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Ethnoveterinary Uses of Certain Yemeni Plants: A Review of the Scientific Evidence

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ABSTRACT

Livestock is an important and integral component of agriculture production in Yemen and contributes 28 % of the total agricultural production income. Research in the field of Yemeni ethnoveterinary medicine is limited to a few studies. Therefore, our work aims to substantiate scientifically the ethnoveterinary use of some documented plant species based on a literature review of their bioactivities and toxicological properties. Searching the scientific literature has revealed various pharmacological activities that may support the claimed healing activities of 11 out of 14 plant species for some of their ethnoveterinary utilization. This comprises the use of *Aloe* spp. latex for constipation, worms, boils, and wounds; *Boswellia sacra* underbark for wounds and its oleo-gum resin for mastitis; Soqotraen *Boswellia* species as an insect repellent; *Cissus rotundifolia* for stomach pain; *Cyphostemma digitatum* as an appetite stimulant; *Psiadia punctulate* for bone fracture; *Pulicaria undulata* as an insect repellent; combinations of *Aristolochia bracteolate* with *Sorghum bicolor* grains for bloating; *Rumex nervosus* and salt for eye pimples; and *Trigonella foenum-graecum* seeds with *Hordeum vulgare* grains for constipation. Some plants were found to demonstrate various toxic effects in *in vivo* and *in vitro* experimental studies. The local administration of *Calotropis procera* latex was also reported to induce an intense inflammatory response. It can be concluded that our work has provided valuable scientific information on the biological and toxic activities of some Yemeni ethnoveterinary remedies that could be utilized for the benefit of farmers to ration the use of these remedies and avoiding their toxicity.

Introduction

Ethnoveterinary medicine is a complex system of beliefs, skills, knowledge, and practices concerning animal health care. In addition to the use of plants to treat animal diseases, the practice of ethnoveterinary medicine includes the use of diagnostic procedures, animal husbandry practices, and surgical methods [1]. Livestock is an important and integral component of agriculture production in Yemen. Animal production contributes 28 % of the total agricultural production income. The most important livestock types in Yemen are cows, sheep, goats, donkeys, camels, horses, and chickens. Caring for livestock is a matter of constant concern for the rural population, whereby 95 % of the labor force in rural areas are women who are primarily responsible for rearing livestock and possess the knowledge specific to treating sick animals [2]. Some plants used to control animal diseases in some areas of Yemen have been reported in some studies [2–4]. However, ethnoveterinary medicine is still poorly studied, and to the best of our knowledge, no research has yet been done to assess the biological and toxicological activities of the plants used for ethnoveterinary purposes in Yemen. Therefore, our work aimed to confirm the ethnoveterinary uses of 14 documented plant species in different areas of Sana'a, Al Mahwit, Taiz, Ibb, and Dhale governorates [2–3], as well as in the drier, more remote areas of

Soqotra and South Arabian mainland of Yemen [4], based on their uses and the bioactivities associated with their uses as reported in the literature. Reported evaluation on the safety of these plants was also crucial to raise the farmers' awareness of toxic plants that may harm their livestock and lead to harmful economic consequences.

Materials and Methods

Scientific information was retrieved from the electronic databases of Leiden University Library, including ScienceDirect, Google Scholar, PubMed, Scopus, and published e-books. Keywords used for searching of plants used for ethnoveterinary medicine in Yemen were "ethnoveterinary medicine", "ethnoveterinary plants", "animal health problems", "livestock treatment", and "animal diseases" in combination with "Yemen".

Search terms used for the pharmacological activities associated with the ethnoveterinary uses as well as for the toxicological properties of the Yemeni ethnoveterinary plants found in the scientific literature were the scientific name of the plant, plant extract, or plant constituents in conjunction with pharmacological and toxicological activities such as "laxative", "anthelmintic", "antimicrobial", "anti-inflammatory", "antioxidant", "wound healing", "analgesic", "antiulcer", "insecticidal", "side effects", "adverse effects", and "toxicity". The collected information from the scientific papers were the Latin names of the plants used, names of plant families, plant parts used, uses including methods of administration, pharmacological activities of plant extracts and chemical constituents related to their uses, and the side effects and/or toxicological properties.

Results

Database searches revealed that 14 plant species are used in different areas of Sana'a, Al Mahwit, Taiz, Ibb, and Dhale governorates, and in the drier, more remote areas of Soqotra and South Arabian mainland of Yemen for the treatment of a variety of animal diseases [2–4] (Supplementary material, **Table 1S**). Several pharmacological activities that may lend some scientific support for the ethnoveterinary uses were found for 11 out of 14 plants utilized in Yemeni ethnoveterinary medicine. Three plants (*Aloe* species latex, *Aristolochia bracteolate* whole plant, *Trigonella foenum-graecum* seeds) were reported to possess serious toxicological activities (▶ **Table 1**).

No data were found that could help explain and support the claimed healing effects of some plants for treating some diseases, such as *Aloe* spp. latex for colic, as insecticidal, and for shivering attacks and distended belly; *Aloe* spp. leaves as an animal repellent; *Boswellia sacra* underbark for generalized edema; Soqotraen *Boswellia* species as an animal repellent; *Calotropis procera* latex for swellings; *Euphorbia arbuscula* latex as insecticidal; and *Gomphocarpus fruticosus* for heatstroke. In addition, these plants or related species were found to exhibit adverse effects. ▶ **Table 2** illustrates the ethnoveterinary uses and adverse effects of these plants (or related species) used for animal health problems.

Discussion

Traditional use of herbal remedies to treat animals by livestock owners is still prevalent in Yemen due to poverty, the availability of medicinal and aromatic plants, and better accessibility and low cost of herbal drugs, especially when compared to both inaccessible and expensive conventional drugs. However, few studies have reported on the ethnoveterinary use of some plants in Yemen [2–4]. Our work aimed to go a step further by searching for scientific confirmation of the ethnoveterinary uses of the 14 Yemeni plants documented in these studies by reviewing their bioactivities and toxicological properties. The results of researching scientific literature have revealed various *in vivo* and *in vitro* experimental studies demonstrating different pharmacological activities that may support some of the claimed healing activities of 11 herbal remedies (▶ **Table 1**).

The use of *Aloe* latex as a laxative by Yemeni livestock owners and elsewhere [5] is strongly supported by scientific evidence on its laxative properties, based on the well-established cathartic properties of anthraquinone glycosides such as aloin and aloe-emodin found in aloe latex [88]. The laxative activity of the *Aloe vera* latex is due to a common metabolite, aloe-emodin-9-anthrone, as well as aloe-emodin and other metabolites in the colon, where they produce their cathartic effects by multiple mechanisms leading to an increase in intestinal peristalsis, water, electrolyte content, and mucous secretion [6]. The laxative activity of fenugreek seeds and barley grains, on the other hand, is based on the well-known fecal bulking effect of dietary fibers, especially insoluble fibers contained in fenugreek seeds [78] and barley grains [79]. The use of Aloe latex to treat worms could be justified by the *in vitro* anthelmintic activity of its constituents (aloin and aloe-emodin, ▶ **Table 1**).

Worldwide, disease caused by gastrointestinal strongyles (GIS) is considered one of the most critical health constraints affecting productivity in small ruminants. GIS may limit sheep production by causing retarded growth, weight loss, reduced food consumption, lower milk production, impaired fertility, and even mortality in heavy parasite burden [8]. Aloin and aloe-emodin effectively targeted the larval developmental stages of gastrointestinal strongyle larvae. When used at the same concentration, aloe-emodin especially showed the same efficacy as the reference drug thiabendazole (0.1%, ▶ **Table 1**).

A recent publication [112] confirmed via its *in vitro* and *in vivo* results the anthelmintic action of *A. vera* extract in sheep. The antimicrobial, anti-inflammatory, and antioxidant activities play an essential role in wound healing by reducing the microbial load, decreasing prolonged and chronic inflammation, and protecting vital tissue of the wound bed from free radicals' destructive effect, respectively [89]. Consequently, these activities produced by *Aloe* species latex and its anthraquinone constituents (aloe-emodin and aloin) and by *B. sacra* underbark and its content of oleo-gum resin [90] (with its constituents, α- pinene [42, 91] and boswellic acids [90, 92]) alongside the wound healing activity of aloe-emodin and analgesic effect of *B. sacra* oleo-gum resin and boswellic acids, could substantiate their use for wound healing activity (▶ **Table 1**).

▶ **Table 1** Uses, pharmacological activities of extracts, chemical constituents, and toxicological properties of some plants utilized in ethnoveterinary medicine in Yemen.

