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Research Paper

Medicinal plants used by traditional healers for the treatment of malaria in the Chipinge district in Zimbabwe

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ABSTRACT

Ethnopharmacological relevance: Because about 50% of the Zimbabwean population is at risk of contracting malaria each year, the majority of people, especially in rural areas, use traditional plant-based medicines to combat malaria. This explorative ethnobotanical survey was undertaken to document how malaria is conceptualized and diagnosed by traditional healers, and to record the medicinal plants used in the prevention and treatment of malaria, their mode of preparation and administration.
Materials and methods: The research was conducted in three villages in Headman Muzite's area and in Chiriga village. These villages are located in the Chipinge district in the Manicaland Province in Zimbabwe.Traditional healers were selected with the assistance of the headman of the Muzite area and a representative of the Zimbabwe National Traditional Healers Association. Semi-structured interviews were conducted with 14 traditional healers from four villages in the Chipinge district in Zimbabwe.
Results: In total, 28 plants from 16 plant families are used by the healers who manage malaria with medicinal plants. The most cited plant is *Cassia abbreviata* Oliv. (Leguminosae) followed by *Aristolochia albida* Duch (Aristolociaceae) and *Toddalia asiatica* (L.) Lam. (Rutaceae). Roots (55.3%) are the most common part used. Most of the plant parts used to treat malaria are stored as dried powders in closed bottles. The powders are soaked in hot or cold water and the water extract is taken as the active medicine. The healers consider their medicinal knowledge as a spiritual family heritage. Only 25% of the healers refer the malaria patients that do not respond to their treatment to hospital – they believe evil spirits cause their remedies to failure and they would rather try a different plant or perform a cleansing ceremony.
Conclusions: Local knowledge of medicinal plants in the treatment of malaria still exists in all four villages surveyed and traditional healers appear to play an important role in primary health care services in this remote rural area in Zimbabwe. This explorative survey underscores the need to preserve and document traditional healing for managing malaria and for more future scientific research on the plants to determine their efficacy and their safety. This could improve their traditional anti-malarial recipes and might contribute to a better integration of Zimbabwean traditional medicine into the national health system in the future.

1. Introduction

World-wide, an estimated number of 3.4 billion people are still at risk of malaria. In 2012 approximately 207 million cases of malaria occurred globally with most cases (80%) and deaths (90%) occurring in Africa. Most deaths (77%) occur in children under the age of five (WHO, 2013). In other words, malaria continues to be a major cause of morbidity and mortality. It is caused by five species of parasite that affects humans. All the parasites belong to the genus *Plasmodium*: *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium ovale*, *Plasmodium malariae*, *Plasmodium knowlesi*. Of these, *Plasmodium vivax* and *Plasmodium falciparum* are the most important. The latter is the most deadly form and it predominates in Africa.

Approximately 15 million people belonging to the five countries in the low-transmission Southern African subregion (Botswana, Namibia, Swaziland, Zimbabwe and South Africa) are at some risk of malaria and 10 million people are at high risk. In 2012 the number of

Abbreviations: MOHCW, Ministry of Health and Child Welfare; ZINATHA, Zimbabwe National Traditional Healers' Association

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confirmed malaria cases reported for this region was 283,000 of which 98% were from Zimbabwe. The reported number of deaths from malaria in this sub-region was 437 in 2012, of which 80% occurred in Zimbabwe (WHO, 2013). Malaria is highly seasonal and mostly caused by *Plasmodium falciparum* in Zimbabwe. *Anopheles arabiensis* is the major vector for malaria. Resistance to antimalarial drugs and the absence of vaccines are major challenges in controlling malaria (Midzi et al., 2004; Kurth et al., 2009; Mayer et al., 2009).

It is estimated that about 50% of the country's population is at risk of contracting malaria each year (WHO, 2013). According to the Ministry of Health and Child Welfare of Zimbabwe (MOHCW, 2008), 54 of the 59 rural districts in Zimbabwe have malaria levels which vary from very high and seasonal to sporadic. The incidence of malaria in 33 (61%) of the districts is classified as high (Midzi, et al., 2004; MOHCW, 2008) and therefore warranting intervention. These are mostly low-altitude districts with warm and wet summers. Although the highest malaria prevalence occurs between February and April, some areas have year-round transmission.

The National Malaria Control Programme is the unit in the Department for Disease Prevention and Control in MOHCW that spearheads the prevention and control of malaria. This unit has reintroduced dichlorodiphenyltrichloroethane (DDT) for indoor residual spraying as the main strategy to reduce the transmission of malaria by reducing the prevalence of mosquitos (MOHCW, 2008). The objectives set by the Ministry of Health of Zimbabwe include achieving the prevention of malaria and personal protection of over 80% of the population by strengthening community and other stakeholders' participation which would maximize people's access to malaria control interventions (MOHCW, 2008). However, the Traditional Medical Practitioners Act, promulgated in 1981, which aimed to integrate Zimbabwean traditional medicine (TM) into the national health system, made no significant contribution because it was not followed up with the necessary institutional and financial support. And so, although TM practices remain largely undocumented, unregulated and, consequently, poorly integrated into the formal health sector, many people still use traditional plant-based medicines for primary health care in Zimbabwe, especially in rural areas.

Documentation of TM and plants traditionally used for the prophylaxis and treatment of malaria in Zimbabwe constitutes an important step not only in preserving the local traditions and indigenous knowledge but also in improving access to and participation in improving traditional malaria control interventions by the communities. Documentation of TM could facilitate future research on the safety and efficacy of medicinal plants and could provide a starting point for identifying single chemical entities with antimalarial activity which could lead to the development of standardized phytomedicines. Because the drug-resistance of *Plasmodium falciparum* and the resistance of *Anopheles* mosquitos to insecticides are widespread, the search for new antimalarial drugs is increasingly important.

So far only a limited number of studies (e.g. Vundule and Mharakurwa, 1996; Lukwa et al., 1999; 2001; Kraft et al., 2003; Kazembe et al., 2012) have been conducted in Zimbabwe on traditional healers' use of medicinal plant for the treatment of malaria. The aim of this study was to collect comprehensive data from traditional healers on medicinal plant-based remedies commonly used to treat malaria in order to document their methods of preparation and administration, together with information on how the healers conceptualize and diagnose malaria to contribute to the overall documentation of anti-malarial plant species used by traditional healers in Zimbabwe.

2. Materials and Methods

2.1. Study area

This explorative study was conducted in the Manicaland Province in the Chipinge district of Zimbabwe (Fig. 1).

The villages of Chindedzwa (32.625°E, 20.527°S), Mazundu (32.559°E, 20.509°S), and Zuzunye/Madhlope (32.544°E, 20.563°S) where the research took place are located in Headman Muzite's area which is a mountainous area near the south-eastern border of Zimbabwe and south-western Mozambique. The village of Chiriga (32.662°E, 20.269°S) is located 45 km further towards the north-west in a flat countryside and at lower altitude. Both areas have a poorly developed road network and infrastructure. The people belong to the Ndau ethnic group and the main language spoken is Ndau, a dialect of Shona. The major source of livelihood is subsistence farming with limited assistance from agricultural extension officers. The communities are well known for their traditional beliefs and use of plants for primary health care and are all located within the Chipinge district which has high seasonal malaria hot spots (Midzi et al., 2004; MOHCW, 2008).

