Chapter 5
Plants for Controlling Parasites in Goats

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5.1 Introduction

Of the many farmed livestock species, goats are one of the most exploited species, due to their resilience as demonstrated by their ability to thrive under harsh environmental conditions characterized by high ambient temperatures, low humidity and restricted feed availability (Zvinorova et al. 2016). Goats contribute greatly to the livelihoods of communities through the provision of nutrient-dense foods for human consumption, in the form of chevon (meat) and milk, products such as fibre and skins, manure and a "ready-to-use rural-household bank" (Anaeto et al. 2010; Dube et al. 2016; Babiker et al. 2017). This translates into improved socio-economic status of communities that farm them. In developing countries where unreliable veterinary services exist and where poor management (inadequate feed, poor parasite and disease control and inappropriate housing) is the "norm", external and internal parasite infestations compromise goat productivity through stress induced by parasite-mediated skin irritation, anaemia and other diseases that ultimately lead to death of

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the animals (Molefe et al. 2012). Importantly, this parasite-induced stress also leads to poor fertility that manifests as reduced oestrus activity and early embryonic death and increased early post-partum kid deaths, all which negatively impact reproductive capacity (Dobson et al. 2012; Papadopoulos et al. 2013). External parasites like mange mites, ticks, biting and blood-sucking flies (tabanids) and internal parasites particularly *Haemonchus contortus* and *Fasciola hepatica* are more common in developing countries where they compromise goat health and reduce productivity (Roeber et al. 2013; Molina-Hernández et al. 2015; Sargison 2016). In view of the parasites' devastating effects on goat welfare and productivity, parasite control is therefore of utmost importance.

The use of conventional pharmacological agents in the form of acaricides and anthelmintics to control external and internal parasites in goats is characterized by the development of drug resistance within the parasite populations (Zeryehun 2012; Nyahangare et al. 2015; Sargison 2016). Environmental and animal product contamination that stems from the release of drug residues into the environment ultimately results in pollution of the environment. Over and above the problem of resistance and environmental contamination associated with the use of conventional acaricides and anthelmintics, these pharmacological agents are costly and relatively inaccessible (Ngeh et al. 2007; Lem et al. 2014) especially in rural farming communities of developing countries which also are saddled with inadequate and inconsistent veterinary service provision (Kebede et al. 2014).

The use of plant-derived ethnoveterinary medicines in the management of the parasite burden in goats and other livestock is on the increase (Soetan et al. 2011; Carvalho et al. 2012; Kommuru et al. 2014). The relative ease of accessibility, lower cost compared to conventional pharmacological agents and acceptability (they are deemed safer to the environment and animal products) are some of the factors that have provided a fertile ground for the increase in the use of plant-derived ethnoveterinary medicines (SriBalaji and Chakravarthi 2010; Wabo et al. 2010). The use of ethnoveterinary medicines and the transmission of information pertaining to their use are part of the indigenous knowledge systems (IKS). In most developing countries, IKS is transmitted orally through word of mouth with no written records (Sanhokwe et al. 2016) which are amenable to distortions and/or loss of information with time. In order to create a data bank of ethnoveterinary medicines and practices in use, there is a dire need to profile and test in vitro and in vivo and to document results of work pertaining to plant-derived ethnoveterinary medicines. Such an approach over and above generating an important data bank on IKS helps preserve such IKS as intellectual property which can be tapped into in the process of developing sustainable pharmacological agents (drugs) for commercial use in the livestock industry. This chapter seeks to bring to the fore the IKS pertaining to the use ethnoveterinary medicines and research around the subject of ethnoveterinary medicine with an ultimate aim of creating an area of research where IKS in livestock health interfaces with conventional knowledge and value systems.

5.2 Gastrointestinal Parasitism in Goats

Helminthiasis, infestation with or diseases caused by parasitic worms [cestodes (tapeworms), trematodes (flukes) and nematodes (roundworms)], is one of the predominant challenges to livestock (goat) productivity in developing countries (Mungube et al. 2006; Vatta and Lindberg 2006). For example, Kenya and South Africa experience between US$ 26 million and US$ 45 million annual losses from nematode infections (Anonymous 1999; Krecek and Waller 2006). A multiplicity of factors, among them poor management (nutritionally inadequate feeds, poor housing, poor or lack of parasite control and disease control), and favourable environments, for example, warm temperatures that promote parasite multiplication (Di Cerbo et al. 2010; Hassan et al. 2011; Belina et al. 2017), are the major causes of helminthiasis. Maphosa (2009) contended that in tropical areas, the management practice whereby ruminant livestock (goats included) graze year-round results in exposure to continuous infection with parasites. Such continuous exposure to infection by parasites causes lower goat productivity that translates to considerable economic losses (Paddock 2010; Roeber et al. 2013). Parasite infestations that result in subclinical infections lead to prolonged production losses (Kumar et al. 2013; Nasrullah et al. 2014) with profound economic outcomes. The production losses stem from compromised weight gains, feed utilization, reproduction efficiency and meat and milk production (Qamar et al. 2011). The production losses to the goat enterprise due to parasite infestation are aggravated by the cost of anthelmintic drugs required to control the infections (Molina-Hernández et al. 2015).

In goats *Trichostrongylus* species, *Trichuris* species, *Bunostomum* species, *Haemonchus* species, *Oesophagostomum* species and *Ostertagia* species are the major causes of helminthiasis (Kumar et al. 2013). Of the many worm species that cause helminthiasis, *Haemonchus contortus* (barber's pole worm) is the most pathogenic nematode that severely compromises goat productivity and leads to loss through death (Roeber et al. 2013; Villarroel 2013). Infestation with *Haemonchus contortus*, especially in kids, is characterized by high mortalities (Adhikari et al. 2017). This nematode parasite sucks blood leading to loss of blood which manifests as severe anaemia (Roeber et al. 2013).