Species/part used/ Family	Uses	Pharmacological activities of extract and chemical constituents	Side effects/toxicological properties
Soqotraen *Aloe* spp. (*Aloe vera* [L.] Burm. f. and other endemic species such as *A. forbesii* Balf. f., *A. haggeherensis* T. A. McCoy & Lavranos, *A. jawiyon* S. J. Chirstie, D. P. Hannon & Oakman ex A. G. Mill, *A. perryi* Baker, and *A. squarrosa* Baker ex Balf. f.)/latex/Asphodelaceae [4]	Constipation and worms by using fresh latex [4]	**Laxative effect** **1,8 dihydroxy-anthraquinone glycosides (Aloin)** ▪ Laxation (↑ of intestinal peristalsis, water, electrolyte content, and mucous secretion in the colon) [5, 6] **Anthelmintic effect** **Aloin** ▪ A dose-dependent paralysis effect, which ultimately progressed to the death of roundworms (*Ascaridia galli*) and earthworms (*Pheretima phostuma*). The effect is comparable to standard piperazine [7]. **Aloin and Aloe-emodin** (The *in vitro* anthelmintic activity on sheep gastrointestinal strongyle eggs and larvae) ▪ 0.5 % aloin gave highly significant ($p < 0.01$) inhibition of egg hatch (39.7 %), compared to the untreated controls (13.4 %), followed by 0.1 % aloe-emodin (16.6 %) but these values were significantly lower than that observed in the reference drug 0.1 % thiabendazole (TBZ) (94.8 %) ($p < 0.01$) controls. ▪ Both 0.1 % aloe-emodin (97.7 %) and 0.5 % aloin (96.9 %) almost completely prevented the larval development from L1 to L3, showing no significant differences ($p < 0.01$) when compared to 0.1 % TBZ control (100 %). ▪ The larval mortality observed by 0.5 % aloin (65.4 %) was significantly higher ($p < 0.01$) than that observed in both the untreated controls (4.2 %) and in 0.1 % TBZ treated controls (27.7 %) [8].	▪ Classified as the American Herbal Products Association (AHPA) classes 2b (not to be used during pregnancy), 2c (not to be used while nursing), and 2 d (other specific use restrictions such as not to be used in persons with any inflammatory condition of the intestines) and contraindicated in children under 12 years of age [22–23]. It is not known if similar side effects will occur in animals. ▪ Prolonged use is associated with watery diarrhea leading to electrolyte imbalance, and the increased loss of potassium can lead to hypokalemia [6]. **Genotoxicity and Mutagenicity** ▪ A high proportion of anthraquinones including danthron (1,8 dihydroxy-anthraquinone) (synonym: chrysazin) and aloe-emodin were found mutagenic in several strains of *Salmonella typhimurium*, for example, TA1537, TA1538, TA102, and TA98 [24]. ▪ The genotoxicity and mutagenicity induced by danthron, emodin, and aloe-emodin were due to the inhibition of the catalytic activity of topoisomerase II (Topo II), with danthron being the most potent [24]. **Carcinogenicity** ▪ The 1,8 dihydroxy-anthraquinones (danthron, aloe-emodin, chrysophanol, and rhein) were found to cause a 2–3-fold increase of DNA synthesis of primary rat hepatocytes and danthron, rhein, and chrysophanol to enhance the transformation of C3H/M2 mouse fibroblasts initiated by *N*-methyl-*N'*-nitro-*N*-nitrosoguanidine or 3-methylcholanthrene [25]. ▪ Carcinogenic activity of 1 % hydroxy-anthraquinones and emodin (0, 280, 830, or 2500 ppm/rats) and (0–1250 ppm/mice) has been reported in several feeding studies [24]. ▪ Induction of primary cutaneous melanin-containing tumors in C3H/HeN mice treated with aloe-emodin (in ethanol vehicle) and ultraviolet radiation, whereas no skin tumors were induced using aloe-emodin alone [24]. ▪ Cells pre-treated with aloe-emodin showed increased sensitivity to both UV-A and visible light. Significant photo-oxidative damage to both RNA and DNA was associated with the phototoxicity induced by aloe-emodin. The phototoxicity mechanism involves the generation of reactive oxygen species and stable photoproducts with cellular components [6].
	Boils, suppurating abscess, large fresh laceration, and infected bites of ticks, lice, or flies by local application of fresh latex [4].	**Antimicrobial activity** Antimicrobial activity was assessed with broth tube dilution, MBC assay, Agar diffusion method, microtiter assay using a metabolic color indicator Alamar blue. Antibiofilm activity screened with crystal-violet screening assay for biofilm inhibitors **Latex:** active against ▪ *Staphylococcus aureus 209, Streptococcus pyogenes, Corynebacterium xerosis,* and *Salmonella paratyphi* [9]. ▪ *Escherichia coli, Staphylococcus epidermidis, Salmonella typhimurium, S. aureus, Bacillus subtilis, Enterococcus faecalis, Proteus vulgaris,* and *Pseudomonas aeruginosa* [10]. **Aloe-emodin:** active against ▪ *B. subtilis*, *S. aureus*, enveloped viruses and plant-pathogenic fungi [5]. ▪ *Aeromonas hydrophilia, E. coli,* and *B. subtilis* [11]. ▪ Four strains of methicillin-resistant *S. aureus* (MRSA) and a strain of methicillin-sensitive *S. aureus* (with MIC = 2 µg/ml) [12]. ▪ *Bacillus cereus, Bacillus licheniformis,* and *S. epidermidis* [13]. ▪ *S. aureus* biofilm development in a dose-dependent manner [14]. ▪ *Candida albicans* (MIC = 50 µg/ml) and *Trichophyton mentagrophytes* (MIC = 50 µg/ml) comparing to ketoconazole (MIC = 0.1 and 2.5 µg/ml, respectively) [15]. ▪ Herpes simplex virus type 1 and type 2, varicella-zoster virus, pseudorabies virus, and influenza virus [16]. **Aloin** ▪ Effective against *B. cereus, B. licheniformis,* and *S. epidermidis* [13]. ▪ Dose-dependent noncompetitive inhibitory effects on *Clostridium histolyticum* metalloproteinases and collagenases [6]. ▪ Antiviral but not virucidal activity [6]. ▪ Effective against *S. aureus, B. subtilis, E. coli, Klebsiella oxytoca, P. aeruginosa,* and *C. albicans* (MIC 6, 5, 7, 8, 12, and 14 µg/ml, respectively) [7].	

continued

▸ **Table 1** *Continued*

Species/part used/ Family	Uses	Pharmacological activities of extract and chemical constituents	Side effects/toxicological properties
		Anti-inflammatory activity **Aloe-emodin** ▪ Dose-dependent inhibition of inducible nitric oxide synthase (iNOS) mRNA expression and nitric oxide (NO) production at 5–40 µM [17]. ▪ Suppression of cyclooxygenase-2 (COX-2) mRNA expression and prostaglandin E2 (PGE2) production by 40 µM [17]. ▪ Inhibitory activity (39.9 %) on carrageenan-induced rat-paw edema [18]. **Aloin** ▪ Suppression of NO production at 5–40 µM, but it did not suppress PGE2 production [17]. ▪ Strong inhibition (70 %) of histamine release induced by Ca^{2+}-independent inducer, compound 48/80, from mast cells comparing with indomethacin (35 %) [19]. ▪ Inhibitory activity (28.8 %) on carrageenan-induced rat-paw edema [18].	
		Antioxidant activity **Aloe-emodin** ▪ Inhibitory activity against linoleic acid peroxidation catalyzed by soybean 15-lipoxygenase (IC_{50} 65 ± 3 µmol/l) [20].	
		Wound healing activity **Aloe-emodin** ▪ A significant increase in wound healing rate ($p < 0.05$), a higher level of re-epithelialization and angiogenesis, and a significant reduction of burn wound area ($p < 0.05$) of excision wounds in mice [21].	
Aristolochia bracteolate Lam./ unspecified part/ Aristolochiaceae [3]	For bloating given together with *Sorghum bicolor* (Poaceae) grains [3]	***Aristolochia bracteolate*** **Antimicrobial activity** **Methanol extract of leaf and bark:** active against ▪ *B. subtilis* (MIC = 39.06 µg/ml), *Salmonella typhi* (MIC = 625 µg/ml), *P. aeruginosa* (MIC = 1250 µg/ml), and *S. aureus* (MIC = 2500 µg/ml). [26]. ▪ *Rhizopus stolonifer* and *Penicillium notatum* [26]. **Chloroform extract of leaf and bark:** active against ▪ *E. coli* (MIC = 312.5 µg/ml), *B. subtilis* (MIC = 2500 µg/ml), *P. aeruginosa* (MIC = 2500 µg/ml), and *S. typhi* MIC = 2500 µg/ml) [26]. ▪ *Aspergillus terreus* [26]. **Water extract of leaf and bark** ▪ Active against *A. terreus*, *Aspergillus niger*, and *P. notatum* [26]. **70 % methanol extract and its chloroform fraction of the whole plant** ▪ Moderately active against *S. aureus*, *B. subtilis*, and *P. aeruginosa* [27]. **Methanolic extract of the whole plant:** active against ▪ *S. aureus*, *Micrococcus luteus*, *B. subtilis*, *S. epidermidis*, *E. faecalis*, MRSA and *Enterobacter aerogenes*, *Yersinia enterocolitica*, and *P. vulgaris*, with a zone of inhibition nearly equal to that of the standard streptomycin against *B. subtilis* and *P. vulgaris* and exceeding that of streptomycin against *Y. enterocolitica* [28]. ▪ *A. niger*, *Botyritis cinerea*, *Trichophyton rubrum*, *Curvularia lunata*, *A. flavus*, and *T. mentagrophytes* [28].	*Aristolochia* species were reported to be poisonous to man and livestock due to aristolochic acids, which were nephrotoxic, genotoxic, and carcinogenic in humans [35].

continued

▸ **Table 1** *Continued*

Species/part used/ Family	Uses	Pharmacological activities of extract and chemical constituents	Side effects/toxicological properties
		Methanolic and aqueous extracts of leaves and stems of Yemeni *Aristolochia bracteolate* ▪ Methanolic extract was more active than aqueous extract against standard *S. aureus* (MIC = 250 µg/ml), *B. subtilis* (MIC = 500 µg/ml), and *Micrococcus flavus* (MIC = 250 µg/ml). The methanol and aqueous extracts were active against MRSA strains (*S. epidermidis* 847 and *S. aureus* north German epidemic strain) [29]. **Acetone, ethanol, and petroleum ether extracts of the leaves, stem, and root** ▪ Active against *E. coli, P. aeruginosa,* and *K. pneumoniae* except for the ethanol extract of the leaves and the acetone extract of the stems, which were inactive against *K. pneumoniae* [30]. **Chloroform, ethyl acetate, and methanol extracts of the roots** ▪ Active against *B. subtilis* and *E. coli*, with ethyl acetate extract as the most active extract, especially against *E. coli* [31]. **96 % ethanol extract of the plant** ▪ Active against *E. coli, P. aeruginosa, B. subtilis, S. aureus*, and *C. albicans* [32]. **Aristolochic acid I** ▪ The dose of 50 µg/ml showed antimicrobial activity approaching that of the positive control (ciprofloxacin 50 µg/ml) against *E. coli* and exceeding that of the ciprofloxacin against *B. subtilis.* [31].	
		Anti-inflammatory activity **Leaves ethanol extract** ▪ Significant reduction (60 %) of induced hind paw edema in rats compared to positive control ibuprofen (69 %) [33]. ▪ Anti-inflammatory activity using cotton pellet method in rats [34]. **Aristolochic acid** ▪ Inhibition of the inflammation induced by immune complexes as well as immunological and nonimmunological agents. Its activity mainly results from its inhibitory effects on phospholipase A_2 (PLA_2) in regulating the synthesis of arachidonic acid, an intermediate in the production of prostaglandins [35].	
		Antioxidant activity **Leaves ethanol extract, its ethyl acetate, and ether fractions:** ▪ Promising antioxidant activity in reducing 1-diphenyl-2 picryl hydrazyl (DPPH) in a concentration-dependent manner up to 1 mg/ml. The ether fraction showed scavenging activity against NO-induced release of free radicals with 0.5 mg/ml and 1 mg/ml exhibiting maximum NO inhibition of 45 %, thereby supporting the anti-inflammatory activity of the ethanolic extract [33]. **Methanol extract of *A. bracteate* (leaf, stem, and roots)** ▪ Significant increase in the antioxidant enzymes (catalase, ascorbate oxidase, glucose 6 phosphate dehydrogenase), as well as superoxide, DPPH, and hydroxyl radical scavenging activity [36]. **Methanolic extract of Yemeni *A. bracteate* (leaves, stems)** ▪ DPPH radical scavenging activity at high concentrations (69.9 % by 1000 µg/ml and 30.7 % by 500 µg/m) [29]. **96 % ethanol extract of the plant** ▪ Moderate DPPH radical scavenging activity (48.8 %) compared to the standard propyl gallate (89.7 %) [32]. **Ethyl acetate and crude methanol extracts of the leaves:** ▪ Potent scavenging activity of 2,2′-azino-bis (3-ethylbenzo-thiazoline-6-sulfonic acid ($ABTS^{\bullet +}$) radical cations with IC_{50} values of 17.08 ± 0.44 and 28.12 ± 2.87 µg/ml, respectively, compared to the positive control ascorbic acid (IC_{50} = 11.25 ± 0.49) [37].	

