Ethnomedicinal uses and *in vitro* anti-salmonella activity of indigenous herbal concoctions sold in the Bamenda food market for the treatment of typhoid fever

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Research

Abstract

Background: Typhoid fever remains a significant public health burden in Cameroon. Rising antibiotic resistance has made its treatment increasingly challenging. This study surveyed and assessed the anti-typhoid properties of herbal concoctions sold for typhoid fever treatment in the Bamenda Food Market

Methods: Concoctions used to treat typhoid fever and their plant components were identified through an ethnomedicinal survey. Extracts were prepared via: infusion of dry powders, decoction of fresh plant parts, and direct drying of liquid concoctions. Anti-*Salmonella* activity was evaluated using the microdilution method against clinical isolates (*S. typhimurium*, *S. enteritidis*, *S. paratyphi* B, *S. typhi*) and a reference strain (*S. typhimurium* ATCC 14028).

Results: The survey identified 18 typhoid-treatment concoctions sold in the Bamenda market (Mezam Division). These contained 33 plant species from 22 families, with leaves being the most common plant part used. Decoction and infusion were the primary preparation methods. *In vitro* testing revealed 5 concoctions with anti-*Salmonella* activity, exhibiting minimum inhibitory concentrations (MICs) between 2.5 and 10 mg/mL. Concoction P16 (*Detarium senegalensis* J.F.Gmel. and *Cochlospermum tinctorium* Perrier ex A.Rich.) showed the highest activity against multiple *Salmonella* strains (MIC range: 2.5-10 mg/mL).

Conclusions: Concoction P16 demonstrated significant anti-typhoid activity *in vitro*. Further research is warranted to confirm these findings in animal models, identify its active compounds, and develop standardized formulations.

Keywords: Ethnomedicinal survey; Typhoid fever; Antibiotic resistance; Herbal concoctions; Anti-*Salmonella* activity; *Detarium senegalensis*; *Cochlospermum tinctorium*; Bamenda food market

Background

Typhoid fever, caused by *Salmonella enterica* serovar *typhi* (S. typhi), is an acute systemic infection primarily transmitted through poor sanitation and untreated water (Levine 2018; Carey *et al.* 2023). Symptoms, including fever, abdominal pain, headache, nausea, constipation, and occasionally diarrhea, typically manifest after a two-week incubation period (Meiring *et al.* 2023). Untreated, it can lead to severe complications such as inflammation of the terminal ileum and colon, intestinal hemorrhage, brain infections, and neurological disorders (Li 2022; Meiring *et al.* 2023; Iftikhar *et al.* 2018). Typhoid disproportionately affects developing regions with limited access to safe water and sanitation, particularly sub-Saharan Africa and South Asia, causing an estimated 9 million infections and 110,000 deaths annually (Carey *et al.* 2019 data). In Cameroon, prevalence estimates vary widely (4.4% to 44%) depending on locality and diagnostic method (Achonduh-Atijegbe *et al.* 2016; Akwa & Simone 2020), and children under five are especially vulnerable.

First-line antibiotic treatment (e.g., chloramphenicol, fluoroquinolones, cephalosporins) is increasingly compromised by multidrug-resistant *S. typhi* strains, side effects, and limited accessibility in resource-poor settings (Michalak *et al.* 2017). This has driven interest in alternative therapies, particularly traditional herbal medicines. In Cameroon, where approximately 75-80% of the rural population relies on traditional remedies, herbal concoctions are a cornerstone for treating ailments like typhoid fever (Fokunang *et al.* 2011; Abia *et al.* 2015). Plants such as neem, mango, guava, pawpaw, aloe vera, and *Tectona grandis* L.f. (teak, shown to be safe in rats at >5000 mg/kg) are commonly used and some demonstrate anti-typhoid activity (Kamsu *et al.* 2021; Bello & Usman 2022; Oyedeji-Amusa *et al.* 2024; Kengni *et al.* 2016; Ikhoyameh *et al.* 2024).

However, despite widespread use, many traditional remedies, including those sold specifically for typhoid/salmonellosis in markets like Bamenda Food Market (Mezam Division), lack rigorous scientific validation of their efficacy and safety. Documenting and scientifically evaluating these herbal products is crucial to: establish a foundation for safe and correct usage, enable production of quality standardized products, provide accessible treatment options (potentially reducing antibiotic resistance), promote local knowledge, and validate therapeutic claims for global acceptance and regulatory compliance (Dubale *et al.* 2025; Sangho *et al.* 2024).

Therefore, this study aimed to document and evaluate the efficacy of herbal concoctions sold in the Bamenda Food Market, Mezam Division, Cameroon, for the treatment of typhoid fever.

Materials and Methods

Ethnomedicinal survey

Study area

The study was conducted at the Bamenda Food Market, located in the Mezam Municipality, North-West Region, Cameroon (geographic coordinates: longitude 10.146° E, latitude 5.960° N; source: NASAs MERRA-2 satellite-era reanalysis) (Fig. 1). Situated in the regional capital, the market benefits from its central location near landmarks such as the Centre de Sport and the Municipal Stadium. It is a major regional market known for the wide variety of herbal concoctions available. Its accessibility and the presence of numerous reputable herbalists from diverse tribes and regions across Cameroon make it an ideal site for this ethnomedicinal investigation.

Study design and data collection

The study focused on herbal practitioners aged 25 and older, who had at least three years of experience and provided consent to participate. Individuals under 25, those with less than three years of experience, and those who did not consent were excluded from the study.

A culturally appropriate, semi-structured questionnaire was developed in collaboration with local stakeholders. This questionnaire aimed to collect demographic information, local knowledge of typhoid fever, and details on herbal remedies, including the local and scientific names of plant species, preparation methods, and dosage regimens. During the interviews, the interviewer took detailed notes to accurately capture the participants' responses. To facilitate effective communication with participants from diverse backgrounds, individual interviews were conducted in both English and Pidgin.