5.3 External Parasitism in Goats

External parasites such as lice, ticks, fleas and mange mites cause mechanical tissue damage, irritation, inflammation, hypersensitivity, abscesses, weight loss, lameness, anaemia and death in severely infested animals (Beyecha et al. 2014; Seyoum et al. 2015). Therefore, external parasitism in goats is of economic importance as it reduces meat and milk yield and results in losses due to culling and cost of treatment and prevention of parasites. They are also responsible for great preslaughter skin defects, resulting in downgrading and rejection of skins (Mersha 2013; Yacob 2014). Furthermore, external parasites are of zoonotic importance due to their blood-sucking habit, causing the transmission of diseases from animals to animals and from animals to humans (Mersha 2013).

The spread of lice, tick, flea and mite infestations is enhanced by unhygienic conditions, increased population density, poor housing, high temperatures and humidity (Pandita and Ram 1990; Oberem and Schröder 1993). Lice are small wingless ectoparasites that have stout legs and claws which enable them to cling to the host (Wall and Shearer 1997). Lice infestation in goats is a major concern worldwide (Iqbal et al. 2014). The biting lice (*Damalinia caprae*) and the sucking lice (*Linognathus africanus*) are the two most common parasites affecting goats (Giri et al. 2013). The major clinical manifestations of lice infestation in goats are ascribed to the irritation and hypersensitivity reactions to the antigens in the saliva of the lice (Iqbal et al. 2018).

Ticks are one of the most economically important parasites of goats. About 35 tick species are found in Southern Africa (Parola and Raoult 2001). Ticks also cause tick worry by irritating goats and causing discomfort leading to severe energy loss and weight. Hunter (2004) noted that reduced growth in tick-infested goats is due to the presence of toxins in the saliva of ticks. The toxins in saliva affect the entire host's organs which later cause paralysis (Kahn 2006). Severe blood loss which eventually leads to anaemia has been reported in tick-infested goats. Ticks are also vectors which are responsible for transmitting tick-borne diseases such as theileriosis, babesiosis, anaplasmosis and heartwater (Plumb 2008). The common tick species affecting goats include *Demodex caprae*, *Ixodes holocyclus*, *Rhipicephalus sanguineus*, *Rhipicephalus microplus* and *Boophilus decoloratus* (Papadopoulos et al. 1996; Plumb 2008).

Fleas are obligate parasites that affect mammals and birds. In South Africa, about 100 flea species are only responsible for parasitizing domestic livestock (McDermott et al. 2000). High temperatures and humidity favour proliferation of fleas. The most common flea species affecting goats are *Ctenocephalides felis* and *Ctenocephalides canis* (Rahbari et al. 2008). Fleas have been reported to suck blood, therefore causing anaemia and eventually death in heavy infestations (Salam et al. 2009). They also cause severe irritation, and, in some cases, their bites open severe wounds which then become an entry site for other secondary infection.

Mange mite is one of the most important diseases that dreadfully damages small ruminant skins and hides. Mites are very tiny external parasites that burrow beneath the skin surface of hosts and inject subcutaneous secretions which damage the skin (Curtis 2004; Nejash 2013). Mange mites feed on blood, lymph and skin debris of the host (Nejash 2013). The species more commonly found on goats include *Demodex caprae* (goat follicle mite), *Sarcoptes scabiei* (scabies mite), *Psoroptes cuniculi* (psoroptic ear mite) and *Chorioptes bovis* (chorioptic scab mite) (Fentanew et al. 2015).

5.4 Conventional Methods of Controlling Parasites

Under intensive goat production, conventional anthelmintic drugs are routinely used to control internal parasites (Kumar et al. 2013), while in small-scale goat production, due to the high cost and inaccessibility, the use of these conventional drugs to control worms is marginal, non-strategic and characterized by the application of inadequate doses (Shalaby 2013). In the small-scale goat farming sector, worm control using conventional drugs is done when the animals show definite signs of infestation/infection, by which time productivity is already compromised. While it is the norm to practice strategic worm control by dosing every 3–4 weeks, research points to greater benefit (a reduction in pasture infectivity and worm burden) being realized when dosing against internal parasites is done just before and after rain (Shalaby 2013).

As predicted by van Wyk (1990) two decades ago, the routine use of anthelmintic drugs has led to the problem of parasite resistance. The resistance to conventional anthelmintic drugs has become a problem globally that is significantly impacting goat productivity (Fairweather 2011; Dalton et al. 2013; Kotze et al. 2014). In Denmark, notable examples are resistance by *Trichostrongylus* and *Ostertagia* worm species to thiabendazole and levamisole (Maingi et al. 1996). Terrill et al. (2001) contend that in the USA nematode worms that infect the GIT of goats have developed resistance against ivermectin, albendazole and levamisole, while in South Africa *Haemonchus* spp. have developed resistance against albendazole, levamisole and ivermectin (Tsotetsi et al. 2013; Van Wyk et al. 1999; Vatta et al. 2001). High levels of resistance to benzimidazoles by small ruminant internal parasites have been reported in Malaysia (Dorny et al. 1994). The cited examples of resistance point to ample evidence for multiple resistances encompassing all broad-spectrum anthelmintics.

