Ethnopharmacological insights into *Uvaria chamae* P.Beauv.: a potential remedy for combating antimicrobial resistance in Benin

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Research

Abstract

Background: Medicinal plants offer a promising avenue for the discovery of novel antimicrobial agents. This study aimed to document the traditional knowledge and applications of *Uvaria chamae* P.Beauv. in the treatment of infectious diseases in Benin.

Methods: An ethnopharmacological survey on practical knowledge of traditional medicine practitioners of *U*. *chamae* in Benin was conducted between June and July 2024, involving 45 traditional medicine practitioners across eight departments of Benin. Key ethnobotanical indices such as Frequency of Citation, Fidelity Index, and Use Value were employed to analyze the data.

Results: The findings reveal a strong consensus among traditional healers regarding the use of *U. chamae* for treating infectious diseases, evidenced by a high-Fidelity Index of 86.66%. The plant is utilized across multiple disease categories, with a Use Value of 1.27. In cases of multi-drug resistance*, U. chamae* is often combined with other plants such as *Garcinia kola* Heckel, *Piper nigrum* L., *Carica papaya* L. and *Allium sativum* L. Remedies based on *U. chamae* are pre-dominantly administered orally (82.61%), with therapeutic responses observed within 1 to 14 days (60.71%), and are generally regarded as non-toxic (63.34%).

Conclusion: The therapeutic properties of *U. chamae* highlight the urgent need for further research to explore its potential as an innovative therapeutic agent in the fight against antimicrobial resistance.

Keywords: Medicinal plants, Traditional practitioners, Infectious diseases, *Uvaria chamae*

Background

Antimicrobial resistance (AMR) is a critical global public health challenge that has intensified in recent years, severely compromising our ability to effectively treat diseases caused by microorganisms (WHO 2014; CDC, 2019). This threat, long anticipated by microbiologists and infectious disease specialists, has been fueled by the overuse of antibiotics for therapeutic

purposes. It is characterized by complex interactions among microbial populations within favorable environments, posing serious risks to human health (Zinsstag *et al*. 2012; So *et al*. 2015; O'Neill 2016; McEwen *et al.* 2018;). AMR is a growing threat to modern medicine, contributing to rising mortality and morbidity rates worldwide. By 2050, it is projected that AMR will impose a staggering economic burden, with costs estimated between USD 300 billion and 1 trillion annually (Naylor *et al*. 2018; Chokshi *et al*. 2019; Dadgostar 2019; Ioannou *et al*. 2023). In 2019 alone, approximately 1.3 million deaths were attributed to multidrug-resistant bacteria (Motayo *et al*. 2013; Witzany *et al.* 2020). Furthermore, over 25% of healthcare-associated infections are now linked to antibiotic resistance. In Nigeria, Benin's neighbor, the prevalence of carbapenem-resistant bacteria ranges between 10% and 36% (Yusuf *et al*. 2014; Ouedraogo *et al*. 2017), while in Benin, a study reported a 19.10% prevalence of multidrug-resistant infections (Anago *et al*. 2015). These alarming statistics underscore the urgent need for effective solutions to manage infectious diseases in Africa, particularly in Benin.

In response to this challenge, scientists have explored various approaches, including antimicrobial peptides, phage therapy, and phytotherapy. While these strategies demonstrate promising efficacy, understanding their precise mechanisms of action remains a significant barrier to their widespread validation. Recognizing the potential of traditional medicine, the World Health Organization (WHO) has advocated for the integration of medicinal plants and traditional remedies as complementary alternatives to modern medicine, especially in Africa where reliance on traditional medicine is deeply ingrained (WHO 2002; Dieye & Sarr 2020). According to WHO estimates, over 80% of the African population depends on the therapeutic virtues of plants for primary healthcare (Akoegninou *et al*. 2006; Agbebi *et al*. 2024).

Benin's rich flora includes thousands of medicinal plants used in treating various ailments (Madiba *et al*. 2023). Among these, *Uvaria chamae* P.Beauv., a member of the *Annonaceae* family, is frequently employed by local communities for its effectiveness in managing infectious diseases (Omotayo *et al*. 2012; Maeda *et al*. 2021; Daï *et al*. 2023). Studies on extracts of *U. chamae* have demonstrated significant antibacterial activity, particularly against *Staphylococcus epidermidis* (IC50 of 7.9 µM) and *Bacillus subtilis* (EC50 of 8.7 µM) (Christopher 2022).

Traditionally, the roots of *U. chamae* are used to treat conditions such as gastroenteritis, wounds, sore throats, vomiting, dysentery, inflamed gums, and even as a contraceptive (Adomou *et al*. 2005). In many African communities, particularly in Benin, traditional healers are custodians of ancestral knowledge, passing down the therapeutic uses of medicinal plants through generations. These healers, who often serve as herbalists, naturopaths, and phytotherapists, play a crucial role in preserving and applying this knowledge. Their involvement in this study aims to uncover the therapeutic potential of *U. chamae* in managing infectious diseases, thereby contributing to the fight against AMR. Additionally, the study will explore how ethnic and religious diversity influences the selection of plant parts, extraction solvents, and preparation methods. Despite its recognized antimicrobial properties, existing research on *U. chamae* has predominantly focused on general scientific data, with limited emphasis on its role in ethnobotanical practices for treating infectious diseases. This gap in knowledge prompts a vital question: how is *U. chamae* perceived and utilized by traditional practitioners in the context of infectious diseases, and what unique applications might enhance our current understanding? A comprehensive ethnobotanical investigation of *U. chamae* could uncover traditional knowledge and specific practices that merit further exploration to optimize its use in combating multidrug-resistant infections. This study aims to document the traditional knowledge and applications of *U. chamae* in the treatment of infectious diseases in Benin.

Materials and Methods

Study area and participants

This study was conducted from June to July 2024 across eight departments of the Republic of Benin: Atacora, Couffo, Collines, Donga, Mono, Ouémé, Plateau, and Zou. The selection of departments is based on the geographical distribution of *U. chamae* in Benin. Indeed, *U. chamae* is a plant that is not found in all the departments of Benin. This plant is reparted in the center and sud Benin. Participants included a diverse group of traditional medicine practitioners, encompassing naturopaths, phytotherapists, and herbalists from twenty-two communes: Agbangnizoun, Aplahoué, Athiémè, Avrankou, Bantè, Bassila, Bohicon, Comè, Djakotomey, Djougou, Glazoué, Grand-Popo, Ifangni, Kérou, Lokossa, Natitingou, Missérété, Ouaké, Ouèssè, Porto-Novo, Savalou, and Savè (Fig. 1).

