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Contribution of phytotherapy to the management of typhoid fever in Cameroon: between traditional knowledge and public health challenges

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ABSTRACT

Ethnopharmacological Relevance: Typhoid fever remains a major public health concern in developing countries, where the high cost of conventional treatments and the emergence of antimicrobial resistance limit effective disease management. In Cameroon, medicinal plants are widely used as alternative therapeutic resources.

Aim of the Study: This study aimed to document medicinal plants used in the traditional management of typhoid fever in Douala (Cameroon) and to evaluate the therapeutic outcomes of the most frequently cited herbal remedies.

Materials and Methods: An ethnobotanical survey was conducted among 505 respondents recruited from three non-timber forest product markets and four neighborhoods in Douala. Data on medicinal plant use, herbal formulations, and treatment practices were collected using semi-structured questionnaires. Ethnobotanical indices were calculated to assess species importance. In addition, an ethnopharmacological follow-up was performed on 45 patients treated with three frequently cited herbal recipes.

Results: A total of 968 recipes involving 91 plant species belonging to 43 botanical families were recorded. Asteraceae and Fabaceae were the most represented families. The species with the highest ethnomedicinal importance were *Combretum micranthum*, *Carica papaya*, and *Mangifera indica*. Most remedies were polyherbal formulations (92.35%), prepared mainly from leaves (51.88%) as aqueous decoctions (62%) and administered orally (85.94%). Ethnopharmacological monitoring revealed marked clinical improvement and a low recurrence rate within three months after treatment. Mild adverse effects, including pollakiuria, nausea, vomiting, dizziness, and excessive sweating, were occasionally reported.

Conclusions: The findings highlight the richness of Cameroonian traditional medicine and identify promising plant species with potential anti-typhoidal properties. Further phytochemical, pharmacological, and toxicological investigations are needed to support the development of evidence-based phytomedicines.

Keywords: Alternative Therapeutic; *Carica papaya*; Cameroon; *Combretum micranthum*; Ethnopharmacological Follow-up; Herbal Recipes; *Mangifera indica*; Medicinal Plants; Traditional Medicine; Typhoid Fever.

1.0. Introduction

1.1. Background

Typhoid fever affects nearly 21 million individuals worldwide each year, resulting in 222.000 deaths. Caused by the bacterium *Salmonella enterica serovar typhi*, it is treated with antibiotic therapy. S*almonella* spp., encompassing over 2.500 distinct serovars, are ubiquitous bacteria that are often multidrug-resistant to conventional antibiotics (Dougnon *et al*. 2018). In Vietnam, for instance, 90% of *Salmonella typhi* strains isolated from typhoid fever patients exhibit resistance to multiple antibiotics (Virlogeux-Payant *et al*. 2020). These bacteria are also among the four leading causes of diarrheal diseases globally (WHO 2014), alongside typhoid fever, both transmitted via consumption of contaminated food or water (Aguoru and Agaba 2010; Iroha *et al*. 2010). Typhoid fever represents a major public health challenge, particularly in developing countries like Cameroon, where access

to potable water and primary healthcare remains limited (Mvogo-Ottou *et al*. 2020). Current treatments rely on second-generation fluoroquinolones and ceftriaxone. However, the relatively high cost of generic antibiotics restricts access for affected populations. These vulnerable groups, exacerbated by growing impoverishment and precarious living conditions, urgently require new therapeutic options to combat this disease. In biotopes close to rural populations, a rich and diverse medicinal flora offers substantial potential for antimicrobial plants (Betti *et al*. 2011 ; Dibong *et al*. 2015 ; Ngouondjou-Foze *et al*. 2020).

Medicinal plants, due to their lower cost and fewer side effects, serve as an inexhaustible source of active metabolites for the pharmaceutical industry (Mvogo-Ottou 2019 ; Mvogo-Ottou *et al*. 2020 ; 2022). Throughout the world, plants have long satisfied humanity's diverse needs, including nutrition, recreation, and protection. They provide firewood, timber, and the primary source of fodder for livestock in certain pastoral areas. Beyond these essential functions, they play a key role in traditional medicine through the use of plant organs, which form a vital part of local livelihoods (Cunningham *et al*. 2006 ; Mehdioui *et al*. 2007). As a source of medicines, these plants are central to activities spanning both traditional and popular pharmacopeias. Africa boasts significant diversity in medicinal plants, which constitute valuable resources for the vast majority of rural populations, where over 80% rely on them for healthcare (Jiofack *et al*. 2010 ; Dibong *et al*. 2011 ; Ebenye-Mokake *et al*. 2026).

1.2. Problematic

Ethnobotanical studies on medicinal plants enhance knowledge about these plants both qualitatively and quantitatively. They also enable the development of sustainable management strategies for the harvested resource. Indeed, Cameroon possesses a vast plant biodiversity wealth that, combined with traditional therapeutic knowledge, could open the door to new therapies. This is all the more relevant given that conventional medicine demonstrates an inability to provide effective solutions against typhoid fever; this is due to the high cost of modern practices, the undesirable side effects associated with them, and the numerous resistances exhibited by Salmonella strains (Shao and Li 2008 ; Dougnon *et al*. 2018).

Furthermore, Law No. 2014/018 of 23 December 2024 on the practice and organization of traditional medicine in Cameroon aims to promote the development of traditional medicine as a modality for populations' access to healthcare. Traditional medicine, of which the traditional pharmacopoeia is an integral part, forms part of the Cameroonian health system and contributes to universal access to quality health care and services. Given that plant extracts provide the active principles for pharmaceuticals in the pharmaceutical industry, the challenge is to develop tools to assist the health sector in better managing typhoid cases while preventing relapses, primarily by identifying medicinal plants with high activity against Salmonella, and by developing a standardized therapeutic regimen based on these plants.

According to the WHO report (2014), Salmonella ranked among the bacteria responsible for diarrheal diseases worldwide (WHO 2014). These ubiquitous bacteria, often multi-resistant to conventional antibiotics, can survive for several weeks in dry environments and several months in water; thus posing genuine public health problems, especially in developing countries like Cameroon, where access to potable water and primary healthcare remains precarious (Kidik-Pouka *et al*. 2015 ; Ngene *et al*. 2015; Dougnon *et al*. 2018). However, compared to generic

drugs, traditional medicine offers, through plant secondary metabolites, greater efficacy in treating numerous diseases (Mvogo-Ottou 2019).

1.3. Objectives

The aim of this study is to enrich the database on research into plant-based medicines in general, and those for treating typhoid fever in particular. Specifically, it will involve (1) characterizing the recipes and plants used in the treatment of typhoid fever, and (2) establishing the therapeutic profile of some of these recipes.

2.0. Material and Methods

2.1. Matérials

2.1.1. Study Site

Douala (latitude, 03° 40'-04° 11' N; longitude, 09° 16'-09° 52' E; altitude, 13 m) is the capital of the Littoral Region, which comprises four departments: Moungo, Sanaga Maritime, Nkam, and Wouri. This region encompasses a variety of ecosystems, including dense humid evergreen forests particularly the coastal dense humid evergreen forest between 0 and 100 m altitude and the Biafran dense humid forest between 100 and 500 m (Letouzey 1985) as well as mangroves, swamps, riparian vegetation, agroecosystems, and more or less anthropized vegetation. Douala has an equatorial climate. As a cosmopolitan port city, it has established itself as the country's economic capital through its port, which drives nearly 80% of Cameroon's industrial activity. Douala has about 2.5 million inhabitants, and population growth is not always matched by economic resources (Priso *et al*. 2011).

Douala's population is highly heterogeneous. Broadly speaking, it includes indigenous groups such as the Douala people, alongside allochthonous populations like the Beti, Bamiléké, Haoussa, Ewondo, Anglophones, and a host of other ethnic groups. Nevertheless, the Douala remain the majority. The main religions practiced in the commune, in order of prevalence, are Christianity, Islam, and animism. Douala's economic fabric is dominated by individuals in the informal private sector around 94% while only 5% are public administration civil servants.

2.1.2. Sampling site

The markets and households in the city of Douala were subjected to ethnobotanical surveys; specifically:

- For the markets:

- Dakar Market, located in the 3rd arrondissement of Douala, precisely near the axis leading to Logbaba, at approximately 4°02'36" N, 9°44'33" E;

- New Bell Market, situated in the neighborhood of the same name "New Bell" in Douala II. It lies approximately at 4°03' N, 9°70' E. Its geographic landmarks place it south of the neighborhood, near the "New Bell gare" area and the shopping center;

- Nkoulouloun Market (or Nkololoun), located in the Douala II arrondissement, at the heart of the New Bell neighborhood. The approximate geographic coordinates of the neighborhood/market are 4°02'30" N and 9°42'30" E. Nkoulouloun Market is positioned near the central mosque of New Bell and Roi Njoya Street.

- For the neighborhoods :

- The Bependa neighborhood, located in the Douala V district, with approximate geographic coordinates of 4◦03′24″4◦03′24″ N, 9◦43′20″9◦43′20″ E. Bependa is a popular and central neighborhood in the Wouri area, known for zones like Bepanda Omnisport ;

- The Makepe Missoke neighborhood, located in the Douala V district. Its approximate geographic coordinates are 4◦03′38″4◦03′38″ N (latitude) and 9◦44′09″9◦44′09″ E (longitude), or in decimal degrees: 4.0605, 9.73592. This is an old and expansive neighborhood crossed by waterways. It is known as a formerly rural area (village) absorbed by rapid urbanization and is characterized by a highly densified population ;

- The Bonabéri neighborhood, located in the Douala IV municipality, with approximate geographic coordinates of 4◦04′44″4◦04′44″ N and 9◦40′00″9◦40′00″ E. It lies on the right bank of the Wouri River, featuring an industrial and residential zone with an average elevation of 5 m. The Douala IV municipality has Bonassama as its administrative center; Bonabéri is a mixed area comprising artificial surfaces (60%) and mangroves. Bonabéri is connected to downtown via the Wouri Bridge and serves as a gateway to the country's west ;

- The "Village" neighborhood, located in the Douala III district. It is situated in the eastern part of the city, with approximate geographic coordinates of 4◦02′00″4◦02′00″ N and 9◦46′00″9◦46′00″ E, along the major Douala-Yaoundé axis (city entry zone).

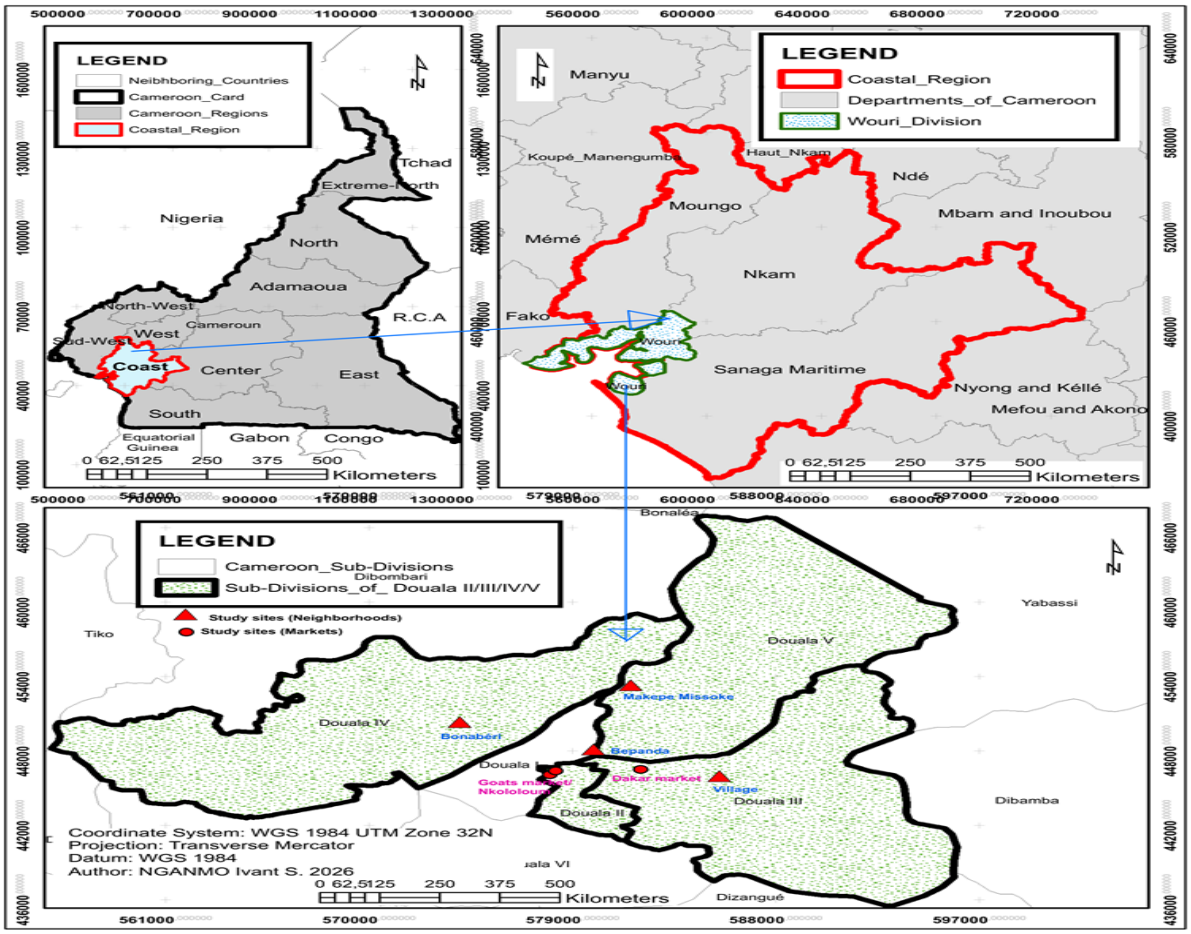


Figure 1. Map of Littoral Region, Cameroon, showing the study area.

2.1.3. Justification for Site Selection

The selection of markets was determined by the significance of trade in medicinal Non-Timber Forest Products (NTFPs) and the number of actors likely to grant interviews in those markets. In contrast, neighborhood selection accounted for ethnic clustering and the willingness of local residents to contribute to this study (Figure 1). Additionally, entry-point neighborhoods from the northern, southern, eastern, and western sectors of the city were also targeted.