Commercially available chemical acaricides have been used extensively worldwide to control external parasites. Ticks and mites are usually controlled by acaricides which are applied in different ways. Acaricides can be applied by dipping, pour on and spraying (Rajput et al. 2006). Fleas are controlled by insecticides which are formulated as dust sprays or fine sprays (Boone et al. 2001). Anti-tick vaccines have also been developed and are environmentally friendly (Uilenberg 2005). Ivermectin can be used to control parasites such as ticks, fleas and mites. However, in many developing countries, the availability of these commercial acaricides may be inconsistent or completely unavailable (Scialabba 2000). The escalating costs of acaricides, environmental pollution and residues in animal products are also challenges stemming from the use of acaricides (Graf et al. 2004). Commercial drugs also tend to harm non-target organisms (Uilenberg 2005). The development of widespread host resistance is another problem which makes parasite control difficult (Graf et al. 2004; McNair 2015). For example, *Boophilus* ticks are resistant to organophosphate carbonates (Mekonnen 1998).

The high cost, unavailability, inaccessibility, inappropriate and inaccurate use, development of resistance and drug-induced environmental and product contamination associated with the use of conventional acaricidal and anthelmintic drugs to control parasites in goats result in a dire need to search for and develop alternatives that are more natural and whose use is sustainable in the long term.

5.5 Plant-Derived Ethnoveterinary Medicaments for Controlling Parasites

Plant-derived ethnoveterinary medicines have been and continue to be used as acaricidal and anthelmintic drugs in the developed world. Due to the emergence of parasites that are resistant to conventional acaricidal and anthelmintic drugs, there is renewed interest in using plant-derived ethnoveterinary medicaments as alternatives to conventional drugs in the control of parasites in goats (Kumar et al. 2011; Muthee et al. 2011; Burke et al. 2012; Juliet et al. 2012; Koné et al. 2012).

In Katanga province, the Democratic Republic of Congo, nine plant species commonly used to treat gastrointestinal parasitic infections were identified. Among these plants, *Vitex thomasii* (Kikoto muchi), family name Verbenaceae, is commonly used (Embeya et al. 2014). Djoueche et al. (2011) report *Anogeissus leiocarpus* and *Gardenia ternifolia* to be among the plants used to treat intestinal worms in sheep and goats in the Bénoué, Cameroon. In Palestine, 140 plant species with health beneficial medicinal activities are noted to be used in the preparation of ethnoveterinary medicines utilized in treating several livestock diseases including gastrointestinal infections (Ali-Shtayeh et al. 2016). *Trachyspermum ammi*, *Amomum subulatum*, *Punica granatum*, *Nicotiana tabacum*, *Acacia nilotica* and *Withania coagulans* are among the many plants from which ethnoveterinary medicaments are prepared and used successfully in the control of worm infestations (Badar et al. 2017). In Kenya, *Aloe latifolia*, *Azadirachta indica*, *Commiphora eminii*, *Crotalaria laburnifolia*, *Kigelia africana*, *Olea europaea*, *Solanum incanum* and *Warburgia ugandensis* are used by the Meru tribe as anthelmintics (Gakuubi and Wanzala 2012). In South Africa, livestock farmers have a long history of using plant-derived preparations for animal health care (Dold and Cocks 2001; McGaw and Eloff 2005) largely due to the broad diversity of plants with health beneficial activities for livestock health management (Table 5.1). *Aloe ferox*, *Aloe arborescens*, *Acokanthera oppositifolia*, *Elephantorrhiza elephantina*, *Albuca setosa*, *Centella coriacea*, *Bulbine latifolia*, *Teucrium trifidum*, *Strychnos henningsii*, *Leonotis leonurus*, *Cleome gynandra*, *Maerua angolensis* and *Monsonia angustifolia* are among the plants used to control gastrointestinal parasites in South Africa (Maphosa and Masika 2010; Fouche et al. 2016; Sanhokwe et al. 2016).

Table 5.1 Indigenous plants known to have anthelmintic activity in South Africa

Plant species	Family	Local names	Plant part used	Method of preparation	Dosage	Reference
Aloe ferox	Asphodelaceae	Ikhala elikhulu Bitter aloe	Leaves	Infusion	The leaves are crushed, and the juice is mixed with drinking water	Maphosa and Masika (2010), Sanhokwe et al. (2016)
Elephantorrhiza elephantina	Fabaceae	Intolwane Elephant's root	Roots	Decoction	The roots are ground and boiled in water for about 30 min until the water turns red. The animal is dosed with 300 ml	Maphosa and Masika (2010), Sanhokwe et al. (2016)
Acokanthera oppositifolia	Apocynaceae	Intlungunyemba Bushman's poison	Leaves	Decoction	The leaves are ground and boiled, and the mixture is allowed to cool. The animals drenched with a dose of a 1 l bottle for adults and 300 ml bottle for kids	Hutchings et al. (1996), Van Wyk et al. (1997), Maphosa and Masika (2010), Sanhokwe et al. (2016)
Bulbine latifolia	Asphodelaceae	Ingcelwana	Leaves	Decoction	The leaves are ground and boiled. The animals are drenched with 1litre	Sanhokwe et al. (2016)
Albuca setosa	Hyacinthaceae	Ingwebeba	Tuber	Decoction	The tubers are crushed and boiled. The animals are dosed with a 500 ml bottle	Sanhokwe et al. (2016)
Centella coriacea	Apiaceae	Inyongwana	Bark	Decoction	The bark is chopped to make a decoction. After sieving the animal is dosed with approximately 500 ml	Sanhokwe et al. (2016)
Cussonia spicata	Araliaceae	Umsenge	Bark	Infusion	The bark is ground and soaked overnight, and a dose of 300 ml is given to the animal	Sanhokwe et al. (2016)
Gunnera perpensa	Gunneraceae	Iphuzi	Tuber	Decoction	The tuber is crushed and boiled, and a dose of 300 ml is administered to the animal	Sanhokwe et al. (2016)
Agapanthus praecox	Agapanthaceae	Umkondo	Leaves	Infusion	The leaves are ground and soaked in water overnight, and a dose of 500 ml is given to the animal	Sanhokwe et al. (2016)