continued

▶ **Table 1** *Continued*

Species/part used/ Family	Uses	Pharmacological activities of extract and chemical constituents	Side effects/toxicological properties
		Antiulcer activity Aqueous extract of leaves ▪ Significant ($p < 0.01$) decrease of the ulcerated area and the volume and acidity of the gastric juice of ethanol-induced and pylorus ligation-induced gastric ulceration in pre-treated rats with the extract 800 mg/kg/body weight/day [38]. Ethanol whole plant extract ▪ Significant ($p < 0.05$) decrease in the gastric volume and total acidity, number of ulcers, and ulcer score index of HCl-induced ulceration in the albino pre-treated rats with the extract. The percentage of ulceration inhibition was 59.09 %, compared to 75.87 % by the standard ranitidine [39].	
		Sorghum bran diets Suppression of ulcerative colitis ▪ Polyphenol (3-deoxyanthocyanins and condensed tannins)-rich sorghum brans mitigate colonic injury and epithelial dysfunction induced during dextran sodium sulfate colitis by modulating epithelial cell proliferation and upregulating the proliferation and expression of *Tff3, Tgf β*, and short-chain fatty acids (SCFA) [40].	
Boswellia sacra Flueck./underbark/ oleo-gum resin/ Burseraceae [4]	Infected wounds by local appl. of hot aqueous extract of underbark or paste made of ground underbark [4].	**Antimicrobial activity** **Essential oil and methanolic extract of the branches** ▪ Active against reference strains such as *B. cereus, E. faecalis, E.coli, Listeria innocua, Salmonella enterica, Shigella dysenteria, S. aureus, Staphylococcus camorum,* and *Proteus mirabilis* (with MIC of 1–32 µg/ml for essential oil and MIC of 100–200 µg/ml for methanol extract) and clinical strains such as *S. aureus* (with MIC of 2 µg/ml for essential oil and 100 µg/ml for methanol extract) and *P. aeruginosa* (with MIC of > 32 µg/ml for essential oil and 200 µg/ml for methanol extract), as well as the fungal strains (standard *C. albicans,* clinical isolates of *C. albicans, A. niger,* and *Aspergillus sp.* (with MIC of 0.25–1 µg/ml for essential oil and MIC of 50 – > 200 µg/ml for methanol extract) [41]. **Essential oil of oleo-gum resins:** active against ▪ Clinical isolates of *B. subtilis, M. luteus, S. aureus, K. pneumoniae, E. aerogenes, P. aeruginosa, E. coli, P. vulgaris* and standard *S. aureus, E. coli*, and *P. aeruginosa* [42]. ▪ Standard *S. aureus* (MIC = 4.0 mg/ml), *B. cereus* (MIC = 2.0 mg/ml), *E. coli* (MIC = 4.0 mg/ml), and *P. vulgaris* (MIC = 3.0 mg/ml) and *C. albicans* (MIC = 8.0 mg/ml) [43]. ▪ **Acetyl-11-keto-*β*-boswellic acid was more active (with MIC range of 2–8 µg/ml), and 11-keto-*β*-boswellic acid**, as well as *β*-boswellic acid, were moderately active (MIC ≈ 8–64 µg/ml) against standard *S. aureus*, MRSA, *E. faecalis, E. faecium, S. epidermidis*, and 112 isolates of various bacterial pathogens (MRSA 50, *E. faecalis* 22, *E. faecium* 18, *S. epidermidis* 12, and vancomycin-resistant *E. faecalis* 10). All compounds were bacteriostatic and exhibited a MIC of > 128 µg/ml [44]. ▪ **Acetyl-11-keto-*β*-boswellic acid** effectively inhibited the formation of *S. aureus* and *S. epidermidis* biofilms, with a 50 % biofilm inhibition concentration of 16–32 µg/ml. It also effectively eradicated the preformed biofilms. The 50 % biofilm reduction concentration ranged from 32–64 µg/ml for both bacteria [44].	Boswellia gum is included in the list of safe substances, and the U. S. FDA permits its use as a food additive. The side effects are relatively very mild and not severe, and it can be considered quite safe when taken in the required and therapeutic dosages [51].

continued

▸ **Table 1** *Continued*

Species/part used/ Family	Uses	Pharmacological activities of extract and chemical constituents	Side effects/toxicological properties
		α-Pinene ▪ Active against some strains of *S. aureus* (MIC = 10–20 µL/mL), *S. epidermidis* (MIC = 5 µL/mL), and *S. pyogenes* (MIC = 5–10 µL/mL) [45]. ▪ More active than streptomycin (positive control) against *P. aeruginosa*, *E. coli*, *B. subtilis*, *S. aureus*, yeast strains (*Hansenula anomala* and *Saccharomy cescerevisiae*), and fungi (*A. niger*, *Chaetomium globosum*, *Mucor racemosus*, *Monascus anka*). The MIC values ranging from 62.5 to 125 µg/ml [46]. **A fraction containing 99.5 % α-pinene** ▪ Active against *E. coli, P. aeruginosa, Corynebacterium sp., S. aureus, B. cereus*, fungi (*Alternaria sp., Aspergillus nidulans*, and *A. niger*), yeast (*C. albicans*) with inhibition zones approaching as well as exceeding those of some commercial antibiotics [47].	
		Anti-inflammatory activity **Essential oil of Omani *B. sacra* oleo-gum resin (Shabi grade):** ▪ Significant reduction of rats hind paw edema by 21.3, 18.8, 17.1, and 25.8 % after 1, 2, 3, and 4 h, respectively, compared to aspirin (standard drug), which showed 12.9, 14.4, 14.7, and 22.0 % edema inhibition after 1, 2, 3, and 4 h, respectively [48]. **α-Pinene** ▪ Inhibitory effects on histamine release in rat peritoneal mast cells, the activation of inhibitor of Kappa B Kinase (IKK-*β*), nuclear factor-kappa B (NF-*κ*B), and caspase-1 in human mast cells, and NF-*κ*B and Jun N-terminal kinase (JNK) activation in chondrocytes [49]. ▪ Decrease in the production of interleukin-6 (IL-6), tumor necrosis factor-*α* (TNF-*α*), COX-2 and iNOS expression, PGE2 and NO production; activations of the mitogen-activated protein kinases (MAPKs) and NF-*κ*B in lipopolysaccharide (LPS)-stimulated mouse peritoneal macrophages. [49]. ▪ Abolishing mechanical sensitization induced by complete Freund's adjuvant at 70 mg/kg, p. o. similar to the positive control drug gabapentin (70 mg/kg, p. o.). This indicates its role in the management of inflammatory and neuropathic pain [50]. Boswellic acids ▪ Acetyl-11-keto-*β*-boswellic acid is the most important inhibitor of 5-lipoxygenase [51].	
		Analgesic activity **Essential oils of different grades of Omani *B. sacra* oleo-gum resin and methanol crude extract of Hougari regular grade and its subfractions:** ▪ In the acetic acid-induced writhing test, the highest inhibition was observed by 70 % chloroform/n-hexane sub-fraction of Hougari regular grade in phase 1 (64.0 %) and by Shabi frankincense (SF) in phase II (65.5 %), compared to the positive control, aspirin (67.6 % in phase I and 66.8 % in phase II). The SF oil sample in phase III inhibited the abdominal constrictions even more significantly (54.5 %) than aspirin (37.9 %), while in the formalin test, the 60 % and 70 % chloroform/n-hexane subfractions of Hougari regular grade showed the highest inhibition (55.3 % and 59.6 % in early phase [neurogenic pain] and 66.7 % and 63.0 % in late phase [inflammatory pain]), respectively, and this is far greater than aspirin (36.2 % in early phase and 29.6 % in late phase) [52].	

continued

▶ **Table 1** *Continued*

Species/part used/ Family	**Uses**	**Pharmacological activities of extract and chemical constituents**	**Side effects/toxicological properties**
		Acetyl-11-α-keto-β-boswellic acid (AKBA) ▪ In the acetic acid-induced writhing test, AKBA inhibited dose-dependently the induced writhing (40.98 % by 100 mg/kg and 55.19 % by 200 mg/kg), compared to the positive control nimesulide (47.54 % by 2 mg/kg p. o.), while in tail-flick method, AKBA at 100 mg/kg and 200 mg/kg exhibited similar antinociceptive activity (58.37 % and 58.74 maximum possible effect [MPE], respectively, compared to positive control with 62.59 % MPE), as early as 30 min. The % MPE of the AKBA (100 mg/kg and 200 mg/kg) was increased up to 60 min (97.28 % and 114.79 % MPE, respectively compared to positive control with 136.42 % MPE) [53].	
		Antioxidant activity **Essential oils of different grades (Hougari regular, royal upper, and Royal lower grades), as well as the sub-fractions (n-hexane and 40 % MeOH/CH_2Cl_2 extracts of the crude methanol extract) obtained from Omani *B. sacra* oleo-gum resin:** ▪ Inhibition of superoxide anion (> 50 %), while the CH_2Cl_2 fraction and the sub-fraction of 40 % CH_2Cl_2/n-hexane fraction, as well as essential oil of Shabi frankincense grade, showed moderate inhibitory activity of DPPH free radicals [54]. **α-Pinene** ▪ Moderate DPPH, superoxide anion radicals scavenging activity, and reducing power activity [46].	
	Mastitis by local appl. of a paste made of fresh oleo-gum resin boiled with milk [4].	**Antibacterial, anti-inflammatory, and antioxidant** ▪ **Acetyl-11-α-keto-β-boswellic acid**-mediated silver nanoparticles showed superior antibacterial, anti-inflammatory, and antioxidant properties than cefepime in mastitis-induced mammary glands in mice [55].	
Soqotraen *Boswellia* species (such as *B. ameero* Balf.f.; *B. bullata* Thulin; *B. dioscoridis* Thulin; *B. elongate* Balf.f.; *B. nana* Hepper; *B. popoviana* Hepper; *B. socotrana* Balf.f.)/wood, oleo-gum resin/Burseraceae [4]	Insect repellent by the smoke of burning dead wood [4].	**Insecticidal activity** **α- Pinene** ▪ As an insecticide, especially on mosquitoes like *Culex pipiens* causing avian paludisme and Nile fever vector, or on dengue's vector *Aedes aegypti* [56].	
Cissus rotundifolia Vahl/unspecified part/Vitaceae [3]	Stomach pain by giving boiled plant to livestock [3].	**Antibacterial activity** **Methanolic extract of the leaves of Yemeni plant** ▪ Showed some activity against standard *S. aureus, B. subtilis,* and *P. aeruginosa* with MIC of 500, 500, and 250 µg/ml, respectively [57].	In an acute oral toxicity study, the 70 % methanol extract of nonflowering aerial parts showed no toxicity up to 1 g/kg in albino rats [58].
		Anti-inflammatory activity **70 % Methanolic extract of nonflowering aerial parts** ▪ Showed the highest anti-inflammatory potency at 4 h (33.33 % and 47.06 % inhibition of carrageenan-induced rat paw edema at 100 and 200 mg/kg bw, respectively) compared to the reference drug indomethacin (35.29 % edema inhibition at a dose of 10 mg/kg bw) [58].	

