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UNDERUTILIZED FOOD PLANTS AS A SUSTAINABLE FOOD ALTERNATIVE TO IMPORTED FOOD IN ANGOLA, AFRICA

editora itacaiúnas

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1ª edição

Editora Itacaiúnas
Ananindeua – PA
2024

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Editoração eletrônica/ diagramação: Walter Rodrigues
Projeto de capa: dos autores
Foto de capa: imbondeiro (Adansonia digitata L.). Conda, Cuanza Sul, Angola (Schüler et al., 2022)

Dados Internacionais de Catalogação na Publicação (CIP) de acordo com ISBD

UN55 Underutilized food plants as a sustainable food alternative to imported food in Angola, Africa [recurso eletrônico] / Silmo Schüler e Eduardo Alcayaga Lobo. - Ananindeua: Editora Itacaiúnas, 2024.

83 p.: il.: PDF , 7,0 MB.

Inclui bibliografia e índice.

ISBN: 978-85-9535-297-1 (Ebook)
DOI: 10.36599/itac-978-85-9535-297-1

1. Meio ambiente; Conservação e Proteção I. Título.

CDD 333.72
CDU 502.13

Índice para catálogo sistemático:
1. Meio ambiente; Conservação e Proteção: 333.72
2. Conservação e proteção ambiental: 502.13

E-book publicado no formato PDF (*Portable Document Format*). Utilize software Adobe Reader para uma melhor experiência de navegabilidade nessa obra.

Esta obra foi publicada pela **Editora Itacaiúnas** em novembro de 2024.

ACKNOWLEDGEMENTS

During several incursions into the provinces of Angola, Africa, over more than a decade, observing food from the rural areas, we identified several underutilized or neglected food plants. This experience made it possible to write the book **"*Foods from the rural environment of Angola: production and preparation*" (in Portuguese, "*Alimentos do ambiente rural de Angola: produção e preparo*")**, published in 2022, indeed a transformative journey that offered us several opportunities for learning and growth in different aspects.

This personal and professional growth broadened our worldview through immersion in Angola's different cultures and customs, challenging our beliefs and prejudices and promoting a more open and tolerant vision. It promoted the development of interdisciplinary skills, having the experience of stimulating creativity, written communication, and the ability to adapt to new environments. The improvement in the capacity for observation and analysis stands out when documenting experiences and identifying patterns and nuances in culture and food in the rural environment of Angola. Furthermore, facing the challenges of traveling through a country with diverse cultures and dialects strengthened resilience and the ability to deal with adverse situations.

The contribution to scientific knowledge is brought to light by research and documentation of food from the rural environment of Angola. It revealed underutilized or neglected plants, preparation techniques, and traditional knowledge valuable to food and nutrition science. In turn, culture influences the food choices, eating habits, and health of the Angolan population. Therefore, this book can provide insights into the challenges and opportunities related to food and nutrition security in Angola. It can also bridge Western science and African cultures, promoting intercultural dialogue and the appreciation of underutilized or neglected food diversity.

In this context, the book ***"Underutilized food plants as a sustainable food alternative to imported food in Angola, Africa"*** aims to contribute to the appreciation of the rich diversity of underutilized foods, combating stereotypes and promoting the recognition of their cultural and nutritional importance. It also raises awareness among the population about food security challenges in Angola. It encourages public policies and actions to promote sustainability and social justice. The experience seeks to inspire new scientific research on underutilized plant foods, food culture, and food and nutritional security challenges in Angola.

The authors express their deep gratitude to the researchers and secretaries of the Postgraduate Program in Environmental Technology (master and doctorate) at the University of Santa Cruz do Sul (UNISC), represented by its coordinator, Dr Rosana de Cassia de Souza Schneider, for their constant support and encouragement, which were fundamental in the completion of this book. This study was partially funded by the Coordination for the Improvement of Higher Education Personnel - Brazil (CAPES) - Code 001. CAPES Consolidation of Postgraduate Course, Protocol 88881710390/2022-1.

PRESENTATION

This exploratory and quantitative study aimed to (i) identify underutilized food plants from Angola, Africa; (ii) characterize bromatologically those most cited in the scientific literature; (ii) quantify volumes and values; (iii) chemically characterize the main foods imported by Angola, and (iv) carry out a comparative analysis of nutritional equivalence between underutilized foods and the main imported foods. We provide subsidies for public policies to promote–domestic food production, aiming to preserve ecosystem biodiversity through developing a sustainable agri-food system. Nine underutilized plant species were researched: two of which were cereal species, massambala (*Sorghum bicolor* (L.) Moench) and massango (*Pennisetum glaucum* (L.) R.Br.); three fruit tree species imbondeiro (*Adansonia digitata* L.), maboqueiro (*Strychnos spinosa* Lam.) and dendezeiro (*Elaeis guineensis* Jacq.); two types of tubers, inhames (*Dioscorea spp*.) and assipi (*Colocasia esculenta* (L.) Schott); and two species of leafy vegetables, fumbua (*Gnetum africanum* Welw.) and uce (*Hibiscus sabdariffa* L.). Another fifteen underutilized food species were also listed. In 2022, Angola imported 780,734 tons of corn, wheat and flour, potatoes, orange juice, edible oil, and vegetables, worth USD 677,480,000.00, which could be replaced by promoting local production of underutilized food species. Therefore, it is recommended to develop and implement public policies to strengthen food production systems and structures with these underutilized plants as a sustainable solution to food scarcity, food and nutritional insecurity, malnutrition, environmental sustainability, and the maintenance of associated ecosystems in Angola.

FOREWORD

It is no secret that Angola, as a country, has faced many challenges with 27 years of civil war, climate change, population growth, land mines, etc., factors that have caused rural exodus.

Faced with food shortages, the use of imports and the concentration of many people in urban areas, there was a change in lifestyles, altering eating habits and, at the same time, there was a clear underutilization of local production.

In its efforts towards sustainable development and food security, the Angolan Executive aims to optimize the type of crops and improve the productivity of endogenous products, including fishing, livestock and forestry, doing justice to their soil and climate conditions.

With 56.9 million hectares of potentially agricultural arable lands, of which only 5.9 are actually occupied and exploited, Angola still faces the challenge of food insecurity, which requires multiple and innovative measures aimed at reinvigorating underutilized plantations.

While corporate agriculture plays a crucial role in intensive crops that require the productivity of larger areas of land, investments and more complex techniques, family farming represents more than 80% of national production. On the other hand, it will require a large investment, aiming at its transition from a rudimentary subsistence agriculture to a sustainable commercial agriculture, and in this way increase national competitiveness and above all reduce imports and thus contribute significantly to Angola's Gross Domestic Product (GDP)[1].

Therefore I congratulate doctoral student Silmo Schüler and Dr. Eduardo Alcayaga Lobo, authors of the book "Underutilized food plants as a sustainable alternative to food imports in Angola", because during their trips to the interior of Angola they had the opportunity to observe the existence of many underutilized or neglected food plants and experience different cultures, uses and customs, eating habits, secular knowledge, beliefs, forms and production techniques.

This work is a perfect symbiosis between science, academia and actions of the Executive, being, without a doubt, a true contribution to public policies for the production of organic food, with the aim of preserving the biodiversity associated with the ecosystem through the development of a sustainable agri-food system. This exploratory and essentially quantitative

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[1] Angola 2050 Estratégia de Longo Prazo

study is recommended to agronomists, academic institutions, economic and social researchers, environmentalists, among other scholars.

The scientific study of underutilized or neglected plants provides insights into the challenges and opportunities related to food and nutrition security, malnutrition, environmental sustainability and the maintenance of associated ecosystems in Angola, while serving as a bridge between Western and African cultures, thus promoting intercultural dialogue and the recognition of dietary diversity.

The effectiveness and efficiency in the use of underused or neglected food plants in Angola, as a replacement for imported products and for the development of sustainable agriculture for current and future generations, was demonstrated in the study of nine underutilized plants, highlighting massambala and massango; three fruits such as baobab, maboqueiro and oil palm; two tubers such as yam and taro; two vegetables such as fumbua and uce, in addition to fifteen other types of food. We can observe its food and nutritional composition, which can be an alternative to imported products, in addition to being resistant to climate change and serving as a source of income for the rural population.

With this interconnection between science, the effective implementation of public policies and the actions of the Executive, we will be able to materialize Agostinho Neto's legacy that "agriculture is the basis and industry the decisive factor" for the development of Angola.

Dr. Maria **Filomena** de Fátima Lobão Telo **Delgado**.

Sociologist, Former Minister of Family and Women's Promotion of Angola and current Ambassador of Angola to Switzerland.

PREFÁCIO

Não é segredo que Angola enquanto país, enfrentou muitos desafios com os 27 anos de guerra civil, mudanças climáticas, crescimento populacional, minagem dos solos etc, factores que provocaram o êxodo rural.

Face à escassez alimentar, o recurso à importação e a concentração de muitas pessoas nos meios urbanos, contribuíram para a mudança do modo de vida alterando ao mesmo tempo os hábitos alimentares com um claro subaproveitamento da produção local.

Nos seus esforços visando o desenvolvimento e a segurança alimentar sustentável, o Executivo angolano tem como objectivo optimizar o tipo de culturas e melhorar a produtividade dos produtos endógenos, incluindo a pesca, a pecuária e a silvicultura, fazendo jus às suas condições edafoclimáticas.

Com 56,9 milhões de hectares de terras aráveis potencialmente agrícolas, das quais apenas 5,9 efectivamente ocupadas e exploradas, Angola enfrenta ainda o desafio da insegurança alimentar, o que requer medidas múltiplas e inovadoras que visem revigorar as plantações subutilizadas.

Se por um lado a agricultura empresarial tem um peso crucial nas culturas intensas que obrigam a produtividade de maiores extensões de terra, investimentos e técnicas mais complexas, a agricultura familiar representa mais de 80% da produção nacional, por outro lado, exigirá um grande investimento, visando a sua transição de agricultura de subsistência rudimentar para agricultura comercial sustentável e desta forma aumentar a competitividade nacional e sobretudo reduzir as importações e assim contribuir significativamente para o Produto Interno Bruto (PIB) de Angola[2].

Felicito, por isso, o Doutorando Silmo Schüler e o Doutor Eduardo Alcayaga Lobo, autores do livro "Plantas alimentícias subutilizadas como alternativa sustentável à importação de alimentos em Angola", pois, ao longo das suas deslocações ao interior de Angola, tiveram a oportunidade de observar a existência de muitas plantas alimentícias subutilizadas ou negligenciadas e vivenciar as diferentes culturas, usos e costumes, hábitos alimentares, conhecimento secular, crenças, formas e técnicas de produção.

[2] Angola 2050 Estratégia de Longo Prazo

Esta obra é uma perfeita simbiose entre a ciência, a academia e as acções do Executivo, sendo, sem sombra de dúvidas, um verdadeiro contributo às políticas públicas para a produção de alimentos orgânicos, com o objectivo de preservar a biodiversidade associada ao ecossistema através do desenvolvimento de um sistema agroalimentar sustentável.

Este estudo exploratório e essencialmente quantitativo é recomendado aos agrónomos, instituições académicas, investigadores económicos e sociais, ambientalistas, entre outros estudiosos.

O estudo científico sobre as plantas subutilizadas ou negligenciadas providencia subsídios aos desafios e oportunidades relacionadas com a segurança alimentar e nutricional, a desnutrição, a sustentabilidade do ambiente e a manutenção dos ecossistemas associados em Angola, servindo ao mesmo tempo como uma ponte entre o ocidente e as culturas africanas, promovendo, deste modo, o diálogo intercultural e o reconhecimento da diversidade alimentar.

A eficácia e eficiência no uso das plantas alimentícias subutilizadas ou negligenciadas em Angola, em substituição dos produtos importados e para o desenvolvimento da agricultura sustentável para as actuais e futuras gerações, vem demonstrado no estudo de nove plantas subutilizadas, se destacando a massambala e o massango; três frutas como o imbondeiro, o maboqueiro e o dendezeiro; dois tubérculos como o inhame e o taro; dois vegetais como a fumbua e o uce, para além de outros quinze tipos de alimentos.

Podemos observar a sua composição alimentar e nutritiva, que podem ser a alternativa aos produtos importados, para além de serem resistentes às mudanças climácticas e servirem de fonte de renda da população rural.

Com esta interligação entre a ciência, a implementação efectiva das políticas públicas e as acções do Executivo, poderemos sim materializar o legado de Agostinho Neto de que “a agricultura é a base e a indústria o factor decisivo” para o desenvolvimento de Angola.

Dra. Maria **Filomena** de Fátima Lobão Telo **Delgado**.

Socióloga, Ex-mininistra da Família e Promoção da Mulher de Angola e actual Embaixadora de Angola na Suíça.

SUMMARY

1 INTRODUCTION

Feeding and providing food security for all people is a significant challenge to be achieved with the United Nations 2030 Agenda through the Sustainable Development Goals (SDGs) (ONU, 2019). Population growth, climate change, intensive monoculture, and depletion of natural resources are among the challenges that threaten the increasingly damaged global agri-food system (Tan *et al*., 2020). In this regard, Africa is the home to several nutritious food crops that were used as food in the past. However, these crops remain underutilized as the global effort against nutrition warfare suffers a record setback due to recent climate change (Ogbuagu *et al*., 2023). According to Muhammad *et al*. (2020), the global agricultural system is centered on a small number of crop species, thus posing a threat to food security and supply. Throughout history, humans have used more than 5,538 crop species for food. In contrast, only 12 crop species currently share the highest percentage of food security worldwide (Hossain *et al*., 2021).

Around a thousand neglected and underutilized crop species worldwide have been estimated as future survival crop species as they are nutrient-enriched and have greater adaptability to climate change (Hossain *et al.,* 2021). As global hunger increases, especially in Africa, it becomes essential to address food insecurity by maximizing the potential of existing food resources, including underutilized and neglected species (Ferdaus *et al*., 2023). Several problems hinder the use of underutilized food plants in Africa (Schüler *et al.,* 2024). The concentration of the population in urban areas leads to a nutritional transition from traditional diets (based on indigenous foods) to a Western diet, generating the prevalence of associated malnutrition and non-communicable diseases (Kesa *et al*., 2023).

Several problems hinder innovation and sustainable development in agriculture in Africa: (i) inadequate strategies and public policies; (ii) the lack of crop varieties that are more resilient to climate change; (iii) the lack of adequate digital technologies; (iv) little technical and financial support; (v) the need to identify underutilized crops with the greatest potential for success, and prioritize them for research; (vi) gender inequality and the lack of more research on the topic by African institutions (Schüler *et al*., 2023). Angolan peasant agriculture grows many varieties of food without specializing in these varieties. The transformation of these peasants into competitive farmers requires public policies that promote sustainable agricultural activity (Schüler *et al*., 2022).

Angola is known for its rich biomes, ecoregions, fauna, and flora. With habitats ranging from the rainforests of Cabinda in the north to the Namib Desert in the south, Angola's ecosystem diversity is greater than any other African country (Mawunu *et al*., 2018). Angola has a rich diversity of ecosystems, but this natural wealth is poorly recorded compared to other countries in the region. Both colonization and prolonged wars have interfered with the evolution of biodiversity research and conservation (Huntley *et al*., 2019). In Angola, the Congo River Delta is home to a wide variety of rare, endemic, migratory, or threatened species that provide essential ecosystem services (Kirkman & Nsingi, 2019).

This book aimed to support solving these problems to guarantee the sustainability of Angolan agriculture for current and future generations. Maintaining biodiversity associated with more sustainable and healthy food systems will increase Angola's food and nutritional security. In this context, the research aims to (i) identify underutilized food plants in Angola and perform their bromatological characterization, (ii) quantify (volumes and values) and chemically characterize the corn, wheat and flour, potatoes, oranges and juice, edible oil and fresh, dehydrated, frozen or preserved vegetables imported by Angola, (iii) perform a comparative analysis of nutritional equivalence between underutilized foods and corn and wheat, and (iv) provide subsidies for public policies to promote domestic food production, aiming at the preservation of biodiversity associated with ecosystems, through the development of a sustainable agri-food system.

In this sense, the efficiency in the use of underutilized food plants in Angola, replacing imported foods, for the development of sustainable agriculture, is demonstrated with nine species of plants, among many that have food and nutritional potential (Fig. 1). There are two species of cereals: massambala and massango, three fruit tree species; imbondeiro, maboqueiro, and dendezeiro; two types of tubers: yam and assipi, and two species of leafy vegetables: fumbua and uce.

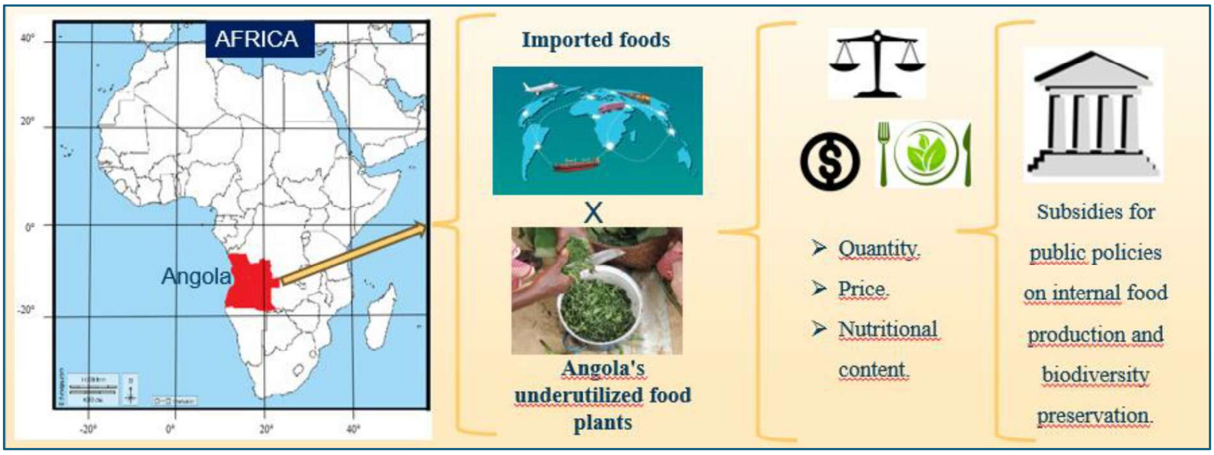


Fig. 1. Infographic summary of the research.

2 MATERIAL AND METHODS

Schüler *et al*. (2022) documented from 2014 to 2020 in the eighteen provinces of Angola, documenting the science, technology, and anthropology practiced by peasants. Based on this study, there was interest in deepening scientific research to strengthen agri-food systems and structures with underutilized or neglected species as a sustainable solution to food scarcity, food and nutritional insecurity, malnutrition, environmental sustainability, and maintenance of associated ecosystems in Angola.

Therefore, this study is exploratory and quantitative (Gerhardt & Silveira, 2009). The data were obtained from databases of international agencies such as the Food and Agriculture Organization of the United Nations (FAO) (FAO, 2024), government agencies such as the United States Department of Agriculture (USDA, 2024), academic institutions such as the University of São Paulo through the Brazilian Food Composition Table (USP, 2023), and in scientific literature databases, such as Google Scholar, Scopus, Science Direct and Web of Science.

3 RESULTS AND DISCUSSION

3.1 Massambala

Figure 2 presents the infographic of the research on the massambala cultivar, underutilized in Angola, and the corn imported by Angola.

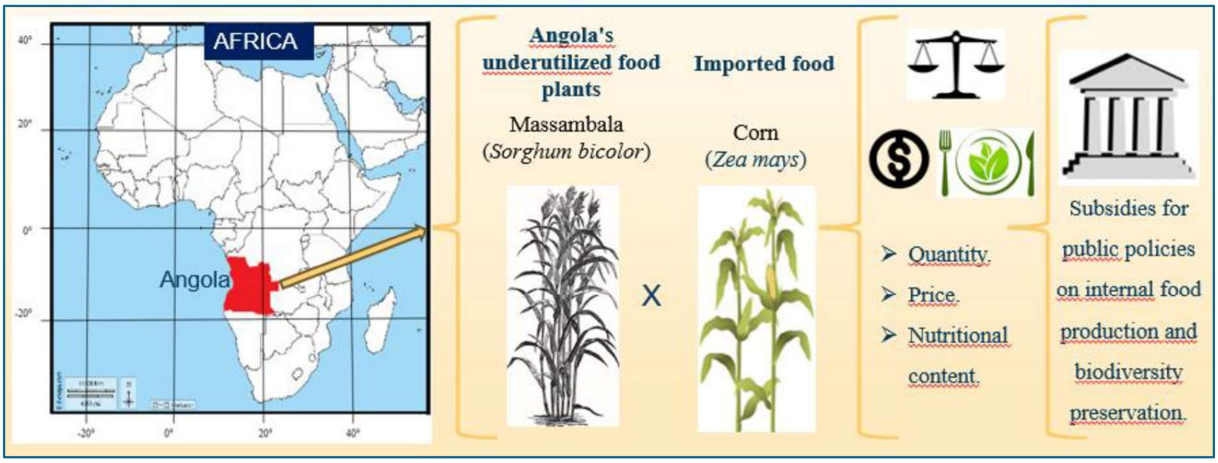


Fig. 2. Infographic summary of the research on massambala and corn.

Massambala is considered one of the most underutilized crops, having only started to receive attention in recent years (Lee *et al*., 2023), highlighting that it has the potential to contribute to food security and the livelihoods of smallholder farmers (Fig. 3a,b). It was domesticated approximately 6,000 years ago in the eastern Sahel region of Africa (Beldados & Ruiz-Giralt, 2023). Also known as millet, it is an important cereal that grows well in adverse environmental conditions such as drought, heat, and nutritionally poor soils (Somegowda *et al*., 2024). It is one of the primary sources of food grains in drylands in Africa, helping small-scale agriculture become more resilient, productive, and profitable and improving carbon sequestration (Kuyah *et al*., 2023).

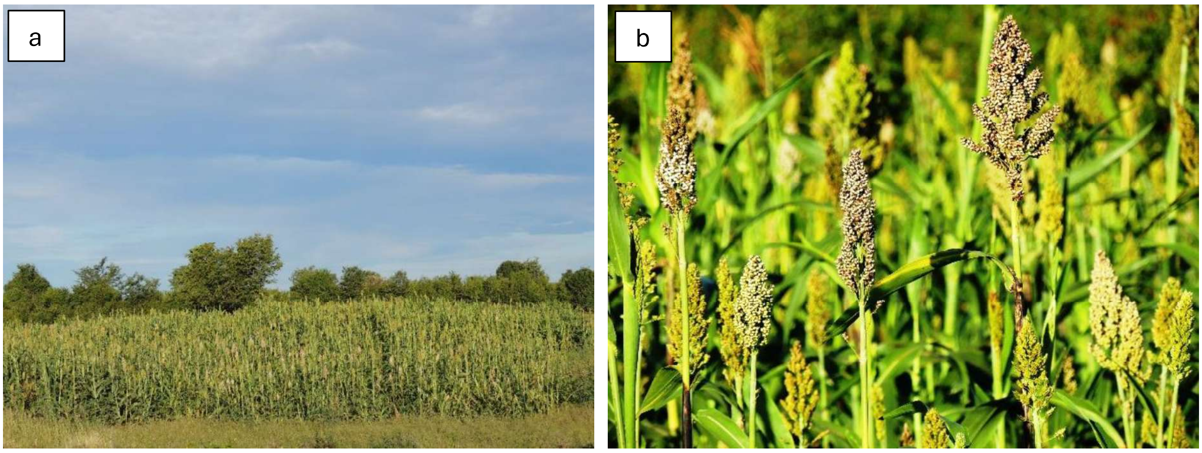


Fig. 3. Massambala cultivation, Cahama, Cunene, Angola. 2a: Peasant farm of massambala. 2b: massambala with bunches and grains.

