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A Review: Herbal Medicine as an Effective Therapeutic Approach for Treating Digestive Disorders in Small Ruminants

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ABSTRACT

Gastrointestinal (GIT) disorder is a significant health and economic problem that account for extraordinary financial loss in small ruminants. Despite the great efforts in management, GIT disorder remains the main cause of animal mortality, weight gain retardation and production loss in the small ruminant industry. Traditionally, herbal medicine has been used to treat and prevent various ruminant disorders. Herbs have nutritional and pharmaceutical properties that interact with one another polyvalently to increase the depth and breadth of the clinical effects compared with those seen in conventional pharmacological drugs. Recently, there has been an increase in the utilization of herbal medicine, reflecting an expanding trust in such therapeutic approaches. These methods have the advantage of utilizing locally available plants with high medicinal properties. Additionally, medicinal plants have the advantages of availability, compatibility with the body, simplicity of storage and negligible side effects. Here, we review representative examples of research available on the most commonly used traditional herbal remedies for the treatment of the most common digestive disorders (diarrhea, rumen insufficiency and GIT nematodes) in small ruminants. We also provide an extensive background on the recent advancement in the adoption of modern platforms in this field and research possibilities for future drug discovery and development.

1-INTRODUCTION

Small ruminants are a very important ecological niche among livestock, as they have a high digestion coefficient for converting poor feedstuffs to very useful products for humans, such as meat, milk and wool (Abd El-Raof et al., 2007). The economic significance of small ruminants in developing countries and the tropics cannot be overestimated (Ghanem et al., 2006). Subsequently, it is important to focus on the illnesses and disorders that influence small ruminants, with a specific end goal of improving and maintaining the profitability of these animals to benefit the human population in such countries.

Gastrointestinal disorders have been the main cause of animal mortality, weight gain retardation and production loss in small ruminant husbandry (Kaplan and Pesca, 2007; Zein Eldin et al., 2013). Varied efficacies of conventional medicaments against GIT disease have been reported. However, concurrently, the pernicious effects of the overuse and misuse of these chemicals, the increased prevalence of resistance and high treatment cost necessitate the development of alternative therapies for the treatment and management of GIT diseases in small ruminants (Rahmann and Seip, 2007). These alternative treatment options include genetic resistance control, pasture management, nutrition adjustment, biological regulation, vaccination, and the use of herbal medicine (LeJambre et al., 2008). Recently, a large number of pharmaceutical companies and researchers from various fields have focused on the potential effectiveness of medicinal herbs as a wealthy resource for drug discovery (Malla et al., 2015; Hossen et al., 2016). In developing countries, approximately 25% of current therapies are developed from traditionally used medicinal plant a source, which has led to the discovery of 75% of the currently available herbal drugs (Jia and Tang, 2003). Meanwhile, in growing countries, the

contribution of medicinal plants to therapeutic medications is as high as 80% (Joy et al., 2001; Jia and Tang, 2003). The history of using herbal medicine to treat illness and enhance overall health has been reviewed by (Engel, 2007), with an emphasis on GIT diseases in small ruminants. Medicinal herbs have been proven to be economical, efficient, easily available and safe to use with almost no side effects (Hossen et al., 2016).

In this review, we focus on the previous and current status of traditional herbal medicine used for the treatment of selected GIT disorders (diarrhea, rumen insufficiency and GIT nematodes) in small ruminants. We also provide an extensive background on the recent advancement in the utilization of modern technology platforms in this field and possibilities for further research in the future.

