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Participatory inventory of plant-based ethnoveterinary medicine used to control internal parasites of goats in the Ngamiland region of Botswana.

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ABSTRACT

The effect of internal parasites on goats is of major concern, particularly in the tropics where there are limited resources and financially constrained farmers. The ethnic knowledge on controlling and treating internal parasites is of value to sustainable and organic product production which are essential for long-term prosperity of goat farmers. Using participatory approaches, this study identified and documented popular plants used by farmers to control internal parasites in goats in the Ngamiland region of Botswana. A total of 120 communal farmers were interviewed using a structured questionnaire consisting of demographic parameters and ethnobotanical information. The data was analysed using Statistical Package for the Social Sciences (SPSS) and the most popular plants were identified using fidelity levels (FL). Most of the informants were secondary educated males of 50 to 60 years and relied on livestock for their livelihoods. It was recorded that a total of 13 local plant species from 11 families are commonly used in the treatment of intestinal parasites in goats. The plant family Fabaceae (27.3 %) was common among the farmers. The roots (76.9 %) were the most frequently used plant part while decoction (46 %) was popular in medicinal preparations. The prepared plant-based medicine is often administered orally. The highest FL values were found for the following plant species; *Terminalia sericea, Gnidia capitata* and *Aloe ferox,* scoring 89.3 %, 88.0 % and 86.3 %, respectively. The safety and efficacy of these plants should be validated to inform strategic utilization and alternative cost-effective strategy in managing internal parasites in Botswana.

1. Introduction

Goat production plays a significant role in both developing and developed nations. It contributes significantly to the promotion of human health by providing animal protein of high value in the form of meat and milk (Sujon et al., 2008). There are more than one billion goats in the world, and most have adapted to challenging conditions of different production systems (FAO, 2021). Africa is a host to about 423 million goats, with southern Africa contributing about 35 million (Mataveia *et al*., 2021). Most of the goats in the continent are kept by resource-limited farmers where they are used in alleviating poverty, improving living standards, contributing to gender equity (Monau *et al*., 2020). For example, in Botswana, there are approximately 22 000 female goat holdings compared to 36,000 male goat holdings. Although there is quite a difference between genders, there is growth compared to 9000 of female cattle holdings and 26,000 male cattle holdings (Statistics Botswana, 2019). Compared to other livestock species, production efficiency of goats lags behind, particularly in developing countries including Botswana. Several reasons have been attributed to this effect, such as poor management, low financial input, diseases and parasites (Monau et al., 2017) and lack of organised markets.

The goat production cycle is relatively short, with 5–6 months gestation and 4 months to wean a kid (Peaker, 1978). Therefore, potentially it is possible to take 2 years to produce 3 kiddings and when combined with high litters size (twins or triplets) it means meat production is increased many folds and is achieved within a relative short span of time. However, these good attributes of goat production in the tropics and subtropics are often stifled by internal parasites. This is due to climatic conditions, inadequate husbandry practices and poor control measures (Zvinorova *et al*., 2016).

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According to a study by Sharma and Busang (2013), several parasitic gastrointestinal parasites have been reported in goats in Botswana, with eight genera of strongylid nematodes, namely *Trichostrongylus, Haemonchus, Oesophagostomum, Cooperia, Chabertia, Bunostomum, Trichuris* and *Strongyloides* species, one species of trematode *Paramphistomum* and proglottids of *Moniezia* species, a cestode, being identified. The impact of internal parasites includes reduced feed intake, increased age at puberty and treatment costs (Molefe *et al*., 2012; Roeber *et al*., 2013). The internal parasites can further contribute to a decrease in animal weight gains (Hogberg *et al*., 2023) and a negative economic impact on the production systems (Tachack *et al*., 2022). The common method of controlling internal parasites consist of synthetic anthelmintic medications whose active ingredients include benzimidazoles, levamisole and macrocyclic lactones (N'guessan *et al*., 2021). However, the use of synthetic anthelmintic medications may promote several issues which include the development of drug resistance (Besier 2007; Tsotetsi *et al*. 2013), soil micro and macrofauna destabilization (Lumaret *et al*., 2012), and increased consumption of chemical residues in meat and milk (Jayathilakan et al., 2012). In marginalised areas of sub-Saharan Africa, the use of anthelmintic medications has been impractical due to incorrect dosages, inadequate supply of drugs by government institutions, inability to reach veterinary shops and ever-increasing drug prices (Ndlela *et al*., 2022).

In this context, cutting-edge interventions, such as the use of local knowledge of ecological resources for veterinary care, become necessary. The plant kingdom is renowned for offering a wide variety of secondary metabolites which possess chemical structures that are not present in synthetic compounds and play a significant role in controlling diseases and parasites (McGaw et al., 2007). Currently, most pastoralists and agricultural communities in the southern African region practice plant based ethnoveterinary medicine in goats. For instance, in South Africa, KwaZulu Natal Province, twelve (12) plant species were commonly used to control internal parasites in goats, with *Cissus quadrangularis* L. being the most predominant (97 %) (Ndlela *et al*., 2022). In Botswana, Kweneng region, about 17.65 % aloe plant species have been reported to control internal parasites in goats (Setlalekgomo and Setlalekgomo, 2013). This study, however, does not represent ethnoveterinary practices in other regions of Botswana hence the need for further documentation. Moreover, ethnoveterinary medicine differ from ethnic group to the other as well as from region to region. Comprehending the utilisation of plant based ethnoveterinary medicine create a groundwork for future scientific interventions that are relevant for sustainable resource management practices and goat productivity. The objective of this study was to identify and document local plants used to control internal parasites in goats in the Ngamiland region of Botswana. The Ngamiland region has about 80 thousand goats (Statistics Botswana, 2019) and possess a vast diverse range of plant species that serves as an important medical resource and plant based ethnoveterinary is mostly practiced. The habitat is quite unique compared to other regions in Botswana. This region also obtains the least annual rainfall and possess diverse wildlife animals which affect crop production. Livestock production is key to livelihoods of farmers in this region and any intervention that helps improve livestock productivity will directly improve livelihoods of these communities.