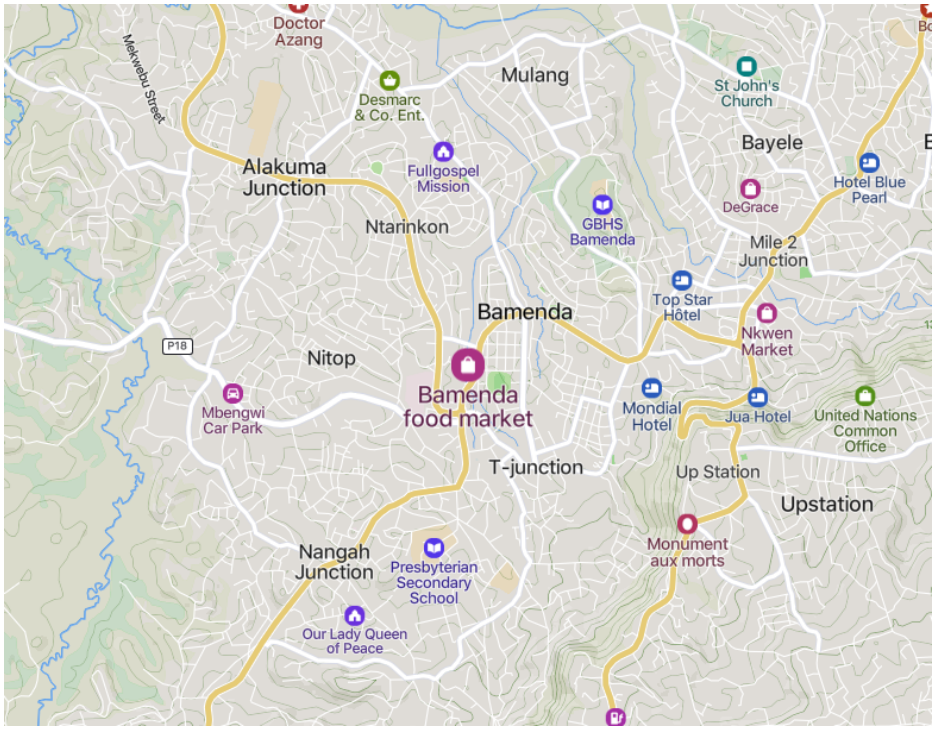

Figure 1. Map indicating study site in Food Market, Bamenda. Source: (Google map)

Herbal concoctions and collection

Different herbal concoctions were purchased in September 2023 from herbalist who had set up a market place in Food market (Bamenda). Collected alongside were parts of the plant species, which were used as ingredients in the recipe for these medicines. All plants listed were botanically identified by a botanist by comparison with voucher numbers of specimen deposited at the National Herbarium of Cameroon. Furthermore, the plant names were authenticated using https://wfoplantlist.org/ .

Frequency of citation

The frequency of citation (FC) for each plant was determined according to the previously described protocol (Totter and Logan., 1986). For each cited plant species, the frequency of the citation (FC) per locality was determined as:

$$FC = \frac{N_p}{N} \times 100$$

Where:

- N_p = Number of times a particular species was mentioned across all products.
- N = Total number of times that all species were mentioned (which is 48).
-

Assessment of *in vitro* anti-salmonella activity of concoction extracts

Sample procurement and preparation of extracts from concoctions

Market-sourced herbal concoctions (Fig. 2, Table 2) were transported to the laboratory and processed according to the herbalists' instructions to ensure consistency. Solid powdered concoctions were prepared by infusing 10 g of powder in 500 mL of boiling distilled water for 10-15 minutes, followed by filtration. Both infusion filtrates (from powders) and liquid concoctions were then oven-dried at 45-50°C. The resulting dry extracts were stored at 4°C for subsequent analysis.

Preparation of extract stock solution and reference antibiotic

Stock solutions of extracts (250 mg/mL) were prepared by dissolving 250 mg of dry extract in 1 mL of sterile distilled water. Ciprofloxacin (a second-generation fluoroquinolone) was used as the positive control. Its stock solution (1 mg/mL) was prepared by dissolving 1 mg of powder in 1 mL of acidified sterile distilled water.

Preparation of bacteria inoculums

The antibacterial activity was performed using six bacterial isolates and reference strains including *Salmonella typhimurium* (STm ATCC 14028, STm NR-13555 and STmcpc), *Salmonella typhi* (STcpc), *Salmonella paratyphoid* B (SPBcpc) and Salmonella enteritidis (SEcpc) generously offered by Centre Pasteur of Cameroon (CPC), Yaoundé and Bei Ressources.

The bacteria were sub-cultured on Mueller Hinton agar at 35 ± 2°C for 24 hours prior to each experiment. Aseptically collected colonies were introduced into 10 mL of saline solution (0.9% NaCl) and adjusted to a turbidity of 0.5 McFarland standard (1.5×10^6 CFU/mL). The bacterial suspensions were diluted in Mueller Hinton Broth (MHB) to a final concentration of 1×10^6 CFU/mL in 15 mL Falcon tubes.

Antibacterial activity

A preliminary antibacterial activity assays were performed in triplicate at fixed concentrations (10 mg/mL) using sterile 96-well microplates. Briefly, each well received 180 µL of Mueller Hinton Broth (MHB) and 20 µL of each plant extract tested at 10 mg/mL with 2µL of positive control tested at 1 mg/mL. A bacterial suspension (1×10^6 CFU/mL) was then added to each well, bringing the final volume to 200 µL. The negative control consisted of bacteria and culture media, the positive control contained ciprofloxacin, culture media, and bacteria, and the sterility control contained only culture media. The plates were covered and incubated at 37°C for 24 hours. After incubation, 20 µL of freshly prepared resazurin (0.15 mg/mL) was added to each well, and the plates were re-incubated for 30 minutes. Wells that remained blue after incubation, indicating no visible bacterial growth, were considered to contain the active concentration of the plant extract.

Samples active on at least one bacteria strain were further submitted for Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC) determination using broth micro-dilution method according to MO7A9 protocol of the Clinical and Laboratory Standards Institute (CLSI 2012).