Massambala is an important crop in Angola, ranking third in cultivated area and cereal production after corn and rice. There are mentions of its cultivation in several provinces of the country (Fig. 3): Huambo, the central producing region, with around 40% of national production; Benguela, the second largest producer, with around 25% of national production; and Cuanza Sul, the third largest producer, with around 15% of national production. Other provinces mentioned with relevant production are Bié, 5% of national production; Huíla, 5% of national production; Malanje, 4% of national production; Cuanza Norte, 3% of national production; and Uíge, 3% of national production. Massambala is cultivated in other provinces of Angola, but on a smaller scale: Cabinda, Cuando Cubango, Cunene, Moxico, Namibe, and Zaire (Fig. 4) (Costa *et al*., 2004; Tomás, 2012; Pacheco *et al*., 2013; Nuñgulu, 2014; Bonga, 2016; Urso *et al*., 2016; Mwaikafana, 2018; Coelho, 2020; Schüler *et al*., 2022).

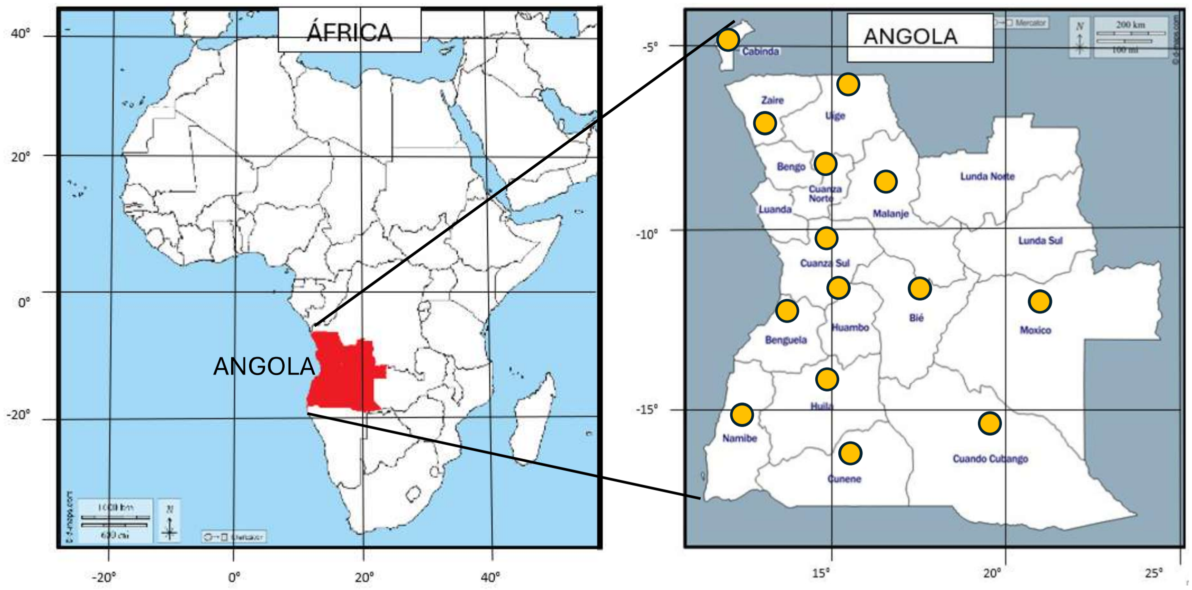


Fig. 4. Location of the 18 provinces of Angola, highlighting the provinces with the occurrence of massambala (orange circles). Source: prepared by the authors at www.d-maps.com.

Table 1 presents the nutritional composition of the massambala cultivar in the form of dry, whole, and raw grains and corn imported by Angola. Figure 5 presents a comparative analysis of the nutritional composition of these cultivars.

The analysis shows an equivalence (±10%) in food energy (345 Kcal), potassium (305 mg), niacin (3.3 mg), thiamine (0.35 mg), and monosaturated fatty acid (1.16 g). Meanwhile, the massambala cultivar presented a superior composition to corn concerning protein content (11.5g), total dietary fiber (11.9g), ash (1.9g), calcium (26mg), iron (6.8 mg), magnesium (193 mg), phosphorus (371 mg), copper (0.30 mg), vitamin E (0.70 mg), and folate equivalent (64 mcg). However, the massambala cultivar presented lower levels of fat (3.5 g), available carbohydrate (61.1 g), sodium (9 mg), zinc (1.88 mg), vitamin A RAE (1 mcg), riboflavin (0.15 mg), vitamin B6 (0.25 mg), monounsaturated fatty acid (0.48 g), and polyunsaturated fatty acid (0.86 g).

Massambala has great potential as a functional and sustainable food and can be used in human nutrition as a substitute for common cereals such as wheat, rice, and corn (Aguiar *et al*., 2023). Massambala molasses is an excellent source of minerals and bioactive compounds and an extraordinary food for human nutrition (Assis *et al*., 2023). Native or modified starches from underutilized seeds, such as massambala, represent an alternative and sustainable source of unconventional starch with potential applications in the food industry (Magallanes-Cruz *et al*., 2023), being a popular alternative to barley for brewing (Kerr *et al*., 2023).

Massambala has adaptive characteristics for cultivation in areas of water stress, which is much superior to corn (Tabosa *et al*., 2021). The cost of massambala grain in animal feed is, on average, 25% lower than that of corn. At the same time, its nutritional value, measured in the form of metabolizable energy, reaches at least 95% of the value of corn. Thus, this plant is an important alternative for supplying the grain market as an alternative energy ingredient to corn (De Menezes *et al*., 2021). It is cultivated in many countries as a food source due to its excellent nutritional value, drought and pest resistance, and gluten-free properties (Nagy *et al*., 2023).

Addressing the challenge of food and nutritional insecurity in Sub-Saharan Africa, where Angola is located, will require innovative agricultural production systems that favor multiple objectives (Akplo *et al*., 2023). Reinvigorating crops such as massambala and the agrobiodiversity they represent bring benefits for healthier and more sustainable food systems (Pereira & Hawkes, 2022).

Table 1. Nutritional composition of massambala and imported corn.

ITEM	DESCRIPTION	MASSAMBALA VALUE/100g	CORN VALUE/100g
1	Food energy (kcal)	345	365
2	Water (g)	10.2	10.37
3	Protein (g)	11.5	9.42
4	Fat (g)	3.5	4.74
5	Available carbohydrate (g)	61.1	74.26
6	Total dietary fiber (g)	11.9	7.3
7	Ashes (g)	1.9	1.3
8	Calcium (mg)	26	7
9	Iron (mg)	6.8	2.71
10	Magnesium (mg)	193	1.27
11	Phosphor (mg)	371	210
12	Potassium (mg)	305	287
13	Sodium (mg)	9	35
14	Zinc (mg)	1.88	2.21
15	Copper (mg)	0.30	0.08
16	Vitamin A RE[1] (mcg)	3	214
17	Vitamin A REA[2] (mcg)	1	11
18	Vitamin D (mcg)	0	0
19	Vitamin E (mg)	0.70	0.49
20	Thiamine (mg)	0.35	0.38
21	Riboflavin (mg)	0.15	0.20
22	Niacin (mg)	3.3	3.63
23	Vitamin B6 (mg)	0.25	0.62
24	Folate Equivalent (mcg)	64	19
25	Vitamin B12 (mcg)	0	0
26	Vitamin C (mg)	0	0
27	Cholesterol (mg)	0	0
28	Saturated fatty acid (g)	0.48	0.67
29	Monounsaturated fatty acid (g)	1.16	1.25
30	Polyunsaturated fatty acid (g)	0.86	2.16

[1] Retinol Equivalent. [2] Retinol-equivalent activity. [3] Da: dashes (symbol). Source: organized by the authors from the database of the University of São Paulo (USP, 2023).

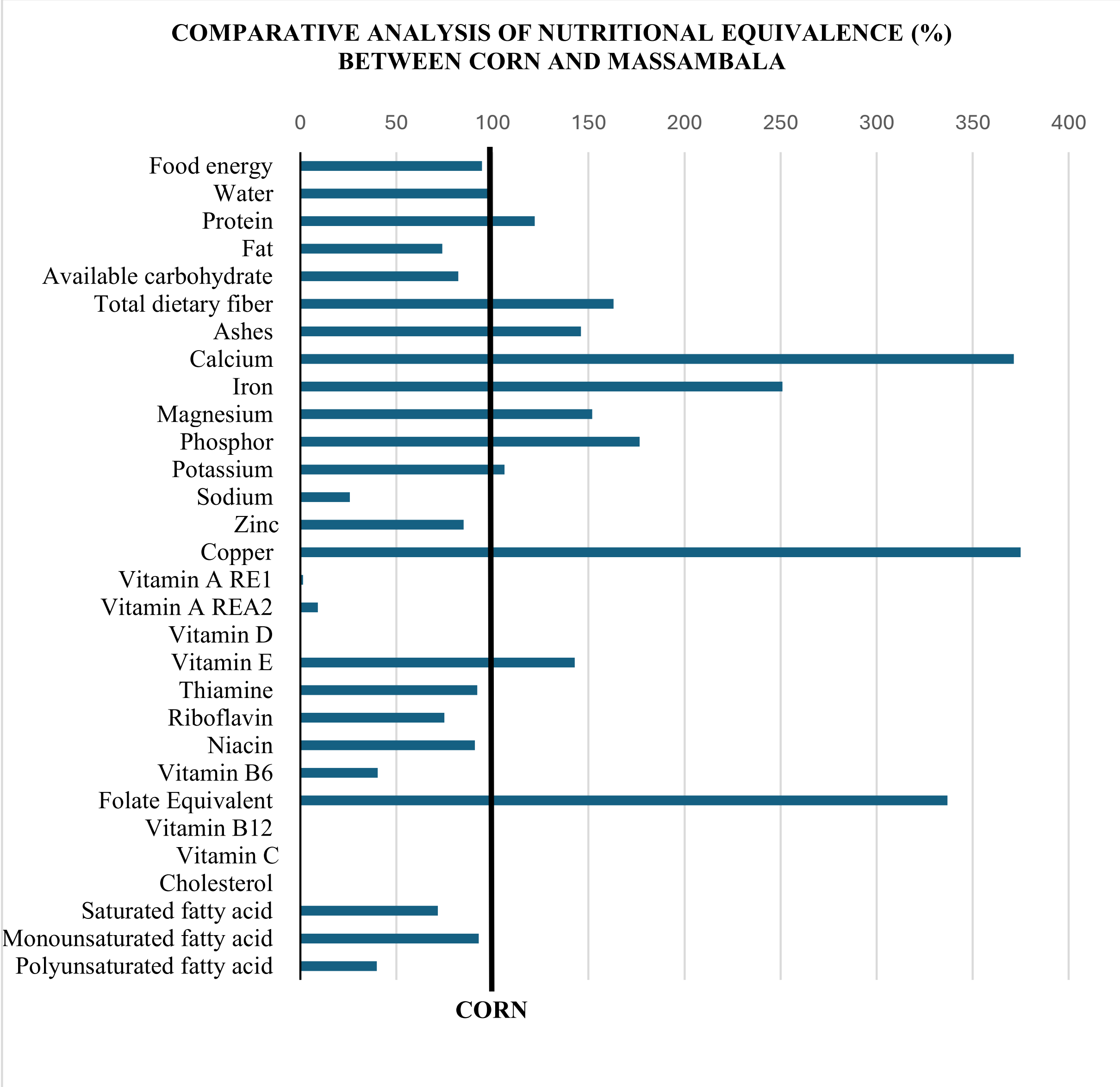


Fig. 5. Comparative analysis of nutritional equivalence between massambala and corn imported by Angola. Blue horizontal bars: massambala. Source: organized by the authors based on the Food and Agriculture Organization of the United Nations (FAO, 2024), the database of the University of São Paulo (USP, 2023), and the United States Department of Agriculture (USDA, 2024).

It is worth noting that Angola imported 2,488,396 tons of corn from 2013 to 2022 at an estimated cost of USD 1,021,498,000.00 (FAO, 2024). Considering the nutritional quality of massambala due to its proteins, carbohydrates, fats, fiber, vitamins, and mineral content, the use of imported corn in the Angolan diet could be replaced by local production of massambala, characterizing sustainable agriculture with local income generation.

3.2 Massango

Figure 6 presents the infographic of the research on the massango cultivar, underutilized in Angola, and the wheat imported by Angola.

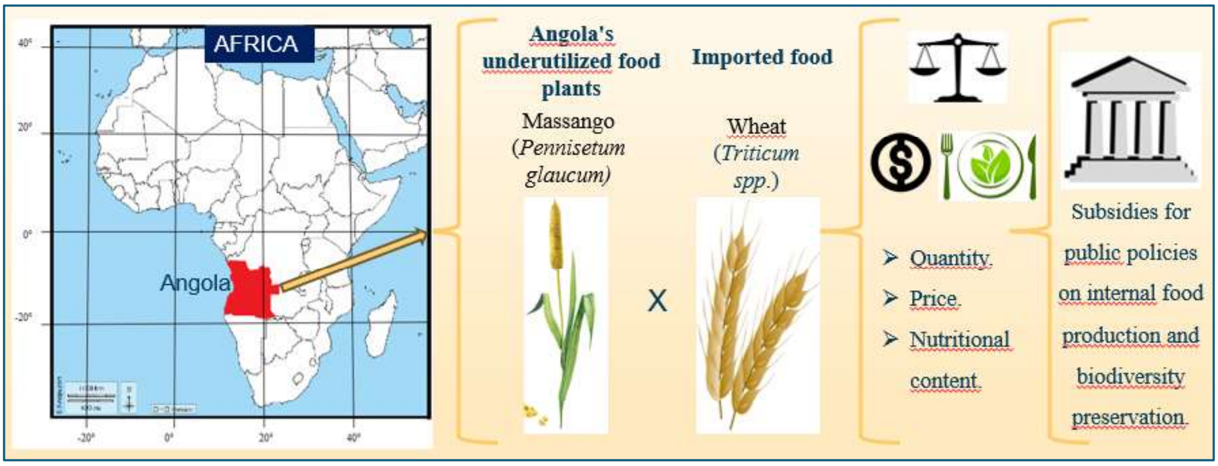


Fig. 6. Infographic summary of the research on massango and wheat.

Massango, also called millet, is an important cereal cultivated in arid and semi-arid regions of Asia and Africa. It is used in the staple diet of millions of people and as fuel and forage. In addition to resisting adverse environmental conditions (Karthikeyan *et al.*, 2023), it is a sustainable and underutilized cereal (Fig. 7a,b) (Singh *et al.*, 2023).

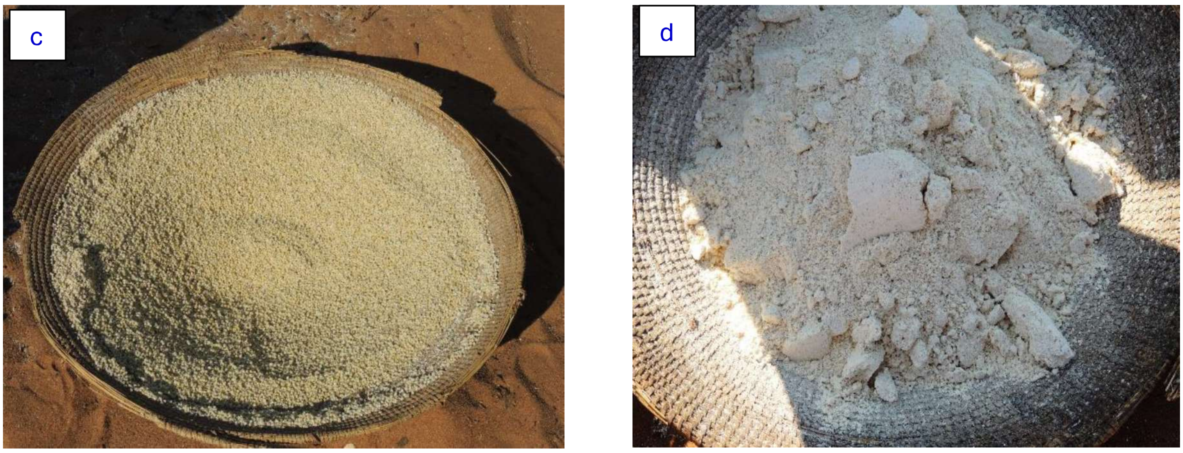


Fig. 7. Massango Cultivation. 7a: massango peasant farm, Lubango, Huíla, Angola. 7b: massango bunches, Lubango, Huíla, Angola. 7c: massango grains, Cahama, Cunene, Angola. 7d: massango flour, Cahama, Cunene, Angola.

In recent years, several high-yielding and nutrient-rich varieties, including massango, have been developed as dual-purpose varieties in sub-Saharan Africa to meet human nutrition and animal feed needs (Fig. 5c,d) (Akplo *et al*., 2023). Maggs *et al*. (1998), in their research on plant genetic resources, focused on species of potential or actual agricultural importance, such as massango, a plant with considerable genetic diversity and development potential.

Massango is an important cereal for Angola's food security, cultivated in several provinces: Benguela, the central producing region; Huambo, the second-largest producer; Cuanza Sul, the third-largest producer; Bié, the fourth-largest producer; and Malanje, the fifth-largest producer. Other provinces with production are Cuando Cubango, Cunene, Huíla, Lunda Norte, Lunda Sul, Moxico, Namibe and Uíge (Fig. 8) (Tomás, 2012; Pacheco *et al*., 2013; Bonga, 2016; Urso *et a*l., 2016; Mwaikafana, 2018; Coelho, 2020; Schüler *et al*., 2022).

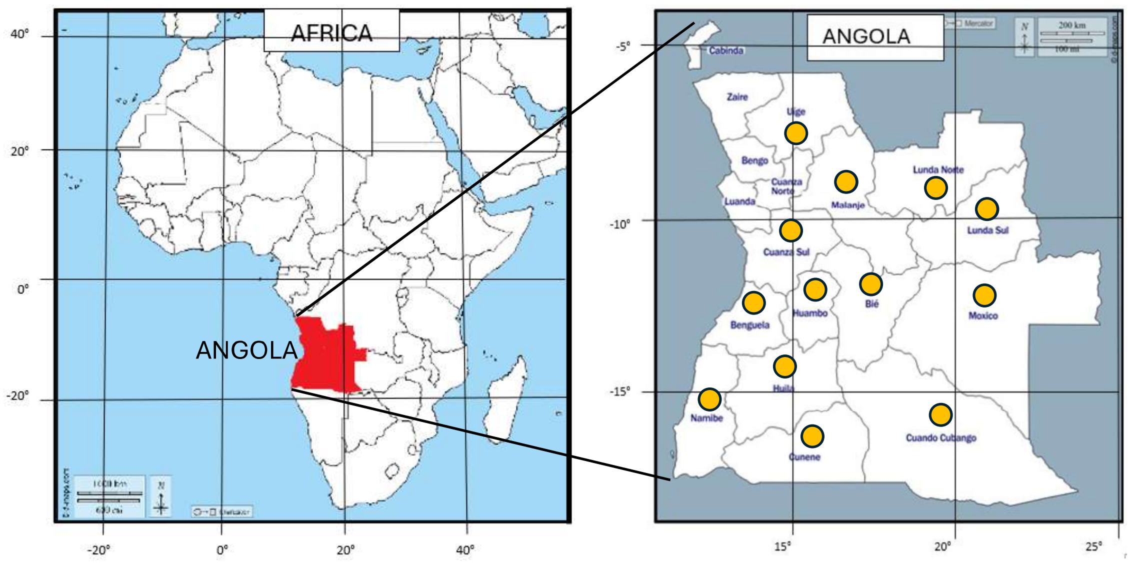


Fig. 8. Location of the 18 provinces of Angola, highlighting the provinces with the occurrence of massango (orange circles). Source: prepared by the authors at www.d-maps.com.

Table 2 presents the nutritional composition of the massango cultivar in the form of dry, whole, and raw grains and wheat imported by Angola. Figure 9 presents a comparative analysis of the nutritional composition of these cultivars.

The analysis shows an equivalence (±10%) in protein (9.3 g), phosphorus (402 mg), copper (0.45 mg), and vitamin B6 (0.35 mg). Meanwhile, the massango cultivar presented a superior composition to wheat concerning food energy (365 Kcal), fat (5.9 g), available carbohydrate (64.2 g), ash (2.1 g), iron (15.2 g), magnesium (96 mg), sodium (12 mg), riboflavin (0.19 mg), folate equivalent (160 mcg), saturated fatty acid (0.96 g), monounsaturated fatty acid (1.10 g), and polyunsaturated fatty acid (2. 19 g). However, this cultivar had lower levels of dietary fiber (9 g), calcium (23 g), potassium (332 g), zinc (2.58 mg), vitamin E (0.36 mg), thiamine (0.29 mg), and niacin (2.0 mg).

Comparative analysis shows that massango has 10% more food energy than imported wheat. In minerals, there is an equivalence in phosphorus and copper. However, wheat has more zinc, potassium, and calcium, and the massango has higher iron, magnesium, and sodium levels. In vitamins, massango stands out in riboflavin and folate equivalent. It presented higher levels of saturated, monounsaturated, and polyunsaturated fatty acids. It has high phenolic content, moderate reducing capacity, and high free radical scavenging activity and, therefore, can serve as a source of antioxidants in the human diet (Odusola *et al*., 2013).

Climate change is expected to significantly impact the arid savanna regions of southwest Africa. In this case, massango is the most suitable crop in all scenarios, especially considering that the cultivation of corn, sorghum, and beans may be affected by a possible decrease in precipitation in a high-emission scenario (Weinzierl & Heider, 2015).

As an alternative to imported wheat in the African baking industry, Adepehin *et al*. (2023) evaluated the physicochemical parameters of bread made from underutilized local cereals, such as massango, in a 50:50 ratio. The breads produced have better nutritional content compared to conventional wheat bread.

Table 2 Nutritional composition of massango and imported wheat.

ITEM	DESCRIPTION	MASSAMBALA VALUE/100g	WHEAT VALUE/100g
1	Food energy (kcal)	365	336
2	Water (g)	9.4	10.4
3	Protein (g)	9.3	10.7
4	Fat (g)	5.9	1.99
5	Available carbohydrate (g)	64.2	62.7
6	Total dietary fiber (g)	9	12.7
7	Ashes (g)	2.1	1.54
8	Calcium (mg)	23	34.0
9	Iron (mg)	15.2	5.37
10	Magnesium (mg)	96	90
11	Phosphor (mg)	402	402
12	Potassium (mg)	332	435
13	Sodium (mg)	12	2.0
14	Zinc (mg)	2.58	3.46
15	Copper (mg)	0.45	0.43
16	Vitamin A RE[1] (mcg)	1	0.00
17	Vitamin A REA[2] (mcg)	0	0.00
18	Vitamin D (mcg)	0	0.00
19	Vitamin E (mg)	0.36	1.01
20	Thiamine (mg)	0.29	0.41
21	Riboflavin (mg)	0.19	0.11
22	Niacin (mg)	2.0	4.77
23	Vitamin B6 (mg)	0.35	0.38
24	Folate Equivalent (mcg)	160	41.0
25	Vitamin B12 (mcg)	0	0.00
26	Vitamin C (mg)	0	0.90
27	Cholesterol (mg)	0	0
28	Saturated fatty acid (g)	0.96	0.37
29	Monounsaturated fatty acid (g)	1.10	0.23
30	Polyunsaturated fatty acid (g)	2.19	0.84

[1] Retinol Equivalent. [2] Retinol-equivalent activity. [3] Da: dashes (symbol). Source: organized by the authors from the database of the University of São Paulo (USP, 2023).

