Chapter

Carissa spinarum L.: A Case Study in Ethnobotany and Bioprospecting Research

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Abstract

This study explores ethnobiological and bioprospecting research through the lens of *Carissa spinarum* L., using it as a case study to examine wider trends in such research. Hunn's Phasing in Ethnobiology is used as a framework, analysing the extensive research of a species used in healing, diet and other domains. Most reported studies are illustrative of Phase I Ethnobiological research based on the lack of basic context, emic or ecological detail, or a sense of collaboration with participants or across disciplines. Elements of Phases II, III and IV are evident in some studies highlighting ethnographic context, ecological issues or indigenous knowledge and rights. The extractive character of Phase I research, usually used for bioprospecting purposes, decontextualises plant use and may contribute to the historically poor results from ethno-directed bioprospecting. The widespread marginalisation of the social sciences in bioprospecting research can invalidate the whole research project and in turn ethnomedical plant use itself. A species such as *Carissa spinarum* L., emerging from Phase I research, can become a mere collection of its phytochemical parts, invalidated if those parts do not meet scientific measures of value. The collaborative character of Phase IV and V Ethnobiology would reward with more ethical and effective research with healing plants.

Keywords: Hunn phases of ethnobiology, ethnopharmacology, traditional medicine, medicinal plants, bioprospecting, emic, research ethics

1. Introduction

In August 2010, Reverend Ambilikile Mwasupile, a retired pastor in the Loliondo area of northern Tanzania began to treat people for a range of chronic ailments including diabetes, cancer, epilepsy, herpes, HIV/AIDS, liver disorders and asthma. A report on the phenomenon by Malebo and Mbwambo [1] describes how he was instructed in dreams to use a decoction of the root of the *Mugariga* tree to heal people with chronic illnesses. He would pray over the root before preparing the decoction, and pray again before personally administering it to the patient using Babu's own "miraculous cup" known as *kikombe cha Babu* [2]. He was, for a brief period, a media sensation throughout East Africa and was known as Babu wa Loliondo providing what was known as the "miracle cure". People travelled long distances by road and helicopter in order to get the once-off treatment. The flocks of people making their way to the remote village caused great disruption locally (**Figure 1**). The Loliondo cure was reported in local, national and international media including in the BBC [3] and the New York Times [4].

After initial scepticism, the Tanzanian government, local health officials and the national research hospital endorsed Babu wa Loliondo [2]. Popularity waned after 10 months, at least in part because the pastor called for a break due to the chaos caused locally. It was also reported that some elderly people died as they waited in queues for days [4] and that some HIV positive patients died, having stopped their anti-retroviral treatment subsequent to treatment with *Mugariga* [2]. Vähäkangas [2] describes how Babu wa Loliondo was, during that brief time, able to bridge the gap for people in the region between the scientific, traditional and Christian worldviews and between physical and spiritual healing.

Mugariga was identified as *Carissa spinarum* L. (*C. spinarum*), a plant known among several local ethnic groups as having healing properties [1]. In fact, prior to this, KEMRI (Kenya Medical Research Institute) was already investigating *C. spinarum* for its antiviral properties and in 2014 produced *Zedupex*™ containing *C. spinarum* [5]. Interest in the Loliondo "miracle cure" has re-emerged recently in relation to COVID-19. It was reported in the media that KEMRI was investigating *Zedupex*™ for efficacy against SARS-CoV-2 [6, 7].

C. spinarum, a member of the Apocynaceae family, is a complex and varied species that is widely distributed geographically throughout Sub-Saharan Africa, Australia, and parts of Asia [8]. This research will show that it has a large body of associated ethnobiological data, spanning its geographical range, dating from 1886 through to the present. This study aims to analyse this data through the lens of changes in ethnobiological research since its inception as a discipline, in the late nineteenth century, to the present.

Ethnobiology as a discipline is defined by the Society of Ethnobiology [9] as "the scientific study of dynamic relationships among peoples, biota, and environments"

Figure 1.
Queues of traffic as people make their way to Loliondo (photo with permission from Jonathan Kalan).

with ethnobotany a major subdiscipline of ethnobiology. Ethnobiology is concerned with the material and symbolic aspects of interactions between humans and their environments, having multidisciplinary foundations and outlooks. It has undergone many changes since its academic beginnings in the late 1800s. Hunn describes four phases in the development of ethnobiology, although the characteristics of each phase are not limited to the defined time periods (see **Table 1**) [10]. Hunn's Phase I, characteristic of the later nineteenth century to the 1950s, is primarily descriptive presenting lists of plant species and their medicinal and other uses [11]. Phase II, dating from the 1950s to the 1970s, examined the role of cognition in human relationships with their environments researching folk classification, linguistics and symbolic aspects, representing the perspective of the person whose culture is being studied. It is described as the emic phase [12]. Phase III developed from the 1970s through to the 1990s examining indigenous knowledge and the broader ecological context which resulted in the formation of the ISE Code of Ethics [13]. Phase IV from the 1990s onwards is characterised by the rise to prominence of concerns around the rights of local communities, specifically: the exploitation of indigenous knowledge and intellectual property rights of indigenous knowledge holders. The indigenous voice is heard in this phase as a research collaborator rather than as a participant. A developing Phase V involves deeper networking and collaborative work between researchers across geographies and disciplines to address pressing issues of ecological and cultural crises [11]. D'Ambrosio identifies the same broad phasing as illustrated in **Table 1** [12]. In Phase IV, he identifies both biocultural and ethical components in the focus and conduct of research.

Ethnobiology has, thus, historically had a significant focus on ethnomedicine (EM). The main emphasis within EM research from its inception has been on finding new drug leads in what Reyes-García [14] called the "romance of ethnopharmacology" as a route to this end. The interest in mining medicinal plants for economic purposes dates back to the colonial period [15]. This search for new drugs has resulted in the prominence of Phase I-type research in Hunn's classification where medicinal species and their therapeutic uses are documented [11, 16].

C. spinarum is a species with a wealth of associated biocultural knowledge including practical and ritual uses across its range, with its use in health and healing

Time period	Hunn Phases	Character of era—D'Ambrosio	Some Academic Fields
Late 19th C–1940s	I	Ethnography Cultural Anthropology Uses of biota	Ethnography Economic Botany
1950s–1970s	II	Cognitive and emic classification Secondary metabolites	Ethnoscience Linguistics Ethnopharmacology Phytochemistry
1970s–1991	III	Ethnoecology Ethnopharmacology	Ecology and conservation Traditional Ecological Knowledge Bioprospecting
1992–present	IV	Indigenous Ethnobiology Bioculture Ethics Reflexivity	Indigenous rights Biocultural Diversity Research Ethics Global Change

Table 1.
Elements of history of ethnobiology (adapted from D'Ambrosio 2014).

being the most widely reported in the literature. Despite its widespread usage, it is not well-known outside the oral and folk traditions of Africa, South Asia and Australia as evidenced by a Google search. Using the Google Trends search function, as used in an analysis of global and regional interest of Açai berries [17], there is a low level of interest in *C. spinarum* relative to other medicinal species of global and regional importance such as *Azadirachta indica* A. Juss, *Withania somnifera* (L.) Dunal, *Argemone mexicana* L., and *Echinacea purpurea* (L.) Moench. Written records began during the colonial era and there has been recent media interest in its medical potential in East Africa [1]. There is limited recorded usage in the ancient texts of Traditional Chinese Medicine (TCM) and Ayurvedic and Siddha medicines although a similar species, *C. carandas* L., is listed in Ayurvedic databases [18]. The focus on healing properties may be a function of the studies that have been conducted where the emphasis is often on ethnomedicine (EM) and the ultimate potential for bioprospecting. Broad ethnobotanical studies and anthropological research would help to situate this healing focus in the context of the wider value of biodiversity as integral to existence in communities of the Global South [19].

Previous articles reviewing *C. spinarum* have examined the phytochemistry and pharmacology of the species with limited attention to the wider ethnobiology of this species [20–26]. The scope of this chapter is to:

- analyse the available indigenous knowledge regarding the cultural role of *C. spinarum* across the multiple reported domains with an in-depth analysis of the ethnomedical domain

- analyse the presentation of emic or insider's perspectives on the role of *C. spinarum* and other species in the study communities

- analyse the data through the framework of Hunn's phases of ethnobiology, using *C. spinarum* as a case study of wider trends in ethnobiology research of medicinal species

- question whether this analysis informs future research on *C. spinarum* and other species with substantial associated biocultural knowledge?

2. Botany of *Carissa spinarum L.*

2.1 Description and distribution

The species *Carissa spinarum* L. (*C. spinarum*) (Apocynaceae) grows as a thorny highly branched evergreen shrub or small tree of up to 6 m tall with evergreen leaves and masses of fragrant white flowers tinged with pink/purple. Fruits are green, then red ripening to purplish black and are edible when ripe (see **Figure 2**) [27].

C. spinarum is among the most widely distributed of all Apocynaceae species [28]. It occupies a wide range of habitats from wet or dry forest, to thickets and savannahs, at altitudes of 0–2450 m though it is not found in very wet climates or in equatorial rainforests [28]. Its wide ecological tolerance is reflected in the geographic distribution of botanical and ethnobotanical samples. *C. spinarum* is found in 74 countries and territories across 3 continents: Australia, throughout Sub-Saharan Africa and the Indian Ocean islands, the Arabian Peninsula; and in countries of South, East and Southeast Asia (see **Figure 3**) [8].

Figure 2.
C. spinarum *L., by SAplants, CC BY-SA 4.0 via Wikimedia Commons.*

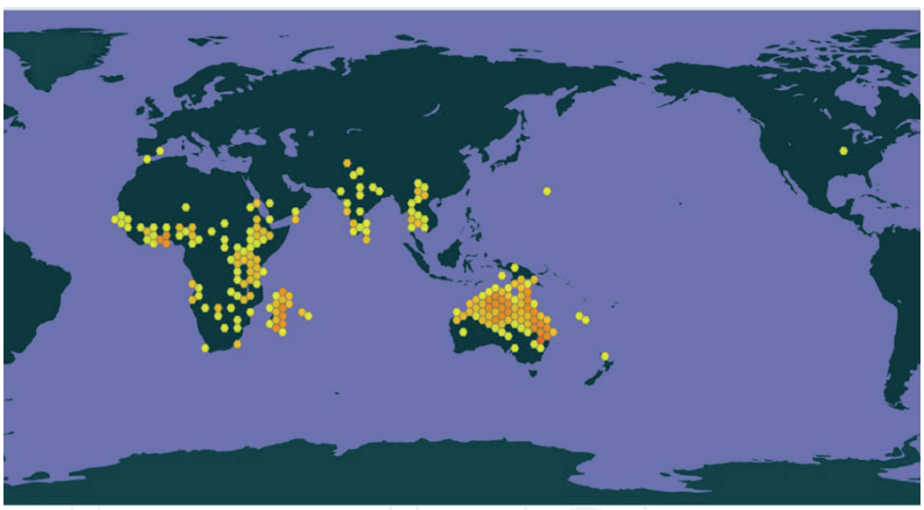

Figure 3.
C. spinarum *L. in GBIF Secretariat (2019). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF*.org *on 2020-10-11.*

2.2 Botanical nomenclature and synonymy

C. spinarum is the currently accepted name of the species. It is listed in World Flora Online [29] as having 98 synonymic botanical names. The genus *Carissa* is described as having significant inter- and intra-species variation [30] and this, along with its wide geographic distribution, may contribute to its numerous botanical synonyms. The key synonyms that appear in the ethnobotanical literature are *C. spinarum* L. (accepted name), *C. edulis* (Forssk. Vahl.) (Sub-Saharan Africa), *C. opaca* Stapf ex Haines (India and Pakistan), *C. congesta* Wight (India), *C. xylopicron* Thouars (Mauritius) and *C. lanceolata* R.Br. (Australia). As a heterogeneous species, there are disagreements around plant identification, naming and synonymy with the added problem of misspellings. The complexities in the naming of *C. spinarum* carry through in all subsequent study findings as described in best-practice documents [31–33].

3. Ethnobiology of *C. spinarum*

This section will analyse the available indigenous knowledge regarding the cultural role of *C. spinarum* across the multiple reported domains. It begins with the ethnobiological distribution and nomenclature of the species. It then examines how the relationship of people and plants has been explored through qualitative and quantitative means. Specific cultural domains of use are then examined, with a particular focus on ethnomedical—human and animal—use as the most common domain (80%). Inclusion in human and animal diet is the second most common domain of use reported (9%). It is also valued as an insect and snake repellent, for firewood and charcoal making, for fencing and live hedging and as a timber. The examination of broad ethnobotanical usage across multiple domains is most commonly found in research from Ethiopia and Australia. The body of data is then analysed with respect to the historical phases of ethnobiological research.