For MIC determination, 60 µL of MHB were dispensed into the first wells and 100 µL in the remaining wells. Afterward, forty microliters (40 µL) of each test sample were added into the first wells followed by 5 serial two-fold dilutions and100 µL of microbial suspensions prepared at 1×10^6 CFU/mL to obtain a final volume of 200 µL. The final concentration of extract ranged from 10 mg/mL to 0.625 mg/mL. The negative control was made up of bacteria and culture media while the positive control constituted of ciprofloxacin ranging from 1 mg/mL to 0. 0626 mg/mL, culture media and bacteria suspension. The culture media alone constituted the sterility control. The plates were covered and incubated for 24 hours at 37°C. At the end of incubation period, 20 µL of freshly prepared resazurin (0.15 mg/mL) was added into wells for each concentration and the plates were further re-incubated in the same conditions for 30 min. The MIC was defined as the smallest concentration of sample in which no change in coloration from blue to pink was observed corresponding to no visible bacteria growth.
The Minimal Bactericidal Concentration (MBC) was determined by sub culturing 25 µL of culture media corresponding to wells without color changes (without resazurin) into 175 µL of drug-free broth medium. After 24 hours incubation at 37°C the MBCs were revealed by addition of resazurin as above and defined as the lowest concentration with no color change. The classification criteria for the antimicrobial activity of extracts, were based on the MIC threshold reported by (Kuete 2010). The ratio MBC/MIC was calculated to determine the bactericidal (MBC/MIC ≤ 4) and bacteriostatic (MBC/MIC > 4) effects.

Results

Ethnomedicinal findings

Demographic profile of the survey population

Demographic data (age, sex, marital status) were collected from nine herbal vendors participating in the survey at Bamenda Food Market (Table 1). Participant ages ranged from 28 to 70 years. All participants except one were married.

The cohort was predominantly male (8 males, 1 female). This gender distribution may reflect cultural norms within specific communities represented at the market. Notably, vendors from the Hausa community (who practice Islam) constituted a significant portion of respondents, where traditional gender roles often limit women's participation in public market activities. Additionally, broader sociocultural factors in the region may influence women's involvement in herbal vending.

Reported herbal concoctions

The survey revealed a wide diversity of plant species used in the preparation of herbal concoctions for the treatment of typhoid. As shown in the table and figure, a total of eighteen (18) different herbal concoctions are used in the treatment of typhoid (Table 2 & Figure 2).

Table 1. Demographic data of participants

SN	Participant	Age group	Gender	Marital status
1	MN	40-50	Female	Married
2	ML	28-35	Female	Single
3	NC	50-60	Female	Married
4	AG	30-45	Male	Married
5	MH	35-40	Male	Married
6	PA	50-60	Male	Married
7	LI	38-45	Male	Married
8	FA	35- 40	Male	Married
9	FB	60-70	Male	Married

SN: serial number, MN, ML, NC, AG, MH, PA, LI, FA, & FB are codes of participant

Figure 2. Selected commercial herbal concoctions commonly found in the Municipality of Mezam Division for the Treatment of Typhoid Fever, Bamenda. Powdered herbs used in the production of concoctions (A), Some liquid concoctions (B),

Table 2: Reported commercial herbal concoctions used in the treatment of typhoid.

Product Code	Product name/trade name	Dosage	Duration	Age	Content	Preservation	Plant part used
P1	Blood purification	Adults half glass (100-125 mL) twice a day.	2 days	Children above 6 years	*Aloe vera* (L.) Burm.f. [25567/SRF/cam]	Keep in cold place after preparation and dry before preparation.	Stem of aloe vera
P2	African IBA herbal mixture	200ml for adult and 100ml for children, once daily.	2 days	Children above 6years	*Kigelia Africana* (Lam.) Benth. [159/HNC], *Nauclea latifolia* [20144/SRF/Cam], water.	Dry leaves after harvesting keep in cold place after macerating and producing liquid.	Leaves
P3	Typhoid malaria medicine	1 glass (200-250 mL) morning and evening	Till relief of symptoms	Children above 1 year	*Azadirachta indica* A. Juss (**neem**)[4447 SRFK], *Cinchona pubescens* Endl. (**quinine**), *Momordica charantia* (**bitter pear**)[42520HNC], *Panax ginseng* C.A.Mey (**ginseng**)	Dry plants part before producing liquid. use lime, lemon or parabine to preserve liquid.	Leaves, barks, roots whole plant
P4	Typhoid malaria yeast cell medicine	1 glass (200-250 mL) twice daily	1-2weeks 1month	No limit	*Cinchona pubescens* Endl.) (**quinine**), *Azadirachta indica* A. Juss (**neem**)[4447 SRFK] and *Swietenia mahagoni* (L.) Jacq. (**mahogany**)[23711/HNC]	Dry plant parts for easy crushing to powder. refrigerate mixture produced from powder.	Roots, leaves and stems
P5	No on label	1 glass (200-250 mL) for adults and a quarter for children.	8dys of 5litres	No limit	*Cinchona calisaya* Wedd**.** (**yellow quinine**), *Azadirachta indica* A. Juss (**neem**)[4447 SRFK], *Momordica charantia* (**bitter pear**)[42520HNC],.	Refrigerate mixture	Barks, leaves and fruit.
P6	Enancine B	1 glass (200-250 mL) thrice daily	7 days	No limit	*Artemisia vulgaris* (**artemesia**), *Moringa oleifera* Lam. (**moringa**) [8573/SRF/cam], *Viscum album* L. (**mistletoe**), *Conyza canadensis* (L.) Cronq. (**horseweed**), *Curcuma longa* L. (turmeric) [38292/HNC], *Momordica charantia* (**bitter pear**)[42520HNC], strong salt, *Podocarpus latifolius* (**yellow wood**).	*Store in a cold dry place*	Leaves, bark, fruit,
P7	No on label	1 glass (200-250 mL) thrice daily	7 days	2 years and above	***Lantana*** *camara* L. [30440/HNC/Cam], *Eucalyptus globulus* Labill. (**eucaleptus**)[4077/SRF K]	*Refrigerate*	Leaves, flowers, seeds
P8	No on label	1 glass (200-250 mL) twice daily	7 days	No limit	*Allium sativum* L. (**garlic**)[44810/HNC], *Carica papaya* L. Daniel (**paw paw**)[18647/SRF/cam], *Zingiber officinale* Roscoe (**ginger**)[14757/SRF/cam] and *Aloe vera* (L.) Burm.f. [25567/SRF/cam].	Refrigerate	Clubs, fruit, leaves