2.1.4. Ethnobotanical Survey Materials and Plant Collection

A series of ethnobotanical surveys conducted in the city of Douala were based on a standardized questionnaire. Key sections of the questionnaire covered sociodemographic and cultural information on respondents, data on plants used to treat typhoid fever, and local knowledge of this disease among the population.

2.1.5. Biological Material

The plant material consisted of all organs from identified medicinal plant species (trees, shrubs, lianes, and herbs) collected from various sites. Specifically, these included specimens of medicinal plants that were preserved for subsequent identification at the National Herbarium of Cameroon.

2.2. Methods

2.2.1. Inventory of Plants Used in Typhoid Fever Treatment

2.2.1.1. Ethnobotanical Surveys

A series of ethnobotanical surveys were conducted in medicinal plant markets and households in densely populated neighborhoods of Douala city. These surveys specifically targeted the Dakar, New-Bell, and Nkololoun markets, as well as the Bepanda, Village, Makepe Moussoke, and Bonaberi neighborhoods. The semi-structured surveys aimed to document traditional and folk medicinal knowledge of healers regarding typhoid fever. They were carried out from June to July 2025 using a standardized survey questionnaire. Key questionnaire items included information on plants used to prepare remedies against typhoid fever, preparation methods for these remedies, administration routes, and other diseases treated by these plants. Additionally, to assess the credibility of respondents' information, the questionnaire captured their knowledge of the treated disease, specifically incriminated causes/risk factors, clinical manifestations/symptoms, and potential complications associated with typhoid fever.

The approach with market herbalists was based on dialogue in French. Access and interviews in the markets were facilitated by a guide an herbalist from each market who had been contacted in advance. This individual served as the liaison with their colleagues. Additionally, the purchase of plant organs used in recipes against typhoid fever further facilitated interviews with the herbalists. As a result, some organs were collected, and the species were identified.

Three (3) markets and four (4) neighborhoods were visited, with a total of 505 respondents surveyed. All respondents were able to enumerate and describe the symptoms and/or manifestations of typhoid fever, sometimes providing local language names for the disease. Willing respondents first cited the various signs and clinical

manifestations of the disease and, for those capable of treating it, provided full details on the recipes used in its management.

For each respondent who agreed to answer the questions, information was collected using a standardized template inspired by Pharmel sheets (Adjanohoun *et al*. 1989). Thus, for each therapeutic indication, recipe details were meticulously recorded, and, whenever possible, the medicinal plant was observed, photographed, and collected (Betti 2001; Kidik-Pouga *et al*. 2015; Dibong *et al*. 2015). Furthermore, the divergence of indigenous knowledge was assessed by documenting other diseases treated with the plants used for typhoid fever (Zerbo *et al*. 2010).

2.2.1.2. Collection and Identification of Samples

Plant samples were collected either *in situ* from their respective biotopes or by purchasing the plant parts used in the recipes cited during surveys at market sites. The collected organs consisted of bark, fruits, and roots for woody species, and leaves or whole plants for herbaceous species. These samples were photographed and preserved as voucher specimens in a reference herbarium following the techniques and methods described by Schnell (1960). Identification was performed by comparing the vernacular and/or commercial names obtained from informants and the voucher specimens with data from the literature, websites (e.g., PROTA4U.org), and reference materials available at the Laboratory of Plant Biology and Physiology, University of Douala. This identification was validated by botanists at the National Herbarium of Cameroon.

2.2.1.3. Entry and Analysis of Ethnobotanical Data

Data processing began with the entry of recipes and their characteristics by site and informant into Microsoft Excel (Version 2013), followed by informant coding and subsequent statistical analysis.

Given the large number of informants per visited site, they were grouped by market or household rather than by individual respondent, as described in Dibong *et al*. (2015). Consequently, all information obtained from informants at a given market or neighborhood was treated as originating from a single informant.

A dendrogram illustrating the similarity of plant use against typhoid fever across survey sites (markets and households) was generated using the Jaccard similarity coefficient in XLSTAT software. This coefficient was calculated based on the presence or absence of a species in recipes cited by all informants at a given site, thereby quantifying species associations and recipe similarity while accounting for the plants used (Dibong *et al*. 2015).

2.2.1.4. Evaluation of Species of Interest

Quantitative analysis of ethnobotanical data is one of the methods for identifying plants with pharmacological potential. It has been shown that analyzing quantitative data increases the likelihood of identifying promising plants (Andrade-Cetto and Heinrich 2011). Here, the relative importance of a plant cited by respondents for treating typhoid fever is determined based on the number of citation "events" across different recipes. A given plant species is considered capable of treating typhoid fever if it is cited at least twice for this condition (Betti *et al*. 2013). Indeed, the higher the number of citations for a specific ailment, the more confirmed the plant's use in traditional medicine for treating that ailment (Betti *et al*. 2013).

To assess informant agreement on plant use against typhoid fever and better interpret the cultural medicinal value of plants, the Usage Agreement Value index (VAUs) (Ilumbe *et al*. 2014) which combines the Use Value index (VUs) and the Confirmation Index (ICs) was employed (Ilumbe *et al*. 2014).

$$VAUs = VUs \times ICs$$

The Use Value index (VUs) is expressed as:

$$VUs = \sum_{i=1}^{N} \frac{Uis}{Ns}$$

Where *Ui*s represents the number of uses reported for species « s » by all informants at site « i », and *N*s is the total number of sites where the species was mentioned.

A technique that accounts for participant consensus and can thus evaluate the cultural importance of plants is the informant agreement proportion (Thomas *et al*. 2009; Ilumbe *et al*. 2014). For this study, the formula proposed by Ilumbe *et al*. (2014) for informant consensus or the medicinal plant confirmation index was adapted. Informant consensus is thus calculated as:

$$ICs = \frac{Na}{Nt}$$

Where *IC*s refers to the confirmation index, *Na* corresponds to the number of sites where the species was observed, and *Nt* corresponds to the total number of sites visited.

The Spatial Use Convergence index (Betti 2001) was used to evaluate similarities in plant use for the same health problem (typhoid fever in this case). This index is based on the following hypothesis: "A plant is confirmed for its use in traditional medicine when cited by at least two people for the same condition; this confirmation is stronger when those people are from different regions (Betti 2001)." The CUS is thus determined on an arbitrary scale from 0 to 1 as follows: CUS = 0 when the plant species is cited by only one person (low importance); CUS = 0.5 when cited by at least two people at the same site (moderate importance); CUS = 0.75 when cited at two different sites (high importance); and CUS = 1 when mentioned at all three sites (very high importance).

2.2.1.5. Floristic Characterization of Species

As defined by Betti, the ‘florule’ of the collected PFNL was characterized by phytogeographic distribution types, morphological types, biotope types, and diaspore dispersal modes (Betti 2001 ; Betti 2007).

2.2.2. Ethnopharmacological Follow-Up

To validate the use of plants in treating typhoid fever, a follow-up study was conducted on thirty adult patients who received treatment with three plant-based recipes prescribed by traditional healers at the Marcket. This follow-up was performed at patients' homes over a two-month period starting from treatment initiation. Key observations included the time required for symptom resolution and alleviation of disease-related morbidity, the number of patients relieved by the administered recipes, the frequency of visits to traditional healers, and the reasons for these consultations. Additionally, adverse and toxic effects associated with the medications, as well as any recurrences during the observation period, were recorded. At the end of the follow-up, telephone interviews were conducted

with patients twice weekly for one month to confirm complete recovery and the absence of adverse effects (N'Guessan *et al*. 2009; Ngouondjou-Foze *et al*. 2021).

3.0. Results

3.1. Ethnosociological and Ethnobotanical Studies

3.1.1. Ethnosociological Knowledge on Typhoid Fever

3.1.1.1. Participant Profile

Ethnobotanical surveys conducted in three major NTFP markets in Douala and four densely populated neighborhoods in the same city involved 505 participants, comprising 72 from the markets and 433 from households across the neighborhoods. Among these participants, women (285) accounted for 56.44% of the study contributions. The majority (49.91%) were adults aged 30-50 years. A substantial proportion originated from the West region (62.57%) (Table 1).

Table 1. Sociodemographic profile of respondents.

Paramètres socio-démographiques		**Number of participants**	**Frequencies (%)**
Gender:	Women	285	56.44
	Men	220	43.56
Age groups	[18 - 30 ans [«Youth »	59	11,68
	[30 - 50 ans [« Adults »	247	48.91
	[50 - 71 ans] « older adults»	199	39.41
Regions of origin	East	13	2.57
	West	316	62.57
	Centre	102	20.20
	Littoral	39	7.72
	North	12	2.38
	South	23	4.55
Religions practiced	Animism	33	6.53
	Christianity	461	91.29
	Islam	11	2.18
Educational level	No response	43	8.51
	Primary	81	17.62
	Secondary,	230	45.54
	Higher education	143	28.32

The occupations of the interviewees were documented. The results indicate that a large majority operated in the informal sector (78.23%). The most frequently reported occupation was "merchant" (27.33%). Among these, 57 traditional medicine vendors were identified. Additionally, 12 students contributed to the survey (Fig.2).

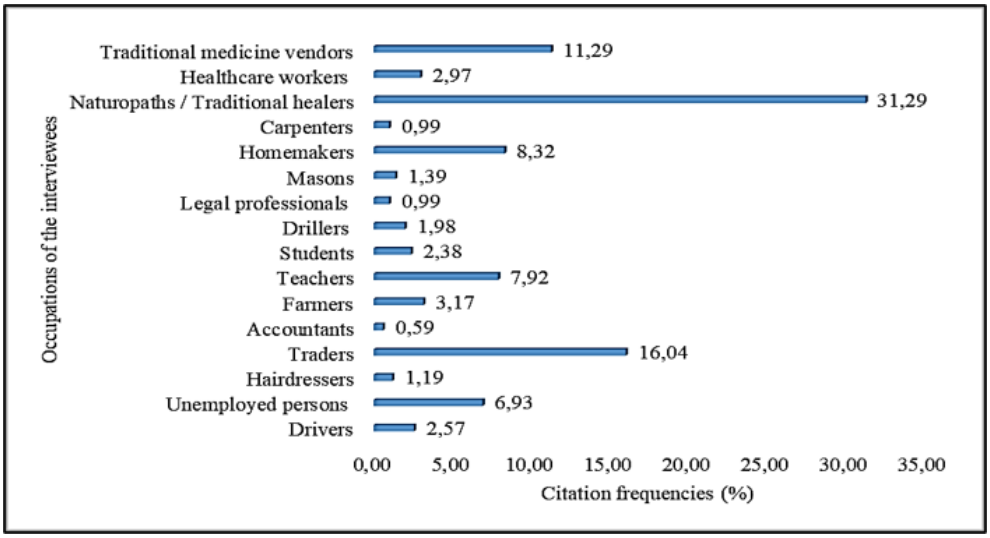


Figure 2. Professions of the interviewees.

3.1.1.2. Participants' Knowledge of the Disease

To assess the interviewees' knowledge level regarding typhoid fever, parameters such as the causes of the disease, symptoms, and treatment methods were investigated.

3.1.1.3. Causes of Typhoid Fever

The causes of typhoid fever, as reported by the interviewees, are illustrated in Fig.3.

This figure reveals that the respondents predominantly cited causes inherent to poor hand hygiene (6.93%), contaminated food (23.56%), and unsafe water (63.76%). However, 11 respondents identified "mosquito bites" as a cause.

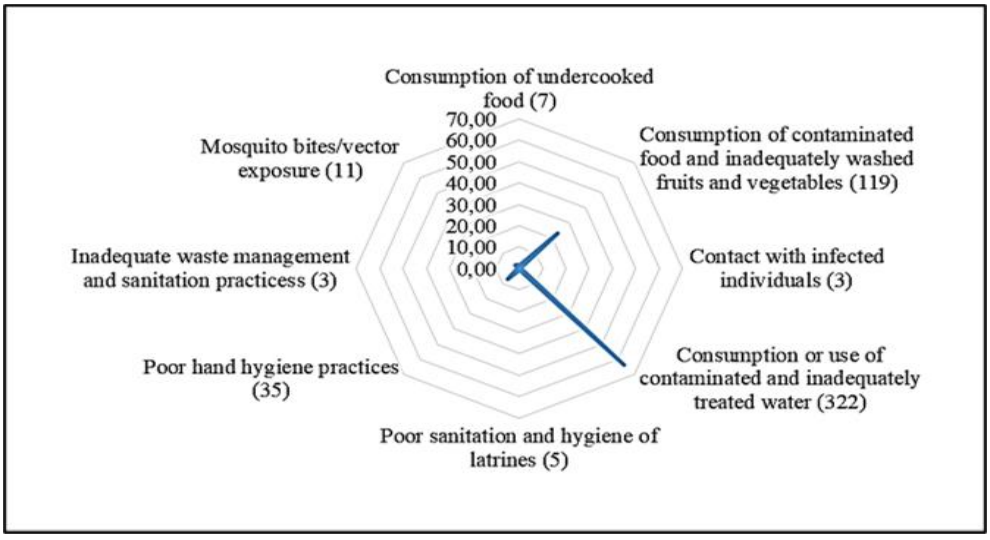


Figure 3. Causes of typhoid fever reported by survey participants.

3.1.1.4. Symptoms of typhoid fever

Many symptoms were reported by interviewees as indicative of typhoid fever. Respondents rarely mentioned symptoms in isolation. Headache, fever, diarrhea, abdominal pain, and joint pain were reported by more than 60% of participants (Fig.4).