3.1 Ethnobiological distribution and nomenclature of *C. spinarum* L.

C. spinarum has a wide ethnobiological distribution. Overall, a total of 284 documents were reviewed for this study including medical and other ethnobotanical uses. There are ethnobotanical reports from 35 countries across 3 continents as illustrated in the map in **Figure 4**. This is less than the botanical distributions and could indicate that it is not considered a useful species in the remaining 29 countries, that such research has not been conducted or that the knowledge has been lost. For the purposes of our analysis, the geographical regions have been divided as follows: Eastern Africa (Kenya, Tanzania, Rwanda, Uganda, Ethiopia); Southern Africa (Angola, Botswana, Mauritius, Madagascar, Malawi, Mayotte, South Africa, Zimbabwe); Central Africa (Chad, "Congo Belge" and "Ruanda-Urundi", DRC, Burundi); West Africa (Benin, Côte d'Ivoire, 'French West Africa', Ghana, Guinea, Mali, Nigeria, Senegal, Togo); Northern Africa (Sudan); Arabian Peninsula (Saudi Arabia); Eastern Asia (China); Southeast Asia

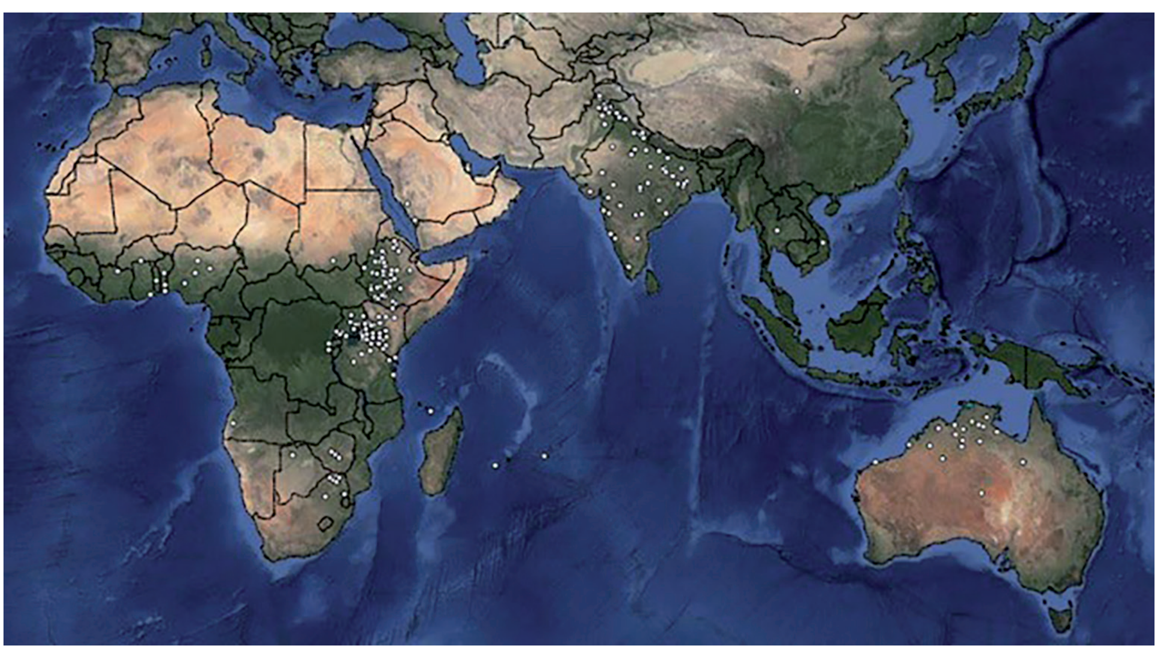

Figure 4.
Distribution of ethnobotanical reports on C. spinarum *(courtesy of Robbie Kelleher).*

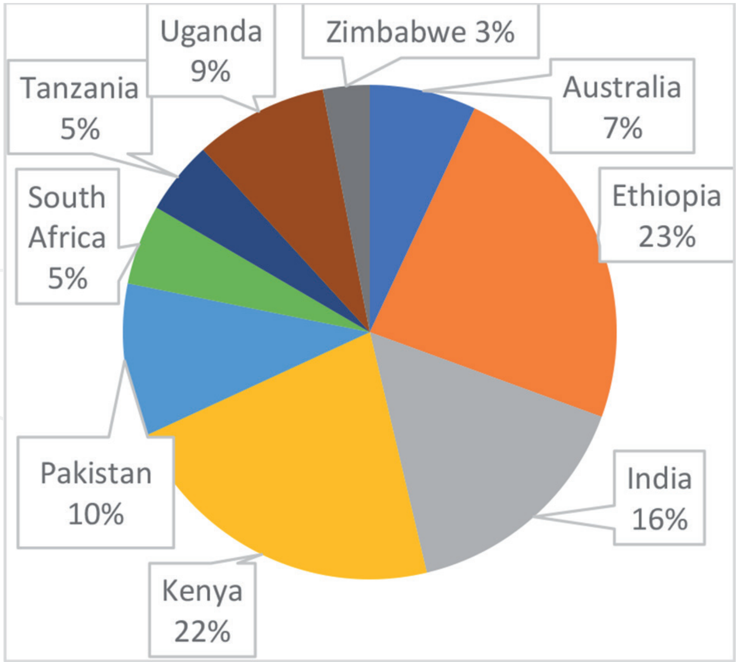

Figure 5.
Documents % per country (>6 = 80% total) citing ethnobotanical use of C. spinarum.

('Indo-China' i.e., Vietnam) and South Asia (India, Pakistan). The proportional geographical distribution of these studies is illustrated in the chart in **Figure 5** showing that most of the research has occurred in Kenya, Ethiopia and India with Uganda, Pakistan, South Africa, Tanzania and Australia being proportionally in a second tier of the data. The Kew Medicinal Plant Names Service [34] lists 162 common names. In this study, the most common vernacular names found are *Agam* (and variations—Ethiopia), *Muyonza* (and variations—Kenya), *Legetetwo* (and variations—Kenya), *Lamuriei* (and variations—East Africa), *Olamuriaki* (and variations—East Africa); *Bois drone* (Mauritius), *Konkerberry* (and variations—Australia), *Currant bush* (and variations—Australia), *Gara-asur* (India), *Karamarda* (and variations—India) and *Karaunda* (and variations—India and Pakistan).

3.2 Some emic perspectives on the ethnobiology of *C. spinarum*

Anthropology has historically been an integral part of ethnobotanical investigations dating to the colonial era. The emic approach in anthropology came to the fore in the 1960s whereby the researcher attempted to experience and interpret the culture from the insider's perspective. In ethnobiological research, techniques to gain the insider perspective are used in order to understand and interpret the relationship of people and plants. In ethnomedical research, this can take the form of understanding local illness aetiologies, concepts of health and healing, the meaning of different elements of the healing process and the meaning attached to different plants and habitats. In Hunn's four phases, the emic aspect becomes significant in Phase II from the 1950's through to the 1970's though Frazão-Moreira illustrates clearly the ongoing centrality of ethnographic research in ethnobiology [35]. An anthropological perspective in ethnobotanical and ethnomedical studies has been considered vital for decades [31, 32, 36, 37]. This view can give valuable context for the medicinal use of plants and can help direct further study and practice in many fields such as health care provision, sustainable plant use, environmental protection and bioprospecting. There is very little of the insider's understanding available in this analysis on *C. spinarum*. Of all primary ethnomedical studies involving *C. spinarum*, 75% have no contextual information at all including no information on local morbidity, mortality or availability of biomedical healthcare. Some 25% of studies, provide some emic information with short descriptions of selected aspects of local traditional medicine such as causation and diagnosis, specific illness understandings and descriptions, knowledge distribution and transmission, information on the place of plants in healing and biomedical health context [38–53]. However, a view on how this species has a role in health and healing in some communities is presented in research from Australia and Eastern Africa.

3.2.1 Australia: "Boonyja Bardag Gorna—All trees are good for something"

The phrase "*Boonyja Bardag Gorna*—All trees are good for something" is the title of the book authored by Esther and Sandy Paddy and Moya Smith [54] and is an illustration of the centrality of biocultural knowledge to life for the authors. Attempts to record that knowledge are ongoing in parts of Australia.

There are elements of Aboriginal biocultural knowledge that makes Australian ethnobiological research different to that conducted in other cultural contexts. These elements relate to the historical context and cultural norms relating to biocultural knowledge, knowledge transmission and plant usage. *C. spinarum* is a widely distributed species in northern Australia [55]. However, there is relatively little ethnobotanical data in comparison to the high level of botanical sampling. This might be explained by the fact that significant ethnobiological research in the area is relatively recent, being concentrated in the past 35 years with the greater part of that local ecological knowledge already lost (Glenn Wightmann, Ethnobiologist, Northern Territory Government pers. comm 2020). Most of the research analysed in relation to Australian Aboriginal ethnobiology is not published in online academic journals but is mostly in the form of Botanical Bulletins. The research is collaborative with community members as primary authors and is published for the purposes of transmission of biocultural knowledge, a cultural requirement for Aboriginal Elders [56]. Research with the Wik peoples in Queensland, has illustrated how ethnobotanical research methods need to be culturally appropriate [57]. They stated that for Aboriginal Communities with whom they have conducted research, widely used ethnobotanical methods such as those described by Cotton [58] and Martin [37] are not appropriate in this environment. Factors contributing to this include: categories of public and secret biocultural knowledge, inappropriate questions and inappropriate questioning. Researchers need to be aware that only selected people may speak on behalf of "country" by law. In this analysis of the ethnobotany of *C. spinarum*, the reality of public and secret knowledge is described by several authors [56, 59–62]. These studies highlight the fact there is a vast amount of knowledge of Aboriginal medicines including gendered knowledge, which is secret, culturally sensitive and cannot be shared in publications.

In a large study of Australian Aboriginal medicinal plant usage, Latz [63] found that, in contrast to western medicines, fewer than 10% are taken internally and that about 70% are used as a wash or an ointment. The use of fumes from heated plant parts is also common in Australia especially for children in a process known as "smoking" [63–65]. These general findings are reflected in the research on *C. spinarum* in Australia. The most common routes of administration are fumigation and external application. Latz stated that most important species have several uses. Connelly and Wallis [64] added that there is knowledge of all of the different elements of a plant and how they may each be used in different ways. In these Australian studies, *C. spinarum* is used medicinally and ritually but is also included in diet, as an insect repellent, for carving and for firewood. This multifunctionality of plant species is reflected across the global range of *C. spinarum*. The possibility of multifunctionality of species recorded in ethnobotanical research may be important to bear in mind when asking why a particular species may be chosen by local people. It's very multifunctionality may be a central reason for its choice as a medicinal species. While emic description of Australian aboriginal EM is provided in some documents, as elsewhere, detailed anthropological information in relation to *C. spinarum* in particular is limited. McDonald [66], in an anthropological study in the East Kimberley region researching concepts of health and illness, described the "smoking" process: Aboriginal peoples "smoke" the bodies of children and adults with medicinal plants in order to clear the body of "rubbish"—debris that can clog the flow of *birlirr*, the body's life-force. In the study community, *C. spinarum* is an excellent smoking medicine [60, 66]. Aromatic leaves are believed to be strong medicinally as the smoke can be felt entering the body through the senses and the skin:

> *You can feel the jiluwa working, feel the blood flowing [during a smoking treatment]. I was heavy before, just like sin. I'm fresh and light now. We can feel the medicine going into us. Feel cold coming through the body. When we take gardiya tablets, we don't feel anything. Gija woman, [66] p. 90. [Note: Jiluwa are body channels, gardiya tablets are whitefella medicine or pharmaceuticals. Coldness is a healthy state].*

For Aboriginal peoples, bush medicine is considered to have been in the ground from *ngarrangkarni*—the Dreaming time, placed there by the ancestors [66]. This elicits trust in users of bush medicine. *C. spinarum* is included in some Dreaming stories and thus is part of Aboriginal cosmology, which links plants, animals, humans, and places, past and present [67]. The inclusion of this and other aspects of the social and natural environment in these stories indicate a cultural importance that extends beyond the utilitarian realm.

The loss of biocultural knowledge is a well-established phenomenon in the ethnobotanical literature in general [68, 69]. Latz [63] and Wightmann (2020 pers. commun.) described the loss of many aspects of traditional Aboriginal knowledge due to changes in the way of life and the influx of new diseases. Other authors describe how many of the plant species and the practices involving them are still in use by many adults as "domestic" medicine and need to be documented [61]. The value of the publication of the Dalabon biocultural knowledge from North Australia was asserted in [56]. Given that traditional modes of transmission of knowledge relating to native species from elders to the next generation are being interrupted through the lack of access to sacred sites and ceremonial practices, some elders feel that the transmission of knowledge through publication is a way of fulfilling their duty.

3.2.2 Buda (Evil Eye) in Ethiopia

Spirit-Related Illness, usually *Buda* (Evil Eye) is commonly reported to be treated with *C. spinarum* in Ethiopian studies. Treatment often involves *C. spinarum* in combination with other species in the form of fumigation. Literature shows that there is a wide geographical and historical spread of Evil Eye. It is referenced in Classical Greek literature, the Bible, Islamic literature and is reported among some Asian peoples and in most European, African and American countries [70]. However, there is no description of the presentation of *Buda* or other spirit-related illness in any of the Ethiopian documents on *C. spinarum*. In other Ethiopian research with a sociological rather than ethnobiological focus, *Buda* has been studied. The ability to inflict Evil Eye/*Buda* is described as being innate and that the identity of people who can inflict *Buda* is secretly known within a community [71]. Abbink [72] wrote that the Amhara people of Ethiopia believe *Buda* to be held by people outside of the Amhara group, perhaps landless or with no permanent home or people of certain professions such as blacksmiths or potters. They have a hereditary, malevolent power which is used, perhaps involuntarily, to cause harm. He wrote that the victims of *Buda* become weakened with a sense of being drawn to their death. *Buda* is described as causing many animal and human health problems as well as damage to property and is commonly treated by ritual [71–74]. Jacobsson [75] wrote that it can cause any kind of illness including neuroses and psychosomatic illness, though it often manifests as gastrointestinal disorders. Jacobsson argues that there is no clear distinction between physical and mental disorders, and consequently there is none between associated healing methods. Thus, physical and spiritual means may be used as part of the healing process. The treatment with medicinal plants can have ritual and physical components, and the burning of *C. spinarum* in the treatment of *Buda* disorders could be interpreted in this light. The most common method of preparation of *C. spinarum* for treatment of *Buda* is the administration of root smoke by fumigation (for example see [51]). In a few cases, the root is mixed in water alone and inhaled or taken orally or the root may be tied around the neck as protection [76–78]. Ritual and physical effects may combine in the use of *C. spinarum* to treat *Buda*. In an examination of ritual plant use in Benin and Gabon from a biomedical (BM) (conventional medicine) perspective, Quiroz et al [79] illustrated that ritual use does not imply a lack of pharmacological activity. Pharmacological activity of the smoke of *C. spinarum* may augment the socio-cultural healing benefits of the ritual components of healing.

The example of spirit-related illnesses illustrates that an understanding of the context of healing, can help to situate the use of plants in the healing process and to interpret it from a cross cultural perspective.

3.2.3 Kenya: Pokot and Luo health-seeking behaviour

There are two anthropological studies from Kenya, whereby the context of *C. spinarum* use is provided through in-depth emic information in relation to health and illness in the study areas. These studies are conducted with the Pokot people in north western Kenya [80] and the Luo of Western Kenya [81] with some emic information from some other studies [41, 82–90].