2. Methodology

2.1. Ethical statement

All the data collection methods used in this study were conducted in accordance with relevant guidelines and regulations provided by the Botswana University of Agriculture and Natural Resources Ethical Committee (Reference number: BUAN-AEC-2023–04). Informed consent which ensured anonymity, protection, privacy, dignity, and integrity of the participants in the study was carried out before data collection, and the objectives of the study were thoroughly explained. The consent was obtained through signatures for literate participants and verbally for the illiterates. The verbal consent form was completed in the presence of the Botswana University of Agriculture and Natural Resources Ethical Committee member. All participants were informed that they are free to drop out from the study at any time.

2.2. Study site

The study was carried out in Ngamiland region which is in the Northwest part of Botswana between latitudes 20°00′00 S and 22° 30′00 E (Fig. 1) and possess a total surface of 129 130 km2 (Mcfarlane and Eckardt, 2004). Ngamiland is situated within the sand-veld and its vegetation is largely characterised by savannah with tall grasses, bushes, and trees such as *Colophospermum mopane* and *Terminalia sericea* (Tedder, 2012). The area experiences 490 mm of rain on average each year with most rains in the summer (Moses, 2019). The average minimum and maximum temperatures are 16.4 °C and 31.5 °C, respectively (World climate Guide, 2020). The human population of the region is about 193 725 (Statistics Botswana, 2022) and the most ethnic groups found include Batawana, Baherero, Bahambukushu, Bayeyi and Basarwa (Larson, 1989). Most of the households are active in livestock production, for instance, there are about 2075 female goat households and 3086 male goat households (Statistics Botswana, 2019). The most prevalent livestock diseases in the study area are both internal and external parasites, Foot and Mouth and Dermatophilosis diseases (Gabalebatse *et al*., 2013).

2.3. Data collection

Six villages were randomly selected from the Ngamiland region, namely Ghani, Chukumuchu, Mohembo Tsau, Semboyo and Makakung (Fig. 1). A snowball sampling approach (Patton 1990) was used to select goat farmers. According to Patton (1990), snowball sampling is a method for identifying key informants who are rich in information, contacting them for interviews, and those individuals can recommend to the interviewer other possible respondents. A structured questionnaire was used to collect data. The questionnaire included demographic data such as gender, age, and source of income. The ethnobotanical information gathered included local name of plant used, plant parts utilized, method of preparation, undesirable effects, and dosages. Other information gathered included information source, and other ways of managing internal parasites. Consent of farmers was acquired before administration of the questionnaire. The survey was conducted orally using both English and Setswana.

2.4. Data analysis

The data was analysed using Statistical Package for the Social Sciences (SPSS) software, version 28.0.1 (SPSS Inc, 2022). The most popular plants in the region were identified using fidelity level (FL) values, which was a sign of a plant's potential effectiveness. The fidelity level was calculated using the formula,

FL= (Na /N) × 100 where Na is the number of respondents who use a specific plant for the treatment of internal parasites and N is the total number of respondents who use plant species for the treatment of internal parasites (Alexiades, 1996). The data analysis also focused on generating descriptive statistics (frequencies/percentages) related to participants' demographics, livestock species kept and ethnoveterinary practices.