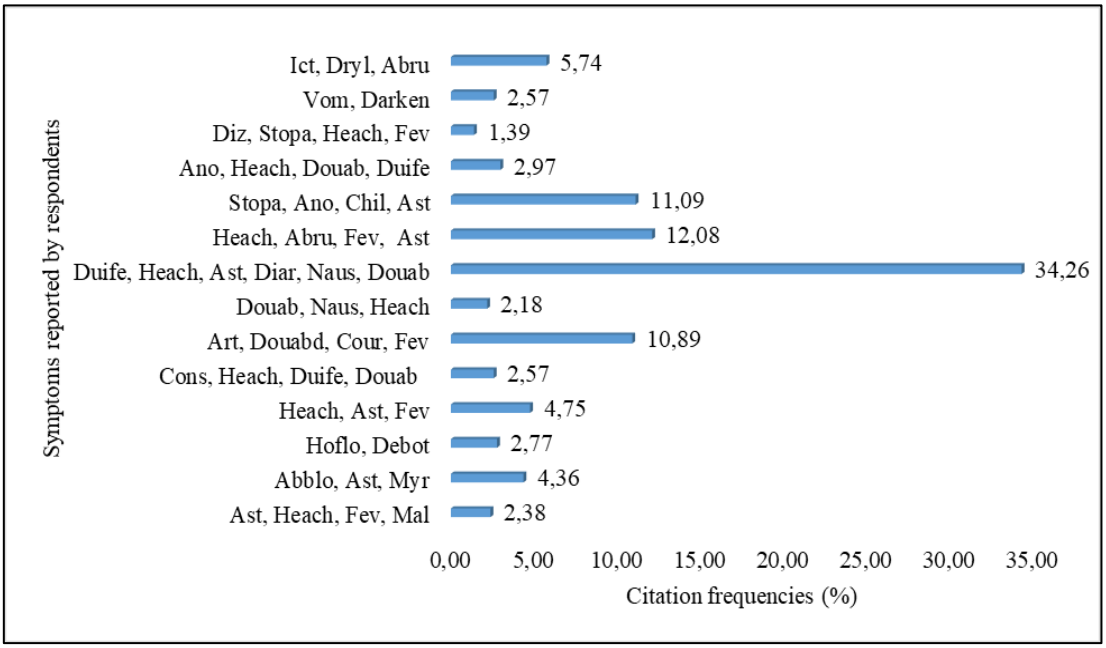


Figure 4. Symptoms of typhoid fever as reported by interviewees.

Legend: Ast = Asthenia (weakness/fatigue), Fev = Fever, Pal = Malaria, Abblo = Abdominal bloating, Myr = Myalgia (muscle aches), Hoflu = Hot flushes, Debot = Decreased body temperature (hypothermia or temperature drop), Cons = Constipation, Diufe = Diurnal fever (daytime fever), Douab = Abdominal pain, Art= Arthralgia (joint pain), Naus = Nausea, Diar = Diarrhea, Abru = Abdominal rumbling (borborygmus), Stopa= Stomach pain, Ano = Anorexia (loss of appetite), Chil = Chills, Diz = Dizziness, Vom = Vomiting, Darken = Darkening/yellowing of urine (choluria), Ict = Icterus (scleral/conjunctival jaundice), Dryl = Dry lips, Heach= Headaches

3.1.1.5. Epidemiology and treatments reported by interviewees

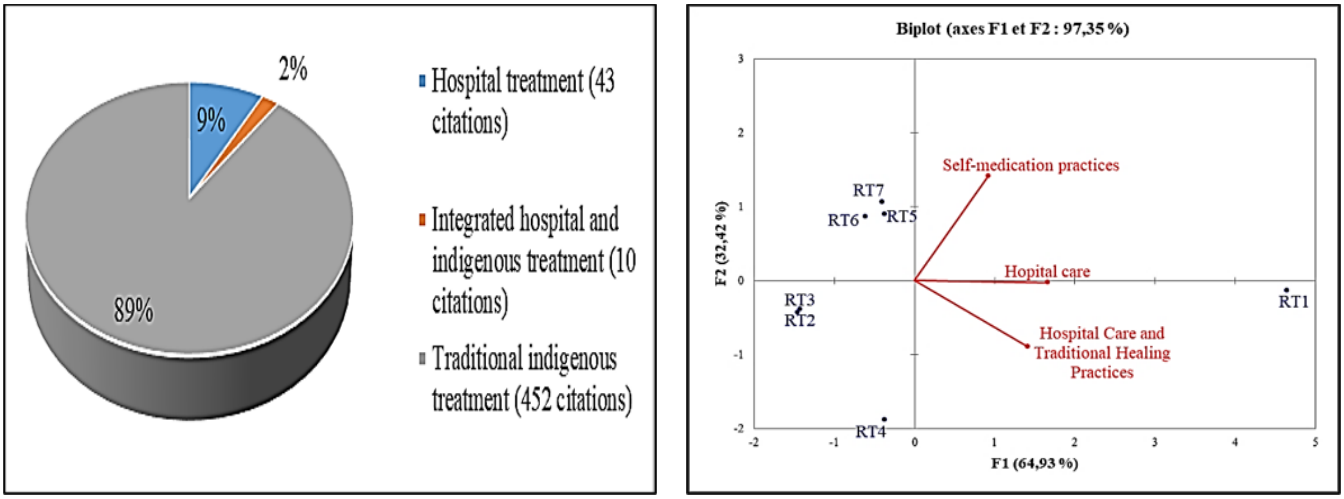
All respondents (100%) reported a prior episode of typhoid fever. Only 11% initially sought conventional medical treatment, whereas 91% resorted to self-medication predominantly using indigenous remedies (312 mentions) (Fig.5a).

By combining the treatment choice values with the reasons for treatment selection (R1-R7), a Principal Component Analysis (PCA) was performed. The PCA yielded the results presented in Fig.5b. The PCA revealed a positive and significant correlation among treatment choices. The correlation between self-medication and hospital treatment was stronger ($r = 0.87$; $p < 0.05$) than that between hospital treatment and hospital + indigenous treatment ($r = 0.37$; $p < 0.05$).

Along the F1 axis, the Correspondence Factor Analysis (CFA) explained 64.93% of the total information shared between the reasons for treatment choice and the treatment options selected. RT1 was therefore the factor that best explained the choice of the three treatment options, whereas the other reasons for treatment choice (RT2 to RT7) were negatively correlated with treatment selection. Consequently, RT4 to RT7 were only weakly correlated with treatment choice.

Table 2. Contingency table of treatment choice and reasons for selection.

Rationale for Treatment Selection	Hospital treatment	Integrated hospital and indigenous treatment	Traditional indigenous treatment	Total
Provides reliable diagnosis, directly eradicates the pathogen, and promotes rapid recovery (R1)	39	6	111	156
With 100% efficacy (R2)			27	27
Full recovery (R3)			29	29
He two treatments exhibit complementary effects (R4)		4		4
A natural plant-based therapy offering broad-spectrum activity with reduced adverse effects on the body (R5)	3		93	96
A cost-effective and efficacious treatment (R6)			91	91
Rapid and highly efficient treatment (R7)	1		101	102
Total	43	10	452	505



(a) (b)

Figure 5. Links between treatments and the reasons for choosing a treatment. (a) selected treatment types; (b) correlation between the reasons underlying treatment choice and the chosen treatment.

3.1.2. Ethnobotanical knowledge on the management of typhoid fever

3.1.2.1. Characterization of formulations

3.1.2.1.1. Plants used for medicinal preparations

A total of 1.101 formulations were recorded from the 505 individuals interviewed. However, only 968 formulations, representing 87.92% of the total citations, were included in the analyses. One hundred thirty-three citations related to treatments based on non-plant substances, as well as citations referring to species that were still being identified, were excluded.

The formulations are presented in Table 3 as follows: the plant's scientific name followed by its family, the vernacular name in one of the local languages, and a detailed description of the formulation specifying the plant organ used, the method of preparation, and the route of administration.

Table 3. Description of the formulations employed in typhoid fever treatment.

Botanical/Vernacular Names	Families	Plant Parts Used	Associated Plants and/or Ingredients	Preparation Methods |	Routes of Administration
Abies alba/ Fir tree	Pinaceae	Leaves, seeds	Lemon + lemongrass + mango tree, Maize silk	Aqueous decoction	Drink 3 glasses 3 times daily (morning, noon, evening) for 9 days
Ageratum conyzoides (L.) L. / King of herbs	Asteraceae	Whole plants	Lime + kinkeliba + lemongrass+pineapple	Aqueous decoction	Drink 3 glasses 3 times daily (morning, noon, evening) for 7 days
Alchornea cordifolia (Schumach. & Thonn.) Mull.Arg./Aboue	Euphorbiaceae	Leaves or stem bark	Garlic + lemon + table salt	Infusion	Drink half a glass twice daily (morning and evening) for 1 month
Allium sativum L./ Garlic	Amaryllidaceae	Bulbs	Lemon+neem + guava + skimmed milk	Decoction prepared in milk	Drink 1 glass while fasting for 9 consecutive days
Aloe barbadensis (L.) Burm.f./Aloe verra	Asphodelaceae	Leaves	Papaya + ginger + garlic + lime	Aqueous decoction	Drink 1 liter per day for 2 weeks.
Alstonia boonei De Wild. LC. / Ekouk	Apocynaceae	Leaves, stem bark	Kinkeliba + yellow bark + loum + quinine	Maceration	Drink 3 glasses 3 times daily (morning, noon, evening) for 1 month
Ananas comocus (L.) Merr. / Pineapple	Annonaceae	Pineapple peel	Lime + ginger	Aqueous decoction	Drink 2 glasses per day for 3 weeks
Annickia chloranthia (Oliv) Setten & Maas/ Yellow bark (Mfôol)	Annonaceae	Stem bark	Garlic+lemon+rock salt	Maceration	Drink 2 liters per day for 4 weeks
Annona muricata L. / Soursop tree	Annonaceae	Leaves	Lemon + guava + avocado tree	Aqueous decoction	Drink 3 glasses 3 times daily (morning, noon, evening) for 3 weeks
Anonidium mannii (Oliv.) Engl. & Diels/ Ebom afane	Annonaceae	Stem bark	Kinkeliba + yellow bark + loum + quinine	Maceration	Drink 3 glasses 3 times daily (morning, noon, evening) for 1 month
Artemesia vulgaris L. / Artemisia	Asteraceae	Leaves	Aloe vera+ kinkéliba	Aqueous decoction	Drink 1 liter per day for 3 weeks
Asplenium scolopendrium L./ Fern	Aspleniaceae	Leaves	Kinkéliba	Aqueous decoction	Drink one glass daily on an empty stomach for one month
Azadirachta indica A.JUSS. / *Neem*	Meliaceae	Leaves, fruits	Guava+lemon+ garlic	Aqueous decoction	One glass was consumed twice daily
Bambusa vulgaris Schrad/ Bamboo	Poaceae	Leaves	Lemon + lemongrass + corn silk	Aqueous decoction	One glass was consumed twice daily
Beta vulgaris L. / Beet	Amaryllidaceae	Leaves	Twins' cane+ eucalyptus	Aqueous decoction	Drink 3 glasses 3 times daily (morning, noon, evening)
Biden pilosa L. / Wild injection	Asteraceae	Whole plants	Lime + garlic + ginger	Aqueous decoction	Drink 1 liter per day
Caesalpinia pulcherrima (L.) SW. / Pride of China	Fabaceae	Leaves	Moringa + honey	Maceration	Consume two glasses per day for three weeks
Capsicum frutescens L./ Ondodôo below	Solanaceae	Fruits	Massep+king of herbs + red on one side + ginger	Aqueous decoction	Purging was performed every 3 days for 2 weeks
Carica papaya L./ Papaya	Caricaceae	Leaves, roots, seeds	Lemongrass + mfôl + Kinkeliba + avocado tree + loum	Aqueous decoction	Drink 1 liter per day

Cestrum nocturnum L./ Night poison	Solanaceae	Leaves	Honey + guiness	Grinding followed by maceration	Administered three times daily
Chromolaena odorata (L.) R.M.King & H.Rob./ Alolongo	Asteraceae	Leaves	Mfô + lemongrass + papaya leaves	maceration followed by decoction.	To be taken twice daily (morning and evening)

Cinchona officinalis L./ Quinquina	Rubiaceae	Stem bark	Palm wine (matango) + ékouk	Maceration	Administer twice daily (morning and evening)
Cinchona pubescens Vahl./ Quinine	Rubiaceae	New leaves	Honey + Guinness	Infusion	Administer orally on an empty stomach, two glasses per day
Citrus limon (L.) Osbeck/ Lemon	Rutaceae	Fruits	Papaya + plantain banana + guava	Aqueous decoction	Drink 3 glasses 3 times daily
Colatropis gigantea (L.) Dryand./ Crown flower	Apocynaceae	Stem bark	Lemongrass + papaya + garlic	Aqueous decoction	Consume one glass twice daily.
Combretum micranthum G. Don/ Kinkeliba	Combretaceae	Fruits	Papaya +avocado + mfôl+ ekouk +loum+ aken+ lemongrass+ Mango tree	Aqueous decoction	Consumption of 1 L/day
Costus afer Ker Gawl./ Twins' stick	Costaceae	Leaves	Beet root + bubinga + eucalyptus	Aqueous decoction	A daily intake of three glasses
Cucumis metuliferus E.Mey. Ex Naudin/ Coribong	Cucurbitaceae	Leaves	Black manyanga oil	Maceration	Administer one glass per day on an empty stomach for one month
Curcuma longa L./ Turmeric	Cucurbitaceae	Rhizomes	Black pepper + honey	Maceration	Drink 2 glasses 3 times daily for 2 weeks
Cylicodiscus gabunensis Harms/ Soap bark (Loum)	Fabaceae	Stem bark	Aboe+Aloe vera+ Akeng +twins' stick+ nfôo + ékouk	Aqueous decoction	Consume 1 L of fluid per day and take a steam bath every evening
Cymbopogon citratus (DC.) Stapf/ Lemongrass	Poaceae	Leaves	Lemon + papaya + onion + garlic + moringa	Aqueous decoction	To be taken three times daily
Daucus carota L./ Carrot	Apiaceae	Leaves	Avocado tree + plum tree + lime + garlic	Ground and macerated	Drink 2 glasses 3 times daily
Diospyros crassiflora Hiern/Mevini	Ebenaceae	Stem bark	Palm wine (mantango)	Maceration	Drink half a glass per day
Dracaena fragrans (L.) Ker Gawl/ Tree of peace	Asparagaceae	Leafy stems	Lime	Aqueous decoction	Drink 1 glasses 2 times daily
Dracaena trifasciata (Prain) Mabb./ Knife	Asparagaceae	Leaves	Avocado tree + plum tree + lime	Aqueous decoction	Drink 1 glasses 3 times daily
Eclipta prostrata (L.) L./ Nette	Asteraceae	Leaves	Papaya + guava + *Chamaesyce hirta* (L.) Millsp.	Maceration	Drink 1 liter per day for 1 week.
Elaeis guineensis Jacq./ Palm oil	Arecaceae	Fruits, sap	Kinkéliba+ékouk+ mfôl	Maceration	Drink two glasses after eating
Eremomastax speciosa (Hochst.) Cufod/ Two sides	Acanhthaceae	Leaves	King of herbs + garlic + lemongrass + turmeric + plum tree	Aqueous decoction	Consume 1 l per day and undergo purging three times weekly
Eucalyptus globulus Labill./ Eucalyptus	Myrtaceae	Leaves	Lemon + rock salt	Maceration	Drink 1 glasses 3 times daily
Erythrophleum suaveolens (Guill. & Perr.) Brenan/ Elon	Fabaceae	Stem bark	Bubinga+akeng+loum+ Avocado tree + mango tree	Aqueous decoction	Purging was performed three times per week for two weeks
Garcinia kola Heckel/ Mbimbé	Clusiaceae	Stem bark	Black manyanga oil + mfôl+ akeng	Aqueous decoction	Drink 1 liter per day
Garcinia mangostana L/ Mangosteen	Clusiaceae	Stem bark, leaves	Clove + cinnamon	Aqueous decoction	Drink 1 glasses 3 times daily