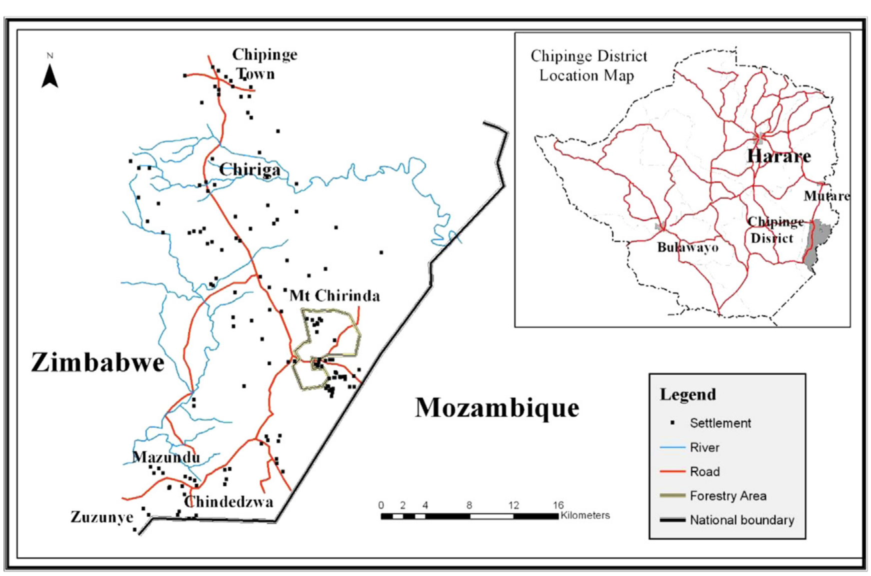

Fig. 1. Map of Zimbabwe and research area. Source: Dr C. Barker, Geography Department, Free State University.

2.2. Data collection

Ethnobotanical fieldwork for this explorative study was conducted between March and April 2012. After consultation with the local headman and the Zimbabwe National Traditional Healers Association (ZINATHA), it was decided to conduct the research in the four villages (Chindedzwa, Mazundu, and Zuzunye/Madhlope and Chiriga). With the assistance of ZINATHA, a total of 17 traditional healers were initially identified, of whom only 14 were available to be interviewed between March and April 2012. Two of the 14 healers interviewed claimed not to have any malarial remedies and said that they did not treat malaria. Data was collected through a survey employing open-ended semi-structured interviews with 12 traditional healers (three per village) providing information on bio-data, herbal anti-malarial medicines, vernacular plant names and methods of preparation and administration of these anti-malarial remedies (see Appendix A). The healers were also asked to state the causes of malaria, how they diagnosed and treated the disease and how they could minimize transmission. They were also asked about their alternatives in case of remedy failure and the possible causes of such failure. Furthermore, healers were asked if they referred their malaria patients to local hospitals or clinics. The interviews were conducted by the researchers in the official language of Shona. Plants used to manage malaria in each of the villages were compared to establish consensus. The semi-structured interviews have been analyzed and responses grouped into classes expressing similar ideas. The recorded plants have been entered in a separate Excel spreadsheet.

The interviews were supplemented by direct observation and transect walks. During the transect walks, plants were collected under the supervision of the traditional healers. Plant voucher specimens (MAL2001–MAL2026) were collected and deposited at the Herbarium of the Harare Botanical Gardens in Zimbabwe for identification. Plant names have been checked and updated with the online website (www.theplantlist.org) of the Royal Botanic Gardens, Kew, accessed on 3 April 2014.

Ethical approval for this study was obtained from the headmen of the studied areas and the ZINATHA. All respondents were asked to sign a prior informed-consent form after the objectives and possible consequences of the study had been explained. The prior informed consent (PIC) form was translated into the local Shona language.

The use value (Trotter and Logan, 1986), a quantitative method that demonstrates the relative importance of species known locally, was calculated for the Chipinge district according to the following formula: $UV = U/N$, where UV refers to the use value of a species; U to the number of citations per species; and N to the number of informants.

3. Results

3.1. Socio-demographic details respondents

All 14 traditional healers belong to the Ndau tribe which is a subtribe of the Shangani people. They comprised 57% men and 43% women and were between the ages of 40 and 83 (the majority were between 50 and 65 years old). The average age for female healers was 45 years while the male average age was 62 years. The healers had little formal education – mostly up to primary level only – while three of them had extra qualifications (Table 1). Only two of the interviewed healers were formally employed, one as a secondary school principal and the other as an agriculture extension officer. Four of the 12 healers who provided extensive information on malaria are spiritualists and bone throwers, and eight are locally renowned herbalists.

Table 1
Demographic characteristics of respondents ($n = 14$).

Characteristic	Frequency
Gender	
Male	8
Female	6
Education	
Primary education	14
Secondary education	3
Extra teaching qualification	1
Extra agricultural college	1
Religion	
Christian	7
Traditionalist	7
Etnicity	
Ndau tribe which (subtribe of the Shangani)	14
Years of experience as healer	
Between 1–10 years	2
Between 11–20 years	6
Between 21–30 years	2
Between 31–40 years	0
Between 41–50 years	3
51- > years	1

3.2. Diversity of medicinal plants and their uses

A total of 28 plant species were recorded to be used in antimalarial remedies (Table 2). Twenty-six specimens were collected and identified at the Harare Botanic Garden, Zimbabwe. Unfortunately, the other two species could not be found, even in faraway areas (between 20 and 30 km away). They are known locally as *munyabangwa* and *muranga*, are collected by traditional healers from urban areas only and sold in towns and cities. For this reason, the plants could not be collected on the spot and scientific names could not be established.

The identified 26 species comprised trees (38.5%), shrubs (30.8%), climbers (23.0%) and herbs (7.7%), and belong to 16 families. Most plant species belong to the Apocynaceae (15.4%), Compositae (11.5%) and Leguminosae (11.5%), followed by the Aristolochiaceae, Rubiaceae and Cucurbitaceae (7.7%). The other 10 families contributed one species each (3.8%). Twenty (76.9%) of the collected species are used for treatment only, four (15.4%) for prevention only and two (7.7%) are used for both treatment and prevention. The plant most cited was *Cassia abbreviata* (Leguminosae) followed by *Aristolochia albida* (Aristolociaceae), *Toddalia asiatica* (Rutaceae) and *Strychnos potatorum* (Loganiaceae). Two species (*Momordica foetida* and *Capsicum annuum*) are cultivated while the rest are wild species. *Euclea natalensis* (Ebenaceae) is not considered to have antimalarial properties but is added to improve appetite and body strength. Use values of the recorded plant species have been calculated which showed a highest use value of 0.67 for *Cassia abbreviata.*

3.3. Mode of preparation and administration

Most of the parts of the plant used to treat malaria are stored as dried powders in closed bottles, except *Capsicum annuum*, *Momordica balsamina* and *Momordica foetida*. The powders are soaked in hot or cold water and the water extract is taken orally as the active medicine. The fruit of *Capsicum annuum* (syn. *Capsicum frutescens*) is swallowed directly without chewing since it is very bitter. *Momordica balsamina* and *Momordica foetida* are eaten as prophylactic vegetables (relishes) during meals from freshly collected plant material. Remedies based on mixtures of different plants are common. In a few cases, different healers use different parts of the same plant.

