Ethnomedicinal survey of antidiarrheal plants of the Nyamwezi people of Nsenda ward in Urambo District, central western Tanzania

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Ethnobotany Research and Applications 24:21 (2022)

Research

Abstract

Background: Globally, diarrhea is a primary public health concern associated with high mortality and morbidity. In Tanzania's rural areas, a paucity of contemporary health facilities and poverty have necessitated pursuing traditional remedies. However, the usage of traditional remedies is poorly documented. Therefore, this study aimed to document medicinal plants (MPs) used by traditional healers (THs) to treat diarrhea in the Nsenda ward, Tanzania.

Methods: A semi-structured questionnaire was used to gather ethnobotanical data from 21 THs on the use of MPs in treating diarrhea in Nsenda ward. The purpose and significance of the study were communicated to THs, and their consent was requested before interviewing them.

Results: Twenty-four MPs belonging to 17 families and 24 genera were recorded as antidiarrheal. Most reported MPs belong to Fabaceae (13%) family. *Clerodendrum myricoides* (Hochst.) Vatke (0.76)*, Psidium guajava* L. (0.66), and *Coffea arabica* L. (0.62) had the highest relative frequency of citation. Tree (67%) and root (46%) were the most utilized life form and plant part, respectively. The wild (79%) environment offered the most utilized plant materials. Decoction (37%) was the preferred preparation technique, and all the remedies were administered orally. About 21% of the preparations involved the addition of different ingredients and solvents, 13% were consumed freshly, and 56% involved dilution of remedies in water.

Conclusion: The study has uncovered substantial numbers and knowledge of MPs used to treat diarrheal infections in the ward. The study recommends that scientific endorsement is needed to understand the pharmacological potentials of the recorded MPs.

Keywords: Antidiarrheal, diarrhea, ethnomedicine, medicinal plants, Tanzania, Urambo

Background

Diarrhea is a major public health burden in low- and middle-income countries, particularly in Sub-Saharan Africa and South Asia (Kotloff *et al.* 2013, Troeger *et al.* 2018). The disease affects all age groups, but it is more critical in children under the age of five as it causes malnutrition, growth retardation, and reduced cognitive development (Samie *et al.* 2009, Williams *et al.* 2020). Diarrhea is the second leading cause of global child mortality and morbidity, and it is responsible for 0.525 million children's deaths under the age of five annually out of 1.7 billion episodes (WHO 2017).

Manuscript received: 18/07/2022 – Revised manuscript received: 09/10/2022 - Published: 12/10/2022
http://dx.doi.org/10.32859/era.24.21.1-14

Diarrhea, often referred to "as the passage of three or more loose or watery stools per day", is linked with several risk factors, including unsafe water, poor sanitation, and childhood wasting in low- and middle-income countries (Gahamanyi *et al.* 2021). The three clinical forms of diarrhea include (1) acute watery diarrhea, which lasts for several hours or days, including cholera, (2) acute bloody diarrhea, which includes dysentery, and (3) persistent diarrhea, which lasts 14 days or longer (Troeger *et al.* 2018, WHO 2017).

In Tanzania, despite efforts to prevent childhood diarrheal deaths through rotavirus immunization and make health sector reforms, diarrhea is the fourth contributor to outpatients and the fifth cause of mortality among children under the age of five (Mashoto *et al.* 2014, O' Connell *et al.* 2017). The lack of access to clean and safe drinking water and insufficient sanitation and hygiene have contributed to diarrhea infections and deaths (Mashoto *et al.* 2014). In areas where clean and safe water infrastructure is absent, particularly in rural areas, drinking contaminated water is a significant cause of diarrhea (Benetti 2007). Moreover, the disease is the fourth causing morbidity in the Urambo District (URT 2008).

Since prehistoric times, MPs have been used to manage various human and animal ailments. Traditional medicine plays a vital part in Tanzania's culture, particularly for those living in rural areas (Chhabra & Mahunnah 1994, Hilonga *et al.* 2019, Kacholi and Amir 2022, Ramathal & Ngassapa 2001). The MPs are essential and sometimes the only source of therapeutics for nearly 80% of the rural Tanzanian population. The prevalent use of MPs among Tanzanian societies could be linked to cultural acceptability, efficacy, accessibility, availability, and affordability. Also, the dependency on MPs in some areas is due to the lack of modern health facilities (Augustino & Gillah 2005, Kacholi & Amir 2022, Moshi *et al.* 2009). In the rural areas of the Urambo District, particularly the Nsenda ward, people rely chiefly on MPs for their primary health care needs, including management of related diarrheal infections.