The 1982 study of Pokot health-seeking behaviour illustrated the dynamic nature of this behaviour in the context of the availability of traditional and BM forms of health care [80]. The Pokot understanding of illness causation is detailed as having naturalistic/biological, interpersonal and/or spiritual basis. Treatment and prevention can involve addressing each of these planes of causation with the treatment for biological cause being more specific to the symptomatology and treatments for interpersonal and spiritual cause being more diffuse. Some ailments such as infertility and mental illness are considered to have an interpersonal or spiritual basis while others such as malaria are thought to have a more naturalistic causation. Treatments usually involve administration of medicinal plants, ritual and instructions on foods to eat or avoid. The use of purgatives and emetics by the Pokot in the study area to prevent and treat illness is understood in the context of illnesses residing in the gut. The process is thought to "clean up the system". The treatment for malaria, for instance, may involve the use of pharmaceuticals complemented by the subsequent use of purgatives and emetics to ensure the complete expulsion of the illness. The use of emetics and laxatives was likewise discussed elsewhere in the context of Pokot ethnobotany [89] and among the Luo [81].

Ethnobotanical research with Luo mothers was conducted with reference to the authors' earlier extensive anthropological research with the Luo of western Kenya [81]. It is an instance of rich emic understandings presented in this analysis of *C. spinarum.* As with the Australian example above, there is an amount of secret knowledge among the Luo mothers, especially in the treatment of more complex ailments resulting in lacunae in the recorded knowledge. Their research found that gastrointestinal illnesses are the most commonly treated with medicinal plants while fever and headache are rarely treated using plant medicines despite the high prevalence of malaria in the study area. The authors attribute this to the availability of pharmaceuticals in local shops to treat these symptoms. The extent of secret knowledge and the availability of effective pharmaceuticals could result in an overall skewing of the ethnobotanical findings towards gastrointestinal use. Illness itself is considered to be a constant element of life and plant remedies are used, not to eliminate illness but rather to find a balance in a constant process. In the case of helminth infections, worms are considered to live permanently in the gut and it is important to maintain worms in a healthy equilibrium in the gut for the health of the individual. Treatment of other illnesses, such as diarrhoea, require the illness to be removed from the body with purgatives. This concept of healing also finds the BM healing by suppression of illness to be unhealthy such that sometimes the use of BM is prohibited in the pursuit of health:

> *Luo medicine makes the illness come out; injections push it back inside. If you inject, it moves through the body and you swell and may die. (Luo mother [81] p. 44).*

Many illnesses including diarrhoea may be thought to be caused by *Yamo*, an overarching illness concept that can manifest in many ways but is treated through eliminating it from the body. The constant presence of illness in the body, even when it is healthy, requires that a child be constantly treated to make illness emerge from the body and as such keep the forces of *Yamo* and other forces of illness at bay:

> *'a (young) child ought to be ill regularly' (nyathi onego otuore) lest it would die, once the illness (i.e., Yamo) finally 'comes out'. (Luo saying, [81] p. 44).*

In their research with Luo mothers, the authors report the use of *C. spinarum* (*Ochuoga*) in the treatment of diarrhoea and *Ang'iew* (a childhood febrile illness with rash) [81]. While no individual species is singled out as culturally important, the presentation of in-depth emic understandings of health and illness described in brief here gives valuable context to the listing of 91 medicinal species. From a BM perspective such as researching health-seeking behaviour or bioprospecting, it is important to understand the socio-cultural understandings of health and illness as a backdrop to the choice of treatments. The use of *C. spinarum* as a purgative to treat malaria, for instance, does not imply that it is ineffective as an anti-malarial but the knowledge could modify the perspective of the bioprospecting ethnopharmacologists. For BM healthcare workers, the knowledge of local purgative and emetic practices is important in providing care to the communities served.

3.3 Ethnobotanical uses—*C. spinarum* in human and animal medicine

Ethnomedical (EM) analysis of *C. spinarum* took into consideration the following basic elements: plant parts used, methods of preparation, route of administration and ailments treated using *C. spinarum*, followed by analysis of the use of different plant parts for different ailments. Plant harvesting details were searched but were only reported on in three studies out of a total of 284 documents and 513 use reports (URs) analysed. Each of these aspects of EM plant use bears a relationship to the phytochemistry, bioactivity and toxicity of plant extracts which then have a bearing on the outcomes of ethno-directed bioprospecting studies. The global geographical variation in usage of *C. spinarum* and the ethnoveterinary use of *C. spinarum* were also examined.

The geographical distribution of the ethnobotanical data is illustrated in **Figure 6**. The key areas reporting the EM use of *C. spinarum* are Eastern Africa (mainly Kenya and Ethiopia) and South Asia (mainly India and Pakistan). *C. spinarum* is also used across the rest of Sub-Saharan Africa, Northern Africa and the Arabian Peninsula, East and South East Asia and Australia.

3.3.1 C. spinarum *in human ethnomedicine: plant parts used*

A summary of *C. spinarum* plant part used in medicinal preparations for human use across all regions is seen in **Figure 7**. It illustrates that, for *C. spinarum*, the primary plant part used is the root followed by leaf, fruit, rootbark, stem and bark while 9% of reports do not state what plant part is used (N/S).

The data was analysed across 5 key geographical regions: Eastern Africa, Western Africa, Southern Africa, South Asia and Australia. The summary of key plant parts used is illustrated in **Figure 8** and shows that, at regional level, the root is still the most commonly used plant part. However, in Eastern Africa, the predominance is more marked where the root and rootbark together account for three quarters of all URs. Fruit and leaf use are minimal by comparison. In Western Africa, the root and rootbark together account for most usage with leaf, fruit and stem used infrequently. In Southern Africa the root accounts for over half of usage with stem and other parts lower. In South Asia,

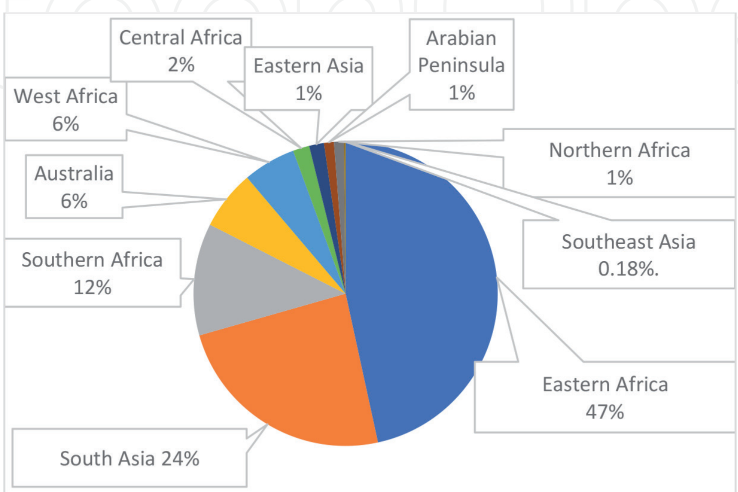

Figure 6.
Geographical distribution of human EM Use Reports (URs) for C. spinarum.

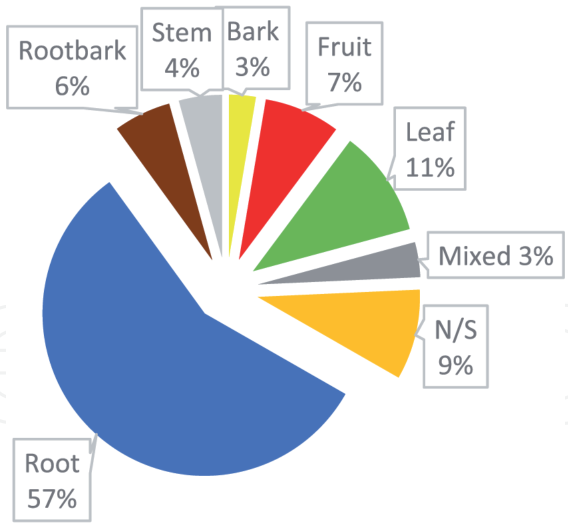

Figure 7.
C. spinarum *for human use: plant parts used in the preparation of EM.*

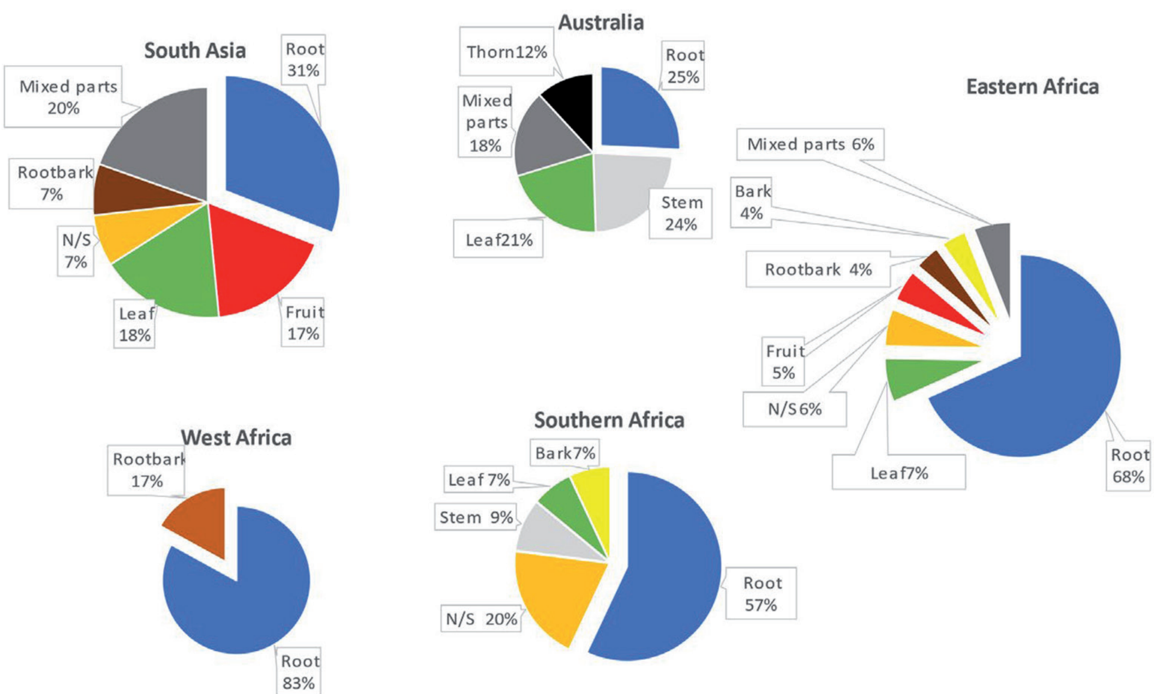

Figure 8.
C. spinarum *and variation in plant part usage across global regions (UR > 3, 85% of all URs; N/S = not stated; chart areas approximately reflect relative nos. of URs).*

root use is less dominant and followed by leaf and fruit. In Australia, the different plant parts are more evenly divided between root, stem and leaf. In most areas a proportion do not state what plant part is used, particularly so in Southern Africa.

More broadly in EM research, there are a number of reasons hypothesised for differences in the choice of plant and plant part such as availability and related cultural norms, the presence of bioactive metabolites, organoleptic qualities, appearance, time of year and location of a species.

A study of the most commonly used plant parts in East Africa stated that with trees and shrubs, the bark and root are more commonly used [91]. A study in a semi-arid region of Kenya found that most medicinal plants are trees and shrubs, and their bark and roots are the most commonly used parts [89]. Research in the Caatinga (semi-arid) region in North-eastern Brazil found that the species and plant parts that are available throughout the year are the most important medicinal species. Stem-bark was the most commonly used plant part [92]. The authors reported that herbaceous plants and leaves, which are only available for a few months of the year, are less commonly used in the same study. The authors examined tannin concentration in two medicinal species, assuming tannins to be responsible for much of the medicinal activity though they acknowledge that this may not be wholly correct. They found that both leaf and stem-bark contained significant quantities of tannins although the stem-bark is the part used medicinally. They postulated that the community develops a stronger relationship with the perennial woody plant parts regardless of the fact that the leaf may be as effective as the stem.

Organoleptic qualities of taste, smell, colour and texture are reported to be important to decision making around medicinal plants as described by Etkin [36] and are linked to explanatory models of illness. A study in Peru illustrated how sensation is at the centre of medicinal plant selection connecting culture and the environment [93]. A study in Brazil found that taste and smell are associated with therapeutic indications [94]. Studies in Mexico indicated a similar connection between taste, smell and therapeutic indication where, for instance, bitter and aromatic plants are valued in the treatment of gastrointestinal disorders [95]. Bitterness is a characteristic of aphrodisiac tonics in West Africa and the Caribbean [96]. Among the Pokot people in Kenya, bitter medicines were considered to be more effective at treating all illness [80]. Sensory attributes of plants were, likewise, seen, as an important indicator of healing power among the Suiei Dorobo of Northern Kenya [85]. The "doctrine of signatures" may be a contributor to the choice of plant or plant part such that, for instance, a root with a red extract may be considered to be useful in blood disorders [36, 97].

The choice of plant part in EM may be directly related to the presence of bioactive ingredients in different plant parts, an assumption often made in ethnodirected bioprospecting studies [98]. Secondary metabolites may benefit plants through action as pollinator attractants, as simple feeding repellents or as toxicants to prevent herbivory [99]. Voeks [99] states that this phenomenon, referencing a study on the presence of alkaloids, is more pronounced in low-latitude countries and is more likely in herbs and shrubs. Further studies in the Caatinga of Brazil reported that, in such semi-arid areas, plants invest more heavily in secondary metabolites based on phenolic compounds (such as tannins) providing quantitative defences against herbivory [98]. In comparison, in humid forest regions, plants are more likely to produce qualitative defences in the form of highly bioactive compounds such as alkaloids. Another consideration is that phenotypic plasticity is known to occur within a species across different habitats in response to different environmental stressors [98]. Plant defences are determined by the availability of resources such as light, water and nutrients in an ecosystem. The lack of resources such as water and nutrients in semi-arid habitats may result in a "metabolic specialisation" in quantitative defences such as phenolics [98]. The authors add that woody species growing in semi-arid areas could have lower concentrations of bioactive ingredients in the leaf than in perennial plant parts due to the short growth-period of the leaf, thus favouring the perennial parts as medicinal ingredients.