2-Complexity of herbal medicine

Herbal medicine is generally defined as a pharmaceutical product extracted from the entire plant or from any part of a plant, including leaves, bark, roots, seeds and flowers (Winslow and Kroll, 1998). Herbal remedies may contain a single plant or a mixture of pharmacologically dynamic plants that are accepted as having synergetic impacts (Rotblatt and Ziment, 2002). Herbal plants are sold as either raw herbs or concentrates of the active substance from the entire plant or from the predefined part of the plant. Both the crude plant and the concentrate contain blends of organic chemicals, which may incorporate fatty acids, sterols, alkaloids, flavonoids, glycosides, saponins, tannins, and terpenes (Rotblatt and Ziment, 2002). In this manner, it is difficult to decide which constituent of the plant is responsible for the biological and pharmacological action. Moreover, the procedure for extracting the dynamic substance may change the concoction structure and the pharmacological action of the natural constituents. Additionally, a few natural variables (soil, distance, seasonal variability in temperature, humidity, daylight period, rainfall, shade, dew, and frost conditions) may influence the concentrations of the active plant compounds. Other vital variables, including seeding, harvesting time, genetic component, infections, and competition with other plant species, play a vital role in creating uniform herbal products (Wijesekera, 1991). Due to numerous elements that influence the congregation of active ingredients in the final products, producers have endeavored to make a more consistent product by recognizing certain interesting synthetic segments of a plant that are defined as markers and adjusting the production process to produce a reliable level of these markers in the final batch of the herbal product. Currently, plant markers are defined to have a pharmacological spectrum, but very few are known to have clinical impacts (Zein-Eldin et al., 2014). Additionally, some producers have demonstrated that the standardization during the extraction process by adding purified active markers to the extract impacts the original balance of the organic ingredients in the final product (Ernst, 2005). Therefore, the toxicity and safety profile of the herbal extract should be considered before finalizing herbal products. Despite the multi-faceted quality of herbal products, their efficacy and desirability are superior to those of synthetic chemical drugs (Ernst, 2005).

3-Current technology in the herbal medicine industry

Recently, the international community has turned the modernization of the herbal medicine industry into a crucial component of the comprehensive acknowledgment of alternative therapy. The standardization and quality management of herbal treatment using current science and innovation have become critical. Herbal plants contain multiple active constituents, which can work harmoniously within the host body and yield particular therapeutic activities with minimal or no undesirable side effects. Therefore, the development of modern technology for the herbal therapy industry is likely to play a crucial role in providing high-quality herbal products to customers worldwide (Huie, 2002). For example, the use of modern technology in plant preparation can aid in the extraction of the required chemical ingredients from plants for further separation and characterization. These modern techniques include solid-phase micro-extraction, ultrasonic extraction, supercritical fluid extraction, pressurized liquid extraction, microwave-assisted extraction, solid-phase extraction, and surfactant-mediated extraction. A detailed explanation of the basic principles of modern sample-preparation techniques is available in many published reviews (Huie, 2002). After plant processing, identification of the concentration of biologically active components in the plant should be performed to achieve qualitative and quantitative estimates of quality based on sensitive analytical techniques (Porfírio et al., 2016). Another field of modern technology in herbal medicine is toxicogenomics (Borner et al., 2011), which targets the interaction between the structure and activity of the genome and the negative biological effects of exogenous agents. This field is dependent on the notion that the toxic impacts of xenobiotics on biological systems are generally reflected at the cellular level by their impact on gene expression (transcriptomics), protein determination

(proteomics) and the production of small metabolites (metabonomics). All of these techniques can be powerful tools for future study that will facilitate the development of highly sensitive and real-time detection and the evaluation of active substances in medicinal plants.