Various studies conducted in and outside the country (Ariyo *et al.* 2020, Kacholi & Mvungi 2021) have reported that the knowledge of MPs is getting lost due to disinterest shown by the younger generation. Also, since the traditional knowledge is conveyed verbally from generation to generation, the basic facts about used plant parts, methods of preparing and administering the remedy, ailments cured, and others may be lost during the transfer process. Documenting MPs is vital for preserving indigenous knowledge and identifying candidate species to develop modern therapeutic drugs. Thus, this study aimed to document MPs used by traditional healers to treat diarrheal diseases in Nsenda ward, Urambo District, and propose perspectives for future research.

Material and Methods

Description of the study area

This survey was carried out in Nsenda ward located in Urambo District in central western Tanzania. The ward covers an area of 1,088 square kilometers with a population of 14,382 and an average population density of 13.22 per square kilometer. The community is boarded by Kasisi and Ugalla ward to the west, Imalamakoye ward to the north, Ukondamoyo ward to the East, and Sikonge District to the South (Figure 1). The climate of the area is bimodal. The rainy season starts around November and ends mid-April, while the dry season commences around May and ends mid-October. The study experiences a mean annual rainfall of 1370 mm, and maximum and minimum temperature of 29°C and 17°C, respectively (Kacholi & Amir 2022). Miombo forests characterize the vegetation of the study area. The principal inhabitants in the ward are the Nyamwezi tribe, who practice agriculture for their livelihood. Tobacco and rice are the significant cash and food crops grown in the District, respectively. Currently, there is only one public health in the whole District and no one in the study ward. The ward lacks clean and safe water infrastructure, making the locals rely on drinking water from shallow wells; hence, drinking contaminated water is a significant cause of diarrhea.

Ethnobotanical Data Collection

This ethnobotanical study was conducted from August to October 2020 in four villages, namely Itebulanda, Kangeme, Nsenda, and Utenge, within the Nsenda ward in Urambo District, Tanzania. A total of 21 traditional healers (THs) were involved in the survey through the snowball method. The involvement of THs is because they are good custodians of traditional knowledge on MPs utilization and primary source of health care in various rural societies (Junsongduang *et al.* 2020; Gakuya *et al.* 2020). The survey was conducted using interviews, whereby a semi-structured questionnaire was administered through personal contact discussion. The questionnaire was used to gather data such as names of plant species used as antidiarrheal, parts used, accessibility, preparation methods, and administration route of the remedies. This technique is a feasible and functional option for data collection. Interviews were conducted in the Swahili language and later translated to English. Afore cross-examining the THs, the purpose and significance of the study conversed to them, and their consent was requested. An experienced

botanist identified the MPs, exclusive of taxonomically challenging plants collected, pressed, and identified in the College laboratory. All scientific names were confirmed using internationally recognized plant databases, such as the Useful Tropical Plants Database (www.tropical.theferns.info) and Global Plants Database (www.jstor.org).