How do these general hypotheses and findings in relation to the choice of plant parts in EM relate to *C. spinarum*? While *C. spinarum* has a wide ecological tolerance, it can be seen from the map of ethnobotanical usage in **Figure 4** that many of the areas in which *C. spinarum* is used are semi-arid. This lends credence to the use of the perennial parts of this shrub, as these are available throughout the year. Organoleptic qualities may be a factor with choice of *C. spinarum* root. It is somewhat bitter in taste which, as described above, may lead to its being considered medicinal [89, 100, 101]. The root has an oily, volatile sap with a pleasant smell which lends itself to use as a rub for chest and muscle conditions and as an inhalant. *C. spinarum* is a member of the Apocynaceae family, a family which is known to produce toxic and medicinal metabolites such as the Vinca alkaloids. The choice of plant part may be related to the avoidance of toxic components in other plant parts. A review of the ethnobotany of Apocynaceae species in Kenya (25 in all), found that the root is the most commonly used plant part for medicinal use (63%) [102]. In contrast, a review of some medicinally important Apocynaceae species found that there is no particular preponderance of root use [103]. Rather, EM use in different species was found to be generally distributed across plant parts. This correlates with the finding in India and Pakistan where the plant part usage of *C. spinarum* is much more evenly distributed across plant parts than in Eastern Africa. This difference could point to factors such as availability of plant material, cultural norms around medicinal preparations or ecological differences across its range leading to different secondary metabolite patterns.

3.3.2 C. spinarum *in human ethnomedicine: methods of preparation*

The predominant methods of preparation of *C. spinarum* globally are summarised in **Figure 9**. In the data as a whole, where a method is given, it may be simply written as a single word such as decoction, infusion, paste, juice or raw. There is relatively little detailed description of the preparation of *C. spinarum* in the studies analysed. In the reviewed studies, over one third do not to include a method of preparation. The preparation of medicinal products by decoction i.e., boiling of the plant part in water for a length of time, is by far the most common method reported followed by use of the untreated plant, burning for smoke, cold water mixture, infusion, powder, juice, decoction with soup and mixing with alcohol (4 citations).

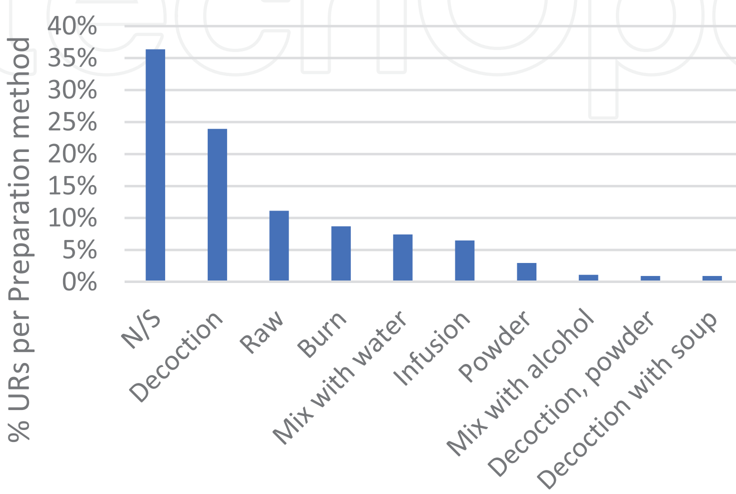

Figure 9.
Methods of preparation of human EM containing C. spinarum *(UR > 4) ("Decoction, powder" where unclear which method used per ailment).*

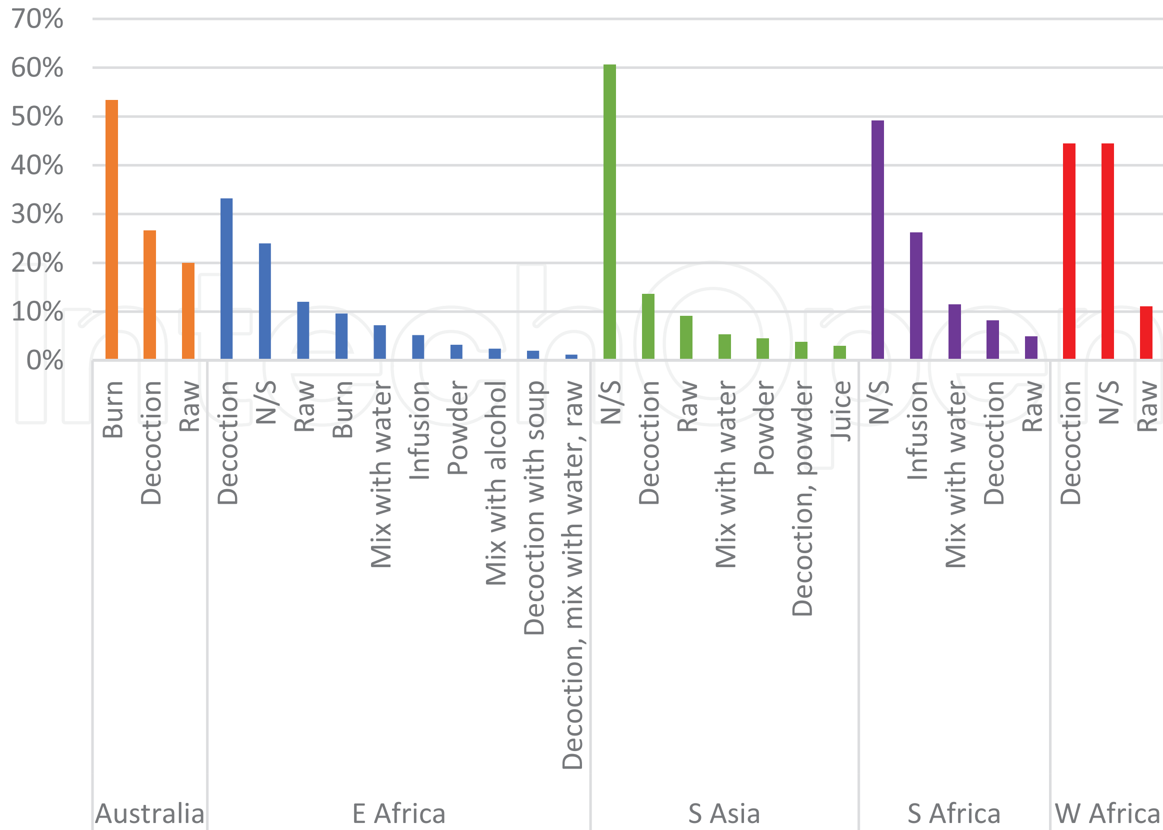

Figure 10.
Regional variation in method of preparation of C. spinarum *expressed as % URs per region (UR > 2). Methods with low occurrence are excluded.*

Methods of preparation vary across the geographical range represented in **Figure 10**. A significant proportion in each geographical area, except Australia, does not state the method of preparation. In South Asia, Eastern Africa and West Africa, decoction is the most common method used. In Southern Africa, infusion is the most popular method of preparation. In Australian studies the most common method is burning followed by decoction and untreated. Burning as a method of preparation globally is relatively high. When we examine the data in relation to burning, it is apparent that this is greatest in Australia and in Ethiopia with the emic context described above in Section 3.2. In Australia, burning is used in the main as a treatment to protect children by "smoking" while in Ethiopia, the primary illness category where burning is used is *Buda* (Evil Eye) (see Sections 3.2.1 and 3.2.2).

3.3.3 C. spinarum *in human ethnomedicine: methods of preparation x key plant parts*

It is useful to take a closer view of the methods of preparation that are used for each plant part. The chart in **Figure 11** presents an overview of the most common methods of preparation for each plant part. The chart shows that the fruit is most often used raw; the bark is most often prepared by infusion; the leaf, root and root-bark are each most commonly prepared by decoction and the stem by burning.

Where fruit is treated, the minimal treatment is illustrated as follows:

> *Fruits are crushed, dried, pounded into powder and sprayed on wound ([104] p. 6 Ethiopia).*

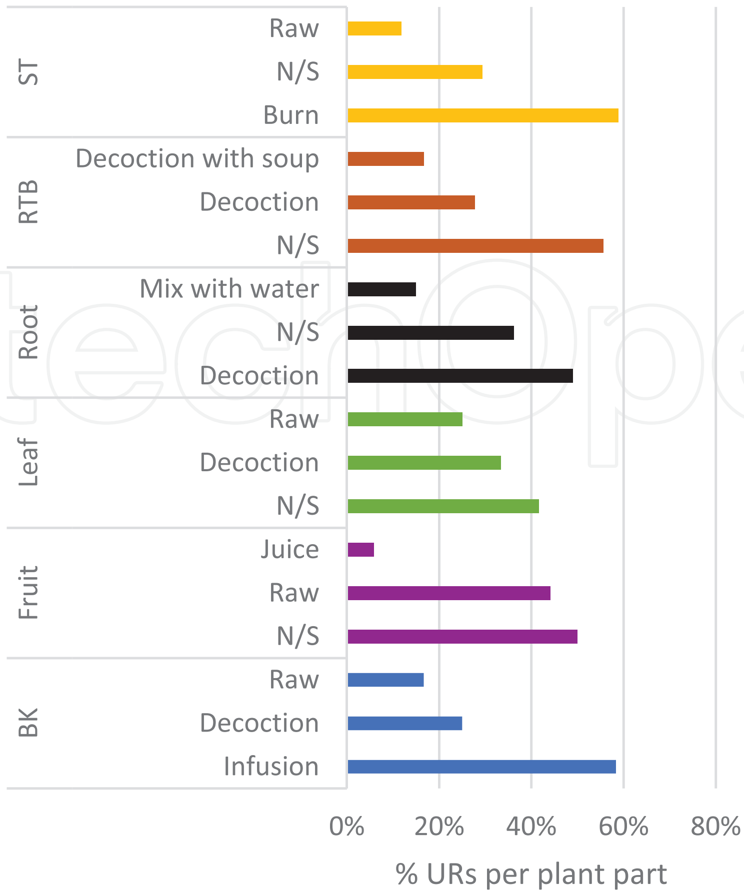

Figure 11.
Salient methods of preparation for each plant part (top 3, excludes combinations; 54% of total URs) (BK = Bark; ST = Stem; RTB = Rootbark).

and of leaf:

> *Leaves are crushed, squeezed and liquid taken (orally) with coffee (to treat febrile illness) ([104] p. 6 Ethiopia).*

Simple decoctions are prepared as follows:

> *Among the Mitakoodi, it [root] is scraped and soaked in water and then boiled. The resultant liquid is drunk as a tea to treat aches and pains and used as an eyewash ([64], p. 14, Australia).*

Leaves are boiled in water and liquor is used to treat jaundice [105] Pakistan. Some additional ingredients may be added as part of the treatment prescribed:

> *Rootbark is crushed and mixed with black pepper and given (for typhoid fever). [106] India.*
> *Fresh root of C. spinarum pounded mixed with cold water. One cup of tella [beer] is used as a drink for three days [to treat gonorrhoea] [49] Ethiopia*

The method of preparation of medicinal plants can have a significant influence on the extraction of active constituents. This can be seen in Chinese Herbal Medicine (CHM) whereby a variety of processing methods may be used to improve efficacy and/or to reduce toxic effects [107]. In a study on the preparation of CHM, a variety of extraction methods is described whereby special preparation instructions relate to different physical, chemical and pharmacological activities of active compounds [108]. The authors describe the preparation of the two-herb formula, Danggui Buxue Tang (DBT), illustrating the variability in yields of marker compounds with duration of boiling, the drug/solvent ratio, the number of extractions and co-extraction vs. individual extraction of each plant. In relation to *C. spinarum* preparation in the studies analysed, the level of detail seen in CHM research is not provided. However, the example of DBT illustrates the importance of accurate data recording in EM studies. The use of decoction or maceration for root preparation, as described with *C. spinarum*, can be seen to aid extraction of active compounds in harder plant materials such as roots, bark and stem [109]. It may also have a role in reducing the toxicity of phytochemicals or plant extracts given that *C. spinarum* belongs to the Apocynaceae family, known to produce toxic metabolites. In bioprospecting, detail on EM preparation can be a crucial guide for ethnopharmacologists in their investigations [108]. Detailed ethnographic descriptions on preparation give a clearer view of the elements of the healing process as a whole which has relevance across other research foci such as cultural record, health care provision and sustainable plant use [32].

3.3.4 C. spinarum *in human ethnomedicine: route of administration*

The most commonly used route of administration globally for *C. spinarum* is the oral route as seen in **Figure 12** with external application, fumigation and inhalation being the most commonly used routes otherwise. However, the route is not specified at all in 40% of URs. In **Table 2**, the primary methods of preparation and route of administration for each plant part are listed. The table illustrates that the root and rootbark are most commonly prepared by decoction and administered orally. The fruit usually undergoes no preparation and is administered orally. The stem is burned and used as a fumigant or inhalant. The leaf is most commonly burned as an inhalant and boiled as a decoction.