4-Herbal medicine use for the treatment of diarrhea in small ruminants

Diarrhea is one of the most significant economic problems in small ruminants and can cause great losses, especially in sheep herds due to the death of many affected animals, particularly in early life (Scott, 2007; Schoenian, 2007). The economic losses arise not only from lamb mortalities but also from the treatment cost and labor required to treat the sick animals. Moreover, acute diarrheal infections encountered in a herd are often difficult to control because of the large numbers of potential enteropathogens and the variability in individual animal immunity within the herd (Benavides et al., 2015). Diarrhea is not generally defined as a GIT disease but rather is a sign of other health problems in food-producing animals (Offiah et al., 2011). The etiology of diarrhea is complex and includes infectious agents, poor management, reproductive circumstances, dietary changes, and host immune status (Diaz-Lee et al., 2011). Thus, diarrhea continues to be the major therapeutic threat in small ruminant production systems (Grayson, 2011). In ruminants, different antimicrobials (oxytetracycline, neomycin, ampicillin, amoxicillin and colstin) are commonly administered for the treatment and control of diarrhea (Bywater, 2005). The use of antibacterial drugs orally, parentally, or by both routes simultaneously for the treatment of bacterial diarrhea is a controversial subject in both human and veterinary medicine due to the development of antimicrobial resistance (Suter et al., 2005). Antimicrobial treatment could additionally aggravate the GIT microbial communities and delay the clinical evolution of the diseased animals (Jiménez et al., 2007). Recently, the therapeutic use of medicinal herbs in the treatment of diarrhea has become a common practice due to the adoption of traditional folk medicines (Devi et al., 2013; Li et al., 2015). Medicinal plants contain multiple active ingredients, such as alkaloids, glycosides, flavonoids, terpenes and tannins, that have potential enhancing and/or neutralizing effects and are considered to be relatively safe for prolonged use (Maikai et al., 2010; Offiah *et al.,* 2011; Gilani and Attaur, 2005). The active constituents of medicinal plants may alleviate diarrhea through interaction with several types of cells in the GIT tract, including epithelial cells, immune cells, commensal microbiota, and pathogenic microbial communities (Teke et al., 2007). A wide range of herbs, including *Anarcardium occidentale*, *Psidium guajava* (Lans and Brown, 1998), *Myristica fragrans* (Zain Eldin et al., 2013) and a granule mixture of *Coptischinensi, Magnoliaofficinalis, Atractylodeslancea, Prunusmume* and *Poriacocos* (Li et al., 2015), have been used for the treatment of diarrhea in small ruminants. In the study by Offiah et al. (2011), 132 medicinal herbs were examined through 248 questionnaires survey, in which 57 plants were properly identified for their antidiarrheal properties. The predominant plant families in this group are the Fabaceae (21%) and Combretaceae (14.04%) families. The medicinal properties of various parts of these herbs were also detected, with the leaves being the most commonly identified part. The route of administration mainly depended on the type of plant processing. Medicinal plants are usually processed by moistening the fresh or raw plant in water and used by drenching the whole extract. In some cases, the plant materials are blended into the diet to improve their palatability. In another study, 43 medicinal herbs belonging to 26 families were found to be used in ethnoveterinary practices for the treatment of GIT disorders in a livestock-rearing system (Mussarat et al., 2014). The results of this study demonstrated that *Zingiber officinale*, *Punica granatum*, *Triticum aestivum*, *Gossypium hirsutum*, and *Withania coagulans* were the most commonly approved species for diarrhea treatment. Medicinal plants used in the treatment of diarrhea in small ruminants are shown in Table 1. Generally, the herbs used in the treatment of diarrhea in small ruminants are administered orally to the affected animal; for example, the crushed stem of *Allium sativum* is boiled in water and decocted to treat gastrointestinal problems in goats and sheep (Casella et al., 2013). Phytochemical screening of *Allium sativum* confirmed the presence of allicin, which is responsible for its action against the gastrointestinal pathogens *Escherichia coli* and *Salmonella typhi* (Saravanan et al., 2010). Moreover, *Cassia fistula* fruit and the fruit cover of *Punica granatum* exhibit strong anti-*Escherichia coli* activity that may be due to the existence of various classes of phenols, flavonoids, terpenoids, saponins, steroids, anthraquinone, and glycoside compounds in the tested extracts (Bhalodia et al., 2012). Some plants are used in a mixture with other plants or as additives for herbal formulations; for example, the seeds of *Foeniculum vulgare* are mixed with different additives, and the root of *Glycyrrhiza glabra* is mixed with flour and used for GIT problems in ruminants. Manonmani et al. (2011) studied *Foeniculum vulgare* seeds in vitro and found that aqueous extracts of the seeds exhibit