Gossypium hirsutum L./ Cotton plant	Malvaceae	seeds	Lemon + rock salt	Crush and macerate	Drink half a glass daily for 14 days
Guibourtia demeusei (Harms) J.Léonard/ Kouamo	Fabaceae	Stem bark	Twins' stick + bett + bubinga	Aqueous decoction	Drink 1 liter per day

Guibourtia tessmannii (Harms) J.Léonard/ Essinguan (bubinga)	Fabaceae	Stem bark	Kouamo+ Nkeng (aken) + lemon	Aqueous decoction	Drink 1 glasses 3 times daily
Harungana madagascariensis Lam. ex Poir./ Atonogoo	Hypericaceae	Leaves and Stem bark	Red on one side	Aqueous decoction	Purging was performed 3 times per week for 2 weeks
Irvingia gabonensis (Aubry-Lecomte ex O'Rorke) Baill/ Andôoo	Irvingiaceae	Stem bark	Mango tree bark+ avocado tree bark	Aqueous decoction	Drink 1 glasses 3 times daily
Leptadenia hastata (Pers.) Decne./ Menanbia	Apocynaceae	Leaves and roots	Honey + Guinness	Maceration	Drink 1 liter per day
Leucanthemum vulgare Lam./ Marguerite	Asteraceae	Leaves	Garlic + lemon+ salt	Infusion	Drink half a glass twice daily (morning and evening)
Lilium bulbiferum L./ Lilier	Liliaceae	Leaves	Papaya + ginger + garlic+ lemon	Aqueous decoction	Drink 1 liter per day
Mangifera indica L./ Mango tree	Anacardiaceae	Leaves, Stem bark	Avocado tree + mfôl+ kinkéliba	Aqueous decoction	Drink 1 glasses 3 times daily
Manihot esculenta Crantz/ Cassava	Euphorbiaceae	Leaves	Soursop tree + mango tree + lemongrass	Aqueous decoction	Ingest one glass daily while fasting
Mentha viridis L./ Mint	Lamiaceae	Leaves	Thyme + massep+ basil	Maceration	Consume 0.5 l per day
Mimosa pudica L./ Baby is asleep herb	Mimosaceae	Whole plants	King of herbs + lemongrass + garlic	Maceration	Drink 1 liter per day
Morinda lucida Benth./ Akeng	Rubiaceae	Stem bark	Yellow bark (mfôl) + kinkeliba + avocado tree+ Loum + Ekouk	Aqueous decoction	Drink 1 glasses 3 times daily
Moringa oleifera Lam./ Moringa	Moringaceae	Leaves, seeds	Lemongrass	Crush	Consume one glass per day in the fasting state
Musa paradisiaca L./ Plantain	Musaceae	Plantain peels, inflorescences	Guava + pineapple + papaya + corn silk	Aqueous decoction	Drink 1 liter per day
Musanga cecropioides R.Br. Ex Tedlie/ Parasolier	Cecropiaceae	Stem bark	Black manyanga oil	Infusion	Drink 2 glasses 3 times daily for 3 weeks
Ocimum basilicum L./ Massep (Ocim nnam)	Lamiaceae	Leaves	Thyme + massep + basil + ringworm tree	Maceration	Drink 3 glasses 3 times daily
Ocimum gratissimum L./ Massep	Lamiaceae	Leaves	Lemon + basil + garlic+ lemongrass + rock salt	Aqueous decoction	Drink 2 glasses 2 times daily for 3 weeks
Ocimum tenuiflorum L./ Holy Basil	Lamiaceae	Leaves	Thyme + mint	Maceration	Drink 2 glasses 3 times daily
Panax ginseng C.A.Mey./ Ginseng	Araliaceae	Rhizomes	Aloes vera	Aqueous decoction	Drink 1 glasses 2 times daily
Parkia biglobosa (Jacq.) R.Br. Ex G. Don/ Noum	Fabaceae	Stem bark, seeds	Papaya + guava + plum tree	Aqueous decoction	Drink 1 liter per day
Persea americana Mill./ Avocado tree	Lauraceae	Stem bark	Papaya + ginger + garlic + lemon	Aqueous decoction	Drink 1 liter per day
Phœnix dactylifera L./ Date-palm	Arecaceae	Fruits	Lemongrass	Maceration	Consume two glasses per day for one month

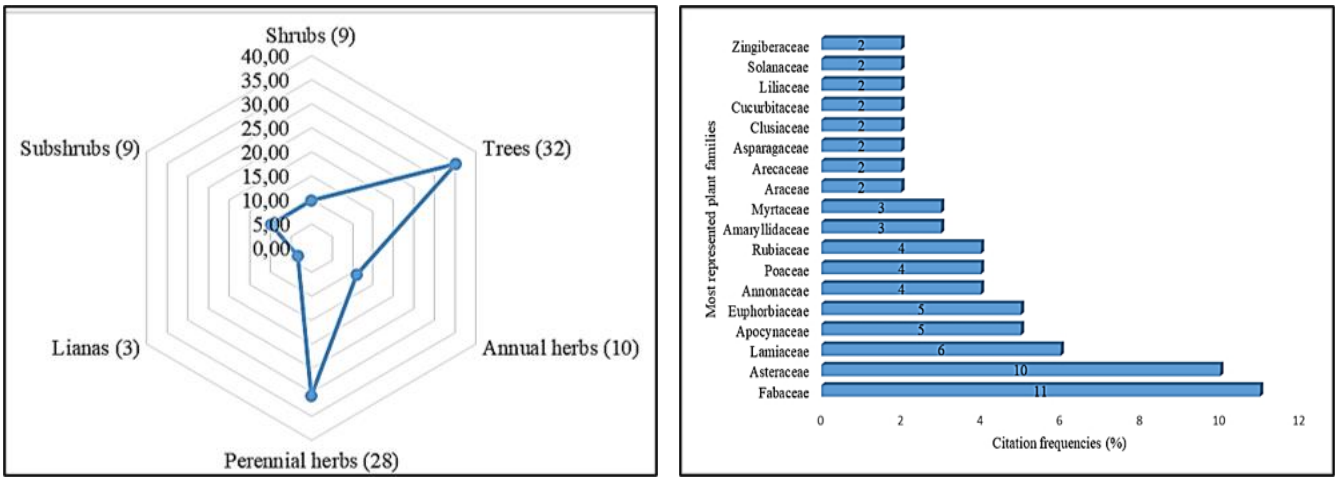
Picralima nitida (Stapf) T.Durand & H. / Ebam	Apocynaceae	Stem bark	Mango tree + guava tree + papaya	Aqueous decoction	Drink 1 liter per day
Piper nigrum L./ Poor man's sting	Piperaceae	Stem bark, leaves	Chili peppers + cloves	Crush	Drink half a glass twice daily (morning and evening)
Polyalthia longifolia (Sonn.) Thwaites/ Veuve pleureuse	Annonaceae	Leaves	Garlic + lemon + rock salt	Aqueous decoction	Drink 1 liter per day
Prunus africana (Hook.f.) Kalman/ African plum (pegyum)	Rosaceae	Stem bark	Aloe vera + lemon	Aqueous decoction	Consumption of two glasses per day for two weeks
Psidium Guajava L./ Goyavier	Myrtaceae	Leaves	Papaya + ginger + garlic + lemon	Aqueous decoction	Drink 1 liter per day
Senna alata (L.) Roxb./ Longkana (ringworm tree)	Fabaceae	Leaves	Lemongrass + papaya + garlic	Maceration	To be taken three times daily
Senna alexandrina Mill. / Ngom ntanga	Fabaceae	Leaves	Lemongrass + papaya + garlic	Maceration	To be taken three times daily
Spondias mombin L./ Cassimanga	Anacardiaceae	Stem bark	Djangsang bark + massep + papaya	Aqueous decoction	Consume 2gla sses per day for 1 month
Syzygium aromaticum (L.) Merr. & L.M.Perry/ Clove	Myrtaceae	Flower buds	Garlic+turmeric +thyme+ cinnamon + basil + lemon	Crush	Consumed on an empty stomach, 2 glasses per day
Telfairia occidentalis Hook.f/ Okoribong	Cucurbitaceae	Leaves	Guinness	Infusion	To be taken three times daily
Thymus vulgaris L./ Thyme	Lamiaceae	Leaves	Avocado tree + plum tree + thyme + garlic	Aqueous decoction	Consume one glass three times daily
Vernonia amygdalina Delile/ Ndolé	Asteraceae	Leaves	Avocado tree + plum tree + thyme + garlic	Aqueous decoction	Consume one glass three times daily
Zanthoxylum gilletii (De Wild.) P. G. Waterman/ Bongo	Rutaceae	Stem bark	Lemongrass + lemon + guava leaves	Aqueous decoction	Consume one glass three times daily
Zea Mays L. / Maize	Poaceae	Maize silk	Papaya + lemon + plantain inflorescence	Maceration	Drink 1 liter per day
Zingiber officinale Roscoe/Djindja (ginger)	Zingiberaceae	Rhizomes	Lemon + ginger	Crush	Consume one glass three times daily

It appears from this table that practitioners prepare remedies for typhoid fever predominantly using plant combinations (92.35%). Specifically, of the cited formulations, 74 were single-species preparations using only one plant, while 894 consisted of combinations in which an additional plant was associated with the principal species.

Among the plants cited in these formulations, several are used both as primary remedies and as adjuncts; examples include the yellow-barked *Annickia chlorantha* (Oliv.) Setten & Maas, the soap-bark *Cylicodiscus gabunensis* Harms, the mango-bark *Mangifera indica* L., kinkeliba *Combretum micranthum* G. Don, lemongrass *Cymbopogon citratus* (DC.) Stapf, and lemon *Citrus limon* (L.) Osbeck. Other species, however, are employed exclusively as adjuncts; these include african plum *Dacryodes edulis* (G. Don) H.J. Lam, the creeping tick-trefoil (owondo bekone) *Desmodium adscendens* (Sw.) DC., njangsang *Ricinodendron heudelotii* (Baill.) Pierre ex Heckel, and the hairy spurge (okoulou bifess) *Chamaesyce hirta* (L.) Millsp.

In total, 91 medicinal species were recorded in recipes used against typhoid fever, of which 47 were woody species, 35 herbaceous species, and 10 subshrubs (Fig.6a).

These plants are distributed across 79 genera within 43 families, the most represented being Asteraceae and Fabaceae (10 species each). They are followed by Lamiaceae (6 species), Apocynaceae (5 species), and Annonaceae, Poaceae, and Rubiaceae (4 species each) (Fig.6b).



(a) (b)

Figure 6. Morphological types of species utilized in the recipes and most represented botanical families. (a) morphological types of species; (b) most represented families.

Among the principal plant species used in remedies for treating typhoid fever, *Combretum micranthum* G. Don (119 citations) is the most frequently cited. It is followed by *Carica papaya* L. (117 citations), *Mangifera indica* L. (74 citations), *Citrus limon* (L.) Osbeck (44 citations), *Psidium guajava* L. (44 citations), *Cymbopogon citratus* (DC.) Stapf (44), and *Ageratum conyzoides* (L.) L. (38 citations) (Fig.7).

Moreover, 93.40% of the principal plants used in recipes to treat typhoid fever are also cited as accessory plants in other formulations. Indeed, the most frequently employed accessory species in recipes containing at least two species is *Citrus limon* (107 citations), followed by *Carica papaya* (98 citations) and *Mangifera indica* (90 citations).

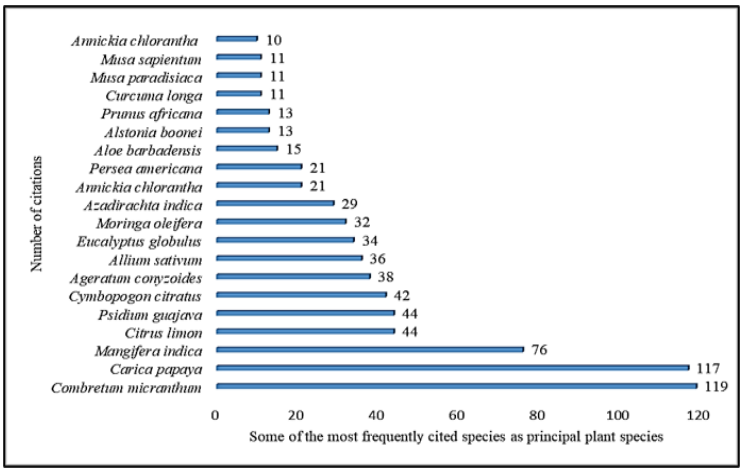


Figure 7. Principal plant species most frequently used in the treatment of typhoid fever.

Only six species that are not among the principal plants were reported as accessory plants: *Allium cepa* L. (3 citations), *Cinnamomum verum* J. Presl (3 citations), *Dacryodes edulis* (G. Don) H.J. Lam (18 citations), *Erigeron*

floribundus (Kunth) Sch. Bip. (1 citation), *Chamaesyce hirta* (L.) Millsp. (3 citations), and *Tithonia diversifolia* (Hemsl.) A. Gray (1 citation).

3.1.2.1.2. Pharmaceutical characteristics of antityphoid remedies

The pharmaceutical characteristics of these remedies are defined by the plant parts used in recipe preparation, the methods of preparation, routes of administration, dosage regimens, storage techniques, adverse effects, and the remedies' spectrum of activity.