Plants such as *Ageratum houstonianum* and *Tephrosia vogelii* have been reported to possess strong acaricidal effects (Pamo et al. 2005; Njoroge and Bussmann 2006), while *Tagetes minuta*, *Tithonia diversifolia* and *Lavandula officinalis* have tick repellent properties (Alawa et al. 2002; Njoroge and Bussmann 2006). Botanical surveys carried out in Ethiopia revealed medicinal plants traditionally used against ectoparasites of goats in ethnoveterinary practices. These plants include *Calpurnia aurea* (Aiton) Benth., *Jatropha curcas* L. (Euphorbiaceae) and *Nicotiana tabacum* L. (Solanaceae) (Bekele et al. 2012; Teklay et al. 2013; Alemu and Kemal 2015). In Zimbabwe, several plants are employed against ectoparasites such as *Aloe chabaudii*, *Lippia javanica*, *Musa paradisiaca*, *Nicotiana tabacum*, *Solanum panduriforme*, *Strychnos spinosa* and *Vernonia amygdalina* (Madzimure et al. 2011; Maroyi 2012). Table 5.3 shows some of the plants with demonstrated acaricidal activity in South Africa.

The widespread use of plant-derived ethnoveterinary medicines has led to research that resulted in the isolation of compounds (from these plants) with demonstrable anthelmintic activity: famous examples include santonic acid from *Artemisia maritima* and filicic acid from *Dryopteris filix-mas* (Setzer and Vogler 2006). Tea tree oil is also a commercially available plant-based compound with acaricidal effect against mites (Walton et al. 2000). Due to the multiplicity of plants used in ethnoveterinary medicine in developing countries, there is a need to fully characterize these in order to develop a database of plants and plant-derived compounds with anthelmintic activity for possible commercial exploitation in goat (livestock) production (Table 5.2).

5.6 Preparation of Plant-Derived Ethnoveterinary Medicines and Administration

Water, which is viewed as a universal solvent, is largely used in the preparation of plant-derived ethnoveterinary medicines by farmers (Belmain et al. 2012). Unlike farmers that make use of water, scientists generally use organic solvents to optimize the extraction of health beneficial phytochemicals from plant materials (Grzywacz et al. 2013). Commonly used organic solvents include ethanol, methanol, acetone and hexane (Paulsamy and Jeeshna 2011; Tiwari et al. 2011). Different solvents extract different active compounds due to differences in their solubility (Tiwari et al. 2011; Intisar et al. 2015).

Plant leaves and stem bark (aerial parts) are mostly used in the preparation of the plant-derived ethnoveterinary remedies (Benítez et al. 2012). Of the many plant parts used by farmers, leaves stand out as the most commonly used (Fig. 5.1). Although also found in the stem and root bark, health-giving phytochemicals are found in large concentration in the aerial parts (leaves, flowers, fruits or seeds) of plants (Geetha and Geetha 2014; Sanhokwe et al. 2016). The use of leaves is

Table 5.2 Indigenous plants known to have acaricidal activity in South Africa

Plant species	Family	Local names	Plant part used	Method of preparation	Dosage	Reference
Elephantorrhiza elephantina	Fabaceae	Intolwane	Roots	Decoction	The roots are ground and boiled in water for 30 min until the water turns red. The animals are sprayed with the decoction	Sanhokwe et al. (2016)
Aloe ferox	Asphodelaceae	Ikhala elikhulu	Leaves	Infusion	Leaves are crushed, and the juice is poured on to the skin	Sanhokwe et al. (2016)
Acokanthera oppositifolia	Apocynaceae	Intlungunyemba	Leaves	Decoction	The leaves are ground and boiled. The mixture is allowed to cool before applying to the skin	Sanhokwe et al. (2016)
Bulbine latifolia	Asphodelaceae	Ingcelwana	Leaves	Decoction	The leaves are ground and boiled. After the mixture is allowed to cool, it is applied to the skin	Sanhokwe et al. (2016)

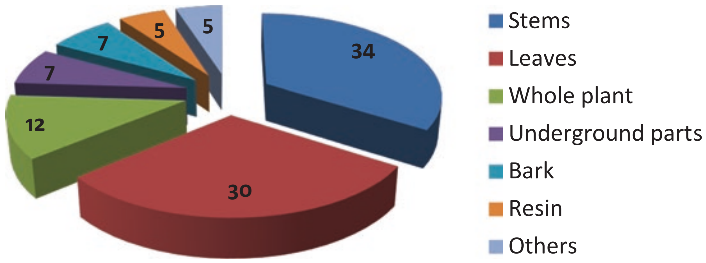

Fig. 5.1 Parts of plants used in the preparation of ethnoveterinary medicaments. (Adapted from Benítez et al. 2012)

considered sustainable (Belmain et al. 2012) since their harvest does not necessarily lead to the death of plants compared to the use of the stem or root bark.