strong inhibitory activity against gastrointestinal pathogens such as *Escherichia coli*, *Salmonella typhi*, and *Bacillus cereus*. The pharmacological justification of herbal remedies through different sampling procedures and extraction protocols should ensure strong validity and reliability of traditional knowledge of the respondents before any decision is made to use the plants for treatment (Devi et al., 2013). Therefore, further investigations of all the plants listed above should be performed to validate their efficacy in the treatment of diarrhea in small ruminants.

5-Herbal medicine for the treatment of rumen function insufficiency in small ruminants

In ruminant production systems, consuming high-concentrate feeds can impact rumen fermentation dysfunctions and cause serious GIT disorders such as lactic acidosis and bloating (Beauchemin and Buchanan-Smith, 1990). Lactic acidosis is mainly defined as an acute GIT disorder (Zein-Eldin et al., 2014) and is clinically characterized by depression, anorexia, inactivity, abdominal distension, diarrhea and general weakness (Ullah et al., 2013). Lactic acidosis occurs due to a disproportionate consumption of readily fermentable carbohydrates that decrease ruminal pH to improper levels and lead to the rapid production of lactic acid with rapid fermentation (Mickdam et al., 2016). Lactic acidosis is considered a dramatic form of ruminal microbial fermentative disorder and is lethal in less than 24 hours in some cases (Huo et al., 2014). In addition to lactic acidosis, sheep are subjected to many other GIT diseases; one of these important diseases is bloat, which is a costly disease due to the grazing of these sheep on high protein pastures (Stanford et al., 2001).

Table 1. Medicinal plants used in the treatment of diarrhea in small ruminant

Botanical name	Family	Used part	Citation
Adansonia digitata	Bombacaceae	Fruits	Offiah et al., 2011
Albizia amara	Fabaceae	Bark	Maroyi, 2012
Aloe greatheadii	Asphodelaceae	Leaves	Maroyi, 2012
Anarcardium occidentale	Anacardiaceae	Bark	Lans and Brown, 1998
Atractylodes lancea	Asteraceae	Roots	Li et al., 2015
Capsicum annum	Solanaceae	Fruit	Maroyi, 2012
Cassia fistula	Caesalpinaceae	Whole plant	Mussarat et al., 2014
Cinnamomum zeylanicum	Lauraceae	Inner bark	Lans et al., 2007
Citrus reticulata	Rutaceae	Leaves	Mussarat et al., 2014
Daniellia oliveri	Fabaceae	Bark	Chah et al., 2009
Dioscorea dametorun	Dioscoreaceae	Root	Chah et al., 2009
Ficus burkei	Moraceae	Root	Maroyi, 2012
Gossypium hirsutum	Malvaceae	Biennial	Mussarat et al., 2014
Khaya senegalensis	Meliaceae	Leaves	Offiah et al., 2011
Landolphia spp	Apocynaceae	Leaves	Chah et al., 2009
Lepidium sativum	Brassicaceae	Seed	Araya et al., 2015
Leucaena spp	Fabaceae	Leaves	Chah et al., 2009
Magnolia officinalis	Magnoliaceae	Flowers	Li et al., 2015
Manihot esculenta	Euphorbiaceae	Roots	Chah et al., 2009
Meriandra dianthera	Lamiaceae	Leaf	Araya et al., 2015
Musa paradisiacal	Musaceae	Fruit	Mirani et al., 2014
Myristica fragrans	Myristicaceae	Seed	Zein Eldin et al., 2013
Myrothamnus flabellifoilius	Myrothamnaceae	Root	Maroyi, 2012
Oryza sativa	Poaceae	Seed	Mirani et al., 2014
Parinari curatellifolia	Chrysobalanaceae	Bark	Maroyi, 2012
Plantago lanceolata	Plantaginaceae	Leaves and Husk	Mirani et al., 2014
Poria cocos	Polyporaceae	filaments	Li et al., 2015
Potentilla recta	Rosaceae	Aerial parts	Lans et al., 2007
Prospis cineraria	Fabaceae	Leaves	Mirani et al., 2014
Prunus mume	Rosaceae	Flower	Li et al., 2015
Psidium guajava	Myrtaceae	Buds, leaves	Lans and Brown, 1998
Punica granatum	Lythraceae	Fruits	Mussarat et al., 2014
Salix alba	Salicaceae	Bark	Lans et al., 2007
Sarcostemma viminale	Asphodelaceae	Stem	Maroyi, 2012
***Senna* sp.**	Fabaceae	Pod	Lans et al., 2007
Solanum spp	Solanaceae	Leaves	Chah et al., 2009
Triticum aestivum	Poaceae	Stem	Mussarat et al., 2014
Ulmus fulva	Ulmaceae	Inner bark	Lans et al., 2007
Vernonia conferta	Asteraceae	Leaves	Chah et al., 2009
Withania coagulans	Solanaceae	Leaves /Fruits	Mussarat et al., 2014
Xeroderris stuhlmannii	Fabaceae	Bark	Maroyi, 2012
Zea mays	Poaceae	Grains	Chah et al., 2009
Zingiber officinale	Zingiberaceae	Rhizome	Mussarat et al., 2014

