Urban ethnobotany, medicinal plant diversity, commercialization, and biosafety in the public markets of Recife, Pernambuco, Brazil

José Alex Alves dos Santos, Philipe Souza Rufino, Celso Ramos Rodrigues Neto, Karla Mikaelly dos Santos Bezerra, Rosallyne Hosana Vanderlei das Chagas, Sílvio Marçal de Vasconcelos Júnior, René Duarte Martins, Jeymesson Raphael Cardoso Vieira

Correspondence

José Alex Alves dos Santos[1,2*], Philipe Souza Rufino[1], Celso Ramos Rodrigues Neto[2], Karla Mikaelly dos Santos Bezerra[2], Rosallyne Hosana Vanderlei das Chagas[2], Sílvio Marçal de Vasconcelos Júnior[2], René Duarte Martins[3], Jeymesson Raphael Cardoso Vieira[2]

[1]Department of Nursing, Instituto Federal de Pernambuco, Abreu e Lima, Pernambuco, Brazil.
[2]Department of Morphology, Universidade Federal de Pernambuco, Recife, Pernambuco, Brazil.
[3]Department of Public Health, Universidade Federal de Pernambuco, Vitória de Santo Antão, Pernambuco, Brazil.

*Corresponding Author: alex.alves@abreuelima.ifpe.edu.br

Ethnobotany Research and Applications 34:65 (2026) - http://dx.doi.org/10.32859/era.34.65.1-35
Manuscript received: 20/02/2026 - Revised manuscript received: 04/06/2026 - Published: 05/06/2026

Research

Abstract

Background: Urban public markets are central nodes for the circulation of medicinal plants and ethnomedical knowledge, yet integrative analyses combining species diversity, commercialization dynamics, and biosafety remain scarce in Northeastern Brazil.

Methods: A cross-sectional ethnobotanical study was conducted in public markets of Recife using semi-structured interviews, market inventories, and ethnographic observation. Species were identified through a triangulated taxonomic approach. Therapeutic indications were classified according to ICD-11, and quantitative ethnobotanical indices and similarity analyses were applied.

Results: A total of 100 medicinal plant species belonging to 50 families were recorded, with predominance of Lamiaceae (16 spp.), Fabaceae (14 spp.), and Asteraceae (7 spp.). Herbaceous (41%) and arboreal (38%) species were the most frequent life forms, and leaves were the main commercialized plant part (n = 51). Highly versatile species (RI = 0.9) included *Ocimum campechianum*, *Mentha longifolia*, *Mentha spicata*, and *Laurus nobilis*. Knowledge and commercial autonomy increased with age ($\rho = 0.68$; $p < 0.001$), and similarity analysis indicated a central redistribution role for major markets. Plant-part commercialization differed significantly among markets (two-way ANOVA, $F = 4.78$; $p < 0.001$). Botanical identification relied predominantly on vernacular recognition, and labeling, storage, and traceability revealed heterogeneous biosafety patterns.

Conclusions: Recife's public markets sustain a diverse and socially structured urban pharmacopoeia in which knowledge transmission, trade networks, and therapeutic versatility are closely interconnected. Uneven biosafety practices highlight the need for participatory governance strategies that reconcile sanitary standards with traditional medical systems.

Keywords: Urban ethnobotany, medicinal plant trade, public markets, biocultural knowledge, biosafety, Brazil.

Background

Medicinal plants have been used throughout human history as primary therapeutic resources and continue to play a significant role in health care systems worldwide, particularly in regions where access to biomedical services remains uneven or economically restricted (Salmerón-Manzano *et al*., 2020). Traditional plant-based practices constitute dynamic knowledge systems that integrate empirical experience, cultural transmission, and locally available biodiversity. Within contemporary ethnobiology, increasing attention has been directed toward urban environments, where medicinal knowledge persists through commercial networks, social interactions, adaptive practices shaped by socioeconomic change (Abreu *et al.* 2015, Ladio *et al.* 2023).

Urban public markets represent key socioecological spaces for the circulation of medicinal plants and ethnomedical knowledge (Rangel *et al.* 2024, Zhang *et al.*, 2026). These environments facilitate the exchange of plant materials, therapeutic experiences, and diagnostic reasoning among traders and consumers, functioning simultaneously as commercial centers and arenas of cultural continuity. Studies conducted across Latin America, Africa, and Asia have demonstrated that urban markets maintain hybrid pharmacopoeias composed of native and exotic species while supporting livelihoods and sustaining informal health economies (van Andel *et al*., 2007, van Andel & Fundiko, 2016, van Wyk & Prinsloo 2018, Astutik *et al*. 2019, Uzun & Koca 2020, Ajoseh & Odejimi 2024, Zhang *et al.* 2026). In such contexts, medicinal plant trade is closely linked to processes of cultural resilience, knowledge transmission, and adaptive responses to urban transformation.

In Brazil, medicinal plant use is deeply embedded in pluralistic health systems that combine biomedical care with traditional and complementary practices. Public markets in Northeastern Brazil play a particularly important role in maintaining regional ethnobotanical knowledge, reflecting Afro-Brazilian, Indigenous, and rural cultural influences that continue to shape urban therapeutic practices (Bitu *et al*. 2015, Molina 2021, Magalhães *et al.* 2022, Silva *et al*. 2022, Leite *et al*. 2024). Studies conducted in Recife and other Northeastern Brazilian cities indicate that these markets function as major nodes for medicinal plant circulation, knowledge exchange, and household healthcare strategies (Silva *et al*. 2005, Albuquerque *et al*. 2007, Macêdo *et al*. 2015, Saraiva *et al*. 2015). Despite the growing interest in urban ethnobotany, previous research has focused predominantly on rural or peri-urban environments (Saraiva *et al*. 2015, Macêdo *et al*. 2015, Ferreira *et al*. 2021), leaving urban ethnomedical systems comparatively underexplored. Therefore, it is necessary to conduct comprehensive analyses that integrate floristic diversity, therapeutic organization, socioeconomic dynamics, and the spatial distribution of the medicinal plant trade in large metropolitan markets.

This study addresses this gap by examining medicinal plant trade in public markets of Recife, Northeastern Brazil. The research integrates ethnographic observations, quantitative ethnobotanical indices, and spatial analyses to investigate how medicinal plant knowledge is produced, circulated, and maintained within urban commercial environments. Specifically, the study aims to document the diversity of medicinal plant species commercialized in public markets; characterize therapeutic uses and commercialization practices, and biosafety-related handling and labeling conditions; examine patterns of knowledge transmission among traders; and analyze similarities and differences among markets in terms of species composition and commercialization dynamics. By integrating quantitative ethnobotanical indices, spatial similarity analyses, and biosafety assessment in a large metropolitan context, this study provides a multidimensional approach to understanding traditional urban medical systems.

Materials and Methods

Study area

The study was conducted in Recife, the capital of Pernambuco State in Northeastern Brazil (8°04'03" S, 34°55'00" W). The city is located on a low-lying coastal plain with an average elevation of approximately 4 m above sea level and is administratively divided into six Political-Administrative Regions (PARs) and 94 neighborhoods (Recife 2025) (Fig. 1).

Recife has a tropical humid climate and represents one of the main metropolitan centers in Northeastern Brazil, characterized by intense commercial, cultural, and technological exchanges (Recife 2022). Within the urban landscape, 18 public markets function as important commercial and sociocultural spaces where medicinal plants are traded and traditional knowledge circulates among traders and consumers (Medeiros & Albuquerque 2012).

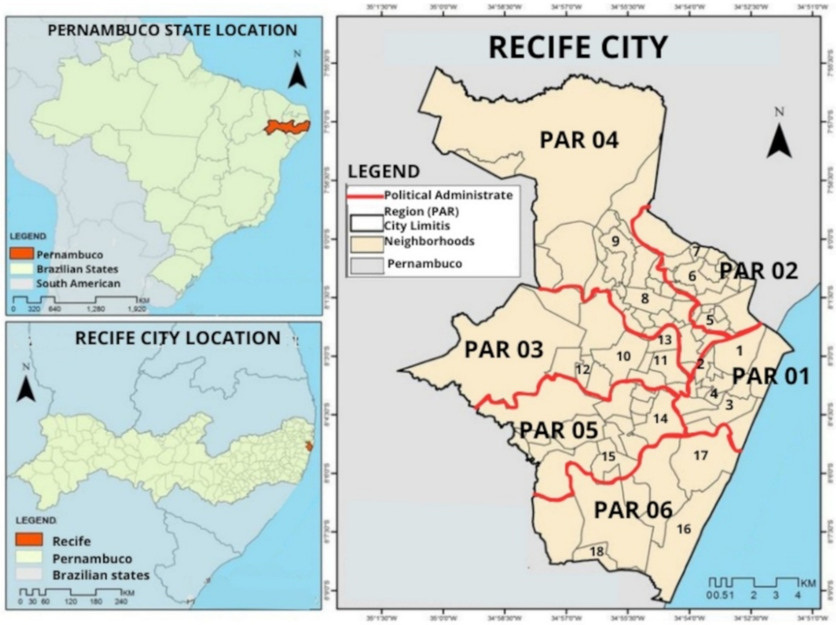

Figure 1. Geographic location of the study area showing the public markets of Recife, Pernambuco, Brazil, and their distribution by Political-Administrative Regions (PARs). Markets: 1 - Santo Amaro; 2 - Boa Vista; 3 - São José; 4 - Coelhos (PAR 01 - Central Recife); 5 - Encruzilhada; 6 - Água Fria; 7 - Beberibe (PAR 02 - Northern Recife); 8 - Casa Amarela; 9 - Nova Descoberta (PAR 04 - Northeastern Recife); 10 - Cordeiro; 11 - Madalena; 12 - Engenho do Meio; 13 - Torre (PAR 03 - Western Recife); 14 - Afogados; 15 - Areias (PAR 05 - Southwestern Recife); 16 - Boa Viagem; 17 - Pina; 18 - Jordão (PAR 06 - Southern Recife). Source: IBGE/PCR Digital Vector Base. Map production: Ferreira (2017). Adapted by the authors.

The Political-Administrative Regions included in this study encompass socially, economically, and environmentally heterogeneous urban sectors of Recife. Central areas (PAR 01) are characterized by intense commercial circulation, historical public markets, and strong regional trade networks, whereas northern and northeastern sectors (PARs 02 and 04) include densely populated neighborhoods with predominantly lower-income populations and strong traditions of informal commerce. In contrast, southern sectors (PAR 06), including Boa Viagem and Pina neighborhoods, are among the city's highest-income areas and present more vertically urbanized landscapes, greater infrastructure availability, and distinct commercial dynamics. Western and southwestern regions (PARs 03 and 05) represent mixed residential and commercial zones with intermediate socioeconomic characteristics and important local public markets.

These urban contrasts influence market structure, commercialization dynamics, access to medicinal plant resources, consumer profiles, and the circulation of traditional knowledge within Recife's public markets. The coexistence of markets located in areas with markedly different socioeconomic conditions provides an important opportunity to investigate how urban heterogeneity shapes medicinal plant trade systems in a large Northeastern Brazilian metropolis, particularly regarding the effects of urbanization on traditional knowledge transmission, intermedicality, sociocultural adaptation, and medicinal plant commercialization dynamics (Dutta et al. 2021; Arjona-García et al. 2021; Casagrande et al. 2023). Similar dynamics involving medicinal plant diversity and commercialization in urban and semi-arid markets have also been documented in Northeastern Brazil (Albuquerque et al., 2007; Bitu et al., 2015; Oliveira et al. 2021).

For similarity analyses, the six PARs were grouped into three geographic clusters based on administrative adjacency: G1 (PARs 01-02), G2 (PARs 03-04), and G3 (PARs 05-06).

Study design

The study employed a mixed-methods ethnobotanical design combining participant observation, semi-structured interviews, and market inventories (Albuquerque *et al*. 2014). Fieldwork was conducted across all 18 public markets of Recife to ensure geographic coverage and representation of different urban contexts. Data collection focused on commercialization practices, medicinal plant diversity, therapeutic uses, and perceptions related to market organization and biosafety.

Sampling and participants

Participants were selected using snowball sampling to identify specialist knowledge holders actively involved in medicinal plant trade (Albuquerque et al. 2010; Goodman 2011). Initial contacts were established during preliminary visits to Recife's public markets, and subsequent participants were indicated by previously interviewed traders recognized for their experience in medicinal plant commercialization.

A total of 34 medicinal plant traders participated in the study across Recife's 18 public markets. Inclusion criteria comprised: (i) being actively involved in the commercialization of medicinal plants or herbal products; (ii) possessing knowledge regarding the medicinal use or commercialization of the products sold; (iii) being 18 years of age or older; and (iv) voluntarily agreeing to participate through the signing of a Free and Informed Consent Form.

Exclusion criteria included refusal to participate, interruption of the interview process, or failure to meet the inclusion criteria. Not all traders identified during fieldwork agreed to participate, and in some markets the absence of medicinal plant vendors or temporary interruption of commercial activities limited participant recruitment.

Sampling was conducted across all public markets to reduce geographic bias and ensure representation of different administrative regions and commercialization contexts within Recife.

Ethical considerations

This study was approved by the Human Research Ethics Committee of the Federal Institute of Education, Science and Technology of the Sertão Pernambucano (Instituto Federal de Educação, Ciência e Tecnologia do Sertão Pernambucano - IF Sertão PE), under approval number 6.793.694.

All participants were informed about the objectives of the research, the voluntary nature of participation, confidentiality procedures, and their right to withdraw at any moment without prejudice. Interviews and photographic records were conducted only after participants signed the Free and Informed Consent Form.

Interviews

Semi-structured interviews were conducted with medicinal plant traders using a questionnaire developed by the research team to document socioeconomic characteristics, trade structure, vernacular plant names, plant parts sold, preparation methods, and therapeutic indications. The use of a semi-structured instrument allowed flexibility in the dialogue while ensuring the systematic recording of comparable information across participants (Albuquerque *et al*. 2014).

Therapeutic indications were classified according to the International Classification of Diseases (ICD-11), grouping reported uses into major body-system categories, including respiratory, digestive, integumentary, circulatory, endocrine, and musculoskeletal conditions (WHO 2018). This procedure ensured standardization of disease categories and supported subsequent quantitative ethnobotanical analyses.

In addition to interviews, structured field observations were conducted at medicinal plant stalls to document commercialization dynamics and biosafety-related practices associated with the handling and storage of medicinal plant products. Direct observations followed ethnobiological approaches commonly applied in studies of traditional medicinal plant markets and urban ethnobotany (Albuquerque et al. 2014; Heinrich et al. 2009).

For the purposes of this study, biosafety was operationally defined as the set of observable practices potentially associated with medicinal plant conservation, contamination risks, traceability, and consumer safety during commercialization, based on quality-control recommendations proposed for herbal materials and medicinal plant trade systems (WHO 2003; WHO 2011).

Observational variables included storage and packaging materials, environmental exposure conditions (humidity, ventilation, and sunlight exposure), labeling practices, expiration information, botanical identification methods, geographic origin and traceability of plant materials, and empirical quality-control procedures adopted by traders. These procedures included sensory evaluation, pest monitoring, and packaging sealing.

Data were obtained through direct observation, field notes, photographic documentation when authorized by participants, and complementary questions incorporated into the semi-structured interviews. Knowledge transmission patterns were investigated through questions regarding how traders acquired and maintained ethnobotanical knowledge, including family-based transmission, empirical learning through commercial experience, interactions with suppliers and consumers, and self-directed learning processes.

The biosafety and commercialization assessment was qualitative and semi-quantitative in nature and aimed to characterize observable practices rather than perform formal sanitary or microbiological inspections.