Various processes are utilized in the preparation of plant-derived medicaments resulting in medicines being made in the form of extracts, mixtures, decoctions, infusions and macerations. Decoctions are prepared by adding cold water to the target plant material followed by boiling and simmering for 5–10 min and then straining to remove plant residues. For infusions, boiling water is added to the plant material(s), then allowing the mixture to simmer for 5–10 min before straining. Macerations are prepared by steeping the plant material(s) in cold water for up to 8 h prior to straining (Varma 2016). Some of these ethnoveterinary medicaments are prepared from mixtures of two or more plants and are deemed to act either additively and/or synergistically. All plant-derived ethnoveterinary medicinal preparations used to control internal parasites are administered through oral gavage, while the medicaments used to control external parasites are administered topically.

5.7 Anthelmintic and Acaricidal Efficacy of Plants Indigenous to South Africa

South Africa is home to a diversity of plants with some health beneficial activities. Research has been and continues to be undertaken to determine the efficacy of plant-derived ethnomedicines regarding their potential to control helminths and ectoparasites (Tables 5.3 and 5.4). As a result, characterization of medicinal plants has led to the isolation of compounds with anthelmintic activities. Waller et al. (2001) isolated lactones, like santonin from *Artemisia maritima*, which is effective against *Ascaris* species. Maphosa and Masika (2010) also noted the purgative effects of *Elephantorrhiza elephantina*, which resulted in an improved gastric and intestinal cleaning which is important in the treatment of worm infestations (Maphosa and Masika 2010).

Table 5.3 Indigenous plants screened for anthelmintic potential in South Africa

Plant species	Family	Plant part used	Assay method	Test organism	Concentration/ dose	Findings	Reference
Artemisia afra	Asteraceae	Leaves	Developmental and behavioural assay – in vitro	*Caenorhabditis elegans*	1 and 2 mg/ml	Water extract of *A. afra* had anthelmintic activity against *C. elegans*	McGaw et al. (2000)
Aloe ferox	Asphodelaceae	Leaves	Egg hatching and larval development assay	*Haemonchus contortus*	20, 10, 5, 2.5, 1.25 and 0.625 mg/ml	*A. ferox* extracts inhibited (100%) egg hatching and larval development at concentrations of 20 mg/ml	Maphosa et al. (2010a)
Leonotis leonurus	Lamiaceae	Leaves	Egg hatching and larval development assay	*Haemonchus contortus*	20, 10, 5, 2.5, 1.25 and 0.625 mg/ml	*L. leonurus* extracts inhibited (100%) egg hatching and larval development at 1.25 mg/ml	Maphosa et al. (2010a)
Elephantorrhiza elephantina	Fabaceae	Roots	Egg hatching and larval development assay	*Haemonchus contortus*	20, 10, 5, 2.5, 1.25 and 0.625 mg/ml	*E. elephantina* had 100% egg hatch inhibition at concentrations of 2.5 and 1.25 mg/ml	Maphosa et al. (2010a)
Elephantorrhiza elephantina	Fabaceae	Roots	Faecal egg count	Gastrointestinal nematodes in goats	250 and 500 mg/kg	*E. elephantina* caused a reduction ($P < 0.05$) of *Trichuris* spp. eggs on days 3 and 6 of treatment, at a dose of 250 mg/kg	Maphosa and Masika (2012)
Aloe ferox	Asphodelaceae	Leaves	Faecal egg count	Gastrointestinal nematodes in goats	250 mg/kg 500 mg/kg	A reduction ($P < 0.05$) in strongyle egg count was caused by *A. ferox* extract 500 mg/kg on days 3, 6 and 9 of treatment	Maphosa and Masika (2012)
Leonotis leonurus	Lamiaceae	Leaves	Faecal egg count	*Trichuris* spp. and coccidia oocysts	250 mg/kg 500 mg/kg	A reduction ($P < 0.05$) of faecal egg count of *Trichuris* spp. and *Eimeria* spp. oocysts were observed at 250 mg/kg dose day 9 of treatment	Maphosa and Masika (2012)

Table 5.4 Indigenous plants screened for acaricidal potential in South Africa

Plant species	Family	Plant part used	Assay method	Test organism	Findings	References
Lavandula angustifolia Mill.	Lamiaceae	Aerial parts	Tick climbing repellency	*Hyalomma marginatum rufipes*	200 mg/ml (aqueous) caused 100% repellency up to 2 h post treatment	Mkolo and Magano (2007)
Lippia javanica (Burn. F.) Spreng	Verbenaceae	Aerial parts	Tick climbing repellency	*Hyalomma marginatum rufipes*	107 mg/ml (essential oil) resulted in a repellency index of 100% at 1 h 30 min post treatment	Magano et al. (2011)
Tagetes minuta L.	Asteraceae	Aerial parts	Tick climbing repellency	*Hyalomma rufipes*	Essential oil of *T. minuta* showed a significant dose-dependent effect resulting in delayed moulting in 60% of nymphs after 25 days	Nichu et al. (2012)
Ptaeroxylon obliquum (Thunb.) Radlk	Ptaeroxylaceae	Bark	Adult immersion test	*Rhipicephalus sanguineus*	400 mg/ml (aqueous) repelled ticks for 40 min post treatment	Moyo and Masika (2013)

Nearly all of the preliminary research on the interrogation of anthelmintic activity from plant-derived preparations employ in vitro techniques in bioassaying for activity against helminths (Aremu et al. 2012). In vitro approaches, over and above being cheaper when compared to in vivo approaches, are a necessary tool in the preliminary screening process. They are essential for authentication of potential activity and can be used to determine the mechanism of action.