P9	No on label	1 glass (200-250 mL) twice daily	7 days	No limit	*Carica papaya* L. Daniel (**paw paw**)[18647/SRF/cam], *Citrus aurantiifolia* (Christm.) (lime)[65106/HNC], *Psidium guajava* L. (**guava**)[2884/SRF K]	Warm when cold, refrigerate when keeping for longer periods	Leaves, fruit, leaves
P10	No on label	1 glass (200-250 mL) twice daily	7 days	No limit	*Citrus limon* (L.) Osbeck (**lemon**)[65106/HNC], *Carica papaya* L. Daniel (**paw paw**)[18647/SRF/cam], *Mangifera indica* L. (**mango**)[32875/HNC]	Cold place	Fruit, leaves
P11	No on label	1 glass (200-250 mL) twice daily	7 days	No limit	*Carica papaya* L. Daniel (**paw paw**)[18647/SRF/cam], *Cymbopogon citratus* (DC.) Stapf (**lemon grass**)[18628/SRF/cam]	Cold place	Leaves, root
P12	No on label	1 glass (200-250 mL) twice daily	7 days	No limit	*Vernonia amygdalina* Delile (b**itter leaf**)[1737/SRF], *Cymbopogon citratus* (DC.) Stapf (lemon grass)[18628/SRF/cam]	Cold place	Leaves
P13	No on label	1 glass (200-250 mL) twice daily	7 days	No limit	*Vernonia amygdalina* Delile (**bitter leaf**)[1737/SRF], *Telfairia occidentalis* Hook. F. (**okongobong**, **fluted pumpkin**)[42523/HNC]	Cold place	Leaves
P14	No on label	1 glass (200-250 mL) twice daily	7 days	No limit	*Conyza canadensis* (L.) Cronq. (**horseweed**), *Euphorbia hirta* L. (**euphorbia**)[33585/HNC]	Cold place	Leaves
P15	No on label	1 glass (200-250 mL) twice daily	7 days	No limit	*Tithonia diversifolia* (Hemsl.) A.Gray (**sunflower**)[57410HNC], *Eucalyptus globulus* Labill. (**eucaleptus**)[4077/SRF K].	Cold place	Flower, leaves
P16	No on label	3 glasses (600-750 mL) daily	7 days	No limit	*Detarium senegalense* J.F.Gmel. [27869 /HNC] [HNC/], *Cochlospermum tinctorium* Perrier ex A.Rich. [7890 SRF/Cam]	Cold place	Leaves, seeds
P17	No on label	1 glass (200-250 mL) thrice daily	7 days	No limit	*Cinchona pubescens* Endl. (**quinine**) and *Azadirachta indica* A. Juss (**neem**)[4447 SRFK]	Refrigerate or place in cold area**.**	Fruit, leaves, barks, seeds.
P18	No on label	1 glass (200-250 mL) thrice daily	7 days	No limit	*Commelina diffusa* Burm[SRFC/35189] and *Stachytarpheta jamaicensis* (L.) Vahl. and S..	Refrigeration	Leaves and flowers

Botanical characteristics and plant diversity

Analysis of the 18 documented herbal concoctions identified 33 plant species belonging to 22 botanical families (Table 2). The plant species, their taxonomic families, plant parts utilized, and Frequency of Citation (FC) are summarized in Table 3.

Table 3: Identified plant species: families, parts used, and frequency of citation.