The amounts of powder used to make the concoction were described in terms of a full, half or quarter of a teaspoon or tablespoon

Table 2
Plants used in the prevention and treatment of malaria.

Family	Scientific name	Collection number	Local name	Part used	Purpose	Preparation	Growth form	Village	Times stated (per village)	Use value (per species)
Apocynaceae	*Catharanthus roseus* (L.) G. Don	MAL18	Muruwa	Root	Treatment	Decoction	Shrub	Chindedzwa	1	0.08
	Diplorhynchus condylocarpon (Müll.Arg.) Pichon	MAL15	Mutowa	Stem bark	Treatment	Cold infusion	Tree	Chiriga	1	0.08
	Holarrhena pubescens Wall. Ex G. Don	MAL02	Masunungure	Root	Treatment	Decoction	Tree	Mazundu	2	0.17
	Tabernaemontana elegans Stapf	MAL11	Muchenya	Root	Treatment	Hot infusion	Shrub	Mazundu	1	0.08
Aristolochiaceae	*Aristolochia albida* Duch.	MAL25	Ruzangariro	Tuber	Treatment	Hot infusion	Climber	Chindedzwa	2	0.42
		MAL25	Ruzangariro	Tuber	Both	Hot infusion	Climber	Mazundu	3	
	Aristolochia heppii Merxm	MAL13	Chividze	Root	Treatment	Hot infusion	Climber	Zuzunye/ Mahlope	1	0.08
Caricaceae	*Carica papaya* L.	MAL01	Mupopo	Root	Treatment	Decoction	Tree	Chindedzwa	1	0.08
Compositae	*Baccharoides adoensis* (Sch. Bip. ex Walp.) H. Rob.	MAL27	Chipenembe	Leaf	Treatment	Hot infusion	shrub	Mazundu	1	0.08
	Brachylaena huillensis O. Hoffm.	MAL14	Muphahla	Root	Treatment	Hot infusion	Tree	Mazundu	1	0.08
	Erythrocephalum zambesianum Oliv. & Hiern	MAL03	Muhloni	Root	Treatment	Cold infusion	Shrub	Chindedzwa	1	0.25
		MAL03	Muhloni	Root	Treatment	Cold infusion	Shrub	Chiriga	2	
Cucurbitaceae	*Momordica balsamina* L.	MAL19	Ngaka	Leaf	Prevention	Relish, especially during rainy season	Climber	Mazundu	1	0.17
		MAL19	Ngaka	Leaf	Prevention	Relish, especially during rainy season	Climber	Zuzunye/ Mahlope	1	
	Momordica foetida Schumach	MAL20	Muchukubaba	Leaf	Prevention	Relish, especially during rainy season	Climber	Mazundu	1	0.17
		MAL20	Muchukubaba	Plant	Prevention	Relish, especially during rainy season	Climber	Zuzunye/ Mahlope	1	
Ebenaceae	*Euclea natalensis* A.DC.	MAL23	Mushangura	Root	Treatment	Take with porridge. May cause diarrhoea	Shrub	Chiriga	1	0.08
Lamiaceae	*Ocimum angustifolium* Benth.	MAL09	Mufuranhema	Tuber	Treatment	Cold infusion. May induce nausea	Herb	Zuzunye/ Mahlope	1	0.08
Leguminosae	*Cassia abbreviata* Oliv	MAL21	Murumanyama	Root/bark	Treatment	Cold or hot infusion	Tree	Chiriga	1	0.67
		MAL21	Murumanyama	Root	Prevention	Cold or hot infusion	Tree	Chindedzwa	2	
		MAL21	Murumanyama	Bark/Root	Treatment	Cold or hot infusion	Tree	Mazundu	3	
		MAL21	Murumanyama	Root/bark	Treatment	Cold or hot infusion	Tree	Zuzunye/ Mahlope	2	
	Elephantorrhiza goetzei (Harms) Harms	MAL08	Chiurayi	Root	Treatment	Hot infusion	Tree	Zuzunye/ Mahlope	1	0.08
	Senna septemtrionalis (Viv.) H. S. Irwin & Barnaby	MAL24	Mumwahuku	Root	Treatment	Decoction	Shrub	Mazundu	1	0.08
Loganiaceae	*Strychnos potatorum* L. f.	MAL06	Mudyambira	Root	Treatment	Decoction	Tree	Mazundu	1	0.25
		MAL06	Mudyambira	Root/stem	Treatment	Decoction	Tree	Zuzunye/ Mahlope	1	
		MAL06	Mudyambira	Root	Treatment	Decoction	Tree	Chiriga	1	
Menispermaceae	*Cissampelos mucronata* A. Rich.	MAL17	Chipombafodya	Tuber	Treatment	Hot infusion	Climber	Mazundu	1	0.17
		MAL17	Chipombafodya	Tuber	Treatment	Hot infusion	Climber	Zuzunye/ Mahlope	1	
Passifloraceae	*Adenia cissampeloides* (Planch ex Hook) Harms	MAL04	Muore	Root	Prevention	Cold or hot infusion	Climber	Chindedzwa	1	0.17
		MAL04	Muore	plant	Prevention	Cold or hot infusion	Climber	Zuzunye/ Mahlope	1	
Plumbaginaceae	*Plumbago zeylanica* L.	MAL10	Mhisepise	Root	Treatment	Cold infusion	Herb	Chiriga	1	0.08
Rosaceae	*Prunus persica* (L.) Batsch	MAL12	Mupirikisi	Leaf/root	Both	Hot infusion	Tree	Zuzunye/ Mahlope	1	0.08
Rubiaceae	*Crossopteryx febrifuga* (Afzel. ex G. Dion) Benth.	MAL05	Chikobengwa	Stem bark	Treatment	Cold infusion or take with porridge	Tree	Zuzunye/ Mahlope	1	0.25
		MAL05	Chikobengwa	Stem bark	Treatment	Take with porridge or cold infusion	Tree	Mazundu	1	

Table 2 (*continued*)

Family	Scientific name	Collection number	Local name	Part used	Purpose	Preparation	Growth form	Village	Times stated (per village)	Use value (per species)
		MAL05	Chikobengwa	Stem bark	Treatment	Cold infusion or take with porridge	Tree	Chiriga	1	
	Pavetta schumanniana F. Hoffm. ex K. Schum.	MAL22	Muchena	Root	Treatment	Cold infusion	Shrub	Chindedzwa	1	0.08
Rutaceae	*Toddalia asiatica* (L.) Lam	MAL16	Gato	Root	Treatment	Decoction	Tree	Chiriga	2	0.25
		MAL16	Gato	Tuber	Treatment	Decoction	Tree	Zuzunye/ Mahlope	1	
Solanaceae	*Capsicum anuum* L.	MAL07	Mhiripiri	Fruit	Prevention	Swallow 4 fruits 3 times a day for 3 days	Shrub	Mazundu	1	0.08
	Not identified		Munyabangwa	Root	Treatment	Cold and hot infusion	Tree	Zuzunye/ Mahlope	2	0.33
	Not identified		Munyabangwa	Root	Treatment	Cold and hot infusion	Tree	Mazundu	2	
	Not identified		Muranga		Treatment	Cold infusion	Tree	Zuzunye/ Mahlope	2	0.33
	Not identified		Muranga	Root	Treatment	Cold infusion	Tree	Mazundu	2	

or even a pinch. The concoctions were usually prescribed to be taken two or three times a day for between three and seven days or until the patient had healed. Most healers were very clear about their recipes and dosages but not precise about quantities of plant material and volume (e.g. handful and teacup). Different dosages for the same concoction were described by different healers. The most common volume of water used was 750 ml. This is the most freely available container since cooking oil is sold in 750 ml bottles. Other volumes mentioned were one or two litres or a teacup. No clear pattern or any consistency existed between healers as far as dosage was concerned.