Ethnobotanical survey

Market inventories were conducted collaboratively with herbalists to document the medicinal plant taxa sold under their vernacular names. Only plant materials actively commercialized at the time of the field visits, including fresh and dried products, was recorded.

Conventional botanical voucher collection and herbarium deposition were not feasible because most commercialized materials consisted of fragmented, processed, dried, or otherwise incomplete plant parts that lacked sufficient diagnostic morphological structures for standard taxonomic collection procedures. Consequently, species identification followed a triangulated approach integrating vernacular nomenclature, photographic documentation, consultation of specialized taxonomic literature, and comparison with authenticated digital specimens available in virtual herbaria, particularly collections originating from Northeastern Brazil.

For each taxon, the total number of available herbarium records was documented, and the most recent voucher specimen from Northeastern Brazil, when available, was preferentially selected as the primary comparative reference; otherwise, the most recent Brazilian voucher was used (Marinoni et al. 2024). Taxonomic validation was additionally supported through comparison with verified specimens available in the Reflora Virtual Herbarium (Pinheiro et al. 2024; Reflora 2025), while scientific nomenclature followed the World Flora Online database (WFO 2025).

This approach has been widely adopted in ethnobotanical studies conducted in medicinal plant markets where commercialization frequently involves processed plant materials that preclude conventional herbarium voucher preparation.

Ethnobotanical indices

Quantitative ethnobotanical indices were selected on their widespread use ethnobotanical research to evaluate cultural importance, therapeutic versality, knowledge distribution, and similarity among geographic clusters.

Relative Importance

Relative Importance (RI) was calculated to evaluate the therapeutic versatility of each species by considering both the diversity of body systems treated and the number of attributed medicinal properties. The index was calculated using the following formula:

$$RI = NST + NP$$

where NST corresponds to the number of body systems treated by a species divided by the maximum NST, and NP corresponds to the number of attributed properties divided by the maximum NP (Albuquerque *et al*. 2010).

Informant Consensus Factor

The Informant Consensus Factor (ICF) was used to assess the level of agreement among informants regarding the use of medicinal plants within therapeutic categories. The index was calculated using the following formula:

$$ICF = (Nur - Nt) / (Nur - 1)$$

where Nur represents the number of citations in a therapeutic category and Nt represents the number of species cited (Andrade-Cetto & Heinrich 2011, Benyaich *et al*. 2025).

Popular Recognition Knowledge

Popular Recognition Knowledge (PRK) was calculated to estimate the relative cultural prominence of each species based on the proportion of respondents who cited its use. The index was calculated as follows:

$$PRK = (FC / N) \times 100$$

where FC (Frequency of Citation) corresponds to number of respondents citing a species and N is the total number of respondents (Asiimwe *et al*. 2021).

Fidelity Level
Fidelity Level (FL) was used to determine the degree of specialization of species for specific therapeutic indications. The index was calculated using the following formula:

$$FL = (Np / N) \times 100$$

where Np corresponds to the number of citations for the principal use of a species and N represents the total number of citations for that species (Acharya *et al.* 2022).

Rahman's Similarity Index
Rahman's Similarity Index (RSI) was calculated to evaluate similarities in medicinal plant use among geographic clusters based on shared species and therapeutic uses. The index was calculated as follows:

$$RSI = d / (a + b + c - d) \times 100$$

where d corresponds to the number of species shared between two regions with similar therapeutic uses; a and b correspond to the total number of species in each region; and c corresponds to the total number of shared species regardless of use (Rahman *et al*. 2019). RSI was calculated for each geographic cluster pair (G1 × G2, G1 × G3, G2 × G3).

Data analysis
Descriptive field observations were used to document patterns related to market organization, knowledge transmission, commercialization practices, and environmental conditions observed during the fieldwork. Quantitative ethnobotanical indices were applied to evaluate therapeutic versatility, cultural prominence, and knowledge distribution across medicinal plant species (Yu 2025, Nguyen *et al*. 2025), supporting an integrated socioecological interpretation of Recife's public market pharmacopeia.

Descriptive and inferential statistical analyses were conducted using R version 4.4.0 (R Core Team 2024) and IBM SPSS Statistics version 28 (IBM Corp. 2024). Data normality was assessed using the Shapiro-Wilk test. Differences in the number of species cited according to sociodemographic variables were evaluated using Mann-Whitney U tests, and associations between age class and number of cited species were assessed using Spearman's rank correlation (Ilie *et al*., 2025). Differences among therapeutic categories were evaluated using Kruskal-Wallis and Mann-Whitney U tests. Relationships among ethnobotanical indices were examined using Spearman's rank correlation (Dapar *et al*. 2020)

For the analysis of commercialization patterns of plant parts, a two-way analysis of variance (ANOVA) was performed to test the effects of plant-part category and commercialization condition (fresh vs. dried), followed by evaluation of interaction effects. Associations between categorical variables were assessed using chi-square (χ^2) tests (McDonald 2023).

Statistical significance was established at $p < 0.05$.

Results

Socioeconomic profile of medicinal plant traders
A total of 40 medicinal plant traders were identified across Recife's 18 public markets during fieldwork, of whom 34 agreed to participate in the study, representing 85.0% of the identified traders. The distribution of traders was markedly heterogeneous among markets (Table 1).

São José Market concentrated the largest number of herbalists (n = 14 identified; n = 13 interviewed), followed by Casa Amarela (n = 5), Afogados (n = 4), and Nova Descoberta and Areias (n = 3 each). In contrast, several markets presented no active medicinal plant trade during the study period, including Coelhos, Engenho do Meio, Jordão, Santo Amaro, and Torre. Sociodemographic characteristics of the interviewed traders are summarized in Table 1. Women predominated (58.8%) among traders, and most participants were over 40 years old, with a marked concentration in the ≥51-year age group. Participants were predominantly single (44.1%) or married (38.2%), while educational attainment was generally low-moderate, concentrated at International Standard Classification of Education (ISCED) levels L2 (38.2%) and L3 (55.9%). Household income levels were primarily within lower economic brackets, with most traders reporting earnings of up to three minimum wages. Slightly more than half operated as self-employed stall owners (55.9%), while the remainder worked as employees (44.1%).

Table 1. Socioeconomic profile of herbalists in public markets of Recife, Pernambuco, Brazil.

Public Market (PAR)	NH (NI)	Gender		Marital Status				Age (≤)				Education - Level ISCED				Family income (≤ MV)				Commercial agents	
		M	F	S	Mr	W	O	30	40	50	51	ILL	L2	L3	L6	1	3	5	PNA	SE	E
Afogados (5)	4 (3)	2	1	2	1	0	0	0	0	1	2	1	1	1	0	1	2	0	0	2	1
Água Fria (2)	1 (0)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Areias (5)	3 (3)	2	1	2	1	0	0	0	0	0	3	0	1	2	0	3	0	0	0	2	1
Beberibe (2)	2 (1)	1	0	0	1	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1	0
Boa Viagem (6)	1 (1)	1	0	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1
Boa Vista (1)	1 (1)	0	1	1	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	1
Casa Amarela (4)	5 (5)	1	4	2	1	1	1	1	0	3	1	0	3	1	1	2	1	0	2	2	3
Coelhos (1)	0 (0)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cordeiro (3)	2 (2)	0	2	0	0	1	1	0	0	1	1	0	1	1	0	0	0	1	1	2	0
Encruzilhada (2)	2 (2)	0	2	2	0	0	0	0	2	0	0	0	0	2	0	0	0	0	2	0	2
Engenho do Meio (3)	0 (0)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jordão (6)	0 (0)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Madalena (3)	1 (0)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nova Descoberta (4)	3 (3)	0	3	2	1	0	0	0	1	1	1	0	2	1	0	3	0	0	0	2	1
Pina (6)	1 (0)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Santo Amaro (1)	0 (0)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
São José (1)	14 (13)	7	6	4	7	0	2	3	2	3	5	0	4	9	0	6	6	0	1	8	5
Torre (3)	0 (0)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	40 (34)	14	20	15	13	2	4	4	6	10	14	1	13	19	1	16	11	1	6	19	15

The table summarizes the demographic and socioeconomic characteristics of herbalists interviewed in 2025 across the city's Political-Administrative Regions (PARs).

Abbreviations: PAR = Political-Administrative Regions; NH = Total number of herbalists identified in each public market during field surveys ; NI = Number of herbalists interviewed; M = Male; F = Female; O = Others; S = Single; Mr = Married; W = Widowed; ISCED = International Standard Classification of Education (UNESCO, 2012); ILL = Illiterate; L2 = Lower Secondary Education; L3 = Higher Secondary Education; L6 = Higher Education (Undergraduate); MW = Minimum Wage; PNA = Prefers not to answer; SE = Self-employed; E = Employee. Note: No other gender identities were reported during the interviews.

Statistical analyses revealed significant associations between sociodemographic variables and commercial roles. Older herbalists were more likely to own their stalls (Spearman's $\rho = 0.68$; $p < 0.001$). Income differed significantly between employees and self-employed traders (Mann-Whitney U test; $p = 0.007$), and education level showed negative correlation with self-employment (Spearman's $\rho = -0.52$; $p = 0.009$). Spatial distribution demonstrated a strong concentration of traders in central markets, particularly in PAR 01, which hosted 44.1% of herbalists. Chi-square analysis confirmed significant differences in spatial distribution across Political-Administrative Regions ($\chi^2 = 35.95$; $p = 0.003$). São José Market (Fig. 2A-B) alone concentrated 13 active herbalists and represents one of the principal medicinal plant trade hubs in Recife due to its historical commercial importance, intense consumer circulation, and high diversity of medicinal products. Casa Amarela Market (Fig. 2E-F), located in a traditional northern commercial district, also presented elevated commercialization activity, characterized by organized stalls and continuous product turnover. In contrast, Cordeiro Market (Fig. 2C-D), situated in a mixed residential-commercial sector, exhibited an intermediate commercialization profile, with lower trader density and more variable product display and storage conditions. Smaller peripheral markets generally showed reduced numbers of herbalists, less standardized packaging and exposure practices, and greater variability in commercialization structure, reflecting differences in neighborhood socioeconomic characteristics, local demand, and market infrastructure.

Figure 2. Representative public markets and medicinal plant commercialization environments across distinct Political-Administrative Regions (PARs) of Recife, Pernambuco, Brazil. (A) External view of São José Market, located in Central Recife (PAR 01), characterized by historical urban architecture and intense commercial circulation; (B) Interior commercialization environment at São José Market showing medicinal plant stalls and product exposure patterns; (C) Internal corridor of Cordeiro Market (PAR 03), representing mixed residential-commercial urban sectors; (D) Medicinal plant products commercialized at Cordeiro Market, illustrating storage and display practices; (E) External view of Casa Amarela Market (PAR 04), located in a traditional northern commercial sector of Recife; (F) Internal commercialization environment at Casa Amarela Market showing an interview with a medicinal plant trader illustrating storage and display practices.

Table 2. Medicinal plant species sold in public markets of Recife, Pernambuco, Brazil.

Family/species	Total number of specimens/ Herbarium no. (Regions of Brazil) / Year	Vernacular name	H	Part used	Method of preparation	Method of use	Therapeutic indication and most cited use (Np)	FC (N/RPM)	RI	FL (%)	PRK (%)
Acanthaceae Juss.											
Justicia pectoralis Jacq.	326/ FLOR00076466 (S)/ 2023	**chambá**	He	Le	Infusion, decoction	Oral intake, inhalation	Cough (3), expectorant, aromatic use	5/ 7,17	0.4	60	14.7
Amaranthaceae Juss											
Dysphania ambrosioides L. Mosyakin & Clements	297/ TEPB0032559 (NE)/ 2022	**mastruz**	He	Le	Infusion	Oral intake, inhalation	Worms (4), vomiting, flu, aromatic use	9/ 1,5,6,9,17	0.6	44.4	26.4
Anacardiaceae R.Br.											
Myracrodruon urundeuva Allem.	794/ HURB000025537 (NE)/ 2019	**aroeira-do-sertão**	Tr	Ib	Decoction, Maceration	Topical application, oral intake	Wounds (5), peptic ulcer, inflammations wounds, hair loss, urticaria	16/ 1,3,4,7,9,10,17	0.6	31.3	47.1
Anacardium occidentale L.	2594/ TEPB0032560 (NE)/ 2022	**caju roxo**	Tr	Ib	Decoction	Topical application, oral intake	Wounds (5) inflammations, mycoses, wounds	11/ 1,3,7,9,14,17	0.4	45.4	32.4
Annonaceae Juss.											
Annona muricata L.	225/ TEPB0032654 (NE)/ 2022	**graviola**	Tr	Le	Infusion	Oral intake	Hyperglycemia (3)	3/ 17	0.3	100	8.8
Apiaceae Lindl.											
Kalanchoe pinnata (Lam.) Pers.	134/ RB01444182 (SE)/ 2021	**coroma branca**	He	Le	Infusion, poultice	Topical application, oral intake	Inflammation (2) headache	3/ 4,17	0.3	66.6	8.8
Pimpinella anisum L.	30/EAC0059965 (NE)/ 2016	**erva doce**	Sh	Se	Infusion	Oral intake	Abdominal cramps (7), aromatic use, Inflammations, enhanced digestion, anxiety	17/ 1,3,6,7,9,10,14,17	0.7	41.1	50

Arecaceae Bercht. & J.Presl											
Cocos nucifera L.	48/ TEPB0032655 (NE)/ 2023	**coco**	Tr	Fr	Oil	Topical application	Hair loss (1)	1/ 17	0.2	100	2.9
Asphodelaceae Juss.											
Aloe vera (L.) Burm. f.	80/ TEPB0032694 (NE)/ 2023	**babosa**	He	Le	Mucilage	Topical application, oral intake	Dry skin (6), urticaria, skin hyperpigmentation, burns, nail growth, prostatic hyperplasia	18/ 1,3,5,7,9,14,17	0.8	33.3	52.9
Asteraceae Giseke											
Achyrocline satureioides (Lam.) DC.	1964/ ALCB00080786 (SE)/ 2023	**macela**	He	Fl	Infusion	Oral intake	Abdominal cramps (1), vomiting (1), aromatic use (1)	1/ 7	0.4	100	2.9
Cynara scolymus L.	13/ RFA00057950 (SE)/ 2016	**alcachofra**	He	Le	Infusion	Oral intake	Enhanced digestion (1)	1/ 10	0.2	100	2.9
Erigeron bonariensis L.	15/ FLOR00077403 (S)/ 2023	**rabo de raposa**	Sh	Le, Fl	Infusion	Topical application	Mycoses (2)	2/ 1,17	0.2	100	5.9
Taraxacum officinale F.H.Wigg.	177/ FURB00073289 (S)/ 2022	**dente de leão**	He	Le	Infusion	Oral intake	Enhanced diuresis (1), high cholesterol (1)	1/ 10	0.3	100	2.9
Calendula officinalis L.	63/ FLOR00076402 (S)/ 2022	**calêndula**	He	Fl	Infusion, essential oil	Topical application, oral intake	Inflammation (2), wounds, skin hyperpigmentation, aromatic and antiseptic use	3/ 7,17	0.6	66.6	8.8
Matricaria chamomilla L.	141/ ALCB00076037 (NE)/ 2022	**camomila**	He	Fl	Infusion	Oral intake	Anxiety (9), acne, skin hyperpigmentation and aromatic use	12/ 1,3,5,7,9,10,17	0.6	75	35.2
Baccharis trimera var. carqueja	428/ FLOR0066407 (S)/ 2018	**carqueja**	He	Le	Infusion	Oral Intake	Enhanced diuresis (2), enhanced digestion, suppressant appetite	2/ 7,10	0.5	100	5.9
Bignoniaceae Juss.											