Plant Species (with Accession Numbers)	Family	Plant Part Used	Count (N_p)	Frequency of Citation (FC)
Allium sativum L. [44810/HNC]	Amaryllidaceae	Bulbs	1	2.1% (1/48)
Mangifera indica L. [32875/HNC]	Anacardiaceae	Leaves, Barks	1	2.1% (1/48)
Panax ginseng C.A.Mey.	Araliaceae	Leaves, Barks, Roots	1	2.1% (1/48)
Aloe vera (L.) Burm.f. [25567/SRF/cam]	Asphodelaceae	Leaves, Gel	2	4.2% (2/48)
Artemisia vulgaris L.	Asteraceae	Leaves	1	2.1% (1/48)
Conyza canadensis (L.) Cronq.	Asteraceae	Leaves	2	4.2% (2/48)
Tithonia diversifolia (Hemsl.) A.Gray [57410/HNC]	Asteraceae	Leaves, Flowers	1	2.1% (1/48)
Vernonia amygdalina Delile [1737/SRF]	Asteraceae	Leaves	2	4.2% (2/48)
Kigelia africana (Lam.) Benth. [159/HNC]	Bignoniaceae	Leaves, Fruits	1	2.1% (1/48)
Cochlospermum tinctorium Perrier ex A.Rich. [7890 SRF/Cam]	Bixaceae	Roots	1	2.1% (1/48)
Carica papaya L. [18647/SRF/cam]	Caricaceae	Leaves, Fruits	4	8.3% (4/48)
Commelina diffusa Burm. [SRFC/35189]	Commelinaceae	Leaves	1	2.1% (1/48)
Momordica charantia L. [42520/HNC]	Cucurbitaceae	Leaves, Fruits	3	6.3% (3/48)
Telfairia occidentalis Hook.f. [42523/HNC]	Cucurbitaceae	Leaves	1	2.1% (1/48)
Euphorbia hirta L. [33585/HNC]	Euphorbiaceae	Leaves, Roots	1	2.1% (1/48)
Detarium senegalense J.F.Gmel. [27869/HNC]	Fabaceae	Barks, Leaves	1	2.1% (1/48)
Azadirachta indica A.Juss. [4447/SRFK]	Meliaceae	Leaves, Bark	4	8.3% (4/48)
Swietenia mahagoni (L.) Jacq. [23711/HNC]	Meliaceae	Stems	1	2.1% (1/48)
Moringa oleifera Lam. [8573/SRF/cam]	Moringaceae	Leaves, Seeds	1	2.1% (1/48)
Eucalyptus globulus Labill. [4077/SRFK]	Myrtaceae	Leaves	2	4.2% (2/48)
Psidium guajava L. [2884/SRFK]	Myrtaceae	Leaves, Fruits	1	2.1% (1/48)
Cymbopogon citratus (DC.) Stapf [18628/SRF/cam]	Poaceae	Leaves	2	4.2% (2/48)
Nageia wallichiana Kuntze (cited as *Podocarpus latifolius* W.) [32109/HNC]	Podocarpaceae	Bark, Leaves	1	2.1% (1/48)
Melanopsidium nigrum Colla (cited as *Cinchona pubescens* Endl.) [60105/HNC]	Rubiaceae	Bark, Roots	3	6.3% (3/48)
Cinchona calisaya Wedd [62325/HNC]	Rubiaceae	Bark	1	2.1% (1/48)
Nauclea latifolia Sm. [20144/SRF/Cam]	Rubiaceae	Leaves	1	2.1% (1/48)
Citrus aurantiifolia (Christm.) Swingle [65106/HNC]	Rutaceae	Fruits, Leaves	1	2.1% (1/48)
Citrus limon (L.) Osbeck [65106/HNC]	Rutaceae	Fruits, Leaves	1	2.1% (1/48)
Viscum album L. [43909/HNC]	Santalaceae	Leaves, Stems	1	2.1% (1/48)
Lantana camara L. [30440/HNC/Cam]	Verbenaceae	Leaves, Flowers	1	2.1% (1/48)
Stachytarpheta jamaicensis (L.) Vahl.	Verbenaceae	Leaves	1	2.1% (1/48)
Curcuma longa L. [38292/HNC]	Zingiberaceae	Rhizomes	1	2.1% (1/48)
Zingiber officinale Roscoe [14757/SRF/cam]	Zingiberaceae	Rhizomes	1	2.1% (1/48)

$\boldsymbol{N_p}$**:** = Number of times a particular species was mentioned across all products.

The Asteraceae family was the most frequently represented, with four documented species, followed by Cucurbitaceae, Myrtaceae, Rubiaceae, Verbenaceae, and Zingiberaceae, each contributing two species. Commonly cited Asteraceae species included *Artemisia vulgaris*, *Conyza canadensis*, *Tithonia diversifolia* (Hemsl.) A.Gray, and *Vernonia amygdalina* Delile, among

others. This diversity highlights the wide range of plant families utilized in traditional typhoid treatments within the study area.

Plant Parts Utilized

The relative frequency of plant parts used, weighted by citation count across all concoction entries (Table 3), is summarized in Figure 3. Analysis revealed a clear hierarchy in part utilization.

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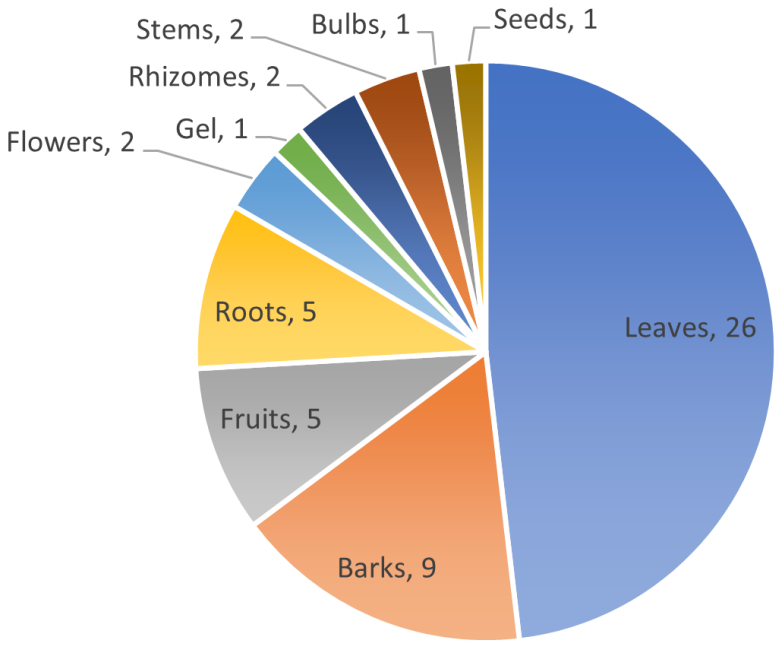

Figure 3. Frequency of plant part usage in herbal concoction. The total occurrences of each plant part mentioned across all entries, even when multiple parts are listed for a single plant species, with percentages calculated against the total mentions.

Leaves were the dominant plant part, accounting for 26 occurrences (representing 78.8% of the 33 documented species). This prevalence is likely attributable to their year-round availability, ease of collection, and recognized concentration of bioactive phytochemicals. Bark ranked second (9 occurrences), followed by fruits and roots (5 occurrences each). Flowers, stems, and rhizomes were cited twice each, while bulbs (*Allium sativum*), gel (*Aloe vera*), and seeds appeared once.

Consequently, leaves featured in most documented species. Bark utilization was prominent in tree species, notably *Mangifera indica* (mango) and *Azadirachta indica* (neem). Specialized parts like bulbs and gel remained comparatively rare. The strong preference for easily renewable aerial parts (leaves, fruits, flowers) over destructive harvesting of underground structures (roots, rhizomes) suggests an inherent alignment with sustainable practices. The use of bark and stems also reflects the importance of woody tissues in these traditional formulations.