Having this large pool of plants indigenous to South Africa with purported anthelmintic and acaricidal potential and those that have been screened in vitro and in vivo calls for more focused studies that will help identify phytochemicals responsible for the purported and/or observed activity. Importantly, there is need to also determine the safety of these plant-derived medicaments in the animals in order to avoid a situation whereby the helminthic or ectoparasitic problem is solved at a cost to the health of the animal (Table 5.4).

5.8 Phytochemical Composition and Their Health Beneficial Activities

The health beneficial properties of medicinal plants are attributed to naturally occurring phytochemicals within the plants. Organic compounds inclusive of polyphenols, tannins, terpenes, triterpenoids, flavonoids, saponins and many others constitute phytochemicals. These phytochemicals are produced by plants largely as a mechanism against herbivory and possess biological activity that elicit physiological activities when administered to animals (Bernhoft 2010; Muthee et al. 2016). Importantly, these phytochemicals elicit many health beneficial activities such as antibacterial, antifungal, antiprotozoal and antioxidant among others (Fig. 5.2). Nkohla et al. (2015) contend that these phytochemicals, besides having prophylactic activity against parasites, are effective in the treatment of diseases.

Alkaloids, flavonoids, phenols, saponins and condensed tannins are major phytochemicals with anthelmintic activity (Van Wyk et al. 1997; Naidoo et al. 2005; Ahmed et al. 2013). Satou et al. (2002) reported that alkaloids are effective against *Strongyloides* spp., namely, *S. ratti* and *S. venezuelensis*. Alkaloids act on the central nervous system thus causing worm paralysis. Alkaloids also act as antioxidants

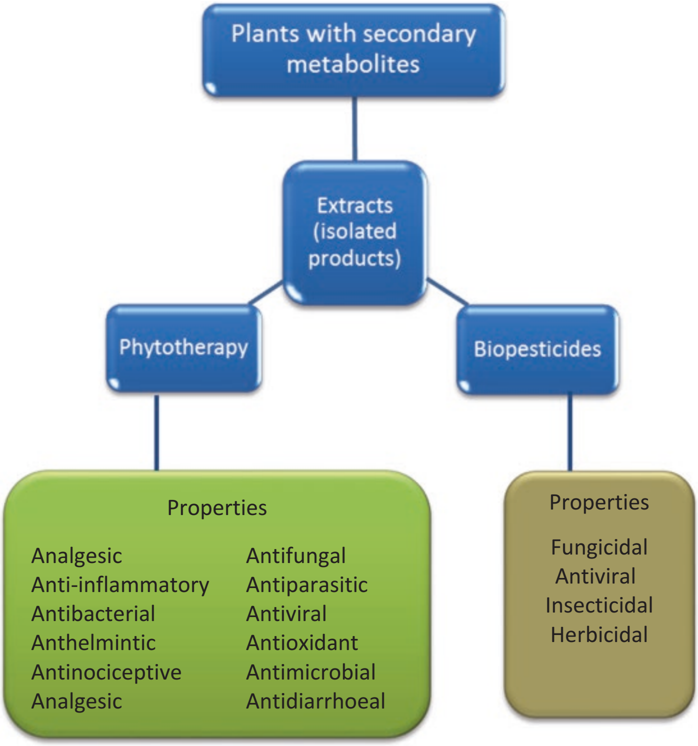

Fig. 5.2 Biological properties of phytochemicals. (Adapted from Van Wyk and Wink 2004)

by reducing nitrate generation which may impede the local homeostasis which is important for the development of parasites (Roy et al. 2010). Phenols affect the energy generation mechanism by uncoupling the oxidative phosphorylation and also impede the glycoprotein of the cell surface of the parasites thereby causing death (John et al. 2009). Saponins are reported to disrupt the cell membrane of the parasites, thereby changing the morphology of the cells in the cuticle (Geidam et al. 2007; Hrckova and Velebny 2013). Vacuolization and disintegration of tegumes consequently affect feed intake and nourishment of the parasites, resulting in parasites dying (Melzig et al. 2001; Hernandez et al. 2014).

Tannins restrict the energy generation of worms by uncoupling oxidative phosphorylation or by binding to the free protein of the gastrointestinal tract of the host or glycoprotein on the cuticles of the worms, leading to death (Patel et al. 2010; Roy et al. 2010).

Terpenes, stilbenes, coumarins, acids, alcohols, sulphurated compounds and aldehydes have been reported to have acaricidal properties (Pamo et al. 2005; Cetin et al. 2010). Terpenes are known to produce a smell that has defence mechanisms against parasites (Tawatsin et al. 2001; Dudareva et al. 2004). Flavonoids and phenols interfere with the reproduction of external parasites by inhibiting the development and maturation of oocytes (Ghosh et al. 2013). Catechin, rutin, myricitrin and quartterin are effective against external parasites through their antifeedant property (Osman et al. 2014).

5.9 Toxicity Effects of Medicinal Plants

While it is the general view that plant-derived ethnomedicines and ethnoveterinary medicines are less toxic compared to conventional pharmacological agents, it is important to interrogate and establish potential toxicity of such medicaments (Aremu et al. 2012). The fact that phytochemicals have specific biological activities warrants the need to determine accurately safe doses of ethnoveterinary medicines. The potential toxic effects of plant-derived ethnomedicines are ascribed to the same phytochemicals accountable for the anthelmintic activity (Athanasiadou et al. 2007). The excessive oral intake of alkaloids, terpenes, saponins, lactones, glycosides and phenols has been observed to cause negative effects (Athanasiadou et al. 2007).