The healers claimed that patients did not always comply with their prescribed dosages. This could be a problem in the malaria treatment. Successful administration of the treatment might also depend on the patient's capacity to persist with the treatment. For example, 750 ml of the very bitter concoction of *Cissampelos mucronata* roots should be taken three times a day for seven days.

3.4. Perceptions about, causes and symptoms of malaria

All the respondents were aware that mosquito bites might transmit malaria. However, 35.7% of the interviewees reported that eating fruits such as mangos, guavas and melons, drinking water from unprotected wells, and exposure to morning dew may cause malaria as well. The disease is commonly known as malaria by the healers, though the older respondents (65 years old and above) refer to it as *muswarara* and *ndangaranga.* While *muswarara* means 'goose pimples' in the local Shona language, *ndangaranga* indicates a 'state of dizziness or lack of balance'. The common use of the term malaria as opposed to local terms could reflect the extensive education campaign on malaria that the MOHCW conducted throughout the country.

The general patterns of diagnosing malaria were similar among the healers from the four villages. The symptoms of malaria, according to the healers, are presented in Table 3. The most important symptoms were feeling cold/goose pimple and headaches. None of the interviewees indicated sweating and wasting away of the body with time, suggesting that the infections tend to be short-lived. The healers would diagnose an infection as malaria if the patient presented with at least three of the listed symptoms.

The healers were aware that their patients might not get better after taking their remedies. In such cases, 25% of the healers referred the patients to hospital. However, most of the healers attributed the lack of a patient's improvement to evil spirits (41.7%). These healers would cleanse the patient of the bad spirits and might repeat or give a different prescription thereafter. Other healers believed the lack of patients' improvement was a result of misdiagnosing a patient with malaria (16.7%), a compromised immune system of the patient (8.3%) or non-compliance in taking the remedies (8.3%).

Table 3
Symptoms that are used by traditional healers to diagnose malaria.

Symptom	Frequency (no. of healers that mentioned it)
Feeling cold/goose pimple	6
Headache	10
Fever	8
Sweating	1
Loss of appetite	4
Body weakness/feeling sleepy	5
Vomiting	2
Dizziness	2
Nausea	2
Pain	1

3.5. Prevention practices

Besides the administration of herbal remedies to reduce the chance of contracting malaria, the respondents' measures to prevent malaria, are the use of treated bed nets, the destruction of mosquito breeding and resting areas, and the reduction of unwanted undergrowth and puddles within and around the homesteads. These practices are 'overseen' by village/community health workers and environmental health workers, who are government employees. Other preventive practices mentioned are the use of drinking water from protected wells only, not eating fruits such as green mangos, guavas and melons, and avoiding morning dew. In addition, the healers were aware that indoor residual spraying killed the mosquitoes. However, there was no reference to the use of repellents, neither commercial nor traditional ones by the healers themselves.

4. Discussion

4.1. Traditional knowledge

Traditional knowledge and the use of plant-based medicines remain important in the prevention and treatment of malaria in the Chipinge district and probably in other rural areas of Zimbabwe. This is important because traditional African medicine is often quickly accessible and affordable to the rural communities in Africa. Government clinics are often difficult to reach (the nearest Gwenzi clinic to Chipinge is about 12 km on a poorly maintained gravel road) and are poorly resourced: community health workers in the villages often run out of commercial drugs while traditional herbal medicines provided by traditional healers are quick and constantly available at the time of need.

The healers interviewed were mostly men (57%) with an average age of 62. The female healers were younger with an average age of 45 years. The large percentage of female healers is surprising because it is often claimed that Africans believe that traditional healers should be male (Okello and Ssegawa, 2007; Bekalo et al., 2009; Cheikhyoussef et al., 2011).

The traditional healers from the four villages in Chipinge district all understood that malaria is transmitted by mosquitos. This may be due to government's anti-malaria interventions in the area. However, other factors were also mentioned to play a role. Some healers mentioned that people need to avoid eating some fruits such as green mangos, guavas and melons, drinking water from unprotected wells and exposure to morning dew. Tabuti (2008) reports that, in Uganda the respondents believe that drinking dirty water is responsible for causing malaria. Dirty water is also mentioned in Lukwa et al.'s (2001) study at Kariba in Zimbabwe in which 87.3% of healers mentioned that mosquitoes transmit malaria and 12.4% did not know the cause of malaria. In Ghana, Ahorlu et al. (1997) found that respondents believed that malaria was caused by eating raw or overripe fruits such as mangos while exposure to morning dew was reported in Kenya by Dye et al. (2010). Important symptoms reported in this study are headache, fever and feeling cold/goose pimples as was also reported by Tabuti (2008).

The failure of a remedy is generally believed to be caused by evil spirits which need to be exorcised before the plant-based remedies will be effective again. Only 25% of the healers send their patients to hospital after a remedy has failed. The low referral to hospitals could reflect the efficacy of the remedies and/or a lack of understanding of the disease by healers and the communities at large. This is a worrying trend given the progressive and virulent nature of malaria.

Most of the remedies described in this study are administered orally as water-based concoctions. This is in agreement with the findings of Adekunle (2008), Musa et al. (2011) and Maroyi (2013). Although there was agreement about the general mode of preparation (most commonly soaking dried plant material in water), there was a wide variation in the quantities of plant material soaked in a specific amount of water. The concentration of active ingredient in the concoctions and the amount ingested by the malaria patients thus differed widely. Randrianarivelojosia et al. (2003) and Ugulu (2012) report similar observations. This wide variation in the amount of the active ingredient ingested and the low compliance creates the possibility of subminimum doses.

Roots (55.3%) are usually regarded as the most important parts of the plant. Next, the bark (13.7%) and tubers (12.8%) followed by leaves (10.6%) and fruit (2.1%). Also whole plants (4.3%) are used in the remedies. These observations resonate with those of Bussmann (2006), Musa et al. (2011), Cheikhyoussef et al. (2011) and Maroyi (2013). It deviates from the work of Bekalo et al. (2009), Ogbe et al. (2009) and Rahmatullah et al. (2012) who observe that leaves are the most used plant parts. Bark, leaves or roots from the same plant are also used interchangeably by different healers. Randrianarivelojosia et al. (2003) make a similar observation.

The healers were aware of the possibility of unfair bioprospecting practices from institutions such as pharmaceutical companies and were concerned about legal protection of their intellectual property and a possible lack of proper compensation, similar to the findings described by Uprety et al. (2012) amongst the aborigines of Canada. We were thus surprised by the absence of significant resistance from the healers to supply us with traditional knowledge and plant material. We attribute this to the involvement of the local headman and ZINATHA and the prior informed-consent forms that explained the objectives, benefits, risks and general procedures of the survey in Shona before the start of the project.