The study identified four distinct professional categories of traditional medicine practitioners. It concerned naturopaths, phytotherapists, traditional healers and herbalists. Socio-demographic, ethnic, religious, and ecological characteristics of the study area are detailed in Table 1: Demographics, Ethnicity, Religion, and Ecology of study area.

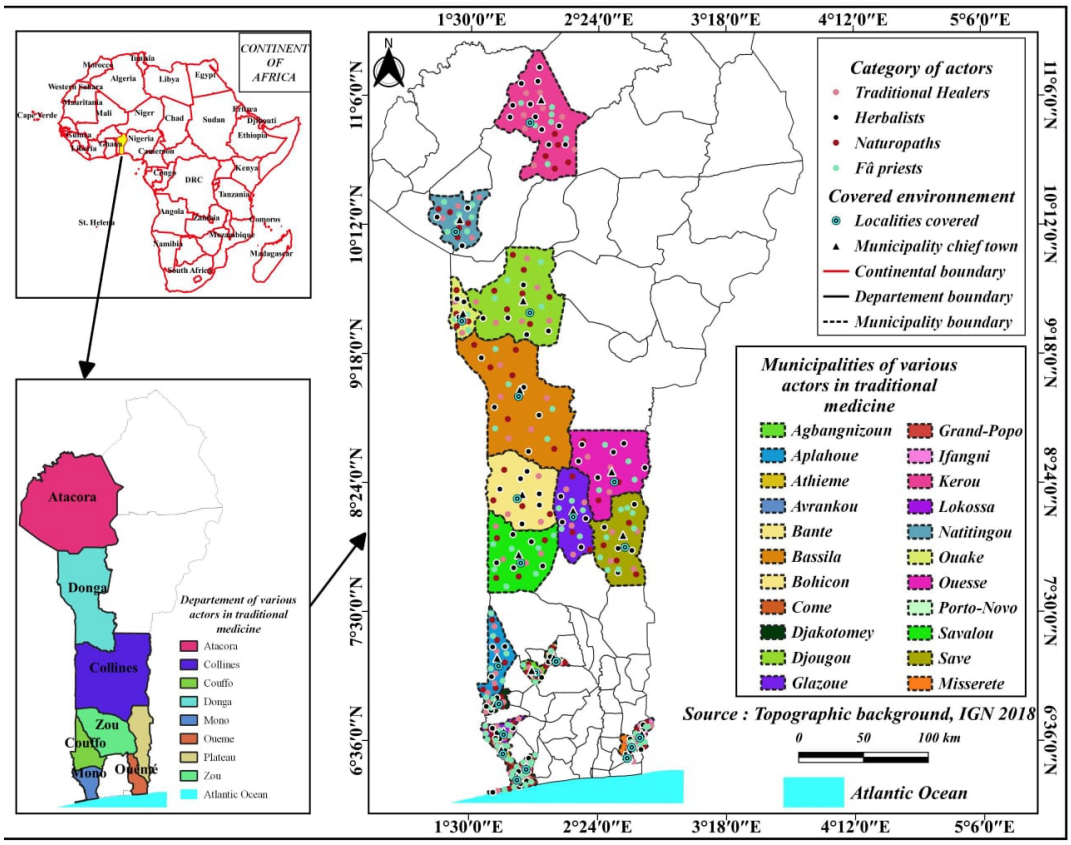


Figure 1. Map showing surveyed areas

Selection of participants

Participants were selected with the assistance of the National Pharmacopoeia and Traditional Medicine Program under the Ministry of Health of the Republic of Benin. These participants comprised traditional medicine practitioners from various legally recognized categories organization within the Republic of Benin who expressed willingness to participate in the study. They included members of National Federation of Associations of Traditional Medicine Actors of Benin (FANAMETRAB), National Federation of Traditional Medicine of Benin (FeNaMeTraB) and National Federation of True Practitioners of Traditional Medicine of Benin (FENAVPraMETRAB).

Only those practitioners who provided informed consent following a detailed presentation of the study's objectives were included. A total of 56 participants (7 per department) were selected on the basis of their experience in the practice of traditional medicine. Following the list provided by the National Pharmacopoeia and Traditional Medicine Program in the Republic of Benin, these actors were contacted for informed consent to participate in the study. At the end of this process, only 45 traditional medicine practitioners were available during the period and agree to participate in the study. The total of 45 traditional medicine practitioners, representing both genders, were interviewed in accordance with the ethical guidelines of the International Society of Ethnobiology (IES) (IES 2008).

Data collection

The study utilized semi-structured interviews to collect data. *Uvaria chamae* plant, including its various parts (leaves, fruits, roots, and bark), was authenticated at the Benin National Herbarium (Voucher No. YH 924/HNB) and presented to participants during interviews (Figure 2). This method involved asking each participant about their knowledge, attitudes, and practices regarding the use of *U. chamae* in managing bacterial infections or infectious diseases caused by pathogenic bacteria of the Republic of Benin.

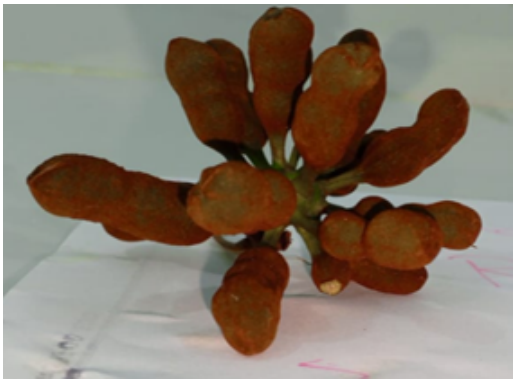
Table 1. Demographics, Ethnicity, Religion, and Ecology of study area