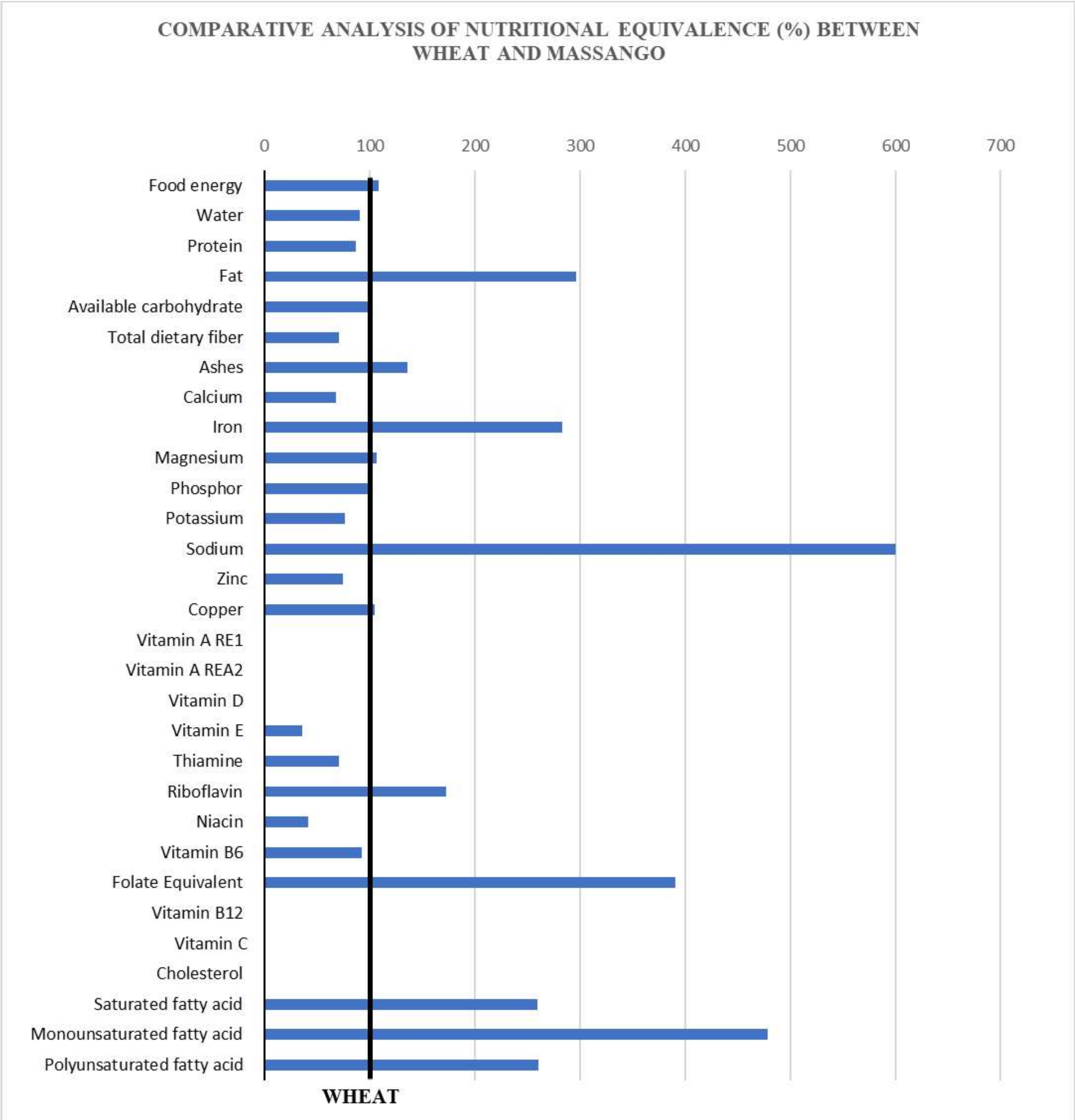


Fig. 9. Comparative analysis of nutritional equivalence between massango and wheat imported by Angola. Horizontal blue bars: massango. Source: organized by the authors based on the Food and Agriculture Organization of the United Nations (FAO, 2024), the database of the University of São Paulo (USP, 2023), and the United States Department of Agriculture (USDA, 2024).

It is worth noting that Angola imported 6,152,621 tons of wheat from 2013 to 2022 at an estimated cost of USD 2,766,332,000.00 (FAO, 2024). Considering the nutritional quality of massango, the use of imported wheat in the Angolan diet could be replaced by local production of massango, characterizing sustainable agriculture with local income generation.

3.3 Imbondeiro (Baobab)

Figure 10 presents the infographic of the research on the underutilized múcua (fruit of the imbondeiro tree) in Angola and the orange juice imported by Angola.

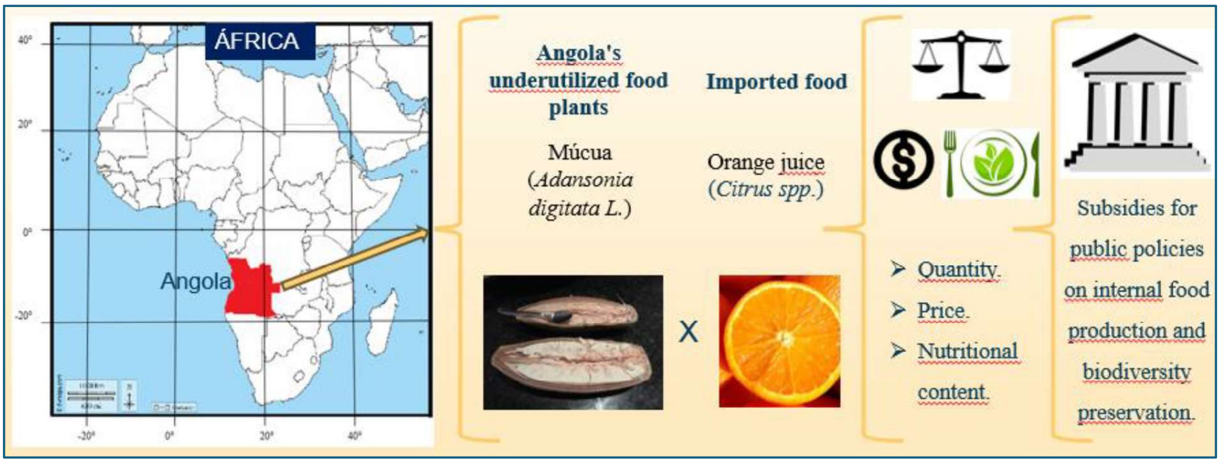


Fig. 10. Infographic summary of the research on múcua and orange juice.

Imbondeiro is widely found in the forests and savannas of sub-Saharan Africa (Figure 11a). The fruit of the imbondeiro, popularly known as múcua, has a pulp with a sour and slightly sweet flavor, widely consumed by natives. It contains a high nutritional value and is a source of income for the rural collector population (Figures 11b-11d) (Monteiro *et al*., 2022). Múcua, widely used to make juices, has a thick, woody skin (Figures 11e and 11f) (Kempe *et al*., 2018). Due to its numerous uses, its high nutritional and medicinal value, its drought tolerance, and its relatively easy cultivation, the imbondeiro has been qualified as one of the most important edible forest trees to be conserved, domesticated, and valued in Africa (Sanchez *et al*., 2010). The benefits provided by this species in combating malnutrition and poverty have become more explicit as awareness increases regarding concerns about climate change and food security increases (Sanchez *et al*., 2010).

In the province of Cuanza Norte, Heinze *et al*. (2019), comparing the cultural value with the economic value of the imbondeiro tree, highlighted its profitability, being promising for a more detailed economic and ecological analysis due to its high local importance and national and international demand. In Namibe province, southern Angola, Mopane forests play a fundamental role in the livelihood strategies of local native populations; however, they have been little investigated by ethnobiologists, and currently, little is known about the plants traditionally used by local communities.

Imbondeiro. Conda, Cuanza Sul, Angola.

Múcua, fruit of the imbondeiro tree. Conda, Cuanza Sul, Angola.

Múcua, fruit of the imbondeiro tree, displayed for sale. Belize, Cabinda, Angola.

Múcua pulp displayed for sale. Cuanza Norte, Angola.

Múcua split lengthwise.

Múcua juice.

Fig. 11. Imbondeiro, fruits, and juice.

The imbondeiro occurs naturally in Angola in arid and semi-arid regions, on mountainous plateaus, in mature forests, and as a component of savannah ecosystems in the provinces of Bengo, Benguela, Bié, Cuanza Norte, Cuanza Sul, Cunene, Huambo, Luanda, Malanje, Namibe, and Uíge, as shown in Figure 12 (Assogbadjo & Loo, 2011; Mawunu *et al*., 2016; Urso *et al*., 2016; Canga *et al*., 2022; Monteiro *et al*., 2022; Schüler *et al*., 2022).

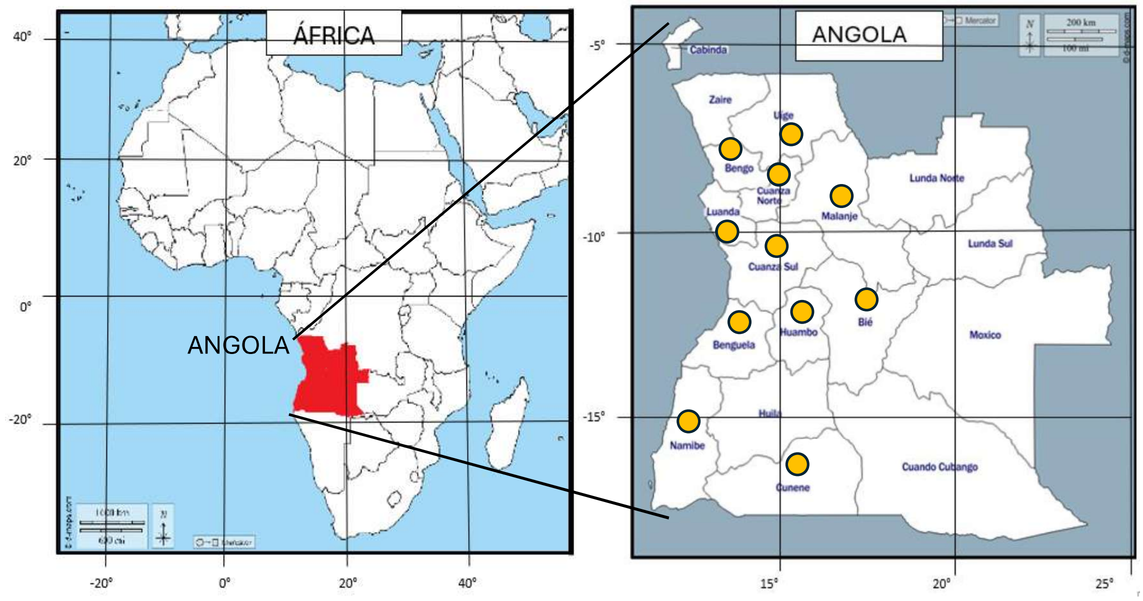


Fig. 12. The location of the 18 provinces of Angola, highlighting the provinces with the occurrence of imbondeiro (orange circles). Source: prepared by the authors at www.d-maps.com.

Table 3 presents the nutritional composition of múcua pulp in the form of raw ripe fruit and orange juice imported by Angola. Figure 13 presents a comparative analysis of the nutritional composition between múcua and orange juice.

Table 3. Nutritional composition of múcua pulp and orange juice imported by Angola.

ITEM	DESCRIPTION	MÚCUA VALUE/100g	ORANGE JUICE VALUE/100g
1	Food energy (kcal)	305	45
2	Water (g)	16.2	87.6
3	Protein (g)	2.1	0.90
4	Fat (g)	0.3	0.24
5	Available carbohydrate (g)	70.0	8.81
6	Total dietary fiber (g)	7.0	2.02
7	Ashes (g)	4.4	0.41
8	Calcium (mg)	254	29.9
9	Iron (mg)	6.4	0.12
10	Magnesium (mg)	139	10.9
11	Phosphor (mg)	73	20.2
12	Potassium (mg)	1920	159
13	Sodium (mg)	23	0.53
14	Zinc (mg)	1.44	0.11
15	Copper (mg)	0.53	0.04
16	Vitamin A RE[1] (mcg)	12	2.96
17	Vitamin A REA[2] (mcg)	6	1.48
18	Vitamin D (mcg)	0	0.00
19	Vitamin E (mg)	0	0.36
20	Thiamine (mg)	0.04	0.07

21	Riboflavin (mg)	0.20	0.04
22	Niacin (mg)	1.5	Da[3]
23	Vitamin B6 (mg)	0.02	0.03
24	Folate Equivalent (mcg)	50	28.1
25	Vitamin B12 (mcg)	0	0.00
26	Vitamin C (mg)	251	47.3
27	Cholesterol (mg)	0	0.00
28	Saturated fatty acid (g)	0.02	0.04
29	Monounsaturated fatty acid (g)	0.05	0.06
30	Polyunsaturated fatty acid (g)	0.04	0.06

[1] Retinol Equivalent. [2] Retinol-equivalent activity. [3] Da: dashes (symbol). Source: organized by the authors from the database of the University of São Paulo (USP, 2023).

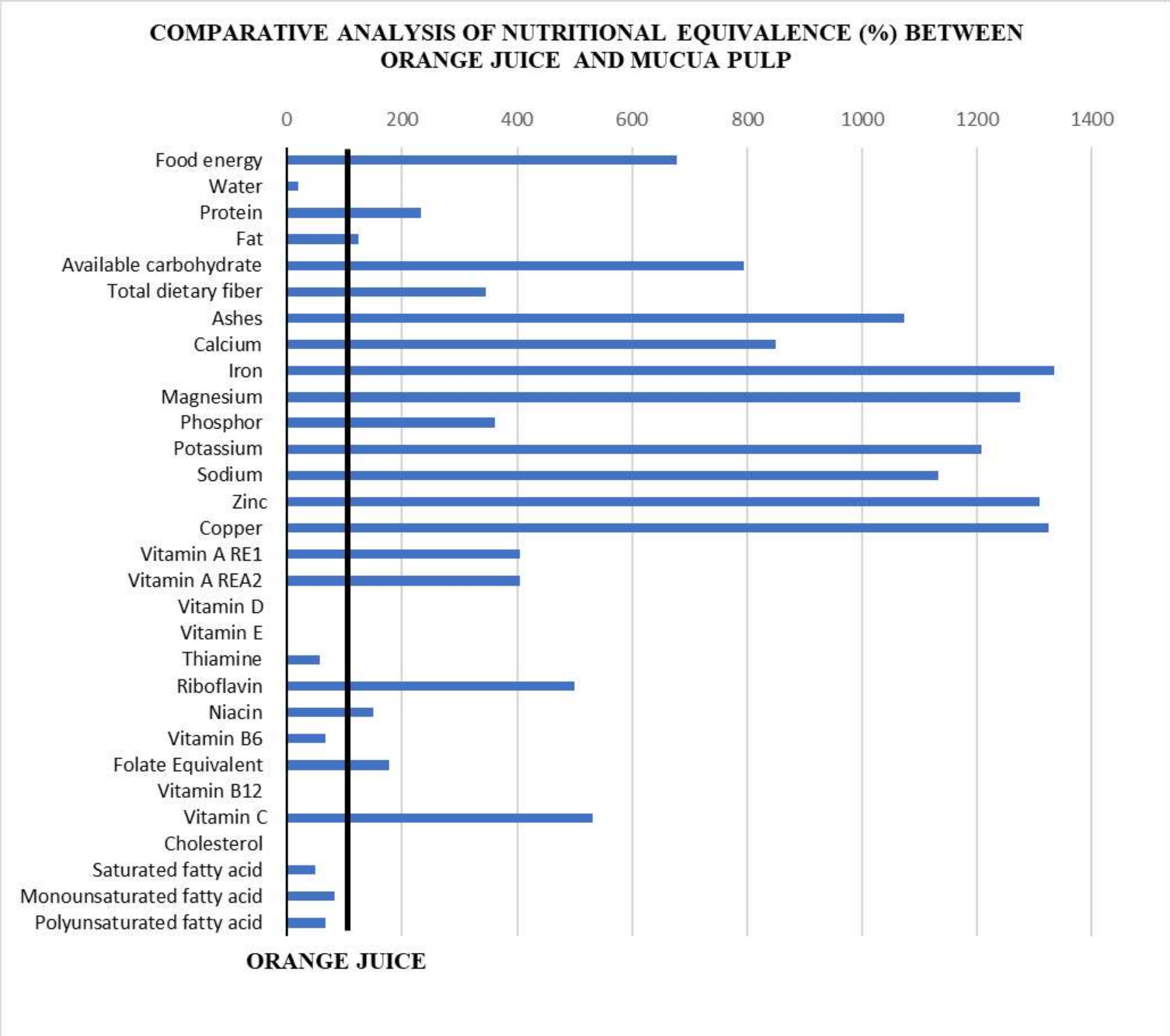


Fig. 13. Comparative analysis of nutritional equivalence between múcua pulp and imported orange juice. Horizontal blue bars: múcua pulp. Source: organized by the authors from the database of the University of São Paulo (USP, 2023) and the United States Department of Agriculture (USDA, 2024).

The comparative analysis of the nutritional composition between múcua pulp and orange juice imported by Angola shows that múcua has almost seven times more dietary energy (305 kcal), twice the protein content (2.1 g), and nine times more available carbohydrates (70.0 g). In terms of minerals, múcua has higher levels of calcium (254 mg), iron (6.4 mg), magnesium (139 mg), phosphorus (73 mg), sodium (23 mg), zinc (1.44 mg), copper (0.53 mg), and potassium (1920 mg). Múcua has higher levels of vitamin A (12 mcg), C (251 mg), and folate equivalent (50 mcg).

It is worth noting that Angola imported 2.915 tons of orange juice from 2013 to 2022 at an estimated cost of USD 1.864.000,00 (FAO, 2024). Considering the nutritional quality of múcua pulp, the use of imported orange juice in the Angolan diet could be replaced by local production of múcua pulp and other underutilized local fruits. Múcua pulp could be widely cultivated in most southern African countries, with Angola considered highly suitable for cultivating this species (Sanchez *et al*., 2010). The high nutritional value of the múcua fruit has the potential to qualitatively improve the diet of thousands of people in Africa (Monteiro *et al*., 2022).

3.4 Maboqueiro (green monkey orange)

Figure 14 presents the infographic of the research on the underutilized maboque (fruit of the maboqueiro tree) in Angola and the orange juice imported by Angola.

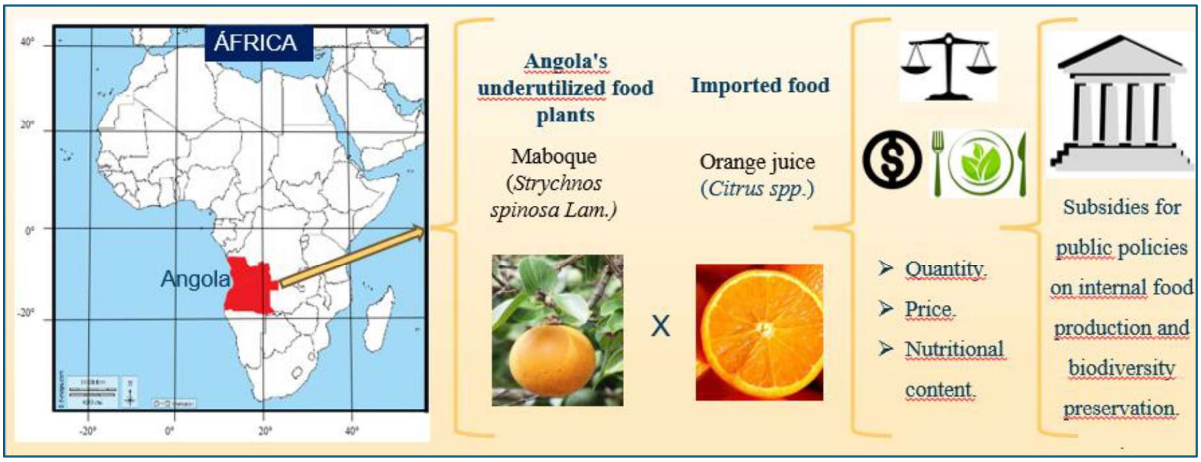
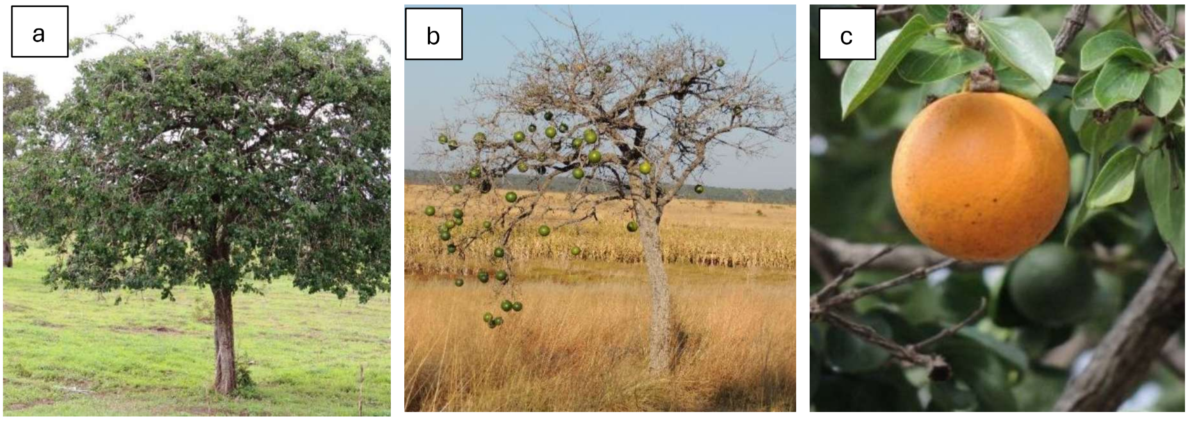


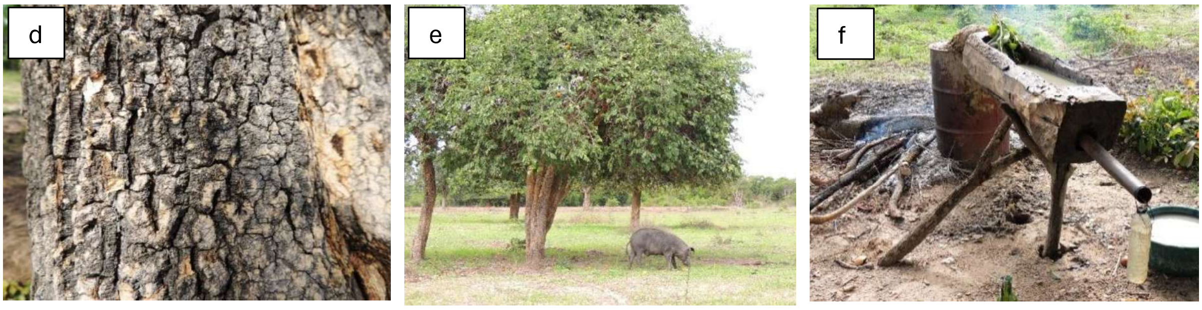
Fig. 14. Infographic summary of the research on maboque and orange juice.

The maboqueiro is an economically important species of fruit tree, endemic to sub-Saharan Africa, that grows in nutrient-poor sandy soils and is currently threatened due to overexploitation and climate change (Dzikiti *et al*., 2022). It is a deciduous tree with approximately 0.5 to 10 height and a rounded crown of one or more trunks (Figures 15a and 15b). The fruits are 7 to 15 cm in diameter and contain 10 to 100 flat, round seeds (Figure 15c) with a hard shell about 0.8 to 8 mm wide (Figure 15d). It spreads through seeds distributed by mammals that can break their shell (Figure 15e) (Sanfilippo, 2014). It is an indigenous fruit rich in nutrients and prevalent in Southern Africa. Its nutritional composition compares favorably with oranges (Omotayo & Aremu, 2021).

The average composition of the fruits is 44% pulp, 41% pericarp (skin), and 15% seeds (Mwamba & Peiler, 2005). They are consumed with fermented corn flour, fruit, jam, juice, and alcohol (Figure 15f) and fermented porridge, representing one of the highest-priority fruit species for domestication in Southern Africa (Mbhele *et al*., 2022).



Maboqueiro. Quipungo, Huíla, Angola.	Maboqueiro with green fruits. Cuito Cuanavale, Cuando Cubango, Angola.	Ripe maboque fruit. Quipungo, Huíla, Angola.