In order to develop the use of herbal medicines, the plant species must be easy to collect. However, the healers believe that cultivated medicinal plants are less potent than those harvested from the wild and therefore the latter is still preferred. Only two of the recorded species (*Momordica foetida* and *Capsicum annuum*) are cultivated while all other species are still collected from the wild. This agrees with the findings of Bussmann (2006) in South Turkana, Kenya, Okello and Ssegawa (2007) in Uganda, and Simbo (2010) in Babungo and Cameroon and Musa et al. (2011) in Sudan.

4.2. Plants used in the treatment of malaria

Medicinal plants play a major role in many communities over the world in the treatment and prevention of disease and the promotion of general health. Previous studies have shown that more than 1200 medicinal plants from 160 families are used worldwide to treat malaria or fever (Willcox and Bodeker, 2004) and still many anti-malarial plant species remain to be discovered. The present study documented 28 plants which were used in the prevention and treatment of malaria by traditional healers in four villages in the Chipinge district in Zimbabwe (Table 2).

The low correlation in the plants used in villages that are close to each other and even in the same village by the three healers involved is surprising. This may be due to the secret spiritual family heritage considerations discussed above. Because of this, no focus-group discussion was performed in this study. Significant discrepancies thus exist between healers from the same area as far as the plant species and part of the plant used are concerned. Of the 26 plant species identified in this survey, 13 were used in Mazundu village, 12 in Zuzunye/Mahlope village, 8 in Chindedzwa village and 7 in Chiriga village. The most overlap was with the root or bark of *Cassia abbreviata* that is used in all four villages and was mentioned by eight of the 12 healers. *Strychnos potatorum* roots and *Crossopteryx febrifuga* bark are commonly used in Zuzunye, Mazundu and Chiriga villages. *Adenia cissampeloides* root or bark is used for treatment in Chindedzwa and Zuzunye villages, while *Momordica balsamina* and *Momordica foetida* whole plants are used for prevention in Zuzunye and Mazundu villages and *Aristolochia albida* tuber is used for treatment in Chindedzwa and Mazundu villages. This low overlap might be due to the explorative character of the study in which no saturation could be reached. The plant mostly cited was *Cassia abbreviata* (Leguminosae) followed by *Aristolochia albida* (Aristolociaceae) and *Toddalia asiatica* (Rutaceae). These plants are also known in literature as medicinal plant species. Little correspondence between the uses of the same species in the same village was surprising. The greatest agreement of species and plants parts was recorded in Mazundu village, where three of the 13 species, *Cassia abbreviata* roots or bark, *Holarrhena pubescens* roots and *Aristolochia albida* tubers, are used by at least two of the three interviewed healers. Zuzunye/Mahlope reflected the least overlap of species used where only *Cassia abbreviata* is used by two of the three healers that were interviewed.

The conservation status of the collected plants has been checked by consulting the IUCN Red List of Threatened Species (version 2014.1, www.iucnredlist.org, downloaded on 9 July 2014). *Brachylaena huillensis* is listed as 'low risk' but might become 'nearly threatened' in future; *Catharanthus roseus* and *Senna septemtrionalis* as 'not threatened'; and *Holarrhena pubescens* as of 'least concern'. The other species are not on the list. The online Catalogue of Life website (http://www.catalogueoflife.org) showed no further conservation issues on any of the reported plants. However, the fact that roots and bark are the most commonly used parts in the remedies suggests that the continuous collection of plants may threaten local populations of plants in the future.

4.3. A brief literary review of the antiplasmodial activity of extracts from the antimalarial plants identified in this study and identified secondary metabolites

In vitro antiplasmodial activity of crude extracts of 12 of the 26 plants identified as antimalarial treatments in this study have been reported in the literature namely *Adenia cissampeloides, Aristolochia heppii, Carica papaya, Cassia abbreviata, Catharanthus roseus, Cissampelos mucronata, Crossopteryx febrifuga, Holarrhena pubescens, Momordica balsamina, Momordica foetida, Plumbago zeylanica* and *Toddalia asiatica*. These results are summarized in Table 4. Secondary metabolites, some with antiplasmodial activity, have been reported from seven of these 12 plants and from *Aristolochia albida*. The published phytochemical investigations of these eight plants are discussed below.

The potential of antiplasmodial and antimalarial compounds with known molecular structures from African medicinal plants was reviewed by Amoa et al. (2013) and Ntie-Kang et al. (2014). These included alkaloids, terpenoids, flavonoids, coumarines, phenolics, polyacetylenes, xanthones, quinones, steroids, and lignans. They concluded that African flora hold an enormous potential for the development of phytomedicines for malaria.

The more promising plants from this ethnobotanical survey are briefly reviewed below in terms of their known photochemistry, other traditional uses and related medicinal species.

The bark of *Cassia abbreviata* yielded a 4-methoxyflavan (Volker et al., 1998), flavan-3-ols (afzelechin and epiafzelechin) and proanthocyanidin dimers (proguiboergtinidins) (Malan et al., 1996). Similar compounds, including proanthcyanidin trimers, have been isolated from the root bark and leaves and twigs (Erasto et al., 2003; Mongolo and Mafoko, 2013). Kiplagat et al. (2012) isolated an antiplasmodial flavanone (5-hydroxy-4′,8-dimethoxyflavanone) and a 3-methoxyflavan (4′,7-dihydroxy-4-methoxyflavan) from the root bark.

The bark of *Cassia abbreviata* is also used to treat sexually transmitted diseases in Zimbabwe (Kambizi and Afolayan, 2001), bovine Dermatophilosis (Ndlovu, Masika, 2013), bilharzia, skin disease, cough, pneumonia, fever, abdominal pain, headache and snakebite (Erasto et al., 2003). Watt and Breyer-Brandwijk (1962) reported its use by the Bushman in the Kalahari (Botswana and South Africa) for dysentery, diarrhoea, severe abdominal pain and toothache. A review of *Cassia abbreviata's* ethnomedicinal uses, toxicity, phytochemistry, possible propagation techniques and pharmacology was published in 2013 by Mongalo and Mafoko.

Other species in the genus *Cassia* used traditionally against malaria are *Cassia fistula* L., used in Tanzania, Zimbabwe, Mozambique and Brazil. The leaves, containing the most active extracts, yielded bioactive phytol (a diterpene alcohol), lutein (a xanthophyll) and di-lineolylgalactopyranosyl-glycerol as antiplasmodial compounds upon activity-guided fractionation (Grace et al., 2012). Antiplasmodial alkaloids and a chromone were isolated from the flowers of *Senna siamea* (Lam.) H.S. Irwin & Barneby (synonym *Cassia siamea* Lam.), used traditionally in Indonesia (Oshimi et al., 2009). The stem bark yielded the antiplasmodial compound emodin (6-methyl-1,3,8-trihydroxyanthraquinone) and lupeol (a triterpenoid). The leaves also yielded antiplasmodial alkaloids (Morita et al., 2007). *Senna alata* (L). Roxb. (synonym *Cassia alata* L.) and *Senna occidentalis* (L.) Link. (synonym *Cassia occidentalis* L.) are used traditionally in the Democratic Republic of Congo and quinones with antiplasmodial activity were isolated from these two plants (Kayembe et al., 2010). These authors also isolated terpenes from *Sarracenia alata* (Kayembe et al., 2012).