Departments	Atacora	Couffo	Collines	Donga	Mono	Ouémé	Plateau	Zou
Area	20.499 km², with a density of 38 inhabitants per km²	Area of 2.404 km²	Area of 13.931 km²	Area of 11.126 km², with a population density of 49 inhabitants per km².	1,605 km²	Area of 1.281 km²	Area of 3.264 km²	5.243 km²,
Ethnicity	the Gua or Otamari and related 59.3%, the Bariba and related in a proportion of 19.0%; the Fulani or Fulani 12.5%	Adja (88.4%) and Fon (8.3%)	Yoruba and related (46.8%) and Fon and related (39.2%)	These include the Yowa, the Lokpa, the Ani, the Fulani and the Dendi and Yoruba and related groups	Sahouè (39.9%), Kotafon or Tchi (21.3%), Ouatchi (8.2%) and Adja (8.0%).	Fon and related (78.5%), Yoruba and related (10.2%) and Adja and related (7.5%).	The Yoruba and Relatives (Nago) (67.7%), and the Fon (28.9%) are the majority ethnic groups	Fon and related groups (92.4%), Yoruba (3.2%) and Adja (1.7%)
Religion	Islam 26.9%, Catholicism (20.7%), Other traditional religions 18.0%, people with no religion make up 19%	Vodoun (28.3%)	Protestant Methodists (20.7%), other Protestants (12.3%), Catholics (11.5%). Snas religion (10.6%)	Islam (77.99%) and Catholicism (11.9%) are the most important religions	Vodoun (40.5%), Catholics (20.4%) and Other Traditional Religions (13.8%)	Catholicism (37.1%), Celestial Christianity (12.3%), Islam (12.1%). Animism (12.1%)	Protestant Methodist and Other Protestant (19.3%), Celestial (8.6%) and Other Christian (11.3%), Traditional Religion (17.9%)	Vodoun (20.7%), celestial (14.9%), other religions (12.8%). No religion (10.7%)
Number of inhabitants	772,262 inhabitants	524,586 inhabitants, including 244,050 men and 280,536 women, with a density of 218 inhabitants per km².	535,923 inhabitants	543.130 inhabitants	360,037 inhabitants, density of 224.3 inhabitants per km²	730,772 inhabitants, density of 570 inhabitants per km²	293,718 inhabitants with a density of 125 inhabitants per km²	599,954 inhabitants, population density 114.4 inhabitants per km²
Ecology (Climate, Vegetation)	Tropical Sudanian-type climate with two	Sudano-Guinean climate with two rainy seasons and	Four-season Sudano-Guinean climate. A main rainy season (March to	Sudano-Guinean climate with a	A sub-equatorial climate at	Sub-equatorial region with a climate of four seasons of which: two	Sudano-Guinean climate with two rainy seasons, annual rainfall ranging	Sudano-Guinean climate with an

	seasons. Rainy season (April-October), Dry season (November to April), marked by the harmattan. There is an annual rainfall of 1200 to 1350 mm. Vegetation: gallery forests, young fallow land	two dry seasons. Rainfall 800 mm to 1200 mm per year. Relative humidity up to 85%. About 100 days of rain per year with a favorable period of vegetative growth ranging from 210 days to 240 days.	July), a minor dry season (August to September), a minor rainy season (October to November) and a main dry season (December to March) are distinguished. The vegetation is composed of a few classified forests, which are highly threatened by human actions. This makes it favourable to the search for fertile land, the exploitation of timber and firewood.	dry season from mid-October to mid-April; a rainy season from mid-April to mid-October. Precipitation: 1200 mm to 1300 mm (August is the rainiest month. The Ouémé River rises in the Tanéka-Koko region, flowing towards the Atlantic Ocean. Dense vegetation along watercourses: gallery forests. Classified forests: more than half of Bassila. Wooded savannah in Djougou.	four seasons with rainfall varying between 850 mm and 1,160 mm,	main rainy seasons (main season: April - July and short season: October - November) and two dry seasons (short season: August - September and main dry season: December - March). The vegetation is mainly anthropogenic: thicket, shrubby, dense with oil palm and grasses predominating. There is grassy savannah, grasslands, swampy raffia formations and a few Mangroves.	from 800 mm to 1,200 mm in the west of the department and from 1,000 mm to 1,400 mm in the east. Growth vegetative vegetative of less than 240 days in the western part compared to 240 days in the eastern part, northern part	average annual rainfall varying between 900 mm and 1,200 mm of water. Favorable for a vegetative growth that varies between 80 days and 100 days. There are two seasons of rains (March to July and August to October)

Leaves

Stems



Fruits

Roots

Figure 2. Photos of the different organs of *Uvaria chamae* (YH 924/HNB)

Plant identification

Uvaria chamae used in association with others medicinal plants for the management of infectious diseases were identified and authenticated by Professor Yedomohan Hounnankpon, curator of the Benin National Herbarium. The plants used in association with *U. chamae* are *Mangifera indica* L., *Xylopia aethiopica* (Dunal) A.Rich., *Calotropis procera* (Aiton) W.T.Aiton, *Borassus aethiopum* Mart., *Newbouldia laevis* (P.Beauv) Seem, *Carica papaya* L., *Garcinia kola* Heckel, *Parkia biglobosa* (Jacq.) R.Br. ex G.Don, *Ocimum americanum* L., *Allium sativum* L., *Cymbopogon citratus* (DC.) Stapf, *Piper nigrum* L., *Gardenia ternifolia* Schumach. & Thonn. and *Vitellaria paradoxa* C.F.Gaertn. Herbarium specimens were prepared and deposited at the National Herbarium of Benin, University of Abomey-Calavi. The complete botanical names of all medicinal plants listed in this study were confirmed using the Plants of the World Online database (https://powo.science.kew.org/).

Data processing and analysis

Data processing was conducted using Microsoft Excel 2019, with graphs and figures generated using GraphPad Prism 7 software. Descriptive statistics were employed to calculate the frequency of the study variables. The Chi-square test was utilized to assess relationships between:

- The level of education and category of traditional medicine practitioners,
- The various uses of *U. chamae* and the parts of the plant used to treat illnesses,
- The respondents' ethnicity and the use of *U. chamae* for treating infectious diseases,
- The respondents' ethnic groups and the diseases treated with *U. chamae*.

Three ethnobotanical indices were applied:

Relative Frequency of Citation (RFC)

The relative citation frequency represents the number of times a specific plant species is cited out of the total number of plant citations. The RFC was calculated using the formula:

$$RFC=CF/N \times 100$$

Where CF is the number of citations of a variable and N is the total number of citations in the category (Kachmar *et al*. 2021).

Fidelity Index (IF)

The IF measures the intensity of the association between a medicinal plant and its use in treating a specific disease category (e.g., infectious diseases). It is calculated as:

$$IF\ (\%) = Ip/Iu \times 100$$

Where Ip is the number of informants who use the species for a particular disease category, and Iu is the total number of informants who have cited this species for any disease category (Friedman *et al*. 1986).

Use Value (UV)

The UV evaluates the relative importance of a medicinal species based on its reported use among informants. It is calculated as:

$$UV = U/NS$$

Where U is the sum of the total number of use citations for a species, and NS is the total number of informants (Friedman *et al*. 1986).