continued

▶ **Table 1** *Continued*

Species/part used/ Family	Uses	Pharmacological activities of extract and chemical constituents	Side effects/toxicological properties
		Analgesic activity **70 % methanolic extracts of nonflowering aerial parts** **Central analgesic effect** ▪ Significant delay of the mean reaction time on the hot plate (9.86 and 10.56 s at 100 and 200 mg/kg bw, respectively) compared to the reference drug indomethacin (10.30 s at 10 mg/kg bw) [58]. **Peripheral analgesic effect** ▪ Significant reduction of acetic acid-induced writhing in mice (19.22 ± 0.86 and 18.25 ± 0.58 writhes at 100 and 200 mg/kg bw, respectively) compared to the indomethacin (17.60 ± 1.21 writhes at 10 mg/kg bw) [58].	
		Antioxidant activity **Fresh Yemeni plant juice 0.59 ml/g fresh weight** ▪ Moderate antioxidant activity (41.26 ± 3.96 %, 69.95 ± 0.13 %, 85.92 ± 1.64 %) inhibition of guinea pig liver homogenate oxidation at 50, 100, and 200 µl, respectively measured by the thiobarbituric acid reagent substances method [59]. **Methanolic extract of leaves and stems of Yemeni plant** ▪ 59.8 % and 92.4 % DPPH radical scavenging activity at 500 and 1000 µg/mL, respectively [29]. **Ethanolic extract and its fractions of the aerial part (leaves and stems) of Yemeni plant** ▪ n-Butanol fraction showed a high activity to scavenge DPPH radical with IC_{50} 25.04 ± 0.76 µg/ml compared to ascorbic acid (IC_{50} 38.55 ± 0.83 µg/ml). In streptozotocin-induced diabetic rats, the ethanolic extract (300 mg/kg, p. o.) and its fractions (methylene chloride and n-butanol) at 2 doses (150 and 300 mg/kg, p. o.) showed a significant decrease in the content of malonaldehyde (lipid peroxidation products). All the tested samples at dose (300 mg/kg p. o.) significantly normalized the liver non-enzymatic antioxidant glutathione content of diabetic rats [60]. **Astragalin (kaempferol-3-*O*-*β*-D-glucopyranoside) and *β*-Amyrin** isolated from unflowering aerial parts exhibited significant DPPH radical scavenging activity (IC_{50} = 5.77 and 5.79 µg/mL, respectively) relative to that of ascorbic acid (IC_{50} = 33.3 µg/mL) [61].	
		Anti-ulcerative activity **70 % methanolic extracts of nonflowering aerial parts** ▪ Pre-treatment with 100 and 200 mg/kg bw produced a significant protection against ulcer formation in indomethacin-induced ulcers in pyloric-ligated rats [58].	
Cyphostemma digitatum (Forssk.) Desc./leaves/ Vitaceae [3]	Appetite stimulation by a beverage made of boiled leaves with salt given with water [3].	Food flavoring ▪ Acidic [62] and salty taste. Nutritional value ▪ Vitamin C and E (including *β*- and *γ*-tocotrienol forms that are very rare in nature), provitamin A, carotenoids, and phenolic compounds [62].	The fresh leaves are highly toxic and corrosive to the mouth and palate mucosa, and no herbivore was found feeding on this plant in more than 1,500 visited sites in central Yemen. The toxicity may be caused mechanically by microscopic spiny crystals (presumably composed of calcium oxalate) on the leaves photographed under the polarized light microscope [62].
Psiadia punctulate (DC.) Vatke/ unspecified part/ Asteraceae [3, 63]	Bone fracture by applying plant mixed with eggs as a cast [3, 63]	Analgesic activity **Leaf exudate** ▪ Analgesic effect in a mouse tail-flick experiment [64]. **A diterpene (6 p, 17, 19-ent-trachylobanetriol) isolated from leaf exudate and stem extracts** ▪ Appreciable analgesic effect at a dose of 50 mg/kg bw with a p-value of 0.02 when compared with aspirin [64].	The shrub is known to be avoided by goats even during severe drought even though its leaves remain green for a long time as it is quite drought resistant [65].

continued

▶ **Table 1** *Continued*

Species/part used/ Family	Uses	Pharmacological activities of extract and chemical constituents	Side effects/toxicological properties
Pulicaria undulata (L.) C. A. Mey./ unspecified part/ Asteraceae [3]	Insect repellent in livestock shelters [3].	**Insecticidal activity** **Aerial part essential oil:** ▪ Active against *Tregoderma granarium* and larvae of *Tribolium castaneum* [66]. **Methanolic extract** ▪ Toxic effect on *Spodoptera littoralis* (the cotton leafworm) [67]. **Carvotanacetone** ▪ A high larvicidal activity on 6 mosquitoes with LC50 lower than 10 µg/ml [68].	Adding the aerial part methanolic dried extract to chicken food was found as safe growth promotors [69].
Rumex nervosus Vahl/unspecified part/Polygonaceae [2]	Pimples in goats' eyes, treated with *Rumex nervosus* mixed with salt [2].	**Antibacterial activity** ▪ Buffered methanol, ethanol leaf extracts of Yemeni plant [70], and methanol extracts of aerial part [71] and leaves [72], as well as the ethanolic leaves extract [73], were active against *S. aureus*. ▪ Sub-fraction (containing palmitoleic acid methyl ester [28.35 %] and palmitic acid methyl ester [25.37 %] as major components) obtained from the ethyl acetate fraction of the crude methanolic extract of the Yemeni plant leaves showed promising activity against *S. aureus* [74]. ▪ Salt was found to have antimicrobial activity against several microorganisms, including *S. aureus* [75].	
		Antioxidant activity **Methanolic extract of Yemeni plant** ▪ DPPH radical scavenging activity with IC_{50} value of 450 ± 14.3 compared to standard antioxidant, ascorbic acid (IC_{50} of 320 ± 12.0) [76]. **Leaf and stem extracts** ▪ The scavenging activities, investigated by measuring $ABTS^{\bullet +}$ scavenging activity, ferrous ions chelating activity, superoxide anion radical scavenging activity, and ferric reducing antioxidant power activity of both tissue extracts increased dose-dependently and were significant ($p < 0.05$) using low concentrations of the leaf extract [77]. **Sub-fraction (containing palmitoleic acid methyl ester [28.35 %] and palmitic acid methyl ester [25.37 %] as major components) obtained from the ethyl acetate fraction of the crude methanolic extract of the Yemeni plant leaves** ▪ Significant DPPH radical scavenging activity (93.558 ± 0.4635 % at 60 µg/ml) compared to ascorbic acid (94.47 % at 60 µg/ml) [74].	
Trigonella foenum-graecum L. seeds/ Fabaceae [3]	For constipation by giving the fenugreek seeds together with *Hordeum vulgare* (Poaceae) grains [3].	**Mild bulk-forming laxative effect** ***Trigonella foenum-graecum* L. seeds** ▪ Mild bulk-forming laxative effect due to the content of dietary fibers (insoluble [20 %] and soluble fraction [30 %], which is mostly galactomannan) [78]. ***Hordeum vulgare* grains** ▪ Mild bulk-forming laxative effect due to high content of dietary fibers (soluble [mostly β-glucan] and insoluble fibers) [79].	***Trigonella foenum- graecum* seeds** ▪ Included in the AHPA class 2b. (not to be used during pregnancy), as well as in the list of generally recognized as safe when used as a spice or flavoring [80]. ▪ Myopathy in ruminants [80]. ▪ Some serious toxicological side effects, such as teratogenic, reproductive (antifertility, abortifacient), effects, neurotoxicity, and other cellular and molecular alterations, not without controversy, have been reported [81–84].

▶ **Table 2** Uses and adverse effects of some plants utilized in ethnoveterinary medicine in Yemen.

Species/part used/Family	Uses	Side effects/toxicological properties
Soqotraen *Aloe* spp. (*Aloe vera* [L.] Burm. f. and other endemic species such as *A. forbesii* Balf. f., *A. haggeherensis* T. A. McCoy & Lavranos, *A. jawiyon* S. J. Chirstie, D. P. Hannon & Oakman ex A. G. Mill, *A. perryi* Baker, and *A. squarrosa* Baker ex Balf. f.)/latex/Asphodelaceae [4]	For colic by using fresh latex	
	For insecticidal activity against blowfly or screw-worm fly attack in the rainy season and protecting fodder container from insects and rodents by smearing fresh latex sometimes mixed with ash around the tail/on the wound and the fodder container, respectively [4].	
	For shivering attacks by inserting the paste (dried latex mixed with water) into the nostrils and anus [4].	
	For distended belly or swollen liver or spleen by smearing the paste (dried latex mixed with water) on the belly and around the anus [4].	
Soqotraen *Aloe* spp./leaves/Asphodelaceae [4]	For protection against raven and wild cat attack by smearing crushed fresh aloe leaves around the neck and anus of young stock [4].	*Aloe vera* whole leaf cream applied topically in male and female SKH-1 hairless mice for 1 y showed a weak enhancing effect on the photocarcinogenic activity of simulated solar light, as manifested by significantly increased histopathologically-determined squamous cell neoplasm in some mice [24].
Boswellia sacra Flueck./underbark/Burseraceae [4]	For generalized edema by dressing and rubbing all over the body with a paste made of underbark [4].	
Soqotraen *Boswellia* species [4]	Anti-vermin (scorpions, giant centipedes, wolf spiders, snakes, etc.) by the smoke from burning oleo-gum resin [4].	
Calotropis procera (Aiton) Dryand./milky latex/Apocynaceae [3]	For swellings by topical application of milky latex [3].	The local administration induces an intense inflammatory response. Even accidental exposure to the latex produces contact dermatitis, keratitis, and toxic iridocyclitis. The acute inflammation is attributed to the presence of histamine in the latex and the release of histamine and prostaglandins [85].
Euphorbia arbuscula Balf.f (endemic to Soqotra)/latex/Euphorbiaceae [4]	For deterring the blowfly or screw-worm fly attacks on wounds or around the tail in the rainy season by applying a dressing of the latex, sometimes mixed with fine wood ash [4].	The latex of some Euphorbiaceae species containing diterpenes such as phorbol and its derivatives were found to have toxicity against insects and mammals, tumor-promoting activity, and to cause skin inflammation [86].
Gomphocarpus fruticosus (L.) W. T. Aiton/unspecified part/Apocynaceae [3]	For heat stroke by applying the plant to the body of the cow [3].	It is an unpalatable plant (contains cardenolides) and rarely eaten by livestock and therefore of little veterinary importance [87].

The mechanisms of action of these pharmacological activities were reported for some constituents. The antimicrobial activity of anthraquinones was ascribed to several mechanisms such as the inhibition of the microorganisms enzymes (such as penicillinase) by rhein, emodin, and aloe-emodin [93]; the inhibition of nucleic acids synthesis in *B. subtilis* by anthraquinones extracted from different *Aloe* species [94]; the inhibitory effect of aloe-emodin on the initial adhesion and proliferation stages of *Staphylococcus aureus* biofilm development [14]; and the partial disruption of virus envelopes by aloe-emodin [16]. Moreover, aloe-emodin showed a concentration-dependent reduction of virus-induced cytopathic effect and inhibition of the replication of influenza A in MDCK cells. A 50 % inhibitory concentration value of aloe-emodin on virus yield was less than 0.05 µg/ml [95]. The antibacterial mechanism of action of acetyl-11-keto-*β*-boswellic acid (AKBA) was attributed to its ability to disrupt the permeability barrier of microbial membrane structures [44]. *α*- Pinene was also found to induce toxic effects on the membrane structure (membrane expansion, increased membrane fluidity) and functions (inhibition of a membrane-embedded enzyme) of yeast and bacteria [56].