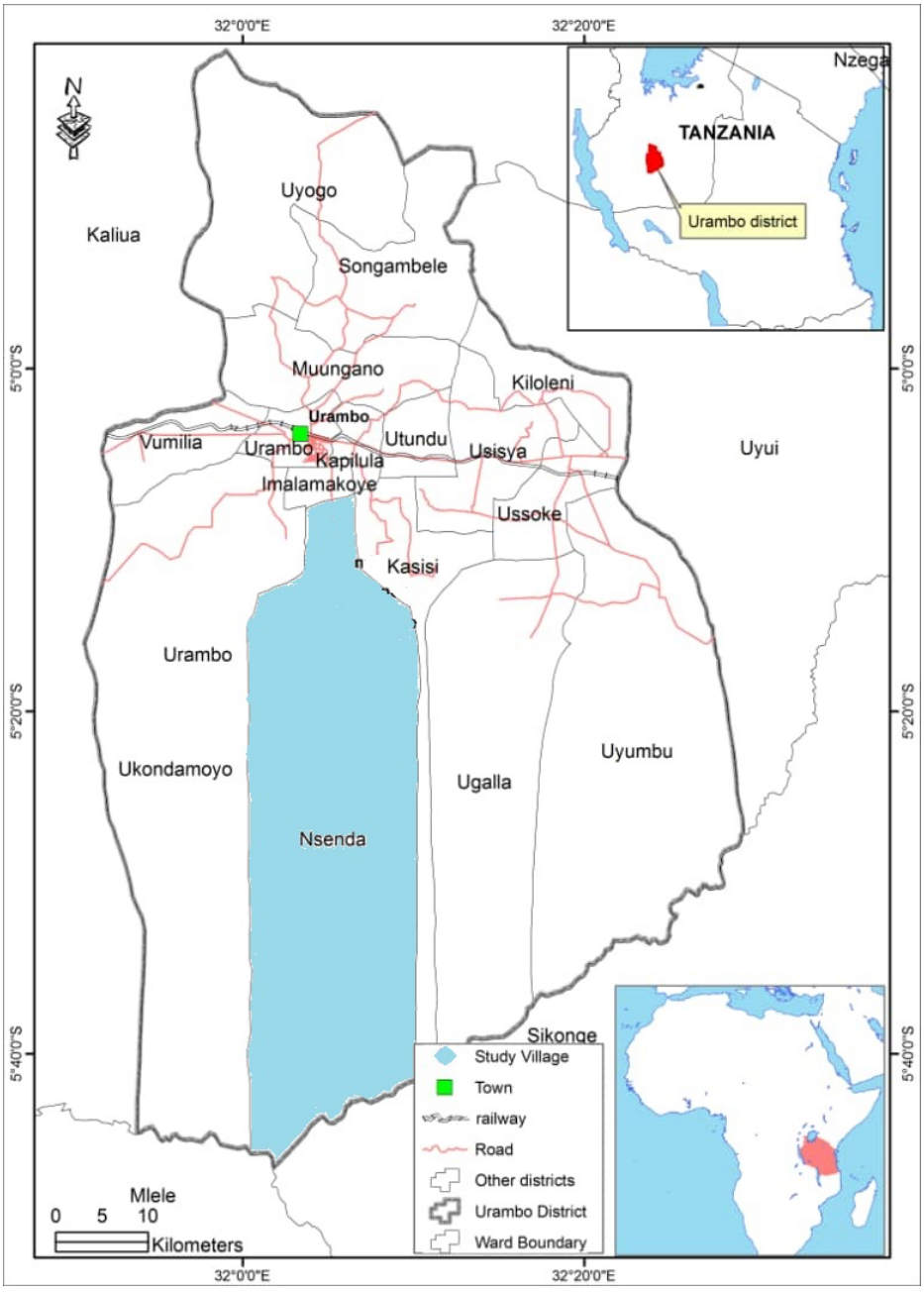

Figure 1. Map showing the location of Nsenda ward in Urambo District, the position of the District in the country, and the setting of Tanzania in Africa.

Data Analysis

The collected ethnobotanical information was analyzed for descriptive and inferential statistics such as frequencies and percentages using Microsoft Excel 2013 version and QED statistic software. The relative frequency of citation (RFC) for each medicinal plant was calculated to determine the number of THs that considered a particular species worth antidiarrheal. RFC values range between 0 and 1, whereby RFC of 1 suggests the uppermost level of THs consensus on using a particular plant species as antidiarrheal. The RFC determines the importance of each plant species based on the number of informants who reported its utilization. The RFC was calculated using the formula shown below:

$$RFC = \frac{FCs}{N} = \sum_{i=1}^{N} \frac{uRi}{N}$$

Whereby FC is the number of THs who cited a particular species, and N is the total number of THs involved in the survey. It should be noted that this study has taken on board only the MPs mentioned by at least three THs.

Results and Discussion

Socio-demographic profile of the traditional healers

The informants are the central component in the success of any ethnobotanical study, and their socio-demographic information about the THs helps to interpret and analyze furnished data in their natural social context (Merouane *et al.* 2022). In the present study, males constituted 76% of the total interviewed THs in the ward, while females represented 24%. The gender disparity might be explained by the fact that male THs are more highly trusted in African traditional healing practices than females, who face many cultural restrictions. Similar findings were also reported in Livingstone, Southern Province, Zambia (Chinsembu 2016), and Katsina State, Nigeria (Kankara *et al.* 2018). Also, the study revealed that most of the THs are members of the higher age group, as shown in Table 1. The finding indicates a wide gap in ethnomedicinal knowledge between the elderly and the younger generation. A similar observation was also reported in an ethnomedicinal study conducted in Bukoba Rural District in Tanzania, whereby 73% of the respondents were age group above 50 years (Kisangau *et al.* 2007). However, this jeopardizes indigenous knowledge as it may be lost following the demise of the older generation (Kacholi & Amir 2022, Kankara *et al.* 2018). Cultural changes due to modernization have considerably contributed to making the younger generation undermine traditional values (Giday *et al.* 2003).

In terms of education, most THs (67%) had primary education (Table 1). Previously, it was reported that formal education contributes to the degradation of traditional knowledge. For instance, an ethnobotanical study conducted in northern Kenya reported a negative correlation between formal education and medicinal plants' knowledge, attributing it to the constraints formal education places on students' time and the dismissiveness of traditional knowledge (Bruyere *et al.* 2016). Most THs (52%) acquired their traditional healing practice from family members, while others gained knowledge from herbalists (19%), friends (14%), ancestor spirits (10%), and 5% trained themselves. The finding is in-line with an ethnobotanical study conducted in the Samburu community in Kenya (Kamanja *et al.* 2015). Usually, family plays a vital role in adapting the traditional healing practices as it is responsible for transferring the culture through observation and developing motivation for the practice (Bibon 2021).