Table 2. The most common species of gastrointestinal nematodes infecting small ruminants

Gastrointestinal nematodes species	Location in the host
Haemonchus contortus	Abomasum
Teladorsagia circumcincta	Abomasum
Trichostrongylus axei	Abomasum
Trichostrongylus colubriformis	Anterior small intestine
Trichostrongylus vitrinus	Anterior small intestine
Trichostrongylus rugatus	Small intestine
Cooperia curticei	Small intestine
Nematodirus spathiger	Small intestine
Nematodirus filicollis	Small intestine
Bunostomum trigonocephalum	Small intestine
Oesophagostomum columbianum	Large intestine
Oesophagostomum venulosum	Large intestine
Chabertia ovina	Large intestine

Bloat is mainly caused by the failure of the animal to release gas pressure (Stanford et al., 2001). Treatment of such conditions mainly relies on prohibiting concentrates and feeding hay to stimulate saliva secretion. Additional lactic acidosis treatment includes oral antacids, such as sodium bicarbonate and oral electrolyte solutions, and the administration of antimicrobial treatments, such as penicillin, potentiated sulphonamides and tetracycline (Baruah, 2008). Antimicrobial treatment should be given with other supportive treatments to control the adverse effects of histamine release and endotoxemia.

Current scientific research highlights the potential significance of using plant-based medicine to enhance rumen function in ruminants. However, many of these studies are only laboratory-based. Nevertheless, their results provide evidence that plant extracts and their constituents have the potential to enhance rumen function and feed utilization in ruminants (Benchaar et al., 2008). In livestock husbandry systems, antibiotics are widely administered to prevent infection and improve feed utilization. The emergence of antibiotic-resistant bacteria has increased public health concerns regarding the conventional use of antimicrobial drugs in livestock feed. Consequently, a considerable attempt has been made to develop alternatives to antimicrobial therapies. Several theories have been proposed to explain the mechanism of the antibacterial action of plant extracts. It is believed that the active ingredients in the plant extract exert their activities by interaction with a wide variety of cellular processes associated with the bacterial cell membrane, including electron transport, ion gradients, protein translocation, phosphorylation, and other enzyme-dependent reactions (Dorman and Deans, 2000; Acamovic and Brooker, 2005).