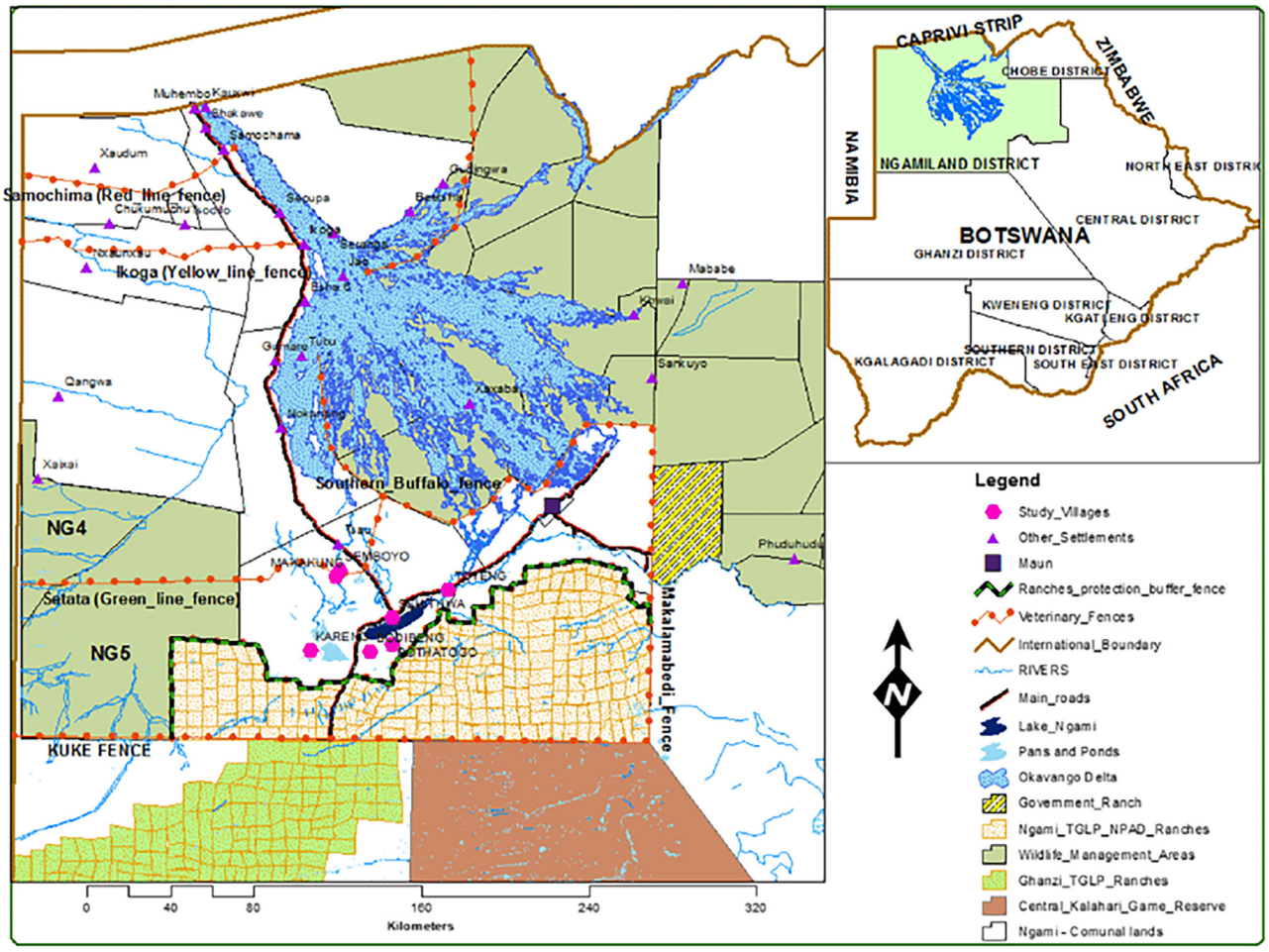

Fig. 1. Ngamiland region of Botswana- Study area (source- Ministry of Agriculture, Botswana, 2017).

3. Results

3.1. Demographic data

A total of one hundred and twenty (120) informants were interviewed in six villages (n = 20 each) of the Ngamiland region. The majority of the informants were males (71 %) and females were in the minority at 29 % (Table 1). The most represented age groups were 51–60 (36.7 %) followed by 61–70 (20 %) and 41–50 years (15 %). The majority of informants acquired secondary education (43 %) whilst a total of 20 % never went to school. Regarding their upkeep, most of the informants depended on the sale of livestock and crops (Table 1). Most of the informants acquired knowledge on ethnoveterinary medicine orally from their elderly parents (93,3 %) (Table 1).

Fig. 2 summarises the purpose of keeping goats as articulated by informants in the Ngamiland region. All the informants kept goats for meat (100 %) and about 92 % of the informants kept goats for income generation (Fig. 2).

All respondents owned livestock, which included cattle, sheep, goats, chickens, pigs, donkeys, and horses as shown on Table 2. Most livestock kept are cattle and goats whilst pigs are in the minority (Table 2).

3.2. Ethnobotanical information

Fig. 3 summarises the common methods used by respondents in Ngamiland region for controlling internal parasites. The majority (65 %) of respondents use local plants, while 25 % use commercial

Table 1
Summary of demographic characteristics of the respondent in the Ngamiland region.

Characteristics	Total Participants (n = 120)	Percentages
Gender		
Male	85	70.8
Females	35	29.2
Age		
20–30	04	3.3
31–40	16	13.3
41–50	18	15.0
51–60	44	36.7
61–70	24	20.0
71–80	10	8.3
81 and above	04	3.3
Level of Education		
Primary	34	28.3
Secondary	51	42.5
University/College	11	9.2
Informal education	24	20.0
Source of income		
Crop sales	92	76.7
Livestock sales	120	100
Salary/wages	45	37.5
Pension	22	18.3
Social grants	63	52.5
Source of information		
Elderly people	112	93.3
Books	04	3.3
Internet	02	1.7
Traditional doctors	02	1.7

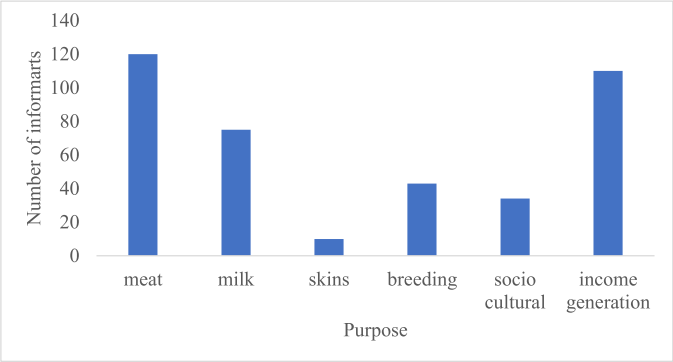

Fig. 2. Reasons for keeping goats as stated by respondents in the Ngamiland region.

Table 2
Total number of livestock kept by respondents across the six villages in the Ngamiland region.