Table 1. Socio-demographic profile of the traditional healers

Biodata	Category	Frequency	Percentage
Sex	Male	16	76
	Female	5	24
Age (years)	< 30	4	19
	31-40	3	14
	41-50	5	24
	> 50	9	43
Education level	No formal education	4	19
	Primary education	14	67
	Secondary education	3	14

Medicinal Plants Diversity

This study documented 24 MPs as useful antidiarrheals in the Nsenda ward in Urambo District, Tanzania. The plants were distributed among 17 families and 24 genera. Most medicinal plant species (54%) are from 6 families (Table 2). The family with the highest number of plant species used to treat diarrheal diseases was Fabaceae (13% of all species), followed by Anacardiaceae, Asteraceae, Lamiaceae Myrtaceae, and Rubiaceae (with 8% each). The remaining 18 families were represented by one plant species only. Similar to this study, ethnobotanical studies conducted in South Africa (Appidi *et al.* 2008, Bisi-Johnson *et al.* 2010) and Ethiopia (Woldeab *et al.* 2018) reported Fabaceae as the wealthiest family in terms of antidiarrheal plant species. The same family was also reported in Nigeria to be widely used to treat animal diarrhea (Offiah *et al.* 2011). The dominance of Fabaceae is due to its extensive distribution in the tropics compared to other families (Bello *et al.* 2021), and it comprises many genera that are beneficial in the management of many other diseases besides diarrhea (Boakye *et al.* 2022, Joudi & Bibalani 2010, Kacholi & Amir 2022, Maema et *al.* 2019, Maroyi 2013). Species in this family are known to contain secondary metabolites like alkaloids, phenolics, and tannins for their bioactivity (Boadu & Asase 2017). Also, most species

belonging to Fabaceae are widely traded for treating various ailments in Ghana (Boakye *et al.* 2022) and South Africa (Rasethe *et al.* 2019). The knowledge of their bioactivity may account for their dominance in the Nyamwezi herbal pharmacopoeia. Other families, like Lamiaceae, Asteraceae and Rubiaceae were also reported in Rwanda (Gahamanyi *et al.* 2021), Ethiopia (Woldeab *et al.* 2018), and Turkey (Karahuseyin & Sari 2019) to have a good number of species used as antidiarrheal.

The number of antidiarrheal plants recorded in this study is less compared to those reported in Rwanda (Gahamanyi *et al.* 2021), Ethiopia (Woldeab *et al.* 2018), Turkey (Karahuseyin & Sari 2019), and South Africa (Bisi-Johnson *et al.* 2010). The variation could be due to the locals' diverse knowledge, and the duration of the research works in the study area. Among the medicinal plant species documented in the present study, 58% (14 species) have been reported elsewhere as being used to treat diarrhea (Table 2). The utilization of these plant species in different localities indicates that the plants are rich in antidiarrheal bioactive ingredients. Therefore, further pharmacological and antimicrobial studies are vital for discovering contemporary drugs.

Relative Frequency of Citation

The relative frequency of citation (RFC) is used to ascertain the crucial MPs in treating certain disorders (Amjad *et al.* 2020). In this study, the RFC values ranged from 0.14 to 0.76. The highest RFC was recorded for *Clerodendrum myricoides* (Hochst.) Vatke (Lamiaceae) (0.76), followed by *Psidium guajava* L. (Myrtaceae) (0.66), *Coffea arabica* L. (Rubiaceae) (0.62), *Zingiber officinale* Roscoe. (Zingiberaceae), *Bidens pilosa* L. (Asteraceae), and *Ficus sycomorus* L. (Moraceae) (with 0.57 each). Usually, the high RFC indicates abundant use and widespread knowledge among the locals in the study area. The high RFC values for the above seven MPs indicate that they are abundant in the area; therefore, the local THs are familiar with them and know much about their ethnobotanical practicality against diarrhea. Hence, MPs with high RFC values would be interesting for phytochemical and pharmacological profiling, future drug discovery, and commercial authentication (Kayan *et al.* 2014, Ahmad *et al.* 2017, Amjad *et al.* 2020).

Figure 2: Medicinal plants with high Relative Frequency of Citation (RFC); (a) *Clerodendrum myricoides,* (b) *Psidium guajava,* (c) *Coffea arabica,* (d) *Zingiber officinale,* (e) *Bidens pilosa,* and (f) *Ficus sycomorus*

Table 2. List of antidiarrheal plants, parts used, preparation and administration methods