Active areas of plant metabolite research have demonstrated that some medicinal plants, especially those containing essential oils, flavonoids, saponin and tannin, enhance ruminal fermentation and improve nutrient utilization in ruminants (Hristov et al., 1999; Rochfort et al., 2008). The inclusion of some plant extracts in ruminant feed results in the inhibition of deamination and methanogenesis processes, a reduction of acetate or methane production, and an increase in propionate and butyrate concentrations (Calsamiglia et al., 2007). For this reason, ruminant nutritionists have become interested in using natural products instead of chemical compounds as manipulators of rumen function to improve feed efficiency and increase ruminant productivity (Santoso et al., 2006).

Recently, anise oil, garlic oil, cinnamaldehyde, gentian, oregano, eugenol, and cloves have been studied as an alternative to antimicrobials and as a natural alternative growth promoter in livestock (Ertas et al., 2005). Plant extracts containing essential oils have the potential to inhibit the development of induced lactic acidosis using rumen fluid as an in vitro batch system (Hutton et al., 2009). However, knowledge of the underlying mechanism and an explanation of this protective effect are lacking. While some herbs were able to maintain pH, and inhibit both overall microbial activity and gas production, others appeared to have more extensive effects. The use of such natural plants is under explored in sheep. In contrast, the effects and mechanisms of the action of plants containing saponins and tannins on rumen microbial fermentation have been extensively researched and reviewed (Piacente et al., 2005). Plants containing a range of proanthocyanidins also have considerable effects on ruminal microbial population and the inhibition of foam production (Sivakumaran et al., 2004). In the study of Zein-Eldin et al. (2014), gentian root was used as an alternative to the ordinary treatment of induced lactic acidosis in sheep, and this experimental study

proved that this herb could be used to modulate and restore rumen function. From the previous literature, considerable awareness has been raised on the potential use of herbal medicine to modulate rumen microbial fermentation. However, several controversies need to be resolved before specific recommendations for commercial use can be made. Future research into additional medicinal plants that could be of interest is needed.

6- Herbal medicine as an alternative treatment for gastrointestinal nematodes

GIT parasitism remains one of the major health and economic problems in small ruminant husbandry worldwide, particularly in ruminants owned by the poor populations (Canul-Ku et al., 2012; Carvalho *et al.*, 2012). The most common gastrointestinal parasite species found in small ruminants are listed in Table 2. Anthelmintic treatment of GIT parasites is currently inexpensive and simple; however, as nematodes develop anthelmintic resistance, treatment will become less viable and the economic impact of GIT parasites will increase (Stear et al., 2007). Anthelmintic resistance is defined as a heritable change in the ability of individual parasites to survive the prescribed therapeutic doses of an anthelmintic drug (Prichard et al., 1980; Prichard, 1994; Coles, 2005). As a result of anthelmintic resistance, and the public health concern regarding the use of chemical therapeutics in the livestock industry, many research studies have been designed to examine alternative strategies for treating GIT parasites. The bioactive constituent produced by medicinal herbs to counteract GIT nematodes is of growing interest in anthelmintic drug research as a promising alternative to conventional anthelmintic drugs.

Until recently, most of the evidence of the anti-parasitic activities of herbal extracts and the determination of therapeutic doses have been preliminary and lacked scientific validity (Attindéhou et al., 2012). Various herbs have been used to treat parasitic diseases either through feeding ruminants the entire plant or administering plant extracts to the diseased animal (Jabbar et al., 2007), and several of them have been scientifically approved (Hordegen et al., 2003; Hasan et al., 2015; Macedo et al., 2015; Sanhokwe et al., 2016). For example, the seeds of squash and pumpkins, garlic, onion, walnuts, dill, parsley, mint and many other vine crops are accepted to contain a deworming substance and have been considered for use in sheep with varying outcomes (Strickland et al., 2009). In addition, ginger has been utilized as an anthelmintic plant for ruminants (Iqbal et al., 2006). The use of Acacia, Artemisia and tobacco extracts in parasitic animals has resulted in a decrease in the number of worms (Deharo et al., 2001). Throughout many years of study, numerous herbs have been identified as having the potential to be used as deworming agents for livestock. Table 3 provides a representative list of these plants.