The anti-inflammatory mechanisms of action of *Aloe* latex, *B. sacra,* and *A. bracteolate* were reported for some of their constituents (▶ **Table 1**). AKBA, as the most important inhibitor of 5-lipoxygenase, binds to 5-lipoxygenase in a calcium-dependent and reversible manner and acts as a nonredox type, noncompetitive inhibitor [51]. In addition, studies have revealed that boswellic acids can also inhibit microsomal prostaglandin E2 synthase (mPGES)-1 in cell-free, cellular, and *in vivo* studies [96]. AKBA was also found to exert its anti-inflammatory effect by inhibiting NF-κB. The inhibitory effects of boswellic acids on NO production and the expression of pro-inflammatory cytokines and mediators *via* inhibition of phosphorylation of MAPKs, JNK, and p38 have been observed [97]. In addition to the anti-inflammatory effects of boswellic acids (beta-boswellic acid, 3-acteyl-beta-boswellic acid, 11-keto-beta-boswellic acid, and 3-acetyl-11-keto-beta-boswellic acid) through systemic application by inhibiting 5-lipoxygenase, boswellic acids were effective against inflammatory disorders through topical application by using different models of acute and chronic inflammation (*i.e.*, arachidonic acid and croton oil-induced mouse ear edema, carrageenan-induced rats paw edema, and adjuvant-induced developing arthritis in rats). The effect observed through this route is in accordance with the study conducted with the systemic route, thus establishing that boswellic acids, when used through topical application, are as effective as through the systemic route [98].

The analgesic effect of AKBA could be linked to its highly specific inhibition of 5-lipoxygenase, the key enzyme for the biosynthesis of leukotrienes. It has been shown that leukotrienes play a role in acute pain. Leukotriene LTB_4 and 5-hydroxyeicosatetraenoic acid are potent chemotactic factors for the polymorphs, which lower the firing threshold of pain fibers and therefore stimulate the nociceptors directly. In addition, the metabolic products of the lipoxygenase are reported to activate capsaicin receptors, which were suggested to play a role in thermal and chemical pain. Moreover, 5-lipoxygenase products act as a second messenger, downstream to protein kinase A and protein kinase C, and modulate their action in primary afferent nociceptors to mediate their sensitization to the mechanical and chemical stimuli [53].

The antioxidant activity of several extracts and chemical constituents of the studied plants (▶ **Table 1**) was assessed by several mechanistic methods based on either a single electron transfer reaction or a hydrogen atom transfer reaction from an antioxidant or oxidant to a free radical. The change of optical absorbance of either antioxidant or oxidant is measured for the quantitation for antioxidant capability [99].

Mastitis is a disease with a severe economic impact, causing production losses in the dairy industry. *S. aureus* is one of the leading causes of mastitis, resulting in an annual economic loss of $2 billion globally. *S. aureus* is also responsible for the emergence of resistant organisms and antibiotic residues in dairy products [55]. Acetyl-11-α-keto-β-boswellic acid-mediated silver nanoparticles (BANS, 0.12 $mg \cdot kg^{-1}$, intramammary and intraperitoneal) were reported to exert superior antibacterial (36%), anti-inflammatory (95%), and antioxidant effects compared with the antibiotic cefepime (1 $mg \cdot kg^{-1}$, intraperitoneal) in *S. aureus*-induced murine mastitis. BANS treatment significantly ($p < 0.05$) reduced bacterial load, C-reactive protein, superoxide dismutase, catalase activities, and neutrophil infiltration in affected mammary glands [55]. The antibacterial, anti-inflammatory, and antioxidant effects of acetyl-11-α-keto-β-boswellic acid could lend some support for the local use of oleo-gum resin of *B. sacra*, which may be able to target pathogens such as *S. aureus* present at the teat opening and thus help to prevent bacteria that cause mastitis from entering the teat canal and colonizing the mammary tissue, as well as reduce the inflammation of the udder surface.

S. aureus is among the most common causes of ocular infections, including blepharitis, dacryocystitis, conjunctivitis, keratitis, and endophthalmitis. Humans are not the only reservoir for this organism because the organism can be isolated from companion animals, livestock, and wild animals [100]. In the infection process, myeloperoxidase, NADPH oxidase, and NO synthase generate reactive species [101]. Therefore, the antibacterial activity of both *Rumex nervosus* and salt against *S. aureus*, together with the antioxidant activity of *R. nervosus* to reduce the oxidative stress triggered by this bacterial infection, could justify their combined use to treat pimples in goats' eyes.

Bloating is a disorder of ruminants caused by gas retention in the stomach. It results most commonly from excessive foaming of the contents of the rumen, which is the primary cause of bloating in animals feeding on legumes or lush young grass, and of feedlot bloating. Nonfoamy or free gas bloating is less common than foamy bloating and results from a variety of causes. It is predominantly a disorder of cattle but may also occur in sheep and other domestic ruminants. The total economic cost of bloating comes in many forms: losses by death and culling of bloating prone animals; losses of production from animals that were bloated and survived and the disruption of regular farm work and management programs; losses due to the use of less productive but safer pastures; and the cost of preventive measures and treatment [102]. Bloating can develop by the action of ruminal microflora, such as bacteria, fungi, and protozoa, that break down cellulose and protein by microbial fermentation. As such, antibiotics can control bloating based on the principle of reduced microbial activity. Penicillin was the first antibiotic used to control legume bloating, but its use was soon discontinued because of the drug's rapid development of microbial resistance. Recently, the ionophore antibiotics monensin (rumensin) and lasalocid have been used for bloating protection [103]. Consequently, the antimicrobial activity, together with the anti-inflammatory, antioxidant and antiulcer activities of *A. bracteolate* (with its constituent aristolochic acid) and the antiulcer effect of *S. bicolor* grains (▶ **Table 1**), could support their combined use to reduce livestock bloating by decreasing microbial fermentation, and inflammation (e.g., inflammation of the peritoneum, a common cause of vagal nerve damage, in the case of free gas bloating [104]) as well as the stress facing the animals during bloating.

In cattle, the source of abdominal pain can originate from visceral stretch receptors within the mesentery, organ capsules, or ligaments, muscular spasms or inflammation, and ischemia. Pain can also arise from parietal sources, including the parietal peritoneum, abdominal muscles or rib cage, or bacterial-associated mechanical or functional obstruction, inflammation, or other damage to the gastrointestinal tract wall. Additionally, extra-abdominal conditions can mimic intra-abdominal pain [105]. Hence, the pharmacological properties (antibacterial, anti-inflammatory, antioxidant, analgesic, and antiulcer activities, ▶ **Table 1**) of *C. rotundifolia* and its constituents, astragalin and β-amyrin, could explain its effectiveness for combating livestock abdominal pain and associated inflammation.

The use of *P. punctulate*, mixed with eggs as a cast, for bone fracture (▶ **Table 1**) could be supported by the analgesic effect of a diterpene, isolated from its leaf exudate and stem extracts, that may lessen the pain associated with a bone fracture. The suitability of this method will depend on the type of fracture. In simple closed fractures, casting may be enough to stabilize the bones and allow healing, and the analgesic action of *P. punctulate* may support the animal's wellbeing. However, this will not be enough to heal the bones in open and complicated fractures, and other measures are needed.

The use of *P. undulata* as insect repellent is substantiated by the insecticidal activity of the essential oil of *P. undulata* aerial part [66], methanolic extract [67], and the compound carvotanacetone [68], which is also found as a major constituent (91.4%) of the Yemeni *P. undulata* leaves essential oil [106]. On the other hand, no data were available on the insecticidal activity of Soqotraen *Boswellia* species and the latices of *Aloe* species and *E. arbuscula*. However, related *Boswellia* species such as *Boswellia carterii* essential oil, containing α-thujene (69.16%), α-pinene (7.20%), and α-phellandrene (6.78%) as the major components were found to exhibit insecticidal activity against both the pulse beetle *Callosobruchus chinensis* and *C. maculatus* [107]. Moreover, α-pinene was reported to act as an insecticide, especially on mosquitoes such as *Culex pipiens* causing paludisme and Nile fever vector or dengue's vector, *Aedes aegypti* [56]. Consequently, we suggest that the insecticidal activity of smoke from burning dead wood of Soqotraen *B. dioscoridis* could be attributed to α-thujene (9.3%) and α-pinene (8.3%), identified in the essential oil of the bark [108]. Similarly, related Aloe species such as fresh and dried *A. arborescens* leaves extracts (containing water-soluble tannins) were reported to exert *in vitro* acaricidal activity against *Rhipicephalus* (*Boophilus) microplus* engorged females [109], and the latex of some *Euphorbiaceae* species (containing diterpenes such as phorbol and its derivatives) showed toxicity against insects [86]. Thus, it is worth investigating the insecticidal activity of these plants.

In addition to the medicinal uses, the household processed leaves (dried thick paste of boiled leaves) of *Cyphostemma digitatum* is utilized in Yemen for a variety of culinary purposes (*e.g.*, as a spice and food flavoring in salads and some Yemeni dishes) for generations without any noticeable side effects or acute or chronic toxicity [62]. Likewise, the beverage made of boiled leaves of *C. digitatum* with salt is used as an appetite stimulant for livestock, presumably because of its flavoring effect (acidic and salty taste). Moreover, the leaves of *C. digitatum* could be of nutritional value for the livestock due to its content of vitamins C, E, provitamin A, carotenoids, and phenolic compounds (▶ **Table 1**).

In addition to the bioactivity, it is essential to consider the safety of the studied plants. The constituents of *Aloe* species latex (1,8-dihydroxy-anthraquinones) and *A. bracteolate* (aristolochic acids) were reported to possess some serious toxicological properties (▶ **Table 1**). Despite the toxicological activities of *Aloe* latex constituents, the use of the latex as a laxative in human medicine has not been prohibited, but it was restricted in dosage and period of treatment for cases of occasional constipation and when no laxative effect can be attained through diet change or the use of bulk-forming products [23]. Moreover, it has been reported that by considering the minimal use of Aloes in veterinary medicine (very infrequent, short-term treatment of individual animals only) and the limited absorption of the active principles after oral administration, the risk from veterinary use of Aloes to the consumer of foodstuffs of animal origin is considered negligible [5].

Fenugreek is included in the list of GRAS (generally regarded as safe) when used as spice or flavoring and is also classified as AHPA class 2b, not to be used during pregnancy (this classification is based on relatively high doses used for therapeutic purposes in contrast to lower amounts generally used in cooking and has not been associated with its use as a spice) [80]. Studies in animal models suggest a low acute toxic potential of fenugreek seeds by oral route at 2 and 5 g/kg bw in mice and rats, respectively, and intraperitoneal route at 0.65 and 3.5 g/kg bw in mice and rats, respectively [81]. As described in cattle [80], myopathy may be caused by feeding cattle solely on fenugreek straw, leading to intoxication or an induced deficiency state [110].