It can be seen from **Figure 13** that the predominance of the oral route is common to all geographical zones apart from Australia where it is more common to apply externally and to fumigate. The oral route of administration is common in EM as it is in BM [110, 111]. This may be explained by factors such as safety, convenience, cost and

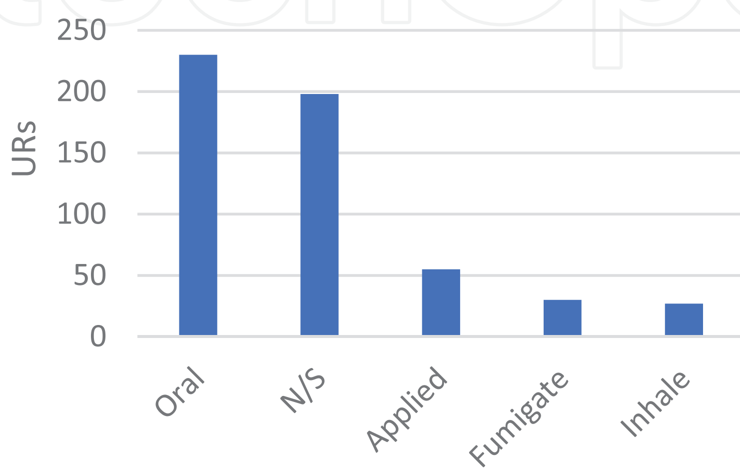

Figure 12.
Top 5 routes of administration of C. spinarum *globally.*

Plant part	Preparation	Route	URs
Root	Decoction	Oral	70
Root	Burn	Fumigate/inhale	21
Root	Mix with water	Oral	18
Root	Infusion	Oral	17
Fruit	Raw	Oral	15
Root	Decoction	Applied	9
Stem	Burn	Fumigate/inhale	9
Root	Mix with water	Applied	8
Root	Raw	Applied	8
Leaf	Burn	Inhale	8
Bark	Infusion	Oral	7
Leaf	Decoction	Oral	7
Root	Mix with alcohol	Oral	6
Root	Powder	Oral	6
Leaf	Raw	Oral	5
Root	Raw	Inhale	4
Leaf	Raw	Applied	3
Root	Powder	Applied	3
Root	Raw	Oral	3
Rootbark	Decoction	Oral	3
Rootbark	Decoction with soup	Oral	3
Leaf	Decoction	Applied	2
Leaf	Raw	Inhale	2

Table 2.
Most common route x preparation x plant part in C. spinarum *used in EM.*

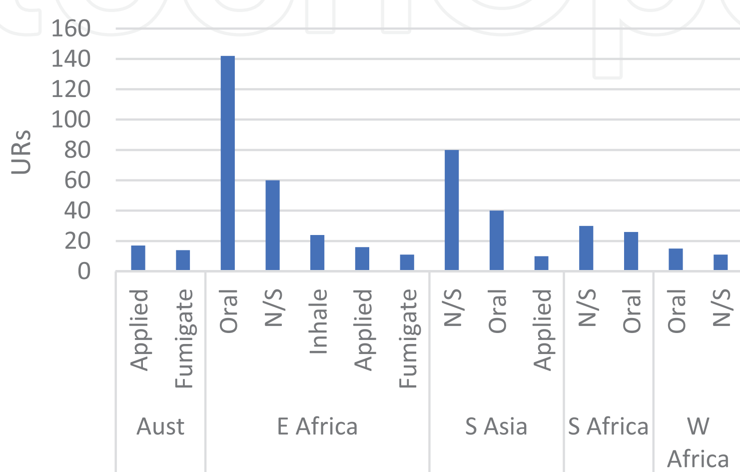

Figure 13.
Key routes of administration of C. spinarum *in different geographical regions (URs > 9).*

acceptability [111, 112]. Route of administration may also be related to the ailments treated. *C. spinarum* is commonly used to treat gastrointestinal ailments and oral administration would thus be logical. In addition, some theories of health and illness in the study areas necessitate the oral route of administration where emesis or purgation is required. In some cases, a mixture of routes is used for one treatment. In the following example oral and topical routes are combined for the treatment of syphilis:

> *Infusion (of root) drunk in malwa, sitz bath ([113] Uganda; malwa is local beer made from Eleusine coracana).*

In Tanzania, oral and topical use are combined for the treatment of unspecified chest conditions:

> *Root crushed and scraped and pulp is applied as a poultice for chest complaints. Root extract drunk at same time. Tanzania [114].*

In Uganda for the treatment of epilepsy, the root is used internally and externally as follows:

> *Powder drunk, bathed, smeared to body. Uganda [113].*

In a study in Uganda, where eight different species used to treat epilepsy, most are applied in some manner rather than taken orally [113]. This includes smearing, bathing, instilling into eye or nostril, fumigating, inhaling or licking. Use of non-oral routes could be a reflection of the practical difficulty of administering orally if a person is having a seizure, or may be a reflection of a ritual component of treatment of a complex illness, or both [79]. The choice of route could be related to the bioactive metabolites present. It is asserted by Le [111] that some phytochemicals such as alkaloids may be more active orally whereas terpenoids may be well absorbed through external or nasal administration.

3.3.5 Human ailments treated using C. spinarum

This section will first outline the form of classification used for this analysis on human ailments treated. The data is then analysed in relation to medicinal usage of *C. spinarum*. The WHO-ICPC system (International Classification of Primary Care) of illness classification was developed for the BM primary care setting as a patient-centred model of classification [115]. The ICPC template is promoted by some researchers to classify certain EM studies as they often lack precise BM diagnoses [32, 116]. This analysis of *C. spinarum* uses a modified ICPC classification system for cross-cultural comparison of EM usage. This is a bi-axial system of Body Systems and Ailment Categories. Modifications of the ICPC system are made to both axes to reflect salience in the *C. spinarum* data of particular body systems and ailments. A summary of the overall classification system is presented in **Table 3a and b**.

Some Body Systems listed in **Table 3a** are self-explanatory such as digestive, musculoskeletal etc. The General and Unspecified grouping is often used where the ailment relates to the whole body such as Malaria or other infectious diseases/symptoms. The *C. spinarum*-data-specific classifications of Spirit-Related and Ill-Defined are created to reflect their prevalence in the data, with the former including Evil Eye, bewitchment, sorcery and evil spirits. The classification of Ill-Defined is created to

(a)

ICPC body system (plus)	**ICPC body system (plus)**
Blood, blood forming & immune	Psychological
Cardiovascular	Respiratory
Digestive	Skin
Endocrine/metabolic & nutrition	Spirit-related
Eye	**GU system sub-classification:**
General and unspecified	Andrology
Ill-defined	Genital (gender not specified)
Musculoskeletal	Women's Health
Neurological	Urology (gender not specified)

(b)

ICPC ailment categories (selected)	**Added ailment categories**
Infection	Cough
Injury	Constipation
Neoplasm	Diarrhoea
Symptom/complaint	Evil Eye
Other/misc.	Fever
Added ailment categories	Jaundice
	Pain
Abdominal pain	Seizure
Asthma	Snakebite

Table 3.
Modified bi-axial ICPC classification for C. spinarum*: (a) body systems and (b) selected ailment categories (GU = Genito-urinary).*

reflect ambiguity or lack of descriptions of illness e.g., "Cold-sick" where it is not clear what this means from the text [117]. Genito-urinary (GU) ailments are frequently cited in EM systems as reflected in many global studies [118] and in African *C. spinarum* related studies [91, 119–124]. The ICPC Body System classifications of women's health, andrology and urology are modified in this analysis of *C. spinarum* such that the Genito-Urinary ailments are grouped under four Body System classifications: Women's Health, Genital (not gender specific), Urology (not gender specific) and Andrology. Women's Health includes the ICPC "Female Genital" and "Pregnancy, Childbearing, Family Planning and Female Reproductive System"; Genital includes ailments which are not gender specific and this mainly refers to Sexually Transmitted Infections (STIs); Urology refers mainly to urinary tract infections and Andrology refers mainly to virility. The ICPC modification is made so that the true prevalence of women's' health issues can be evaluated rather than splitting the data into smaller categories. The original ICPC Ailment Categories of Infection, Injury, Symptom/Complaint, Neoplasm and Other are retained while some symptoms, diagnoses and injuries are added as Ailment Categories to aid the analysis. These occur frequently in the data and would otherwise be subsumed under a broad generic Category such as

Symptom/Complaint (**Table 3b**). The added Ailment Categories are Abdominal Pain, Asthma, Cough, Diarrhoea, Evil Eye, Fever, Jaundice, Pain, Seizure and Snakebite. Examples of the bi-axial classification include: amoebiasis classified as Digestion (Body System) and Infection (Ailment Category); gonorrhoea classified as Genital and Infection; post-partum haemorrhage classified as Women's Health and Symptom/Complaint. This is a means of analytical cross-referencing of the data.

The key Ailment Categories treated with *C. spinarum* are Infection, Pain, Evil Eye, Abdominal Pain, Fever, Diarrhoea and Symptom/Complaint, with a more complete list of 15 Categories presented in **Table 4**. These Key Ailment Categories are cross-referenced with the key ailments within those Categories. It illustrates that while.

Ailment category and ailment	URs
Infection	**94**
Malaria	24
Genital Infection	22
Worms/other parasites	14
Infectious disease other	11
Gastrointestinal infection	10
Upper respiratory infection	7
Pain	**47**
Teeth/gum symptom/complaint	15
Headache	14
Joint symptom/complaint	12
Pain general/multiple sites	6
Evil eye	**27**
Abdominal pain	**26**
Fever	**22**
Diarrhoea	**21**
Symptom/complaint	**20**
Impotence/sexual function—male	7
Digestive symptom/complaint other	7
Lymph gland(s) enlarged/painful	6
Constipation	**17**
Ill-defined	**14**
Jaundice	**10**
Cough	**13**
Snakebite	**13**
Injuries	**11**
Asthma	**8**

Table 4.
Key ailment categories with key ailments treated using C. spinarum *(ailment category UR > 5; ailment UR > 4) (61% of URs).*

Infection is the most common Category treated, Evil Eye is the most common specific Ailment treated followed by Abdominal pain, Malaria, Fever and Genital Infection.

C. spinarum is used across multiple Body Systems with the Digestive system predominant (**Table 5**). The other key Systems treated are General/Unspecified, Spirit-Related and Genital. The breakdown of key ailments treated within the Body Systems is illustrated showing that in the Digestive System, the key ailments treated are Abdominal pain, Diarrhoea and Constipation. The main ailments of the General/Unspecified Body System are Malaria and Fever. Spirit-related illnesses are Evil Eye for the most part. STIs are the most common ailment treated in the Genital System, joint symptoms in the Musculoskeletal System, cough in the Respiratory System, headache in the Neurological System and snakebite is the most common ailment treated affecting the Skin.

Body system (plus) and ailment	URs
Digestive	**116**
Abdominal pain epigastric	26
Diarrhoea	24
Constipation	17
Teeth/gum symptom/complaint	15
Worms/other parasites	14
Gastrointestinal infection	10
Jaundice	10
General and unspecified	**58**
Malaria	24
Fever	22
Infectious disease other	12
Spirit-related	**32**
Evil Eye	32
Genital (gender not specified)	**22**
Genital Infection	22
Musculoskeletal	**14**
Joint symptom/complaint	14
Respiratory	**13**
Cough	13
Neurological	**14**
Headache	14
Skin	**24**
Snake bite	13
Laceration/cut	11

Table 5.
Main body system with key ailments treated with C. spinarum *(UR > 9; 54% of total URs).*

The four dominant geographical zones with EM data for the use of *C. spinarum* in humans are Eastern Africa and South Asia—having the most data—and Southern Africa and Australia. The top 4 ailments in each of these four regions are listed in **Table 6**, which illustrates a diversity in ailments treated across the regions. Spirit-related illness is the most reported ailment, mainly from Ethiopia. Eastern and Southern Africa both list Abdominal Pain and Genital Infection among the most commonly treated ailments. Southern Africa and South Asia both register Fever, Constipation and Diarrhoea among the top 4 ailments treated. Southern Africa and Australia alone list respiratory symptoms among the top individual ailments treated. The treatment of malaria is high in Eastern Africa relative to South Asia corresponding to current and historical relative incidence of malaria [125, 126]. The relatively low level of treatment of fever with *C. spinarum* in Eastern Africa could

Top 4 ailments in highest use global regions	URs
Australia	**17**
Upper respiratory infection	3
Teeth/gum symptom	3
Ill-defined	3
Breast/lactation symptom	2
Health maintenance/prevention	2
Eye symptom	2
Respiratory symptom	2
Eastern Africa	**85**
Spirit-related	30
Malaria	20
Genital infection	19
Abdominal pain epigastric	16
South Asia	**43**
Fever	16
Constipation	10
Jaundice	9
Diarrhoea	8
Southern Africa	**19**
Diarrhoea	5
Abdominal pain epigastric	4
Worms/other parasites	3
Cough	3
Genital infection	3
Fever	3
Constipation	3

Table 6.
Key ailments in each of the top 4 global regions (31% of URs).

reflect the choice of alternative treatments such as other plant species or pharmaceuticals as suggested in Section 3.2.3 or the overdiagnosis of fever as malaria, a recognised phenomenon [127]. Jaundice and hepatic complaints are mainly reported in South Asia. Given the prevalence in Sub-Saharan Africa of malaria and other contributors to liver ailments such as hepatitis, typhoid fever, dengue and leptospirosis this is unusual [128]. Possible explanations may be that jaundice may not be common in study areas other than South Asia, it may not be treated as a symptom *per se* in those regions or *C. spinarum* may not be a chosen treatment outside of South Asia.

Examining the Body Systems classifications illustrates more inter-regional similarity in the top 5 Systems treated (**Table 7**). The Digestive and Respiratory Systems are commonly treated in each region. The Digestive System is the most commonly treated System in all regions except Australia though to varying degrees. Likewise,

Region and body system	URs	% Total regional URs
Australia	**18**	**50% (total 36)**
Respiratory	6	17%
Skin	4	11%
General and unspecified	4	11%
Digestive	4	11%
Eastern Africa	**154**	**56% (total UR 274)**
Digestive	52	19%
General and unspecified	50	19%
Spirit related	30	12%
Neurological	22	8%
Respiratory	21	8%
South Asia	**97**	**72% (total UR 135)**
Digestive	48	36%
General and unspecified	24	17%
Skin	14	10%
Respiratory	11	8%
Cardiovascular	9	6%
Southern Africa	**41**	**60% (total UR 68)**
Digestive	19	28%
General and unspecified	9	13%
Skin	6	9%
Respiratory	6	9%
Neurological	4	6%
Genital	4	6%
Total	**347**	**513**

Table 7.
Top 5 ICPC body systems treated by CS across 4 geographical zones (68% of total URs).

the General and Unspecified Body System is commonly treated in each region, mainly accounted for by malaria in Eastern Africa and fever in South Asia.

The Skin has a high relative importance in all zones except Eastern Africa. The Musculoskeletal System is a key System treated with *C. spinarum* in Eastern Africa whereas the Cardiovascular System is commonly treated in South Asia. In Australia, the Body Systems treated are comparable to the other regions. Study aims and objectives contribute to variability in reports of ailments treated across different regions.