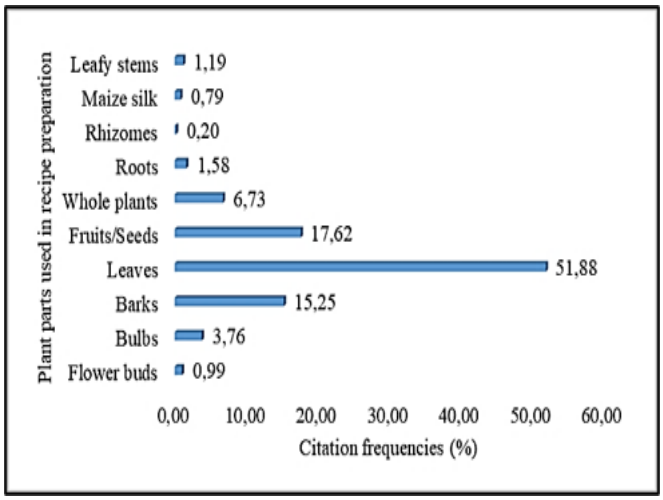
Various plant organs are harvested to prepare remedies for typhoid fever, notably leaves (55.88%), fruits and/or seeds (17.62%), barks (15.25%), bulbs (3.76%), roots (1.58%), and leafy stems (1.19%). In addition, some formulations (6.73%) required the use of the whole plant (Figure 8a).

Three main preparation methods were reported by respondents for remedies used against typhoid fever. These were decoction (62%), in which fresh or dried plant parts are boiled in water for 30-45 minutes or in skimmed milk for 3-5 minutes; maceration (21%), in which plant parts either previously crushed or left intact are soaked in water and/or an alcoholic solvent for at least 24 hours; and infusion (17%), in which boiling water is poured over very finely cut plant material.

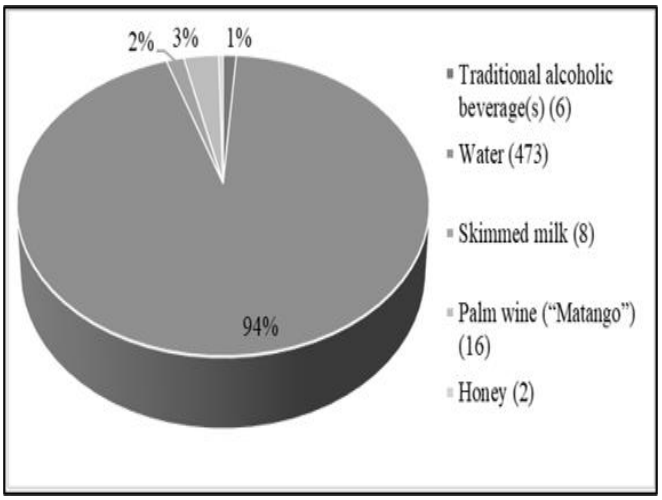
The respondents reported water (94%) to be the solvent of choice for preparing antityphoid remedies. Other solvents cited included palm wine (mentioned 16 times) and skimmed milk (mentioned 8 times), which respondents also use to prepare typhoid treatments (Fig.8b).

The remedies used for typhoid fever are administered in liquid form. They are given to patients orally (99.60%), by steam bath (fumigation) (14.06%), and rectally (3.96%) (Fig.8c).

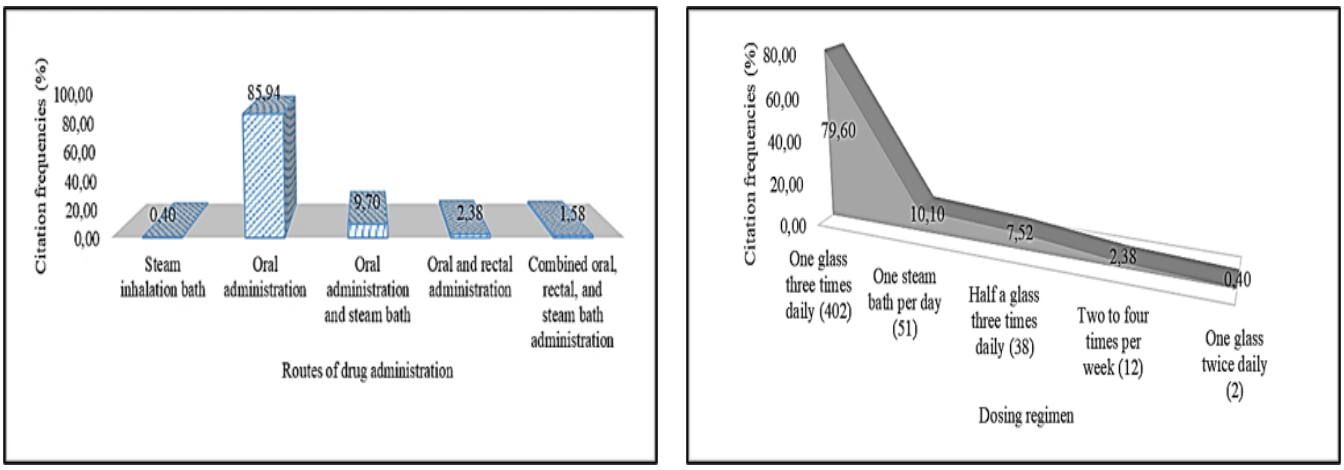
The dosage reported varied according to the interviewees, the formulation, the route of administration, and the patient's age. However, 79.60% of respondents indicated that, for oral administration, the medicine should be taken as one glass three times a day, while 10% specified that steam inhalation should be performed once daily (Fig.8d)



(a)



(b)



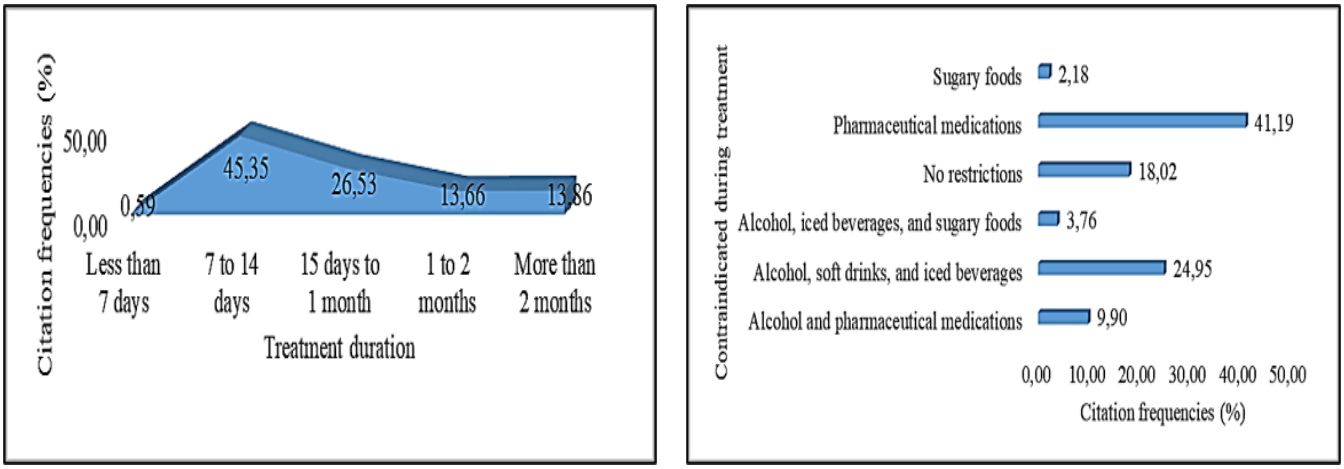
(c) (d)

Figure 8. Pharmaceutical characteristics of traditional medicinal preparations used in the treatment of typhoid fever. (a) organs involved in the preparation of remedies; (b) solvents used to prepare medications; (c) different routes of drug administration; (d) recommended dosages for administering medications.

Medicinal preparations used to treat typhoid fever are kept exposed to the air (80.39%). Treatment durations also vary depending on the preparation. However, 229 respondents (45.35%) indicated that the remedies should be administered for no fewer than 7 days, and that these treatments do not exceed 14 days (Fig.8).

Many respondents (265; 52.48%) reported some adverse effects following the use of medicinal remedies to treat typhoid fever. These effects ranged from dizziness/fatigue (131 mentions) and nausea/vomiting (116 mentions) to abdominal bloating (15 mentions). However, a large proportion of respondents (240; 47.52%) reported that the treatments administered to patients for typhoid fever did not produce any adverse effects.

The holders of empirical knowledge on phytotherapeutic treatments for typhoid fever report that 41.19% consider it inappropriate to use pharmaceutical drugs while undergoing phytotherapeutic medication. Additionally, 24.95% recommend avoiding alcohol and carbonated and/or iced beverages (Fig.9).



(a) (b)

Figure 9. Treatment durations reported by respondents and associated restrictions during different therapeutic regimens. (a) Treatment durations during typhoid fever medication; (b) Precautions and contraindications to observe while using herbal treatments for typhoid fever.

3.1.2.1.3. Other Ailments Treated with Plant Species Used for Typhoid Fever Management

The plants reported by local people to treat typhoid are also used for a variety of other therapeutic purposes. In total, interviewees mentioned twenty additional therapeutic indications (related diseases and symptoms); the most frequently cited were malaria (45.04%), jaundice (17.46%), diarrhea and/or dysentery (9.92%), fever (4.65%), anemia (4.34%), cough (3.14%) and asthenia (2.38%) (Fig.10).

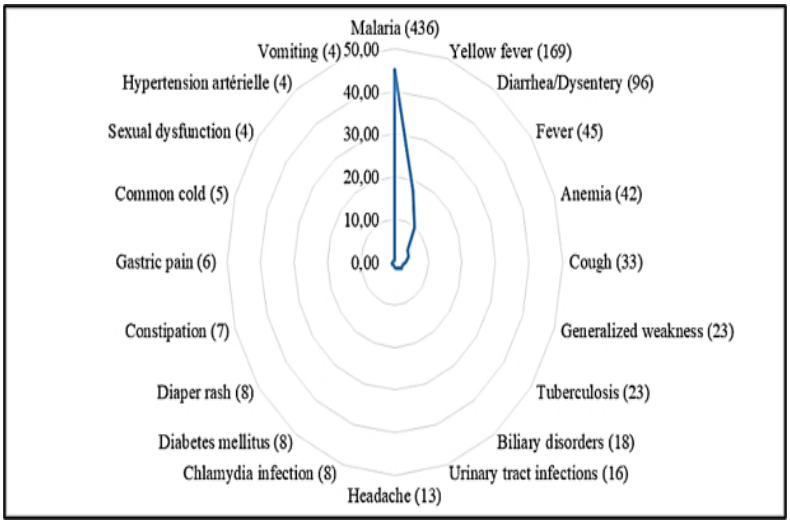


Figure 10. Other ailments treated with plant species used for typhoid fever management.

3.1.2.2. Ethnobotanical indices

The number of citations or "events" in different remedies alone is insufficient to identify species of interest for treating a given disease. It is therefore preferable to combine this measure with other ethnobotanical indices. Table IV shows, for species used in remedies to treat typhoid fever in markets and households, values of *VU*s (Use-Value index), *ICF*s (Informant Consensus Factor), *VAU*s (Cultural Value indices of the species), and *CUS* (Convergence of Spatial Use index).

Table 4. Ethnobotanical indices of the most frequently used plants in the treatment of typhoid fever.

Plant species	**Households**				**Markets**			
Sites	*ICF*s	*VU*s	*VAU*s	*CUS*s	*ICF*s	*VU*s	*VAU*s	*CUS*s
Ageratum conyzoides	0,19	1	0,19	1,00	0,22	3,75	0,83	0,33
Allium sativum	0,22	1	0,22	1,00	-	-	-	-
Aloe barbadensis	0,08	1	0,08	0,50	0,05	3	0,16	0,33
Alstonia boonei	0,04	1,5	0,07	0,50	0,05	4	0,22	0,33
Annickia chlorantha	0,13	1	0,13	0,50	0,27	3,2	0,88	0,67
Annona muricata	0,06	1	0,06	0,75	-	-	-	-
Azadirachta indica	0,13	1	0,13	0,50	0,16	3	0,5	0,67
Carica papaya	0,63	1,03	0,66	1,00	0,33	3,83	1,27	1,00
Cinchona officinalis	-	-	-	-	0,05	4	0,22	0,33
Cinchona pubescen	-	-	-	-	0,16	3	0,5	0,67
Citrus limon	0,28	1,04	0,30	0,75	-	-	-	-
Combretum micranthum	0,53	1,04	0,55	1,00	0,88	3,31	2,94	1,00
Curcuma longa	0,07	1	0,07	0,50	-	-	-	-

Cylicodiscus gabunensis	0,01	1	0,01	0,25	0,22	2,5	0,55	0,67
Cymbopogon citratus	0,28	1	0,28	1,00	0,05	4	0,22	0,33
Eucalyptus globulus	0,13	1	0,13	0,75	0,38	3,28	1,27	1,00
Mangifera indica	0,43	1	0,43	1,00	0,22	2,75	0,61	1,00
Moringa oleifera	0,20	1	0,20	0,75	-	-	-	-
Musa paradisiaca	0,07	1	0,07	0,75	-	-	-	-
Persea americana	0,09	1	0,09	0,50	0,16	3,33	0,55	1,00
Phoenix dactylifera	-	-	-	-	0,11	3,55	0,38	0,33
Psidium guajava	0,24	1,05	0,25	0,75	0,11	2	0,22	0,67
Prunus africana	0,08	1	0,08	0,75	-	-	-	-
Senna alata	0,04	1,25	0,06	0,75	-	-	-	-
Syzygium aromaticum	0,04	1	0,04	0,25	-	-	-	-
Telfairia occidentalis	0,06	1	0,06	0,50	0,05	4	0,22	0,33
Vernonia amygdalina	0,04	1	0,04	0,25	-	-	-	-
Zea Mays	0,03	1,33	0,04	0,25	-	-	-	-
Zingiber officinale	0,06	1	0,06	0,50	-	-	-	-

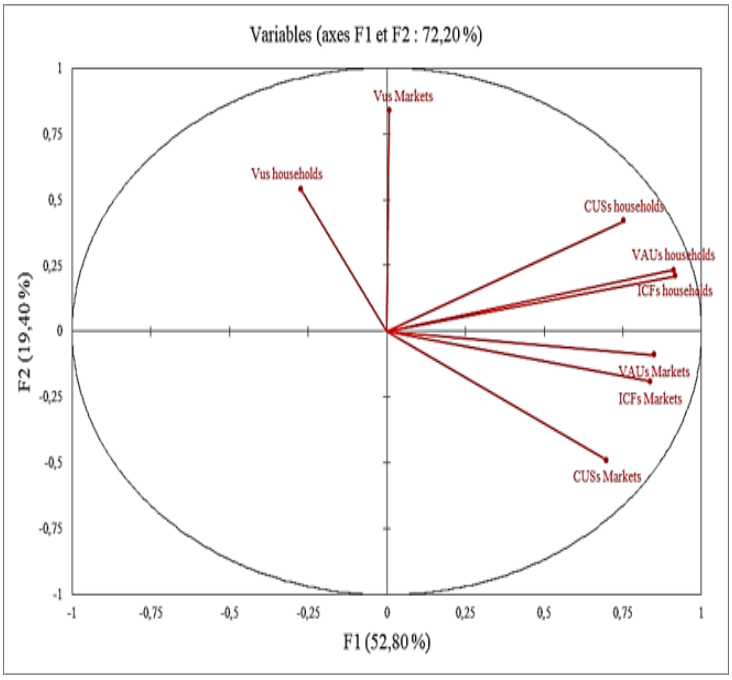


Figure 11. Principal Component Analysis (PCA) showing correlations among different ethnobotanical indices.