Scientific name (Voucher no.)	Vernacular name	Family name	Life form	Source	Parts used	Preparations and administration	RFC	Literature reports supporting the claim
Bidens pilosa L. (UR012)	Ndasa	Asteraceae	Herb	Wild	Bark	Decoction, taken orally	0.57	(Walusansa *et al.* 2022, Woldeab *et al.* 2018)
Cajanus cajan (L.) Millsp. (UR039)	Mbaazi	Fabaceae	Shrub	Cultivated	Leaf	Powdering, then mix with hot water or tea and consume orally	0.42	(Walusansa *et al.* 2022)
Cassipourea mollis (R.E. Fries) Alston (UR062)	Mlugala	Rhizophoraceae	Shrub	Wild	Root	Chew and swallow the fluid	0.19	Not found
Citrus limon (L.) Burm.f. (UR010)		Rutaceae	Tree	Cultivated	Fruit	Squeeze fruits to make juice, then mix with leaves extract of *Cordia Africana* Lam. and consume orally	0.52	(Woldeab *et al.* 2018)
Clerodendrum myricoides (Hochst.) Vatke (UR002)	Mpugambu	Lamiaceae	Shrub	Wild	Root, leaf	Powdering, mixed with water, porridge, or tea and taken orally	0.76	(Gahamanyi *et al.* 2021)
Coffea arabica L. (UR003)		Rubiaceae	Tree	Cultivated	Seed	Roast seeds eaten on an empty stomach, make powder mixed with honey, and then take orally.	0.62	(Woldeab *et al.* 2018)
Combretum zeyheri F. Hoffm. (UR012)	Musana	Combretaceae	Tree	Wild	Root, leaf	Powdering the dried roots/leaves, then mixed with tea or porridge, and taken Oral	0.23	Not found
Cordia africana Lam. (UR024)		Boraginaceae	Tree	Wild	Root, leaf	Pound leaves, add a few drops of water, drink the concoction alone, or mix with boiled *C. arabica* and drink. Crush bark, mixed with water and consumed orally	0.38	(Woldeab *et al.* 2018)
Crossopterix febrifuga (Afzel. ex G. Don) Benth. (UR011)	Musaswambeke	Rubiaceae	Tree	Wild	Root	Decoction, taken orally	0.42	(Maroyi 2013)
Ekebergia benguellensis (Welw. ex C.DC.) (UR020)	Mtuzya	Meliaceae	Tree	Wild	Root	Dry, make powder, then mix with tea or hot water and take orally	0.28	Not found
Ficus sycomorus L. (UR083)	Mkuyu	Moraceae	Tree	Wild	Root, bark	Crush barks to make juice and drink or Crush roots, soak in water and drink	0.57	(Woldeab *et al.* 2018)
Hymenocardia mollis Tul. (UR018)	Mupala	Phyllanthaceae	Shrub	Wild	Root	Decoction, taken orally	0.14	Tor-Anyin *et al.* 2013
Jatropha gossypiifolia L. (UR016)	Mbono	Euphorbiaceae	Shrub	Wild	Root, Bark	Powdering is then mixed with hot water and taken orally	0.19	Not found
Lannea schweinfurthii (Engl.) Engl. (UR031)	Mtinje	Anacardiaceae	Tree	Wild	Root	Decoction, taken orally	0.14	Not found

Scientific name (Voucher no.)	Vernacular name	Family name	Life form	Source	Parts used	Preparations and administration	RFC	Literature reports supporting the claim
Launaea cornuta (Hochst. ex Oliv. and Hiern.) (UR044)	Mchunga	Asteraceae	Herb	Wild	Root	Infusion, taken orally	0.23	Not found
Ozoroa insignis Del. (UR026)	Mukalakala	Anacardiaceae	Tree	Wild	Root, leaf	Decoction, taken orally	0.33	(Maroyi 2013)
Psidium guajava L. (UR004)	Mpera	Myrtaceae	Tree	Cultivated	Leaf, fruit	Fruits are consumed freshly, and a decoction of crushed leaves is taken orally	0.66	(Bisi-Johnson *et al.* 2010, Kisangau *et al.* 2007, Maroyi 2013, Ngezahayo *et al.* 2015, Walusansa *et al.* 2022)
Pterocarpus tinctorius Welw. (UR027)	Mkulungu	Fabaceae	Tree	Wild	Root, bark	Decoction, taken orally	0.19	Not found
Syzygium guineense (Willd.) DC. (UR080)	Mzambarau	Myrtaceae	Tree	Wild	Bark	Decoction, taken orally	0.47	(Woldeab *et al.* 2018)
Tamarindus indica L. (UR050)	Musisi	Fabaceae	Tree	Wild	Fruit	Crushing fresh fruits to make juice, then taken orally	0.52	(Woldeab *et al.* 2018)
Vitex mombassae Vatke (UR077)	Mutalali	Lamiaceae	Tree	Wild	Root, leaf	Decoction, taken orally	0.14	Not found
Ximenia americana L. (UR033)	Mutundwa	Olacaceae	Tree	Wild	Root	Crushing and squeezing, then taken orally	0.23	Not found
Xylopia antunensii L. (UR021)	Mushenene	Annonaceae	Tree	Wild	Root, leaf	Decoction, taken orally	0.19	Not found
Zingiber officinale Roscoe. (UR006)	Tangawizi	Zingiberaceae	Herb	Cultivated	Rhizome	Chew and swallow the fluid	0.57	(Walusansa *et al.* 2022, Woldeab *et al.* 2018)