It has also been reported that the excessive consumption of tannins has negative effects such as reduced intake and digestibility of feed, impaired rumen metabolism and mucosal toxicity (Wright 2015). Saponins are known to haemolyse erythrocytes (Athanasiadou et al. 2001). Ingestion of a saponin-rich plant is known to cause a reduction in feed intake that manifests in a host of nutritional deficiencies. Cyanogenic glycosides, terpenes or alkaloids when consumed may elicit neurological damage (Bolarinwa et al. 2016), while cysteine proteinases are very harmful in spite of their efficacy against helminths (De Amorin et al. 1999; Stepek et al. 2005). The effectiveness, mechanism of action, possible environmental pollution and also toxicity of plant-derived ethnomedicines and ethnoveterinary medicines need to be clearly established (Aremu et al. 2012). There is a misplaced view that due to their being obtained from plants (which are natural and adapted to local environs), ethnomedicines and ethnoveterinary medicaments are safe to humans and livestock, respectively (Verschaeve and Van Staden 2008). Prior to use and promotion of such plant-derived medicines, it is critical to undertake full toxicity studies in order to establish safety and potential toxic dosages (Aremu et al. 2012).

The safety assessment of the aqueous extract of *E. elephantina* was tested in rats. The safety assessment showed low toxicity on blood parameters (Maphosa et al. 2010b). Histopathological changes included pulmonary granulomas of the liver and renal crystals and pyelonephritis in the kidney. A high dose of 1600 mg/kg bwt of *E. elephantina* was not toxic, but it decreased the respiration rate in rats (Maphosa et al. 2010b). Sub-acute toxicity was observed at higher doses of 400 and 800 mg/kg bwt of *E. elephantina* through increased white blood cells, lymphocytes and serum levels of creatinine (Maphosa et al. 2010b). Chronic toxicity results showed that a dose of 400 mg/kg bwt of *E. elephantina* increased lymphocytes and platelets (Maphosa et al. 2010b). Thus, *E. elephantina* is to some extent safe because it is traditionally used at dosages lower than the doses used in the toxicity evaluation.

The toxicity evaluation of aqueous extract from *L. leonurus* caused death in rats receiving a dose of 3200 mg/kg (Maphosa et al. 2008). The extract also caused alterations in red blood cells; packed cell volume, haemoglobin concentration, mean corpuscular volume, platelets, white blood cells and its differentials at doses of 1600 mg/kg in sub-acute toxicity and 200 mg/kg in chronic toxicity (Maphosa et al. 2008). The chronic toxicity of the extract decreased the levels of urea and creatinine at 1600 mg/kg dose and reduced urea, total bilirubin, total protein, albumin, globulin, glutamine transference gamma-glutamyl transferase (GGT) and alanine transaminase at 400 mg/kg dose (Maphosa et al. 2008; Maphosa and Masika 2012). Due to the toxicity of *L. leonurus*, careful considerations should be made when using the plant for the control of helminths.

The aqueous extract from *Rhus lancea* showed toxic effects against brine shrimps ($LC_{50} = 0.6$ mg/ml) (McGaw et al. 2007). Thus further in vivo tests are necessary to validate the potential toxicity.

5.10 Mechanism of Action of Plants Used to Control Parasites in Goats

Although some plant preparations have anthelmintic activity in most cases, the mechanisms of action are still to be established. Phytochemicals separately or in synergy may inhibit tubulin polymerization and block glucose uptake of parasites (Jain et al. 2011). The inhibition of tubulin polymerization affects feed intake and nourishment of the parasites which leads to death of parasites. Impairment of the mucopolysaccharide membrane of worms leads to the damage of the external layer of the worm which results in a limitation of motility. The limitation in motility is known to cause paralysis and eventual death of the parasite (Chandrashekhar et al. 2008; Jain et al. 2013). The efficacy of tannins against helminths is due to their protein-binding activity (Chandrashekhar et al. 2008; Mulla et al. 2010; Tiwari et al. 2011). By binding proteins, tannins deprive the worms of dietary protein triggering malnourishment which ultimately leads to helminth death (Chandrashekhar et al. 2008; Mulla et al. 2010; Tiwari et al. 2011). Alkaloids affect the central nervous system resulting in worm paralysis (Roy et al. 2010). This effect is thought to be caused by steroidal alkaloids and oligoglycosides, which inhibit the exchange of sucrose in the gastrointestinal tract. Alkaloids also have an antioxidant effect, which may interfere with homeostasis which is essential for the development of the worm (Vadivel and Panwal 2016). In the schematic flow chart below (Fig. 5.3), some of