6-Conclusion and future direction

This review article aimed to cite the most common medicinal plants for the treatment of the most common GIT disorders in small ruminants and to document the interest among scientists in utilizing natural methods for the benefit of the livestock production industry. This therapeutic approach has the advantages of having fewer side effects and being cost effective, highly available and beneficial to the health of small ruminants. The present records of the medicinal uses of herbs may serve to deepen our knowledge and elucidate the mechanisms of action of these herbs in treating a range of small ruminant disorders. The rapid advancement of modern technology creates a good opportunity to employ such technologies in herbal therapy preparation and analysis to improve the quality of herbal products and understand the underlying mechanisms of action. Most of these technologies are not standardized, which will be the main challenge for pharmaceutical companies to overcome in establishing uniform interpretation methods. Considering the aforementioned issues, future studies are needed to reach a conclusion about the reliability, bioavailability, permeability and effective safe doses of active medicinal compounds for clinical trials.

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Conflict of interest

The authors declare no conflict of interest.

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Table 3. Medicinal plants used in the treatment of GIT nematodes in small ruminants.

Botanical name	Family	Used part	Citation
Acokanthera oppositifolia	Apocynaceae	Shrub	Sanhokwe et al., 2016
Adhatoda vesica	Acanthaceae	Root and leaves	Khan et al., 2012
Albizia anthelmintica	Fabaceae	Bark	Grade´ et al., 2008
Allium cepa	Amaryllidaceae	Bulbs	Mehlhorn et al., 2011
Allium sativum	Liliaceace	Bulbs	Hasan et al., 2015
Aloe ferox	Asphodelaceae	Flowers	Sanhokwe et al., 2016
Ananas comosus	Bromeliaceae	Leaves	Hordegen et al., 2003
Ananas comosus	Bromeliaceae	Leaves	Shaha et al., 2015
Artemisia absinthium	Asteraceae	Aerial parts	Tariq et al., 2009
Artemisia campestris	Asteraceae	Leaves	Akkari et al., 2014
Artemisia maritima	Asteraceae	Whole plant	Irum et al., 2015
Artemisia vestita	Asteraceae	Whole plant	Irum et al., 2015
Azadirachta indica	Meliaceae	Leaves and Seeds	Hördegen et al., 2003; Shaha et al., 2015
Butea monosperma	Fabaceae	Seeds	Singh et al., 2015
Caesalpinia crista	Caesalpiniaceae	Seeds	Hördegen et al., 2003; Mushtaq et al., 2015
Calliandra portoricensis	Leguminosae	Roots, leaves, flowers	Iqbal et al., 2005
Calotropis (C.) procera	Asclepiadaceae	Flowers	Iqbal et al., 2005
Calotropis procera	Apocynaceae	Leaves and flowers	Aggarwal et al., 2015
Carica papaya	Caricaceae	Leaves and seeds	Attindehou et al., 2012
Carissa caranta	Apocynaceae	Root	Khan et al., 2012
Cassia obtusifolia	Caesalpiniaceae	Leaves	Saidou et al., 2015
Chenopodium album	Chenopodiaceae	Whole plant	Jabbar et al., 2007
Chenopodium ambrosioides	Amaranthaceae	Leaves	Ketzis et al., 2002