Village	Number of livestock Cattle Goats Sheep Donkeys Horses Chickens Pigs
Ghani	1010 710 210 234 104 98 00
Chukumuchu	988 568 198 232 98 40 00
Mohembo	906 668 201 237 178 62 18
Tsau	1084 690 188 240 115 78 00
Makakung	1034 700 204 250 160 44 10
Semboyo	1062 677 207 229 111 100 26
Total	**6084 4013 1208 1422 766 422 54**

Table 3
Frequency of administration of plant remedies by different farmers.

Frequency of administration	Number of respondents
Once a year	50
Twice a year	36
Thrice a year	10
Others	24

drugs and 10 % use both medicinal plants and commercial drugs to treat and control internal parasites in goats (Fig. 3A). The common commercial drug used by respondents was Invermax 1 % (ivermectin) injectable solution as indicated in Fig. 3B.

Table 3 summarises the frequency of administration of plant remedies by respondents. Majority of respondents administered plant remedies once a year, while only a few gave plant remedies thrice a year.

Table 4 designate thirteen (13) plant species used by the informants in the treatment of internal parasites of goats. Most of the medicinal plants are found in the wild. Fabaceae is the most frequently mentioned plant family (Table 4). The common plant parts used in preparing the remedies are roots (76.9 %) followed by leaves (69.2 %) and bark (15.4 %). In preparing ethnoveterinary medicine, a total of 46 % respondents uses decoctions, while 31 % use infusions and 23 % use both decoctions and infusions methods. Fresh and dried plant parts are used in preparing concoctions. The participants reported no side effects of plant used.

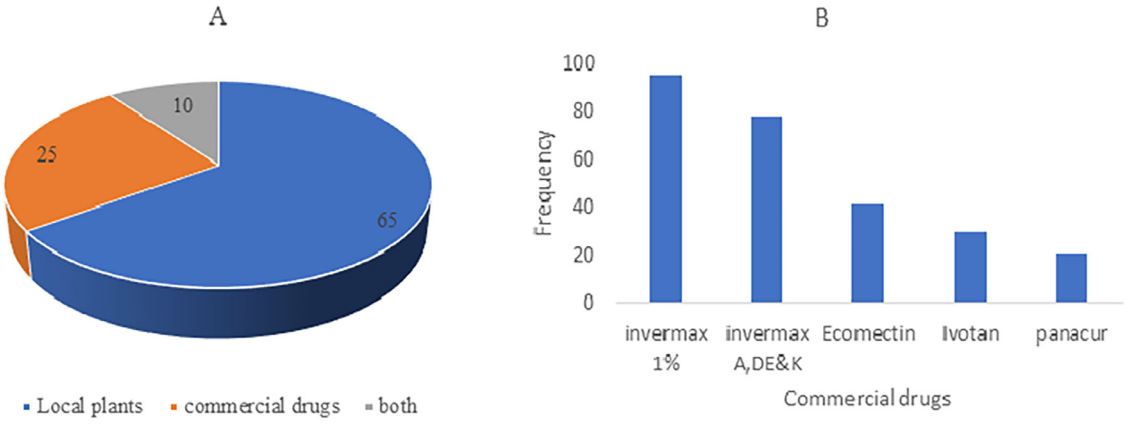

Fig. 3. Methods used in controlling internal parasites and commercial drugs used by respondents in the Ngamiland region.

Table 4
Ethnobotanical information on local plants used to control internal parasites in goats in the Ngamiland region.

Family name	Scientific name	Setswana name	Parts used	*Method of preparation	Route	Dosage (ml)
Capparaceae	*Boscia albitrunca* (Burch.) Gilg & Gilg-Ben.	Motlopi	Leaves, roots	Decoction	Oral	100
Fabaceae	*Colophospermum mopane* (J.Kirk ex Benth.) J.Léonard	Mophane	Bark, leaves	Infusion, decoction	Oral	100
Rhamnaceae	*Ziziphus mucronata* Willd.	Mokgalo	Roots, leaves	Decoction, infusion	Oral	50
Malvaceae	*Grewia flavescens* Juss.	Motsotsojane	Leaves, roots	Infusion	Oral	100–300
Combretaceae	*Terminalia sericea* Cambess.	Mogonono	Roots	Infusion	Oral	100–200
Asphodelaceae	*Aloe ferox* Mill.	Mokgwapha	Leaves	Infusion	Oral	150
Thymelaceae	*Gnidia capitata* L.f.	Mokaikai	Roots, leaves	Decoction, infusion	Oral	100–200
Orchidaceae	*Ansellia Africana* Lindl.	Palamela	Roots	Decoction	Oral	200
Solanaceae	*Solanum nigrum* L.	Makgonatsotlhe	Roots	Infusion	Oral	200
Compositae	*Tarchonanthus camphoratus* L.	Moologa	Roots	Infusion	Oral	50–100
Fabaceae	*Elephantorrhiza elephantina* (Burch.) Skeels	Mositsane	Leaves	Decoction	Oral	100
Apocynaceae	*Acokanthera oppositifolia* (Lam.) Codd	Serekolo	Leaves	decoction	Oral	200
Fabaceae	*Peltophorum africanum* Sond.	Mosetlha	Roots, leaves, bark	Decoction	Oral	100

*Decoction is a method of extracting plant materials by boiling to dissolve the chemicals of the material. Infusion is a process of extracting chemical compounds from plant material by soaking in water.

Table 5
Fidelity level indices of local plants used to control internal parasites in goats.