All parts of *Toddalia asiatica* are used to treat malaria in Kenya but the roots were considered to be the most potent. Oketch-Rabah et al. (2000) isolated an antiplasmodial 1′-butene-coumarin from the ethyl acetate extract of the root. Alkaloids with antiplasmodial activity were isolated from the metanolic extract of the root bark by Gakunja et al. (1995) and Nyahanga et al. (2013). Nyanga and co-workers also isolated antiplasmodial coumarins. Recently eight new alkaloids were isolated from the roots by Jiang Hua et al. (2014). Columbin (a diterpenoid furanolactone) was isolated from the whole plant and found to be active against Trypanosoma brucei (Nok et al., 2005).

The genus Aristolochia contains about 500 herbaceous plants which are widely used in traditional medicine (Wu et al., 2004). More than 60 species have been studied phytochemically and contain a variety of compounds including aristolic acid and derivatives, terpenoids, aristolactams, aporphines, protoberberines, isoquinolines, benzylisoquinolines, amides, flavonoids, lignans, biphenyl ethers, coumarins, tetralones, terpenoids, benzenoids, steroids etc. (Kuo et al., 2011). Aristolochic acid and derivatives occur in many Aristolochia species have been found to be nephrotoxic, carcinogenic and mutagenic (Abdelgadir et al., 2011). Kubmarawa et al. (2007) reported that the roots of *Aristolochia albida* Duch. were used in Nigeria against malaria and that it contains tannins. Kamagaju et al. (2007) reported that the seeds of this plant species were used in Rwanda to treat malaria as well and that preliminary investigations showed that species was rich in alkaloids. This plant species has also been used to treat skin disease, dysentery, colic, snakebite and as an adjuvant (Watt and Breyer-Brandwijk, 1962).

The genus *Strychnos* comprises about 100 species and is well known for its alkaloid content including strychnine and curare. Frederich et al. (2002) reviewed the antiplasmodial activity of 69 *Strychnos* alkaloids. They found weak or no antiplasmodial activity in monoindoles and potent activity in the usambarine-type bisindoles. Twenty-four alkaloids were isolated from the roots of *Strychnos potatorum* (Massiot et al., 1992). Phillipe et al. (2005) found no antiplasmodial activity in the EtOAc extract of the stem of this plant.

Table 4
Literature review on identified plants.

Species	Method of preparation of concoction, part used and country with reference source	Pharmacology
Adenia cissampeloides	No reference found to the treatment of malaria or fever	Ethanolic whole plant extract IC_{50} 1.56 μ/mL (Annan et al., 2012)
Aristolochia albida (syn. *Aristolochia aethiopica*)	Roots prepared in treatment against malaria: various countries in Africa (Neuwinger, 2000), roots prepared in malaria treatment and fever: Ghana (Iwu, 2014); plant used in treatment of malaria: no country specified (Leeuwenberg, 1987 in Heinrich et al., 2009).	No reference
Aristolochia heppii	Plant is powdered and used as an insect repellent against malaria: Zimbabwe (Kazembe and Chauruka, 2012)	Plant active as insect repellent 100% for 1 h, 84% for 2 h, but fell rapidly to 46% by 2.5 h post application (Kazembe and Chauruka, 2012)
Baccharoides adoensis (syn. *Vernonia adoensis*)	The dried roots are eaten: Mozambique **(**Mulhovo, 1999 in Fowler, 2006**),** leaves or fruits are used to treat malaria: Uganda (Stangeland et al., 2011)	Very high anti-plasmodial activity (Stangeland et al., 2010)
Brachylaena huillensis	No reference found to the treatment of malaria or fever	No reference
Capsicum anuum	Fruits are eaten against malaria: Ethiopia (Giday et al., 2007)	No reference
Carica papaya	Crushed leaves are applied on the body to use as insect repellent in the prevention of malaria; Ethiopia (Karunamoorthi and Hailu, 2014), decoction of leaves prepared to treat malaria: Comores Islands (Kaou et al., 2008) and in Uganda (Stangeland et al., 2011). Decoction of the leaves and roots are drunk against malaria: Ethiopia (Giday et al., 2007; Traore et al., 2013). Leaves are burnt and grinded and prepared in a drink: Zimbabwe (Lukwa et al., 2001). Decoction of leaves are boiled with *Azadirachta indica* and drunk or used in steambath: Ghana (Asase et al., 2005).	Methanolic leaf extract IC50 0.2–1.8 μM (Julianti et al., 2014)
Cassia abbreviata	Plant (parts unknown) used against black water fever: East Africa (Bally, 1937), decoction of the roots used as an antimalarial remedy: Tanzania (Haerdi, 1964 in Lye et al., 2008) and to treat fever of malaria: East-Africa (Kokwaro, 1976) Decoction of roots drunk against fever and malaria: East and Southern Africa (Chhabra et al., 1987).	Antimalarial activity tested (Weenen et al., 1990). An extract has been marketed under the name '*Cassia beareana*' and is said to be diaphoretic (Anon. (n.d.) in Watt and Breyer-Brandwijk, 1962; Palgrave, 2002)
Catharanthus roseus	Decoction prepared from leaves against fever (Brendler and Eloff, 2010)	Anti-malarial activity detected against *Plasmodium falciparum* (Ponarulselvam et al., 2012), high antiplasmodial activity (Gakunja et al., 1995; Gathirwa et al., 2007)
Cissampelos mucronata	No reference found to the treatment of malaria or fever	In vitro antimalarial activity against *Plasmodium falciparum* (Gessler et al., 1994)
Crossopteryx febrifuga	Decoction of bark scrapings drunk & used to wash to treat malaria: Burkina Faso (De la Pradilla, 1988 in Fowler, 2006), bark is used as a remedy for fever: Central & S. Africa (Githens, 1948 in Fowler, 2006), parts of the tree provide a remedy for fever: Central & S. Africa (Palgrave, 2002; Watt and Breyer-Brandwijk, 1962), the bark is decocted and drunk, or used to bathe the patient: Côte d'Ivoire Kerharo and Bouquet, 1950 in Fowler, 2006), the shrub is used as a remedy for fever: Ghana, Guinea (Gelfand et al., 1985 in Fowler, 2006), decoction of the bark is used to treat fever: Malawi, Mozambique (Morris, 1996 in Fowler, 2006), leaves are used to treat malaria: Mozambique (Mulhovo, 1999 in Fowler, 2006), scrapings of the fresh roots are eaten against malaria: Tanzania (Haerdi, 1964 in Fowler 2006, Hedberg et al., 1982), bark is used as remedy for malaria and fever: Tropical Africa (Githens, 1948 in Fowler, 2006; Watt and Breyer-Brandwijk, 1962), the bark is infused as remedy for malaria: Zambia: (Haapala et al., 1994 in Fowler, 2006), leaves are used as an enema to cure fever: Zimbabwe (Gelfand et al., 1985 in Fowler, 2006).	In vivo antiplasmodial activity of ethanolic bark extract (Elufioye and Agbedahunsi, 2004); Crude alkaloids from leaves IC50 4–10 μg/mL (Sanon et al., 2003a, 2003b).
Diplorhynchus condylocarpon (syn. *Aspidosperma condylocarpon*)	Root infusion prepared from leaves against malaria to bathe patient or taken orally: Zambia (Vongo, 1999 in Fowler, 2006), bark is used in water against malaria: Zimbabwe (Lukwa et al., 2001).	No reference
Elephantorrhiza goetzei	Infusion of the roots is drunk, and used to immerse the naked patient as a remedy for fever (Gelfand et al., 1985 in Fowler, 2006).	No reference
Erythrocephalum longifolium (syn. *Erythrocephalum zambesianum*)	Root decoction with leaf juice is drunk for malaria: Tanzania (Haerdi, 1964 in Lye et al., 2008)	No reference
Euclea natalensis	Leaves are used to treat malaria and fever: Uganda (Adjanohoun et al., 1993 in Lye et al., 2008; Tabuti et al., 2003; Ssegawa and Kasenene, 2007; Tabuti, 2008).	No reference
Holarrhena pubescens	Leaves used to treat fever externally: Kenya (Omino & Kokwaro, 1993), decoction prepared from leaves and roots used to wash children with fever: East Africa (Greenway, 1941; Kokwaro, 1976 in Lye et al., 2008), decoction prepared from the roots and drunk to treat malaria (Haerdi, 1964 in Lye et al., 2008).	Methanolic bark extracts – IC50 28 μg/mL (Simonsen et al., 2001); Chloroform leaf extract IC50 5.7 μg/mL (Sinha et al., 2013)
Momordica balsamina	Plant reported to be efficient in treating malarial symptoms: Mozambique (Bandeira et al., 2001; Mulhovo, 1999 in Fowler, 2006)	Active against liver stages of *Plasmodium berghei* (Ramalhete et al., 2011 and 2014)
Momordica foetida	Infusion prepared from the leaves to treat malaria: Tanzania (Gessler et al., 1995), leaves are used against malaria (Kakudidi et al., 2000; Tabuti et al., 2003; Ssegawa and Kasenene, 2007; Tabuti, 2008; Adjanohoun et al., 1993 in Lye et al., 2008), leaves are used against fever: Uganda (Kakudidi et al., 1996 in Lye et al., 2008).	In vitro and in vivo antiplasmodial activity of methanolic leaf extract (Froelich et al., 2007 and Waako et al., 2005)