The Body Systems and Ailments treated by *C. spinarum* may be a true reflection of disease prevalence in the study areas. However, in the main there is no reporting of morbidity and mortality data in the ethnobotanical research analysed which makes it difficult to interpret the research results. Some studies have a particular disease focus such as malaria, respiratory disorders, HIV/AIDS, parasitic disease and others. However, the majority of EM information included is from general studies without focusing on a particular ailment. The most common specific research focus is malaria-related from Eastern Africa [82, 83, 129–136]. This could account for the relatively high ranking of malaria in this analysis. A study with the Luo community in Kenya found that abdominal complaints are most commonly treated with traditional medicine in the study area. The authors relate this to the availability of pharmaceuticals for the treatment of other common ailments [81]. An alternative explanation is presented in early research with the Kamba people in Kenya. The author found an organ hierarchy whereby the abdominal and reproductive symptoms were the most important [137]. This hierarchy may be relevant more broadly throughout the Eastern Africa region and could contribute to the prevalence of digestive disorders and treatment of genitourinary ailments with *C. spinarum*. The prevalence of treatment of genitourinary conditions is a common finding in EM studies and may be related as much to cultural treatment norms as to disease prevalence [118]. Its absence from Australian studies may relate to "secret business" not suitable for discussion with a researcher [57].

3.3.6 C. spinarum *in ethnoveterinary medicine (EVM)*

Plant species used for human EM are commonly used for animal healthcare as well, a subject explored in a study of traditional veterinary knowledge in the Algerian steppe [138]. The authors suggested that human use may stem from the observation of animal self-treatment, a behaviour known as zoopharmacognosy. In the case of *C. spinarum*, this may be an element in therapeutic choice. Animals are known to browse on the leaves of *C. spinarum* and it is used in EVM for the treatment of helminthoses and other digestive disorders in animals as in humans. In this analysis of *C. spinarum*, there are 39 documents citing its use in EVM. The geographical spread of documents includes Sub-Saharan Africa—mainly Ethiopia and Kenya and South Asia—mainly India and Pakistan.

The plant part used follows that for human use and is predominantly the root, followed by the bark, leaf, fruit and leaf in **Figure 14a**. Comparing the plant parts used in South Asia to Eastern Africa, **Figure 14b** indicates that while the root predominates in both regions, there is greater variation in Eastern Africa. Here, the root accounts for almost half of URs but the bark is also used a good deal. This contrasts with human use where in Eastern Africa, the root/rootbark far outstrips other plant parts used. This may imply that, in Eastern Africa, the root is considered to be less toxic to humans than other plant parts given the likelihood that greater care is taken with human than animal treatments. In EVM in South Asia, the root accounts for two-thirds of URs and the leaf is used in a minority of cases. This is at variance with the plant parts used for human

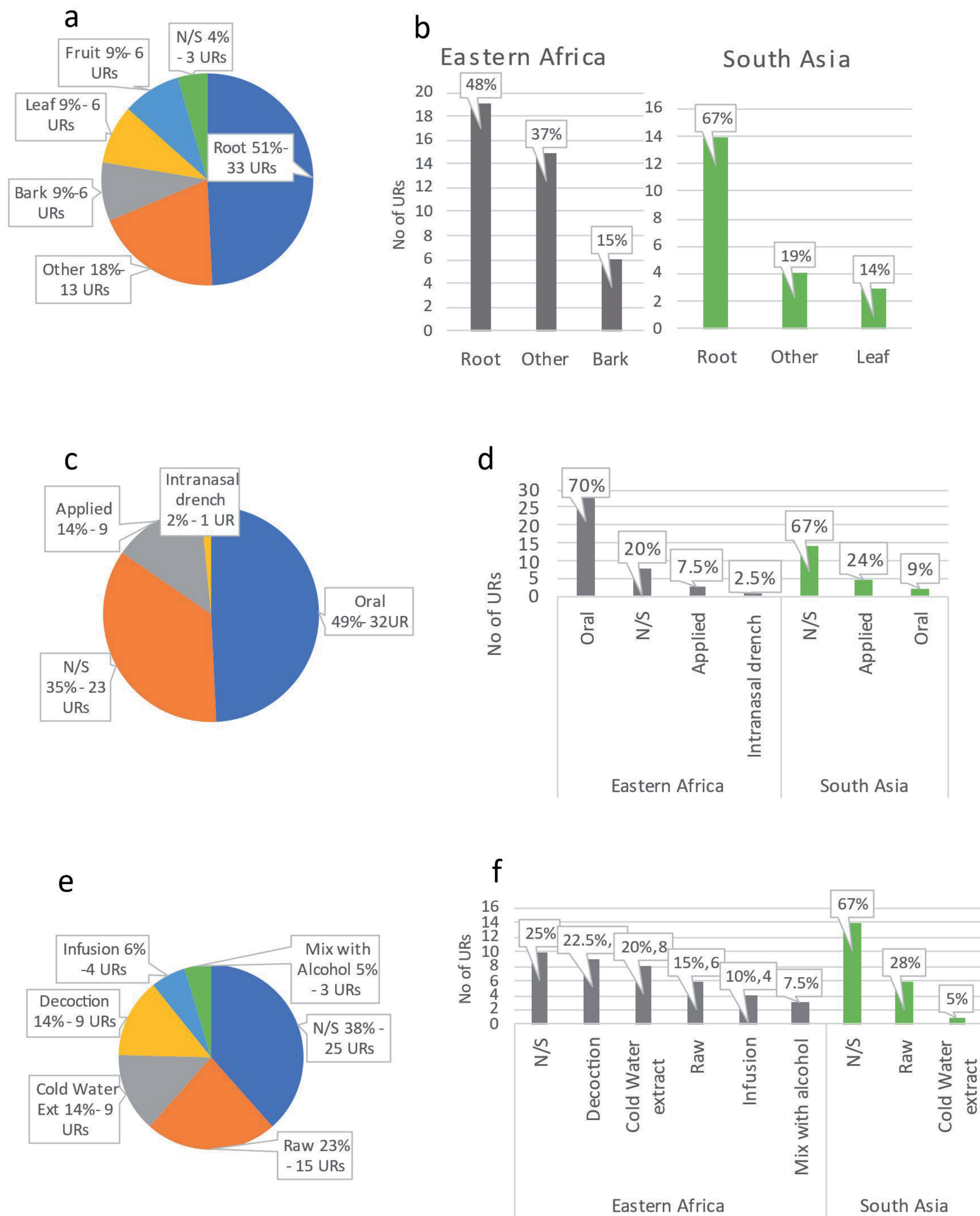

Figure 14.
EVM of CS: (a) key plant parts used globally; (b) key parts used in Eastern Africa and South Asia; (c) key routes of administration; (d) key routes in Eastern Africa and South Asia; (e) key methods of preparation; (f) key methods in Eastern Africa and South Asia.

treatment in South Asia where there is a more even spread between root, leaf and fruit. This could be explained by a number of factors such as the narrower range of diseases treated in EVM, cultural norms, perceived toxicity or acceptability. Similar to human EM of *C. spinarum*, globally the route of administration of EVM is predominantly oral (**Figure 14c**). However, the external route is more common than oral in South Asia whereas in Eastern Africa, the oral route predominates (**Figure 14d**). This may be due to the predominance of skin diseases in animal ailments treated in South Asian studies (see below). In Ethiopia, Tanzania and India it is applied in a similar way to treat worm-infested wounds in cattle whereby the root is ground and applied directly to the wounds [139–141]. The general methods of preparation are much more varied for EVM use. The method is divided more evenly across decoction, cold water extract and raw preparation (**Figure 14e**) though in South Asia the plant is more likely to be used in a raw state relative to the variety of preparations seen in Eastern Africa (**Figure 14f**).

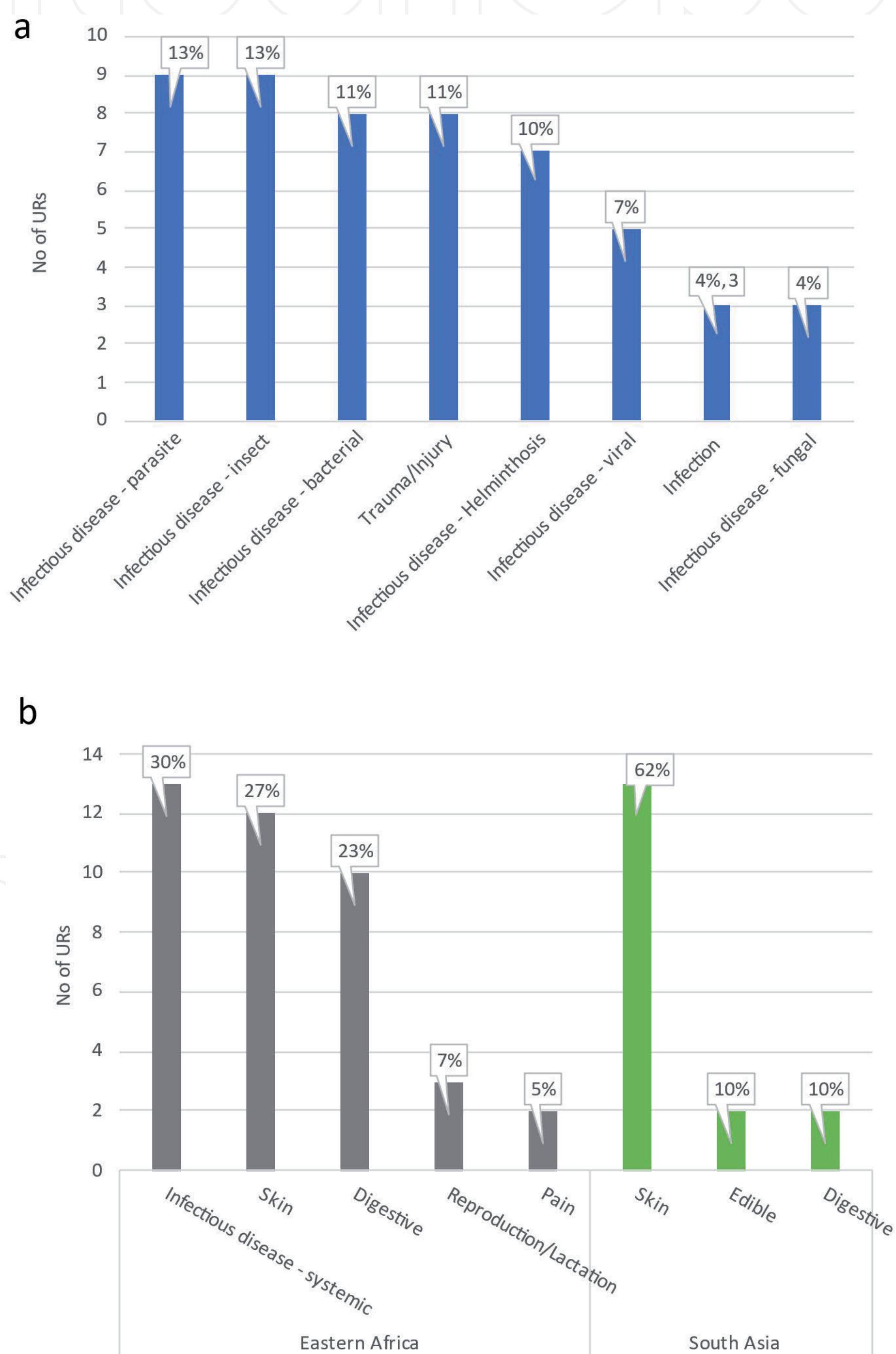

Figure 15.
EVM of CS: (a) key ailments treated globally; (b) key body systems treated in Eastern Africa and South Asia.

In examining the presenting ailments, they can be seen to be primarily related to infection (see **Figure 15a**) with some infections affecting the skin such as ringworm (fungal), lice, ticks, scabies and maggot infested wounds (ectoparasites—all insect related), digestive system (endoparasites—helminthosis), respiratory system in pleuropneumonia (bacterial) or more systemic infections such as theileriosis (endoparasites—protozoa), heartwater, anaplasmosis and salmonellosis (all bacterial), foot and mouth disease, chicken pox, rinderpest and lumpy skin disease (all viral). In a few of the studies, the research teams included members with BM veterinary knowledge and this explains the extent of BM diagnoses provided. Several studies from Eastern Africa have BM veterinary expertise on the research teams which set them apart from the human EM studies where it is rare to have BM diagnoses available [49, 142–149].

The majority of EVM ailments treated using *C. spinarum* are infections affecting the Skin, Digestive system and whole-body System. There is a marked difference in the classifications treated in Eastern Africa relative to South Asia. In the former, Skin infections, Digestive system and Systemic Infectious diseases are the most commonly treated Body System whereas in South Asia, Skin far outweighs any other System treated (**Figure 15b**). This is quite different to the BM systems treated with *C. spinarum* in human EM in South Asia (**Table 7**) where the digestive system is the predominant system treated. Other EVM research in South Asia shows that many body systems are commonly treated [150], which may indicate that *C. spinarum* is particularly effective in treating skin infections.

3.4 *C. spinarum:* structured ethnobotanical methods and cultural importance

The relationship between people and plants can be examined through qualitative and quantitative means. The results of qualitative research are described in Section 3.2. Structured quantitative methods provide an additional means of examining plant use in study communities [32].

The use of statistical methods in ethnopharmacological research dates back to the 1970s [151, 152]. A number of quantitative measures are employed that have been developed and modified over the years [153–155]. The most basic unit to measure is the Use Report (UR). Other measures used are Informant Consensus Factor (ICF), Fidelity level (FL) Relative Importance (RI) and Use Value (UV). The value ranges for these measures vary by study and method of calculation, making it difficult to compare studies [32].

3.4.1 Relative importance of C. spinarum*: primary use reports (URs)*

Given the number of primary studies that are reviewed here, there is relatively little statistical detail on the ethnobotanical use of *C. spinarum*. While there is commonly accurate detail on the number of participants in the studies, few studies provide accurate detail on URs for individual use categories as recommended in best practice documents [31, 32]. Of the Primary studies reviewed, three quarters stated the overall number of participants. Where the number of participants is stated, this could be given as a single number or as a combination of categories of participant: e.g., Focus Group plus Key Informant. One quarter of reviewed studies report the number of URs (number of participants reporting any use of a species) with one third of these being aggregated URs rather than UR per single use category or ailment. One fifth of studies present the primary data as the number of URs per use category. Thus, in 80% of primary studies, including recent ones, there is no indication of relative specific usage of any species. In overviewing the importance of *C. spinarum* where possible from UR data, it is of low to medium importance in most studies when compared to the use of other more frequently used species. This finding corresponds with a common finding in EM research whereby there are only a few species that are known by a large number of participants and many species that are known by just one or two participants [156]. The studies that indicate high importance of *C. spinarum* using the measure of URs include studies from Kenya, Sudan, Ethiopia, Angola, South Africa and Pakistan [43, 49, 157–163]. There are very few Asian studies presenting information on URs and most Australian studies involve participant-authors rather than large-scale surveys. Thus, the better assessments of value measured by UR are from African studies.