Handroanthus impetiginosus (Mart. ex DC.)	825/ RB01461740 (NE)/ 2019	**ipê-roxo**	Tr	Ba	Decoction	Oral Intake	Inflammation (2), cancer, infections, aromatic use	3/ 17	0.8	66.6	8.8
Symphytum officinale L.	110/ FLOR00076382 (S)/ 2022	**confrei**	Sh	Le	Infusion	Topical application	Inflammation (1), wound (1), aromatic use (1)	1/ 17	0.4	100	2.9
Brassicaceae Burnett											
Nasturtium officinale R.Br.	87/ FURB55004 (S)/ 2017	**agrião**	He	Le	Infusion	Oral intake, inhalation	Cough (1)	1/ 17	0.3	100	2.9
Burseraceae Kunth											
Commiphora myrrha (T.Nees) Engl.	1/ RB01416197 (SE)/ 2017	**mirra**	Tr	Le	Infusion	Oral intake	High blood pressure (1), aromatic use (1)	2/ 1,4	0.3	50	5.9
Caprifoliaceae Juss.											
Valeriana officinalis L.	19/ RFA00060393 (SE)/ 2023	**valeriana**	Sh	Le	Infusion	Oral intake	Depression (1), aromatic use (1)	1/ 7	0.3	100	2.9
Caryocaraceae Voigt											
Caryocar brasiliense A.St.-Hil.	921/ CEN00102135 (SE)/ 2016	**pequi**	Tr	Fr	Oil	Topical application	Inflammation (1), wound (1)	1/ 17	0.3	100	2.9
Caryophyllaceae Juss.											
Dianthus caryophyllus L.	33/ EAC0061616 (NE)/ 2017	**cravo amarelo**	He	Le	Infusion	Oral intake	Abdominal cramps (4), inflammation, menstrual cramps	1/ 17	0.4	100	2.9
Celastraceae R.Br.											
Maytenus ilicifolia Mart. ex Reissek	440/ RB01208829 (SE)/ 2015	**espinheira santa**	Tr	Le	Infusion	Oral intake	Gastric ulcer (3), gastritis	4/ 3,17	0.4	75	11.7
Clusiaceae Lindl.											
Vismia guianensis (Aubl.) Pers.	1591/ RB01420221 (NE) 2018	**lacre**	Sh	Le	Infusion	Oral intake, topical application	Enhanced diuresis (4), inflammation, high blood pressure mycoses, bath	6/ 4,9,17	0.8	66.6	17.6
Costaceae Nakai											
Costus spiralis (Jacq.) Roscoe	915/ CEN00095569 (NE)/ 2016	**cana de macaco**	He	St	Infusion	Oral intake	Kidney stones (1)	1/ 14	0.2	100	2.9
Cucurbitaceae Juss.											

Luffa operculata Cogn.	81/ EAC00061251 (NE)/ 2017	**cabacinha**	He	Fr, Se	Infusion	Inhalation	Sinusitis (1), abortive (1)	1/ 3	0.2	100	2.9
Equisetaceae Michx. ex DC.											
Equisetum arvense L.	105/ BHZB00005915 (SE)/ 2021	**cavalinha**	Sh	Le	Infusion	Oral intake	Enhanced diuresis (3)	3/ 7,14	0.2	100	8.8
Erythroxylaceae Kunth											
Erythroxylum vacciniifolium Mart.	366/ HUEFS00242831 (NE)/ 2016	**catuaba**	Tr	Ba	Decoction	Oral intake	Inflammation (1), sexual stimulant (1)	2/ 3,17	0.3	50	5.9
Euphorbiaceae Juss.											
Jatropha gossypiifolia L.	386/ RB01473232 (N)/ 2022	**pinhão roxo**	Sh	Le, Fl	Infusion	Topical application	Bath (3), wounds	4/ 1,4,14,17	0.3	75	11.7
Fabaceae Juss.											
Amburana cearensis (Allemão) A.C. Smith	439/ HUEFS00245869 (NE)/ 2018	**imburana de cheiro**	Tr	Se	Infusion	Inhalation, oral intake	Inflammation (3), cough, aromatic use	4/ 3,9,14	0.5	75	11.7
Pterodon emarginatus Vogel	958/ CEN00132424 (SE)/ 2023	**sucupira**	Tr	Ib	Decoction	Oral intake	Pain (2), aromatic use	3/ 3,17	0.5	66.6	8.8
Erythrina velutina Willd.	343/ HURB000026321 (NE)/ 2021	**mulungu**	Tr	Ba	Infusion	Oral intake	Anxiety (2)	2/ 7,17	0.2	100	5.9
Hymenaea courbaril L.	1560/ CEN00118031 (N)/ 2021	**jatobá**	Tr	Ib	Decoction	Oral intake	Prostate hyperplasia (1), urinary tract infection (1), aromatic use (1)	1/ 17	0.3	100	2.9
Anadenanthera colubrina (Vell.) Brenan	2742/ CEN00122162 (CW)/ 2021	**angico**	Tr	Ib	Decoction	Oral intake	Inflammation (3), aromatic use	4/ 3,17	0.2	75	11.7
Senna occidentalis (L.) Link	946/ RB01425003 (NE)/ 2019	**manjerioba**	Tr	Le	Maceration	Oral intake, topical application	Enhanced digestion (1), inflammation (1), bath (1)	1/ 17	0.6	100	2.9

Stryphnodendron adstringens (Mart.) Coville	751/ CEN00125073 (CW)/ 2022	**barbatimão**	Tr	Ib	Decoction	Oral intake, topical application	Gastric ulcer (5), Inflammation, mycoses, wounds	6/ 1,3,9,17	0.4	83.3	17.6
Mimosa tenuiflora (Willd.) Poir.	893/ RB01446852 (NE)/ 2019	**jurema**	Tr	Ba	Infusion	Oral intake, topical application	Inflammation (1), wounds (1)	1/ 17	0.3	100	2.9
Bauhinia forficata Link	1730/ RB01465728 (NE)/ 2022	**pata de vaca**	Tr	Le	Infusion	Oral intake	Hyperglycemia (2), vomiting	3/ 3,17	0.5	66.6	8.8
Caesalpinia leiostachya (Benth.) Ducke	29/ ASE0031187 (NE)/ 2012	**jucá**	Tr	Fr	Decoction	Oral intake	Bruises (2)	2/ 17	0.2	100	5.9
Copaifera langsdorffii Desf.	2279/ CEN00121125 (CW) / 2022	**copaíba**	Tr	Wd	Resin Oil	Topical application	Hair loss (2)	2/ 17	0.2	100	5.9
Hibiscus rosa-sinensis L.	277/ RB01451574 (SE)/ 2021	**hibisco**	Sh	Fl	Infusion	Oral intake	Enhanced digestion (3), enhanced diuresis, hair loss, suppressant appetite, aromatic use	7/ 1,7,14,17	0.8	42.8	20.6
Senna alexandrina Mill.	17/ HVASF00012457 (NE)/ 2015	**sene**	Tr	Le	Infusion	Oral intake	Constipation (1)	1/ 14	0.2	100	2.9
Trigonella foenum-graecum L.	6/ SPF00118407 (SE)/ 1979	**feno-grego**	He	Se	Infusion	Topical application	Hair loss (1), aromatic use (1)	1/14	0.2	100	2.9
Humiriaceae A. Juss.											
Endopleura uchi (Huber) Cuatrec.	170/ RB01490376 (N)/ 2022	**uxi amarelo**	Tr	Ba	Decoction	Oral intake	Inflammation (2), infections, uterine and ovarian tumors	3/ 3,17	0.6	66.6	8.8
Hypericaceae Juss.											
Hypericum perforatum L.	55/ JOI008116 (S)/ 2005	**erva-de-são-joão**	Sh	Fl	Infusion	Oral intake	Anxiety (1), aromatic use (1)	1/ 7	0.3	100	2.9
Lamiaceae Martinov											
Hyptis suaveolens (L.)	309/ RB01419928 (N) / 2018	**alfazema de caboclo**	He	Le, Fl	Infusion	Topical application	Scabies (1), wounds (1)	2/ 1,3,17	0.3	50	5.9

Lavandula angustifolia Medik.	29/ UPCB00052568 (S) / 2022	**alfazema**	He	Le, Fl	Infusion, essential oil, fumigation	Oral intake, inhalation	Anxiety (3) Enhanced digestion, aromatic use	7/ 3,7,17	0.5	42.8	20.6
Lavandula latifolia Medik.	2/ Not identified in Reflora - Brazilian Herbaria	**lavanda**	Sh	Fl	Infusion, essential oil	Inhalation	Anxiety (1), aromatic use (1)	1/ 7	0.3	100	2.9
Ocimum campechianum Mill.	361/ HURB000026719 (NE)/ 2021	**alfavaca**	He	Le	Infusion	Oral intake, inhalation	High blood pressure (2), sinusitis, fever, aromatic use	4/ 1,17	0.9	50	11.7
Rosmarinus officinalis L.	219/ HUEFS00232595 (NE)/ 2017	**alecrim**	He	Le	Infusion, poultice, essential oil	Oral intake, inhalation, topical application	Hair loss (10), aromatic use, inflammation, high blood pressure, hyperglycemia, flu, acne, enhanced diuresis, dizziness	24/ 1,3,4,5,6,7,9,10,14,17	1.3	41.6	70.6
Aeollanthus suaveolens Mart. ex Spreng.	24/ RB01438929 (N)/ 2020	**macassá**	He	Le	Infusion	Oral intake	Inflammation (3), high blood pressure, aromatic use	8/ 1,7,9,14,17	0.4	37.5	23.5
Lamium flexuosum subsp. Flexuosum	2/ Not identified in Reflora - Brazilian Herbaria	**urtiga branca**	He	Ro	Decoction	Oral intake	Inflammation (2)	2/ 17	0.2	100	5.9
Melissa officinalis L.	83/ NIT00008184 (SE)/ 2024	**erva cidreira**	He	Le, Fl	Infusion	Oral intake	Anxiety (3), inflammation, enhanced digestion, aromatic use	7/ 3,5,6,7,10,17	0.6	42.8	20.6
Mentha longifolia subsp. Longifolia	21/ FLOR00077442 (S)/ 2023	**levante**	He	Le, Fl	Infusion	Oral intake, inhalation, topical application	Antiseptics (4), enhanced digestion, expectorant, menstrual cramps, aromatic use	5/ 1,17	0.9	80	14.7

Mentha spicata L.	137/ FLOR00077430 (S)/ 2023	**hortelã**	He	Le	Infusion, essential oil	Oral intake, inhalation	Sinusitis (6), expectorant, enhanced digestion, worms, high blood pressure, aromatic use	11/ 1,5,6,7,9,10,14,17	0.9	54.5	32.3
Ocimum basilicum L.	395/ R010086742 (SE)/ 2023	**manjericão**	He	Le	Infusion	Oral intake, topical application	Pain (4), inflammation, aromatic use, bath	12/ 1,4,5,6,7,9,10,17	0.5	33.3	35.2
Ocimum basilicum var. purpurascens Benth.	5/ EAC00058556 (NE)/ 2015	**manjericão roxo**	He	Le	Infusion	Oral intake, inhalation	Expectorant (1), aromatic use	1/ 17,14	0.5	100	2.9
Origanum majorana L.	50/ RB01437505 (SE)/ 2019	**manjerona**	He	Le	Infusion	Inhalation	Sinusitis	2/ 1,17	0.2	100	5.9
Origanum vulgare L.	115/ RB01398041 (S)/ 2017	**orégano**	He	Le	Infusion	Oral Intake	Abdominal cramps (2), aromatic use	2/ 7,14	0.4	100	5.9
Pogostemon cablin (Blanco) Benth.	16/ EVB00003676 (S)/ 2018	**patchouli**	Sh	Le	Essential oil	Topical application	Wounds (1), aromatic use (1)	2/ 1,4	0.3	50	5.9
Salvia officinalis L.	116/ FURB57477 (S) 2017	**sálvia**	He	Le	Infusion	Oral intake	Anxiety (2), hyperglycemia, high cholesterol, aromatic use	2/ 9,17	0.6	100	5.9
Lauraceae Juss.											
Nectandra hihua (Ruiz & Pav.)	267/ RB01471487 (S)/ 2022	**sassafráz**	Tr	Ro	Infusion	Oral intake	Pain (1), aromatic use (1)	1/ 17,10	0.6	100	2.9
Cinnamomum verum J. Presl	224/ HJ00008186 (CW)/ 2023	**canela**	Tr	Ba	Decoction	Oral intake	Vomiting (5), anxiety, high blood pressure, hyperglycemia, enhanced diuresis, abortive, aromatic use	14/ 1,3,7,9,10,14,17	1.2	35.7	41.1
Laurus nobilis L.	99/ BHZB00008304 (SE)/ 2019	**louro**	Tr	Le	Infusion	Oral intake, inhalation	Abdominal cramps (5), flu, sinusitis, enhanced diuresis, high cholesterol, aromatic use	16/ 1,3,7,9,10,14,17	0.9	31.2	47.1

Lythraceae J.St.-Hil.											
Punica granatum L.	268/ RB01542480 (SE)/ 2023	**romã**	Sh	Fr	Decoction	Oral intake	Tonsilitis (1)	1/ 7	0.3	100	2.9
Malvaceae Juss.											
Alcea rosea L.	15/ HUENF00014370 (SE) / 2023	**malva rosa**	He	Le	Infusion	Oral intake, inhalation	Expectorant (4), inflammation, aromatic use	10/ 1,4,7,9,17	0.4	40	29.4
Guazuma ulmifolia Lam.	2267/ MBM00432965 (S)/ 2021	**mutamba**	Tr	Ib	Maceration, oil	Topical application	Hair loss (4)	4/ 1,17	0.2	100	5.9
Pseudobombax marginatum (A.St.-Hil.) A. Robyns	238/ RB01433626 (NE)/ 2019	**embiratanha**	Tr	Ib	Decoction	Oral intake	Inflammation (1), kidney stones (1)	1/ 17	0.3	100	2.9
Melastomataceae Juss.											
Miconia albicans (Sw.) Steud.	3851/ SLUI00009239 (N)/ 2022	**carrasco**	Sh	Le	Infusion	Oral intake	Inflammation (4), pain (4), bath	6/ 3,4,9,17	0.4	66.6	17.6
Meliaceae Juss.											
Carapa guianensis Aubl.	360/ HSTM00016014 (N)/ 2022	**andiroba**	Tr	Se	Oil	Topical application, inhalation	Hair loss (1), antiseptic (1), insect repellent (1), aromatic use (1)	1/ 17	0.6	100	2.9
Monimiaceae Juss.											
Peumus boldus Molina	17/ HUFU00073202 (SE)/ 2017	**boldo do chile**	He	Le	Infusion	Oral Intake	Abdominal cramps (4), enhanced digestion (4), high cholesterol vomiting, hyperglycemia	19/ 1,3,5,6,7,9,10,14,17	0.8	21.1	55.8
Myrtaceae Juss.											
Eucalyptus globulus Labill.	49/ ALCB00057667 (NE)/ 2010	**eucalipto**	Tr	Le	Infusion, oil	Oral intake, inhalation, topical application	Fever (2), flu (2), anxiety, aromatic use	10/ 1,6,7,9,10,14,17	0.6	20	29.4

Eugenia uniflora L.	1495/ HUEFS00236195 (NE) / 2022	**pitangueira**	Tr	Le	Infusion	Oral intake	Prostate hyperplasia (2)	2/ 14,17	0.2	100	5.9
Psidium guajava L.	837/ FLOR00077411 (S)/ 2023	**goiabeira**	Tr	Le	Infusion	Topical application	Hair loss (4)	4/ 17	0.2	100	11.7
Syzygium aromaticum (L.) Merr. & L.M.Perry	69/ RBR00058433 (SE)/ 2023	**cravo da índia**	He	Le	Infusion, essential oil	Topical application, inhalation	Mycoses (3), skin hyperpigmentation, wounds, pain, enhanced digestion, cough, flu, enhanced diuresis, high blood pressure, aromatic use	11/ 1,3,7,14,17	1.6	27.2	32.3
Olacaceae R.Br.											
Ptychopetalum olacoides Benth.	85/ RB01482010 (N)/ 2020	**marapuama**	Tr	Ba	Decoction	Oral Intake	Pain (1), muscle relaxant (1)	1/ 17	0.4	100	2.9
Phytolaccaceae R.Br.											
Petiveria alliacea var. tetrandra (Ortega) Hauman	8/ NY00822586 (NE)/ 2024	**guiné**	He	Le	Infusion, maceration	Topical application	Inflammation (2), bath	5/ 9	0.3	40	14.7
Peperomia transparens Miq.	12/ FURB00076065 (S)/ 2023	**língua de sapo**	He	Le	Infusion	Oral intake	Inflammation (2), high blood pressure	2/ 3,17	0.4	100	5.9
Poaceae Barnhart											
Cymbopogon citratus (DC.) Stapf	213/ EAC0062638 (NE)/ 2019	**capim santo**	Gr	Le	Infusion	Oral intake, essential oil	Anxiety (3), pain, enhanced digestion, aromatic use	4/ 5,14,17	0.6	75	11.7
Ranunculaceae Juss.											
Ranunculus repens L.	45/ UPCB00054991 (S)/ 2023	**botão de ouro**	He	Le	Infusion	Oral intake	Inflammation (1), infections (1), aromatic use (1)	1/ 17	0.5	100	2.9
Rhamnaceae Juss.											