Bark of the Maboqueiro trunk. Quipungo, Huíla, Angola.	Maboqueiro. Quipungo, Huíla, Angola. Seed dispersing pigs.	Production of a distilled alcoholic beverage from Maboque pulp. Quipungo, Huíla, Angola.

Fig. 15. Maboqueiro, fruits and uses. Source: Schüler *et al.* (2022).

The maboqueiro has a specific distribution in Angolan territory. The provinces with confirmed records are Benguela, Bié, Cuando Cubango, Cuanza Norte, Cuanza Sul, Huambo, Huíla, Lunda Norte, Malanje and Namibe, as shown in Figure 16 (Leeuwenberg, 1969; Novotna *et al*., 2020; Schüler *et al*., 2022; Sosa & Siquilile, 2023).

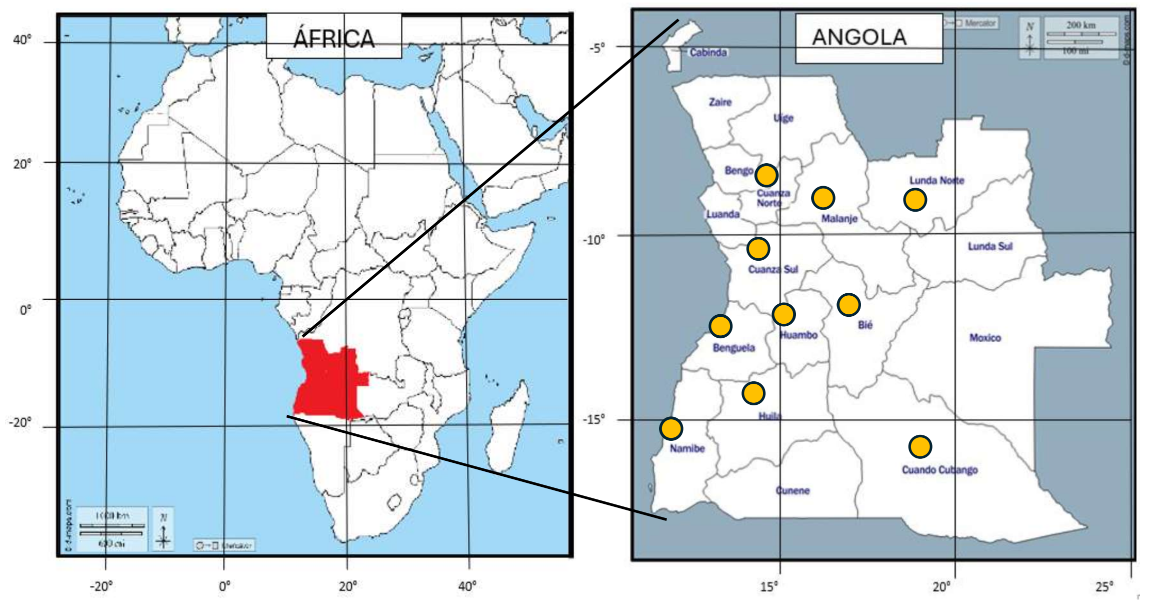


Fig. 16. The location of the 18 provinces of Angola, highlighting the provinces with the occurrence of maboqueiro (orange circles). Source: prepared by the authors at www.d-maps.com.

Table 4 presents the nutritional composition of Angola's imported maboque pulp and orange juice. Figure 17 presents a comparative analysis of the nutritional composition between maboque pulp and orange juice.

Tabela 4. Nutritional composition of maboque pulp and orange juice imported by Angola.

ITEM	DESCRIPTION	MABOQUE VALUE/100g	ORANGE JUICE VALUE/100g
1	Food energy (kcal)	1681	45
2	Water (g)	80	87.6
3	Protein (g)	4	0.90
4	Fat (g)	15.8	0.24
5	Available carbohydrate (g)	28.7	8.81
6	Total dietary fiber (g)	9.2	2.02
7	Ashes (g)	0.75	0.41
8	Calcium (mg)	30	29.9
9	Iron (mg)	3.3	0.12
10	Magnesium (mg)	81.2	10.9
11	Phosphor (mg)	60.3	20.2
12	Potassium (mg)	200	159
13	Sodium (mg)	23.3	0.53
14	Zinc (mg)	0.5	0.11
15	Copper (mg)	0.62	0.04
16	Vitamin A RE[1] (mcg)	-	2.96
17	Vitamin A REA[2] (mcg)	-	1.48
18	Vitamin D (mcg)	-	0.00
19	Vitamin E (mg)	0.45	0.36
20	Thiamine (mg)	0.08	0.07
21	Riboflavin (mg)	0.02	0.04
22	Niacin (mg)	0.44	Da
23	Vitamin B6 (mg)	0.04	0.03
24	Folate Equivalent (mcg)	-	28.1
25	Vitamin B12 (mcg)	-	0.00
26	Vitamin C (mg)	69.0	47.3
27	Cholesterol (mg)	0.00	0.00
28	Saturated fatty acid (g)	0.01	0.04
29	Monounsaturated fatty acid (g)	0.08	0.06
30	Polyunsaturated fatty acid (g)	-	0.06

[1] Retinol Equivalent. [2] Retinol-equivalent activity. [3] Da: dashes (symbol). Source: organized by the authors following Arnold *et al*. (1985). Ngadze, Linnemann *et al*. (2017), Omotayo & Aremu (2021) and the University of São Paulo (USP, 2023).

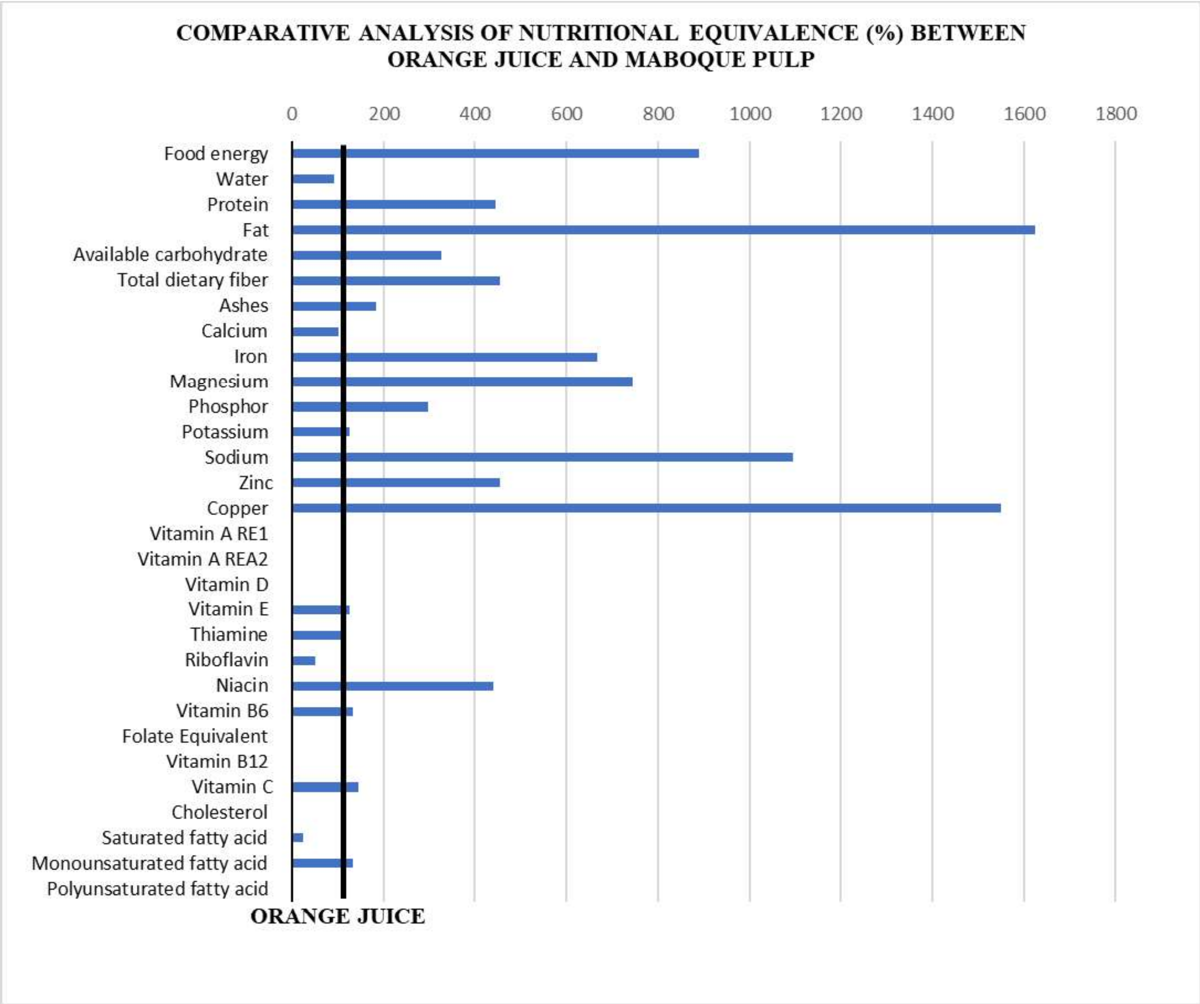


Fig. 17. Comparative analysis of nutritional equivalence between maboque pulp and imported orange juice. Horizontal blue bars: maboque pulp. Source: organized by the authors from the database of the University of São Paulo (USP, 2023), Ngadze, Linnemann *et al*. (2017), Omotayo & Aremu (2021) and Arnold *et al*. (1985).

A comparative analysis of the nutritional composition between maboque pulp and orange juice imported by Angola shows that maboque has 37 times more dietary energy (1681 kcal), 4 times more protein content (4 g), three times more available carbohydrate (28.7 g), and 65 times more fat (15.8 g). Maboque has higher levels of iron (3.3 mg), magnesium (81.2 mg), phosphorus (60.3 mg), sodium (23.3 mg), zinc (0.5 mg), and copper (0.62 mg), and equivalence in calcium content. There is equivalence in vitamins B6, C, and E.

As demonstrated, maboque pulp provides nutritional and health-promoting benefits compared to orange juice. To improve the supply of this species, investments are needed in scientific research on domestication, intensive cultivation, environmental preservation, value chain, and economic potential (Omotayo & Aremu, 2021). Therefore, it is recommended that government entities and organized civil society create and strengthen existing systems. They should also create structures interested in producing maboque fruits as a sustainable solution to food deficiency, food and nutritional insecurity, and malnutrition in urban and rural communities in Angola.

Including fruits in diets provides nutrients and antioxidants, combating malnutrition and, above all, hidden hunger. Exploring native fruits to introduce added value to the production chain can also leverage the creation of new businesses and the development of new value chains (Khan *et al*., 2014). Ngadze *et al*. (2017) assessed communities' knowledge of processed indigenous fruit edible products, such as fermented and distilled maboque pulp beverages, identifying them among the highest-priority fruit species in Southern Africa.

Akweni *et al*. (2022) identified an average productivity of 1,211 ± 971 kg ha^{-1} of fresh maboque fruit biomass. According to the same authors, this potential can support commercial wild fruit harvesting ventures. Furthermore, Avakoudjo *et al*. (2021) identified this species as an important edible wild fruit tree, which is increasingly threatened due to human action. Despite its excellent socioeconomic potential, commercial plantations of this species are rare. In turn, the spread of agroforestry using local species will allow a transition to sustainable agriculture. The appreciation of wild fruits can increase rural villages' income (Sanfilippo, 2014).

3.5 Dendezeiro (Oil Palm)

Figure 26 presents the infographic of the research on the underutilized palm oil (edible vegetable oil derived from the dendezeiro) in Angola and the soybean oil imported by Angola.

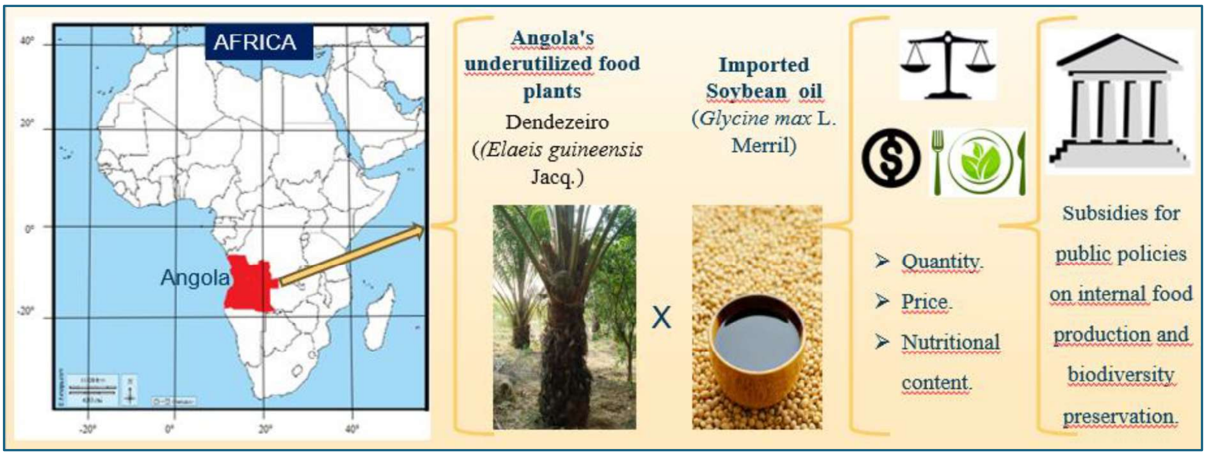


Fig. 26. Infographic summary of the research on palm and soybean oils.

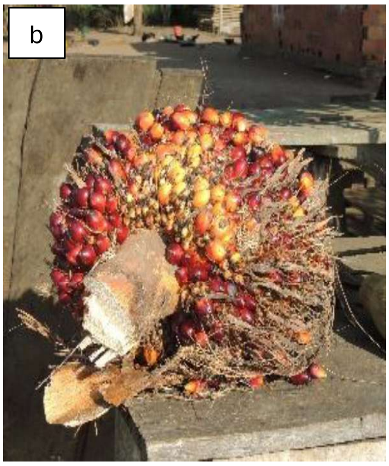
The dendezeiro is native to West Africa and grows in the wild (Figures 27a and 27b) (Hashim *et al*., 2020). In oil palm agriculture in Angola, the fruits and other plant parts of the dendezeiro are used to produce palm oil, wine, or palm milk, called maruvo (Figure 27c), broom, maturation, and other crafts (Luamba & Quissindo, 2021). Palm oil is the most consumed vegetable oil in the world (Padfield *et al*., 2019).

A large percentage of oil palm leaves remain underutilized, making them a source of raw materials that can be transformed into value-added products (Tow *et al*., 2021). Palm leaf analysis is a strategy to find new value-added compounds from this underutilized byproduct of the oil industry (Vargas *et al*., 2016).

The ecological drivers of oil palm pollination are still poorly understood despite pollination being an essential ecosystem service for the yield of this crop, with potential links to biodiversity conservation (Li *et al*., 2019). Among cultivated oilseeds, oil palm is the plant with the highest productivity per cultivated area, producing, on average, ten times more oil than soybeans (Henkes & Lebid, 2015).

The oil extracted from palm nuts, also called palm kernel oil, is widely used by peasant women to treat and beautify their hair and skin. It provides nutrition to the skin, making it soft and lubricated and preserving its natural elasticity. It also helps nourish damaged hair and treat dandruff. The oil extracted from palm nuts is used to prepare soaps and cocoa butter substitutes in the cosmetics and food industries (Figure 27d-27l) (Moreira & Hidrovo, 2001).

Dendezeiro. Buco Zau, Cabinda, Angola.



Bunch of palm fruit. Belize, Cabinda, Angola.

Extraction of palm tree sap for the production of maruvo wine. Buco Zau, Cabinda.

Palm fruits. Belize, Cabinda, Angola.

Roasting of palm fruits to extract skin cream. Cabinda, Angola.

Roasted palm fruit.

Palm fruits in a pestle to extract palm oil. Cabinda, Cabinda, Angola.

Residue from palm oil extraction. Cabinda, Cabinda, Angola.

Palm nut. Belize, Cabinda, Angola.

Palm nut almonds. Belize, Cabinda, Angola.

Extraction of palm kernel oil from palm seeds. Belize, Cabinda, Angola.

Palm kernel oil. Belize, Cabinda, Angola.

Fig. 27. Provision ecosystem services derived from dendezeiro.

The dendezeiro is found in the Angolan provinces of Benguela, Bié, Cabinda, Cuanza Norte, Cuanza Sul, Huambo, Namibe, Uíge, and Zaire, as shown in Figure 28 (Mawunu *et al*., 2016; Mwaikafana, 2018; Schüler *et al*., 2022).

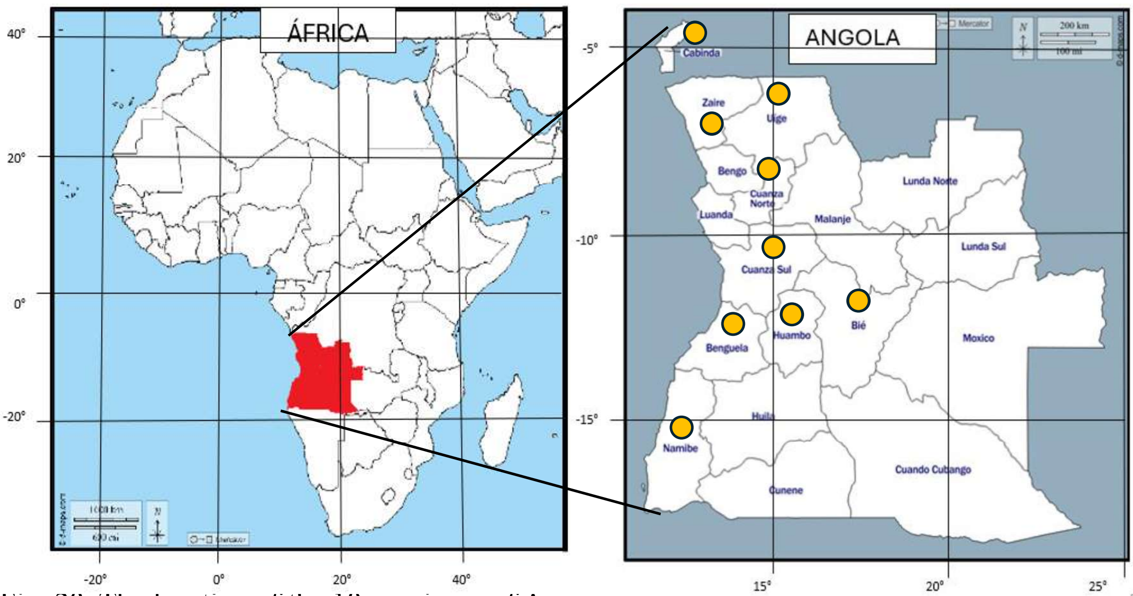


Fig. 28. The location of the 18 provinces of Angola, with emphasis on highlighting the provinces with the occurrence of dendezeiro (orange circles). Source: prepared by the authors at www.d-maps.com.

Table 7 presents the nutritional composition of the palm fruit in the form of raw fruit and soybeans imported by Angola. Figure 29 presents the comparative analysis of the nutritional composition of palm fruit and soybeans.

Table 7. Nutritional composition of palm fruit and soybeans imported by Angola.

ITEM	DESCRIPTION	PALM FRUIT VALUE/100g	SOYBEANS VALUE/100g
1	Food energy (kcal)	540	427
2	Water (g)	28.1	9.70
3	Protein (g)	1.9	39.9
4	Fat (g)	52.6	22.3
5	Available carbohydrate (g)	12.9	10.7
6	Total dietary fiber (g)	3.6	11.9
7	Ashes (g)	1.0	5.44
8	Calcium (mg)	61	203
9	Iron (mg)	4.8	13.5
10	Magnesium (mg)	60	210
11	Phosphor (mg)	56	453
12	Potassium (mg)	23	1590
13	Sodium (mg)	16	10.8
14	Zinc (mg)	0.39	3.54
15	Copper (mg)	0.92	1.17
16	Vitamin A RE[1] (mcg)	10.6	2.44
17	Vitamin A REA[2] (mcg)	5.3	1.22

18	Vitamin D (mcg)	0	0.00
19	Vitamin E (mg)	4.90	0.95
20	Thiamine (mg)	0.13	0.86
21	Riboflavin (mg)	0.08	0.86
22	Niacin (mg)	1.4	1.60
23	Vitamin B6 (mg)	16	0.38
24	Folate Equivalent (mcg)	30	370
25	Vitamin B12 (mcg)	0	0.00
26	Vitamin C (mg)	8	5.92
27	Cholesterol (mg)	0	0
28	Saturated fatty acid (g)	18.1	3.23
29	Monounsaturated fatty acid (g)	19.24	4.94
30	Polyunsaturated fatty acid (g)	4.61	12.6

[1] Retinol Equivalent. [2] Retinol-equivalent activity. [3] Da: dashes (symbol). Source: organized by the authors from the database of the University of São Paulo (USP, 2023).

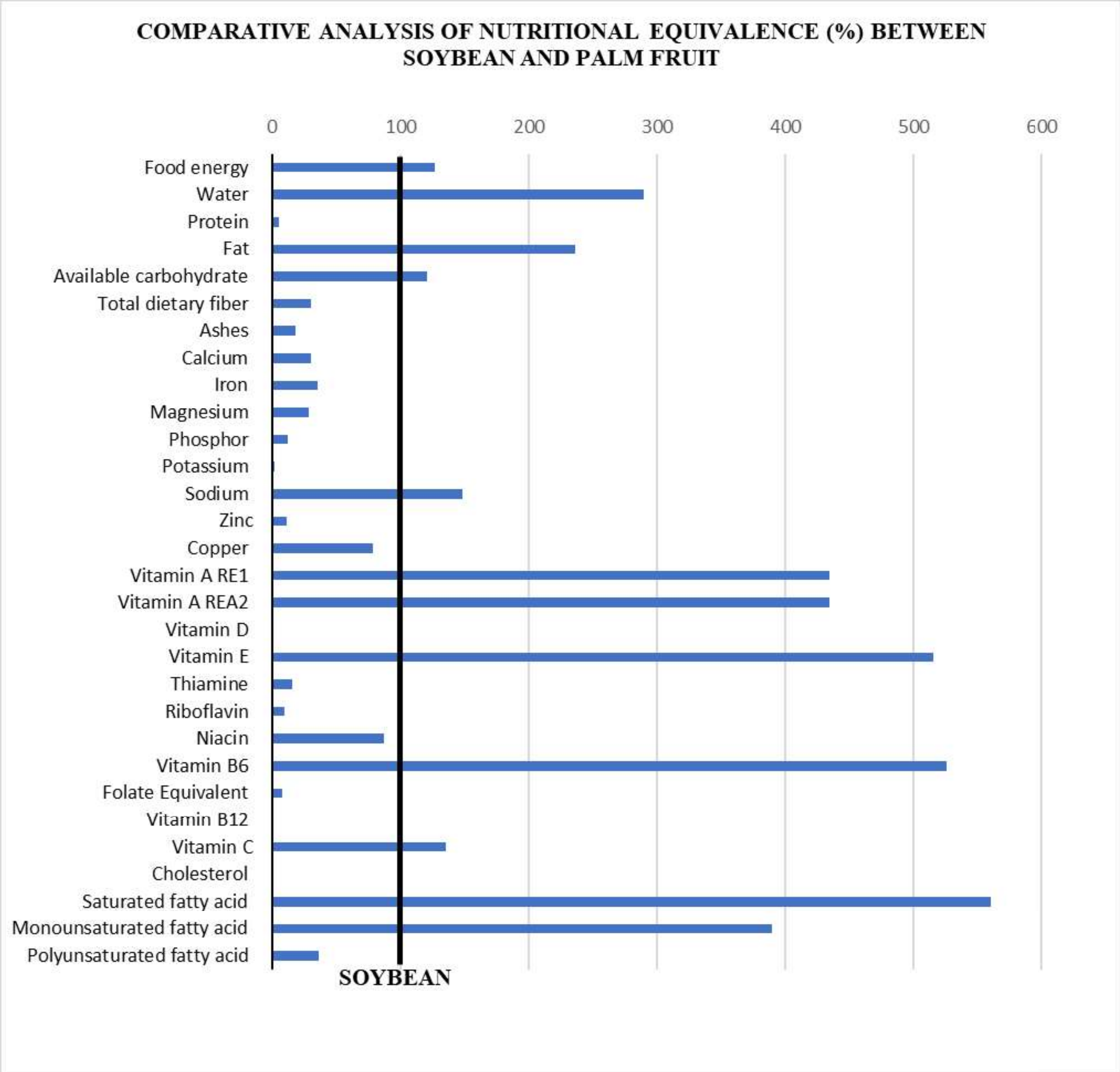


Fig. 29. Comparative analysis of the nutritional composition between the palm fruit and soybeans. Source: organized by the authors from the database of the University of São Paulo (USP, 2023).