Frequency of citation

The citation frequency of plants reflects their perceived importance and traditional efficacy in treating typhoid fever. *Carica papaya* L. (Daniel) and *Azadirachta indica* A.Juss. were the most frequently cited species, each appearing in four distinct concoctions (*C. papaya*: P8, P9, P10, P11; *A. indica*: P3, P4, P5, P17). *Vernonia amygdalina* Delile, *Cinchona pubescens* Endl., and *Cymbopogon citratus* (DC.) Stapf each featured in two preparations (*V. amygdalina*: P12, P13; *C. pubescens*: P3, P4; *C. citratus*: P11, P12). This citation pattern highlights *C. papaya* and *A. indica* as cornerstone species within the region's ethnomedicine for typhoid, with *V. amygdalina*, *C. pubescens*, and *C. citratus* representing widely utilized secondary components of locally sold anti-typhoid herbal formulations.

Mode of preparation

Preparation of the herbal concoctions primarily involved size reduction (drying, crushing, or powdering) of plant materials followed by extraction, predominantly through infusion (steeping dried material in hot water) or decoction (prolonged boiling of fresh parts in cold water, typically 15-60 minutes, followed by filtration). For instance, leaves of *Aloe vera* and *Kigelia africana* (Lam.) Benth. were commonly dried, crushed, and mixed with water. Herbalists emphasized seasonal harvesting practices: plants collected during the rainy season were dried and preserved to maintain bioactive integrity and ensure year-round availability, preventing post-season degradation in their natural habitat.

Mode of Administration and dosage

The herbal concoctions were primarily administered orally. The most common dosage regimen was one glass (approx. 250 mL) twice daily, although some preparations (P16, P17, P18) were prescribed three times daily. Certain remedies were stored as powders and reconstituted with water or other liquids prior to consumption.

Formulation strategies and synergistic beliefs

Recipes frequently combined multiple plant species, reflecting traditional knowledge of potential synergistic effects. For instance, one concoction integrated *Azadirachta indica* A.Juss., *Momordica charantia* L., and *Panax ginseng* C.A.Mey. to address typhoid and malaria symptoms. Another preparation utilized a powdered blend of *Cinchona pubescens* Vahl, *Azadirachta indica* A.Juss., and *Swietenia mahagoni* (L.) Jacq. specifically for typhoid.

Treatment duration and target demographics

Treatment duration varied based on the concoction and symptom severity. While many reported a typical duration of seven days (P11-P18), others noted shorter periods such as two days (P1, P2) or treatment until symptom relief (P3). Preparations involving *Aloe vera* and *Kigelia africana* (Lam.) Benth. were recommended for short-term use (two days), while those containing *Cinchona pubescens* Endl. were suggested for longer durations (up to 8 days or more). The target groups for these concoctions also varied, with some preparations specifically designed for adults and others suitable for children above 6 years of age.

Preservation methods

Key preservation techniques included refrigeration and storage in cool, dry environments. This demonstrates practitioners' awareness of the need to maintain the stability and potency of bioactive compounds. For example, concoctions containing *Cinchona pubescens* Vahl and *Azadirachta indica* A.Juss. were commonly refrigerated.

Overall, this ethnobotanical survey underscores the persistent reliance on traditional herbal remedies for typhoid fever in Bamenda, despite access to conventional medicine. The documented use of diverse commercial concoctions indicates strong community belief in their efficacy. However, rigorous scientific validation of their efficacy and safety profiles remains essential.

In vitro anti-salmonella activity of concoction

Preliminary screening identified five of eighteen concoctions (P7, P14, P15, P16, P18) exhibiting antibacterial activity (MIC ≤ 10 mg/mL) against at least one *Salmonella* strain (Table 4), prompting full evaluation of their Minimum Inhibitory Concentration (MIC), Minimum Bactericidal Concentration (MBC), and MBC/MIC ratios.

Concoction P7 demonstrated moderate activity against all tested strains (MIC = 5-10 mg/mL). Its MBC values generally matched MICs, except against *S. paratyphi* B (SPB_{CPC}, MBC>10 mg/mL). MBC/MIC ratios of 1 (most strains) indicate bactericidal activity, while a ratio of 2 for *S. paratyphi* B (SPB_{CPC}) suggests reduced bactericidal potency.

Concoction P14 showed moderate activity (MIC=5-10 mg/mL) but was inactive against *S. typhimurium* CPC (STmCPC, NA). MBC/MIC ratios of 1 (most strains) indicate bactericidal activity, though a ratio of 2 for *S. enteritidis* (SE_{CPC}) suggests reduced efficacy; activity against *S. typhimurium* CPC (STm_{CPC}) was not determined (ND).

Concoction P15 exhibited activity against most strains at MIC/MBC=10 mg/mL but was inactive against *S. enteritidis* (SE_{CPC}, NA). MBC/MIC ratios of 1 indicate bactericidal activity where active; activity against *S. paratyphi* B (SPB_{CPC}) was indeterminate (MBC>10 mg/mL, ratio ND).

Concoction P16 displayed the strongest overall activity, with the lowest MIC/MBC values (2.5-5 mg/mL) against all strains. MBC/MIC ratios of 2 (most strains) indicate a reduced bactericidal potency effect, while a ratio of 1 for *S. enteritidis* (SE_{CPC}) signifies strong bactericidal activity.

Concoction P18 demonstrated consistent activity (MIC=5-10 mg/mL; MBC=10 mg/mL). An MBC/MIC ratio of 1 for *S. typhimurium* ATCC 14028 indicates bactericidal activity, while ratios of 2 for other strains suggest a reduced bactericidal potency.

MBC/MIC ratios near 1 (observed for P7, P14, P15, and P18 against most susceptible strains) indicate primarily bactericidal activity. Ratios of 2 (e.g., P16 against most strains, P18 against some) suggest reduced bactericidal potency, requiring higher concentrations for killing. Ciprofloxacin (control) exhibited significantly superior potency (MIC = 0.015 mg/mL against all strains). While this confirms ciprofloxacin's efficacy, the higher MIC/MBC values of the concoctions highlight their relative lower potency. Nonetheless, P16's promising activity and the natural origin of these remedies warrant further investigation into their potential advantages and optimization.