The table shows that many species of interest for treating typhoid fever were reported in households, although their ethnobotanical indices are low. For species found both in markets and in households, the ethnobotanical indices are higher in markets. For example, *Cylicodiscus gabunensis* has a household*ICF* (0.01) < market*ICF* (0.22), a household*UV* (1) < market*UV* (2.5), a household*VAU* (0.01) < market*VAU* (0.55), and a household*CUS* (0.22) < market*CUS* (0.67). The same pattern is observed for *Combretum micranthum*, *Ageratum conyzoides*, and several other species listed in the table. Moreover, higher UV values tend to increase *VAU*s values. *ICF* indices correlate positively and significantly with *VAU* values (Spearman correlation coefficients equal to 0.82 and 0.22, respectively, for $p < 0.001$). In addition, species such as *Carica papaya*, *Combretum micranthum*, and *Mangifera indica* showed the highest use agreement indices both in markets and in households.

By combining the values of *UVI* (Use Value Index), *ICF*s (Informant Consensus Factors), *VAU*s (cultural values of species), and *CUS*s (Spatial Use Convergence Indices) for several species used in recipes to treat typhoid fever, the PCA revealed significant positive correlations between household *VAU*s and market *VAU*s ($r = 0.33$, $p < 0.05$), as well as between household *CUS*s and market *CUS*s ($r = 0.25$, $p < 0.05$). Furthermore, positive correlations were observed between household *VAU*s and household *CUS*s ($r = 0.81$, $p < 0.05$), and between market *VAU*s and market *CUS*s ($r = 0.60$, $p < 0.05$) (Fig.11).

3.1.2.2.1. Similarity of species between the different survey sites

The analysis of similarities among the plants cited at the various survey sites is presented by the dendrogram shown in Figure 12. Based on the number of citations across the surveyed areas, the dendrogram reveals three affinity groups among the zones. The degree of similarity, or hierarchical classification, was determined using the Euclidean distance method between these zones. Thus, three groups emerge among the sites, indicating that the species reported in households in Bepanda are very similar to those reported in the Bonaberi and Village neighborhoods, which in turn are somewhat more distant from the species cited in Makepe Missoke. In addition, the three markets surveyed show strong similarity to one another, and their species lists are somewhat closer to those reported in the Makepe Missoke neighborhood (Fig.12).

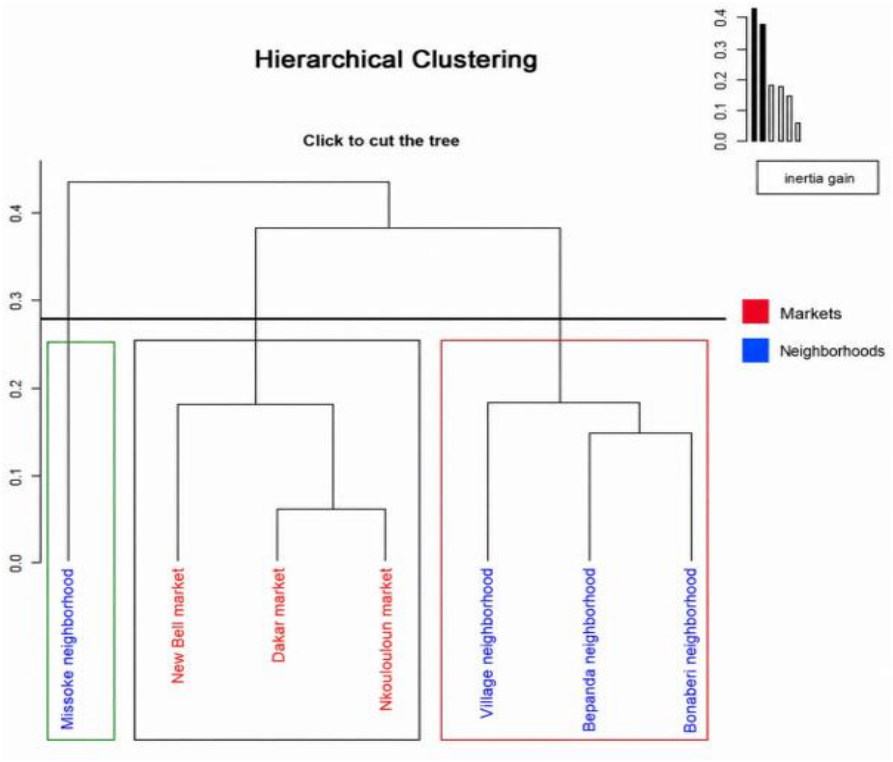


Figure 12. Hierarchical classification of zones for the different plant species used in the recipes.

3.1.2.2.2. Ethnobotanical use diversity

Ethnobotanical use diversity was determined by converting botanical indices into ethnobotanical indices. The indices used were Shannon–Weaver (H), Simpson (D), and Pielou's evenness (E). Overall diversity of medicinal-plant uses was high across the four surveyed areas among the Baka ($H = 6.91$).

Table 5. Ethnobotanical diversity index values

Study sites	Stations	Citations	Species	H'	D	E
Markets	Goat market	95	10	3,027941	0,872687	0,911501
	Dakar market	67	9	2,92062	0,900646	0,921353
	Nkololoun market	154	18	3,528939	0,891845	0,846284
Households	Bepanda	181	38	4,051883	0,938372	0,772092
	Bonaberi	51	18	3,418751	0,939639	0,819859
	Makepe misspoke	150	35	4,30117	0,949733	0,838552
	Village	270	34	4,020872	0,925158	0,790349
Overall indicator values	7	968	162	25,270176	6,41808	5,89999

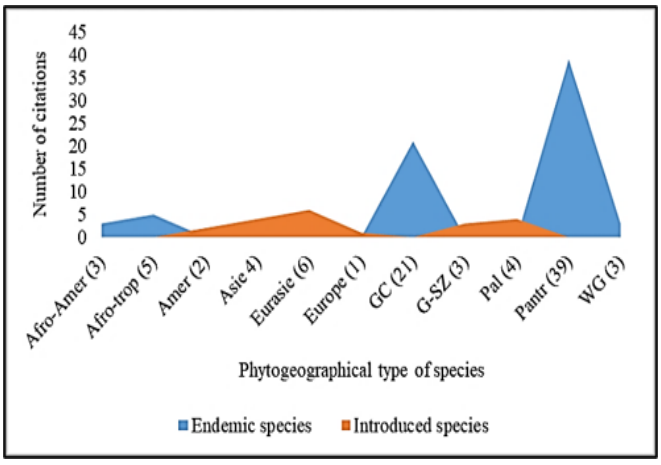
3.1.2.3. Floral characteristics of species used in the treatment of typhoid

The traits used to characterize the flora employed in traditional therapy for treating typhoid fever included, among others: geographic distribution, habitat types, morphological types, and the types and modes of diaspore dispersal.

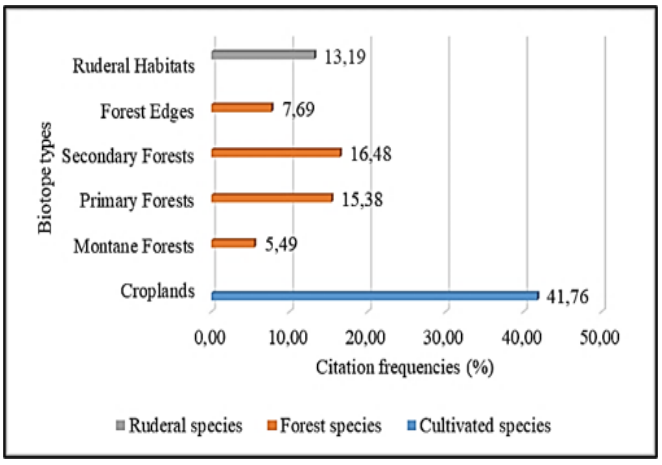
The proportions of the phytogeographical distribution of the species recorded for the treatment of typhoid fever highlight the predominance of regionally distributed species, which number 71, corresponding to a frequency of 78.02%. Among these, pantropical species are the most represented (39 species). Exotic species, totaling 20, also play a significant role in the treatment of typhoid fever, accounting for 21.98% of the inventoried species (Fig.13a).

Among the plants recorded for the treatment of typhoid fever, forest species were the most frequently used (45.04%, n = 41). Within these forest species, those from primary forests were the best represented (15 species, 16.48%). Among species from other biotopes, cultivated species were the most represented (38 species, 41.76%), while ruderal species accounted for 13.19% (Fig.13b).

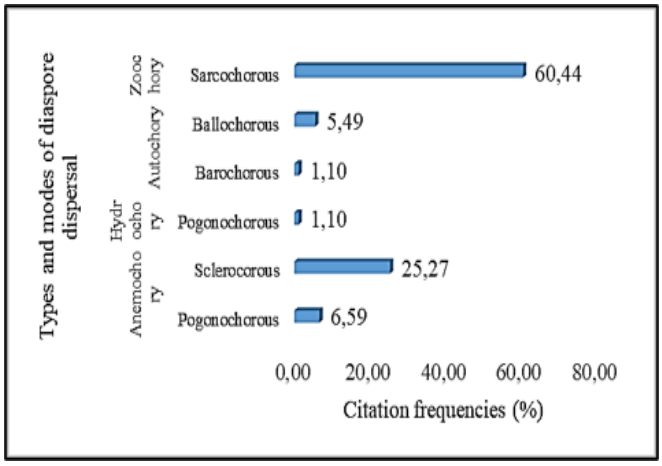
The diaspores of the species recorded in the treatment of typhoid fever are dispersed primarily by zoochory (65.93%, 60 species), anemochory (31.86%, 29 species), and autochory (1.10%, 1 species), with hydrochory also accounting for 1.10% (1 species). Sarcochores, numbering 55, are the most represented diaspore type (60.44%) (Fig.13c).



(a)



(b)



(c)

Figure 13. Floristic Characterization of Medicinal Plants Used for the Treatment of Typhoid Fever. (a) phytogeography of species used by local populations: GC = Guineo-Congolian, G-SZ = Guineo-Sudano-Zambezi, Pant = Pantropical, Afro-trop = Afrotropical, Amer = American, Asia = Asian, Europe = European, (b) habitat types of species recorded; (c) distribution of species according to diaspore types and dispersal modes.

3.2. Patients' behaviors regarding treatment

Patient follow-up through telephone interviews conducted twice weekly enabled the assessment of the time required for the resolution of typhoid fever symptoms, the occurrence of treatment-related adverse events, and the presence or absence of disease relapse among patients receiving the study treatments (Table 6).

Table 6. Ethnopharmacological follow-up information for patients.

Patient ID codes	Treatments administered	Time to symptom resolution	Adverse events	Number of follow-up visits and reasons for consultation	Recurrence after 2 months
Pat1Trai1	Recipe A consisted of BaCyga, FrComi, BaMain, BaAnch, BaAlbo, RoCapa, BaPeam, BaMolu, and LeCyci. The herbal preparation was prepared as a decoction and administered orally three times per day. Rectal administration was additionally	After 7 days	Nausea	4 (Treatment renewal)	No
Pat2Trai1		After 3 days	Nausea and pollakiuria	4 (Treatment renewal)	No
Pat3Trai1		After 3 days	Tiredness	2 (Treatment renewal)	No
Pat4Trai1		After 5 days	Dizziness and nausea	1 (Adverse drug reaction)	No
Pat5Trai1		After 3 days	None	3 (Treatment renewal)	No
Pat6Trai1		After 3 days	None	3 (Treatment renewal)	No
Pat7Trai1		After 3 days	Pollakiuria	2 (Treatment renewal)	No
Pat8Trai1		After 9 days	Pollakiuria	1 (Adverse drug reaction)	Yes
Pat9Trai1		After 3 days	Pollakiuria	3 (Treatment renewal)	No

Pat10Trai1	performed twice weekly for a duration of two weeks, while steam bath therapy was applied for three weeks.	After 3 days	Excessive sweating	2 (Treatment renewal)	No
Pat11Trai1		After 7 days	Nausea and pollakiuria	3 (Treatment renewal)	No
Pat12Trai1		After 7 days	Nausea and pollakiuria	3 (Treatment renewal)	No
Pat13Trai1		After 3 days	None	3 (Treatment renewal)	No
Pat14Trai1		After 3 days	None	3 (Treatment renewal)	No
Pat15Trai1		After 3 days	Dizziness	1 (Adverse drug reaction)	No
Pat1Trai2	Recipe B: FlbuSyar + BuAlsa + RhCulo + LeThvu + LeOcgr + FrCili + LeCyci + RhZiof The herbal formulation was prepared as a decoction and administered orally three times per day for five consecutive weeks.	After 10 days	None	3 (Treatment renewal)	No
Pat2Trai2		After 7 days	Excessive sweating	3 (Treatment renewal)	No
Pat3Trai2		After 12 days	Excessive sweating	3 (Treatment renewal)	Yes
Pat4Trai2		After 3 days	Excessive sweating	3 (Treatment renewal)	Yes
Pat5Trai2		After 7 days	Pollakiuria	No follow-up visit	No
Pat6Trai2		After 7 days	None	No follow-up visit	No
Pat7Trai2		After 3 days	None	No follow-up visit	Yes
Pat8Trai2		After 14 days	None	No follow-up visit	No
Pat9Trai2		After 14 days	Tiredness	No follow-up visit	No
Pat10Trai2		After 12 days	None	No follow-up visit	No
Pat11Trai2		After 21 days	None	3 (Treatment renewal)	No
Pat12Trai2		After 21 days	None	3 (Treatment renewal)	No
Pat13Trai2		After 7 days	None	3 (Treatment renewal)	Yes
Pat14Trai2		After 7 days	Dizziness	1 (Adverse drug reaction)	No
Pat15Trai2		After 14 days	Pollakiuria	No follow-up visit	No
Pat1Trai3	Recipe C: BuAlsa + OiAzin + FrCili (prepared as an	After 5 days	Excessive sweating	1 (Changement)	Yes
Pat2Trai3		After 4 days	Vomiting	No follow-up visit	No