Ziziphus joazeiro (Mart.) Hauenschild	375/ HUEFS00238252 (NE)/ 2019	**juazeiro**	Tr	Le, Fr, Ba	Infusion, maceration	Oral intake, topical application	Dandruff and seborrheic dermatitis (4), hair loss, hyperglycemia	6/ 7,9,14,17	0.5	66.6	17.6
Rosaceae Juss.											
Rubus ulmifolius Schott	12/ RB01471213 (S)/ 2017	**amoreira**	Tr	Le	Infusion	Oral intake	High cholesterol (1), hyperglycemia (1), climacteric (1)	3/ 10,14	0.5	33.3	8.8
Rubiaceae Juss.											
Uncaria tomentosa (Willd. ex Schult.) DC	19/ RFA00060776 (NE)/ 2024	**unha-de-gato**	Cb	Ba, Ro	Decoction	Oral intake	Inflammation (2), infections, tumors, irregular menstruation	2/ 3,17	0.5	100	5.9
Rutaceae Juss.											
Citrus x aurantium L.	8/ IBGE00084043 (S)/ 2018	**laranjeira**	Tr	Fl	Infusion	Oral intake	Anxiety (2), aromatic use	2/ 6	0.3	100	5.9
Pilocarpus microphyllus Stapf ex Wardlew.	188/ IAN194182 (N)/ 2016	**jaborandi**	Tr	Le	Infusion	Topical application	Hair loss (4)	4/ 17	0.2	100	11.7
Ruta graveolens L.	229/ FLOR00076383 (S) / 2022	**arruda**	He	Le	Decoction, maceration, juice	Topical application, oral intake	Pains (3), headache (3), antiseptic (3), bath (3)	12/ 1,3,4,5,7,9,14,17	0.5	25	35.2
Santalaceae R.Br.											
Santalum album L.	1/ Not identified in Reflora - Brazilian Herbaria	**sândalo**	Tr	Ib	Essential oil	Topical application, inhalation	Hair loss (1), inflammation (1), mycosis, dry skin (1), aromatic use (1)	1/ 10	0.5	100	2.9
Sapotaceae Juss.											
Sideroxylon obtusifolium (Roem. & Schult.) T.D.Penn.	700/ FURB00067443 (S)/ 2020	**quixaba**	Tr	Ba	Infusion	Topical application, oral intake	Gastric ulcer (4), wounds	6/ 1,3,7,17	0.3	66.6	17.6

Illicium verum Hook.f.	1/ Not identified in Reflora - Brazilian Herbaria	**anis estrelado**	He	Fr, Se	Infusion	Oral intake	Seborrheic dermatitis and hair loss (2), acne, headache, dizziness, aromatic use	8/ 7,9,10,14,17	0.8	25	23.5
Simmondsiaceae Tiegh.											
Simmondsia chinensis (Link) C.K.Schneid.	15/ ALCB00021169 (NE)/1988	**jojoba**	Sh	Se	Oil	Topical application	Hair loss (1)	1/ 17	0.2	100	2.9
Solanaceae Juss.											
Nicotiana tabacum L.	182/ RB01437145 (SE)/ 2019	**fumo**	He	Le	Maceration	Topical application	Mycosis (1)	1/ 17	0.2	100	2.9
Solanum paniculatum L.	2048/ CEN00116272 (CW)/ 2020	**jurubeba**	Sh	Fr	Juice	Oral intake	Inflammation (1), cough (1)	1/ 17	0.2	100	2.9
Theaceae Mirb.											
Camellia sinensis (L.) Kuntze	56/ RB01525832 (SE)/ 2023	**chá verde**	He	Le	Infusion	Oral intake	Enhanced diuresis (2), appetite suppressant (2), aromatic use	4/ 7,14,17	0.6	50	11.7
Camellia sinensis var. assamica (Royle ex Hook.)	0/ Not identified in Reflora - Brazilian Herbaria	**chá preto**	He	Le	Infusion	Oral intake	Hyperglycemia (1), aromatic use (1)	1/ 17	0.4	100	2.9
Verbenaceae J.St.-Hil.											
***Duranta erecta* L.**	120/ RB01438101 (NE)/ 2019	**pingo de ouro**	Sh	Fr	Infusion	Topical application	Mycosis (1), aromatic use (1)	1/ 7	0.3	100	2.9
Viburnaceae Raf.											
Sambucus nigra L.	214 / RFFP00034952 (SE)/ 2023	**sabugueiro**	Tr	Fl	Infusion	Topical application, oral intake, inhalation	Expectorant (2), acne	2/ 17	0.3	100	5.9
Zingiberaceae Martinov											

Alpinia zerumbet (Pers.) B. L. Burtt & R. M. Sm.	242/ FLOR00076420 (S)/ 2023	**colônia**	Sh	Le, Fl	Decoction	Topical application, oral intake, inhalation	Inflammation (3), fever (3), flu, headache, aromatic use, anxiety	6/ 1,3,6,9,17	0.8	50	17.6
Curcuma longa L.	41 / FLOR00076433 (S) / 2023	**açafrão**	He	Ro	Infusion	Oral intake	High cholesterol (1)	1/ 17	0.2	100	2.9
Zingiber officinale Roscoe	54 / CEN00121133 (CW) / 2022	**gengibre**	He	Ro	Infusion	Topical application, oral intake	Tonsilitis (3)	3/ 7,17	0.2	100	8.8

The table lists species with their vernacular names, growth habits, parts used, preparation methods, and ethnobotanical indices. Botanical identification was verified through the Reflora - Virtual Herbarium (Reflora 2025) and cross-checked with the World Flora Online database (WFO 2025; http://www.worldfloraonline.org) to ensure taxonomic accuracy. Abbreviations: H = Habit; Gr = Grass; He = Herbaceous; Sh = Shrub; Tr = Tree; Cb = Climbers; Le = Leaf; Ba = Bark; Ib = Inner Bark; Fl = Flower; Fr = Fruit; Se = Seed; Ro = Root; Wd = Wood; FC = Frequency of Citation; RPM = Recife public market codes where the species was recorded (1 - Afogados; 2 - Água Fria; 3 - Areias; 4 - Beberibe; 5 - Boa Viagem; 6 - Boa Vista; 7 - Casa Amarela; 8 - Coelhos; 9 - Cordeiro; 10 - Encruzilhada; 11 - Engenho do Meio; 12 - Jordão; 13 - Madalena; 14 - Nova Descoberta; 15 - Pina; 16 - Santo Amaro; 17 - São José; 18 - Torre); N = Number of Citations per Species; N_p = Number of Citations for the Most Frequent Species; RI = Relative Importance; PRK = Percentage of Respondents with Knowledge.

Floristic diversity and botanical composition

A total of 100 medicinal plant species belonging to 50 botanical families were recorded in Recife's public markets (Table 2). Lamiaceae (16 spp.), Fabaceae (14 spp.), and Asteraceae (7 spp.) were the most representative families. Herbaceous species were the most frequent life form (n = 41), followed by trees (n = 39), shrubs (n = 18), and one climber and one grass species. Leaves were the most frequently commercialized plant part (51 citations), followed by flowers (18), bark (16), seeds (7), fruits (6), roots (6), and wood (2). Aromatic use accounted for 56 citations.

Preparation methods were predominantly infusion (70 citations) and decoction (19 citations). Oral administration was the principal mode of use (79 citations), followed by topical applications (37) and inhalation (23).

Ethnobotanical indices

RI values identified *Syzygium aromaticum* (RI = 1.6), *Rosmarinus officinalis* (RI = 1.3), and *Cinnamomum verum* (RI = 1.2) as the most versatile species. *Ocimum campechianum*, *Mentha longifolia* subsp. longifolia, *Mentha spicata*, and *Laurus nobilis* also showed high versatility (RI = 0.9).

FL values reached 100% for several species, including Annona muricata for hyperglycemia and Equisetum arvense for diuretic use. Species with high citation frequencies and lower FL values, such as *Rosmarinus officinalis*, *Peumus boldus*, and *Laurus nobilis*, were associated with multiple therapeutic indications.

PRK values were highest for *Rosmarinus officinalis* (70.6%), *Peumus boldus* (55.8%), *Aloe vera* (52.9%), *Pimpinella anisum* (50%), *Laurus nobilis* (FC = 16), and *Myracrodruon urundeuva* (47.1%).

Therapeutic indications and informant consensus

Therapeutic indications were classified according to ICD-11 body systems (Table 3). Use citations were concentrated in dermatological (n = 109), respiratory (n = 85), and digestive (n = 85) conditions.

High Informant Consensus Factor (ICF) values were recorded for respiratory, nervous, circulatory, digestive, and integumentary systems. A strong positive correlation was observed between ICF values and citation frequency ($\rho = 0.92$; $p < 0.001$).

Lower consensus levels were found for genitourinary and musculoskeletal conditions. *Rosmarinus officinalis*, *Mentha spicata*, *Syzygium aromaticum*, *Aloe vera*, and *Myracrodruon urundeuva* were cited across multiple therapeutic systems.

Table 3. Informant Consensus Factor (ICF) values by therapeutic categories cited by herbalists in Recife's public markets, Pernambuco, Brazil.

Body systems	Number of species/ citations	Therapeutic indication (number of use citations)	Used species	ICF
RDS	20/85	Flu (22), cough (21), expectorant (17), aromatic use for sinusitis (16), inflammation (9)	*Justicia pectoralis* Jacq.; *Dysphania ambrosioides* L. Mosyakin & Clements; *Nasturtium officinale* R.Br.; *Luffa operculata* Cogn.; *Anadenanthera colubrina* (Vell.) Brenan; *Ocimum campechianum* Mill.; *Rosmarinus officinalis* L.; *Mentha longifolia* subsp. longifólia; *Mentha spicata* L.; *Ocimum basilicum* var. purpurascens Benth.; *Origanum majorana* L.; *Laurus nobilis* L.; *Alcea rosea* L.; *Eucalyptus globulus* Labill.; *Syzygium aromaticum* (L.) Merr. & L.M.Perry; *Ranunculus repens* L.; *Solanum paniculatum L.*; *Sambucus nigra* L.; *Alpinia zerumbet* (Pers.) B. L. Burtt & R. M. Sm.	0.77
NSD	4/13	Headache (10), pains (1) dizziness (2)	*Kalanchoe pinnata* (Lam.) Pers.; *Ruta graveolens* L.; *Illicium verum* Hook.f.; *Alpinia zerumbet* (Pers.) B. L. Burtt & R. M. Sm.; *Rosmarinus officinalis* L.	0.75
CSD	9/32	High blood pressure (32)	*Commiphora myrrha* (T. Nees) Engl.; *Vismia guianensis* (Aubl.) Pers.; *Ocimum campechianum* Mill.; *Rosmarinus officinalis*	0.74

			L.; *Aeollanthus suaveolens* Mart. ex Spreng.; *Mentha spicata* L.; *Cinnamomum verum* J. Presl; *Syzygium aromaticum* (L.) Merr. & L.M.Perry; *Peperomia transparens* Miq.	
DSD	23/85	Enhanced digestion (27), vomiting (23), abdominal cramps (18), gastric ulcer (12), tonsillitis (2), inflammation (1), constipation (1), appetite suppressant (1)	Dysphania ambrosioides L. Mosyakin & Clements; *Myracrodruon urundeuva* Allem.; *Kalanchoe pinnata* (Lam.) Pers.; *Pimpinella anisum* L.; *Cynara scolymus* L.; *Baccharis trimera* var. carqueja; *Dianthus caryophyllus* L.; *Maytenus ilicifolia* Mart. ex Reissek; *Mimosa tenuiflora* (Willd.) Poir.; *Bauhinia forficata* Link; *Hibiscus rosa-sinensis* L.; *Lavandula angustifolia* Medik.*; Melissa officinalis* L.; *Mentha longifolia* subsp. longifolia; *Mentha spicata* L.; *Origanum vulgare* L.; *Cinnamomum verum* J. Presl; *Peumus boldus* Molina; *Syzygium aromaticum* (L.) Merr. & L.M.Perry; *Cymbopogon citratus* (DC.) Stapf; *Sideroxylon obtusifolium* (Roem. & Schult.) T.D.Penn.; *Punica granatum* L.; *Zingiber officinale* Roscoe	0.74
SD	31/109	Hair loss (42), acne (18), urticaria (12), skin hyperpigmentation (13), nail growth (1), inflammation (8), antiseptic (5), dandruff and seborrheic dermatitis (7), dry skin (1), skin pigmentosum (2)	*Myracrodruon urundeuva* Allem.; *Anacardium occidentale* L.; *Cocos nucifera* L.; *Aloe vera* (L.) Burm. f.; *Erigeron bonariensis* L.; *Calendula officinalis* L.; *Matricaria chamomilla* L.; *Symphytum officinale* L.; *Caryocar brasiliense* A.St.-Hil.; *Vismia guianensis* (Aubl.) Pers.; *Stryphnodendron adstringens* (Mart.) Coville; *Mimosa tenuiflora* (Willd.) Poir.; *Copaifera langsdorffii* Desf.; *Hibiscus rosa-sinensis* L.; *Trigonella foenum-graecum* L.; *Rosmarinus officinalis* L.; *Mentha longifolia* subsp. Longifólia; *Guazuma ulmifolia* Lam.; *Carapa guianensis* Aubl.; *Psidium guajava* L.; *Syzygium aromaticum* (L.) Merr. & L.M.Perry; *Ranunculus repens* L.; *Ziziphus joazeiro* (Mart.) Hauenschild; *Pilocarpus microphyllus* Stapf ex Wardlew.; *Ruta graveolens* L.; *Santalum album* L.; Simmondsia chinensis (Link) C.K.Schneid.; *Nicotiana tabacum* L.; *Duranta erecta* L.; *Sambucus nigra* L.	0.72
IPOCEC	11/35	Bruises (1), wounds (33), burns (1)	*Caesalpinia leiostachya* (Benth.) Ducke; *Myracrodruon urundeuva* Allem.; *Anacardium occidentale* L.; *Aloe vera* (L.) Burm. f.; *Calendula officinalis* L.; *Symphytum officinale* L.; *Caryocar brasiliense* A.St.-Hil.; *Jatropha gossypiifolia* L.; *Stryphnodendron adstringens* (Mart.) Coville; *Hyptis suaveolens* (L.); *Pogostemon cablin* (Blanco) Benth	0.71
ENMD	15/43	Hyperglycemia (25), high cholesterol (16), climacteric (1), irregular menstruation (1)	*Annona muricata* L.; *Bauhinia forficata* Link; *Rosmarinus officinalis* L.; *Salvia officinalis* L.; *Cinnamomum verum* J. Presl; *Peumus boldus* Molina; *Ziziphus joazeiro* (Mart.) Hauenschild; *Rubus ulmifolius* Schott; *Camellia sinensis* var. assamica (Royle ex Hook.); *Curcuma longa* L.; *Taraxacum officinale* F.H.Wigg.; *Salvia officinalis* L.; *Laurus nobilis* L.; *Peumus boldus* Molina; *Uncaria tomentosa* (Willd. ex Schult.) DC.	0.67
NP	5/12	Prostate hyperplasia (8), uterine and ovarian	*Endopleura uchi* (Huber) Cuatrec.; *Eugenia uniflora L.; Aloe vera* (L.) Burm. f.; *Hymenaea*	0.64