Table 4. Antibacterial activity of herbal concoctions (mg/mL)

Products	Parameters	STm ATCC 14028	ST_{CPC}	SPB_{CPC}	SE_{CPC}	STm_{CPC}	STm NR-13555
P7	MIC	10	5	5	10	10	10
P7	MBC	10	5	10	10	>10	10
P7	MBC/MIC	1	1	2	1	1	1
P14	MIC	10	5	5	5	NA	5
P14	MBC	10	5	5	10	ND	5
P14	MBC/MIC	1	1	1	2	ND	1
P15	MIC	10	10	10	NA	10	10
P15	MBC	10	>10	10	NA	10	10
P15	MBC/MIC	1	ND	1	NA	1	1
P16	MIC	2.5	2.5	2.5	5	2.5	2.5
P16	MBC	5	5	5	5	5	5
P16	MBC/MIC	2	2	2	1	2	2
P18	MIC	10	5	5	5	5	5
P18	MBC	10	10	10	10	10	10
P18	MBC/MIC	1	2	2	2	2	2
Ciprofloxacin	MIC	0.015	0.015	0.015	0.015	0.015	0.015

STm: *Salmonella Typhimurium*; **SPB:** *Salmonella Para typhi* B; **SE:** *Salmonella enteriditis* ; **ST:** *Salmonella typhi*, **CPC:** Centre Pasteur of Cameroon; **NA**: not active (MIC> 10mg/mL); **ND:** not determined. **MIC:** Minimum inhibitory concentration; **MBC:** Minimum bactericidal concentration; **MBC/MIC**: nature of antibacterial activity, **P7-18:** designation of herbal concoctions.

Discussion

Typhoid fever, caused by *Salmonella enterica* serovar Typhi (*S. Typhi*), remains a substantial global public health burden, particularly acute in resource-limited settings within developing countries. While international initiatives strive to control salmonellosis, persistent challenges including the alarming rise of antibiotic resistance, prohibitive treatment costs, and significant side effects associated with conventional antibiotics (such as fluoroquinolones, e.g., ciprofloxacin) underscore the urgent need for alternative therapeutic strategies. In Cameroon, where diagnostic limitations obscure true prevalence, reliance on traditional medicine exceeds 75% in rural communities (Fokunang *et al.* 2011), highlighting the relevance of this study.

Traditional herbal medicines, frequently administered as multi-plant concoctions, present a promising avenue for exploration as complementary or alternative treatments. However, the widespread use of these remedies necessitates rigorous scientific validation of their safety and efficacy profiles, given the potential for unsubstantiated claims, toxicity, or adverse reactions (Dubale *et al.* 2025, Sangho *et al.* 2024). Medicinal plants are repositories of diverse bioactive secondary metabolites—including alkaloids, phenols, and glycosides—which exhibit documented therapeutic properties such as antimicrobial, anti-inflammatory, and immunomodulatory activities (Abdulrahman *et al.* 2021). This study specifically investigated the prevalence and evaluated the *in vitro* antisalmonella activity of herbal concoctions marketed within the Food Market of Mezam Division Municipality for typhoid fever management.

The study engaged nine randomly selected respondents, aged 28-65 years. Participant demographics revealed pronounced gender disparity, with 88% male and 12% female representation. This skew aligns with findings from previous ethnobotanical studies (Togola *et al.* 2005, Ampitan *et al.* 2023, Tsobou *et al.* 2013), which attribute the predominance of male respondents to traditional gender roles where men often assume primary responsibility for sourcing family healthcare, including purchasing medicinal preparations.

Documentation yielded 18 distinct herbal concoctions, collectively comprising 33 plant species across 22 botanical families. Powdered formulations predominated (90% of plants used), contrasting with liquid preparations (10%). Analysis of utilized plant parts revealed leaves as the most frequent component (26 mentions), followed by barks (9 mentions), and then fruits and roots (5 mentions each). This preference for leaves and barks likely stems from their ready availability and recognized high concentration of bioactive compounds, as these structures are primary sites for secondary metabolite synthesis and accumulation (Obakiro *et al.* 2020). Supporting this, research indicates outer plant tissues, such as leaves and barks, often harbor elevated levels of these therapeutic constituents (Rabizadeh *et al.* 2022).

Infusion and decoction emerged as the principal preparation methods. Decoction—involving boiling plant material in water—was notably more common, especially for fresh plants, as this technique efficiently extracts a higher yield of bioactive components (Oyedeji-Amusa *et al.* 2020). Ecological factors, particularly local plant species availability, also significantly influenced preparation techniques. Consistent with prior research (Nankaya *et al.* 2020), most medicinal plants were reportedly harvested from wild sources. Practitioners indicated their ethnobotanical knowledge was predominantly inherited from ancestors, a knowledge transmission mode well-documented in analogous cultural contexts (Tsobou *et al.* 2013).

The common practice of combining multiple plant parts within single concoctions suggests an inherent holistic approach. This strategy potentially leverages synergistic interactions between phytochemical constituents from different plant organs to enhance therapeutic outcomes, reflecting sophisticated empirical understanding (Sofowora 1993, Okwu & Uchenna 2009).

The frequent inclusion of *Azadirachta indica* A. Juss (neem) and *Carica papaya* L. (pawpaw) points to their perceived high efficacy against typhoid fever among traditional healers. This perception is likely grounded in their well-established pharmacological profiles, including potent antimicrobial, anti-inflammatory, and immunomodulatory activities (Subapriya & Nagini 2005). Other commonly utilized plants, such as *Momordica charantia* (bitter melon) and *Aloe vera*, are similarly renowned for broad-spectrum therapeutic applications (Eshun & He 2004, Grover & Yadav 2004). The recurrent citation of *Cinchona pubescens* Endl. (source of quinine) is particularly noteworthy. While quinine is primarily associated with malaria treatment, its incorporation into typhoid remedies exemplifies the cross-application of botanicals for managing diverse febrile illnesses within traditional medical systems (Okwu & Uchenna 2009, Achan *et al.* 2011, David & Wright 1991).