Pat3Trai3	infusion using a skimmed milk vehicle and orally administered at a dose of one-quarter of a glass twice daily for two weeks).	After 4 days	Excessive sweating	No follow-up visit	No
Pat4Trai3		After 13 days	None	No follow-up visit	No
Pat5Trai3		After 4 days	Excessive sweating	No follow-up visit	Yes
Pat6Trai3		After 5 days	Excessive sweating	No follow-up visit	No
Pat7Trai3		After 5 days	None	No follow-up visit	No
Pat8Trai3		After 4 days	None	1 (Patient complaint)	No
Pat9Trai3		After 4 days	None	No follow-up visit	No
Pat10Trai3		After 9 days	None	No follow-up visit	No
Pat11Trai3		After 4 days	None	No follow-up visit	No
Pat12Trai3		After 13 days	None	No follow-up visit	No
Pat13Trai3		After 4 days	None	No follow-up visit	No
Pat14Trai3		After 4 days	Vomiting	1 (Prescription change)	Yes
Pat15Trai3		After 7 days	Excessive sweating	No follow-up visit	No

Analysis of the data presented in this table indicates that, among patients treated with Recipe A, which consisted of a decoction prepared from the bark of *Cylicodiscus gabunensis* (BaCyga), *Annickia chlorantha* (BaAnch), *Mangifera indica* (BaMain), *Persea americana* (BaPeam), *Alstonia boonei* (BaAlbo), and *Morinda lucida* (BaMolu), the fruits of *Combretum micranthum* (FrCoMi), the leaves of *Cymbopogon citratus* (LeCyci), and the roots of *Carica papaya* (RoCapa), administered orally three times daily and rectally twice weekly for two weeks, in combination with steam baths, 26.67% of patients experienced no adverse effects, whereas 20.00% experienced both nausea and pollakiuria, and 20.00% experienced pollakiuria alone. The therapeutic effects, as evidenced by the resolution of typhoid fever symptoms, were observed as early as days 3 and 5 of treatment in 53.34% of the patients. Most patients (80%) receiving this herbal formulation visited the traditional healer between one and four times during the treatment period, primarily to renew their supply of the remedy. Only one relapse was recorded among the 15 patients included in the study.

Recipe B, consisting of decoctions prepared from the flower buds of *Syzygium aromaticum* (FlbuSyar), bulbs of *Allium sativum* (BuAlsa), rhizomes of *Curcuma longa* (RhCulo) and *Zingiber officinale* (RhZiof), leaves of *Thymus vulgaris* LeThvu, *Ocimum gratissimum* (LeOcgr) and *Cymbopogon citratus* (LeCyci), and fruits of *Citrus limon* (FrCili), was administered orally three times daily. During ethnopharmacological monitoring, 53.33% of

patients reported no adverse effects associated with the treatment. Among the 15 patients who were followed up through telephone interviews, 20.0% experienced hyperhidrosis and 13.3% reported polyuria during the treatment period. In these patients, symptom resolution was delayed, with symptoms persisting for 7 days in 26.7% of cases, for 7-21 days in 20.0% of cases, and for 12 days in 13.3% of cases.

Recipe C, composed of bulbs of *Allium sativum* (BuAlsa), *Azadirachta indica* oil (HuiAzin), and *Citrus limon* fruit juice (FrCili), was prepared by infusing the mixture in lukewarm skimmed milk for 5 min and administered orally at a dosage of one-quarter glass twice daily for two weeks. Ethnopharmacological monitoring revealed that 53.33% of the treated patients experienced no adverse effects during the follow-up period. Of the 15 patients monitored through telephone follow-up interviews, 33.3% experienced excessive sweating and 13.3% reported vomiting during the course of treatment. Symptom resolution was achieved within four days in 53.3% of patients. Only one patient revisited the traditional practitioner who had prescribed the remedy to report a treatment-related adverse event. Furthermore, three cases of disease recurrence were recorded.

4.0. Discussion

4.1. Knowledge of typhoid fever and traditional remedies used for its treatment among local populations

4.1.1. Respondents' knowledge of typhoid fever

The present study highlights the level of knowledge among the inhabitants of Douala regarding the importance of phytotherapy in the management of typhoid fever. A total of 505 participants were surveyed, including 72 respondents from local markets and 433 from households across various neighborhoods of Douala. The demographic profile of the respondents revealed a predominance of women (56.44%). This finding may be explained by the extensive knowledge women possess concerning the use of traditional herbal medicine in forested regions, where they play a central role in family healthcare and, consequently, in the preservation and transmission of traditional therapeutic knowledge. This result contrasts with the findings reported by Kidik-Pouka *et al.* (2015) and Mvogo-Ottou (2019), who conducted similar surveys in Douala and observed a notable involvement of men, particularly in the major urban markets. Indeed, increasing economic hardship has prompted many men to engage more actively in the trade of medicinal plants as a means of supporting household livelihoods.

The most represented age group consists of adults aged 30 to 50 years (48.91%). This may be attributed to the fact that this group combines therapeutic experience, family responsibilities, and active involvement in economic activities. Older individuals (39.41%) also account for a substantial proportion of knowledge holders, which confirms the intergenerational nature of the transmission of endogenous knowledge, as highlighted by Sofowora (2008) and Dibong *et al*. (2015). The respondents were predominantly from the Western Region (62.57%). This high proportion of individuals originating from this region may be explained by the demographic weight of this community in the city of Douala, as well as by their strong attachment to traditional medicinal practices. Indeed, Douala serves as an economic and cultural crossroads where diverse populations from different regions of Cameroon and beyond coexist. Furthermore, the significant involvement of traders among the respondents reflects the role of markets for non-timber forest products in the dissemination and preservation of ancestral knowledge.

According to Jiofack *et al*. (2010), urban markets constitute important hubs for the circulation of ethnobotanical knowledge in Cameroon.

All interviewees reported having previously suffered from typhoid fever. They therefore appear to be familiar with the characteristics of the disease. The high epidemiological burden of typhoid fever in the city of Douala may be explained by the fact that in several neighborhoods, a significant proportion of the population still relies on shallow wells, boreholes, or other water sources whose microbiological quality remains poor. This situation is compounded by the absence or insufficiency of sanitation infrastructure, which facilitates the contamination of groundwater and water points used by residents. This hypothesis supports the causes of typhoid fever reported by the population. According to the interviewees, the occurrence of typhoid fever is mainly associated with poor hygiene practices related to water, food, and handwashing. These findings are consistent with those of the World Health Organization (2018), which identifies contaminated water and poor sanitation as the main factors contributing to the transmission of *Salmonella Typhi*.

The symptoms reported by respondents namely fever, headaches, abdominal pain, and diarrhea are consistent with the classical clinical manifestations of typhoid fever described by Crump and Mintz (2010) and the WHO (2018). Waquier (2017) notes that these symptoms typically appear several weeks after bacterial infection. Indeed, none of the interviewed participants reported a single isolated symptom. Approximately 60% of respondents reported a combination of symptoms including headache, fever, diarrhea, abdominal pain, and joint pain as a characteristic symptomatic cluster of the condition. This finding supports the view that typhoid fever, similar to other diseases such as malaria, presents as a syndrome characterized by a constellation of distinct clinical signs (Waquier 2017). Such a clinical presentation often leads patients to engage in self-medication.

Among the interviewed participants, only 11% reported having resorted to conventional treatment as a first-line option. First-line self-medication in response to typhoid fever may be explained by a combination of economic, social, cultural factors, as well as health system related constraints. Many individuals are able to recognize the symptoms of the disease and therefore consider themselves capable of self-treatment. A significant proportion of these individuals resort to traditional treatments, which are generally less expensive and more readily accessible. This observation corroborates the findings reported by the WHO (2013), which indicate that nearly 80% of African populations use medicinal plants as their primary source of healthcare.

4.1.2. Characteristics of traditional remedies used by populations for the treatment of typhoid fever

Several remedies were formulated based on citations collected from the surveyed populations. The plant-to-remedy ratio (91/868) yielded a value of 0.09. This ratio, being lower than 1, suggests a high degree of homogeneity in knowledge among interviewees across different study sites. Indeed, multiple plant species are often used in the preparation of a single remedy. In the Haut Nyong and Littoral regions, 90 remedies were derived from 90 species recorded in the studies of Mpondo-Mpondo *et al*. (2017), while 42 remedies were formulated from 60 species reported by Dibong *et al*. (2015), respectively. Tsabang *et al*. (2016) documented a wide diversity of plant species used against infectious diseases in Cameroon. The targeted survey approach focusing on specific health conditions

likely enhances respondents' ability to report similar remedies and to identify the same plant species as components of these preparations.

Survey data identified the families Asteraceae and Fabaceae as the most important taxa, each represented by 10 species. Similar findings were reported by Kidik-Pouga *et al*. (2015) and Ngene *et al*. (2015), who recorded Fabaceae (7 species) and Asteraceae (6 species) as the most represented families in markets trading medicinal non-timber forest products (NTFPs). The predominance of these families is not surprising, as both Asteraceae and Fabaceae rank among the most species-rich and widely distributed angiosperm families. Their high representation may also reflect the floristic composition of the study area, which belongs to the evergreen and semi-deciduous dense forest zones. Furthermore, species belonging to these families are known to contain a wide range of secondary metabolites and bioactive phytochemicals that contribute to their extensive use in traditional medicine (Mvogo-Ottou *et al*. 2020; 2025).

For the treatment of typhoid fever, household respondents and market-based naturopaths rarely relied on single-plant remedies, with only 74 recipes consisting of isolated plant species. Instead, they predominantly employed polyherbal formulations, combining two to four plant species in 894 recorded recipes administered to patients. Similar findings were reported by Mvogo-Ottou *et al*. (2020) during an ethnobotanical survey of anti-haemorrhoidal medicinal plants in southern Cameroon.

In traditional Cameroonian medicine, healers commonly use mixtures containing at least two to three plant species, as each component is believed to contribute a specific therapeutic role in the management of disease symptoms (Dibong *et al*. 2015; Mpondo-Mpondo *et al*. 2017; Mvogo-Ottou *et al*. 2020 ; Nana-Afiong *et al*. 2025). The present study identified the fruits of *Combretum micranthum* (kinkeliba), the leaves and/or roots of *Carica papaya*, the stem bark of *Mangifera indica*, the fruits of *Citrus limon*, the young leaves of *Psidium guajava*, and the leaves of *Cymbopogon citratus* as the plant materials most frequently incorporated into these polyherbal preparations. The limited availability of accurate biological and laboratory diagnoses for patients may encourage traditional healers to formulate remedies that exploit potential synergistic interactions among multiple plant species. Such combinations are intended to alleviate a broad spectrum of symptoms that may correspond to different clinical syndromes (Mvogo-Ottou *et al*. 2021; Ngouondjou-Foze *et al*. 2021).

Informants from both market vendors and household respondents reported *Alstonia boonei*, *Combretum micranthum*, *Carica papaya*, *Mangifera indica*, *Citrus limon*, *Allium sativum*, *Psidium guajava*, *Cylicodiscus gabonensis*, *Cymbopogon citratus*, and *Ageratum conyzoides* as the most commonly utilized plant species in remedy preparation. The high frequency of citation recorded for these species indicates a substantial degree of agreement among informants, suggesting their recognized therapeutic value within the local pharmacopoeia.

Among the species reported by household respondents, *Alstonia boonei* exhibited relatively high values of spatial use and traditional therapeutic importance indices (VAU = 0.13 and CUS = 0.50, respectively). Previous ethnobotanical investigations have highlighted the medicinal relevance of this species. According to Tajeukem *et al*. (2021), *Alstonia boonei* is widely used in the management of jaundice, malaria, and intestinal helminth infections. Similarly, Dibong *et al*. (2015) documented its use against diabetes mellitus, typhoid fever, malaria, and

jaundice. Phytochemical analyses revealed that hydroethanolic extracts of *Alstonia boonei* contain a diverse array of bioactive secondary metabolites, including alkaloids, flavonoids, phenolic compounds, tannins, saponins, anthraquinones, and terpenoids (Atanu *et al*. 2021). These phytochemical constituents, particularly alkaloids, flavonoids, and tannins, are known to possess significant antioxidant, antiplasmodial, antimicrobial, and anti-inflammatory activities, which may contribute to the therapeutic efficacy of the species reported in traditional medicine (Onguéné *et al*. 2013; Gollo *et al*. 2020).

Despite this, *Cylicodiscus gabonensis* remains a potent antimicrobial species (Mabeku *et al*. 2006). This species exhibited high spatial use and ethnotherapeutic importance indices among market vendors (VAU = 0.55; CUS = 0.67). In Cameroonian traditional medicine, it is commonly applied externally for the treatment of chickenpox, measles, fungal skin infections, and diaper dermatitis. When administered orally as a decoction, it is believed to cleanse the body of a wide range of pathogenic microorganisms. Consequently, *Cylicodiscus gabonensis* is frequently incorporated into traditional herbal remedies used to manage typhoid fever, amoebic dysentery, chlamydial infections, and several other sexually transmitted diseases (Dibong *et al*. 2015; Ngene *et al*. 2015; Ladoh-Yemeda *et al*. 2016).