Plant species	Fidelity Level (%)
Terminalia sericea	80.8
Gnidia capitata	79.2
Aloe ferox	73.3
Grewia flavescens	55.8
Peltophorum africanum	55.0
Elephontorrhiza elephantina	42.5
Solanum nigrum	37.5
Tarchonanthus comphoratus	36.7
Boscia albitrunca	28.3
Ansellia africana	20.8
Ziziphus mucronata	19.2
Colophospermum mopane	8.3
Acokanthera oppositifolia	6.7

Na is the number of respondents who use a specific plant as a remedy for internal parasites.
N is the total number of respondents who use plant species to treat internal parasites.

3.3. Fidelity level of different plants

Table 5 shows fidelity level (FL) indices of different plant species used to control internal parasites in goats in the Ngamiland region. The highest FL values were found for the following plant species; *Terminalia sericea, Gnidia capitata* and *Aloe ferox* each scoring 89.3 %, 88.0 % and 86.3 %, respectively.

4. Discussion

Ethnoveterinary medicine is part of a community-based approach that provides animal health care that is cheaper, easier, and more sustainable (Mkwanazi et al., 2020). It is important to conserve the ethnoveterinary knowledge since it is vulnerable and at risk of extinction due to lack of recording and documentation, lifestyle changes and technological developments. In this study, the male dominance observed in the demographic characteristics could be due to cultural or religious beliefs. In the African culture, males are trained at a younger age to the head of the household by doing certain roles such as herding of goats, performing spiritual and traditional healing. Women are often associated with family care through cooking and nurturing of children. Similar findings have been reported by Adeniran et al. (2020) in Nigeria, Ndlela et al. (2022) in South Africa and Eiki et al. (2022) in Namibia. However, in other parts of the world such as China and Romania where women were predominant in practising plant-based ethnoveterinary medicine (Shen et al., 2010; Bartha et al., 2015).

The present study has shown that the plant-based ethnoveterinary practice is limited to the elderly as compared to the younger generation. The youth tend to migrate to urban areas and foreign countries seeking better employment opportunities. Similar phenomena have been reported by several authors (Bartha et al., 2015; Jambwa and Nyahangare, 2020; Luo et al., 2022; Ndlela et al., 2022). This trend indicates that transmission of information on plant based ethno-veterinary medicine will eventually decline resulting in extinction through death and unsustainability. Therefore, documentation, conservation of information and sustainable management of these plants is vital in the control of internal parasites in livestock.

Domesticated animals continue to play a significant role in the lives of farmers in this study due to lack of employment, poverty and cultural beliefs. In most African societies people believe that owning livestock is a sign of wealth. The farmers kept livestock as a source of food, income and to buy other commodities for the household. Similar findings have been reported by Monau et al. (2017). The study further revealed that farmers attained some form of formal education which is important in the documentation of medicinal plants. The farmers should be encouraged to document and adopt such remedies for future reference as it can assists on natural resource conservation and sustainable management. Our findings are, however, different from ethnoveterinary practitioners of Omusati and Kunene regions of Namibia who attained lower level of education (Eiki et al. (2022).

The frequent use of medicinal plants for the treatment of internal parasites observed in this study is attributed to their cheapness, and easy accessibility. Herbal plants are broad-spectrum and have low chances of drug resistance (Marandure, 2015). Similar findings have been reported by Moreki et al. (2010). The frequent use of Fabaceae plant family in this study was similar to that reported by McGaw et al. (2020) in South Africa, Eiki et al. (2022) in Omusati and Kunene Regions of Namibia and Adeniran et al. (2020) in the north-central region of Nigeria. The Fabaceae family has broad plant species that are renowned for treating illness associated with respiratory infections (Alhaji and Babalobi, 2015) and diarrhoea (Aremu et al. 2012; Offiah et al., 2012). However, in other regions of Botswana, Kweneng district, Lentsweletau area, Asphodelaceae was reported as the dominant plant family in treatment of internal parasites in goats (Setlalekgomo and Setlalekgomo, 2013).

The frequent utilisation of roots noted in this study was similarly observed by Gabalebatse et al. (2013) in Toteng village of Botswana and by Birhanu and Abera (2015) in western Ethiopia. This is mainly attributed to the fact that roots remain in the soil and are easily accessible even during extended dry seasons. Roots are also broad-spectrum and harbour various bioactive molecules which display curative possibilities (Das et al., 2014). However, the use of roots is often not advocated for, due to harmfulness and unsustainability harvesting methods, ultimately leading to plant extinction (Moyo et al., 2015). The results are different with other studies in southern Africa. Setlalekgomo and Setlalekgomo (2013) observed that the use of plant leaves was highly favoured in other areas of Botswana, such as the Kweneng district. Sanhokwe et al. (2016) also noted that most farmers prefer to use fresh plant parts particularly leaves, especially during the rainy season in the Eastern cape, South Africa. The use of leaves in preparation of herbal remedies reduces loss of plants from the natural habitats as it does not destroy the whole plant.

The preference of the decoction process observed in this study was in accordance with Maphosa and Afolayan (2003) in South Africa but in discrepancy with Gabalebatse et al. (2013) in Toteng village of Botswana where infusion preparation method was of preference for treating internal parasites in different livestock species. This is mainly because decoction helps extracts water-soluble polar compounds and the high temperature helps in reducing the toxicity of thermolabile compounds that may be poisonous to the animals (Djoueche et al., 2011). Farmers prefer oral administration which is a simple and non-invasive form of treatment. The route enables sufficient curative power to be delivered along with quick absorption and distribution of the prepared medications (Teklay et al., 2013). The most popular method of treating and controlling internal parasites across many African cultures is oral administration of medicinal plants because it ensures quick and direct interaction with various plant compounds at the site of action (Chakale et al., 2022; Gradé et al., 2009; Yineger et al., 2007).