Novelties

Among the reported MPs in the present study, ten MPs, namely, *Cassipourea mollis* (R.E. Fries), Alston (Rhizophoraceae), *Combretum zeyheri* F. Hoffm. (Combretaceae), *Ekebergia benguellensis* (Welw. ex C.DC.) (Meliaceae), *Hymenocardia mollis* Tul. (Phyllanthaceae), *Jatropha gossypiifolia* L. (Euphorbiaceae), *Lannea schweinfurthii* (Engl.) Engl. (Anacardiaceae), *Launaea cornuta* (Hochst. ex Oliv. & Hiern.) (Asteraceae), *Vitex mombassae* Vatke (Lamiaceae), *Ximenia Americana* L. (Olacaceae), and *Xylopia antunensii* L. (Annonaceae) are reported for the first time being used as antidiarrheal in Tanzania, and they have never been reported elsewhere for the same use (Table 2). These ten MPs had low RFC ranging from 0.14 to 0.28, indicating that they are least known, and few THs know their ethnobotanical usefulness as antidiarrheal. Thus, further investigation is needed to understand the bioactivity potential against diarrhea-related infections.

Life form and Used Parts

The life form analysis of the recorded MPs showed that trees (67%) constitute the highest proportion, followed by shrubs (21%) and herbs (13) (Figure 3). The present finding differs from an ethnobotanical study conducted in Ethiopia (Woldeab *et al.* 2018), where herbs were the dominant life form. The locals in Nsenda ward prefer trees and shrubs for traditional remedies as the two forms are dominant in the study area, easily accessible throughout the year, and are not affected by seasonality. Also, the frequency of using trees and shrubs in drug formulation indicates that the locals may have rich ethnobotanical knowledge in using these life forms as antidiarrheal (Kacholi & Amir 2022).

Six plant parts, roots, leaves, fruits, seeds, bark, and rhizome were used to prepare several remedies for treating related diarrheal infections in the ward (Figure 3). The most frequently utilized parts were root (46%), followed by leaves (23%), bark (17%), and the remaining parts constituted 14% altogether. A similar preference for roots and leaves was reported in South Africa (Appidi *et al.* 2008, Bisi-Johnson *et al.* 2010) and Rwanda (Gahamanyi *et al.* 2021). Roots are most favorite due to possession of a high concentration of bioactive ingredients compared to other parts (Jima & Megersa 2018). During the survey, some unsustainable techniques of gathering plant materials, such as root excavation and bark stripping, were witnessed. These techniques have been reported as the most harmful harvesting methods for plants. For instance, the excavation of roots of herbs and shrubs has harmful effects on the plant itself and the root systems of contiguous plants (Cunningham 2001). Bark stripping upsets the conductive tissues of plants, causing physiological stress, and inhibits the distribution of resources to plants. Both effects reduce plant growth in the long term (Krisans *et al.* 2020) and offer a gateway for pathogens (Cukor *et al.* 2019), reducing trees' growth and vitality and decreasing their mechanical stability (Honkaniemi *et al.* 2017). Also, since trees and roots are the most utilized life form and plant part, this means that to gather tree roots, locals must cut down trees. This tendency not only endangers the existence of trees but can also lead to the loss of some essential MPs. Thus, leaves as an alternative are highly recommended as a sustainable practice due to their less detrimental effect on the parent plant.

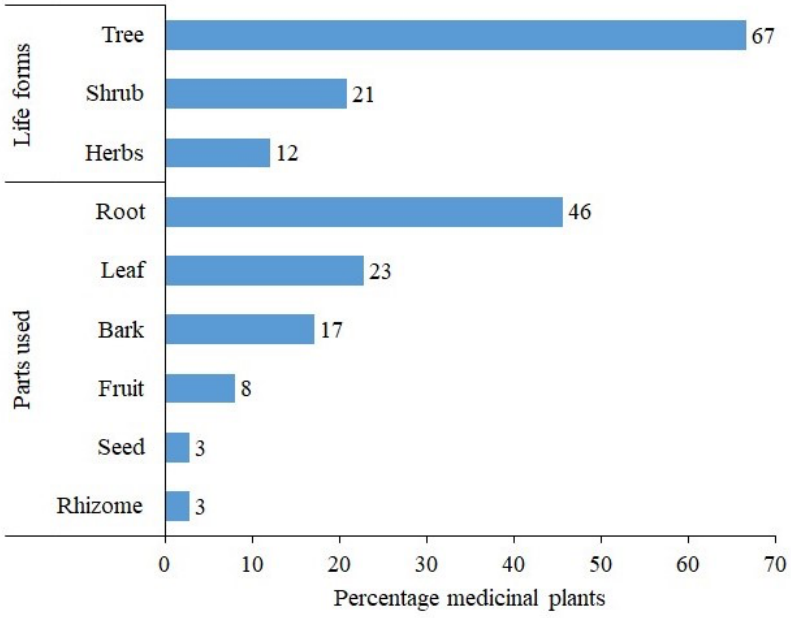

Figure 3. Life forms and Parts used for traditional remedies in Nsenda ward

Sources of medicinal plants

Most medicinal plants (79%) were collected by THs from the wild, while only 21% were from cultivations or farms. The finding reveals that wild habitats are indispensable for the livelihood of the local community in Nsenda ward. The reliance on wild is because wild resources are accessed without restrictions. However, the cultivation of MPs is weak, hence, providing an alert that the wild resources are exposed to overexploitation. Planting useful MPs in home gardens and farms is highly recommended for sustainability, and large-scale farming of commercial MPs should be encouraged too.