Stability and preservation of potency were emphasized for certain concoctions, particularly those containing *Cinchona pubescens* Endl. and *Azadirachta indica* A. Juss. Traditional practices recommended storing powdered plant material in cold or dry environments (Sofowora 1993). Standard oral dosages prescribed were 2-3 glasses, administered twice or thrice daily for two days or until symptomatic relief.

In vitro antimicrobial screening identified five of the eighteen concoctions (P7, P14, P15, P16, and P18) exhibiting significant activity against *Salmonella* strains. The observed antibacterial effects are plausibly mediated by bioactive phytochemicals such as saponins, tannins, and flavonoids, known to inhibit bacterial growth and viability (Idu *et al.* 2007, Patra 2012). Minimum Inhibitory Concentration (MIC) values for active concoctions ranged from 2.5 mg/mL to 10 mg/mL. Concoction P16 demonstrated the most potent activity, with an MIC of 2.5 mg/mL against most tested *Salmonella* strains, except *Salmonella enteritidis* (MIC = 5 mg/mL). The superior efficacy of P16 may be attributable to the synergistic action of flavonoids, alkaloids, and tannins in *Cochlospermum tinctorium*, a key constituent (Senthilkumar *et al.* 2018). Tannins specifically exert antibacterial effects by irreversibly binding proteins and enzymes, disrupting membrane integrity, and interfering with metabolic processes.

Analysis of the MBC/MIC ratios (where a ratio ≤ 4 defines bactericidal activity) confirmed that all herbal concoctions demonstrating inhibitory effects against *Salmonella* strains (P7, P14, P15, P16, P18) exhibited bactericidal activity against their susceptible targets. This is a significant finding, as bactericidal agents are often preferred for treating systemic infections like salmonellosis. However, the potency of this bactericidal effect varied considerably between concoctions and strains.

Concoctions P7, P14, and P15 primarily displayed strong bactericidal activity (MBC/MIC = 1) against their susceptible strains, indicating efficient killing at the MIC concentration. Exceptions included reduced bactericidal potency (ratio = 2) for P7 against S. paratyphi B (SPB_{CPC}) and P14 against *S. enteritidis* (SE_{CPC}), requiring higher concentrations for lethal effect. In contrast, P16 demonstrated bactericidal activity against all strains tested, though predominantly with reduced potency (ratio = 2); its strong bactericidal activity (ratio = 1) against *S. enteritidis* (SE_{CPC}) was notable and aligned with its overall superior MIC/MBC profile. Similarly, P18 exhibited bactericidal effects across the panel but with reduced potency (ratio = 2) against most strains, except for strong activity (ratio = 1) against *S. typhimurium* ATCC 14028. True inactivity (MIC >10 mg/mL, NA) was limited to P14 against *S. typhimurium* CPC (STm_{CPC}) and P15 against *S. enteritidis* (SE_{CPC}), while activity against *S. paratyphi* B (SPB_{CPC}) for P15 remained indeterminate (ND). These results highlight P16 as the most promising candidate, possessing the lowest MIC/MBC values and broad-spectrum bactericidal activity, albeit often at twice the inhibitory concentration. While all active concoctions were bactericidal, their efficacy and potency were demonstrably strain-dependent. Crucially, the significantly higher MIC/MBC values of these natural concoctions compared to ciprofloxacin (MIC = 0.015 mg/mL) underscore their relative lower potency but simultaneously validate their intrinsic antibacterial properties. The potent bactericidal nature of P16, combined with its natural origin, warrants focused investigation into its active constituents and potential for optimization as an alternative or complementary therapeutic strategy.

Conclusion

This study highlights the potential of traditional herbal concoctions as alternative treatments for typhoid fever. The frequent use of plants like *Azadirachta indica* A. Juss and *Carica papaya* L., supported by their documented antimicrobial properties, underscores their established importance in traditional medicine. Furthermore, the study demonstrates that these herbal concoctions possess varying degrees of *in vitro* antibacterial activity against *Salmonella* strains, with concoction P16 exhibiting the most potent effects. Although their potency was lower than ciprofloxacin, their bactericidal nature and potential as natural alternatives position them as promising candidates for further development and optimization. However, rigorous research is essential to validate the safety, efficacy, and precise mechanisms of action of these herbal remedies. The potential synergistic effects arising from combining multiple plant species within these concoctions also warrant detailed investigation to fully elucidate their therapeutic benefits.

Declarations

List of abbreviations: ATCC (American Type Culture Collection), CFU (Colony Forming Units), CIPRO (Ciprofloxacin), CLSI (Clinical and Laboratory Standards Institute), CPC (Centre Pasteur du Cameroun), FC (Frequency of Citation), MBC (Minimum Bactericidal Concentration), MHB (Mueller Hinton Broth), MIC (Minimum Inhibitory Concentration), MBC (Minimum Bactericidal Concentration) NA (Not Active), ND (Not Determined), *S. enteritidis* (*Salmonella enteritidis*), *S. paratyphi* B (*Salmonella paratyphi* B), *S. typhi* (*Salmonella enterica* serovar Typhi), *S. typhimurium* (*Salmonella typhimurium*), SN (Serial Number), and STM (*Salmonella typhimurium*)

Ethics approval and consent to participate: This ethnobotanical survey adhered to current legislation and biodiversity rights of rural communities in Cameroon (Mahop 2004) and the United Nations Framework Convention on Biodiversity (Brazil, 1992). All participants provided oral informed consent, complying with ethical guidelines, national and international agreements like the Convention on Biological Diversity and the Nagoya Protocol. Consent ensured participants understood the study's purpose, risks, benefits, and their right to withdraw at any time.

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