The literature showed controversial results regarding fenugreek seeds' teratogenic, antifertility, and neurotoxic effects, as well as resulting histopathological changes in vital organs (e.g., liver), hematological parameters, and clinical biochemistry. Several human and animal studies revealed teratogenic effects from congenital malformations to death; testicular toxicity and antifertility effects in male animals associated with oxidative stress and DNA damage; and antifertility, anti-implantation, and abortifacient activity in female animals. These effects have been suggested to be the consequences of a saponin compound of fenugreek seeds. In addition, the studies suggest that antifertility effects, hormonal disturbances, and adverse effects during pregnancy can be due to long-term daily use of at least 100 mg/kg bw of animal [81].

On the other hand, the prenatal oral exposure of 250, 500, and 1000 mg/kg/day of furostanol saponin glycoside (75.23%) and low molecular weight galactomannans based standardized fenugreek seed extracts were found safe and devoid of maternal and embryo-fetal toxicity [82–83]. Additionally, no effect on the fertility, and fetus's growth and development was observed in pregnant rats treated with fenugreek seed at 5 or 20% of the diet. Moreover, 75 mg/kg of trigonelline administered orally to pregnant and nonpregnant female rats showed no antifertility or abortifacient effects.

Although several studies have shown fenugreek to be neuroprotective, accumulating evidence suggests that fenugreek seeds may have neurodevelopmental, neurobehavioral, and neuropathological side effects [81]. Several studies claim the lack of histopathological changes in vital organs (e.g., liver), hematological parameters, and clinical biochemistry caused by fenugreek [81, 84]. However, several cellular and molecular alterations have been noted in animal models studies, especially in some vital organs (liver, kidney), hematological parameters, and blood biochemistry (e.g., a significant increase of hematocrit and reduction of serum total protein levels) by a daily oral administration of alcoholic extract 200 mg/kg rat bw for 4 weeks; A necrotic effect on the liver and the kidney tissues was observed at doses of 100,150, or 200 mg/kg of aqueous extract orally administered twice a week for 4 weeks to rats; crude saponins treatment to Hisex-type chicks caused necrosis of hepatocytes with lymphocytic infiltration and epithelial degeneration of renal tubules [81]. Due to multiple beneficial health properties of fenugreek seeds (e.g., antidiabetic effect, hypocholesterolemic influence, antioxidant potency, digestive stimulant action, and hepatoprotective effect) and its usage as a spice for seasoning and a flavoring agent and in comparatively larger quantities in making soups and pancakes [78], the reported toxicological effects should be taken seriously. Further research is needed to clarify these serious side effects and demonstrate their mechanisms of action. However, different extraction methods can lead to a different spectrum of constituents. Since the seeds were fed without extraction and no adverse effects in target animals were described, the risk of ethnoveterinary use may be limited.

The local use of *C. procera* latex in Yemen to treat swelling was documented without mentioning any side effects [3]. However, the local administration of the latex was reported to induce an intense inflammatory response. In addition, the dried latex was found to produce significant inflammation and hyperalgesia in different models of inflammation in rats, and hence, the dried latex-induced inflammation was used to investigate the anti-inflammatory and analgesic activity of anti-inflammatory drugs [85, 111]. No side effects were reported for *E. arbuscula* latex, although related *Euphorbiaceae* species were found to contain diterpenes derivatives (e.g., phorbol derivatives with skin inflammatory and tumor-promoting activities) [86]. Therefore, further research of these remedies is needed to illustrate their effectiveness and safety. Moreover, we emphasize the need to raise the livestock owner's awareness of the harmful side effects of herbal remedies and the appropriate way to use them either by limiting the dosage and period of treatment, avoiding their use during pregnancy and lactation, or by using safer alternatives.

Conclusion

In this paper, 14 ethnoveterinary plant species used in different areas of Yemen have been reviewed for their uses based on a scientific literature search on their biological activities and toxicological properties. The scientific data has indicated several *in vivo* and *in vitro* pharmacological studies that could support the claimed healing activities of 11 plant species, namely, *A. bracteolate, S. bicolor, C. rotundifol*ia, *C. digitatum, P. punctulate, P. undulata, R. nervosus, T. foenum-graecum,* and *H. vulgare*, for their indications, and of *Aloe* species latex, *B. sacra*, and Soqotraen *Boswellia* species for some of their indications. Three of these plants (*Aloe* species, *A. bracteolate, T. foenum-graecum*) exhibited some slight or even serious toxicological properties. Hence, our work offers valuable information on some Yemeni ethnoveterinary remedies that could be utilized for the benefit of livestock owners to justify using these remedies and increase awareness of their side effects and the rational way to use them. Moreover, we highlight the need for further scientific research on the effectiveness and safety of these plants.

Supporting information

The Supporting Information (Supplementary **Table 1S**) describes the plant part, livestock species, indication for use, preparation, ACTvetcode, and references for the 14 remedies for livestock.

Contributors' Statement

R. H. Alasbahi: data collection and design of the study. M. J. Groot and R. H. Alasbahi: analysis and interpretation of the data. R. H. Alasbahi and M. J. Groot: drafting the manuscript. M. J. Groot and R. H. Alasbahi: critical revision of the manuscript.

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Conflict of Interest

The authors declare that they have no conflict of interest.

References

[1] McGaw LJ, Eloff JN. Ethnoveterinary use of southern African plants and scientific evaluation of their medicinal properties. J Ethnopharmacol 2008; 119: 559–574

[2] Al-Hakimi A, Ya'ni AA. Women and coping strategies for adaptation to climate change using agro-biodiversity resources in the rain-fed highlands of Yemen. Report Prepared for the World Bank. Washington: World Bank; 2008

[3] Al-Hakimi A, Ya'ni AA, Pelat F. Using Plants in Response to Animal Health Problems in Chapter: Health Issues in the Mountains of Yemen: healing Practices as Part of Farmers' traditional Knowledge. In: Hehmeyer I, Schönig H, eds. Herbal Medicine in Yemen: Traditional Knowledge and Practice, and their Value for today's World. Leiden: Koninklijke Brill NV; 2012: 212–213

[4] Morris M. The Aloe and the frankincense Tree in southern Arabia: different Approaches to their Use. In: Hehmeyer I, Schönig H, eds. Herbal Medicine in Yemen: Traditional Knowledge and Practice, and their Value for today's World. Leiden: Koninklijke Brill NV; 2012: 103–125

[5] Committee for Veterinary Medicinal Products. Summary Report on Aloes. EMEA/MRL/549/99-FINAL. London: The European Agency for the Evaluation of Medicinal Products; 1999

[6] Boudreau MD, Beland FA. An evaluation of the biological and toxicological properties of *Aloe barbadensis* (miller), *Aloe vera*. J Environ Sci Health C Environ Carcinog Ecotoxicol Rev 2006; 24: 103–154

[7] Dubey PK, Ganeshpurkar A, Dubey S, Kakkar A. Isolation and studies on chemotherapeutic potential of aloin. Int J Green Pharm 2015; 9: 45–49

[8] Fichi G, Mattellini M, Meloni E, Flamini G, Perrucci S. *In vitro* Anthelmintic activity of two Aloe-derived active principles against sheep gastrointestinal nematodes. Nat Prod Commun 2017; 12: 1897–1899

[9] Lorenzetti LJ, Salisbury R, Beal JL, Baldwin JN. Bacteriostatic property of *Aloe vera*. J Pharm Sci 1964; 53: 1287–1290

[10] Kaithwas G, Kumar A, Pandey H, Acharya AK, Singh M, Bhatia D, Mukerjee A. Investigation of comparative antimicrobial activity of *Aloe Vera* gel and juice. Pharmacologyonline 2008; 1: 239–243

[11] Cock I. Antimicrobial activity of *Aloe barbadensis* Miller leaf gel components. Internet J Microbiol 2007; 4: 8

[12] Hatano T, Uebayashi H, Ito H, Shiota S, Tsuchiya T, Yoshida T. Phenolic constituents of Cassia seeds and antibacterial effect of some naphthalenes and anthraquinones on methicillin-resistant *Staphylococcus aureus*. Chem Pharm Bull 1999; 47: 1121–1127

[13] Pellizzoni M, Ruzickova G, Kalhotka L, Lucini L. Antimicrobial activity of different *Aloe barbadensis* Mill. and *Aloe arborescens* Mill. leaf fractions. J Med Plants Res 2012; 6: 1975–1981

[14] Xiang H, Cao F, Ming D, Zheng Y, Dong X, Zhong X, Mu D, Li B, Zhong L, Cao J, Wang L, Ma H, Wang T, Wang D. Aloe-emodin inhibits *Staphylococcus aureus* biofilms and extracellular protein production at the initial adhesion stage of biofilm development. Appl Microbiol Biotechnol 2017; 101: 6671–6681

[15] Agarwal SK, Singh SS, Verma S, Kumar S. Antifungal activity of anthraquinone derivatives from *Rheum emodi*. J Ethnopharmacol 2000; 72: 43–46

[16] Sydiskis RJ, Owen DG, Lohr JL, Rosler KH, Blomster RN. Inactivation of enveloped viruses by anthraquinones extracted from plants. Antimicrob Agents Chemother 1991; 35: 2463–2466

[17] Park MY, Kwon HJ, Sung MK. Evaluation of aloin and aloe-emodin as anti-inflammatory agents in aloe by using murine macrophages. Biosci Biotechnol Biochem 2009; 73: 828–832

[18] Yamamoto M, Masui T, Sugiyama K, Yokota M, Nakagomi K, Nakazawa H. Anti-inflammatory active constituents of *Aloe arborescens* Miller. Agric Biol Chem 1991; 55: 1627–1629

[19] Nakagomi K, Yamamoto M, Tanaka H, Tomizuka N, Masui T, Nakazawa H. Inhibition by aloenin and barbaloin of histamine release from rat peritoneal mast cells. Agric Biol Chem 1987; 51: 1723–1724

[20] Malterud KE, Farbrot TL, Huse AE, Sund RB. Antioxidant and radical scavenging effects of anthraquinones and anthrones. Pharmacology 1993; 47: 77–85

[21] Lin LX, Wang P, Wang YT, Huang Y, Jiang L, Wang XM. *Aloe vera* and *Vitis vinifera* improve wound healing in an in vivo rat burn wound model. Mol Med Rep 2016; 3: 1070–1076

[22] Wynn SG, Fougère BJ, eds. Aloe. Materia Medica Chapter 24, Part IV Veterinary clinical Uses of medicinal Plants, in veterinary herbal Medicine. Amsterdam: Mosby, Elsevier Inc; 2006: 467

[23] Committee on Herbal Medicinal Products (HMPC). European Union herbal monograph on *Aloe barbadensis* Mill. and on *Aloe* (various species, mainly *Aloe ferox* Mill. and its hybrids), folii succus siccatus. EMA/HMPC/625788/2015. London: European Medicines Agency; 2015

[24] Guo X, Mei N. *Aloe vera*: A review of toxicity and adverse clinical effects. J Environ Sci Health, Part C 2016; 34: 77–96

[25] Wölfle D, Schmutte C, Westendorf J, Marquardt H. Hydroxyanthraquinones as tumor promoters: Enhancement of malignant transformation of C3H mouse fibroblasts and growth stimulation of primary rat hepatocytes. Cancer Res 1990; 50: 6540–6544