Results

Socio-demographic characteristics of respondents

The socio-demographic characteristics of participants are summarized in Table 2. Analysis reveals that traditional healers constitute the majority of the sample, representing 80% of the participants. Phytotherapists and Fâ priests each make up 2.22% of the respondents. A significant correlation was found between the participants' level of education and their category of traditional medicine practitioner ($p = 0.001$) (Table 9). Beyond traditional medicine, the participants also engage in various other professions, with farming (32%) and shopkeeping (28%) being the most common. Teachers account for 12% of the sample, despite their primary occupation in educational institutions.

The sample is predominantly male, with 88.89% of the respondents being men. Most participants are aged between 36 and 75 years, with a substantial concentration in the 36 to 55 age group (46.66%).

In terms of education and ethnic diversity, the majority of participants have completed secondary education (57.78%), while smaller proportions have completed primary or higher education. Only 2.22% of participants are uneducated. Ethnically, the sample is diverse, with the Fon (35.56%) and Adja (26.67%) ethnic groups being the most prominent among traditional medicine practitioners. However, ethnicity does not significantly influence the use of *U. chamae* for treating infectious diseases, nor does it affect the various uses of *U. chamae* or the diseases for which it is employed ($p > 0.05$).

Religiously, most participants identify as animists (42.22%), followed by Christians (26.67%) and Muslims (24.44%). A significant majority (91.12%) inherited their knowledge of traditional medicine rather than acquiring it through formal education. Notably, 62.22% of participants have over 20 years of experience in traditional medicine.

Table 2 Socio-demographic characteristics of participants

Parameters	Variables	Total	Frequency (%)
Categories of Traditional Medicine Practitioners	Traditional Healer	36	80
	Naturopath	4	8.89
	Herbalist	3	6.67
	Herbal Therapist	1	2.22
	Fâ priests	1	2.22
Profession outside Traditional Medicine	Farmer	8	32
	Trader	7	28
	Teacher	3	12
	Breeder	1	4
	Auto Mechanic	1	4
	Literacy teacher	1	4
	Quranic teacher	1	4
	Founder	1	4
	Ready Fâ	1	4

	Marketing Communicator	1	4
Sex	Male	40	88.89
	Female	5	11.11
Age	[18 -35]	7	15.56
	[36 -55]	21	46.66
	[56 -75]	14	31.11
	more 75	3	6.67
Level of education	Secondary	26	57.78
	Primary	11	24.44
	Upper	7	15.56
	Uneducated	1	2.22
Ethnic group	Fon and related	16	35.56
	Adja and related	12	26.67
	Yoruba and related	6	13.33
	Other Beninese	4	8.89
	Dendi and related	3	6.67
	Bariba and related	2	4.44
	Peuhl and related	1	2.22
	Other nationalities	1	2.22
Religion	Animist	19	42.22
	Christian	12	26.67
	Muslim	11	24.44
	Other religions	3	6.67
Source of knowledge	Inheritance	41	91.12
	Training	2	4.44
	Other	2	4.44
Year of experience of the pratices	more than 20 years	28	62.22
	10 to 15 years	7	15.56
	15 to 20 years	6	13.33
	5 to 10 years	4	8.89

Ethnopharmacological data

The fidelity index for *U. chamae* is 86.66%, indicating the importance of each plant and a high level of agreement among traditional healers regarding its use in treating infectious diseases. The Use Value (UV) of *U. chamae* is 1.27, suggesting that it is employed in more than one disease category, underscoring its perceived importance among informants.

Assessment of general knowledge and symptom recognition for infectious diseases

Table 3 presents data on the assessment of general knowledge and symptom recognition for infectious diseases. The data indicate that 84.44% of participants possess good knowledge of infectious diseases. The level of knowledge of infectious diseases was assessed by verifying the local language name for the expression “infectious disease” and mainly by the briefly explaining of clinical manifestations of an infectious disease. High body temperature, swollen glands, and joint pain were each identified as symptoms by 10.57% of respondents. Other symptoms, such as abdominal pain, vomiting, and dizziness, were identified by 10.13%, 8.81%, and 8.81% of participants, respectively, with less typical symptoms accounting for 7.06%.

Table 3. Knowledge of traditional medicine stakeholders on infectious diseases

Parameters	Variables	Total	Relative Frequency (%)
Assessment of the level of knowledge of an infectious disease	Good (practitioners of traditional medicine have a good knowledge of infectious diseases)	38	84.44
	Passable (practitioners of traditional medicine have a fair knowledge of infectious diseases)	7	15.56
Symptoms of an infectious disease	Joint pain	24	10.57
	Swollen glands	24	10.57
	High body temperature (> to 38°C)	24	10.57
	Abdominal pain	23	10.13
	Vomiting	20	8.81
	Dizziness	20	8.81

	Cough	20	8.81
	Headache	19	8.37
	Loss of appetite	19	8.37
	Chills	18	7.93
	Other symptoms of infectious disease	16	7.06

Familiarity and recognition of *Uvaria chamae*

Table 4 reveals that familiarity with *U. chamae* is relatively balanced among participants, with 51.11% being familiar with the plant and 48.89% unfamiliar. Recognition skills were notably high, with 83.33% of participants exhibiting good recognition skills, and 50% displaying very good recognition. The level of knowledge about *U. chamae* was assessed by identification samples of *U. chamae* stems, leaves, roots and fruits. Each part of the plant was presented to participants during the survey. Fruits and leaves were the primary organs aiding in the recognition of *U. chamae* cited by 36.36% and 31.82% of respondents, respectively. Physical observation was the most common method used to assess the quality of the collected organs (73.91%).

Table 4. Knowledge and use of *Uvaria chamae* in infectious disease management

Parameters	**Variables**	**Total**	**Relative Frequency (%)**
Familiarity with *Uvaria chamae*	Yes (traditional medicine practitioners are familiar with *Uvaria chamae*)	23	51.11
	No (traditional medical practitioners are not familiar with *Uvaria chamae*)	22	48.89
Uvaria chamae Recognition Ability	Very good (traditional medicine practitioners are very good at recognizing *Uvaria chamae*	12	50
	Good (traditional medicine practitioners are good at recognizing *Uvaria chamae*)	8	33.33
	Passable (traditional medicine practitioners are fairly adept at recognizing *Uvaria chamae*)	4	16.67
Elements of recognition of *Uvaria chamae*	Fruit	16	36.36
	Leaves	14	31.82
	Roots	9	20.45
	Flowers	4	9.1
	Smell	1	2.27
Quality of organs collected	Observation (physical appearance)	17	73.91
	Texture	4	17.39
	Smell	1	4.35
	Other	1	4.35
Ease of access to *Uvaria chamae*	Yes	16	61.54
	No	10	38.46
Harvest availability period	All year round (all seasons)	16	64
	Rainy season	9	36

Accessibility and availability

Uvaria chamae is easily accessible to 61.54% of the population, while 38.46% reported difficulties in access. In terms of availability, 64% of traditional medicine practitioners can harvest the plant year-round. Table 5 summarizes the uses of *U. chamae*, highlighting its medicinal properties (57.9%) and its use as a food source (39.47%). The plant is primarily used to combat bacterial infections (19.15%) and malaria (9.57%).