The comparative analysis of the nutritional composition between the fruit of the palm tree and soybeans imported by Angola shows that the fruit of the palm tree is superior in dietary energy (540 kcal), fat (52.6 g), and carbohydrates available (12.9 g); there are higher levels of vitamin A (10.6 mcg) and vitamin E (4.9 mg). There are higher levels of saturated (18.1 g) and monounsaturated (19.24 g) fatty acids. Soybeans have the highest protein content (39.9 g).

Pollination management can contribute to a more sustainable palm oil production system that values ecosystem services arising from biodiversity while improving producers' livelihoods (Li *et al*., 2019). There is a global trend towards replacing fossil fuels with renewable energy sources, with palm oil cultivation being a viable alternative for the extraction of palm oil and palm kernel oil for biodiesel production. Brazil uses 6% vegetable oil and 94% petroleum diesel oil in its composition, which tends to grow until it reaches 20% vegetable oil (Henkes & Lebid, 2015). Padfield *et al*. (2019) highlighted a need for scientific programs and studies involving consultation with non-academic stakeholders to develop “transformative” solutions for the palm oil sector. Tow *et al*. (2021) highlight the potential for valorizing palm oil leaf extracts as inputs for the pharmaceutical and cosmetology industries.

It is worth noting that Angola imported 3,844 tons of soybean oil in 2022 at an estimated cost of USD 12,597,000.00 (FAO, 2024). Considering the nutritional quality of palm oil, the use of imported soybean oil in the Angolan diet could be replaced by local production of palm oil and other local oilseed plants.

3.6 Inhame (Yam)

Figure 18 presents the infographic of the research on the underutilized yam cultivar in Angola and the potato imported by Angola.

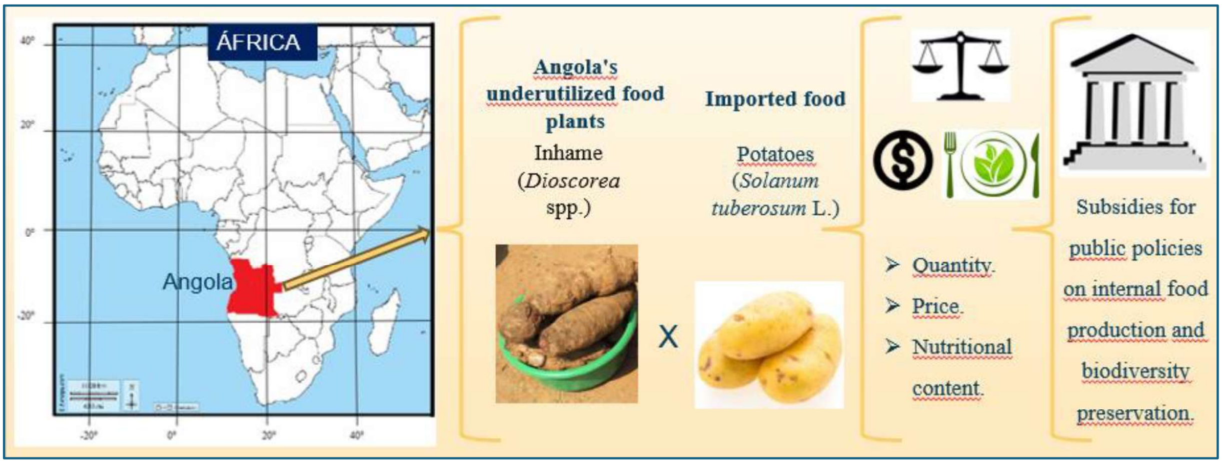
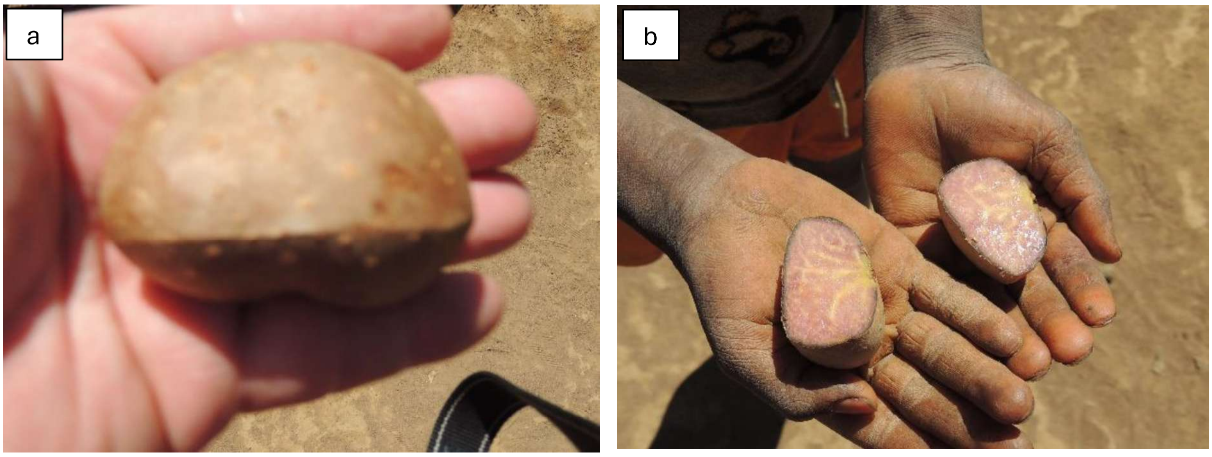


Fig. 18. Infographic summary of the research on inhame and potatoes.

Inhame is a tropical root crop and an important staple food in many tropical and sub-Saharan countries, especially for millions of people in West Africa (Cornet *et al*., 2023; Condé *et al*., 2024). It is also an important food security crop with economic, nutritional, and medicinal value; however, it remains a neglected and underutilized species (Gbemavo *et al*., 2021).

Soil degradation and climate change are significant threats to declining inhame productivity, and demand is expected to double in the next 30 years, threatening food security and cultural heritage preservation (Kouakou *et al*., 2023). It is traditionally used as human food, boiled feed for pigs, laundry starch to stiffen fabrics and clothing, and a medicinal remedy for skin problems (Antonio & Buot, 2023).

Hunter-gatherers collect wild yams (Figures 19a and 19b), and domesticated yams are cultivated in Africa, Asia, and South America. In Africa, they are produced in a small-scale agriculture system and included in the local population's diet (Manuel *et al*., 2023), cultivated from Guinea to Kenya and Angola to Uganda. However, their importance varies greatly (Alexander & Coursey, 2017).



Inhame. Mungo, Huambo, Angola. Inhame cut in half. Mungo, Huambo, Angola.

Fig. 19. Inhame.

The occurrence of inhame is cited in the provinces of Cabinda, Cuando Cubango, Cunene, Huambo, Lunda Norte, Lunda Sul, Malanje, Moxico, Namibe, Uíge, and Zaire, as shown in Figure 20 (Neves, 2010; Mawunu *et al*., 2016; Angop, 2021; Angop, 2022; Schüler *et al*., 2022; Angop, 2023).

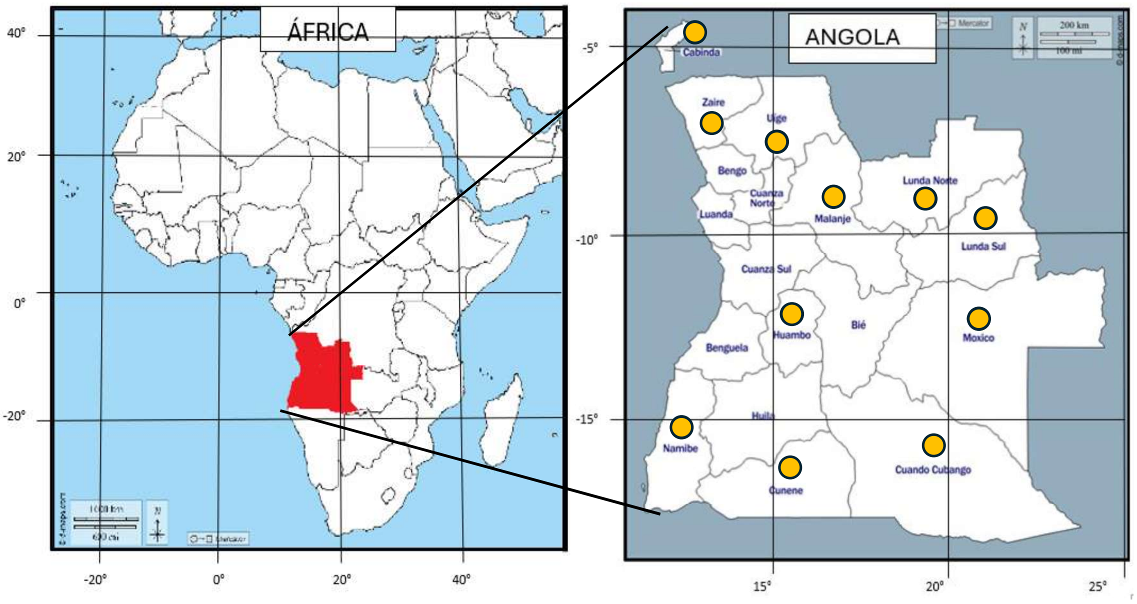


Fig. 20. The location of the 18 provinces of Angola, highlighting the provinces with the occurrence of inhame (orange circles). Source: prepared by the authors at www.d-maps.com.

Table 5 presents the nutritional composition of inhames and potatoes imported by Angola. Figure 21 presents the comparative analysis of the nutritional composition between inhames and potatoes imported by Angola.

Table 5. Nutritional composition of inhames and potatoes imported by Angola.

ITEM	DESCRIPTION	YAM VALUE/100g	POTATO VALUE/100g
1	Food energy (kcal)	126	71
2	Water (g)	64.4	80.5
3	Protein (g)	2.3	2.04
4	Fat (g)	0.4	0.04
5	Available carbohydrate (g)	25.5	15.2
6	Total dietary fiber (g)	5.6	1.32
7	Ashes (g)	1.8	0.85
8	Calcium (mg)	26	3.78
9	Iron (mg)	1.6	0.41
10	Magnesium (mg)	19	15.0
11	Phosphor (mg)	53	43.9
12	Potassium (mg)	383	445
13	Sodium (mg)	7	Da[3]
14	Zinc (mg)	0.64	0.27
15	Copper (mg)	0.11	0.11
16	Vitamin A RE[1] (mcg)	7	Da[3]
17	Vitamin A REA[2] (mcg)	3	Da[3]
18	Vitamin D (mcg)	0	0.00
19	Vitamin E (mg)	0.37	0.01
20	Thiamine (mg)	0.07	0.11
21	Riboflavin (mg)	0.02	Da[3]
22	Niacin (mg)	0.8	Da[3]
23	Vitamin B6 (mg)	0.23	0.17
24	Folate Equivalent (mcg)	27	16.9
25	Vitamin B12 (mcg)	0	0.00
26	Vitamin C (mg)	13	35.4
27	Cholesterol (mg)	0	0.00
28	Saturated fatty acid (g)	0.10	0.01
29	Monounsaturated fatty acid (g)	0.03	Da[3]
30	Polyunsaturated fatty acid (g)	0.16	0.02

[1] Retinol Equivalent. [2] Retinol-equivalent activity. [3] Da: dashes (symbol). Source: organized by the authors from the database of the University of São Paulo (USP, 2023).

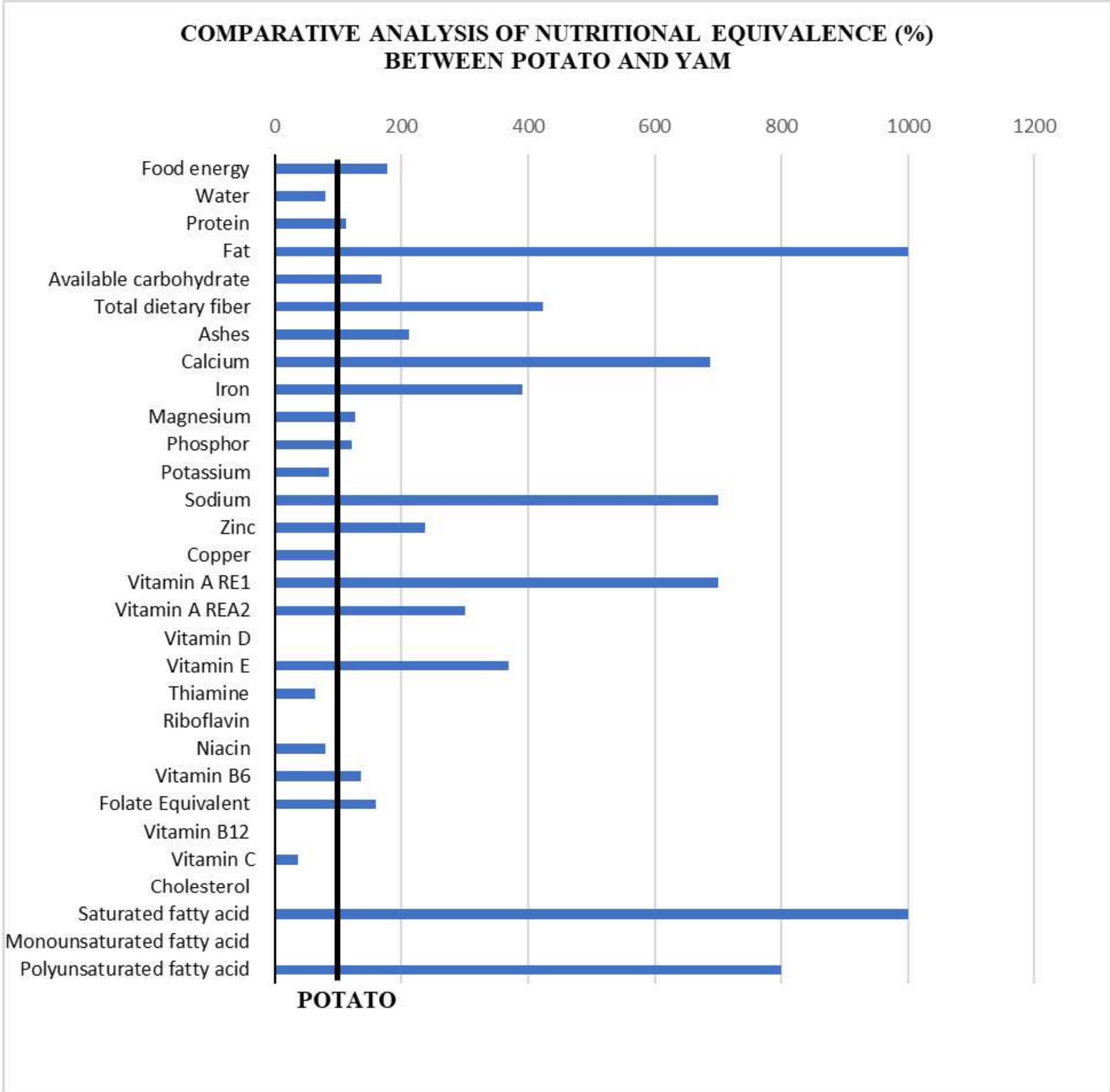


Fig. 21. Comparative analysis of nutritional equivalence between inhame and imported potato. Horizontal blue bars: inhame. Source: organized by the authors from the database of the University of São Paulo (USP, 2023) and the United States Department of Agriculture (USDA, 2024).

The comparative analysis of the nutritional composition between inhame and potato imported by Angola shows that yam has almost twice the dietary energy (126 kcal), with a protein equivalence of 2.3 g. Inhame has higher levels of carbohydrates (25.5 g) and fat (0.4 g). Inhame has higher levels of calcium (26 mg), iron (1.6 mg), magnesium (19 mg), phosphorus (53 mg), sodium (7 mg), and zinc (0.64 mg); lower potassium content (383 mg) and copper equivalent (0.11 mg). Inhame has higher levels of vitamin A (7 mcg), E (0.37 mg), B6 (0.26 mg), and folate equivalent (27 mcg). It also stands out with higher levels of saturated fatty acids (0.10 g), monounsaturated fatty acids (0.03 g), and polyunsaturated fatty acids (0.16 g).

Inhame is superior to potatoes in terms of starch, protein, B vitamins, and sugar content, in addition to being more digestible and requiring less cooking time (Filgueira, 1981). Inhame cultivation does not involve high costs for seeds, pesticides, fertilizers, and labor, typically required in potato cultivation, due to its high rusticity in high temperatures and humidity (Cheng *et al*., 1986).

It is worth noting that Angola imported 6,597 tons of potatoes in 2022 at an estimated cost of USD 5,802,000.00 (FAO, 2024). Considering the nutritional quality of inhame, the use of imported potatoes in the Angolan diet could be replaced by the local production of inhame and other underutilized tubers.

3.7 Assipi (Taro)

Figure 22 presents the infographic of the research on the underutilized assipi cultivar in Angola and the potatoes imported by Angola.

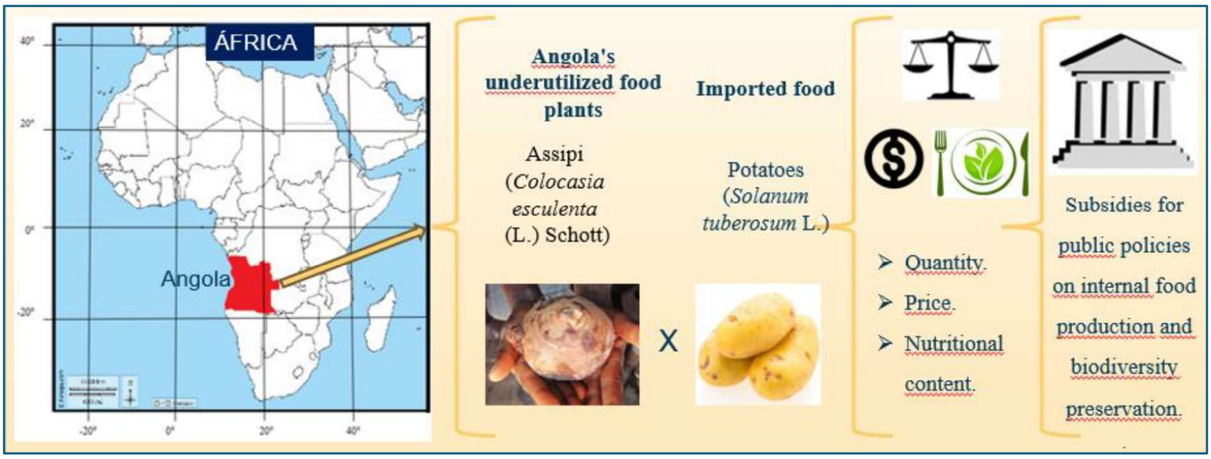
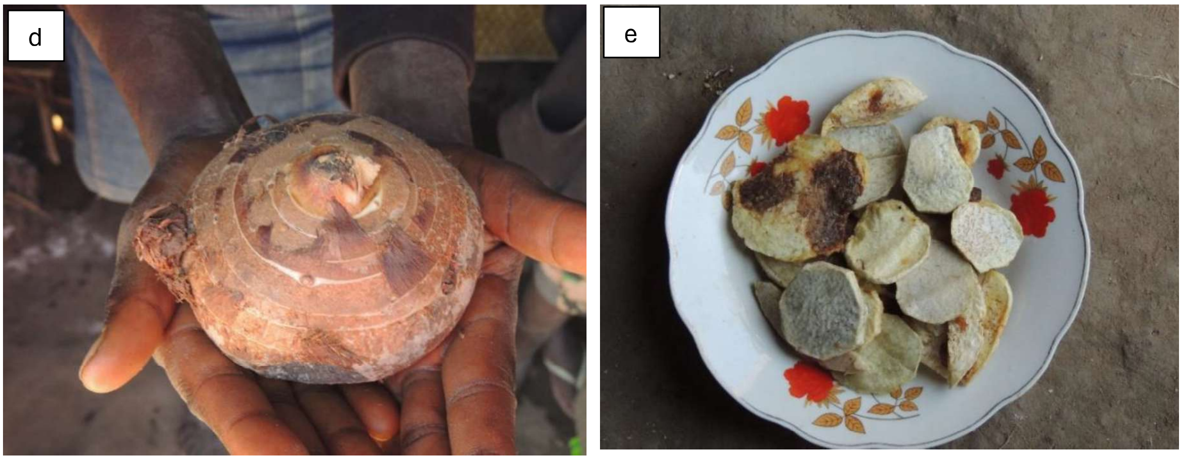


Fig. 22. Infographic summary of the research on assipi and potato.

Assipi is a root crop that remains vastly underutilized despite its abundance and accessibility. Compared to other roots, such as potatoes, carrots, and cassava, assipi stands out as an abundant and low-cost option (Ferdaus *et al*., 2023). They are cultivated primarily for their edible shoots or rhizomes. However, other parts, such as stems, leaves, and inflorescences, are used for human consumption (Figures 23a-23e). They are classified as neglected food crops grown primarily for subsistence use (Muthoni & Shimelis, 2023). Assipi leaves can serve as a valuable source of micronutrients essential for meeting micronutrient needs in vulnerable communities (Beato *et al*., 2024). The FAO suggested the cultivation of neglected plants, such as assipi, as an alternative to increasing the food base of developing countries due to their rustic characteristics and nutritional value, reinforcing their food security (FAO, 2019).

Assipi leaves. Buco Zau, Cabinda, Angola.



Assipi. Andulo, Bié, Angola. Fried assipi chips.

Fig. 23. Assipi plant, leaves, root, and chips.

Assipi is an edible plant native to tropical Asia but adapted to different climates and soils, including those of Angola. It is mentioned in several provinces of the country, such as Bié Cabinda, Cuando Cubango, Cuanza Norte, Cuanza Sul, Huambo, Malanje, Uíge, and Zaire, as shown in Figure 24 (Paixão *et al*., 2021; Schüler *et al*., 2022; Antonio & Buot, 2023)

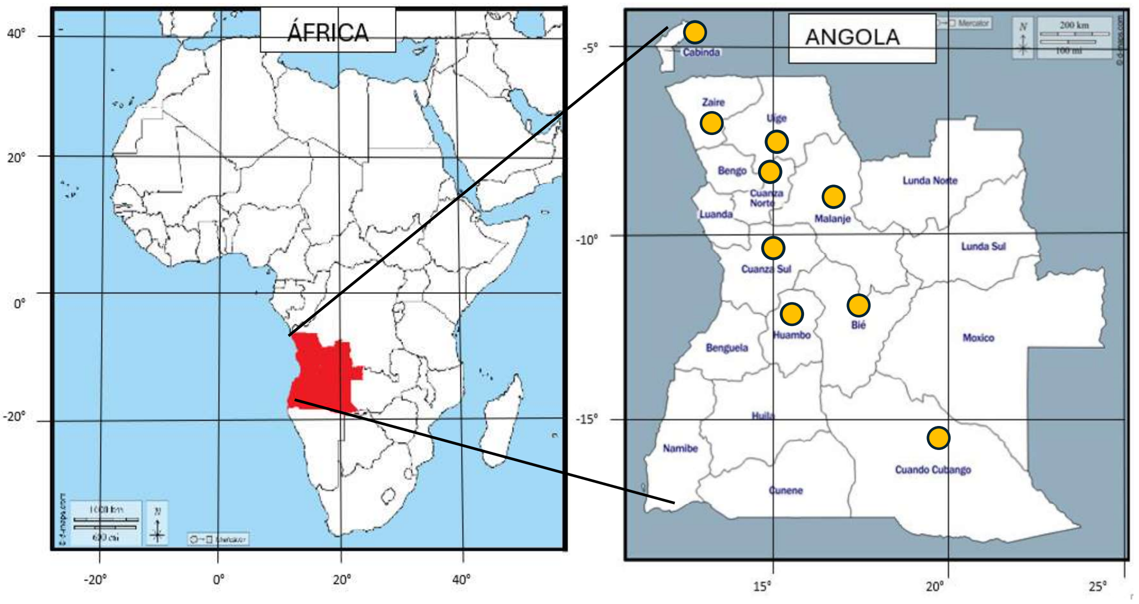


Fig. 24. The location of the 18 provinces of Angola, highlighting the provinces with the occurrence of assipi (orange circles). Source: prepared by the authors at www.d-maps.com.