Table 4 (*continued*)

Species	Method of preparation of concoction, part used and country with reference source	Pharmacology
Ocimum angustifolium (syn. *Becium angustifolium*)	No reference found to the treatment of malaria or fever	No reference
Pavetta schumanniana	Decoction of roots drunk against malaria (Haerdi, 1964 in Lye et al., 2008)	No reference
Plumbago zeylanica	Leaves used to treat malaria and decoction of the roots drunk to treat malaria: Samburu in western Kenya (Heine et al., 1988 in Lye et al., 2008); the herb is used as a sudorific: India (Watt and Breyer-Brandwijk 1962). The plant is used as a fever remedy: Nigeria (Gelfand et al., 1985 in Fowler, 2006), decoction of the leave is drunk: Ethiopia (Giday et al., 2007).	Methanolic leaf extract IC50 17 μg/mL (Simonsen et al., 2001); In vitro antiplasmodial activity (Clarkson et al., 2004)
Prunus persica	Decoction of the seed is used orally to treat malaria: Ethiopia (Giday et al., 2007)	No reference
Senna septemtrionalis (syn. *Cassia septemtrionalis*)	Leaves are used to treat malaria; Uganda (Adjanohoun et al., 1993 in Lye et al., 2008)	No reference
Strychnos potatorum (syn. Strychnos heterodoxa/ *Strychnos stuhlmannii*)	No reference found to the treatment of malaria or fever	No reference
Tabernaemontana elegans (syn. *Conopharyngia elegans*)	No reference found to the treatment of malaria or fever	No reference
Toddalia asiatica	Decoction of aerial parts used to treat malaria: Madagascar (Rasoanaivo et al., 1992), decoction of plant prepared and drunk against malaria (Brendler and Eloff, 2010), roots and leaves used to treat malaria: Uganda (Katuura et al., 2007a, 2007b), treat fever and malaria (Heine et al., 1988 in Lye et al., 2008), plant used against malaria (Njoroge and Bussmann, 2006); decoction of plant used orally against malaria: East Africa (Orwa et al., 2008).	Significant activity found against *Plasmodium falciparum* (Katuura et al., 2007b); Methanolic root extract IC50 2.2 & 1.8 μg/mL (Oketch-Rabah et al., 2000); Root and fruit extract IC50 2.43 and 1.87 μg/mL respectively (Orwa et al., 2013); Parasitaemia suppression in mice (Muregi et al., 2007)

Strychnos potatorum is also known to be used to treat microbial infections, diarrhoea and diabetes (Mallikharjuna et al., 2007).

Crossopteryx febrifuga is the only species in the *Crossopteryx* genus. The alkaloids crossopterine and crossoptine and the glycoside B-quinovine have been isolated from it (Elufioye and Agbedahunsi, 2004). Quercetin derivatives, other flavonoids (Tomás-Barberán and Hostettmann, 1988), a bisdesmonic terpene and a triterpene (Gariboldi et al., 1990) were isolated from the stem bark. A triterpene saponin characterized by a novel ursadienedioic acid aglycone moiety was isolated from the root bark (Babady-Bila et al., 1991). A syrup produced from the fruit is one of the "improved traditional medicines" used in Mali and is well known amongst the population and prescribed by up to 76% of biomedical health workers for dry coughs (Willcox et al., 2012). The leaves are used to treat antiamoebic and spasmolytic antidiarrheal activities. The active ingredient was in the polyphenolic fraction (Tona et al., 2000). The bark is also used to treat diarrhoea, dysentery and fevers (Tomás-Barberán and Hostettmann, 1988).

Baccharoides adoensis var. *kotschyana* (synonym *Vernonia kotschyana*) is used in Mali to treat gastrointestinal disorders and wound healing. This has been attributed to the immunomodulating properties of acidic polysaccharides isolated by Nergards et al. (2004).

Catharanthus roseus is a well-studied medicinal plant. More than 130 terpenoid indole alkaloids (MIAs) including two commercially important cytotoxic dimeric alkaloids used in cancer chemotherapy has been reported from it (Van der Heijden et al., 2004). However, little reference could be found in the literature regarding its traditional use to treat malaria.

Holarrhena pubescens is a well-known medicinal plant in India and Southern Africa. It has been extensively studied for its alkaloids and steroids (Siddiqui et al., 1993, 2001). The stem bark is used to treat amoebic dysentery, helminthic infections, diarrhoea, toothache and as a tonic. The steroidal alkaloids, holamide and pubscinine, were isolated from the ethanolic extract and demonstrated to have hypotensive properties (Aftab et al., 2009). An antimalarial steroidal alkaloid has been isolated from *Holarrhena pubescens* (synonym Holarrhena antidysenterica (Roth) Wall. ex A.DC) (Dua et al., 2013). The leaves of *Holarrhena pubescens* contains the flavonoid naringin, naringenin glycosides and the triterpenes lupeol, lupeol β-hydroxyhexadecanoate and ursolic acid (Pittaya et al., 2006). Three known pentacyclic triterpenoids namely lupeol, betulinaldehyde, and betulinic acid and a steroidal compound stigmasterol were isolated from the seeds (Bhattachartya et al., 2009).