Condition of parts used and collection practices

Fresh organs of *U. chamae* are preferred by 60% of the participants, while 40% use dried organs. Selective harvesting is the predominant practice (41.02%), whereas habitat conservation techniques are rarely used (10.26%).

Choice of solvent and extraction methods

Water is the most commonly used solvent for preparing *U. chamae* -based recipes (55.55%), followed by ethanol (15.56%). Decoction and infusion are the primary preparation methods, with proportions of 33.96% and 30.19%, respectively.

Challenges identified and criteria for combining plants with *Uvaria chamae*

The main challenges in recipe preparation include collection and preservation (47.37%), followed by standardization of methods (18.42%). Plant combinations with *U. chamae* for managing infectious diseases are primarily chosen based on their anti-infectious properties (47.37%) and availability (15.38%).

Table 5. Uses of *Uvaria chamae* by the respondents

Parameters	Variables	Total	Relative Frequency (%)
Different uses of *Uvaria chamae*	Medicinal	22	57.9
	Alimentary	15	39 .47
	Cultural	1	2.63
Diseases or Conditions Requiring the Use of *Uvaria chamae*	Bacterial infection	18	19.15
	Other	10	10.64
	Malaria	9	9.57
	Fever	8	8.51
	Diarrhea	7	7.45
	Hematuria	7	7.45
	Wound healing	6	6.39
	Hemorrhoids	5	5.32
	Dysentery	5	5.32
	Gastroenteritis	5	5.32
	Diabetes	4	4.25
	Menorrhagia	4	4.25
	Inflammation of the people	4	4.25
	Episiotaxy	2	2.13
Condition of the parts used	Fresh	21	60
	Dry	14	40
Collection Practice	Selective harvesting	16	41.02
	Local seasonal harvest	11	28.21
	Crop Area Rotation	8	20.51
	Habitat conservation	4	10.26
Extraction solvent	Water	25	55.55
	Ethanol	7	15.56
	Vegetable oils (palm, peanut, coconut)	5	11.11
	Water-ethanol	4	8.89
	Honey	4	8.89
Recipe preparation technique	Decoction	18	33.96
	Infusion	16	30.19
	Powder	10	18.87
	Maceration	5	9.43
	Dye	4	7.55
Difficulty in preparing recipes with *Uvaria chamae*	Collection and storage	18	47.37
	Standardization of methods	7	18.42
	Dosage and concentration	6	15.79
	Preparation stability	4	10.53
	Proper preparation	3	7.89
Criteria for choosing associated plants for the composition of recipes	Ability to kill microbes	11	28.21
	Availability and accessibility	6	15.38
	Other	6	15.38
	Combined effect of plants	5	12.82
	Scientific evidence	4	10.26
	Botanical knowledge	4	10.26
	Traditional compatibility	3	7.69

Organs used and plant combinations

Fig 3 illustrates that the leaves and roots of *U. chamae* are the most widely used organs, constituting 25.37% and 22.39% of the uses, respectively. Sixteen medicinal plants are frequently combined with *U. chamae*, including *Garcinia kola* Heckel, *Piper nigrum* L., and *Carica papaya* L. (Table 6). These plants belong to diverse botanical families, such as Clusiaceae, Piperaceae, and Anacardiaceae.

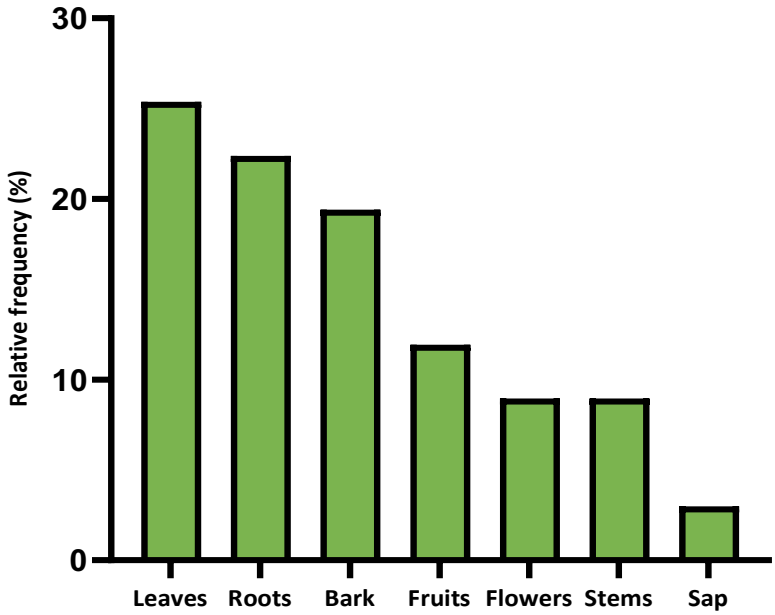


Figure 3. Organs of *Uvaria chamae* used

Table 6. Medicinal plants species used in combination with *Uvaria chamae* in the management of infectious diseases