High fidelity level (FL) values are highly important in the selection of specific plants for further search of bioactive chemicals (Assefa and Bahiru, 2018). In this study three plant species, *Terminalia sericea, Gnidia capitata* and *Aloe ferox* scored the highest fidelity values and should be subjected to further phytochemical and pharmacological investigation to prove their medicinal efficacy. The results are in agreement with Moreki et al. (2010) and Gabalebatse et al. (2013) who reported that *Terminalia sericea* was used for the treatment of internal parasites in livestock in Chobe district, and Toteng village in the Ngamiland district, respectively. Setlalekgomo and Setlalekgomo (2013), also reported the use of *Aloe ferox* for the control of intestinal

parasites in goats in Lentsweletau village. According to Mwale et al. (2006), Aloe vera leaf and juice may be used internally or externally in animals. This agrees with the present study where respondents infused *Aloe ferox* leaves in water to control internal parasites infection. The findings differ with Eiki et al. (2022) in Namibia who reported *Aloe esculenta* with high fidelity level, whilst Sanhokwe et al. (2016) in South Africa reported high fidelity levels in *A. ferox, A. oppositifolia, A. setosa* and *E. elephantina. Aloe ferox* has been reported to contain a wide range of phytochemical compounds, including anthraquinones, chromones, anthrones, phenolic compounds, flavonoids, tannins, steroids and alkaloids, all of which contribute to its various pharmacological activities (Nalimu et al. 2021). Alkaloids and phenolic compounds are probably the two most important phytochemical compounds that are of medicinal value (Singh et al. 2021). *Terminalia sericea* has also been phytochemically investigated for its chemical constituents, and a diverse group of phytochemicals, namely, pentacyclic triterpenoids, phenolic acids, flavonoids, steroids, and alkaloids has been reported from their plant parts (Nair et al. 2018). Pharmacological studies of *Gnidia* spp. have also revealed that they contain certain compounds i.e. diterpene esters, coumarins, flavonoids, chromones, lignans, and neolignans which are of medicinal value (Bhandurge et al. 2013).

The farmers used clinical signs and symptoms to identify internal parasites infection in goats. Some of these clinical signs include weight loss, loss of appetite, skin rough, swelling throat, breathing problem, diarrhoea, and dehydration (Chakale et al., 2022). Therefore, the effectiveness of these plant remedies is based on the disappearance of clinical signs and symptoms. Thus, there is a great need to discover new biologically active compounds from these plants species and develop novel drugs. Few studies are available about ethnoveterinary medicinal plants and their constituents with antimicrobial activities (Chakale et al., 2021), and these indigenous plants may contain pharmaceutically essential compounds. Therefore, it is important to document and conserve these plant species for sustainable treatment of helminthiasis in goats.

5. Conclusions

The study revealed that there were 13 local plant species that Ngamiland goat farmers use as indigenous knowledge to control internal parasites. Despite the gradual sociocultural change over the years, the locals have retained some remarkable knowledge about plants and their current applications. This shows that the Ngamiland people's use of plants to manage internal parasites in goats is still deeply rooted in their culture. However, there is a need to go a step further and conduct safety, efficacy and optimisation trials to verify farmers' claims that the plants are safe and effective for promotion of adoption.

Declaration of competing interest

The authors declare no conflict of interest.

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References

Adeniran, L.A., Okpi, S., Anjorin, T.S., Ajagbonna, O.P., 2020. Medicinal plants used in ethnoveterinary practices in the Federal Capital Territory, North-Central Nigeria. J. Medicin. Plants Res. 14, 377–388.

Alexiades, M.N., 1996. Collecting ethnobotanical data: an introduction to basic concepts and techniques. Selected Guidelines For Ethnobotanical Research: A Field Manual. The New York Botanical Garden, New York, pp. 53–94.

Alhaji, N.B., Babalobi, O.O., 2015. participatory epidemiology of ethnoveterinary practices fulani pastoralists used to manage contagious bovine pleuropneumonia and other cattle ailments in Niger State, Nigeria. J. Vet. Med..

Aremu, A.O., Finnie, J.F., Van Staden, J., 2012. Potential of South African medicinal plants used as anthelmintics–Their efficacy, safety concerns and reappraisal of current screening methods. South Afr. J. Bot. 82, 134–150.

Assefa, A., Bahiru, A., 2018. Ethnoveterinary botanical survey of medicinal plants in Abergelle, Sekota and Lalibela districts of Amhara region, Northern Ethiopia. J. Ethnopharmacol. 213, 340–349.

Bartha, S.G., Quave, C.L., Balogh, L., Papp, N., 2015. Ethnoveterinary practices of Covasna County, Transylvania, Romania. J. Ethnobiol. Ethnomed. 11, 35.

Bhandurge, P., Rajarajeshwari, N., Ganapaty, S., Pattanshetti, S., 2013. The *Gnidia* genus: a review. Asian J. Biomed. Pharm. Sci. 3, 1–31.

Besier, B., 2007. New anthelmintics for livestock: the time is right. Trends Parasitol. 23, 21–24.

Birhanu, T., Abera, D., 2015. Survey of ethno-veterinary medicinal plants at selected Horro Gudurru districts, Western Ethiopia. Afr. J. Plant Sci. 9, 185–192.

Chakale, M.V., Asong, J.A., Struwig, M., Mwanza, M., Aremu, A.O., 2022. Ethnoveterinary practices and ethnobotanical knowledge on plants used against cattle diseases among two communities in South Africa. Plants 11, 1784.