		tumors (3), other tumors (1)	*courbaril* L.; *Uncaria tomentosa* (Willd. ex Schult.) DC.	
MBND	13/33	Aromatic use for anxiety (32), depression (1)	*Alpinia zerumbet* (Pers.) B. L. Burtt & R. M. Sm.; *Pimpinella anisum* L.; *Matricaria chamomilla* L.; *Valeriana officinalis* L.; *Erythrina velutina* Willd.; *Hypericum perforatum* L.; *Lavandula angustifolia* Medik.; *Lavandula latifolia* Medik.; *Ocimum campechianum* Mill.; *Melissa officinalis* L.; *Salvia officinalis* L.; *Cinnamomum verum* J. Presl; *Eucalyptus globulus* Labill.; *Cymbopogon citratus* (DC.) Stapf; *Citrus x aurantium* L.	0.63
CIPD	12/26	Worms (9), scabies (2), other ectoparasites (1), mycoses (13), urinary tract infections (4), fever (7)	*Dysphania ambrosioides* L. Mosyakin & Clements; *Hyptis suaveolens* (L.); *Mentha spicata* L.; *Myracrodruon urundeuva* Allem.; *Anacardium occidentale* L.; *Endopleura uchi* (Huber) Cuatrec.; *Hymenaea courbaril* L; *Carapa guianensis* Aubl.; *Ocimum campechianum* Mill.; *Eucalyptus globulus* Labill.; *Alpinia zerumbet* (Pers.) B. L. Burtt & R. M. Sm.; *Santalum album* L.	0.56
GSD	10/14	Menstrual cramps (7), sexual stimulant (2), inflammation (3), abortive (2)	*Handroanthus impetiginosus* (Mart. ex DC.); *Dianthus caryophyllus* L.; *Erythroxylum vacciniifolium* Mart.; *Endopleura uchi* (Huber) Cuatrec.; *Lamium flexuosum* subsp. flexuosum; *Mentha longifolia* subsp. longifolia; *Cinnamomum verum* J. Presl; *Uncaria tomentosa* (Willd. ex Schult.) DC.; *Sideroxylon obtusifolium* (Roem. & Schult.) T.D.Penn.; *Luffa operculata* Cogn.	0.31
DMSCT	11/15	Analgesic (4), inflammation (9), muscle relaxant (2)	*Ptychopetalum olacoides* Benth.; *Petiveria alliacea* var. tetrandra (Ortega) Hauman; *Peperomia transparens* Miq.; *Handroanthus impetiginosus* (Mart. ex DC.); *Erythroxylum vacciniifolium* Mart.; *Pterodon emarginatus* Vogel; *Senna occidentalis* (L.) Link; *Endopleura uchi* (Huber) Cuatrec.; *Miconia albicans* (Sw.) Steud.; *Syzygium aromaticum* (L.) Merr. & L.M.Perry; *Ptychopetalum olacoides* Benth.	0.29

This table summarizes consensus levels among key informants for major disease categories treated with medicinal plants. Abbreviations: ICF = Informant Consensus Factor; RSD = Respiratory System Diseases; NSD = Nervous System Diseases; CSD = Circulatory System Diseases; DSD = Digestive System Diseases; SD = Skin Diseases; IPOCEC = Injuries, Poisoning or Other Consequences of External Causes; EMND = Endocrine, Nutritional or Metabolic Diseases; NP = Neoplasms; MBND = Mental, Behavioral or Neurodevelopmental Disorders; CIPD = Certain Infectious or Parasitic Diseases; GSD = Genitourinary System Diseases; DMSCT = Diseases of the Musculoskeletal System or Connective Tissue.

Patterns of knowledge distribution and informant consensus

No significant differences were observed in the number of cited species according to sex (Mann-Whitney U; $p > 0.05$) or commercial role (Mann-Whitney U; $p > 0.05$).

Correlation analysis revealed a negative relationship between RI and FL ($\rho = -0.74$) and a positive association between RI and PRK ($\rho = 0.63$).

Structure of therapeutic knowledge revealed by multivariate analysis

Principal Component Analysis (PCA) (Fig. 3A) identified two main components. PC1 was associated with RI and PRK, while PC2 was associated with FL.

Hierarchical Cluster Analysis (HCA) (Fig. 3B) identified three functional groups: (1) respiratory-digestive-anxiety-related species; (2) aromatic and circulatory species with overlapping digestive indications; and (3) dermatological and anti-inflammatory taxa.

Correlation analyses confirmed the inverse relationship between RI and FL and the positive association between RI and PRK.

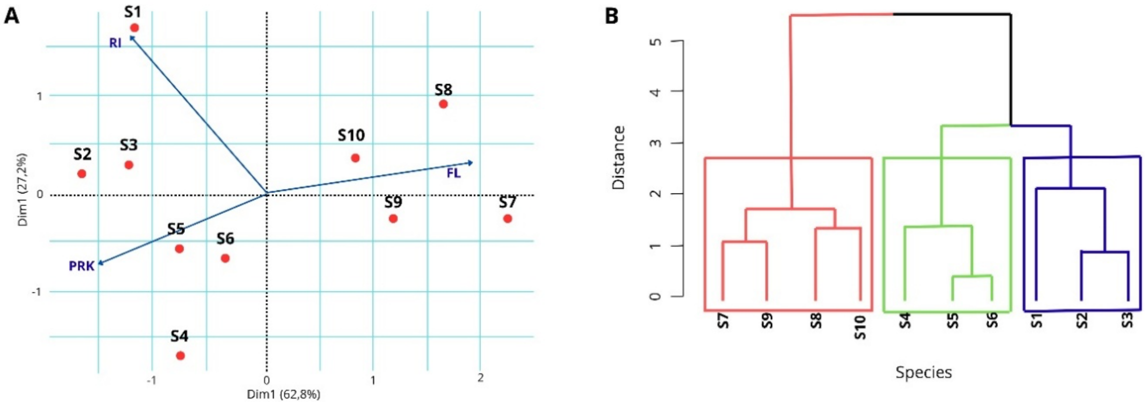

Figure 3. Multivariate analysis of selected medicinal plant species based on ethnobotanical indices and therapeutic uses. (A) Principal Component Analysis (PCA) biplot showing clustering of species according to therapeutic applications; (B) Hierarchical Cluster Analysis (HCA) dendrogram grouping species by similarity in therapeutic categories. Species codes: S1 - *Syzygium aromaticum*; S2 - *Rosmarinus officinalis*; S3 - *Cinnamomum verum*; S4 - *Peumus boldus*; S5 - *Aloe vera*; S6 - *Pimpinella anisum*; S7 - *Stryphnodendron adstringens*; S8 - *Mentha longifolia* subsp. *longifolia*; S9 - *Matricaria chamomilla* L.; S10 - *Alpinia zerumbet*. Blue group: aromatic, digestive, and circulatory plants; green group: dermatological, anti-inflammatory, and digestive plants; red group: respiratory, digestive, and anxiolytic plants.

Regional similarity in medicinal plant composition

Rahman's Similarity Index (RSI) indicated the highest similarity between G1 (PAR 01-02) and G3 (PAR 05-06), followed by moderate similarity between G1 × G2 and G2 × G3 (Table 4).

Table 4. Rahman's Similarity Index (RSI) among the three geographic groups of Recife's public markets.

Comparison	a (Total species in G1)	b (Total species in G2)	c (Total species in G3)	d (Shared species)	RSI (%)
G1 × G2	82	52	44	36	36.7%
G1 × G3	82	44	52	41	48.2%
G2 × G3	52	44	82	26	37.1%

G1 = PAR 01-02 (Central and Northern Recife); G2 = PAR 03-04 (Western and Northeastern Recife); G3 = PAR 05-06 (Southwestern and Southern Recife). RSI values express the percentage similarity in medicinal plant repertoires shared between pairs of regional groups.

Species with high PRK values contributed most to inter-regional similarity, whereas less frequently cited species were associated with cluster-specific distributions.

Regulation and biosafety practices in medicinal plant trade

Quantitative analyses of interview responses and structured field observations also revealed spatial heterogeneity associated with the urban and socioeconomic profiles of Recife's Political-Administrative Regions (PARs). Central markets such as São José Market (PAR 01; Fig. 2A-B), located in Recife's historical commercial district, were characterized by intense consumer circulation, higher concentration of herbalist stalls, wider product diversity, and comparatively more structured commercialization environments. In contrast, markets located in western and mixed residential-commercial sectors, such as Cordeiro Market (PAR 03; Fig. 2C-D), presented intermediate organizational patterns, reflecting the social heterogeneity and transitional urban configuration of these neighborhoods. Northern and northwestern markets, including Casa Amarela Market (PAR 04; Fig. 2E-F), were situated in densely populated areas marked by strong cultural traditions and socioeconomic contrasts, where medicinal plant trade remained highly active but displayed greater variability in storage conditions, packaging practices, and stall organization. Southern markets, associated with areas of real estate expansion and tourism, generally presented lower concentrations of herbalists and more fragmented commercialization dynamics. Together, these observations indicate that local urban context and neighborhood socioeconomic characteristics influenced commercialization structure, product exposure, and biosafety practices across Recife's public markets.

Storage and packaging practices

Storage forms differed significantly among categories ($\chi^2 = 173.09$; $p < 0.001$), with plastic bags representing the predominant packaging method used by traders (Fig. 4). Alternative storage materials such as glass, metal, and sealed paper containers were observed less frequently. Observed exposure conditions varied among markets, particularly regarding ventilation, humidity control, and protection against environmental contamination during commercialization.

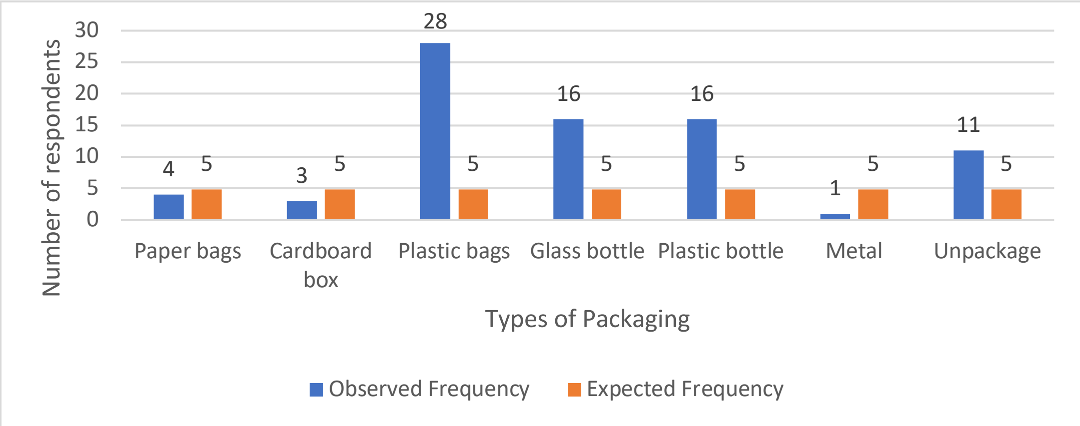

Figure 4. Frequency of packaging reported by herbalist in Recife´s public markets.

Plant origin and traceability

Geographic origin differed significantly among reported supply sources ($\chi^2 = 24.33$; $p < 0.01$), with the Agreste region of Pernambuco representing the most frequently cited origin of medicinal plants commercialized in Recife's public markets (Fig. 5). Traders commonly associated this region with the availability of native and cultivated medicinal species adapted to semi-arid environments, as well as with long-established regional supply networks connecting rural producers, intermediaries, and urban markets.

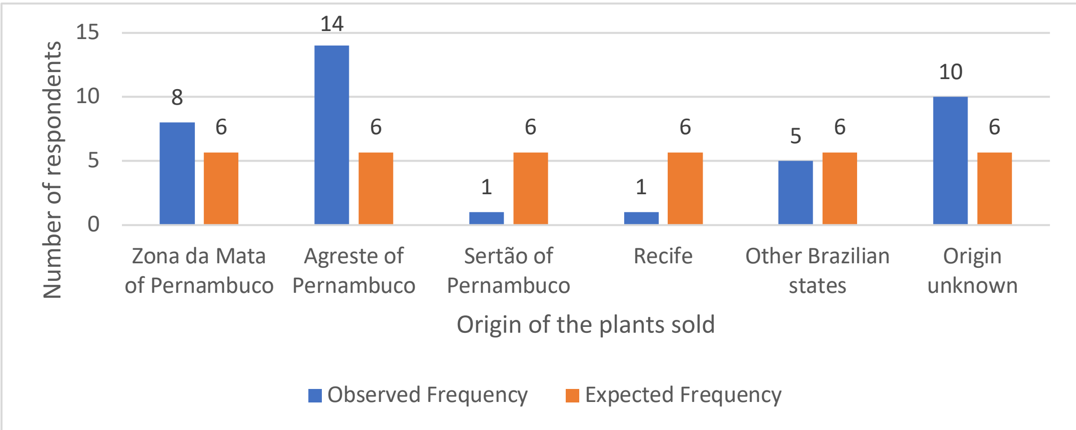

Figure 5. Origin of medicinal plants and traceability information reported by herbalists in Recife's public markets.

Plant sourcing also included materials originating from neighboring municipalities within the Metropolitan Region of Recife, informal urban cultivation, and interstate trade routes involving northeastern commercial distribution centers. However, sourcing information was not uniformly documented among traders. While some herbalists reported specific municipalities or supplier relationships, others referred only to broad geographic regions or were unable to identify precise collection or cultivation sites.

Structured observations further revealed heterogeneous traceability practices among markets, including differences in packaging standardization, supplier identification, and verbal transmission of origin information during commercialization.

Central markets with higher commercial circulation generally presented greater diversity of supply sources, whereas smaller neighborhood markets tended to rely on more localized or informal distribution chains.

Quality control and product handling practices

Significant differences were observed among reported quality control practices used during plant handling and commercialization ($\chi^2 = 44.16$; $p < 0.05$). Observed variables included pest monitoring, humidity and light exposure, packaging sealing, and empirical sensory evaluation. Sensory-based assessment represented one of the most frequently reported practices, whereas structured environmental control measures were less consistently reported across traders (Fig. 6).