Table 6 presents the nutritional composition of assipi and potatoes imported by Angola. Figure 25 presents the comparative analysis of the nutritional composition between assipi and potato.

Table 6. Nutritional composition of assipi and potato imported by Angola.

ITEM	DESCRIPTION	ASSIPI VALUE/100g	POTATO VALUE/100g
1	Food energy (kcal)	127	71
2	Water (g)	65.9	80.5
3	Protein (g)	2.7	2.04
4	Fat (g)	0.8	0.04
5	Available carbohydrate (g)	25.2	15.2
6	Total dietary fiber (g)	4.1	1.32
7	Ashes (g)	1.3	0.85
8	Calcium (mg)	26	3.78
9	Iron (mg)	1.6	0.41
10	Magnesium (mg)	30	15.0
11	Phosphor (mg)	88	43.9
12	Potassium (mg)	350	445
13	Sodium (mg)	17	Da[3]
14	Zinc (mg)	0.61	0.27
15	Copper (mg)	0.84	0.11
16	Vitamin A RE[1] (mcg)	4	Da[3]
17	Vitamin A REA[2] (mcg)	2	Da[3]

18	Vitamin D (mcg)	0	0.00
19	Vitamin E (mg)	0.33	0.01
20	Thiamine (mg)	0.10	0.11
21	Riboflavin (mg)	0.03	Da[3]
22	Niacin (mg)	0.8	Da[3]
23	Vitamin B6 (mg)	0.24	0.17
24	Folate Equivalent (mcg)	22	16.9
25	Vitamin B12 (mcg)	0	0.00
26	Vitamin C (mg)	8	35.4
27	Cholesterol (mg)	0	0.00
28	Saturated fatty acid (g)	0.19	0.01
29	Monounsaturated fatty acid (g)	0.10	Da[3]
30	Polyunsaturated fatty acid (g)	0.34	0.02

[1] Retinol Equivalent. [2] Retinol-equivalent activity. [3] Da: dashes (symbol). Source: organized by the authors from the database of the University of São Paulo (USP, 2023).

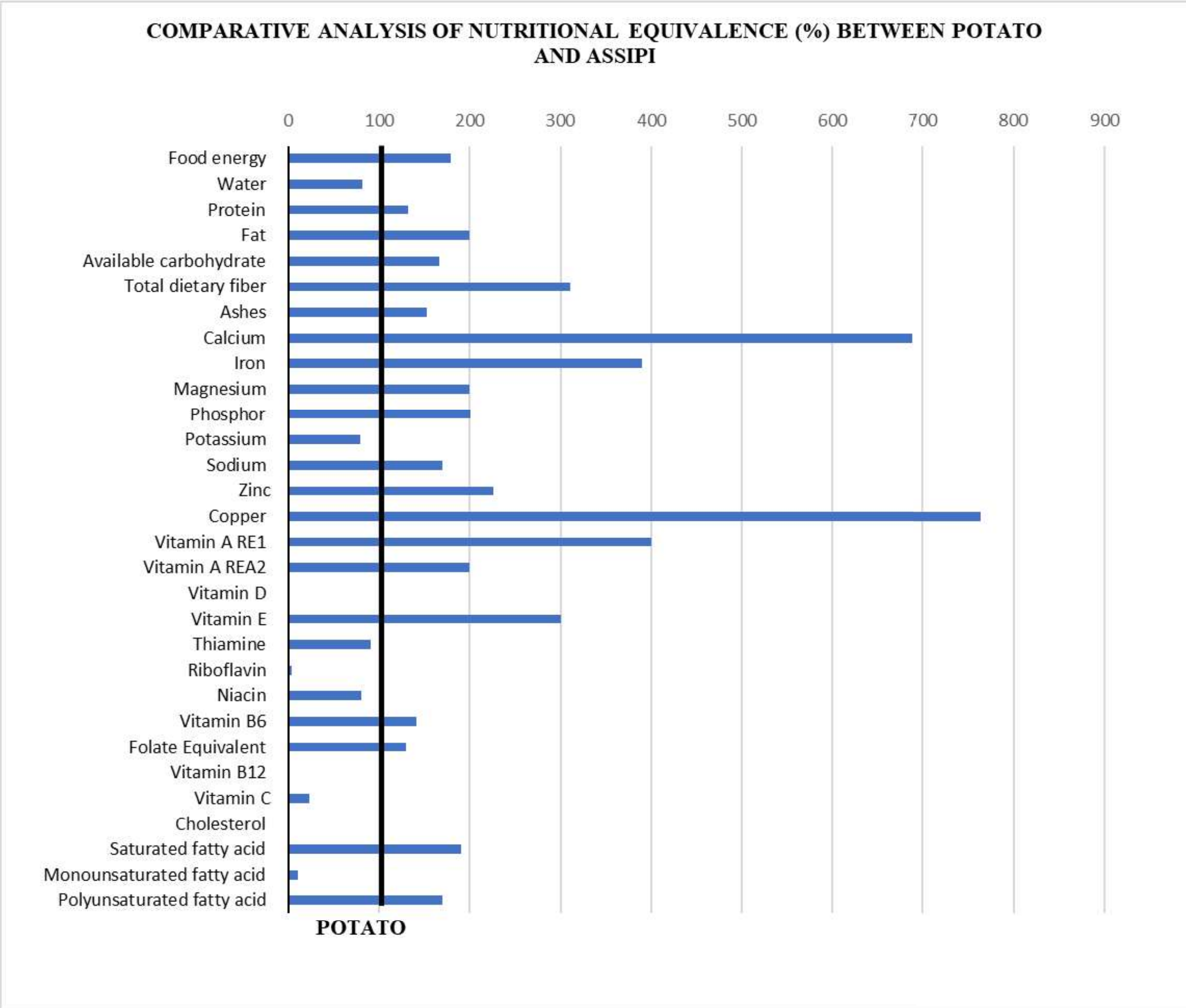


Fig. 25. Comparative analysis of nutritional equivalence between assipi and imported potato. Horizontal blue bars: assipi. Source: organized by the authors from the database of the University of São Paulo (USP, 2023) and the United States Department of Agriculture (USDA, 2024).

The comparative analysis of the nutritional composition between assipi and the potato imported by Angola shows that assipi has almost twice the food energy (127 kcal), with an equivalence in protein content (2.7 g). It has higher available carbohydrates (25.2 g) and fat (0.8 g). In minerals, assipi has higher levels of calcium (26 mg), iron (1.6 mg), magnesium (30 mg), phosphorus (88 mg), sodium (17 mg), zinc (0.61 mg), and copper (0.84 mg); lower potassium content (350 mg). Assipi has higher levels of vitamin A (4 mcg), E (0.33 mg), B6 (0.24 mg), and folate equivalent (22 mcg). It also stands out for its higher levels of saturated fatty acids (0.19 g), monounsaturated fatty acids (0.10 g), and polyunsaturated fatty acids (0.34 g).

The comparative analysis shows that assipi is rich in carbohydrates, dietary fiber, vitamins, and minerals, presenting higher levels than potatoes, making it a valuable nutritional source. Encouraging the commercial use of assipi for flour production and as a raw material for food industries is extremely important (Paixão *et al*., 2021). The need for further research is highlighted to explore the various applications of assipi to improve processing and conservation conditions in agro-industries (Ferdaus *et al*., 2023).

It is worth noting that Angola imported 6,597 tons of potatoes in 2022 at an estimated cost of USD 5,802,000.00 (FAO, 2024). In this context, and considering the nutritional quality of assipi, the use of imported potatoes in the Angolan diet could be replaced by local production of assipi and other underutilized plants.

3.8 Fumbua (wild spinach)

Figure 30 presents the infographic of the research on the fumbua cultivar, which is underutilized in Angola, and the spinach imported by Angola.

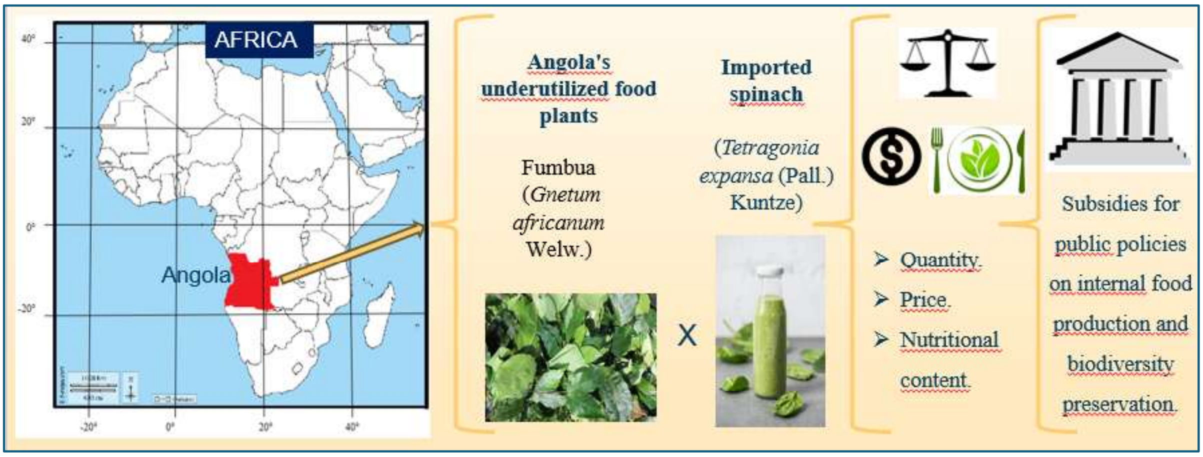


Fig. 30. Infographic summary of the research on fumbua and spinach.

Fumbua is the most important agroforestry plant found in the African rainforest ecosystem. It is classified as a climber because it produces vines that can wrap around the stake in a clockwise direction. It is an indigenous African crop grown primarily for its leaves (Etuk & Edem, 2014). Fumbua are leaves of a perennial vine (Figure 31a), which are collected from the forest ecosystem, processed (Figures 31b and 31c), sold, and consumed as a traditional African dish in Central and West Africa, the United States of America, and Europe (Fuashi *et al*., 2010). Leafy vegetables such as fumbua and other edible greens are a crucial component of traditional diets in sub-Saharan Africa, used in soups, sauces, and stews (Vandebroek & Voeks, 2018).

Tata *et al*. (2019) found that fumbua consumption explains the higher adjusted hemoglobin levels in women from forest communities, showing that forests make essential contributions to diet quality and nutrition and that maintaining forests and ecosystem services is necessary to improve the nutrition and health of forest communities. Deforestation and increased demand for fumbua leaves have resulted in a decline in the wild population of this valuable agroforestry plant found only in Africa (Doungous *et al*., 2019).

Fumbua leaves.

Fumbua leaves being tied into bundles to be cut.

Fumbua leaves being cut.

Fig. 31. Fumbua leaves and preparation.

In Angola, fumbua is found mainly in humid forest regions at altitudes between 500 and 1,500 meters (Mawunu *et al*., 2018). The provinces with occurrences of the species are Cabinda, Uíge, and Zaire, as shown in Figure 32 (Mawunu *et al*., 2016; Schüler *et al*., 2022).

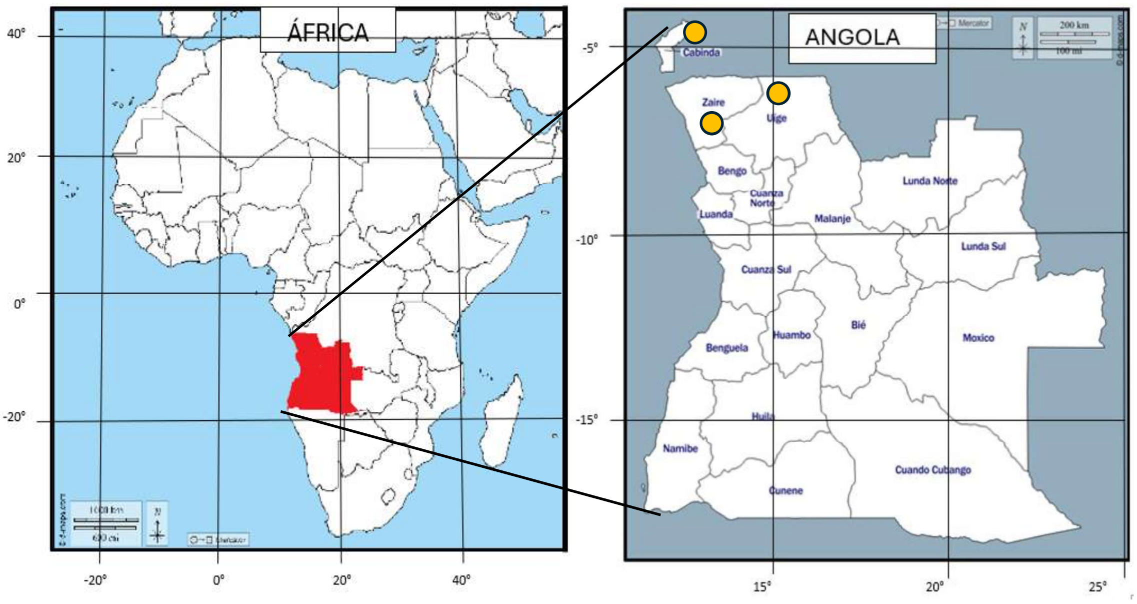


Fig. 32. The location of the 18 provinces of Angola, highlighting the provinces with the occurrence of fumbua (orange circles). Source: prepared by the authors at www.d-maps.com.

Table 8 presents the nutritional composition of fumbua and, for comparative purposes, spinach imported by Angola. Figure 33 presents the comparative analysis of the nutritional composition between fumbua and spinach.

Table 8. Nutritional composition of fumbua and spinach imported by Angola.

ITEM	DESCRIPTION	FUMBUA VALUE/100g	SPINACH VALUE/100g
1	Food energy (kcal)	45	23
2	Water (g)	85.0	92.0
3	Protein (g)	5.1	2.24
4	Fat (g)	0.7	0.35
5	Available carbohydrate (g)	2.5	1.34
6	Total dietary fiber (g)	4.3	2.83
7	Ashes (g)	26	1.29
8	Calcium (mg)	233	91.2
9	Iron (mg)	4.3	0.48
10	Magnesium (mg)	83	72
11	Phosphor (mg)	60	34.3

12	Potassium (mg)	452	452
13	Sodium (mg)	27	23
14	Zinc (mg)	0.70	0.31
15	Copper (mg)	0.22	0.10
16	Vitamin A RE[1] (mcg)	150	287
17	Vitamin A REA[2] (mcg)	75	143
18	Vitamin D (mcg)	0	0,00
19	Vitamin E (mg)	0.42	1.83
20	Thiamine (mg)	0.07	0.13
21	Riboflavin (mg)	0.16	0.28
22	Niacin (mg)	0.6	Da[3]
23	Vitamin B6 (mg)	0.26	0.08
24	Folate Equivalent (mcg)	62	181
25	Vitamin B12 (mcg)	0	0.00
26	Vitamin C (mg)	44	3.26
27	Cholesterol (mg)	0	0
28	Saturated fatty acid (g)	0.18	0.06
29	Monounsaturated fatty acid (g)	0.05	0.01
30	Polyunsaturated fatty acid (g)	0.30	0.15

[1] Retinol Equivalent. [2] Retinol-equivalent activity. [3] Da: dashes (symbol). Source: organized by the authors from the database of the University of São Paulo (USP, 2023).

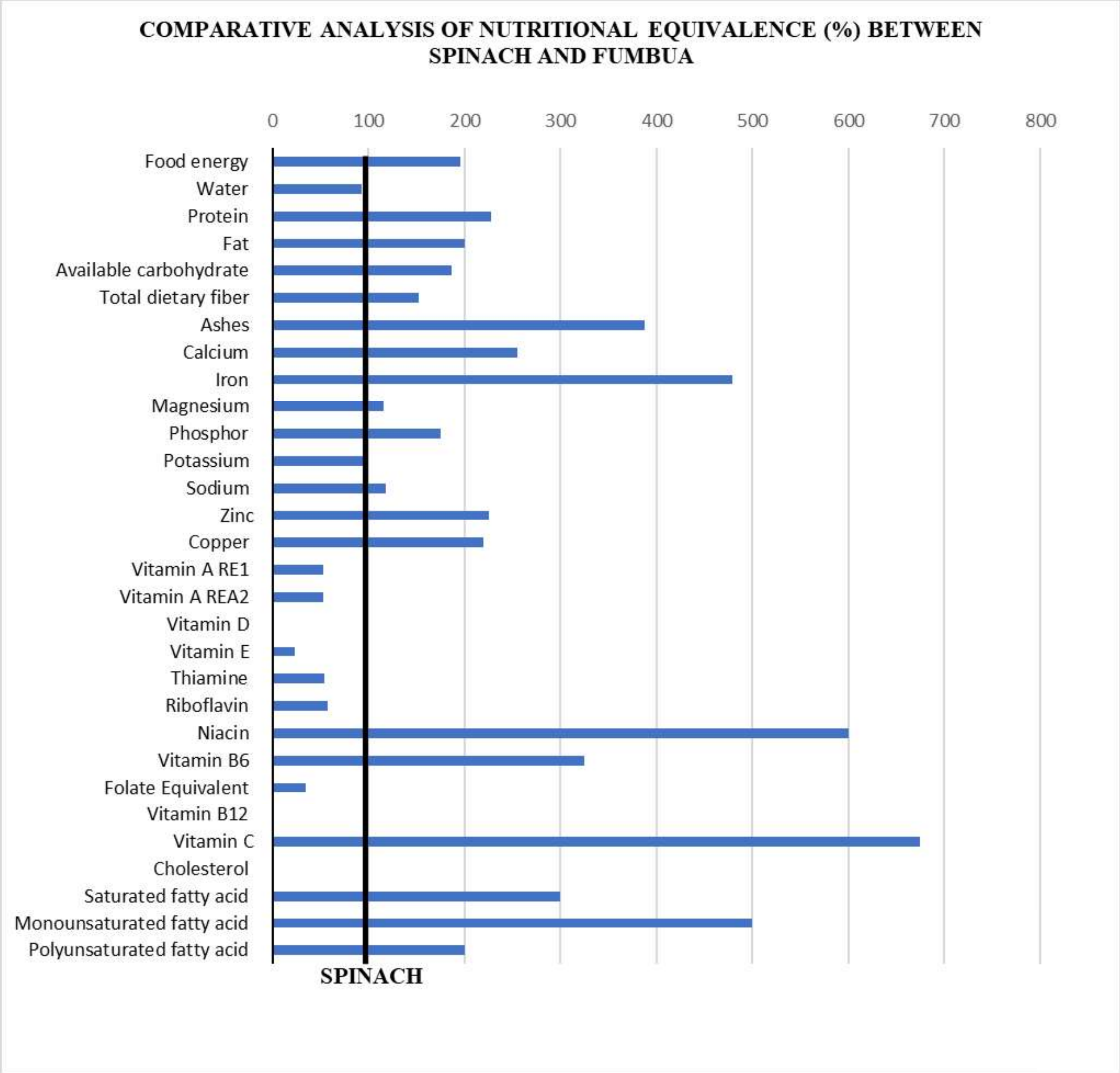


Fig. 33. Comparative analysis of the nutritional composition between fumbua and spinach. Source: organized by the authors from the database of the University of São Paulo (USP, 2023).

The comparative analysis of the nutritional composition between fumbua and spinach imported by Angola shows that fumbua is twice as high in food energy content (45 kcal), protein (5.1 g), carbohydrate (2.5 g), and fat (0. 7 g). Fumbua has higher levels of calcium (233 mg), iron (4.3 mg), magnesium (83 mg), phosphorus (60 mg), sodium (27 mg), zinc (0.70 mg), and copper (0.22 mg); and potassium equivalence (452 mg). Fumbua has higher levels of vitamin C (44 mg), B6 (0.26 mg), and niacin (0.6 mg). It has higher levels of saturated (0.18 g), monounsaturated (0.05 g), and polyunsaturated (0.30 g) fatty acids.

Etuk and Edem (2014), in Nigeria, demonstrated the positive effect of intercropping leguminous tree species on the nutritional and productive performance of fumbua to obtain high yields and improve soil fertility. Concerning the production chain, Fuashi *et al*. (2010) recommended (i) research and development of appropriate technologies for processing fumbua, (ii) development of sustainable fumbua harvesting, as the current harvest is destructive to the ecosystem, and (iii) public policies to encourage the cultivation/domestication of fumbua, in order to avoid the degradation of natural capital and the maintenance of ecosystem services.

It is worth noting that Angola imported 9,707 tons of fresh, dehydrated, frozen, or preserved vegetables in 2022 at an estimated cost of USD 111,576,000.00 (FAO, 2024). Considering the nutritional quality of the fumbua plants, imported fresh, dehydrated, frozen, or preserved vegetables in the Angolan diet could be replaced by local production of fumbua plants and other local underutilized plants.

3.9 Uce (Roselle)

Figure 30 presents the infographic of the research on the uce cultivar, which is underutilized in Angola, and the spinach imported by Angola.