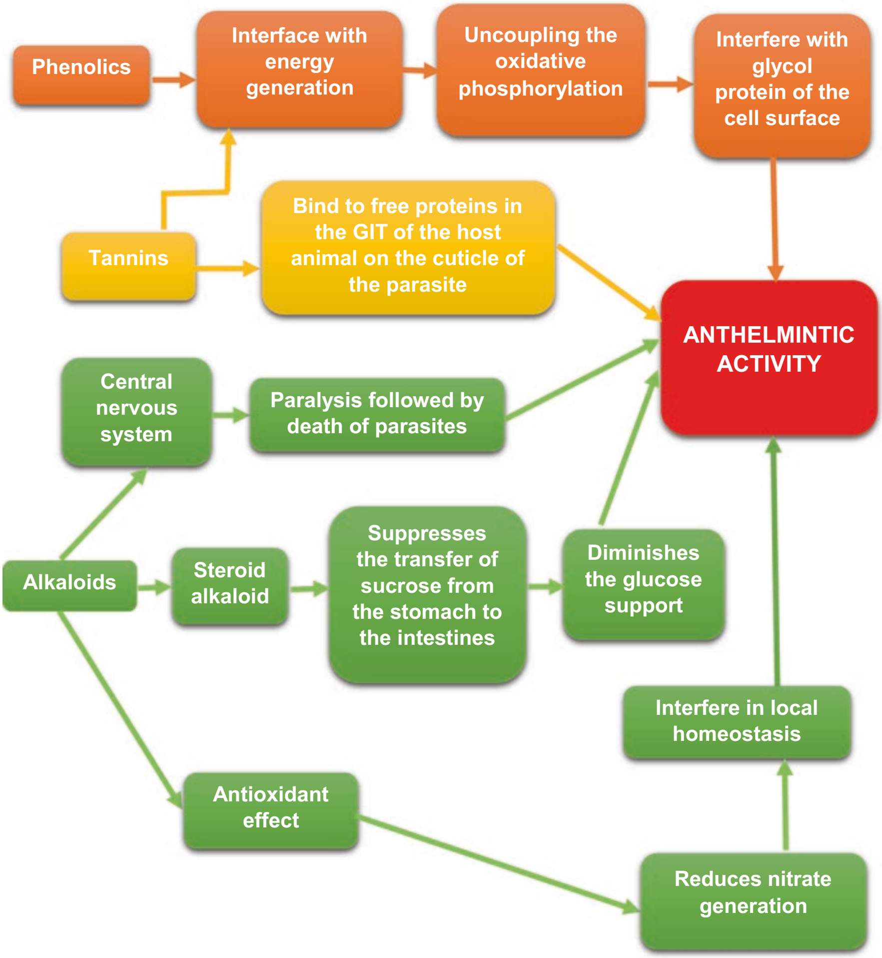

Fig. 5.3 Possible mode of action of phytochemicals as anthelminthics. (Adapted from John et al. 2009; Patel et al. 2010; Roy et al. 2010)

the mechanisms of phytochemicals against helminths are shown (John et al. 2009; Patel et al. 2010; Roy et al. 2010).

The acaricidal role of plants used to control external parasites is not well understood. However, some plant extracts are thought to have toxic effects against parasites causing reduced parasite feeding, moulting, fecundity and viability of eggs (Habeeb 2010), while others have repellent effects (Dautel 2004).

5.11 Challenges in the Use of Plant-Derived Ethnomedicines

The challenges associated with the use of plant-derived ethnoveterinary medicines include incorrect disease diagnosis, ineffective medicinal doses and unhygienic standards of preparation of the medicaments, possible toxicity and lack of transparency regarding the practice of ethnoveterinary medicine (Toyang et al. 2007; Thillaivanan and Samraj 2014). Importantly, the use of ethnoveterinary medicines is limited by geographical area (local application) characterized by poor distribution of information concerning these remedies (Andrews and Blowey 2008). From an environmental and sustainability perspective, most of the ethnoveterinary medicines are derived from indigenous plants in the range (Fig. 5.4), and their use poses a real risk of vegetation and habitat destruction (Yirga et al. 2012). The issues surrounding seasonality, determination of effective doses and treatment schedules are key questions with regard to the use of plant-derived ethnoveterinary medicines (Haverkort et al. 1996; Mosihuzzaman and Choudhary 2008; Obomsawin 2008).

The information on the utilization of medicinal plants is transmitted orally between generations; thus, there is no proper documentation regarding the doses and treatment regimens of the medicaments (Masika and Afolayan 2003; Gurib-Fakim 2006). Importantly, the use of oral narrations to pass information in the twenty-first century results in important information regarding the use of ethnoveterinary medicines being lost because there is no data retrieval system associated with the oral passage of information.

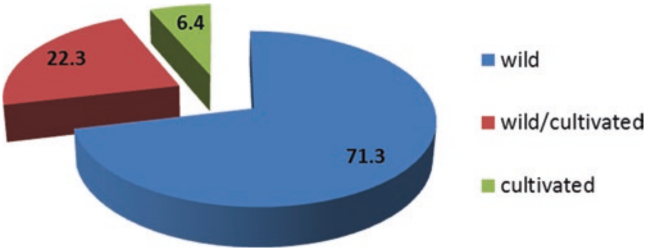

Fig. 5.4 Sources of medicinal plants used in the treatment of livestock diseases. (Adapted from Yirga et al. 2012)

5.12 Future Potential of Plant-Derived Ethnomedicines

Owing to the apparent effectiveness of plant-derived ethnoveterinary remedies in controlling parasites (external and internal), the control of parasites is gaining popularity in sheep (Ahmed et al. 2014; Gemeda et al. 2014; van Zyl et al. 2017), cattle (Moyo and Masika 2009; Min et al. 2015; Nyahangare et al. 2015), poultry (Mwale and Masika 2015; Nghonjuyi et al. 2015), pigs (Lans et al. 2007; Levecke et al. 2014) and goats (Muthee et al. 2011; Burke et al. 2012; Koné et al. 2012; Sanhokwe et al. 2016; Khada et al. 2018). However, there is a paucity of information on the potential effects of these plant-derived ethnoveterinary medicines on the gastrointestinal integrity and immunity of the livestock as well as on product (meat or milk) quality. Studies on the verification of the efficacy and potential toxicity of these plant-derived ethnoveterinary medicines are a necessity for authentication and safety.

5.13 Conclusion

While there is tremendous potential to interrogate and develop viable plant-derived ethnoveterinary medicaments for parasite (external and internal) control in goats and other livestock, there is a need for research to engage and verify claims regarding these potential medicines. Research should focus on determining efficacy, safety and identification of active phytochemicals and establishment of mechanisms of action.

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