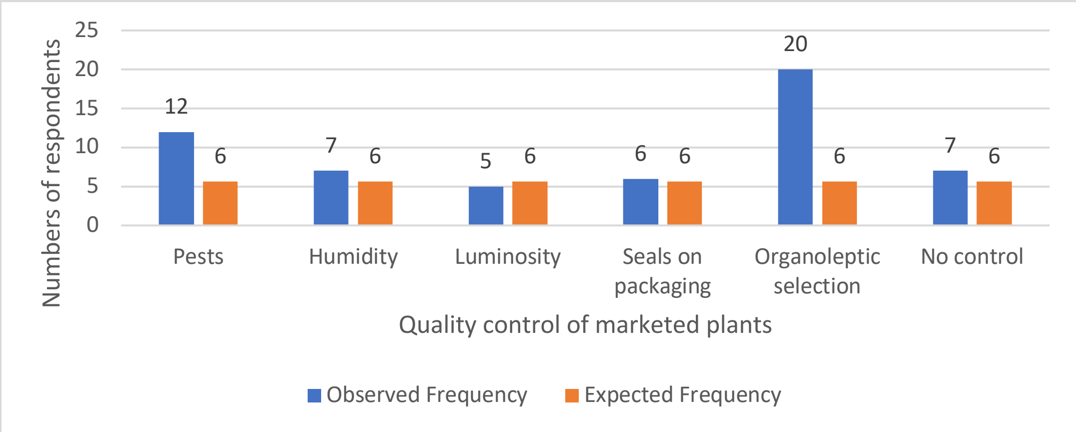

Figure 6. Quality control criteria adopted by herbalists during the commercialization of medicinal plants in Recife's public markets.

Governance practices were also embedded in everyday social interactions, including verbal transmission of product information, reputation-based trust relationships, and shared experiential criteria used by traders and consumers to evaluate medicinal plant quality

Plant parts commercialization

Distribution of plant parts differed significantly among categories (two-way ANOVA: $F = 4.78$; $p < 0.001$), with leaves, bark/stems, and roots representing the most frequently commercialized materials (Fig. 7). No significant differences were observed between fresh and dried commercialization states within individual plant-part categories ($F = 3.90$; $p > 0.05$).

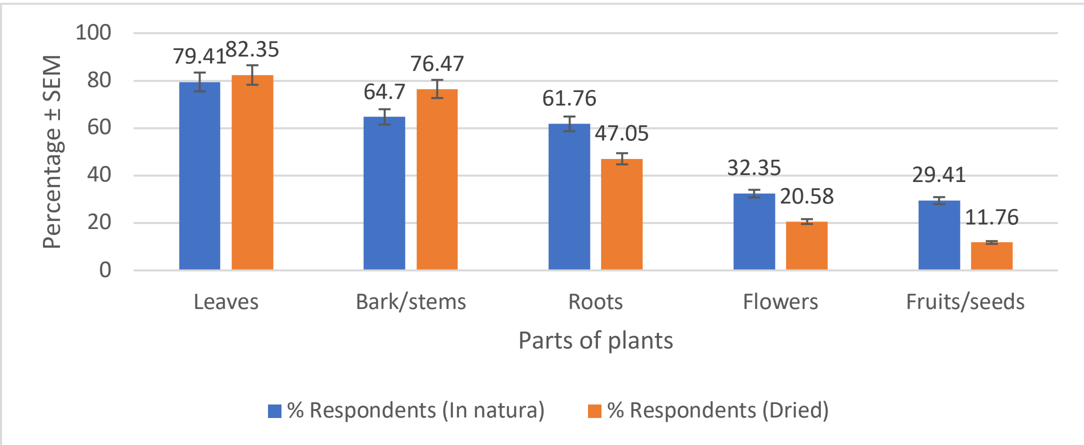

Figure 7. Frequency of plant parts commercialized in Recife's public markets. SEM - Standard Error of the Mean

Botanical identification, labeling, and expiration practices

Significant differences were observed among plant identification categories ($\chi^2 = 47.71$; $p < 0.05$). Products without standardized labeling were more frequent than those with printed tags or formal identification (Fig. 8).

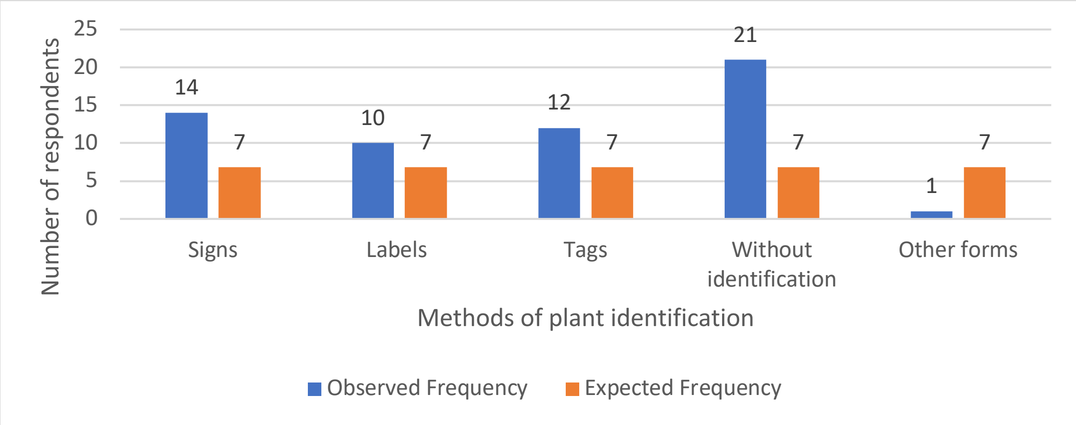

Figure 8. Distribution of plant identification methods and medicinal plant products commercialized in Recife's public markets.

Most traders identified species based on vernacular names and sensory attributes such as odor, color, and texture. No significant differences were observed among categories regarding the presence of expiration information ($\chi^2 = 1.34$; $p > 0.05$).

Nevertheless, the absence of technical labeling or formal identification systems did not correspond to a complete lack of plant identification, since most traders recognized and commercialized the species based on vernacular names and sensory attributes such as odor, color, and texture (Fig. 6). This indicates that botanical identification within Recife's public markets is predominantly structured around traditional nomenclature systems and experiential knowledge rather than formal taxonomic or regulatory frameworks.

No statistically significant differences were observed among categories regarding the presence of expiration information ($\chi^2 = 1.34$; $p > 0.05$), indicating a homogeneous distribution of validity-related practices among traders. Interview responses revealed variability in how product shelf life was communicated, including written indications on packages, verbal guidance provided at the time of purchase, and complete absence of temporal information.

Discussion

The medicinal plant trade in Recife’s public markets is structured around a predominantly female and aging workforce, a pattern widely documented in ethnobotanical studies in Brazil and other tropical regions. This demographic configuration reflects gendered processes of knowledge transmission in which therapeutic practices are maintained through intergenerational learning networks and long-term engagement in market activities (Voeks, 2007; Albuquerque et al. 2007; Medeiros & Albuquerque 2012; Ribeiro et al. 2014; Saraiva et al. 2015; Ferreira et al. 2021; Mantuan & Sannomiya 2024; Silva et al. 2025). The positive association between age and stall ownership reinforces the role of accumulated experience, client trust, and social recognition in shaping commercial autonomy, as observed in urban markets in the Amazon, Caatinga, Suriname, and South Africa (Silva et al. 2005; van Andel et al. 2007; Moeng & Potgieter 2011; Cordeiro & Félix 2014; Lima et al. 2016; Macedo et al. 2018; van Wyk et al. 2018; Magalhães et al. 2019; De La Cruz et al. 2020). At the same time, the limited participation of younger traders raises concerns about the continuity of traditional knowledge systems under conditions of rapid urban transformation (Oluka 2024; Ramavhunga 2025).

Low levels of formal schooling did not limit the complexity of the medicinal repertoire, indicating that traditional medical knowledge is primarily structured through experiential and practice-based learning rather than institutional education. Similar patterns have been reported in Brazil, Uganda, and Pakistan, where specialization is more strongly associated with daily commercial activity and social validation than with formal training (Macêdo et al. 2016; Macedo et al. 2018; Ajaib et al. 2021; Asiimwe et al. 2021; Bibi et al. 2022; Huma et al. 2023). Ethnographic observations further indicated that medicinal plant commercialization involved continuous interpersonal interactions in which traders provided therapeutic recommendations, preparation instructions, and informal health guidance to consumers during routine commercial exchanges. These interactions reinforced relations of trust and contributed to the circulation and maintenance of traditional therapeutic knowledge within urban public market environments (Acosta et al. 2021; Ferreira et al. 2021). In this context, Recife’s public markets operate simultaneously as economic arenas and as spaces for production, circulation, and validation of therapeutic knowledge.

The predominance of empirical botanical identification based on organoleptic criteria and vernacular nomenclature demonstrates a locally coherent classification system adapted to the commercialization of fragmented or processed plant material. Although distinct from academic taxonomic procedures, this strategy functions as an efficient mechanism within the dynamics of traditional markets, where rapid recognition, sensory evaluation, and customer trust are central to trade (Leonti et al. 2002; Albuquerque et al. 2014; Otieno et al. 2015; Koroma et al. 2026). The significant differences among identification forms indicate heterogeneous levels of product standardization, while the uniformly low incorporation of expiration information reinforces the informal character of regulatory practices (Wang et al. 2023; Dawoud & Abdalbagi 2025).

Biosafety conditions, including storage, packaging, and traceability, were characterized by operational variability. Rather than indicating the absence of quality control, these patterns suggest the coexistence of formal and informal regulatory mechanisms grounded in long-term client relationships, experiential assessment of product integrity, and locally negotiated commercial norms. Governance practices were also embedded in everyday social interactions, including verbal transmission of product information and shared experiential criteria used by traders and consumers to evaluate medicinal plant quality. In this context, medicinal plant trade governance emerges through hybrid arrangements involving partial state regulation, market-based trust systems, and traditional knowledge practices operating simultaneously within Recife's public markets. These dynamics indicate that regulatory practices are continuously negotiated through localized social interactions shaped by the socioeconomic and spatial heterogeneity of urban markets. Similar socially negotiated quality systems have been described in traditional medicinal plant markets in Brazil and internationally, where informal mechanisms ensure commercial credibility in the absence of standardized certification protocols (Brandão et al. 2013; van Andel & Fundiko 2016; Rasethe et al. 2019; Ajoseh & Odejimi 2024; Lindberg et al. 2023). This situation reflects persistent challenges in the implementation of Brazil's National Policy on Medicinal Plants and Herbal Medicines and parallels regulatory gaps reported in other urban ethnopharmacopoeias (Brito et al. 2016; Carvalho et al. 2018; Habmorab et al. 2020; Cota et al. 2024).

The heterogeneity observed among Recife's public markets demonstrates that urban medicinal plant trade is shaped not only by cultural traditions but also by socio-spatial inequalities and distinct urban commercial configurations. Central markets with intense circulation and consolidated commercial infrastructure differed substantially from peripheral neighborhood markets regarding organization, product exposure, and biosafety practices, highlighting the importance of local urban context in structuring ethnopharmacological systems. Markets such as São José and Casa Amarela exhibited greater commercial density, higher product turnover, and more structured display patterns, whereas smaller neighborhood markets showed more variable storage, packaging, and traceability conditions associated with localized commercialization dynamics and infrastructure availability. Similar relationships between urban structure, market organization, and traditional medicinal plant trade have been documented in urban ethnobotanical systems in Latin America, Africa, and Asia (van Andel et al. 2007; Moeng & Potgieter 2011; Zhang et al., 2026).

The predominance of leaves, bark/stems, and roots among the commercialized plant parts reflects both ecological availability and therapeutic versatility, as documented in ethnobotanical studies in the Caatinga, Amazonia, and other tropical regions (van Andel et al. 2007; Santos et al. 2012; Madeiro & Lima 2015; Lima et al. 2016; Macêdo et al. 2016; Magalhães et al. 2019). Leaves are frequently preferred because they are easily collected, rapidly regenerated, and commonly associated with aromatic and bioactive compounds used in infusions and topical preparations. In contrast, bark and roots are generally linked to more concentrated therapeutic preparations and longer storage potential, although their extraction may impose greater ecological pressure on harvested species, particularly under conditions of intensive commercialization (El-Saadony et al. 2025). Significant differences among plant-part categories therefore reflect not only therapeutic demand and commercial logistics, but also distinct patterns of resource accessibility, preservation, and extraction intensity within urban medicinal plant supply chains. The absence of differences between fresh and dried forms suggests functional equivalence in commercialization strategies and contributes to year-round availability, reinforcing the adaptive capacity of urban medicinal plant markets (Hilonga et al. 2019; Acosta et al. 2019; Ferreira et al. 2021).

The diversity of therapeutic indications structured according to ICD-11 body systems demonstrates the broad scope of the local pharmacopoeia and its strong orientation toward the treatment of respiratory, digestive, integumentary, inflammatory, and metabolic conditions. This distribution mirrors patterns documented across Northeastern Brazil and other tropical regions and reflects the convergence between culturally salient health priorities and the epidemiological profile of primary health care (Agra et al. 2008; Macedo et al. 2018). The high cultural prominence of certain species, expressed through ethnobotanical indices, indicates a shared core repertoire stabilized through collective experiential validation and occasionally supported by pharmacological evidence (Gurib-Fakim 2001; Tardío & Pardo-de-Santayana 2008; Ghasemian et al. 2016; Déciga-Campos et al. 2021; Domingo-Fernández et al. 2023).

Notably, several of the most versatile and culturally prominent species identified in the study, including *Rosmarinus officinalis*, *Mentha* spp., *Syzygium aromaticum*, and *Cinnamomum verum*, are exotic taxa widely incorporated into Brazilian urban pharmacopoeias. Their high versatility may be associated with broad therapeutic reputations, strong sensory characteristics such as aroma and flavor, long shelf-life after drying, and continuous availability through commercial cultivation and interstate trade networks (Silva et al. 2024). Many of these species are also integrated into culinary practices, facilitating their simultaneous circulation as food, spice, and medicinal resources within urban households (Mojica et al. 2026). The prominence of exotic species in Recife's public markets therefore reflects not only therapeutic uses, but also historical processes of cultural exchange, commercialization, and adaptation of urban medicinal repertoires to widely accessible plant resources.

The integration of ethnobotanical indices, multivariate analyses, and spatial similarity measures revealed a structured pharmacopoeia organized around therapeutic function rather than botanical affinity, a pattern consistent with functional classification systems described in ethnobiology (Berlin 1992; Albuquerque et al. 2014; Gras et al. 2021; Cabrera-Meléndez et al. 2022; Domingo-Fernández et al. 2023). The balance between versatile and specialized species, reflected in the negative relationship between RI and FL and the positive association between RI and PRK, corresponds to diffusion-specialization trade-offs reported in Brazil, Pakistan, Morocco, and Greece (Cordeiro & Félix 2014; Tsioutsiou et al. 2019; Ajaib et al. 2021; Ghabbour et al. 2023). Spatial overlap in species composition among market regions further indicates the existence of a cohesive urban pharmacopoeia maintained through redistributive trade networks, similar to patterns described in Suriname, Mexico, and South Africa (van Andel et al. 2007; Camou-Guerrero et al. 2008; Moeng & Potgieter 2011).

Taken together, these findings position Recife's public markets as dynamic socioecological systems in which biodiversity, cultural knowledge, and livelihoods are continuously co-produced. From an urban ethnobiology perspective, these markets function as arenas of biocultural resilience where traditional medical systems persist through hybrid forms of governance and adaptive commercial strategies (Emery & Hurley 2016; Ladio et al. 2023). The dynamics of medicinal plant commercialization were closely associated with the urban contexts in which markets were embedded. Central markets functioned as major redistributive hubs characterized by intense consumer circulation, greater diversity of medicinal species, and more consolidated commercial structures, whereas neighborhood and peripheral markets operated on smaller spatial scales and maintained stronger relationships with local community demands and informal social networks. In socioeconomically heterogeneous regions, medicinal plant trade also represented an important component of local subsistence economies and culturally rooted therapeutic practices. These patterns reinforce the role of Recife's public markets not only as commercial environments but also as socially embedded spaces where traditional knowledge, urban livelihoods, and regional supply networks continuously interact. Strengthening participatory regulatory approaches that integrate biosafety standards with local expertise may enhance sustainability without undermining the cultural autonomy that sustains these knowledge systems (Arjona-García et al. 2021; Visseren-Hamakers & Kok 2022; Albuquerque et al. 2023; Leguia-Cruz et al. 2024).