The various organs of *Mangifera indica* are widely used in traditional medicine for the management of numerous ailments. Phytochemical investigations of aqueous bark extracts of *Mangifera indica* have led to the isolation and identification of several bioactive constituents, including phenolic acids, phenolic esters, flavonoids, tannins, and particularly the xanthone mangiferin, which has been reported as the predominant compound (Núñez-Sellés *et al*. 2002). These secondary metabolites are believed to contribute to the plant's anti-inflammatory, analgesic, and antimicrobial properties. In the present study, *Mangifera indica* exhibited high values for both the Spatial Use Index and the Traditherapeutic Interest Index among respondents surveyed in markets as well as households. Notably, among market respondents, these indices reached 0.61 and 1.00, respectively. Previous ethnopharmacological studies have highlighted the use of *Mangifera indica* in the treatment of a wide range of respiratory disorders associated with bacterial, fungal, and viral infections (Ngouondjou-Foze *et al*. 2021). Furthermore, the bark of *Mangifera indica* has been reported to possess remarkable anti-inflammatory activity, supporting its extensive use in traditional healthcare systems (Nnanga-Nga *et al*. 2017; Dibong *et al*. 2015; Mvogo-Ottou 2019; Mvogo-Ottou *et al*. 2020).

Allium sativum is widely recognized in traditional medicine for the management of various respiratory disorders, particularly cough, common cold, influenza, and asthma (Fatima *et al*. 2013; Ngouondjou-Foze *et al*. 2021). Among the species reported by household respondents, *Allium sativum* exhibited notably high indices of spatial use value and ethnotherapeutic relevance (VAU = 0.22; CUS = 1.00), highlighting its prominent role in local healthcare practices. Garlic is well known for its antibacterial and antifungal properties and is commonly used in the treatment of gastroenteritis, pneumonia, typhoid fever, and gingivitis (Yinyang *et al*. 2014; Ngene *et al*. 2015; Vandi *et al*. 2016). Furthermore, interviews with respondents revealed a widespread perception that the regular consumption of garlic promotes overall health owing to its protective, antiviral, antibacterial, and antiparasitic effects, as well as its ability to alleviate pain and inflammatory conditions.

Lemon (*Citrus limon* (L.) Osbeck) is a widely used medicinal plant in traditional pharmacopeia, valued for its bactericidal, antiseptic, refreshing, antipyretic, diuretic, blood-thinning, hypotensive, and depurative properties (Hseini and Kahouadji 2007; Ngene *et al*. 2015). Its use in the management of infectious diseases, pulmonary infections, and both pulmonary and osteoarticular tuberculosis has been documented by Hseini and Kahouadji (2007). In the present study, *Citrus limon* exhibited relatively high values for both the spatial use index and the traditional therapeutic interest index (VAU = 0.30 and CUS = 0.75), highlighting its importance in household healthcare practices. Furthermore, *Citrus limon* was the plant species most frequently associated with other medicinal plants in the preparation of traditional herbal remedies (Kidik-Pouka *et al*. 2015; Ngene *et al*. 2015). According to traditional healers, the addition of lemon contributes to the preservation of medicinal preparations, enhances the physical condition of patients weakened by illness, and potentiates the therapeutic efficacy of accompanying plant ingredients (Dibong *et al*. 2011; Dibong *et al*. 2015; Ngouondjou-Foze *et al*. 2021).

For the treatment of typhoid fever, respondents predominantly cited leaves and stem bark as the preferred plant parts. Both organs are readily accessible and can be harvested with relative ease. However, several studies have suggested that, for an equivalent biomass, stem bark may contain higher concentrations of bioactive secondary metabolites than leaves (Mvogo-Ottou *et al*. 2021; Ngouondjou-Foze *et al*. 2021). This could partly explain the widespread recommendation among herbal practitioners that leaves should be collected at specific times of the day to maximize their therapeutic efficacy. Indeed, despite their lower market value (500-1000 FCFA per 500 g), leaves are considered the primary sites of biosynthesis of numerous pharmacologically active metabolites, which may subsequently be translocated and accumulated in stem bark tissues. Consequently, stem bark, which generally commands higher market prices (1500-2500 FCFA per 500 g), may constitute a more concentrated reservoir of these bioactive compounds (Dibong *et al*. 2015; Vandi *et al*. 2016; Mpondo-Mpondo *et al*. 2017).

Decoction was reported by the respondents as the predominant method of remedy preparation. It is specifically performed using water and typically involves boiling for 45 minutes to 1 hour. Decoction remains the most rapid and widely employed preparation technique, as it facilitates the extraction of a greater proportion of bioactive compounds while reducing or eliminating the toxic effects associated with certain herbal formulations (Mvogo-Ottou *et al*., 2020; 2022; 2025). For some remedies that did not involve plant organs, alternative solvents were mentioned. Notably, respondents reported the use of « Guinness » beer combined with sardine oil to alleviate the symptoms associated with typhoid fever, although this preparation was not considered curative. Skimmed milk was also cited as an ingredient in certain formulations. In particular, remedies based on garlic (*Allium sativum*) were generally prepared by boiling skimmed milk for 3-5 minutes before incorporating the plant material, with the aim of reducing the irritant properties of garlic. Boiling plant material offers an additional advantage by eliminating undesirable contaminants that may be present on the plant surface and could potentially pose health risks to consumers.

The remedies administered for typhoid fever are predominantly given orally. Steam baths and purgative treatments are also reported by respondents as recommended practices. Purging involves rectal or colonic enemas and is specifically intended to act directly on the colon to facilitate the elimination of intestinal parasites. In addition, this

route of administration may help to avoid passage through the stomach and liver (hepatic first-pass effect), which could otherwise reduce the bioavailability of the active principle. Administration by steam bath, inhalation, or nebulization is explained by its rapid and targeted action, as well as by its mucolytic effects. In these approaches, the medicinal preparation is inhaled as fine particles or microdroplets that directly deposit on the affected sites, while the heat and humidity of the steam help to hydrate the mucosal surfaces and liquefy mucus secretions.

Typhoid fever, caused by the bacterium *Salmonella typhi*, induces severe intestinal inflammation that may lead to mucosal damage and ulcerations. In this context, the mechanical effects of gas and increased gastric acidity may raise the risk of intestinal perforation, as well as increase intragastric pressure, thereby contributing to abdominal pain. Such pathophysiological mechanisms may justify the recommendation by some phytotherapists to avoid carbonated, iced, and alcoholic beverages during the administration of phytotherapeutic treatments for typhoid fever. Carbonated gas may exacerbate abdominal distension and worsen nausea. Sugary carbonated beverages may accelerate intestinal transit and aggravate diarrhoea, leading to significant losses of water and electrolytes, thereby increasing patient discomfort in individuals suffering from typhoid fever. Iced beverages may induce a sudden vasoconstriction followed by vasodilation, potentially weakening an already compromised intestinal wall. Alcohol, on the other hand, appears to reduce the efficacy of antibiotics and increase the risk of severe adverse effects in affected patients.

4.1.3. Floristic characterization of medicinal plant species used in antityphoid traditional remedies

The exploitation of woody species for the treatment of typhoid fever reflects the significant interest in woody plants within the traditional Cameroonian pharmacopeia (Dibong *et al*. 2011; Kidik-Pouka *et al*. 2015; Vandi *et al*. 2016). Although woody species are highly vulnerable, they provide traditional healers with the advantage of having at least one usable organ available throughout the year (Mvogo-Ottou *et al*. 2022). Herbaceous species, reaching maturity and reproducing early, produce abundant offspring. This characteristic may be particularly advantageous for the sustainable exploitation of species in the pharmaceutical sector (Mpondo-Mpondo *et al*. 2012). The phytogeographical distribution of species clearly reflects both the endemic nature of the plants used and the preservation of knowledge associated with the local pharmacopeia (Kidik-Pouka *et al*. 2015). However, the demonstrated efficacy of certain exotic plants such as *Allium sativum* L., *Leucanthemum vulgare* Lam., *Syzygium aromaticum* (L.) Merr. & L.M.Perry, and *Thymus vulgaris* L., which are cultivated and whose plant parts are sold in markets, highlights the extent to which media contribute to the dissemination of popular herbal medicine (Dibong *et al*. 2015; Ngene *et al*. 2015; Mpondo-Mpondo *et al*. 2017; Mvogo-Ottou *et al*. 2020). Traditional healers tend to cite species available within their local biotope, enabling them to obtain more rapidly the plant organs required for medicinal preparations (Zerbo *et al*. 2010; Kidik-Pouka *et al*. 2015). Moreover, these plant organs are largely found in non-timber forest product (NTFP) markets, which support a supply chain linking harvesters of plant materials and end users.

4.2. Patients' behavior toward treatment

Ethnopharmacological follow-up of patients using herbal treatments was conducted in the work of Ngouondjou-Foze *et al*. (2021). These authors, working on remedies for the treatment of sinusitis, showed that

treatment duration, adverse effects, and symptom relief varied from one formulation to another depending on whether medicinal plants were used alone or in combination with others. This practice presents multiple benefits at medical, scientific, and public health levels. From a clinical perspective, patient follow-up is essential for identifying adverse effects and potential herb-drug interactions. It is important to emphasize that many patients combine traditional and conventional treatments without informing healthcare providers, which often leads to risks of toxicity, overdose, or reduced efficacy of one or both therapies. Furthermore, ethnopharmacological monitoring can help evaluate the real-world effectiveness of herbal formulations. Indeed, traditional uses may guide research toward potentially active compounds that could be valuable for the development of new drugs. Such an approach therefore serves as a bridge between traditional medicine and modern medicine.

In addition, ethnopharmacological follow-up promotes better communication between patients and traditional healers by taking into account local cultural practices. This aims to improve treatment adherence and reduce the risks associated with unsupervised self-medication. Indeed, Articles 1 and 2 of Framework Law No. 2024/018 of 23 December 2024 on the practice and organization of traditional medicine in Cameroon encourage the regulated integration of traditional medicine into healthcare systems, while ensuring the safety and efficacy of such practices.

5.0. Conclusion and Recommandations

5.1. Conclusion

The present study, conducted among households and non-timber forest product (NTFP) markets in the city of Douala, aimed to promote and document the role of phytotherapy in the management of typhoid fever in Cameroon. Specifically, the objectives were to characterize herbal remedies traditionally used for the treatment of typhoid fever and to perform an ethnopharmacological follow-up of selected patients receiving plant-based treatments. The findings revealed that typhoid fever remains a prevalent health concern among the population of Douala. Affected individuals commonly rely on herbal medicines, obtaining plant materials from local markets such as Marché des Chèvres, Nkololoun Market, and Dakar Market. Although these medicinal plants are rarely used individually, they are frequently combined in multi-plant formulations. The most commonly utilized species included the stem barks of *Alstonia boonei*, *Mangifera indica*, and *Cylicodiscus gabonensis*; the fruits of *Combretum micranthum* and *Citrus limon*; the leaves and/or roots of *Carica papaya*, *Psidium guajava*, *Cymbopogon citratus*, and *Ageratum conyzoides*; as well as the bulbs of *Allium sativum*.

These herbal mixtures are generally prepared as decoctions and administered orally (two to three times daily for 7-21 days), rectally (two to three times weekly for one week), or through steam baths (two to four times weekly for one week). The survey also documented several dietary and behavioral restrictions observed during treatment, which are believed to prevent exacerbation of disease-related symptoms. Furthermore, patients included in the ethnopharmacological follow-up exhibited a low recurrence rate within three months after treatment. Nevertheless, some adverse effects were reported, prompting patients to seek further consultation with the prescribing traditional healer. These adverse events mainly included pollakiuria, vomiting, dizziness, excessive sweating, and nausea. Informants also indicated that the herbal preparations were difficult to preserve, thereby necessitating the renewal of remedies every 5-7 days. Further investigations are therefore required to evaluate the pharmacological properties

and therapeutic efficacy of these medicinal plants. In addition, the standardization of herbal formulations is essential to optimize dosage regimens, improve storage conditions, and ensure the safety, quality, and reproducibility of these traditional remedies.

5.2. Recommendations

Based on the findings of this study, the following recommendations are proposed:

1. For the general population, the use of rapid diagnostic tests (RDTs) should be prioritized to improve the differential diagnosis of typhoid fever and reduce diagnostic errors. In addition, the adoption and consistent maintenance of good hygiene and food safety practices are strongly recommended to minimize the risk of disease transmission ;
2. For traditional medicine practitioners, technical and scientific capacities should be strengthened through continuous professional training in order to improve patient management. Furthermore, sustainable harvesting practices for medicinal plant organs should be promoted to ensure the conservation of medicinal plant species and the preservation of biodiversity ;
3. for researchers, further phytochemical, pharmacological, and toxicological investigations of medicinal plants exhibiting anti-Salmonella activity are recommended to identify their bioactive compounds, assess their safety and therapeutic efficacy, and support the development of improved traditional medicines that meet internationally accepted standards of quality, safety, and efficacy.

Declarations

Source of Funding

This work is a research project that does not receive any funding but is part of the promotion of floristic biodiversity for health. The funds used to collect the data come from the personal efforts of the various authors involved in the project, which also aims to initiate and develop among young researchers (research students) the skills to collect and use data in order to solve problems.

Conflict of interest disclosure

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethics approval and consent to participate

This study was conducted in accordance with ethical and legal guidelines governing research involving traditional knowledge and local communities. Ethical approval was obtained from the Institutional Ethics Committee for Research on Human Health of the University of Douala (CEI-UDo) (Approval No. 2768CEI-UDo/07/2021/M). Research authorization was granted by the local administrative authorities of Douala, and executive leaders of the selected neighborhoods were duly informed prior to data collection.

Consent for Publication

The authors declare that they consented to the publication of this study.

Availability of Data and Materials

Not applicable

Competing interests

The authors declare that there is no conflict of interest.

Authors' Contributions

Patrice Brice Mvogo Ottou, Ngamdéré Taïla Maliki, Fidèle Bemadoum Mbezo and Sophonie Adjim Alahomadji participated in field data collection. Data analysis was done by Natacha Nana Afiong, Yannick Djawe Wanguili and Eloge Kambale Muhesi. The drafting of the manuscript was handled by Patrice Brice Mvogo Ottou, Teclaire Ngouondjou Foze and Nadège Madountsap Tagnang. Jacques Bruno Ngotta Biyon and Richard Jules Priso participated in field data collection, data analysis and verification of botanical names. Léa Doumbe Makembe and Seraphine Ebenye Mokake participated in field data collection, especially in the identification of medicinal plants, herbarium preparation and verification of the botanical names. Patrice Brice Mvogo Ottou, Ngamdéré Taïla Maliki and Teclaire Ngouondjou Foze sourced the fund, organised the field activities, participated in data collection and data analysis and reviewed the manuscript.

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