Preparation and administration of traditional remedies

A good number of the remedies preparations involved using a single plant part (92%), whereas the preparations involving mixing dissimilar plants or parts are hardly stumbled upon (8%). The fruits of *Citrus limon* (L.) Burm.f. (Rutaceae) and seeds of *Cordia africana* Lam. (Boraginaceae) were prepared by mixing with leaves of *C. africana* and seeds of *C. arabica*, respectively. The most common method of preparing remedies from plant materials was decoction, which accounted for 37%, followed by powdering (22%) and crushing (15%), while other methods accounted for 26% (Figure 4). Similarly, the decoction method was frequently utilized in making antidiarrheal remedies in South Africa (Bisi-Johnson *et al.* 2010) and Rwanda (Gahamanyi *et al.* 2021). The method is preferred as it helps extract active constituents, detoxify toxic compounds, sterilize used plant materials (Maema *et al.* 2019), and helps preserve herbal medicines for a longer time than cold extraction (Tugume *et al.* 2016).

About 21% of the preparations used different constituents and solvents, such as honey, tea, porridge and hot water, 13% were consumed freshly, and 56% of the preparations involved dilutions of the remedies in water. All the remedies were administered orally. The addition of some constituents aims to restore minerals, water, and other nutrients that could have been lost due to diarrhea and improve the bitter taste of some extracts (Odongo *et al.* 2018, Palombo 2006). On the other hand, dilution helps to enhance healing properties and eliminate undesired side effects. Sometimes, when mixed in making remedies, some extracts make it challenging to understand the impact of each on the treatment. Therefore, the need for phytochemical analysis of each plant material is paramount.