Beyond documenting species diversity and therapeutic uses, this study advances urban ethnobotany by demonstrating that public markets operate as structured socioecological systems in which pharmacopoeias are functionally organized, knowledge is maintained through redistributive trade networks, and biosafety is governed by socially negotiated regulatory practices.

Conclusion

The trade in medicinal plants in Recife's public markets constitutes a structured and socially legitimized urban ethnobotanical system in which biodiversity, therapeutic knowledge, and commercialization are co-produced through long-term empirical practice and culturally transmitted expertise. Quantitative ethnobotanical indices revealed a functionally organized pharmacopoeia where highly versatile and therapeutically specialized species coexist, forming a resilient therapeutic repertoire adapted to the demands of heterogeneous urban contexts. The marked similarity among markets indicates the operation of redistributive circulation networks that sustain regional integration, while local variations reflect adaptive responses to specific socio-spatial and commercial configurations across Recife's Political-Administrative Regions.

At the same time, inconsistencies in labeling, traceability, and formal quality-control procedures expose persistent biosafety and regulatory gaps, demonstrating that quality governance is largely mediated through socially negotiated practices based on trust, experiential knowledge, and informal regulatory arrangements rather than fully standardized institutional frameworks.

By integrating diversity patterns, knowledge transmission, spatial trade structure, and biosafety practices, this study advances urban ethnobotany beyond descriptive inventories and positions public markets as key socioecological infrastructures for biocultural resilience. Strengthening participatory regulatory strategies capable of articulating sanitary standards with local expertise may contribute to improving sustainability and consumer safety without undermining the cultural legitimacy that sustains traditional medical systems in rapidly transforming urban environments.

Declarations

List of abbreviations: FL - Fidelity Level; ICD-11 - International Classification Diseases; ICF - Informant Consensus Factor; ISCED - International Standard Classification of Education; PAR - Political Administration Regions; PRK - Popular Recognition Knowledge; RI - Relative Importance; RSI - Rahman's Similarity Index.

Ethics approval and consent to participate: Ethics approval and consent to participate: The study was approved by the Research Ethics Committee of the Instituto Federal do Sertão Pernambucano (protocol no. 6.793.694). All participants signed a Free and Informed Consent Form prior to data collection.

Consent for publication: All participants shown in images agreed to have their image published.

Availability of data and materials: All relevant data are included in the manuscript.

Competing interests: Not applicable

Funding: Not applicable

Author contributions: JAAS, PSR, CRRN, KMSB, RHVC, and SMVJ conceptualized the study, conducted fieldwork, performed data analysis, and drafted the original manuscript. RDM and JRCV contributed to data analysis, critical revision, and expansion of the manuscript. All authors read and approved the final version.

Acknowledgements

We are deeply grateful to all research participants, locally known as *raizeiros* (medicinal plant traders), for generously sharing their knowledge, time, and life histories, which made this study possible. We also thank CONVIVA - Mercados e Feiras, the municipal authority of the city of Recife, for authorizing and supporting the field activities conducted in public market spaces. We further acknowledge the Postgraduate Program in Morphotecnology at the Universidade Federal de Pernambuco, Brazil, for its institutional support during the postdoctoral internship of JAAS, during which this research was carried out.

Literature cited

Abreu DB, Santoro FR, Albuquerque UP, Ladio AH, Medeiros PM. 2015. Medicinal plant knowledge in a context of cultural pluralism: A case study in Northeastern Brazil. Journal of Ethnopharmacology 175:124-130. doi: 10.1016/j.jep.2015.09.019.

Acosta ME, Lambaré DA, Ladio AH. 2021. Urban trading of medicinal plants in San Salvador de Jujuy (Argentina): How does species composition vary between different biocultural supply sites? Ethnobiology and Conservation 10:1-25. doi: 10.15451/ec2021-10-10.34-1-25.

Acharya M, Divakar MS, Malabadi RB, Chalannavar RK. 2022. Ethnobotanical survey of medicinal plants used by the Nalike community in the Bantwala taluk of Dakshina Kannada district, Karnataka, India. Plant Science Today 9:461-468. doi: 10.14719/pst.1470.

Agra MF, Silva KN, Basílio IJLD, Freitas PF, Barbosa-Filho JM. 2008. Survey of medicinal plants used in the region Northeast of Brazil. Revista Brasileira de Farmacognosia 18:472-508.

Ajoseh SM, Raji SO, Odejimi IO. 2024. Medicinal herb traders in southwest Nigeria. In: Adebayo OO, Oluyomi AO. (eds). The African Informal Economy: Structure and Dynamics. Brill, Leiden, Netherlands. doi: 10.1163/9789004692657_009.

Albuquerque UP, Monteiro JM, Ramos AA, Amorim ELC. 2007. Medicinal and magic plants from a public market in Northeastern Brazil. Journal of Ethnopharmacology 110:76-91. doi: 10.1016/j.jep.2006.09.010.

Albuquerque UP, Lucena RFP, Cunha LVFC. 2010. Métodos e Técnicas na Pesquisa Etnobiológica e Etnoecológica. NUPEEA, Recife, Brazil.

Albuquerque UP, Cunha LVSC, Lucena RFP, Alves RRN. 2014. Methods and Techniques in Ethnobiology and Ethnoecology. Springer, New York, U.S.A. doi: 10.1007/978-1-4614-8636-7.

Albuquerque UP, Ladio A, Almada E, Vandebroek I, Silva MTP, Fonseca-Kruel VS. 2023. Exploring biocultural diversity in urban ecosystems: an ethnobiological perspective. Ethnobiology and Conservation 12:1-12. doi: 10.15451/ec2023-06-12.10-1-12.

Ajaib M, Ishtiaq M, Bhatti KH, Hussain I, Maqbool M, Hussain T, Mushtaq W, Ghani A, Azeem M, Khan SMR, Thind S, Bashir R. 2021. Inventorization of traditional ethnobotanical uses of wild plants of Dawarian and Ratti Gali areas of District Neelum, Azad Jammu and Kashmir, Pakistan. PLoS One 16:e0255010. doi: 10.1371/journal.pone.0255010.

Andrade-Cetto A, Heinrich M. 2011. From the field into the lab: useful approaches to selecting species based on local knowledge. Frontiers in Pharmacology 2:20. doi: 10.3389/fphar.2011.00020.

Arjona-García C, Blancas J, Beltrán-Rodríguez L, Binnqüist CL, Bahena HC, Moreno-Calles AI, Sierra-Huelsz JA, López-Medellín X. 2021. How does urbanization affect perceptions and traditional knowledge of medicinal plants? Journal of Ethnobiology and Ethnomedicine 17:48. doi: 10.1186/s13002-021-00473-w.

Asiimwe S, Namukobe J, Byamukama R, Imalingat B. 2021. Ethnobotanical survey of medicinal plant species used by communities around Mabira and Mpanga Central Forest Reserves, Uganda. Tropical Medicine and Health 49:1-14. doi: 10.1186/s41182-021-00321-9.

Astutik S, Pretzsch J, Kimengsi JN. 2019. Asian medicinal plants' production and utilization potentials: a review. Sustainability 11:5483. doi: 10.3390/su11195483.

Benyaich A, Zaaboul F, Aksissou M. 2025. Exploring medicinal plant diversity and traditional healthcare in Nador (Morocco) through ethnobotanical and pharmacological perspectives. Moroccan Journal of Biological Sciences 1:1-7.

Berlin B. 1992. Ethnobiological Classification: Principles of Categorization of Plants and Animals in Traditional Societies. Princeton University Press, Princeton, NJ

Bibi F, Abbas Z, Harun N, Perveen B, Bussmann RW. 2022. Indigenous knowledge and quantitative ethnobotany of the Tanawal area, Lesser Western Himalayas, Pakistan. PLoS One 17:e0263604. doi: 10.1371/journal.pone.0263604.

Bitu VCNV, Bitu VCNV, Matias EF, Lima WP, Portelo AC, Coutinho HD, Menezes IR. 2015. Ethnopharmacological study of plants sold for therapeutic purposes in public markets in Northeast Brazil. Journal of Ethnopharmacology 172:265-272. doi: 10.1016/j.jep.2015.06.022.

Brandão M, Cosenza GP, Pereira FL, Vasconcelos AS, Fagg CW. 2013. Changes in the trade in native medicinal plants in Brazilian public markets. Environmental Monitoring and Assessment 185:7013-7023. doi: 10.1007/s10661-013-3081-y.

Brito MCA, Godinho JWLS, Ferreira TTD, Luz TRSA, Leite JAC, Moraes DFC, Amaral FMM. 2016. Trade and quality control of medicinal plants in Brazil. International Journal of Pharmacy and Pharmaceutical Sciences 8:32-39. doi: 10.22159/ijpps.2016v8i10.12983.

Cabrera-Meléndez JL, Iparraguirre-León D, Way M, Valenzuela-Oré F, Montesinos-Tubée DB. 2022. The applicability of similarity indices in an ethnobotanical study of medicinal plants from three localities of the Yunga district, Moquegua region, Peru. Ethnobotany Research and Applications 24:1-18. doi: 10.32859/era.24.16.1-18.

Carvalho ACB, Lana TN, Perfeito JPS, Silveira D. 2018. The Brazilian market of herbal medicinal products and the impacts of the new legislation on traditional medicines. Journal of Ethnopharmacology 212:29-35. doi: 10.1016/j.jep.2017.09.040. Epub 2017 Oct 4. PMID: 28987598.

Casagrande A, Ritter MR, Kubo, R.R. 2023. Traditional knowledge in medicinal plants and intermedicality in urban environments: a case study in a popular community in southern Brazil. Ethnobotany Research and Applications 25:1-34. doi: 10.32859/era.25.35.1-34.

Cordeiro J, Félix L. 2014. Conhecimento Botânico Medicinal sobre Espécies Vegetais Nativas da Caatinga e Plantas Espontâneas no Agreste da Paraíba, Brasil. Revista Brasileira de Plantas Medicinais 16:685-692.

Cota BB, Alves JC, Caux AA, Passagli LC, Castro AK, Luz TC. 2024. Use of herbal medicinal products among patients in primary health care in a Brazilian southeastern city: evidence from the Prover Project. einstein (São Paulo) 22:eAO0827. doi: 10.31744/einstein_journal/2024AO0827.

Dapar MLG, Alejandro GJD, Meve U, Arrabal-Jr GA, Reano CE, Pelser PB. 2020. Quantitative ethnopharmacological documentation and molecular confirmation of medicinal plants used by the Manobo tribe of Agusan del Sur, Philippines. Journal of Ethnobiology and Ethnomedicine 16:14. doi: 10.1186/s13002-020-00363-7.

Dawoud A, Abdalbagi M. 2025. Standardization of Medicinal Plants: Ensuring Quality, Safety, and Global Regulatory Compliance in Herbal Drug Development. Plant Biotechnology Persa 7:22-23. doi: 10.61882/pbp.7.4.12.

Déciga-Campos M, Beltrán-Villalobos KL, Aguilar-Mariscal H, González-Trujano ME, Ángeles-López GE, Ventura-Martínez R. 2021. Synergistic herb-herb interaction of the antinociceptive and anti-inflammatory effects of *Syzygium aromaticum* and Rosmarinus officinalis combination. Evidence-Based Complementary and Alternative Medicine 2021:8916618. doi: 10.1155/2021/8916618.

De La Cruz P, Bello E, Muñoz LA, Lugo EE, Arce-Ibarra A, García-Barrios L. 2020. Traditional knowledge in the Colombian Amazon: tensions between Indigenous territorial autonomy and environmental governance. Pp. 29-47. In: Ibarra MA, et al. (eds). Socio-Environmental Regimes and Local Visions: Transdisciplinary Experiences in Latin America. Springer, Cham, Switzerland.

Dutta T, Anand U, Saha SC, Mane AB, Prasanth DA, Kandimalla R, Proćków J, Dey A. 2021. Advancing urban ethnopharmacology: a modern concept of sustainability, conservation and cross-cultural adaptations of medicinal plant lore in the urban environment. Conservation Physiology 9:1. doi:10.1093/conphys/coab073.

El-Saadony MT, Saad AM, Mohammed DM, Alkafaas SS, Abd El-Mageed TA, Fahmy MA, Ezzat Ahmed A, Algopishi UB, Abu-Elsaoud AM, Mosa WFA, AbuQamar SF, El-Tarabily KA. 2025. Plant bioactive compounds: extraction, biological activities, immunological, nutritional aspects, food application, and human health benefits-A comprehensive review. Frontiers in Nutrition 19;12:1659743. doi: 10.3389/fnut.2025.1659743.

Emery MR, Hurley PT. 2016. Ethnobiology in the city: embracing the urban ecological moment. Journal of Ethnobiology 36:807-819. doi: 10.2993/0278-0771-36.4.807.

Ferreira C, Venâncio W, Sá LACM. 2017. Mapeamento Colaborativo: Identificação Espacial de Creches e Abrigos no Município de Recife. Pp. 373-377. In: SBC (ed). Anais do XXVII Congresso Brasileiro de Cartografia e XXVI Exposicarta. Sociedade Brasileira de Cartografia, Rio de Janeiro, Brazil.

Ferreira EC, Lucena RFP, Bussmann RW, Zambrana YNP, Cruz DD. 2021. Temporal assessment of the medicinal plants trade in public markets of the state of Paraíba, northeastern Brazil. Journal of Ethnobiology and Ethnomedicine 17:70. doi: 10.1186/s13002-021-00496-3.

Ghabbour I, Ghabbour N, Khabbach A, Louahlia S, Hammani K. 2023. Ethnobotanical statistics of disease groups treated by medicinal plants used in the province of Taza (Northern Morocco). Ethnobotany Research and Applications 26:1-22. doi: 10.32859/era.26.65.1-22.

Ghasemian M, Owlia S, Owlia MB. 2016. Review of anti-inflammatory herbal medicines. Advances in Pharmacological Sciences 2016:9130979. doi: 10.1155/2016/9130979.

Goodman LA. 2011. On respondent-driven sampling and snowball sampling in hard-to-reach populations and snowball sampling not in hard-to-reach populations. Sociological Methodology 41:347-353. doi: 10.1111/j.1467-9531.2011.01242.x.

Gras A, Hidalgo O, D'Ambrosio U, Parada M, Garnatje T, Vallès J. 2021. The Role of Botanical Families in Medicinal Ethnobotany: A Phylogenetic Perspective. Plants 10:163. doi: 10.3390/plants10010163.

Habimorad PHL, Catarucci FM, Bruno VHT, Silva IB, Fernandes VC, Demarzo MMP, Spagnuolo RS, Patricio KP. 2020. Implementation of Brazil's National Policy on Complementary and Integrative Practices: strengths and weaknesses. Ciência & Saúde Coletiva 25:395-405. doi: 10.1590/1413-81232020252.11332018.

Heinrich M, Kufer J, Leonti M, Pardo-de-Santayana M. 2006. Ethnobotany and ethnopharmacology—Interdisciplinary links with the historical sciences. Journal of Ethnopharmacology 107(2):157-160. doi:10.1016/j.jep.2006.05.035.

Hilonga S, Otieno JN, Ghorbani A, Pereus D, Kocyan A, Boer H. 2019. Trade of wild-harvested medicinal plant species in local markets of Tanzania and its implications for conservation. South African Journal of Botany 122:214-224. doi: 10.1016/j.sajb.2018.08.012.