3.4.2 Relative importance of C. spinarum*: statistical calculations*

Primary research that includes statistical calculations on the relative importance of *C. spinarum* comes from Africa and Asia. Overall, where such research includes *C. spinarum* in its evaluations of importance, it is found to have a low-moderate relative importance. In parts of Uganda and Ethiopia, *C. spinarum* has a high relative importance as an edible species [164, 165]. In Zimbabwe, it has low relative importance for the treatment of schistosomiasis [166]. It is used in the treatment of Non-Communicable Diseases in a study conducted in Rodrigues Island where it has a low-moderate fidelity level for the treatment of diabetes mellitus [167]. In a study of species versatility in Saudi Arabia, *C. spinarum* has a low relative importance in the study area [120]. *C. spinarum* is used to treat malaria in a study in Pakistan but has low importance relative to the well-known *Azadirachta indica* A. Juss. (Neem tree) [168]. A study from southern India found that *C. spinarum* has a low UV and is reported for the treatment of cough alone [169].

The majority of studies that include *C. spinarum* have no measure of the cultural importance, contrary to current best practice recommendations [31, 32]. Where cultural importance is measured in Ethiopian studies, it is found in the main to have a relatively high importance over a broad range of ethnobotanical uses. In other areas, where reported, *C. spinarum* is of moderate or low cultural importance. Some early documents and the Australian studies included in this analysis contain no statistical information. The ethnobotanical information is often detailed but may involve very few participants. This would not be considered adequate according to current best practice guidelines but these studies are a valuable addition to ethnobotanical literature [80, 86, 89, 117, 170].

3.4.3 Relative importance of C. spinarum *in Ethiopia: participatory ranking*

Anthropological participatory Ranking exercises have been developed as central tools in ethnobotanical research [37, 58]. They are a feature of several Ethiopian studies examined for usage of *C. spinarum* and are a semi-quantitative method of measuring the relative frequency of use of species. Ranking exercises create a more in-depth examination of species use in the study area and follow from more general earlier explorations with participants, which can select out key species to include in comparison exercises. Inclusion in a ranking exercise for specific or general utility of itself indicates a high relative importance among participants. Participatory exercises involve the selection of a small number of key participants, 5–10 people, and a selected number of key plant species, usually 5–7 species, identified during the research as having importance for broad or narrow purposes. The exercises examine a range of ethnobotanical uses through one of a number of methods: direct matrix ranking (DMR), pairwise ranking, preference ranking or simply by number of uses.

A total of 25 Ethiopian ethnobotanical participatory ranking studies were identified including *C. spinarum* among the ethnobotanically known species of the area and 16 of these included *C. spinarum* in ranking exercises. There was a total of 170 species included in these exercises. It is evident that *C. spinarum* has a high relative importance in the study areas given its selection from a large pool of species.

3.4.4 Participatory general ethnobotanical rankings of C. spinarum *in Ethiopia*

Several Ethiopian studies examined the non-medical ethnobotanical importance of species using participatory ranking exercises. The range of ethnobotanical categories of importance in ranking exercises included medicine, firewood, furniture, construction, fencing, charcoal, forage, fodder and food.

There are 16 studies listed in **Table 8** that included *C. spinarum* in their ethnobotanical species list, with 7 exercises from these studies listing *C. spinarum* as having significant general ethnobotanical importance. The study areas exhibiting above the median ethnobotanical relative importance for *C. spinarum* are distributed throughout the country. This analysis indicates a high relative importance for *C. spinarum*, which is also evident in the statistical ranking analyses such as UV and RFC in the previous section.

Rank CS (total #) (1 is best)	Study authors
4 (8)	Amenu [49]
2 (6)	Amsalu, Bezie [172]
N/R	Araya, Abera [104]
N/R	Ashagre, Asfaw [165]
5 (6)	Jima and Megersa [173]
5 (11)	Kebebew and Leta [174]
1 (7)	Kebebew [175]
N/R	Kefalew, Asfaw [176]
N/R (uses)	Kidane [177]
11(46)	Kidane [177]
N/R	Lulekal, Kelbessa [43]
N/R	Lulekal, Asfaw [178]
N/R	Megersa, Asfaw [179]
N/R	Mekonen, Giday [180]
1 (6)	Meragiaw, Asfaw [181]
N/R	Tefera and Kim [182]
N/R	Teklay, Abera [183]

Table 8.
Ethiopian rankings of C. spinarum *use through participatory ranking for general ethnobotanical use (N/R = Not ranked) (all DMR except [177] species with >2 uses).*

Ranking exercise	Ranking method	CS rank (total #) 1 best	Study
General EM	Preference	N/R	[185]
Gonorrhoea	Pairwise	1 (6)	
Malaria	Preference	N/R	
Gonorrhoea	Preference	1 (5)	[49]
Evil Eye	Pairwise	2 (6)	
General EM	DMR	2 (6)	
Snakebite	Preference	N/R	[104]
Malaria	Preference	N/R	[171]
Cough	Pairwise	N/R	[186]
Stomach ache	Pairwise	N/R	[187]
Wound	Preference	N/R	
Stop bleeding	Preference	N/R	[188]
Stomach ache	Preference	4 (5)	[173]
General EM	DMR	1 (5)	
General EM	DMR	3 (11)	[174]
Diarrhoea	Preference	N/R	[175]
General EM	DMR	2 (7)	
Gonorrhoea	Pairwise	1 (5)	
Blackleg	Preference	N/R	[176]
Ascariasis	Preference	N/R	[189]
Gonorrhoea	Preference	N/R	[43]
General EM	URs	2 (10)	
Atopic eczema	Preference	N/R	[178]
Diarrhoea in livestock	Preference	N/R	[190]
Blackleg in cattle	Pairwise	N/R	[179]
General EM	DMR	N/R	
General EM	DMR	N/R	[180]
Febrile illness	Preference	N/R	[181]
Stomach ache	Preference	N/R	
General EM	DMR	1 (6)	
Mich	Preference	N/R	[191]
Cancer in humans and livestock	Preference	N/R	[182]
Stomach ache	Preference	N/R	
Wounds in livestock	Preference	N/R	
Abdominal pain	Preference	N/R	[183]
General EM	DMR	N/R	
General EM	Preference	N/R	[192]

Table 9.
Ethiopian EM participatory ranking exercises in study locations listing CS. ***Mich*** *is described as a febrile illness with headache and sore lips [191].*

3.4.5 Ethnomedical participatory rankings of C. spinarum *in Ethiopia*

Several ranking studies specifically examine EM importance both for broad utility and for particular medical purposes. An overview of these rankings is shown in **Table 9** and consists of 22 studies with a total of 37 ranking exercises. *C. spinarum* (CS) appears in 11 exercises using a variety of ranking methods: Preference Ranking, Pair-wise ranking and Direct Matrix Ranking (DMR). In most exercises that include *C. spinarum*, it is ranked above the median value. The study areas where it exhibits importance in the general EM category are distributed throughout the central regions of Ethiopia, north to south along the Rift Valley. The most common medical ranking exercises other than the general ranking are for gastrointestinal complaints and gonorrhoea. *C. spinarum* is ranked as the best for treating gonorrhoea in three studies, it is ranked in one gastrointestinal ranking exercise and in rankings for malaria and febrile illness, *C. spinarum* is not ranked [49, 171, 173, 175, 181, 185]. From these participatory exercises, *C. spinarum* appears to be highly ranked for the treatment of gonorrhoea and not for other specific ailments. It ranks high in several areas for general ethnomedical use.

3.4.6 C. spinarum*: a comparison of cultural value based on statistical measures vs. participatory ranking exercises in Ethiopia*

Interpretation of cultural importance by participatory ranking exercises and UR yields, sometimes, conflicting information. Ethnomedical participatory ranking exercises found that *C. spinarum* did not rank high in the treatment of gastrointestinal complaints. This is in contrast to the finding in **Table 7** whereby, in the ICPC classification, the Digestive system is the most treated Body System with *C. spinarum* in Eastern Africa. In Ethiopia specifically, it is second to Spirit-related illness in being the most commonly treated Body System. This indicates a potential discrepancy between the two forms of analysis. However, in ranking for treatment of gonorrhoea, *C. spinarum* is ranked best in three out of four exercises. This corresponds with that found in **Tables 4** and **6** which indicate its importance in treating genital infection globally and in Eastern Africa. That *C. spinarum* is not ranked in exercises for the treatment of malaria and for febrile illness is at odds with the findings in **Tables 4** and **6**, where malaria and fever are among the ailments most commonly treated with *C. spinarum* globally and in Eastern Africa. There are other sources of variability between statistical and participatory research. In participatory rankings, as in all research, there is a randomness to the choice of participant and all participants have necessarily a different knowledge base. There is also variability in the choice of species to include in the ranking exercises and it is not clarified how particular species are selected for analysis. The choice of a particular ranking subject is a function of the study design and researcher priorities and may not reflect the key ailments treated with traditional medicine in the study areas. This could lead to another layer of bias in the results.

The potential variability of outcomes, depending on research methods and study design should be borne in mind in any interpretation of the results or implementation of the research outcomes.

3.5 Phases in *C. spinarum* research

The framework of Hunn's phases of ethnobiology is applied to the ethnobiological documents analysed relating to *C. spinarum* research following a method employed in a study of Southeast Asian ethnobiology [11]. There were 219 primary ethnobiological research documents analysed. Of these, 85% are EM only, while the remainder relate to mainly to diet and general ethnobotany. Within these studies, in whatever phase they are classified, there is a general lack of detail on the practicalities of medicinal plant use. There is almost total silence on plant harvesting. In 9% of cases, there is no information on the plant part used. In over one third of cases, there is no method of preparation given and where a method is given, rarely is close detail provided. The route of administration is not given in 40% of cases. The lack of such basic detail on plant use devalues the research overall, whatever the research agenda, whether for cultural record, bioprospecting or other purposes. Added to these immediate aspects of medicinal plant use are the omissions on the fabric of local life. Culture is central to healing and plant use. However, cultural elements of EM are omitted in the majority of studies such as the meanings associated with plants, disease concepts, therapeutic indications, or what "healing" actually means in the local context as distinct from BM understandings of being healed [193]. Other aspects that are rarely addressed include, for instance, local healthcare provision, morbidity and mortality, environment and economy, which, among other things, contribute to healthcare choices and to the relationship of people with plants.

The majority of the studies that include *C. spinarum* fall into the Phase I classification, representing two thirds of the total and are, in the main, bioprospecting studies. They are largely descriptive in nature, containing lists of species and their uses, with sparse detail on how they are used, as described above. There is an implication built into this rudimentary data collection, that the "how" and "why" of ethnomedicine has little to do with science. In the bioscience laboratory, studies based on EM catalogues of species generally use organic solvents to extract single or multiple metabolites and test these extracts or compounds in *in-vitro* systems, none of which bears any resemblance to the use of traditional medicines in the field. In an unpublished review by these authors of 125 documents examined for phytochemistry and pharmacology of *C. spinarum*, nine (7%) test the pharmacology of aqueous plant extracts and six (5%) identify phytochemicals from aqueous or distilled extracts (data available on request[1]). This indicates the disjuncture between traditional medical practice and pre-clinical ethnopharmacological studies. There are some studies in the current analysis that have characteristics of each of Phases II to V even where they still contain catalogues of species and their uses. Those with some descriptions of local understandings of illness and healing are ascribed Phase II character. Descriptions such as of disease and causation of TB in a Ugandan community, liver dysfunction in a community in Togo or the meanings associated with plant names in a South African community add to the reader's understanding of EM in those communities [46, 47, 53]. Studies with some Phase II character represent a quarter of the total, with five studies having more detail. For instance, research with Luo mothers, already discussed in Section 3.2.3, situates the treatments of digestive disorders, worms and the use of pharmaceuticals in the study community. Two studies with the Marakwet of Kenya, from 1978 and 2014, give good descriptions of disease perceptions in the study communities. Studies with the Maasai and Samburu in Kenya, give good background descriptions of health in the communities and relationship to environment which allows a deeper understanding of plant usage. Each of these more detailed studies offer an emic perspective which better situates how people use plants for life [41,

[1] This data is part of a PhD dissertation by the first author which includes the phytochemistry and pharmacology of *Carissa spinarum* L.

81, 86, 87, 194]. Those using participatory ranking as described in Section 3.4.5 have Phase III character and represent 11% of the total. They give a sense of how plants form an integral part of life. The participatory studies allow researchers to understand how people think about plants in their immediate environment and how particular species may have cultural value across multiple practical and symbolic domains. Studies conducted in collaboration and co-authorship with community members have elements of Phase IV character such as several Australian publications as described in Section 3.2.1 and two Africa-based studies which mentioned benefit-sharing arrangements [41, 50, 54, 56, 59, 62, 195]. These represent 0.5% of the total. The Convention on Biodiversity (CBD) and related issues such as conservation, sustainable use of resources, prior informed consent and equitable benefit sharing relate to later phases in ethnobiology from the 1970s and Phase III onwards. They are rarely discussed in any of the documents. Consent in any form is reported in 40% of studies though there is no description of the process in any instance. Ethics is referred to where ethical approval of the research has been granted in 16% of studies though the process is not discussed nor the ethical issues examined. The International Society of Ethnobiology (ISE) code of ethics is referred to in six studies (3%) which may imply a greater attention to ethical standards in the research process. Research permits are cited in 15% of studies though the process is not elaborated upon. Intellectual property rights (IPRs) or benefit sharing arrangements are mentioned in eight studies (4%) [59, 62, 132, 157, 195–198]. Half of all studies have no mention of consent, ethics, permits, IPR or other research ethics related issues.

4. Discussion on ethnobiology of *C. spinarum*

C. spinarum (Apocynaceae) is a species that is varied and widely distributed across the globe covering many diverse habitats. There is a volume of ethnobiological knowledge recorded in many of the regions where it is found, particularly in Eastern Africa and South Asia. Across most of its range it is found to be part of the local culture, being valued in ritual, health and healing, diet and a range of other applications.