Botanical family	Scientific name	Vernacular name (Fon and Adja)	Voucher number
Anacardiaceae,	*Mangifera indica* L.	Amanga (FON)	**YH 535/HNB**
Annonaceae	*Xylopia aethiopica* (Dunal) A. Rich.	Kpedjrékoun (FON)	**YH 333/HNB**
Apocynaceae	*Calotropis procera* (Aiton) W.T.Aiton	Wangachiman (ADJA), Amonman (FON)	**YH 297/HNB**
Arecaceae	*Borassus aethiopum* Mart.	Agon (FON)	**YH 292/HNB**
Biognoniaceae	*Newbouldia laevis* (P.Beauv) Seem	Hounman (FON)	**AA 6302/HNB**
Caricaceae	*Carica papaya* L.	Kpinman (FON)	**YH 298/HNB**
Clusiaceae	*Garcinia kola* Heckel	Ahowé (FON)	**YH 260/HNB**
Fabaceae	*Parkia biglobosa* (Jacq.) R.Br. ex G.Don	Afintinman (FON)	**YH 393/HNB**
Laminaceae	*Ocimum americanum L.*	Kesoukesou (FON)	**AA 6633/HNB**
Liliaceae	*Allium sativum* L.	Ayo (FON)	**YH 287/HNB**
Poaceae	*Cymbopogon citratus* (DC.) Stapf	Timan (FON)	**AAC 173/HNB**
Piperaceae	*Piper nigrum* L.	Linlinkoun (FON)	**YH 401/HNB**
Rubiaceae	*Gardenia ternifolia* Schumach. & Thonn.	Dakpla (FON)	**YH 263/HNB**
Sapotaceae	*Vitellaria paradoxa* C.F.Gaertn.	Limouman (FON)	**YH 447/HNB**

Therapeutic efficacy and usage patterns

Table 7 presents the therapeutic efficacy of *U. chamae*. The frequency of use varies, with 30.43% of participants using *U. chamae* at a 10% frequency and 17.39% at a 50% frequency. *Uvaria chamae* products are predominantly stored in powder (56.25%) and liquid (43.75%) forms. When modern medicine fails to treat infectious diseases, 76% of people turn to *U. chamae*, with 60.87% using it in combination with other plants.

Table 7. Information about therapeutic efficacy of *Uvaria chamae* reported by the respondents

Parameters	Variables	Total	Relative Frequency (%)
Shelf life of products with *Uvaria chamae*	Powder (powder form of *Uvaria chamae* product)	18	56.25
	Liquid (liquid form of *Uvaria chamae* product)	14	43.75
How often you use *Uvaria chamae*	10% (frequency with which practitioners use *Uvaria chamae*)	7	30.43
	5% (frequency with which practitioners use *Uvaria chamae*)	5	21.74
	25% (frequency with which practitioners use *Uvaria chamae*	4	17.39
	50% (frequency with which practitioners use *Uvaria chamae*)	4	17.39
	75% (frequency with which practitioners use *Uvaria chamae*)	3	13.05
Reception of Failure Cases of Modern Medicine	Yes (Practitioners see patients after modern medical treatments have failed)	19	76
	No (practitioners don't see patients after the failure of modern medicine)	6	24
Efficacy of *Uvaria chamae* on multidrug-resistant infections	Association (*Uvaria chamae* is effective when used in combination with other medicinal plants)	14	60.87
	Alone (*Uvaria chamae* is effective when used alone)	9	39.13
Common method of administering recipes based on *Uvaria chamae*	Oral (recipes are administered orally)	19	82.61
	Bath (recipes are administered as a bath)	3	13.04
	Gargle (recipes are administered as gargles)	1	4.35
Failure of *Uvaria chamae* treatments	No (no failures reported with *Uvaria chamae*-based treatments)	23	92
	Yes (*Uvaria chamae* treatment failures have been reported.)	2	8
Toxic effect of *Uvaria chamae*	No (no toxic effects reported when using *Uvaria chamae*)	14	63.64
	Yes (toxic effects have been observed when using *Uvaria chamae*)	4	18.18
	Sometimes (toxic effects are occasionally observed when using *Uvaria chamae*)	4	18.18
Method of control of the effectiveness of *Uvaria chamae*-based treatment	Monitoring for symptom cessation (treatment efficacy is assessed by monitoring the patient's cessation of symptoms)	17	70.83
	Laboratory control test (efficacy is verified by laboratory tests	5	20.83
	Other (other efficacy control methods)	2	8.34

Traditional recipes and therapeutic response

Table 8 details various traditional recipes using *U. chamae* for treating infectious diseases, including their composition, dosage, and administration routes. The therapeutic response time of *U. chamae* ranges from 1 to 14 days for 60.71% of cases, with some cases requiring up to 30 days (Fig 4).

Table 8. Traditional recipes based on *Uvaria chamae* for the treatment of infectious diseases

Recipe number	Recipe composition	Diseases treated	Dosage	Route of administration
1	*Uvaria chamae* root (Ayalaha in Fon) *+ *Garcinia cola* (Ahowé in Fon) *	Bacterial infection, Urinary tract infection, Respiratory infection	1 bamboo glass for adults. For adolescents 1 glass morning, noon and evening	Oral
2	*Uvaria chamae* (Ayalaha in Fon) *	Malaria	1 bamboo glass Morning and evening	Oral
3	*Uvaria chamae* root (Ayalaha in Fon) *+ *Alocasia Ninja* (Lindja in Fon) *+ *Syzygium aromatiocum* (Atikingbadota in Fon)*	Bacterial infection, Dermatoses, Respiratory infection	1 bamboo glass Morning and evening	Oral
4	*Uvaria chamae* (Ayalaha in Fon) * + *Carica papaya* root (Kpin in Fon) *	Bacterial infection, Malaria	1 bamboo glass Morning and evening	Oral
5	*Uvaria chamae* (Ayalaha in Fon) * + *Cymbopogon citratus* (Timan in Fon) *	Malaria, Urinary tract infection	1 bamboo glass Morning and evening	Oral
6	*Uvaria chamae* root (Ayalaha in Fon) *	Bacterial infection	1 bamboo glass morning and evening	Oral
7	*Uvaria chamae* (Ayalaha in Fon) * +*Ocimum americanum* (Kessoukessou in Fon)*+*Newbouldia laevis* (Hounman in Fon) *	Bacterial infection, Dermatoses, Respiratory infection, Urinary tract infection, Malaria, Jaundice, Icterus	Infusion, 3 times a day	Bath
8	*Uvaria chamae* (Ayalaha in Fon) * + *Newbouldia laevis* (Hounman in Fon) *	Malaria, Jaundice, Icterus	Infusion or organ trituration (until healing)	Oral or bath
9	*Uvaria chamae* (Ayalaha in Fon) * + *Borassus aethiopum* root (Agon in Fon) *	Bacterial infection	1 to 2 times a day	Oral
10	*Xylopia aethiopica* root (Kpedjrékoun in Fon) *	Bacterial infection, Urinary tract infection	Infusion to be taken 1 time a day	Oral
11	*Uvaria chamae* bark (Ayalaha in Fon) *+*Parkia biglobossa* bark (Afintinman in Fon) *+*Vitellaria paradoxa* bark (Limouman in Fon) *	Bacterial infection, Dermatoses, Urinary tract infection,	Decoction, 2 small glasses morning and evening	Oral
12	*Mangifera indica* bark (Amanga in Fon) *	Malaria	3 times a day, two small glasses (talokpémi), to be taken tierde.	Oral