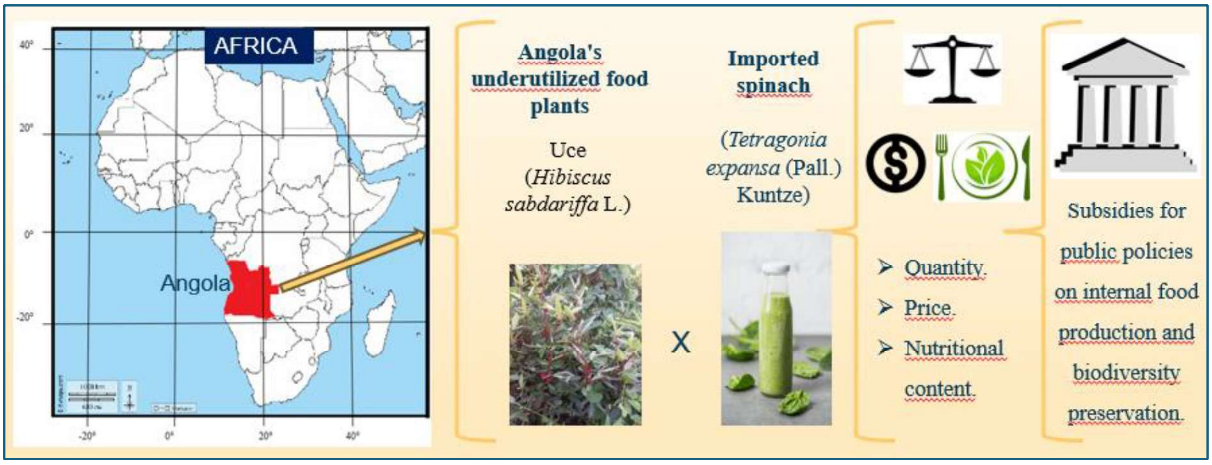
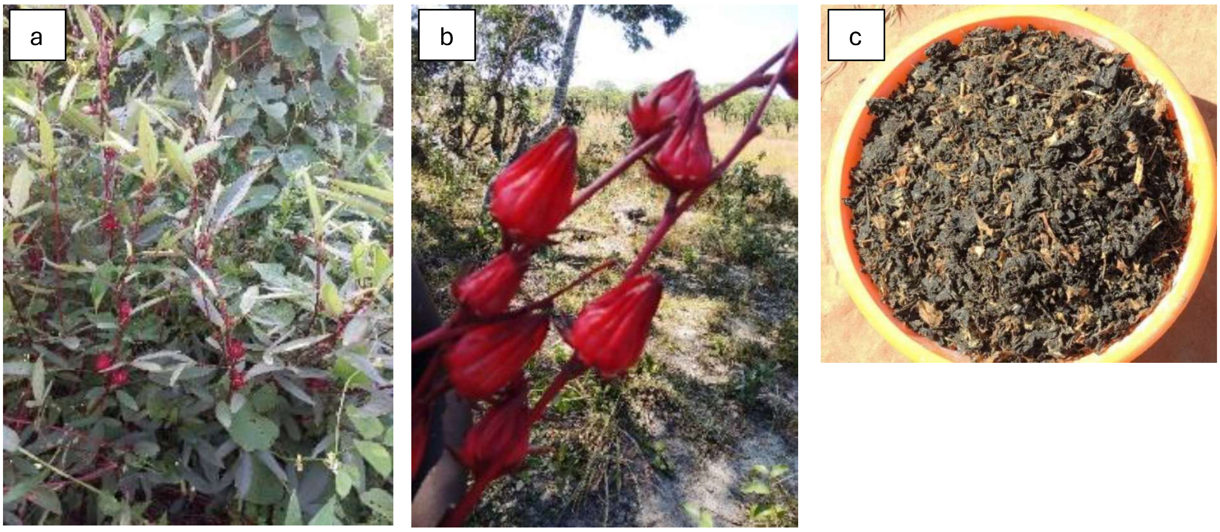


Fig. 30. Infographic summary of the research on uce and spinach.

Uce is a large annual herb, up to 4.5 m tall; the stem is hairy to slightly pubescent, sometimes slightly spiny, green, or reddish (Figures 34a and 34b). It is common in the savannah region of West and Central Africa. Apparently, wild uce plants have been collected in Ghana, Niger, Nigeria, and Angola (Vasavi *et al*., 2019). Uce is a multipurpose plant with great economic importance. It is recognized for its nutritional and therapeutic value (Riaz *et al*., 2021). The calyx and corolla of the uce are used to prepare drinks. The tender leaves and stems are used as fresh cooked vegetables or dehydrated for conservation (Figure 34c) *(Singh et al*., 2006).

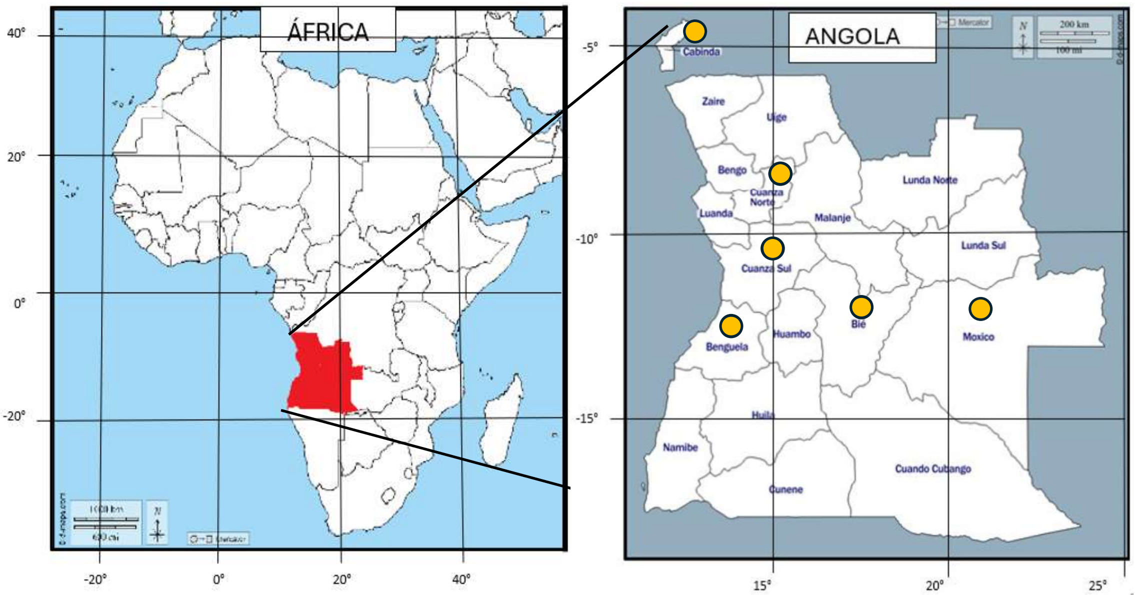
Chweya (1999) documented the value of uce in maximizing the productivity of small areas and stabilizing ecosystems through using niches in agrosystems. People's knowledge and perceptions about the environment are essential elements of cultural identity and biodiversity conservation associated with uce culture (Singh *et al*., 2006).



Uce. | Uce. Lucusse, Moxico, Angola. | Dehydrated uce in Chitembo, Bié, Angola.

Fig. 34 Uce plant, fruits, and dehydrated.

Uce is found in Angola, in the provinces of Benguela, Bié, Cabinda, Cuanza Norte, Cuanza Sul, and Moxico, as shown in Figure 35 (Magos Brehm *et al*., 2022; Schüler *et al*., 2022).



of uce (orange circles). Source: prepared by the authors at www.d-maps.com.

Table 9 presents the nutritional composition of uce and, for comparative purposes, spinach imported by Angola. Figure 36 presents a comparative analysis of the nutritional composition of uce and spinach.

Table 9. Nutritional composition of uce and spinach imported by Angola.

ITEM	DESCRIPTION	UCE VALUE/100g	SPINACH VALUE/100g
1	Food energy (kcal)	40	23
2	Water (g)	87.1	92.0
3	Protein (g)	2.7	2.24
4	Fat (g)	0.3	0.35
5	Available carbohydrate (g)	4.5	1.34
6	Total dietary fiber (g)	4.2	2.83
7	Ashes (g)	1.2	1.29
8	Calcium (mg)	212	91.2
9	Iron (mg)	5.0	0.48
10	Magnesium (mg)	79	72
11	Phosphor (mg)	65	34.3
12	Potassium (mg)	211	452
13	Sodium (mg)	13	23
14	Zinc (mg)	0.66	0.31
15	Copper (mg)	0.20	0.10
16	Vitamin A RE[1] (mcg)	435	287
17	Vitamin A REA[2] (mcg)	218	143
18	Vitamin D (mcg)	0	0.00
19	Vitamin E (mg)	0.50	1.83
20	Thiamine (mg)	0.17	0.13
21	Riboflavin (mg)	0.45	0.28
22	Niacin (mg)	0.6	Da[3]
23	Vitamin B6 (mg)	0.32	0.08
24	Folate Equivalent (mcg)	82	181
25	Vitamin B12 (mcg)	0	0.00
26	Vitamin C (mg)	33	3.26
27	Cholesterol (mg)	0	0
28	Saturated fatty acid (g)	0.06	0.06
29	Monounsaturated fatty acid (g)	0.01	0.01
30	Polyunsaturated fatty acid (g)	0.14	0.15

[1] Retinol Equivalent. [2] Retinol-equivalent activity. [3] Da: dashes (symbol). Source: organized by the authors from the database of the University of São Paulo (USP, 2023).

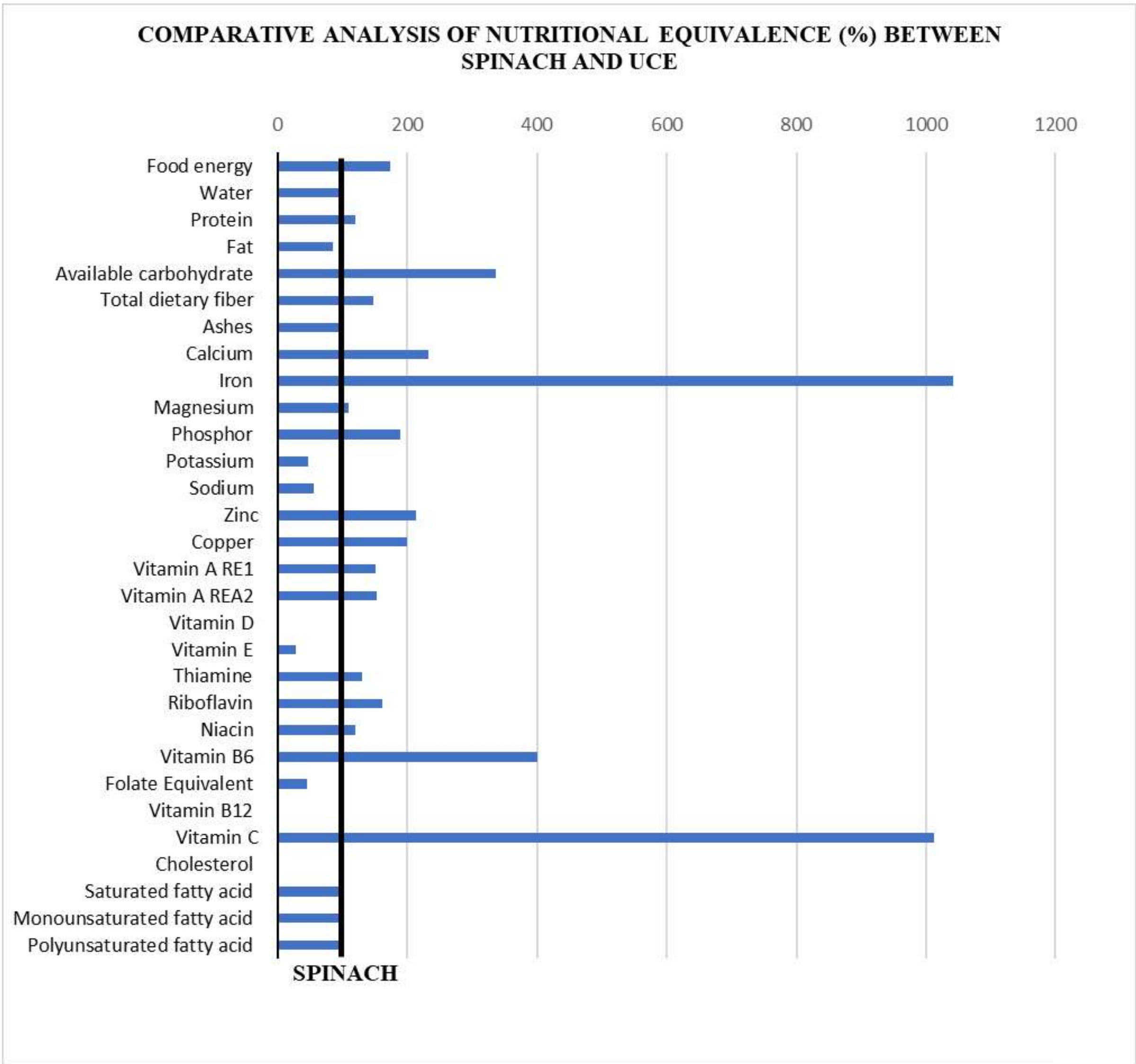


Fig. 36. Comparative analysis of the nutritional composition between uce and spinach. Source: organized by the authors from the database of the University of São Paulo (USP, 2023).

The comparative analysis of the nutritional composition between uce and spinach imported by Angola demonstrates that uce is superior in food energy (40 kcal) and protein (2.7 g) and has three times more available carbohydrate content (4.5 g). Fat content is equivalent (0.3 g). Uce has higher levels of calcium (212 mg), iron (5.0 mg), magnesium (79 mg), phosphorus (65 mg), zinc (0.66 mg), and copper (0.20 mg). It presents higher levels of vitamin A (435 mcg), B6 (0.32 mg), C (33 mg), thiamine (0.17 mg), riboflavin (0.45 mg), and niacin (0.6 mg). There is equivalence in saturated (0.06 g), monounsaturated (0.01 g), and polyunsaturated (0.14 g) fatty acids.

Uce is rich in beta-carotene, vitamin C, proteins, and total sugar, has several medically important compounds called photochemicals, and is known for its nutritional and medicinal properties (Singh *et al.,* 2017). Uce is attractive for nutritional purposes and bioactive and coloring applications in the food, pharmaceutical, and cosmetic industries (Jabeur *et al*., 2017).

It is worth noting that Angola imported 9,707 tons of fresh, dehydrated, frozen, or preserved vegetables in 2022 at an estimated cost of USD 111,576,000.00 (FAO, 2024). Considering the nutritional quality of the uce plant, the use of imported fresh, dehydrated, frozen, or preserved vegetables in the Angolan diet could be replaced by local production of uce plants and other local underutilized plants.

3.10 Other underutilized or neglected food plants in Angola

In addition to the nine underutilized food plants that were studied in this book, we list other underutilized food plants that deserve studies and public policies to be implemented for their use in combating hunger and malnutrition in Angola, as mentioned in Schüler *et al*. (2022).

3.10.1 Cambiambia (*Citrullus lanatus* (Thunb.) Matsum & Nakai). Cucurbitaceae family

Cambiambia, or wild watermelon (Fig. 37a,b), has more than 1,200 varieties and is native to Africa (Schüler *et al*., 2022). An annual climber plant, generally prostrate, cultivated since ancient times. The fruit has a voluminous mesocarp in wild forms and numerous seeds. The improvement gave rise to cultivated watermelon. The seeds contain high percentages of an edible oil rich in vitamin E. In Angola, in the plateau area, the oil is extracted either in factories or at an artisanal level (Ferrão & Liberato, 2015).

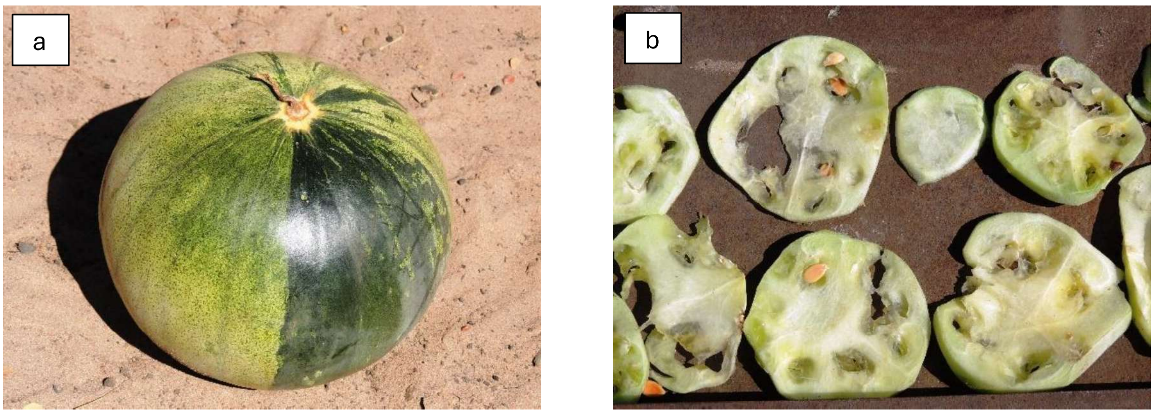


Fig. 37. Cambiambia. Commune of Longa, municipality of Cuíto Cuanavale, Cuando Cubango, Angola. 37a: Overview of cambiambia. 37b: pieces of cambiambia. Source: Schüler *et al.* (2022).

3.10.2 Feijão-macoba (*Voandzeia subterranea* Thouars). Fabaceae family

The macoba bean or bambara bean is a traditional legume. It is identified as an underutilized food plant in Angola (Fig. 38a,b,c) despite its high nutritional value (Soumare *et al*., 2022). It grows well in adverse climatic conditions, ensuring regular production (Okonkwo & Opara, 2010). Macoba bean seeds develop within the soil and can be cultivated in arid and semi-arid regions of the world, which are the most affected by malnutrition (Ogbuagu *et al*., 2023).

Fig. 38. Macoba beans. Cacongo, Cabinda, Angola. 38a: peeled macoba beans. 38b: macoba bean grains. 38c: macoba beans cooking.

3.10.3 Gajaja (*Spondias mombin* L.). Anacardiaceae family

Gajaja is a small fruit that grows abundantly in tropical regions. The fruits have a thin layer of pulp extracted for commercial use. Despite being obtained through an extractive production system, gajaja has aroused commercial interest due to its flavor, aroma, and nutritional quality (Fig. 39a.b.c) (Mattietto & Matta, 2011).

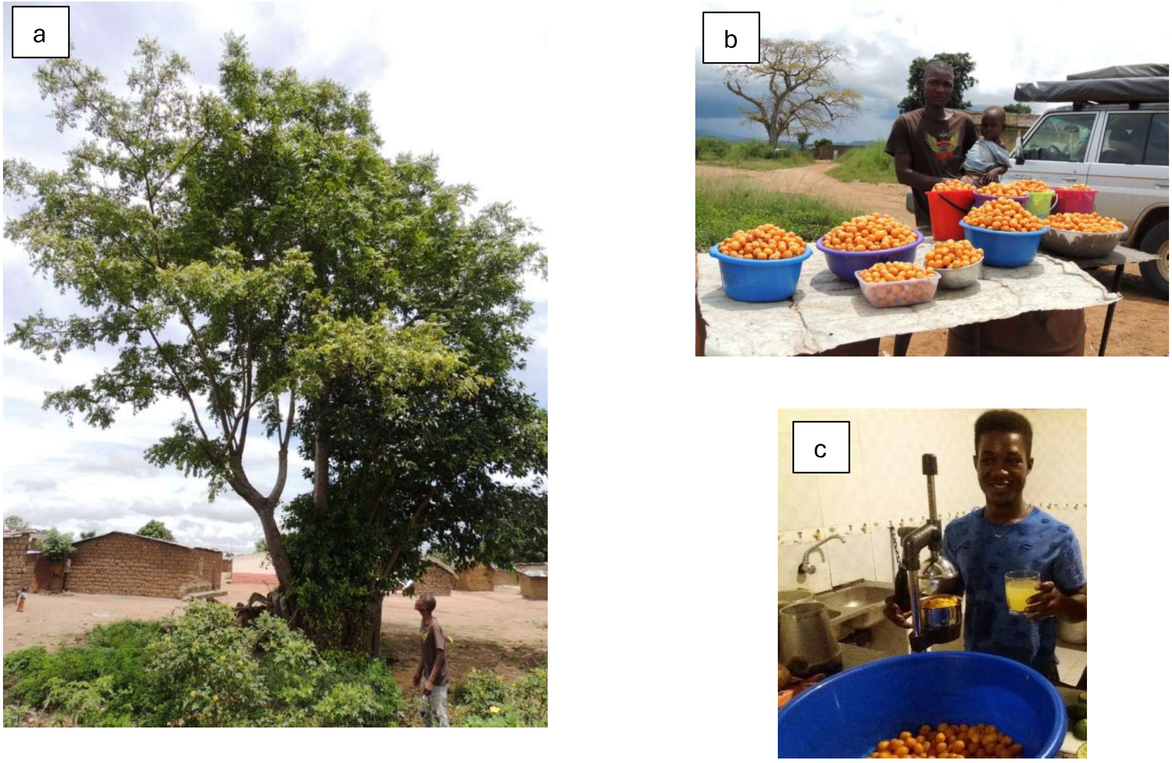


Fig. 39. Gajajas in Golungo Alto, Cuanza Norte, Angola. 39a: gajajeira. 39b: gajaja trade. Munenga, Libolo, Cuanza Sul. 39c: extraction of gajaja juice. Source: Schüler *et al.* (2022).

3.10.4 Gimboa (*Amaranthus viridis* L.). Amaranthaceae family

Gimboa, also known as caruru, originates from the African term Kalalu. In Bantu languages, Jimbwa means bush food (Fig. 40a,b,c). It is a plant that is part of the Angolan diet, with its leaves quickly prepared as a stew combined with other herbs and spices throughout Central and Southern Africa since ancient times (Schüler *et al*., 2022).

Fig. 40. Gimboa in the commune of Neves, municipality of Humpata, province of Huíla, Angola. 40a: harvest. 40b: braising. 40c: braised gimboa (lombí). Sorce: Schüler *et al.* (2022).

3.10.5 Ginguenga (*Aframomum alboviolaceum* (Ridl.) K. Schum.). Zingiberaceae family

Ginguenga is a fruit of the perennial herbaceous plant. Ginguenga produces leafy stems up to three meters high. The fruits are red with juicy white pulp, formed and grouped in branches at the base of the plant, and widely spread throughout Angola and tropical Africa (Ossoko, 2020). Native to open woodlands and savannas of tropical Africa, with a thin, bracteate, and radiating rhizome, sometimes at the soil surface (Fig. 41a,b). The fruit is a bright red berry at maturity (Fig. 41c), with a hard and aromatic pericarp, an edible, pulpy, white, and sweet-sour mesocarp, and black seeds (Ferrão & Liberato, 2015).

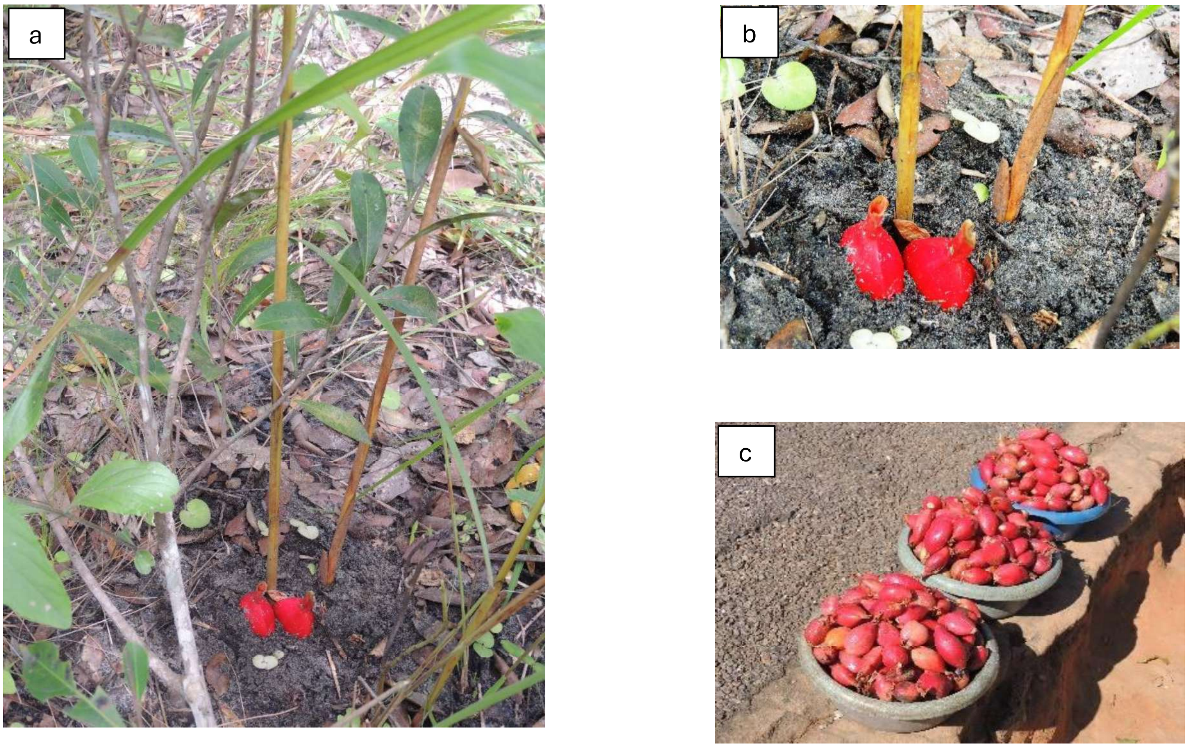


Fig. 41. Ginguenga in the municipality of Camanongue, Moxico, Angola. 41a,b: ginguenga plants. 41c: ginguenga fruits.