The predominant role of *C. spinarum*, in the studies examined in this analysis, is in healing and diet, reflecting the research focus in the analysed studies. All parts of the plant are eaten though eating of ripe berries is most commonly reported. The most common EM use of *C. spinarum* in humans across all geographical areas is in the treatment of digestive system, while other body systems such as respiratory and skin are represented to a lesser extent. An analysis of geographic variation reveals a different picture. In Eastern Africa, malaria, STIs and spirit-related illness such as Evil Eye, are the most commonly treated while in South Asia, fever and digestive complaints predominate. Though the particulars of treatment vary across geographical regions, the dominant documented pattern is that the root is prepared by decoction and administered orally. The exception to this is in Australia where use of *C. spinarum* matches trends in local EM practices more broadly and is mainly administered by fumigation or application.

Ethnobiology is a wide and varied discipline with research agendas covering the natural and social sciences including such diverse subjects as indigenous rights, migration, biocultural diversity, health, research ethics and reflexivity [12]. When conducting research on medicinal species, the research focus could involve, for instance, cultural record, health care provision, sustainable plant use, environmental protection or bioprospecting. The ongoing preponderance of Phase I research, lacking cultural contextualisation and theoretical focus, is continually critiqued within ethnobiology and ethnopharmacology [32, 36, 199]. This holds true whatever the research focus.

The phenomenon is reflected here in the studies containing *C. spinarum* with the majority falling into the Phase I category. Two-thirds of studies analysed are Phase I, lacking even minimal information on the context of plant use or examination of therapeutic indications. They also lack detail on the many aspects of plant remedy preparation and administration. As Phase I research usually represents a bioprospecting agenda, the findings show significant lacunae in the information available on *C. spinarum* for guiding further scientific study. One quarter of studies have Phase II character with some emic detail, providing cultural context to EM practices. The studies ascribed to Phase III involves participatory research and accounts for 11% of studies while 0.5% of studies have Phase IV or V character.

Phase I may be dominant in this analysis due to the nature of this analysis itself. Searching for an individual species may be biased towards cataloguing studies. *C. spinarum* is a medicinal and dietary species and this fact may self-select for Phase I studies with decontextualised catalogues of species and their therapeutic and dietary indications favoured in bioprospecting studies. Another reason for the lack of later phases in this analysis of the ethnobiology of *C. spinarum* could be the nature of ethnobiological research itself. In ethnobiology in general, there has been a shift recognised in Hunn's Phases towards an ecology and action-focused research agenda and away from its roots in anthropology [200]. These research agendas do not necessarily require the naming of particular species, which may explain the relative absence of later ethnobiological phases in this species analysis.

The absence of ethnographic content in this analysis places this body of *C. spinarum* data largely in the Phase I category. The emic perspective, limited in this research, is vital to an improved understanding of plant use and is an essential component of all ethnobiological research, whatever the phase. Frazão-Moreira illustrates the ongoing centrality of ethnographic research in ethnobiology [35]. However, in ethnopharmacological research, the socio-cultural focus has been in decline over the past three decades [201]. The relative lack of ethnographic content in ethno-directed bioprospecting has been criticised by numerous authors. Etkin's early critique of ethnopharmacology as generating lists of species that extract them from their cultural contexts has been reiterated more recently [14, 36]. In the bioprospecting process, the subsequent extraction of active metabolites can then diminish indigenous knowledge, even where it is validated by laboratory science [14]. In either case, indigenous use of medicinal species is reduced to its chemical components in what has been called its "molecularisation", disregarding the wider cultural contexts of use and perceptions of efficacy [15, 16]. With regard to medicinal uses, there has been criticism of the poor description and development of therapeutic indications leading to biased data and poor outcomes [16]. Weiskopf illustrated that there is an assumption that traditional ecological knowledge can be "plugged" in to "academic ecological knowledge" unchanged and that there is an assumed category and explanatory overlap between both as is the case, he argues, in the validation process in medical bioprospecting [202]. Taking the current analysis of *C. spinarum*, a local diagnosis of malaria is assumed in some studies to equate to the BM category malaria or "typhoid" to typhoid [203]. The use of an emetic or a laxative might be assumed to be used for the same purposes as an emetic or laxative in BM which may not be the case [89]. Category overlap thus cannot be assumed but must be underpinned by qualitative research exploring cognition among local participants. A hierarchy of convergence was prevalent in early ethnobiology research on folk classification between local and scientific categories whereby ethnotaxa that fit into the scientific categories were given priority and ethnotaxa that did not converge were marginalised

[200]. Such ethnotaxa could be names of plants, birds or of therapeutic indications in EM. One can interpret the analysis of *Buda* (Evil Eye) in Ethiopian studies in Section 3.2.2 in light of hierarchies of convergence. While it is included as a therapeutic indication, there is no examination of this ethnotaxon in any of the Ethiopian studies analysed here. The local importance of this category is clear, but why is it not explored? Is it thought to be self-explanatory as other therapeutic indications are? Is it being marginalised as described above, a desire to ignore that which did not fit? Is there a lack of anthropological expertise in a natural science focused research team? Is it beyond the scope of the research agenda? Is it due to secrecy among research participants as described in Australian research? Whatever the reason, the lack of exploration of *Buda* in these EM studies is a missed opportunity to document local understandings of health and healing and perhaps illuminate the wider use of *C. spinarum* and other species.

The detailed ethnography needed for a substantial emic perspective in ethnopharmacological research requires collaboration between the natural and social sciences. There are documented barriers to such collaboration which can militate against conducting ethnobiological research beyond Phase I. These include inadequate funding and time and a range of academic issues.

All ethnobiology research touches on material and symbolic aspects of interactions between humans and their environments and as such requires a multidisciplinary approach to research, but this is not common in practice [12, 14, 184, 204]. In the current analysis, some explicitly ethnobotanical studies have multidisciplinary teams however with some exceptions [81, 89], the team members belong to a natural science discipline [134, 205, 206]. D'Ambrosio [12] attributed this to the normal association of ethnobiology research with either anthropology or biology departments with few dedicated ethnobiology schools. He argued that the ethnobiology researcher, rather, takes the disciplinary approach of their primary discipline with either a natural science or a social science/humanities perspective, carrying through their disciplinary origins in their research questions. The natural sciences perspective is largely objective, quantitative and etic in its approach, while a social scientific outlook is more often subjective, qualitative and emic. The natural sciences perspective predominating in the Phase I character of *C. spinarum* studies analysed [12]. Significant roadblocks exist to cross-disciplinary collaboration including in ethnobiology. These barriers revolve around the interrelated aspects of status, funding, time and complexity. An analysis of research collaborations between social and natural sciences found that collaborative research has a lower academic status than natural sciences research [207]. Funding across disciplines is difficult as funding streams generally follow single disciplines [12, 208]. Added to this, it is argued that social science research is chronically underfunded [209]. Within ethnopharmacology, there is a demonstrable lack of funding for ethnographically directed research compared with that for laboratory-based screening for bioactive metabolites [210]. Where social science and humanities research is conducted in collaboration with natural sciences, the latter tends to be the dominant partner in such research. The social science element may be tagged on with no true commitment of time and funding necessary for the incorporation of the social science discipline into the project [209, 211]. Similarly, the time required for communication across disciplines, for creating relationships and mutual understandings among research team members and for integrating research findings is rarely considered in project timelines [209]. Frequently the social science elements of collaborative research are more difficult to translate into action rather than the faster, more reductive natural sciences research [209]. These limits on time and funding can hamper ethno-directed studies and result in poor outcomes in ethnopharmacological research [16].

Collaboration with study communities is a central feature of progressive ethnobiological research, with community voices heard rather than interpreted by academics [182]. However, in this analysis, there is near-total anonymity of the research participants themselves. This is the norm in earlier phases of ethnobiological research as described in recent works [15, 212]. The collaborative approach suffers from some of the same barriers as cross-disciplinary collaborations including skills, funding, time constraints and academic norms. The marginalisation of social sciences in interdisciplinary collaborative research means that the social science skills needed for in-depth community collaboration may not be available. Likewise, the time and associated funding requirements may be lacking making it more difficult to establish the necessary relationships of trust. Academically, research design varies whereby the social sciences often have a flexible approach to research design [213]. Where ethnobiology studies originate in natural sciences departments, academic structures may not permit this fluidity nor the processual approach needed in collaborative work. Collaboration and co-authorship are integral to Phase IV and V research and is considered to be essential to the future of ethnobiology [199]. If ethno-directed bioprospecting is to be conducted within an ethical and collaborative framework, then these barriers need to be addressed. All of these elements - disciplinary silos, funding, status and time- militate against the collaboration with communities and across disciplines necessary for high quality ethnobiological research that can capture the interpenetrative nature of the relationships of humans and their environments in an ethical manner.

Research design and methods used in ethnobiology may produce results which do not properly represent the relationships of people and plants. Shortcomings in quantitative studies, in choice of participants and questionnaire design, in use of common ethnobotanical methods and the interview itself, may each contribute to an ethnobiology that is not representative of the local voice. Quantitative analysis in ethnobiology has become a common component of ethnobiological research especially since the 1990's [214]. It can be a component of a progressive ethnobiology when used judiciously. However, its inclusion has also been critiqued by several authors. The indiscriminate use of statistical methods without a basis in theory or hypothesis is challenged, proposing a better fit of method with the research question [215]. The variability in the use and interpretation of statistics produces research that cannot be compared or synthesised across studies and geographies [32, 214]. In this analysis, the wide variation in sample sizes, the difference in formulae and terms used, different interpretations of use categories make comparisons and syntheses of data difficult or inaccurate. The varying application of statistical measures has led to the recommendation that primary data (URs) are reported to allow for comparison between studies and meta-analysis [32]. In health and medicine directed ethnobiology, there are pitfalls with statistical methods. The equation of the most popular species with the "best" could be misapplied since popularity may have more to do with ease of access or symbolic value than efficacy in BM terms [16]. The format of many ethnobiological studies which result in catalogues of plant knowledge does not necessarily translate into real-world plant use such that what is known is not necessarily what is used [204].

It has been argued at a more fundamental level, that study design including choice of participants and questionnaire design lead to more variability in results than the choices around statistical indices or the grouping of use categories [216]. Sampling bias may emerge when indigenous knowledge is not homogenously distributed across a community or region [217]. The recording and classification of ethnobotanical knowledge may focus mainly on practical utility of species and can ignore other elements of importance to local communities. Elements that may not be categories of interest in study protocols, such as the sacred or aesthetic, may be relevant to community members [218]. Common ethnobotanical methods may not be culturally appropriate in Australian aboriginal research and this necessitates the development of alternative culturally sensitive study designs [37, 57, 58]. The use of tools such as free-listing were found to produce variable outcomes, even within a single participant (in separate interviews), or relating to age or the presence of a third party at the interview [219]. Similarly, a Bolivian study found that even subtle changes in the use of methods of free-listing and semi-structured interviews can produce markedly different results [220]. The core method of the interview itself is a challenged process when the recorded portion, the verbal, is only a fraction of the whole communication. The interviewer changes the outcome of the interaction through their very presence and the questions they ask, bringing their own etic category biases and resulting in an inaccurate representation of indigenous knowledge [221].

As the discipline of Ethnobiology has progressed, the ethics of research has become increasingly central to its conduct. Vandebroek [204] has argued that the normal method of documenting traditional medicinal knowledge and subsequent laboratory research on pharmacological activities has limited if any health benefits for study communities. There are clear ethical implications to such research. There are increasing calls to develop action-focused research protocols, which ask questions that directly address public health problems and make ethnobiological research more relevant to study communities [14, 204]. Vandebroek [204] refers to ethnobiological research in Mali whereby research results were directly returned to the study community through a refinement of local knowledge on an anti-malarial traditional medicine and only secondarily directed towards the development of a phytopharmaceutical [222]. The area of researching traditional knowledge and genetic resources raises ethical issues including of intellectual property rights, benefit sharing and protection of biodiversity. However, in the *C. spinarum* documents, there is little stated attention to ethics. Where ethics is mentioned, it is usually perfunctory. It is true that the lack of discussion of ethics does not mean that the research was conducted unethically. Some journals may require evidence of ethical research conduct as a condition of publication such as the *Journal of Ethnopharmacology*, even though ethical issues are not discussed in the research paper as such. This may not be the case for all journals. Where ethical issues are discussed as in Australian research such as [61], there is a greater sense of the ethical conduct of the research. Likewise, benefit sharing and IPRs may be a component of some research permits. However, the mention or discussion of them within the research paper such as in those listed in Section 3.5 raises the reader's awareness of these essential aspects of ethical research which has a value in itself.

5. Conclusions

This analysis using *C. spinarum* as a case study of a medicinal species illustrates that it has been identified in ethnodirected bioprospecting studies and other forms of ethnobiological research across three continents. Most of the research is categorised as Phase I in Hunn's classification of ethnobiology with little contextual or ethnographic content. Where emic perspectives on the use of this species are reported, it is seen to profoundly alter the perspective of the reader on the use of this and other species within the study community. However, even a minimal "thin description" is lacking in most of the ethnobotanical research, where lists of EM species may be recorded without information on the plant part used, or on the preparation or administration of the plant remedy. The omission of such essential data can invalidate the documentation of ethnobotanical data whatever the purpose, whether cultural record, health care provision, sustainable plant use, environmental protection or bioprospecting.

There is more to be learned about this species and the many other species of broad biocultural value through the design and funding of research which allows local meanings and values to emerge. A more nuanced understanding of its meaning for indigenous people and local communities may be illuminated through study designs that incorporate a blending of qualitative and quantitative research methodologies as proposed in best practice documents in ethnobiology and in ethnopharmacology. A partnership approach with local communities can make for more ethical as well as more fruitful research. Allied to this, is the aim of trans-disciplinarity in ethnobiological research. Such a research process could reveal local ways of knowing biodiversity and environment beyond the categories of utility commonly captured in natural science-directed ethnobotanical research.

The evidence of the current analysis of the ethnobotany of *C. spinarum* illustrates that such an approach is essential to ethical, sustainable, and effective ethnobiological research of this and other culturally valued species. A move beyond the current obstacles to collaborative research is needed to examine in meaningful and effective ways how people interact with plants and the wider environment in response to health challenges with dynamism and creativity.

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Conflict of interest

The authors declare no conflict of interest.

Appendices and nomenclature

Additional information available on request from corresponding author.

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