Legend: * Vernacular names of plants in the local Fon and Adja languages of Benin

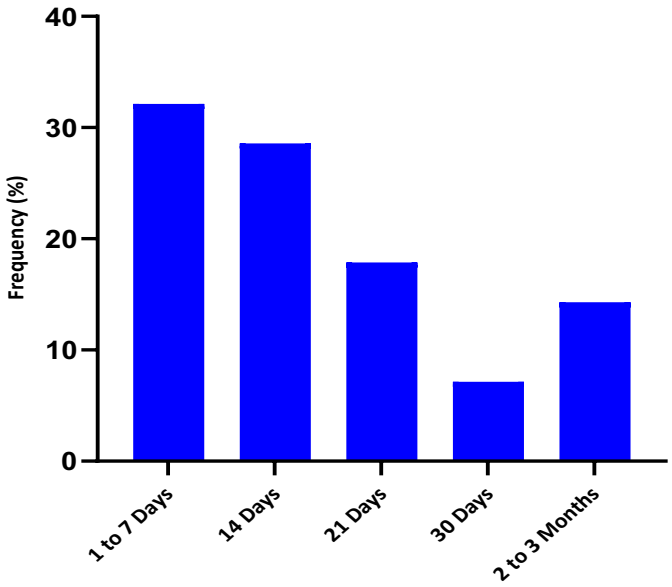


Figure 4. Therapeutic response time of *Uvaria chamae* reported by the respondents

Table 9. Results of Chi-square test utilized to assess relationships between

Parameters	Chi-square test (p value)
level of education and category of traditional medicine practitioners	p = 0.001
the different uses of *Uvaria chamae* and the parts of *Uvaria chamae* used to treat illnesses	p = 0.001
respondents' ethnicity and how *Uvaria chamae* is used to treat infectious diseases.	p = 0.061
the respondents' ethnic group and the various uses made of *Uvaria chamae*	p = 0.094
respondents' ethnic groups and the diseases for which *Uvaria chamae* is used	p = 0.107

Toxicity and efficacy control

Generally, *U. chamae* is considered non-toxic by 63.34% of participants, although 36.36% noted occasional toxicity in certain recipes. The effectiveness of treatments is primarily assessed by the cessation of symptoms (70.83%), with some cases involving laboratory tests to monitor biological parameters (20.83%).

Discussion

The practice of traditional medicine is an ancient history specific to the African people. It is one of the earliest cultural legacies for the younger generation. Its knowledge focuses on the use of medicinal plants to find cures for all human and/or animal diseases. The aim of this study is to record the knowledge of the different professional categories of traditional medicine on *U. chamae* in the management of infectious diseases in Benin. The results of this study highlight the predominance of traditional practitioners, who account for 80% of those involved in traditional medicine. In addition to this predominance, 32% of traditional medicine practitioners are farmers. This practice is associated with agriculture, which is the dominant activity in the Republic of Benin. According to the data, there is a strong predominance of male players aged between 36 and 75, with a high concentration in the 36-55 age bracket. The Fon and Adja ethnic groups play an important role in the transmission of traditional medical knowledge in Benin, where this knowledge is mostly inherited from the fathers of traditional medicine (91.12%). In addition, 62.22% of traditional medicine practitioners have more than 20 years' experience. Knowledge of traditional medicine practices is passed on by resource people who are well experienced in the field and reflects a high degree of trust. The high proportion of inherited knowledge implies a continuity of traditional practices. The low proportion of trained practitioners can lead to ineffective use of medicinal plants. This can lead to poor treatment of disease, leaving the way open for pathogen resistance to natural treatments, as is currently the case in modern medicine.

What's more, untrained practitioners may be unaware of the pharmacological interactions between different plants, putting patients' lives at risk. The consequences of this lack of knowledge can be toxicological or even fatal. Thanks to ethnic diversity, this creates a treasure trove of different practices and uses for future pharmacological, microbiological and botanical research. Our results corroborate those of Vissoh and colleagues, who found in their study ethnic diversity with a predominance of Fon and related groups (Vissoh *et al*. 2024). The same data reinforce the findings of the National Institute of Economic Analysis and Statistics in 2013 following a demographic survey where Fon and related, Adja Yoruba and related ethnic groups are the most represented with respective rates of 39.2%; 15.2% and 14.5% (INSAE 2013). The age of the traditional medicine players and the heritage of knowledge are on the same wavelength as the results of other ethnobotanical studies carried out previously (Koudokpon *et al*. 2017). Good knowledge of the symptoms of infectious diseases (84.44%) is a further sign of the importance of traditional medicine in primary health care. However, the results indicate the importance of each plant and a high level of agreement among the traditional healers of the use of *U. chamae* in the treatment of infectious diseases, with a fidelity index of 86.66%. This means that of all the healers who mentioned the use of this plant, 86.66% specifically used it to treat infections, demonstrating unanimous recognition of its efficacy in this area. What's more, the Use Value (UV) of 1.27 reveals that *U. chamae* is used to treat several disease categories, not just one. This result reinforces the plant's perceived importance among traditional practitioners, underlining its versatility and value in traditional medicine. In short, these indices reflect both a widespread confidence in *U. chamae* role against infectious diseases and a recognition of its usefulness in a variety of traditional medical contexts. This can be explained by the fact that those familiar with the plant are well equipped and competent to recognize it. To easily recognize *U. chamae*, practitioners turn to its fruits (36.36%) and leaves (31.82%). They focus on the physical aspect of the organ (73.91%) to judge its quality. These figures support the regular use of these organs in the preparation of remedies. In terms of organ quality assessment, macroscopic observation is the first step in evaluating the quality of any product. Other studies also stipulates that, the roots, barks, fruits, stems, leaves and other parts of *U. chamae* are used in traditional medicine to combat various ailments (Koudokpon *et al*. 2017; Popoola *et al*. 2021). Data on the various uses of *U. chamae* revealed its use for medicinal purposes (57.9%). These data directly support its effectiveness in the management of bacterial infections (19.15%) and malaria (9.57%). The sum of these results cost it its ability to treat multidrug-resistant infectious diseases with an efficacy of 92%. *Uvaria chamae* therefore, draws its therapeutic potential from its chemical composition rich in bioactive compounds such as tannins, alkaloids and flavonoids which thus arouse the need to be explored to better understand the underlying mechanisms and their effectiveness against various microorganisms. A study conducted on *U. chamae* in West Africa testifies to its solicitation by the population because of its medical and cosmetic uses. It is used to treat several conditions including gastroenteritis, cancer, bronchitis, and wounds (Popoola *et al*. 2021). In parallel with this efficiency, water is the most used solvent in the preparation of recipes (55.55%), with decoction (33.96%) and infusion (30.19%) as preparation methods. In this preparation process, the collection and conservation (47.37%), as well as the standardization of methods (18.42%) are all difficulties encountered by traditional medicine practitioners. The choice of plant combinations with *U. chamae* in the management of infectious diseases is made taking into account the ability to kill microbes (47.37%) and availability and accessibility (15.38%). Practitioners of traditional medicine use the combination of medicinal plants to achieve a synergy of action between the plants' bioactive compounds for greater therapeutic efficacy. What's more, this technique makes it possible to combine plants with different properties and mechanisms of action, offering a strong chance of delaying the onset of pathogen resistance. The logic of these figures can be justified by the fact that the solvent used and the extraction method can influence the stability of the product over time and its therapeutic potential despite a justified choice of combinations. Although 76% of traditional medicine practitioners turn to *U. chamae* in case of failure of modern medicine, it should be noted that 60.87% of its use is in combination with other plants, even though 39.19% use it as monotherapy. Thus, *Garcinia cola, Piper nigrum* L., *Carica papaya* L., *Allium sativum* L., *Xylopia aethiopica* (Dunal) A.Rich., *Mangifera indica* L., *Newbouldia laevis* (P.Beauv.) Seem. Ex Bureau, *Gardenia ternifolia* Schumach. & Thonn., *Parkia biglobossa* (Jacq.) R.Br. ex G.Don, *Vitellaria paradoxa* C.F.Gaertn. and *Ocimum americanum* L. are among many other medicinal plants used in combination with *U. chamae* to successfully cure multidrug-resistant infectious diseases. These results show that *U. chamae* alone is effective, but for cases of multidrug resistance, a combination with other medicinal plants is a much better alternative in order to have a rapid and effective therapeutic effect. It thus opens up other opportunities to discover potential synergies that would undoubtedly contribute to improving therapeutic efficacy. Several studies have found the data similar to those of our study in endorsing the use of *U. chamae* in the treatment of bacterial and parasitic infections (Houehanou *et al*. 2011; Adepiti *et al.* 2013; Emordi *et al*. 2018; Gnatoulma *et al*. 2018).