Chrysanthemum cinerariaefolium	Asteraceae	Flowers	Mbaria et al., 1998
Chrysophyllum cainito	Sapotaceae	Stem	Fernandez, 1991
Citrus sinensis	Rutaceae	Peels	Gaínza et al., 2015
Cocos nucifera	Arecaceae	Fruit	Mehlhorn et al., 2011
Cymbopogon citratus	Poaceae	Leaves	Macedo et al., 2015
Elephantorrhiza elephantina	Fabaceae	Leaves	Sanhokwe et al., 2016
Embelia ribes	Myrsinaceae	Fruits	Hördegen et al., 2003
Eucalyptus globulus	Myrtaceae	Leaves	Kanojiya et al., 2015
Eucalyptus staigeriana	Myrtaceae	Leaves	Macedo et al., 2010
Fumaria parviflora	Fumariaceae	Whole plant and leaves	Hördegen et al., 2003; Mushtaq et al., 2015
Hedera helix	Araliaceae	Ripe fruits	Eguale et al., 2007
Hilderbrantia sepalosa	Myrtaceae	Roots	Gathuma et al., 2004
Iris kashmiriana Linn	Iridaceae	Dried plant parts	Khan et al., 2016
Khaya senegalensis	Meliaceae	Bark	Ademola et al., 2004
Lansium domesticum	Meliaceae	Whole plant	Kumarasingha et al., 2016
Lespedeza cuneata	Fabaceae	Leaves	Ahmed et al., 2014
Leucaena leucocephala	Fabaceae	Leaves	Hernandez et al., 2014
Linariantha bicolor	Acanthaceae	Roots and leaves	Kumarasingha et al., 2016
Lippia sidoides	Verbenaceae	Leaves	Camurc¸a-Vasconcelos et al., 2008
Maesa lanceolata	Myrsinaceae	Leaves and fruits	Tadesse et al., 2009
Melaleuca quinquenervia	Myrtaceae	Leaves	Gaínza et al., 2015
Melia azedarach	Meliaceae	Fruits	Hördegen et al., 2003
Moringa oleifera	Moringaceae	Leaves	Attindehou et al., 2012
Musa spp (banana plant)	Musaceae	Leaves	Gregory et al., 2015
Myrsine africana	Primulaceae	Fruits, mixed with leaves	Gathuma et al., 2004
Nauclea latifolia	Rubiaceae	Bark	Onyeyili et al., 2001
Nicotiana tabacum	Solanaceae	Leaves	Iqbal et al., 2006
Nigella sativa	Ranunculaceae	Seeds	El-Far et al., 2014
Ocimum sanctum	Lamiaceae	Leaves	Kanojiya et al. 2015
Pelargonium endlicherianum	Geraniaceae	Roots	Kozan et al., 2016
Peltophorum africanum	**Fabaceae**	Root bark	Bizimenyera et al., 2008
Petiveria alliacea	Phytolaccaceae	Root	Lans and Brown, 1998
Picria fel-terrae Lour	Scrophulariaceae	Whole plant and leaves	Kumarasingha et al., 2016
Piliostigma reticulatum	Caesalpiniaceae	Leaves	Saidou et al., 2015
Piptadenia viridiflora	Fabaceae	Leaves	Morais-Costa et al., 2016
Pistacia lentiscus	Anacardiaceae	Shrub	Amit et al., 2013
Plectranthus punctatus	Lamiaceae	Aerial parts	Tadesse et al., 2009
Punica granatum	Punicaceae	Fruit peel	Aggarwal et al., 2015
Ruellia tuberosa	Acanthaceae	Root	Lans and Brown, 1998
Salix babylonica	Salicaceae	Leaves	Cedillo et al., 2015
Sesbania grandiflora	Fabaceae	Leaves	Azrul et al., 2016
Spondias mombin	Anacardiaceae	Leaves	Attindehou et al., 2012
Thymus vulgaris	Lamiaceae	Leaves	Ferreira et al., 2016
Tinospora rumphii	Menispermaceae	Stem	Fernandez, 1991
Trichilia claussenii	Meliaceae	Fruits	Cala et al., 2001
Vernonia anthelmintica	Asteraceae	Seeds	Hördegen et al., 2003
Xanthoxylum zanthoxyloides	Rutaceae	Leaves	Attindehou et al., 2012
Zingiber officinale Roscoe	Zingiberaceae	Rhizomes	El-Far et al., 2014;Matthews et al., 2016

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