Chakale, M.V., Mwanza, M., Aremu, A.O., 2021. Ethnoveterinary knowledge and biological evaluation of plants used for mitigating cattle diseases: a critical insight into the trends and patterns in South Africa. Frontl. Vet. Sci. 891.

Das, A., Dan, V., Varughese, G., Varma, A., 2014. Roots of Medicinal importance. Roots Eng. 443–467.

Djoueche, C.M., Azebaze, A.B., Dongmo, A.B., 2011. Investigation of plants used for the ethnoveterinary control of gastro-intestinal parasites in Benoue Region, Cameroon. Tropicultura 29, 205–211.

Eiki, N., Maake, M., Lebelo, S., Sakong, B., Sebola, N., Mabelebele, M., 2022. Survey of ethnoveterinary medicines used to treat livestock diseases in Omusati and Kunene regions of Namibia. Vet. Pharmacol. Toxicol. 9.

FAO., 2021. Livestock Systems. https://www.fao.org/livestock-systems/global-distributions/goats. Retrieved on 28 April 2023.

Gabalebatse, M., Ngwenya, B.N., Teketay, D., Kolawole, D.O., 2013. Ethnoveterinary practices among livestock farmers in Ngamiland district, Botswana. Afr. J. Tradit. Complem. Alternat. Med. 10, 490–502.

Gradé, J.T., Tabuti, J.R.S., Van Damme, P., 2009. Ethnoveterinary knowledge in pastoral Karamoja, Uganda. J. Ethnopharmacol. 122, 273–293.

Högberg, N., Hessle, A., Lidfors, L., Höglund, J., 2023. The effect of weaning age on animal performance in lambs exposed to naturally acquired nematode infections. Vet. Parasitol. 316, 109900.

Jambwa, P., Nyahangare, E.T., 2020. Ethnoveterinary medicine: a Zimbabwean perspective. Ethnovet. Med. 269–283.

Jayathilakan, K., Sultana, K., Radhakrishna, K., Bawa, A.S., 2012. Utilization of byproducts and waste materials from meat, poultry and fish processing industries: a review. J.Food Sci. Technol. 49, 278–293.

Larson, T., 1989. The Bayeyi of Ngamiland. Botsw. Notes. Rec. 21, 23–42.

Luo, B., Hu, Q., Lai, K., Bhatt, A., Hu, R., 2022. Ethnoveterinary survey conducted in Baiku Yao communities in Southwest China. Front. Vet. Sci. 8, 813737.

Lumaret, J.P., Errouissi, F., Floate, K., Römbke, J., Wardhaugh, K., 2012. A Review on the Toxicity and non-target effects of macrocyclic lactones in terrestrial and aquatic environments. Curr. Pharm. Biotechnol. 13, 1004–1060.

Marandure, T., 2015. Concepts and key issues of ethnoveterinary medicine in Africa: a review of its application in Zimbabwe. Afr. J. Agric. Res. 11, 1836–1841.

Mataveia, G.A., Visser, C., Sitoe, A., 2021. Smallholder goat production in Southern Africa: a review. Goat Science-Environment, Health, and Economy.

McGaw, L.J., Famuyide, I.M., Khunoana, E.T., Aremu, A.O., 2020. Ethnoveterinary botanical medicine in South Africa: a review of research from the last decade (2009 to 2019). J. Ethnopharmacol. 257.

Mcfarlane, M.J., Eckardt, F.D., 2004. The transparent linear dunes of North West Ngamiland, Botswana. Botswana Notes Rec. 36, 136–139.

McGaw, L.J., Van der Merwe, D., Eloff, J.N., 2007. In vitro anthelmintic, antibacterial and cytotoxic effects of extracts from plants used in South African ethnoveterinary medicine. Vet. J. 73, 366–372.

Mkwanazi, M.V., Ndlela, S.Z., Chimonyo, M., 2020. Utilisation of indigenous knowledge to control ticks in goats: a case of KwaZulu-Natal Province South Africa. Trop. Anim. Health Prod. 52, 1375–83.

Molefe, N.I., Tsotetsi, A.M., Ashafa, A.O.T., Thekiso, O.M.M., 2012. In vitro anthelmintic activity of *Artemisia afra* and *Mentha longifolia* against parasitic gastro-intestinal nematodes of livestock. Bangladesh J. Pharmacol. 7, 157–163.

Monau, P., Raphaka, K., Zvinorova, C.P., Gondwe, T., 2020. Sustainable utilization of indigenous goats in Southern Africa. Diversity 12, 20.

Monau, P.I., Visser, C., Nsoso, S.J., Van Marle-Köster, E., 2017. A survey analysis of indigenous goat production in communal farming systems of Botswana. Trop. Anim. Health Prod. 49, 1265–1271.

Moreki, J.C., Dikeme, R., Poroga, B., 2010. The role of village poultry in food security and HIV/AIDS mitigation in Chobe District of Botswana. Livest. Res. Rural Dev. 22.

Moses, O., 2019. Weather systems infuencing Botswana rainfall: the case of 9 December 2018 storm in Mahalapye, Botswana. Modell. Earth Syst. Environ. 5, 1473–1480.

Moyo, M., Aremu, A.O., Van Staden, J., 2015. Medicinal plants: an invaluable, dwindling resource in sub-Saharan Africa. J. Ethnopharmacol. 174, 595–606.