Momordica balsamina, known as African pumpkin, is a vegetable used as food, mainly in sub-Saharan Africa. It has also been used in traditional African medicine in Africa to treat diabetes and malaria. Triterpene-type triterpenoids and phenylpropanoid glycosides were isolated from it (De Tommasi et al., 1991; Ramalhete et al., 2009). The presence of chlorogenic acids in the leaves of *Momordica foetida*, *Momordica balsamina* and *Momordica charantia* L. (esters of p-coumaric, caffeic and ferulic acid and quinic acid) was established (Madala et al., 2014). Phenylethanoid and phenylpropanoid glycosides have been isolated from the Brazilian plant *Stachytarpheta cayennensis* (Rich. Vahl) (Verbenaceae) used as a remedy for malaria (Froelich et al., 2007). Five new pimarane diterpenes were isolated from the aerial parts (De Tommasi et al., 1995).

Momordica foetida is closely related to M. balsamica and *Momordica charantia*. Similarly to M. balsamica it is used to treat diabetes and malaria. Cucerbane triterpenoids were isolated from a chloroform extract of the leaves (Mulholland et al., 1997). Froelich et al. (2008) isolated *O*-glycopuranosides (of two flavanones, a flavonol and a chromone from the leaves of Momordica foetida from extracts with antiplasmodial activity. *Momordica charantia* has been intensively investigated because of its antidiabetic properties. More than 50 cucerbane triterpenoids were isolated and characterize the closely related *Momordica charantia* (Chen et al., 2009). No references could be found for *Pavetta schumaniana*. The related species *Pavetta crassipes* K. Schum contains flavonoids (Asusheyi et al., 2014) including a quercetin-

3-O-rutinoside which has good antimicrobial activity (Bello et al., 2011). Its significant antimalarial activity was attributed to alkaloids (Sanon et al., 2003a, 2003b).

The medicinal properties of *Plumbago zeylanica* reviewed by Jain et al. (2014) is an important medicinal plant in Africa and Asia. Plumbagic acid glucosides, naphthoquinones and coumarins have been isolated from the roots (Lie-Chwen Lin et al., 2003).

Adenia cissampeloides has been poorly studied and no pure compounds have been reported from it or related species. Njoku et al. (2011) identified tannins, saponins, phlobatannins, flavonoids, terpenoids, steroids, alkaloids, carbohydrates and glycosides with TLC and spray reagents. Similar results were published for *Adenia lobata* (Jacq.) Engl. used to treat cancer in Nigeria (Agoreyo et al., 2012).

In vitro antiplasmodial activity does not necessarily translate into antimalarial drugs since there may be poor bioavailability and toxicity. The opposite is also true as the molecules with antimalarial properties may occur as prodrugs in plant extracts and need to be metabolized enzymatically in humans to bioactive compounds.

Variability in the composition of the plants due to different chemotypes or physiological stage of the plant or climatic and soil conditions may influence the composition of plant extracts from the same species. It is not known to what extent this is taken into account by healers when collecting plant material. Gessler et al. (1994) demonstrates that plants mentioned in the literature for anti-malarial properties do not necessarily show high activity in an in vitro test. This was for example the case with *Cassia abbreviata* which gave only moderate results in their in vitro test (IC_{50} = 10–50 mg/ml), although it has been known to be used as an anti-malarial treatment in various countries. Some plants may be used in the treatment of malaria, not for their antiplasmodial properties but because of other therapeutic health properties. These would include reducing fever, convulsions and headache, and possibly even immuno-stimulatory effects (Rasoanaivo et al., 1992; Gessler et al., 1994).

Different levels of activity found in samples of material from the same plant species but collected in different regions suggest that the locality and probably also the time of collection may be important in the amount and composition of their active components (Capasso, 1985; Gessler et al., 1994). Gessler et al. (1995) report that the chemical composition of the various plant constituents is affected by the climatic conditions and the locality under which the plant species are growing. Klayman (1985) confirms that the active compounds of *Artemisia annua* can vary significantly within the same plant species growing in different continents.

Another problem is that plants are often used in mixtures and are perhaps only fully active in this combination, due to synergistic effects. Elford et al. (1987) show that certain flavonoids act synergistically with artemisinin against *Plasmodium falciparum* in vitro at concentrations in which they exhibit no individual antiplasmodial activity.

5. Conclusion

Local traditional knowledge and the practice of plant-based medicine are still widespread in rural areas such as the Chipinge district in Zimbabwe and traditional healers play an important role in primary health care. This is probably because of the frequent incidence of malaria and the remoteness of the villages. Easy access to the plants and the simplicity of preparing medicines from plants are essential as well.

The data gathered in this survey could assist in identifying plant species and extraction methods to develop herbal drugs against malaria in Zimbabwe. The most widely used plants for the treatment of malaria reported in this study such as *Cassia abbreviata* and *Aristolochia albida* should be prioritized for further research. In vitro screening programmes, based on this and other ethnobotanical study results, could be important in validating the traditional use of herbal remedies and for providing leads in the search for new active principles. Another method to improve traditional medicines is the *Retrospective Treatment Outcome Study* (RTO). The advantage of applying this method developed by Graz et al. (2005) and described in further detail by Willcox et al. (2011) is that it adds clinical information and statistical analysis to ethnobotanical studies. Scientific validation of herbal medicine may eventually lead to more widespread use of traditional medicines in cheaper health care systems, as in India and China, provided that thorough toxicological investigations, clinical studies and randomized controlled trials are carried out. African traditional knowledge and medicine thus have the potential to play a large role in primary healthcare, particularly in poor and isolated rural areas. This underscores the value of traditional knowledge and the need to collect and preserve traditional health practices.

The wide variation in plant species used by traditional healers in the same area, the absence of standardised preparations and dosages and the low rate of referral to hospitals when a treatment has failed is worrying. This and the lack of scientific knowledge on the toxicity and active ingredients probably explain the low acceptability and adoption of African traditional medicine into national health systems. Traditional healers should be educated as to when patients, particularly children below the age of two and pregnant women, should be referred to clinics and hospitals. The toxicity and efficacy of traditional medicines should be scientifically validated to enable the manufacture of safe and effective standardized herbal treatments. This is not an easy task due to the complex composition of herbal extracts and the uncertainty about whether single chemical entities are metabolized to active drugs after ingestion and whether more than one chemical entity acts in synergy.

Work is in progress to manufacture extracts of the 26 plant species collected during this ethnobotanical survey and to screen these extracts in antiplasmodial bioassays. The results will be published separately.

Authors' contributions

TN conceptualized the study and CK and JJ reviewed the research proposal. TN conducted the ethnobotanical survey and analyzed the field data. TN, CK and JvdW drafted the manuscript. All the authors participated in writing and giving feedback on the manuscript. All authors have read and approved the final manuscript.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jep.2014.11.011.

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