In addition, studies on *Newbouldia laevis* (P.Beauv.) Seem. ex Bureau, *Zanthoxylum zanthoxyloides* (Lam.) Zepern. & Timler, *Xylopia aethiopica* (Dunal) A.Rich., *Tetrapleura tetraptera* (Schum. & Thonn.) Taub, *Mangifera indica* L., *Parkia biglobosa* (Jacq.) R.Br. ex G.Don, support the use of plants cited by traditional medicine practitioners as potential plants worthy of combination with *U. chamae* to combat cases of multidrug-resistant diseases (Azando *et al*. 2011; Yemoa *et al.*

2011;Dougnon *et al*. 2017; Legba *et al*. 2020). The therapeutic efficacy obtained with *U. chamae* products is mostly due to oral administration (82.61%). *Uvaria chamae* has a rapid therapeutic response time of between 1 and 14 days, i.e. 60.71%. It is known as a non-toxic medicinal plant (63, 34%). Nevertheless, there were a few cases of toxicity (36.36%). Its therapeutic effectiveness is most often monitored by cessation of symptoms (70, 83%). Studies carried out by scientific pairs show, in the same way as ours, the non-toxicity of *U. chamae*. This lack of toxicity includes in vivo (animal model and cell line), *in vitro* and human assays, as well as root and leaf extracts (Gordon *et al.* 2016; Olumese *et al.* 2016; Koudokpon et al. 2018). Very few traditional medicine practitioners rely on laboratory biological examinations (20.83%). The therapeutic effects of *U. chamae* may be related to the route of administration that would be better to allow its bioactive compounds to interact effectively. It would therefore be the effective means of minimizing the toxic effects of its products. In addition, the monitoring of symptom arrest as a pioneering method of verifying the therapeutic effect is linked to a lack of information and therefore requires that actors be trained to better assess the therapeutic efficacy of a product. Based on these observations, *U. chamae* is a plant of scientific interest that deserves enough attention for a better exploration of its therapeutic potential.

Conclusion

This study offers a detailed examination of the traditional knowledge and practices surrounding the use of *U. chamae* in treating infectious diseases in Benin. The findings reveal that traditional healers are the predominant practitioners, with a significant portion boasting over 20 years of experience. A strong consensus among these practitioners on the medicinal use of *U. chamae* is reflected in its high-fidelity index of 86.66%. The plant is highly valued for its wide-ranging application across various diseases, as indicated by a use value of 1.27, underscoring its importance in multiple therapeutic contexts. The study also highlights the practical aspects of *U. chamae* usage, including its accessibility, the plant parts utilized, and the challenges encountered in its preparation and preservation. While the plant is generally regarded as non-toxic, some adverse effects were reported, and its effectiveness is primarily monitored through symptom resolution. The findings underscore the culturally rooted and diverse nature of traditional medicine in Benin, with *U. chamae* playing a critical role in infection management. Given the widespread use of *U. chamae* particularly in combination with other plants when modern medicine fails this study emphasizes the necessity for further research into the efficacy and safety of these traditional practices. Such investigations are crucial to better understanding and potentially integrating these traditional remedies into broader healthcare frameworks.

Declarations

List of abbreviations: AMR: Antimicrobial resistance, RFC: Relative Frequency of Citation, IF: Fidelity Index, UV: Use Value, FANAMETRAB: National Federation of Associations of Traditional Medicine Actors of Benin, FeNaMeTraB: National Federation of Traditional Medicine of Benin, FENAVPraMETRAB: National Federation of True Practitioners of Traditional Medicine of Benin, IES: International Society of Ethnobiology

Data Availability Statement: All data generated and/or analyzed during the current study are included in this published article. The datasets used and/or analyzed during this study are also available from the corresponding author on reasonable request.

Ethics approval and consent to participate: Written informed consent has been obtained from the participants

Consent for publication: Not applicable

Availability of data and materials: All data and materials are provided in this manuscript

Competing of Interest: The authors declare no conflicts of interest

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