Mwale, M., Bhebhe, E., Chimonyo, M., Halimani, T.E., 2006. The in vitro studies on the effect of *Aloe vera* ((L) Webb. and Berth.) and *Aloe spicata* (L.F.) on the control of coccidiosis in chickens. Int. J. Appl. Res. Vet. Med. 4, 128–133.

Nalimu, F., Oloro, J., Kahwa, I., Ogwang, P.E., 2021. Review on the phytochemistry and toxicological profiles of *Aloe vera* and *Aloe ferox*. Futur. J. Pharm. Sci. 7, 145.

Nair, A.A., Anjum, N., Tripathi, Y.C., 2018. A review of Ethnomedicinal, phytochemical and Pharmacological significance of *Terminalia sericea* Burch. J. Pharm. Res. 12, 420–430.
Ndlela, S.Z., Mkwanazi, M.V., Chimonyo, M., 2022. Characterisation of the indigenous knowledge used for gastrointestinal nematode control in smallholder farming areas of KwaZulu-Natal Province, South Africa. BMC Vet. Res. 18, 75.
N'guessan, D.U., Coulibaly, S., Ouattara, M., 2021. Pharmacotherapy of gastrointestinal strongylosis of small ruminants: an update. Int. J. Pharm. Chem. Anal. 8, 159–166.
Offiah, N.V., Dawurung, C.J., Oladipo, O.O., Makoshi, M.S., Makama, S., Elisha, I.L., Gotep, J.G., 2012. Survey of herbal remedies used by Fulani herdsmen in the management of animal diarrhoea in Plateau State, Nigeria (August).
Peaker, M., 1978. Gestation period and litter size in the goat. Br. Vet. J. 134, 379–383.
Roeber, F., Jex, A.R., Gasser, R.B., 2013. Next-generation molecular-diagnostic tools for gastrointestinal nematodes of livestock, with an emphasis on small ruminants. A turning point? Advanced Parasitology 83, 267–333.
Sanhokwe, M., Mupangwa, J., Masika, P.J., Maphosa, V., Muchenje, V., 2016. Medicinal plants used to control internal and external parasites in goats. Onderstepoort J. Vet. Res. 83 (1).
Sharma, S., Busang, M., 2013. Prevalence of some gastrointestinal parasites of ruminants in southern Botswana. Botsw. J. Agric. Appl. Sci. 9 (2), 97–103. Available at: https://ubrisa.ub.bw/bitstream/handle/10311/1706/204-833-1-PB.pdf?sequence=1&isAllowed=y.
Shen, S., Qian, J., Jian Ren, J., 2010. Ethnoveterinary plant remedies used by Nu people in NW Yunnan of China. J. Ethnobiol. Ethnomed. 6, 24.
Setlalekgomo, M.R., Setlalekgomo, T., 2013. The use of ethnoveterinary medicine in goats in Lentsweletau village in Kweneng District of Botswana. J. Vet. Adv. 3, 197–202.
Singh, K., Ajao, A.A.N., Sabiu, S., 2021. Ethnobotanical, phytochemistry, toxological and pharmacological significance of underutilized indigenous *Aloe* species of West Africa. South African Journal of Botany 147, 1007–1015.
SPSS Inc, 2022. SPSS Statistics for Windows, Version 28.0.1. SPSS Inc, Chicago.
Statistics, Botswana. Population and housing census. preliminary results. https://www.statsbots.org.bw/2022-population-and-housing-census-preliminary-results.
Statistics Botswana. 2019. Annual Agricultural Survey Report 2013. Ministry of Agriculture, Gaborone, Botswana. Retrieved April 20, 2023, from http://www.cso.gov.bw/images/agricreport2019.pdf.
Sujon, M.A., Mostofa, M., Jahan, M.S., Das, A.R., Rob, S., 2008. Studies on medicinal plants against gastrointestinal nematodes of goats. Bangladesh J. Vet. Med. 6 (2), 179–183.
Tachack, E.B., Socarrás, T.O., Pastrana, M.O., Cogollo, L.C.P., Benavides, Y.H., Pinto, C.R., Garay, V.O., 2022. Status of gastrointestinal nematode infections and associated epidemiological factors in sheep from Córdoba, Colombia. Trop. Anim. Health Prod. 54, 171.
Tedder, M.J., 2012. Dry Woodland and Savannah Vegetation Dynamics in the Eastern Okavango Delta, Botswana. Faculty of Science and Agriculture. University of Kwazul Natal, Pietermaritzburg.
Teklay, A., Abera, B., Giday, M., 2013. An ethnobotanical study of medicinal plants used in Kilte Awulaelo District, Tigray Region of Ethiopia. J. Ethnobiol. Ethnomed. 9, 65.
Tsotetsi, A.M., Njiro, S., Katsande, T.C., Moyo, G., Baloyi, F., Mpofu, J., 2013. Prevalence of gastrointestinal helminths and anthelmintic resistance on small-scale farms in Gauteng Province, South Africa. Trop. Anim. Health Prod. 45, 751–761.
World Climate Guide., 2020. Climate- Ngamiland. https://www.climatestotravel.com/ retrieved on the 10/09/2022.
Yineger, H., Kelbessa, E., Bekele, T., Lulekal, E., 2007. Ethnoveterinary medicinal plants at bale mountains national park, Ethiopia. J. Ethnopharmacol. 112, 55–70.
Zvinorova, P.I., Halimani, T.E., Muchadeyi, F.C., Matika, O., Riggio, V., Dzama, K., 2016. Prevalence and risk factors of gastrointestinal parasitic infections in goats in low-input low-output farming systems in Zimbabwe. Small Rumin. Resour. 143, 75–83.