3.10.6 Lonhandi or Nonhandi (*Diospyros kirkii* Hiern). Ebenaceae family

Lonhandi (Fig. 42) presents a small tree with dark gray to blackish, very rough bark. Leaves arranged in a spiral, broadly elliptical to nearly round, fleshy, spherical fruit, 3.5 to 4 cm in diameter, yellow to orange when ripe. The fruits are edible. In addition to Angola, it occurs in the Democratic Republic of Congo, Tanzania, Malawi, Mozambique, Zambia, and Zimbabwe (Hyde *et al*., 2024).

Fig. 42. Municipality of Quipungo, province of Huíla, with lonhandi fruits. Source: Schüler *et al.* (2022).

3.10.7 Lupro or Lúpulo (*Eriosema albo-griseum* Baker f.). Fabaceae family

The endemic plant of Angola (Fig. 43a) occurs in the provinces of Bié, Benguela, Huambo, Cuanza Sul, and Huíla (Catarino *et al*., 2019). Lupro root (Fig. 43b,c) is a sweetener in a traditional drink: otchisangua, a vernacular name in Umbundo or vimbucu, a vernacular name in Ganguela. It is also very common among the Nyanekas (Tchamba & Camongua, 2019).

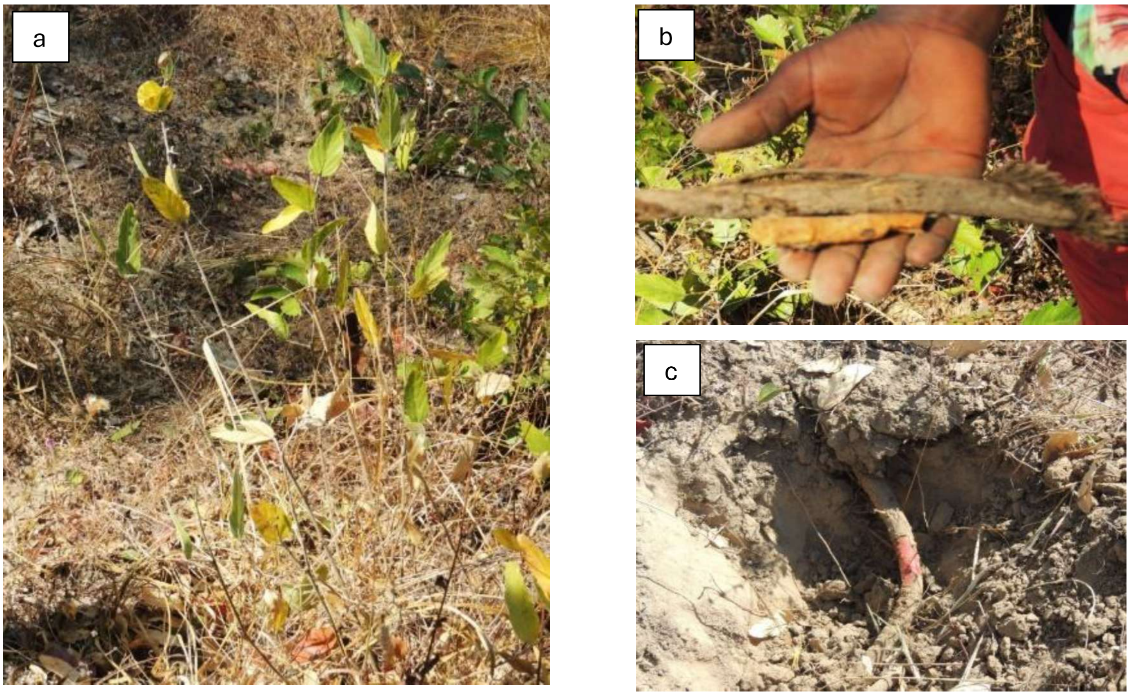


Fig. 43. Lupro in Cuchi, Cuando Cubango, Angola. 43a: lupro plant. 43b,c: lupro roots. Source: Schüler *et al.* (2022).

3.10.8 Marula (*Sclerocarya birrea* (A. Rich.) Hochst). Anacardiaceae family

In Angola, the marula is called Nongongo among the Cuanhama. It is a large tree (Fig. 44a) with a very open crown and can cover a circle with a radius of 15 meters (Schüler *et al*., 2022). In sub-Saharan Africa, marula fruits (Fig. 44b) are widely used to make beer, jam, and juice. The use and trade of fruit are integral elements of local economies and culture. The commercialization of the wood from this tree, the excessive harvesting of its fruits, deforestation, and population growth directly affect the species' survival (Chirwa & Akinnifesi, 2007).

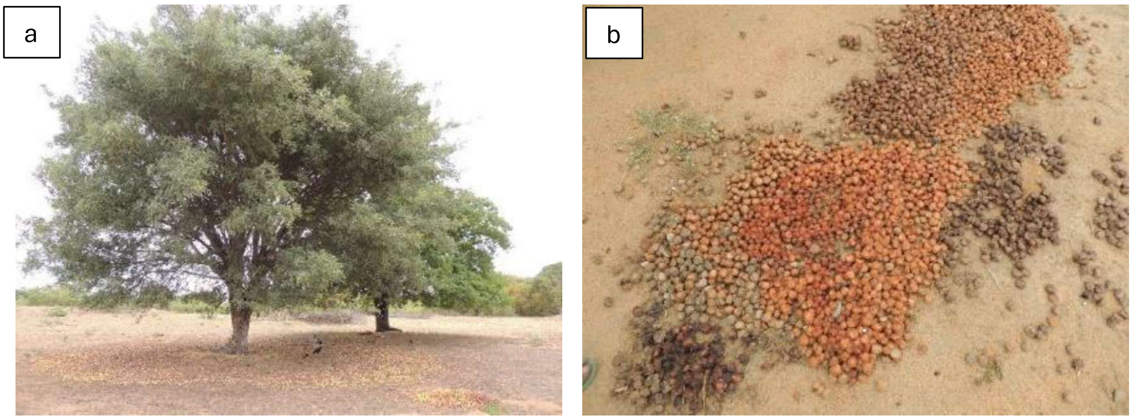


Fig. 44. Marula. Ombadja, Cunene, Angola. 44a: marula tree. 44b. marula fruits fallen on the ground.

3.10.9 Matila (*Lagenaria vulgaris* Ser.). Cucurbitaceae family

Matila, also called calabash (Fig. 45a), is a fresh food, picked, washed, boiled, and consumed (Fig. 45b). African communities use the matila to adjust to the impacts of climate change by producing subsistence crops such as the fresh matila fruit that is boiled and then consumed (Rankoana, 2016).

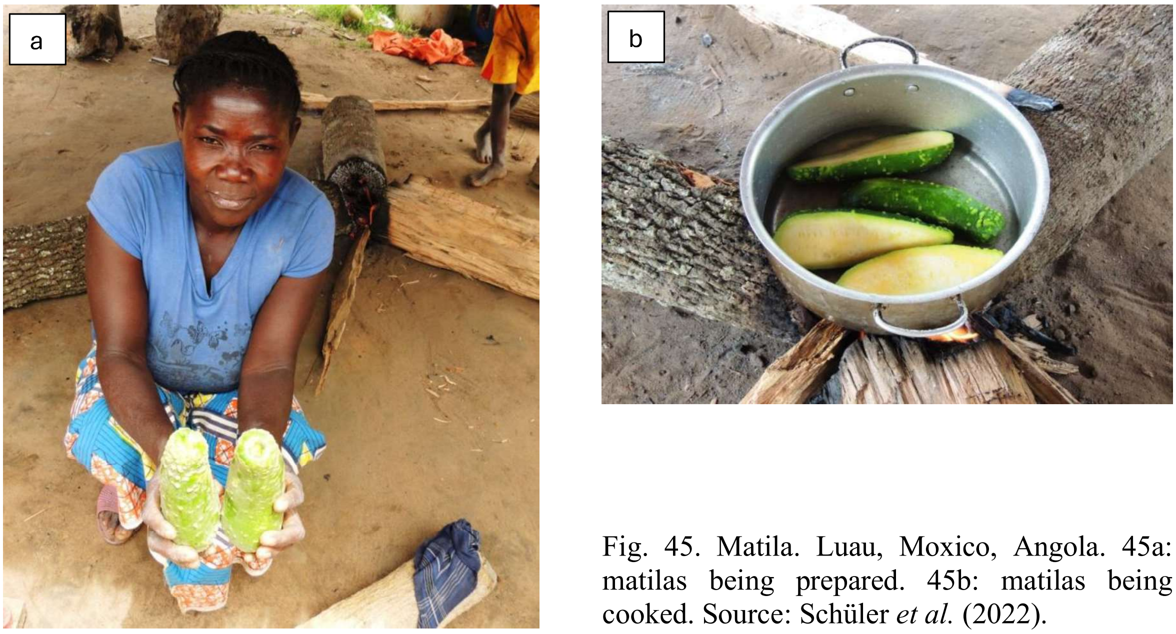


Fig. 45. Matila. Luau, Moxico, Angola. 45a: matilas being prepared. 45b: matilas being cooked. Source: Schüler *et al.* (2022).

3.10.10 Missili (*Pteridium aquilinum* (L.) Kuhn subsp. *centrali-africanum* Hieron). Dennstaedtiaceae family

Missili has large, approximately triangular fronds, 1 to 3 meters long, commonly known as field ferns (Guimarães & Carvalho, 2014). The petiole fibers are edible (Fig. 46a,b). It is a highly adaptable plant that rapidly colonizes disturbed areas, which is why it integrates numerous ecological successions in the stages of degradation, especially after forest fires and vegetation burning (Schüler *et al*., 2022). Extensive stands of this species may indicate disturbance or excessive fire frequency associated with increased human pressure (Goyder *et al*., 2023).

Fig. 46. Missili. Cuimba, Zaire, Angola. 46a: whole missilis. 46b: missilis being cut. Source: Schüler *et al.* (2022).

3.10.11 Palmeira-bordão (*Raphis sp*.). Arecaceae family

Extracting sap from palm trees is the exclusive task of male collectors (Fig. 47a,b,c). The fermented sap produces an alcoholic beverage, wine, or palm milk called maruvo (Luamba & Quissindo, 2021). The beverage ferments up to five days after collection (Schüler & Lobo, 2023). Due to its cultural value, the sap is used as a popular local drink called Raphia, Matombe, or Maruvo wine (Mawunu *et al*., 2022).

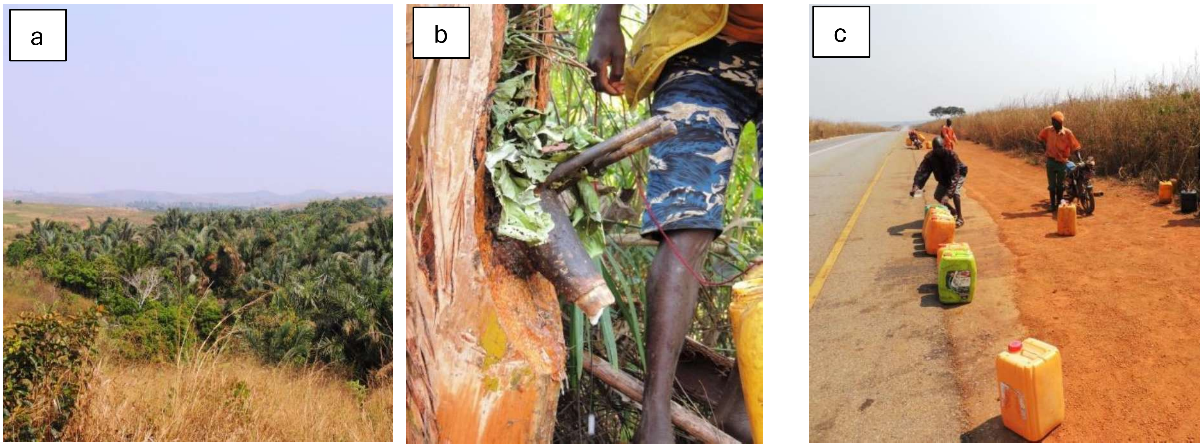


Fig. 47. Palm tree. Ambaca, Cuanza Norte, Angola. 47a: palm tree forest. 47b. detail of the “tap” used to extract sap from the palm tree trunk. 47c: maruvo trade along the highway.

3.10.12 Pervile semente (*Cucurbita sp*.). Cucurbitaceae family

Fresh cucurbit fruits are usually peeled, boiled, and mixed with flour to make a porridge, among countless other preparation methods (Rankoana, 2016) (Rankoana, 2016). In Angola, the seeds are sun-dried, shelled, crushed in a mortar, boiled, and served (Fig. 48a,b,c) with some accompaniment (Schüler *et al*., 2022).

Fig. 48. Pervile. Lucala, Cuanza Note, Angola. Fig. 48a: pervile in the pestle. Fig. 48b: preparation of pervile moamba in the mortar. Fig. 48c: pervile moamba. Source: Schüler *et al*. (2022).

3.10.13 Titende (*Citrullus colocynthis* (L.) Schrad.). Cucurbitaceae family

The titende, called bitter cucumber, is a prostrate, rhizomatous plant originating in regions with sandy soils in Africa, with fleshy, hirsute, ovate, pinnate, lobed, yellowish or orange steam, solitary corolla flowers, globular, and yellowish fruit. The pulp is a violent purgative and, in certain regions, is considered toxic. The branches and leaves are edible (Fig. 49a,b). Oil can be extracted from the seeds (Ferrão & Liberato, 2015).

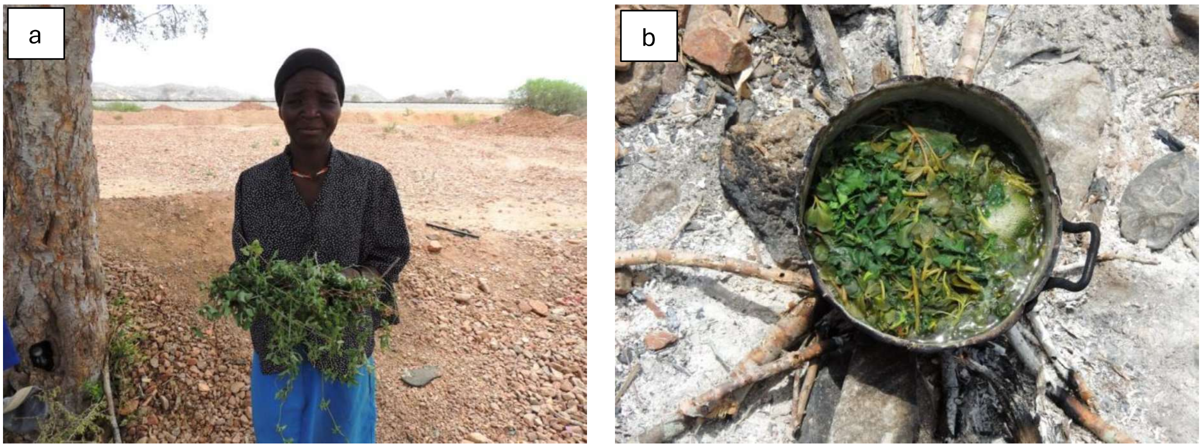


Fig. 49. Titende branch. Namibe Province, Angola. Fig. 49a: freshly harvested titende branch. Fig. 49b: braised titende branch. Source: Schüler *et al.* (2022).

3.10.14 Tortulho

Tortulho is the common name for edible mushrooms in Angola. Mushrooms appear during the rainy season when the spores germinate and grow spontaneously and rapidly. In Angola, several edible species and genera are collected and consumed locally, with the surplus sold on the roadsides (Fig. 50a,b).

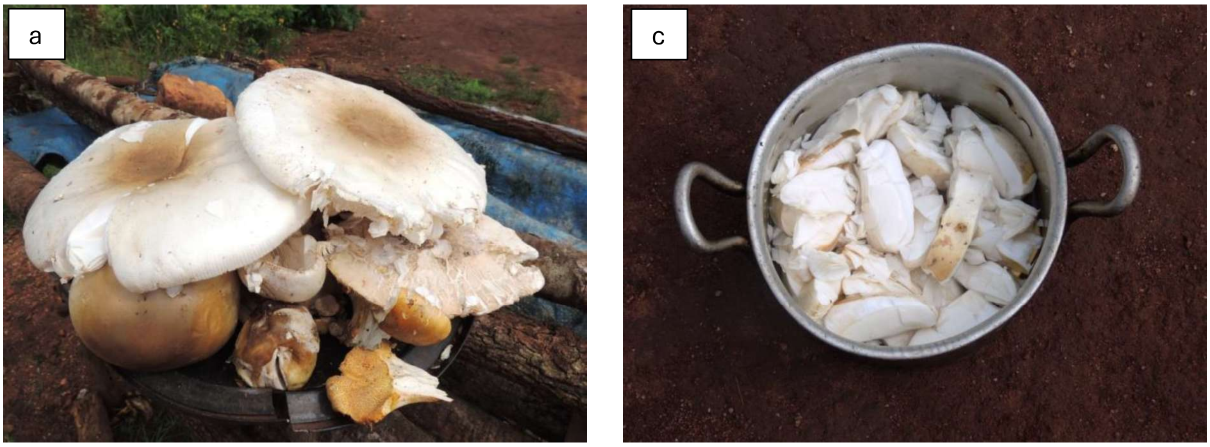


Fig. 50. Tortulho. Huambo Province, Angola. Fig. 50a: Tortulho being collected. Fig. 50b: Tortulho being prepared. Sorce: Schüler *et al.* (2022).

3.10.15 Vitende (*Cucurbita* sp.). Cucurbitaceae family

Vitende is a cucumber cultivar. The cucumber plant's fruit is usually eaten as a salad (Fig. 51). Cucumber is a natural diuretic and a great help in dissolving kidney stones. It is rich in potassium, which provides flexibility to muscles and elasticity to the cells that make up the skin (Schüler *et al*., 2022).

Fig. 51. Vitende cut into slices. Cuchi, Cuando Cubango, Angola. Source: Schüler *et al.* (2022).

3.11 The future of underutilized food plants in Angola

For the United Nations SDGs to be achieved, developing effective strategies to implement sustainable biodiversity conservation is restricted by limited knowledge about the impact of biodiversity conservation policies on indigenous peoples' livelihoods (Ezebilo, 2010).

Understanding the future distribution of Angola's neglected and underutilized food species will help develop climate change adaptation strategies (Mugiyo *et al*., 2022). In the comparative assessment of the eligibility of underutilized food species for viability of intensive commercial production in Angola, Arnold *et al*. (1985) applied four evaluation criteria: (i) nutritional composition, (ii) domestication potential, (iii) relative yield, and (iv) desirability. In the area of sustainable energy, it can be observed that the biofuel production chain has been established, generating employment and income, both in the agricultural phase and in the input and service markets, as well as in logistics, storage, mixing, and marketing of biofuels (Henkes & Lebid, 2015).

Underutilized unconventional food plants have the potential to increase and diversify sources of family income, for example, direct sales at fairs, to agribusinesses, restaurants, and, mainly, through agroecological and gastronomic tourism (Kinupp *et al*., 2021).

For the United Nations SDGs to be achieved, developing effective strategies to implement sustainable biodiversity conservation is hampered by limited knowledge about indigenous peoples' livelihoods (Ezebilo, 2010). Identifying and promoting cheaper and more nutritious foods can effectively address the current global malnutrition crisis so that SDGs 2 (Zero Hunger) and 3 (Good Health and Well-being) are achieved by 2030 (Ogbuagu *et al*., 2023). Addressing sub-Saharan Africa's food and nutrition insecurity challenge will require innovative agricultural production systems that support multiple objectives (Akplo *et al*., 2023). Increasing indigenous foods' consumption and integration into diets should be considered a positive strategy, as their nutritional and health value is known (Kesa *et al*., 2023).

4 CONCLUSIONS

Nine underutilized plant species were researched: two of which were cereal species, massambala (*Sorghum bicolor* (L.) Moench) and massango (*Pennisetum glaucum* (L.) R.Br.); three fruit tree species, imbondeiro (*Adansonia digitata* L.), maboqueiro (*Strychnos spinosa* Lam.) and dendezeiro (*Elaeis guineensis* Jacq.); two types of tubers, inhames (*Dioscorea spp*.) and assipi (*Colocasia esculenta* (L.) Schott); and two species of leafy vegetables, fumbua (*Gnetum africanum* Welw.) and uce (*Hibiscus sabdariffa* L.). Another fifteen underutilized food species were also listed.

In 2022, Angola imported 780,734 tons of corn, wheat and flour, potatoes, oranges and juice, edible oil, and fresh, dehydrated, frozen, or preserved vegetables, worth USD 677,480,000.00. In this context, and considering the demonstrated nutritional quality of the underutilized food plants that were researched in this study, the use of imported foods in the diet of Angolans could be replaced by local production of these underutilized plants. This would promote sustainable agriculture by generating employment and local income.

Competent institutions must invest strategically in the local production of underutilized food species. By adopting public policies that support and develop the local agricultural sector, Angola can reduce its reliance on imports. This approach will foster scientific and technological research, train skilled professionals and technicians, and ultimately boost the competitiveness and sustainability of Angolan commercial agriculture. Such investments will generate jobs, increase income, and strengthen the national consumer market.

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6 GLOSSARY

Gourd: is the fruit of several plants belonging to the Cucurbitaceae and Lagenaria families. It is a versatile fruit with diverse culinary, medicinal and even decorative uses.

Imbondeiro: *Adansonia digitata* L. is a giant tree, from the Bombacacea family. The trunk is thick and bulging, reaching 20 m in height and 10 m in diameter.

Lombi: delicacy served as a garnish, prepared with sautéed leafy vegetables. Originally from southern Angola.

Maruvo: marufo or maluvo. Drink from the fermented sap of palm trees, mainly palm hearts, bordão and matebeira.

Massambala: *Sorghum bicolor* L. Moench. Common name, extended to plants of the *Sorghum* genus.

Massango: *Pennisetum glaucum* (L.) R. Br., also called millet, canary seed or millet.

Moamba or **muamba**: pasty mass obtained by grinding food in a mortar.

Múcua: edible fruit of the imbondeiro tree (*Adansonia digitata* L.).

Pervile: popular name attributed to several seeds of plants in the Cucurbitaceae family (pumpkin, strawberries).

Tortulho: designation given to several fungi (mushrooms), among which some species are edible.

7 ABOUT THE AUTHORS

Silmo Schüler, born on January 5, 1964 in Três de Maio, Rio Grande do Sul, Brazil. He graduated in Physical and Biological Sciences (1986) and Sciences with a specialization in Physics (1990) from Faculdades Integradas de Santa Cruz do Sul - FISC, postgraduate degree in Food Technology (1994), Master in Regional Development, Technological Area - Environmental (2000) and PhD in Environmental Technology (2022) at the University of Santa Cruz do Sul - UNISC. Entrepreneur and consultant in Brazil and the African Continent. Resident in Angola from 2012 to 2020, traveling through all 18 provinces of Angola. In 2014, he coordinated the implementation of 18 agro-industrial cooperatives producing soap, honey, and preserves in 15 provinces of Angola through the Ministry of Family and Promotion of Women – MINFAMU.

Eduardo Alcayaga Lobo, Biologist, graduated from the University of Chile in 1982. Master in Biological Sciences from the Federal University of São Carlos, Brazil, and PhD in Biological Sciences from the University of Marine Sciences and Technology of Tokyo, Japan (1995). In 2000, he completed his post-doctorate in “Environmental Contamination Control” at the National Institute of Environmental Resources, Tsukuba, Japan. He is a full-time Professor and researcher in the Department of Life Sciences at the University of Santa Cruz do Sul (UNISC), RS, Brazil. Since 2005, he has worked as a teacher, researcher, and advisor in the Environmental Technology Program (Master and Doctorate). Limnology stands out as one of its main lines of research, particularly environmental monitoring studies, in addition to ecotoxicology and agricultural sustainability.


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