Huma Z, Zareef H, Gul MT, Qureshi R, Aati H, Munazir M. 2023. Application of ethnobotanical indices to document the use of medicinal plants in Tehsil Kallar Syedan, District Rawalpindi, Punjab, Pakistan. Ethnobotany Research and Applications 25:1-29. doi: 10.32859/era.25.49.1-29.

IBM Corp. 2024. IBM SPSS Statistics for Windows, Version 28.0. IBM Corp., Armonk, New York, U.S.A.

Ilie DM, Tudor VC, Berevoianu RL, Micu MM, Dragomir V, Rodino S. 2025. The Influence of Socio-Demographic Factors on the Sustainable Consumption of Organic Vegetables in Romania. Sustainability 17:9874. doi: 10.3390/su17219874.

Koroma L, Alpha M, Kpaka J, Kpaka A. 2022. Organoleptic Evaluation and Physiochemical Characteristics of Powdered Plant Organs of the Traditional Medicinal Plant Caloncoba Echinata. International Journal of Innovation in Engineering 2:14-22. doi: 10.59615/ijie.2.3.14.

Ladio A, Almada E, Vandebroek I, Silva MTP, Fonseca-Kruel VS. 2023. Exploring biocultural diversity in urban ecosystems: an ethnobiological perspective. Ethnobiology and Conservation 12:1-12. doi: 10.15451/ec2023-06-12.10-1-12.

Leguia-Cruz M, Cerda C, Ortiz-Cubillos N, Mansilla-Quiñones P, Moreira-Muñoz A. 2024. Enhancing participatory governance in biosphere reserves through co-creation of transdisciplinary and intergenerational knowledge. Frontiers in Environmental Science 12:1266440. doi: 10.3389/fenvs.2024.1266440.

Leite A, Westengen O, Catarino L, Monteiro E, Mango SP, Indjai B, Cuní-Sanchez A. 2024. From the wild to the market: the trade of edible plants in Guinea-Bissau. Economic Botany 78:390-408. doi: 10.1007/s12231-024-09614-0.

Leonti M, Sticher O, Heinrich M. 2002. Medicinal plants of the Popoluca, México: organoleptic properties as indigenous selection criteria. Journal of Ethnopharmacology 81:307-315. doi: 10.1016/s0378-8741(02)00078-8.

Lima PGC, Coelho-Ferreira M, Santos RS. 2016. Perspectives on medicinal plants in public markets across the Amazon: a review. Economic Botany 70:64-78. doi: 10.1007/s12231-016-9338-y.

Lindberg K, Martvall A, Bastos Lima M, Franca CCS. 2023. Herbal medicine promotion for a restorative bioeconomy in tropical forests: a reality check on the Brazilian Amazon. Forest Policy and Economics 155:103058. doi: 10.1016/j.forpol.2023.103058.

Macêdo DG, Ribeiro DA, Coutinho HDM, Menezes IR, Souza MM. 2015. Práticas terapêuticas tradicionais: uso e conhecimento de plantas do Cerrado no estado de Pernambuco (Nordeste do Brasil). Boletín Latinoamericano y del Caribe de Plantas Medicinales y Aromáticas 14:491-508.

Macêdo DG, Menezes IRA, Lacerda SR, Silva MAP, Ribeiro DA, Macêdo MS, Oliveira LGS, Santos MO, Almeida BV, Macedo JGF, Sousa FFS, Soares MA, Araújo TMS, Souza MMA. 2016. Versatility and Consensus of the Use of Medicinal Plants in an Area of Cerrado in the Chapada do Araripe, Barbalha-CE, Brazil. Journal of Medicinal Plants Research 10:505-514. doi: 10.5897/JMPR2015.5952.

Macedo JGF, Menezes IR, Matias DAR, Silva MOS, Macêdo DG, Matos MJF, Almeida BV, Oliveira LGS, Leite CP, Souza MMA. 2018. Analysis of the variability of therapeutic indications of medicinal species in the Northeast of Brazil: Comparative study. Evidence-Based Complementary and Alternative Medicine 2018:6769193. doi: 10.1155/2018/6769193.

Madeiro AAS, Lima CR. 2015. Estudos etnofarmacológicos de plantas medicinais utilizadas no Brasil: Revisão de literatura. Ciências Biológicas e da Saúde 3:69-76.

Mantuan V, Sannomiya M. 2024. Women and medicinal plants: a systematic review in the field of ethnobotany. Acta Scientiarum. Biological Sciences 46:e70700. doi: 10.4025/actascibiolsci.v46i1.70700.

Marinoni L, Gasper AL, Chiquito EA, Glienke C, Fonseca CB, Juarez KEM, Basílio DS, Henriques DK, Vandresen DALP, Morais GS, Jorge I, Pimenta AD, Dal Molin A, Souto ASS, Santos CRM, Serejo CS, Souza-Motta CM, Attili-Angelis D, Werneck FP, Carvalho FR, Garbino GST, Stehmann JR, Giacomin LL, Jesus MA, Silva M, Fukuda MV, Rosa RS, Costa-Araújo R, Maués MM, Thiengo SC, Silva TRS, Andrade TS, Cavalcanti TB, Dutra VF, Vicente VA. 2024. Introdução e orientações às boas práticas para as coleções biológicas científicas brasileiras. Zoologia: Guias e Manuais Series. Sociedade Brasileira de Zoologia, Curitiba, Brazil. doi: 10.7476/9786587590042.

Magalhães KDN, Guarniz WAS, Sá KM, Freire AB, Monteiro MP, Nojosa RT, Bieski IGC, Custódio JB, Balogun SO, Bandeira MAM. 2019. Medicinal plants of the Caatinga, northeastern Brazil: Ethnopharmacopeia (1980-1990) of the late professor Francisco José de Abreu Matos. Journal of Ethnopharmacology 237:314-353. doi: 10.1016/j.jep.2019.03.032.

McDonald JH. 2023. Handbook of Biological Statistics. 4th edition. Sparky House Publishing, Baltimore, MD, U.S.A.

Medeiros PM, Albuquerque UP. 2012. The pharmacy of the Benedictine monks: The use of medicinal plants in Northeast Brazil during the nineteenth century (1823-1829). Journal of Ethnopharmacology 139:280-286. doi: 10.1016/j.jep.2011.11.014.

Moeng ET, Potgieter M. 2011. The trade of medicinal plants by muthi shops and street vendors in the Limpopo Province, South Africa. Journal of Medicinal Plants Research 5:558-564.

Mojica L, Luzardo-Ocampo I, Fonseca Hernandez D, Fu L, Zhang Q. 2026. Culinary Herbs and Spices: Uses Across the World, Nutritional and Health Benefits. Annu Rev Food Sci Technol. 17(1):155-179. doi: 10.1146/annurev-food-053124-124422.

Molina D. 2021. Urban spaces, plants, and people in nineteenth-century Bogotá, Colombia. Economic Botany 75:268-286. doi: 10.1007/s12231-021-09524-5.

Nguyen VTH, Le-Huynh T, Gadola S, Nguyen Q, Walters G, Owuor MA. 2025. Local-global linkages in biodiversity governance: The regime complex of the Convention on Biological Diversity agenda for nature pledges. Environmental Science & Policy 173:104246. doi: 10.1016/j.envsci.2025.104246.

Oliveira FCS, Vieira FJ, Amorim AN, Barros RFM. 2021. The use and diversity of medicinal flora sold at the open market in the city of Oeiras, semiarid region of Piauí, Brazil. Ethnobotany Research and Applications 22:1-19. doi: 0.32859/era.22.21:1-19.

Oluka A. 2024. The impact of digital platforms on traditional market structures. Technology Audit and Production Reserves 2:21-29. doi: 10.15587/2706-5448.2024.303462.

Otieno J, Abihudi S, Veldman S, Nahashon M, van Andel T, de Boer HJ. 2015. Vernacular dominance in folk taxonomy: a case study of ethnospecies in medicinal plant trade in Tanzania. Journal of Ethnobiology and Ethnomedicine 11:10. doi: 10.1186/1746-4269-11-10.

Pinheiro FC, Forzza RC, Leitman PM, Prado J. 2024. The REFLORA Program: Implementation, repatriation, and creation of the REFLORA Virtual Herbarium as a tool for biodiversity studies. Biota Neotropica 24:e20241701. doi: 10.1590/1676-0611-BN-2024-1701.

R Core Team. 2024. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.r-project.org/ (Accessed 30/04/2025).

Rahman IU, Hart R, Afzal A, Iqbal Z, Ijaz F, Abd Allah EF, Ali N, Khan S, Alqarawi A, Alusubeie M, Bussmann RW. 2019. A new ethnobiological similarity index for the evaluation of novel use reports. Applied Ecology and Environmental Research 17:2765-2777. doi: 10.15666/aeer/1702_27652777.

Ramavhunga N. 2025. How urbanisation impacts the transmission of cultural knowledge and practices from one generation to the next within Vhavenda communities. International Journal of Research in Business and Social Science 14:313-322. doi: 10.20525/ijrbs.v14i5.4054.

Rangel JML, do Nascimento ALB, Ramos MA. 2024. The influence of urbanization on local ecological knowledge: a systematic review. Journal of Ethnobiology and Ethnomedicine 20:106. doi: 10.1186/s13002-024-00747-z.

Rasethe MT, Semenya SS, Maroyi A. 2019. Medicinal plants traded in informal herbal medicine markets of the Limpopo province, South Africa. Evidence-Based Complementary and Alternative Medicine 2019:2609532. doi: 10.1155/2019/2609532.

Recife. 2022. Recife 500 Years: Long-term Strategic Plan for City Development. 2nd edition. Agência Recife de Inovação e Estratégia (ARIES), Recife, Brazil.

Recife. 2025. Caracterização do território. Prefeitura do Recife, Recife, Brazil. https://www2.recife.pe.gov.br/pagina/caracterizacao-do-territorio (Accessed 15/04/2025).

Reflora - Herbário Virtual. 2025. Herbário Virtual Reflora. https://reflora.jbrj.gov.br/reflora/herbarioVirtual/ (Accessed 15/04/2025).

Ribeiro DA, Oliveira LGSD, Macêdo DG, Menezes IRA, Costa JGM, Silva MAP, Lacerda SR, Souza MMA. 2014. Promising medicinal plants for bioprospection in a Cerrado area of Chapada do Araripe, Northeastern Brazil. Journal of Ethnopharmacology 155:1522-1533. doi: 10.1016/j.jep.2014.07.042.

Salmerón-Manzano E, Garrido-Cardenas JA, Manzano-Agugliaro F. 2020. Worldwide Research Trends on Medicinal Plants. International Journal of Environmental Research and Public Health 17:3376. doi: 10.3390/ijerph17103376.

Santos SLDX, Alves RRN, Barbosa JAA, Brasileiro TF. 2012. Plantas utilizadas como medicinais em uma comunidade rural do semiárido da Paraíba, Nordeste do Brasil. Revista Brasileira de Farmácia 93:68-79.

Saraiva R, Ulisses AVR A, Ribeiro DA, Oliveira LGS, Macêdo DG, Sousa FFS, Menezes IRA, Sampaio EVSB, Souza MMA. 2015. Plant species as a therapeutic resource in areas of the savanna in the state of Pernambuco, Northeast Brazil. Journal of Ethnopharmacology 171:141-153. doi: 10.1016/j.jep.2015.05.034.

Silva ACO, Albuquerque UP. 2005. Woody medicinal plants of the Caatinga in the state of Pernambuco (Northeast Brazil). Acta Botanica Brasilica 19:17-26. doi: 10.1590/S0102-33062005000100003.

Silva ASL, Carvalho MLS, Benevides CMJ. 2022. Ethnopharmacological studies in 21st century Brazil: a systematic review. Research, Society and Development 11:e48211225956. doi: 10.33448/rsd-v11i2.25956.

Silva P, Ferreira Júnior W, Zank S, Nascimento A, Abreu M. 2024. The influence of exotic and native plants on illnesses with physical and spiritual causes in the semiarid region of Piauí, Northeast of Brazil. Journal of Ethnobiology and Ethnomedicine. doi: 20. 10.1186/s13002-024-00667-y.

Silva TC, Silva ML, Silva ML, Medeiros PM, Ferreira Júnior WS, Santos JG, Albuquerque UP, Barros BF, Monteiro Rafael L. 2025. The Role of exotic medicinal plants in the treatment of modern diseases: A study at public markets on a global scale. Ethnobotany Research and Applications 32:1-23.

Tsioutsiou EE, Giordani P, Hanlidou E, Biagi M, De Feo V, Cornara L. 2019. Ethnobotanical study of medicinal plants used in Central Macedonia, Greece. Evidence-Based Complementary and Alternative Medicine 2019:4513792. doi: 10.1155/2019/4513792.

Uzun SP, Koca C. 2020. Ethnobotanical survey of medicinal plants traded in herbal markets of Kahramanmaraş. Plant Diversity 42:443-454. doi: 10.1016/j.pld.2020.12.003.

van Andel T, Behari-Ramdas J, Havinga R, Groenendijk S. 2007. The medicinal plant trade in Suriname. Ethnobotany Research and Applications 5:351-372.

van Andel T, Myren B, van Onselen S. 2012. Ghana's herbal market. Journal of Ethnopharmacology 140(2):368-378. doi: 10.1016/j.jep.2012.01.028.

van Andel T, Fundiko MCC. 2016. The trade in African medicinal plants in Matonge-Ixelles, Brussels (Belgium). Economic Botany 70:405-415. doi: 10.1007/s12231-016-9365-8.

van Wyk AS, Prinsloo G. 2018. Medicinal plant harvesting, sustainability and cultivation in South Africa. Biological Conservation 227:335-342. doi: 10.1016/j.biocon.2018.09.018.

Visseren-Hamakers IJ, Kok MTJ (eds). 2022. Cross-cutting issues central to transformative biodiversity governance. In Transforming Biodiversity Governance, pp. 91-218. Cambridge University Press, Cambridge.

Voeks R. 2007. Are women reservoirs of traditional plant knowledge? Gender, Ethnobotany and globalization in northeast Brazil. Singapore Journal of Tropical Geography 28:7-20. doi: 10.1111/j.1467-9493.2006.00273.x.

Wang H, Chen Y, Wang L, Liu Q, Yang S, Wang C. 2023. Advancing herbal medicine: enhancing product quality and safety through robust quality control practices. Frontiers Pharmacology. 25;14:1265178. doi: 10.3389/fphar.2023.1265178.

World Flora Online (WFO). 2025. Snapshots of the taxonomy. https://wfoplantlist.org/ (Accessed 16/07/2025).

World Health Organization (WHO). 2003. Guidelines on good agricultural and collection practices (GACP) for medicinal plants. World Health Organization, Geneva, Switzerland. https://www.who.int/publications/i/item/9241546271 (Accessed 18/05/2026).

World Health Organization (WHO). 2011. Quality control methods for herbal materials. Updated edition. World Health Organization, Geneva, Switzerland. https://www.who.int/publications/i/item/9789241500739 (Accessed 18/05/2026).

World Health Organization (WHO). 2018. ICD-11: International Classification of Diseases and Related Health Problems, Eleventh Revision. WHO, Geneva, Switzerland. https://icd.who.int/ (Accessed 12/01/2025).

Yu D. 2025. Toward integrated urban observatories: Synthesizing remote and social sensing in urban science. Remote Sensing 17:2041. doi: 10.3390/rs17122041.

Zhang Y, Huang B, Shen W, Lv L, Cen X, Saensouk P, Boonma T, Saensouk S, Jitpromma T. 2026. Diversity, Ethnobotanical Knowledge, and Cultural Food Significance of Edible Plants Traded in an Urban Market in Baise City, China. Diversity 18:93. doi: 10.3390/d18020093.