.37
Piper umbellatum	1.68 ± 0.03
Pseudospondias microcarpa	LOD (< 0.18)
Tristemma mauritianum	LOD (< 0.18)
Vitex madiensis subsp. *madiensis*	LOD (< 0.16)