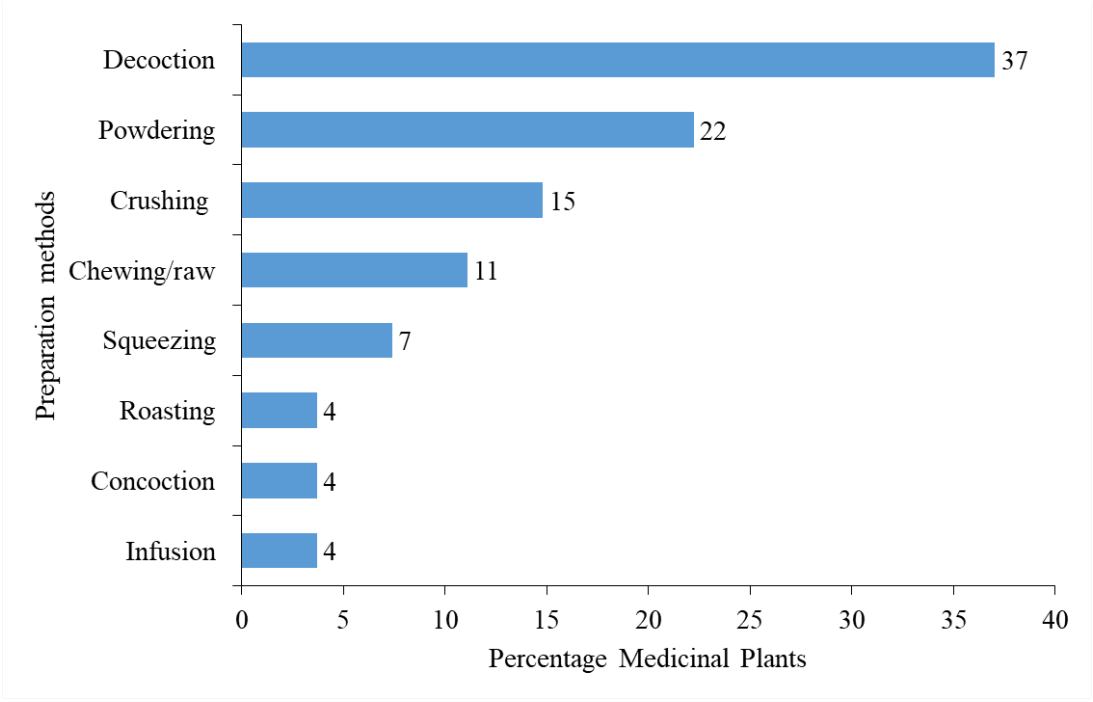

Figure 4. Preparation methods used to make herbal remedies in Nsenda ward

Antidiarrheal activity of some medicinal plants

Some recorded MPs in this study have been reported elsewhere to possess antidiarrheal activities. For instance, a study conducted in India (Birdi & Gupta 2015) confirmed that *P. guajava* leaf extract has a quicker clearance of infectious diarrhea in *Citrobacter rodentium;* hence, it has potential for use in the management of diarrhea infections in humans. Similarly, *C. myricoides* leaf extracts (Desta *et al.* 2021) and *C. arabica* roasted seeds (Alemu *et al.* 2022) were reported to have antidiarrheal activity. The extracts of *B. pilosa* (Shandukani *et al.* 2018), *F. sycomorus* (Ahmadu *et al.* 2007), *Ozoroa insignis* (Mathabe *et al.* 2006), and Tamarindus indica (Kuru 2014) contain

constituents that have pharmacological activities against diarrhea. Moreover, the extracts of *Z. officinale* (Zhang *et al.* 2020), hydromethanolic extract of *C. africana* leaves and root bark (Asrie *et al.* 2016, Ferede *et al.* 2021), and methanol bark extracts of *H. acida* revealed antidiarrheal activities. The literature supports the indigenous knowledge possessed by locals in managing diarrhea in the study area. Hence, the recorded MPs in this study can be used to develop modern antidiarrheal drugs using the current scientific knowledge and technological advancement.

Conservation Measures

Globally, the demand for MPs has increased, and their resources are harvested at an alarming rate (Ssenku *et al.* 2022). The increased demand is because most people prefer to use natural remedies for their health needs, resulting in the heavy exploitation of wild species with medicinal value (Chen *et al.* 2016). MPs with high RFC show high therapeutic potential for a specific ailment, are usually in high demand in urban and rural livelihoods and are an essential source of human survival and well-being. Thus, MPs with high RFC must be prioritized for conservation and sustainable use; otherwise, they will soon be extinct (Ahmad *et al.* 2017, Amjad *et al.* 2020, Ndlovu *et al.* 2021). In the present study, *C. myricoides, F. sycomorus,* and *B. pilosa* are the MPs with high RFC but rare in the study area, and the local THs usually collect them from the wild populations. Such MPs and others sourced from wild environments should be prioritized for conservation. Cultivating these MPs around the villages and home gardens (ex-situ conservation strategy) could be the best conservation measure that can help reduce pressure on the wild resources and ensure their continued survival and supply of resources for drug formulation (Nankaya et al. 2021, Ssenku et al. 2022). Moreover, the use of ecologically widely distributed MPs, such as *P. guajava*, *C. arabica*, and *Z. officinale,* which had high RFC, should be encouraged to safeguard the rare wild MPs from extinction.

Conclusions

This study offers the first documentation of the MPs used to treat diarrhea in Nsenda ward, Urambo District, Tanzania. It opens the door to modern science, which could lead to the transfer of natural wealth from informal traditions to the scientific appraisal of the pharmacological properties of the recorded MPs. The study discloses that despite the penetration of conventional medicine, people in the Nsenda ward still use MPs for their healthcare needs. Twenty-four MPs were recorded to be used by THs as antidiarrheal. *C. myricoides, P. guajava*, *C. arabica, B. pilosa, F. sycomorus,* and *Z. officinale* are preferred MPs for managing diarrheal. The most utilized life form and plant parts are trees and roots, respectively. Most of the plant species are collected from the wild. The decoction is the commonly utilized mode of preparing most herbal remedies, and all remedies are administered orally. The MPs are yet, threatened by many factors related to modernization and expansion of the population. Therefore, it is vital to conserve this cultural heritage by methodically assessing the biological activities of the documented MPs. Also, the population at Nsenda ward should be encouraged to cultivate the rare MPs sourced from the wild for conservation purposes and ensure the sustainable supply of MPs resources, but also, they should be advised to use the MPs with the wide ecological distribution.

Declarations

***Ethics approval and consent to participate**:* All the participants provided prior informed consent before the interviews.

Data and material availability: Voucher specimens have been deposited at the herbarium of the Department of Biological Sciences, Dar es Salaam University College of Education.

Competing interests: The authors declare that there is no competing interest.

Funding: Dar es Salaam University College of Education (DUCE) funded this study through competitive and innovative grants from 2019 to 2020 under project number DUCE-20030.

Author's contributions: DSK conceptualized and designed the study. DSK and HMA conducted data collection, data analysis, and interpretation. DSK drafted the initial manuscript, and HMA improved it. All the authors read, reviewed, and approved the final version of the manuscript.

Acknowledgements

The authors are indebted to all THs for sharing their ethnomedicinal knowledge of antidiarrheal plants. Moreover, the authors are thankful to the District Executive Director and Ward/Village executive officers for creating a good working environment for us to realize this study.

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