[26] Kavitha D, Nirmaladevi R. Assessment of *Aristolochia bracteolata* leaf extracts for its biotherapeutic potential. Afr J Biotechnol 2009; 8: 4242–4244

[27] Mohamed MS, Idriss MT, Khedr AIM, Abd Al Gadir H, Takeshita S, Shah MM, Ichinose Y, Maki T. Activity of *Aristolochia bracteolata* against *Moraxella catarrhalis*. Int J Bacteriol 2014; 2014: Article ID 481686

[28] Das TS, Latha R, Agastian P. Evaluation of *Aristolochia bracteolate* Linn. for antimicrobial activity, α-glucosidase inhibition, and its phytochemical constituents. Asian J Pharm Clin Res 2016; 9: 137–142

[29] Mothana RAA, Kriegisch S, Harms M, Wende K, Lindequist U. Assessment of selected Yemeni medicinal plants for their in vitro antimicrobial, anticancer, and antioxidant activities. Pharm Biol 2011; 49: 200–210

[30] Alagesaboopathi C. Antimicrobial potential of root, stem and leaf extract of *Aristolochia bracteolata* Lam. Int J Curr Res 2011; 3: 019–021

[31] Angalaparameswari S, Mohamed Saleem TS, Alagusundaram M, Ramkanth S, Thiruvengadarajan VS, Gnanaprakash K, Madhusudhana Chetty C, Pratheesh G. Antimicrobial activity of aristolochic acid from root of *Aristolochia bracteata* Retz. World Acad Sci Eng Technol 2011; 57: 1017–1020

[32] Eltayeb IM, Nari FHM. Phytochemical screening, antioxidant and antimicrobial activities of some Sudanese medicinal plants against standard and isolated microorganisms. J Pharmacogn Phytochem 2017; 6: 97–100

[33] Shirwaikar A, Somashekar AP. Anti-inflammatory activity and free radical scavenging studies of *Aristolochia bracteolata* Lam. Indian J Pharm Sci 2003; 65: 67–69

[34] Bharathajothi P, Bhaaskaran CT. Phytochemical and pharmacological evaluations of *Aristolochia bracteolata* Lam. Asian J Plant Sci Res 2014; 4: 15–19

[35] Mei N, Xuan J, Chen T, Ning B, Guo L. Chapter 20. Gene Expression Profiling in evaluating the Safety and Toxicity of Nutraceuticals. In: Gupta RC, ed. Nutraceuticals, Efficacy, Safety and Toxicity. Cambridge, MA: Academic Press; 2016: 249–262

[36] Kalpana Devi B, Kanimozhi S, Suganyadevi P. Phytochemical screening and biological property of *Aristolochia bracteata*. J Pharm Res 2011; 4: 1509–1514

[37] Badami S, Jose CK, Kumar CRK, Dongre SKH, Jagadish PC, Suresh B. *In vitro* antioxidant activity of various extracts of *Aristolochia bracteolata* leaves. Orient Pharm Exp Med 2005; 5: 316–321

[38] Niyas MK, Kumar RM, Mani TT, Rahiman FOM, Bodhanapu S, Phaneendra P, Kumar SB. Antiulcer activity of aqueous extracts of *Aristolochia bracteolata* leaves. Pharmacologyonline 2011; 1: 1078–1082

[39] Tresina PS, Paulpriya K, Mohan VR. Evaluation of antiulcer activity of ethanol extracts of *Aristolochia krisagathra* Sivarajan and Pradeep and *Aristolochia bracteata* Retz. Whole plants in experimental rats. Res J Pharm Biol Chem Sci 2016; 7: 1165–1170

[40] Ritchie LE, Taddeo SS, Weeks BR, Carroll RJ, Dykes L, Rooney LW, Turner ND. Impact of novel sorghum bran diets on DSS-induced colitis. Nutrients 2017; 9: 330

[41] Abdoul-Latif FM, Obame LC, Bassolé IMN, Dicko MH. Antimicrobial activities of essential oil and methanol extract of *Boswellia sacra* Flueck. and *Boswellia papyrifera* (Del.) Hochst from Djibouti. Int J Manage Mod Sci Technol 2012; 1: 1–10

[42] Al-Saidi S, Rameshkumarb KB, Hisham A, Sivakumara N, Al-Kindya S. Composition and antibacterial activity of the essential oils of four commercial grades of Omani Luban, the oleo-gum resin of *Boswellia sacra* Flueck. Chem Biodivers 2012; 9: 615–624

[43] Van Vuuren SF, Kamatou GPP, Viljoen AM. Volatile composition and antimicrobial activity of twenty commercial frankincense essential oil samples. S Afr J Bot 2010; 76: 686–691

[44] Raja AF, Ali F, Khan IA, Shawl AS, Arora DS, Shah BA, Taneja C. Anti-staphylococcal and biofilm inhibitory activities of Acetyl 11 keto β Boswellic acid from *Boswellia serrata*. BMC Microbiol 2011; 11: 54

[45] Leite AM, Lima EO, Souza EL, Diniz MFFM, Trajano VN, Medeiros IA. Inhibitory effect of α-pinene, β-pinene and eugenol on the growth of potential infectious endocarditis causing Gram-positive bacteria. Braz J Pharm Sci 2007; 43: 121–126

[46] Dai J, Zhu L, Yang L, Qiu J. Chemical composition, antioxidant and antimicrobial activities of essential oil from *Wedelia prostrata*. EXCLI J 2013; 12: 479–490

[47] Glisic SB, Milojevic SZ, Dimitrijevic SI, Orlovic AM, Skala DU. Antimicrobial activity of the essential oil and different fractions of *Juniperus communis* L. and comparison with some commercial antibiotics. J Serb Chem Soc 2007; 72: 311–320

[48] Al-Harrasi A, Al-Rawahi A, Hussain J, Ali L, Hussain J, Ur Rehman N, Abbas G, Mehjabeen, Al-Harrasi R. First *in vitro* lipid peroxidation and *in vivo* anti-inflammatory activity of the Omani frankincense of *Boswellia sacra* Flueck. Int J Phytomed 2013; 5: 73–77

[49] Kim DS, Lee HJ, Jeon YD, Han YH, Kee JY, Kim HJ, Shin HJ, Kang JW, Lee BS, Kim SH, Kim SJ, Park SH, Choi BM, Park SJ, Um JY, Hong SH. Alpha-pinene exhibits anti-inflammatory activity through the suppression of MAPKs and the NF-κB pathway in mouse peritoneal macrophages. Am J Chin Med 2015; 43: 731–742

[50] de Cássia da Silveira e Sá R, Andrade LN, de Sousa DP. A review on anti-inflammatory activity of monoterpenes. Molecules 2013; 18: 1227–1254

[51] Hamidpour R, Hamidpour S, Hamidpour M, Shahlari M. Frankincense (Rǔ xiāng; *Boswellia* species): from the selection of traditional applications to the novel phytotherapy for the prevention and treatment of serious diseases. J Tradit Complement Med 2013; 3: 221–226

[52] Al-Harrasi A, Ali L, Hussain J, Ur Rehman N, Mehjabeen, Ahmed M, Al-Rawahi A. Analgesic effects of crude extracts and fractions of Omani frankincense obtained from traditional medicinal plant *Boswellia sacra* on animal models. Asian Pac J Trop Med 2014; 7: S485–S490

[53] Bishnoi M, Patil CS, Kumar A, Kulkarni SK. Analgesic activity of acetyl-11-keto-beta-boswellic acid, a 5-lipoxygenase-enzyme inhibitor. Indian J Pharmacol 2005; 37: 255–256

[54] Al-Harrasi A, Ali L, Ceniviva E, Al-Rawahi A, Hussain J, Hussain H, Ur Rehman N, Abbas G, Al-Harrasi R. Antiglycation and antioxidant activities and HPTLC analysis of *Boswellia sacra* Oleo gum resin: the sacred frankincense. Trop J Pharm Res 2013; 12: 597–602

[55] Muralidhar Y, Raj MA, Prasad TNKV, Kumar TVC, Adilaxmamma K, Srilatha C, Rao GS, Sreevani P, Aparna N. Antibacterial, anti-inflammatory and antioxidant effects of acetyl-11-α-keto-β-boswellic acid mediated silver nanoparticles in experimental murine mastitis. IET Nanobiotechnol 2017; 11: 682–689

[56] Mercier B, Prost J, Prost M. The essential oil of turpentine and its major volatile fraction (α- and β-pinenes): a review. Int J Occup Med Environ Health 2009; 22: 331–342

[57] Al-Fatimi M, Wurster M, Schröder G, Lindequist U. Antioxidant, antimicrobial and cytotoxic activities of selected medicinal plants from Yemen. J Ethnopharmacol 2007; 111: 657–666

[58] Said AA, Aboutabl EA, El Awdan SA, Raslan MA. Proximate analysis, phytochemical screening, and bioactivities evaluation of *Cissus rotundifolia* (Forssk.) Vahl. (Fam. Vitaceae) and *Sansevieria cylindrica* Bojer ex Hook. (Fam. Dracaenaceae) growing in Egypt. Egypt Pharm J 2015; 14: 180–186

[59] Al-Mamary MA. Antioxidant activity of commonly consumed vegetables in Yemen. Malays J Nutr 2002; 8: 179–189

[60] Shalabi A, El-Sakhawy F, Choucry M, EL Awdan S, Abdel-Sattar E. Assessment of biological activities of *Cissus rotundifolia* (Forssk.) Vahl. Growing in Yemen. Res J Pharm Biol Chem Sci 2018; 9: 430–440

[61] Said A, Aboutabl EA, Melek FR, Abdel Jaleel GAR, Raslan M. Phytoconstituents profiling of *Cissus rotundifolia* (Forssk.) Vahl. by HPLC-MS/MS, and evaluation of its free radical scavenging activity (DPPH) and cytotoxicity. Trends Phytochem Res 2018; 2: 65–74

[62] Al-Duais M, Jetschke G. The miraculous Plant ḥalqa (*Cyphostemma digitatum*): From Grandmother's Kitchen in Yemen's south-western Highlands to modern medicinal and culinary Applications. In: Hehmeyer I, Schönig H, eds. Herbal Medicine in Yemen: Traditional Knowledge and Practice, and their Value for today's World. Leiden: Koninklijke Brill NV; 2012: 167–182

[63] Ghazanfar SA. Handbook of Arabian medicinal Plants. Boca Raton, FL: CRC Press, Inc.; 1994

[64] Mulwa LS. Phytochemical investigation of *Psiadia punctulata* for analgesic agents [Doctoral dissertation]. Nairobi, Kenya: University of Nairobi; 2012

[65] Midiwo JO, Yenesew A, Juma BF, Omosa KL, Omosa IL, Mutisya D. Phytochemical evaluation of some Kenyan medicinal plants. 11th NAPRECA Symposium Book of Proceedings, Antananarivo, Madagascar; 2005: 9–19

[66] Elegami AAB, Ishag KE, Mahmoud EN, Abu Alfutuh IM, Karim EIA. Insecticidal activity of *Pulicaria undulata* oil. Fitoterapia 1994; 65: 82–83

[67] Abdullah SM. Effectiveness of certain wild plant extracts as insecticides. Egypt: Ain-Shams Univ., Faculty of Agriculture; 2011

[68] Benelli G, Govindarajan M, Rajeswary M, Senthilmurugan S, Vijayan P, Alharbi NS, Kadaikunnan S, Khaled JM. Larvicidal activity of *Blumea eriantha* essential oil and its components against six mosquito species, including Zika virus vectors: the promising potential of (4E,6Z)-allo-ocimene, carvotanacetone and dodecyl acetate. Parasitol Res 2017; 116: 1175–1188

[69] Elieba EM, Lebda MA, Taha NM, Mandor AWA, El-Magd MA. Consumption of *Pulicaria undulata* and *Salvadora persica* extracts is safe and has a growth promoter effect on broilers. Arab J Med Sci 2018; 1: 31–34

[70] Alzoreky NS, Nakahara K. Antibacterial activity of extracts from some edible plants commonly consumed in Asia. Int J Food Microbiol 2003; 80: 223–230

[71] Abdel-Sattar E, Harraz FM, El Gayed SH. Antimicrobial activity of extracts of some plants collected from the Kingdom of Saudi Arabia. JKAU-Med Sci 2008; 15: 25–33

[72] Al Yahya NA, Alrumman SA, Moustafa MF. Phytochemicals and antimicrobial activities of *Rumex nervosus* natural populations grown in Sarawat Mountains, Kingdom of Saudi Arabia. Arab J Sci Eng 2018; 43: 3465–3476

[73] Kasimala M, Tukue M, Ermias R. Phytochemical screening and antibacterial activity of two common terrestrial medicinal plants *Ruta ahalepensis* and *Rumex Nervosus*. Bali Med J 2014; 3: 116–121

[74] Quradha MM, Khan R, Rehman MU, Abohajeb A. Chemical composition and *in vitro* anticancer, antimicrobial and antioxidant activities of essential oil and methanol extract from *Rumex nervosus*. Nat Prod Res 2018; 19: 1–6

[75] Wijnker JJ, Koop G, Lipman LJA. Antimicrobial properties of salt (NaCl) used for the preservation of natural casings. Food Microbiol 2006; 23: 657–662

[76] Al-Naqeb G. Antioxidant and antibacterial activities of some Yemeni medicinal plants. Int J Herb Med 2015; 3: 6–11

[77] Desta KT, Lee WS, Lee SJ, Kim YH, Kim GS, Lee SJ, Kim ST, Abd El-Aty AM, Warda M, Shin HC, Shim JH, Shin SC. Antioxidant activities and liquid chromatography with electrospray ionization tandem mass spectrometry characterization and quantification of the polyphenolic contents of *Rumex nervosus* Vahl leaves and stems. J Sep Sci 2016; 39: 1433–1441

[78] Srinivasan K. Fenugreek (*Trigonella foenum-graecum*): A review of health beneficial physiological effects. Food Rev Int 2006; 22: 203–224

[79] Stephen AM, Champ MM, Cloran SJ, Fleith M, van Lieshout L, Meiborn H, Burely VJ. Dietary fibre in Europe: Current state of knowledge on definitions, sources, recommendations, intakes and relationships to health. Nutr Res Rev 2017; 30: 149–190

[80] Wynn SG, Fougère BJ, eds. Fenugreek. Materia Medica Chapter 24, Part IV Veterinary clinical Uses of medicinal Plants, in veterinary herbal Medicine. Amsterdam: Mosby, Elsevier Inc.; 2006: 549–552

[81] Ouzir M, El Bairi K, Amzazi S. Toxicological properties of fenugreek (*Trigonella foenum graecum*). Food Chem Toxicol 2016; 96: 145–154

[82] Deshpande P, Mohan V, Pore M, Gumaste S, Thakurdesai P. Prenatal developmental toxicity evaluation of furostanol saponin glycoside based standardized fenugreek seed extract during organogenesis period of pregnancy in rats. Int J Pharm Pharm Sci 2016; 8: 124–129

[83] Deshpande P, Mohan V, Pore M, Gumaste S, Thakurdesai P. Prenatal developmental toxicity evaluation of low molecular weight galactomannans based standardized fenugreek seed extract during organogenesis period of pregnancy in rats. Int J Pharm Pharm Sci 2016; 8: 248–253

[84] Deshpande P, Mohan V, Ingavale D, Mane J, Pore M, Thakurdesai P. Preclinical safety assessment of Furostanol glycoside-based standardized fenugreek seed extract in laboratory rats. J Diet Suppl 2017; 14: 521–541

[85] Sehgal R, Kumar VL. *Calotropis procera* latex-induced inflammatory hyperalgesia-effect of anti-inflammatory drugs. Mediators Inflamm 2005; 2005: 216–220

[86] Agrawal AA, Konno K. Latex: A model for understanding mechanisms, ecology, and evolution of plant defense against herbivory. Annu Rev Ecol Evol Syst 2009; 40: 311–331

[87] Botha CJ, Penrith ML. Poisonous plants of veterinary and human importance in southern Africa. J Ethnopharmacol 2008; 119: 549–558

[88] Ulbricht C, Armstrong J, Basch E, Basch S, Bent S, Dacey C, Dalton S, Foppa I, Giese N, Hammerness P, Kirkwood C, Sollars D, Tangguay-Colucci S, Weissner W. An evidence-based systematic review of *Aloe vera* by the natural standard research collaboration. J Herb Pharmacother 2007; 7: 279–323

[89] Arun M, Satish S, Anima P. Herbal boon for wounds. Int J Pharm Pharm Sci 2013; 5: 1–12

[90] Al-Harrasi A, Ur Rehman N, Khan AL, Al-Broumi M, Al-Amri I, Hussain J, Hussain H, Csuk R. Chemical, molecular and structural studies of *Boswellia* species: β-Boswellic Aldehyde and 3-*epi*-11β-Dihydroxy BA as precursors in biosynthesis of boswellic acids. PLoS One 2018; 13: e0198666

[91] Hakkim FL, Hassan SS, Al-Sabahi J, Al-Buloshi M. Chemical profiling and antimicrobial activity of frankincense (*Boswellia sacra*) derived heavy oil. Comp Res J Microbiol 2016; 1: 001–005

[92] Ali L, Ceniviva E, Al-Rawahi A, Hussain J, Hussain H, Ur Rehman N, Abbas G, Al-Harrasi R. Antiglycation and antioxidant activities and HPTLC analysis of *Boswellia sacra* Oleo gum resin: the sacred frankincense. Trop J Pharm Res 2013; 12: 597–602

[93] Abu-Darwish SM, Ateyyat AM. The pharmacological and pesticidal actions of naturally occurring 1,8-dihydroxyanthraquinones derivatives. World J Agric Sci 2008; 4: 495–505

[94] Yadav A, Bhardwaj R, Sharma RA. Phytochemical screening and antimicrobial activity of anthraquinones isolated from different parts of *Cassia nodosa*. Res J Med Plant 2013; 7: 150–157

[95] Li SW, Yang TC, Lai CC, Huang SH, Liao JM, Wan L, Lin YJ, Lin CW. Antiviral activity of aloe-emodin against influenza A virus via galectin-3 up-regulation. Eur J Pharmacol 2014; 738: 125–132

[96] Iram F, Khan SA, Husain A. Phytochemistry and potential therapeutic actions of Boswellic acids: a mini review. Asian Pac J Trop Biomed 2017; 7: 513–523

[97] Shah BA, Qazi GN, Taneja SC. Boswellic acids: a group of medicinally important compounds. Nat Prod Rep 2009; 26: 72–89

[98] Singh S, Khajuria A, Taneja SC, Johri RK, Singh J, Qazi GN. Boswellic acids: A leukotriene inhibitor also effective through topical application in inflammatory disorders. Phytomed 2008; 15: 400–407

[99] Lü JM, Lin PH, Yao Q, Chen C. Chemical and molecular mechanisms of antioxidants: experimental approaches and model systems. J Cell Mol Med 2010; 14: 840–860

[100] O'Callaghan RJ. The pathogenesis of *Staphylococcus aureus* eye infections. Pathogens 2018; 7: 9

[101] Pobanka M. Role of oxidative stress in infectious diseases. A review. Folia Microbiol (Praha) 2013; 58: 503–513

[102] Clarke RTJ, Reid CSW. Foamy bloat of cattle. A Review. J Dairy Sci 1974; 57: 753–785

[103] Tagesu A. Study on the prevalence of bovine frothy bloat in and around Kebele Lencha, Tokke Kutaye District, Oromia Region. Appro Poult Dairy & Vet Sci 2018; 2: 10

[104] Majak W, McAllister TA, Mcbartney D, Stanford K, Cheng KJ. Bloat in cattle. In: Kaulbars C, ed. Alberta Agriculture and Rural Development, Alberta, Canada. Alberta, Canada: Agriculture and Agri-Food Canada; 2003: 1–28

[105] Depenbrock S. Management of the colicky cow. Penn Annual Conference Proceedings, PAC2017 Proceedings. Philadelphia, PA: Penn-Vet; 2017. Accessed September 8, 2021 at: https://www.vet.upenn.edu/education/continuing-education/penn-annual-conference/ce-credits/proceedings-2017

[106] Ali NAA, Sharopov FS, Alhaj M, Hill GM, Porzel A, Arnold N, Setzer WN, Schmidt J, Wessjohann L. Chemical composition and biological activity of essential oil from *Pulicaria undulata* from Yemen. Nat Prod Commun 2012; 7: 257–260

[107] Kiran S, Kujur A, Patel L, Ramalakshmi K, Prakash B. Assessment of toxicity and biochemical mechanisms underlying the insecticidal activity of chemically characterized *Boswellia carterii* essential oil against insect pest of legume seeds. Pestic Biochem Physiol 2017; 139: 17–23

[108] Mothana RAA, Hasson SS, Schultze W, Mowitz A, Lindequist U. Phytochemical composition and *in vitro* antimicrobial and antioxidant activities of essential oils of three endemic Soqotraen *Boswellia* species. Food Chem 2011; 126: 1149–1154

[109] De Matos AC, Ribeiro CM, Scarminio IS, Afonso S, Vidotto O. Phytochemical analysis and acaricidal activity of *Aloe arborescens* Mill. extracts against *Rhipicephalus* (*Boophilus*) *microplus*. Semina: Ciências Agrárias, Londrina 2017; 38: 3113–3122

[110] Bourke CA. Are bovine fenugreek (*Trigonella foenum-graecum*) staggers and kangaroo gait of lactating ewes two clinically and pathologically similar nervous disorders? Aust Vet J 2009; 87: 99–101

[111] Meena AK, Yadav AK, Niranjan US, Singh B, Nagariya AK, Sharma K, Gaurav A, Sharma S, Rao MM. A review on *Calotropic procera* Linn and its ethnobotany, phytochemical, pharmacological profile. Drug invent today 2010; 2: 185–190

[112] Meenakshisundaram A, Harikrishnan TJ, Anna T. Evaluation of *Aloe vera* as anthelmintic against ovine gastrointestinal nematodes. Indian Vet J 2017; 94: 23–27