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Medicinal plants as alternative for control of livestock parasites. 2. Protozoa

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ABSTRACT

Antiparasitic agents have been used since long to combat the problem of parasites, both internal and external. But the emergence of resistance against industrial products, particularly in gastro-intestinal parasites including coccidia and in ectoparasites, has resulted in search for alternative control strategies. The application of ethnoveterinary practices and harnessing of plants as anthelmintics, anticoccidials and acaricidal agents is gaining popularity worldwide. Natural substances have a long record of safety for man, animals and environment. An increasing number of them are now proving their therapeutic value universally. The acceptability of plant products as alternatives depends largely on their scientific validation. A large number of studies in India and elsewhere have provided evidence for presence of bioactive components through *in vitro*, *in vivo* and clinical screening of plants. The target parasites include all major groups but this review is intended to deal with protozoans. Antiprotozoal activities has been identified in several plant products. They are now providing alternative means for combating some of the economically important livestock diseases with limited existing therapeutic options. Anti-trypanosomal potential was observed in several plants and bioactive compounds sourced from plants have exhibited antioxidant, immuno-modulatory and growth-promoting effects in addition to direct coccidia-suppression, thereby brightening their prospects as replacements for commercial anti-coccidial drugs for poultry. Plant-based agents as components of an integrated approach for the management of several important parasites, are increasingly finding favour.

Key words: Indigenous plants, Bioactive compounds, Protozoan parasites, Antiprotozoals, Anticoccidials

The plant kingdom has been a treasure house of potential drugs since ancient times. A large proportion of the world population reportedly relies on traditional plant-based remedies for primary health care needs of their own as well as their livestock. These remedies are used for the treatment of a wide range of diseases in animals. Further, a major part of the modern drugs are either derived from natural products or are their semi-synthetic and synthetic analogues (Kirby 1996). Unicellular eukaryotic organisms (protozoa) are the causal agents of several major diseases of global reach affecting both man and animals. Some of the most effective and prevalent remedies against devastating human disease are plant-based. The first anti-malarial drug was quinine, produced from bark of cinchona tree. The drug artemisin was introduced by Chinese scientists and is currently used extensively for treatment of malaria. Against cutaneous leishmaniasis endemic in many parts of the world use of emetin, obtained from the root of the plant Ipecac is a safe treatment. Herbals such as wild garlic, eucalyptus and thyme are some of the plants which can kill *Giardia* cysts, against which there is no satisfactory synthetic allopathic remedy. Medicinal plants such as Ipecac, mango and papaya possess anti-amoebic (*Entamoeba histolytica*) activity. Similarly, herbal medical systems were tapped for identifying new anti-protozoal drugs for veterinary usage, exemplified by Halofuginone derived from extract of *Dichroa febrifuga.* Synthetic chemicals and antiparasitic drugs which became, popular as byproducts of industrialization and a 'quick-fix' culture, have seen erosion of their value due to emergence of resistance and concern for safety and sustainability. Renewal of interest in ethnobotanicals has prompted many researchers worldwide to subject natural plant products to systematic and scientific evaluation. For a number of plants documented in literature for activity in variousparasitic conditions, validation based on rational evaluation was earlier lacking. This lacuna is now being filled through some newly developed isolation and characterization techniques together with pharmacological tests. Phyto-chemical analysis of medicinal plants provided evidence of the medicinally important bioactive compounds justifying their use in traditional medicine (Yadav and Agarwala 2011). At the same time, new and hitherto unexplored botanicals with potential for efficacy are re-inforcing the existing herbal antiparasitic armamentarium. Plant preparations are mostly extracts derived from various parts viz. leaves, seeds, bark, fruits, stem and roots. Bioactive substances contained in

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the plants include tannins, alkaloids, terpenoids, flavonoids and saponins. Numerous studies had carried out *in vitro* assays for screening and validation of plants, while *in vivo* assays were less frequent. In the Indian context, parasitic protozoa of livestock had received relatively less attention compared to helminths, and dedicated reviews are virtually non-existent. Of late, *Trypanosoma evansi* and to some extent avian coccidia, are emerging as frequent models for *in vivo* and field evaluations of medicinal plants/herbs, singly or as constituents of formulations.

An oxygenated chalcone isolated from the roots of Chinese licorice plant (Licochalcone A) was found to inhibit growth of both *Leishmania major* and *L. donovani*, in concentration non-toxic to host cells (Chen *et al*. 1993). The strong anti-leishmanial activity demonstrated in licochalcone A raised the possibility that appropriate substituted chalcones might become a new class of antileishmanial drugs, Curcumin, the bioactive compound in turmeric, was reported to have anti-*L. major* effects (Chattopadhyay *et al*. 2004). Dimeric quinones 4 and 5 derived from the roots of *Diospyros assimilis* exhibited good activity against *L. donovani* with IC_{50} of 12.94 and 16.66 µM (Ganapaty *et al*. 2006) *In vitro* antileishmanial efficacy of *Aloe vera* leaf exudates (Dutta *et al*. 2007) was demonstrated with an IC_{50} of 6.0 µg/ml against promastigotes from strain responsible for visceral leishmaniasis. Data indicated that this activity can be further enhanced by activation of host macrophages. *In vitro* assay of an Indian medicinal herb *Selaginella bryopteris* revealed eleven bioflavonoids containing amentoflavone and linoflavone derivates (Kunert *et al*. 2008). Of these, the strongest activity against *L. donovani* was detected for 2.3–dihydrohinokiflavone ($IC_{50=}$1.6µM). In a study on traditional medicinal plants from Garhwal region of North-west Himalaya, India (Dua *et al*. 2011), the chloroform extracts of *Leucas cephalotes* and the petroleum ether extracts of *Viola canescens* exhibited substantial activities against *L. donovani* with IC_{50} values of 3.61 µg/ml (SI=8) and 6.40 µg/ml (SI=30) respectively. Plant extracts of *Agave americana, Azadirachta indica, Eclipta alba* and *Piper longum* induced significant promastigote and amastigote killing effect (Singh *et al.* 2011). Another study (Makwali *et al*. 2012) demonstrated that combination therapy using alternative administration of saponin, acriflavin, trifluralin and plumbagin is effective in treating *L. major* infection in mice. In this regard the authors suggested that efficacy of these combined therapies against other *Leishmania* strains should be explored. *Xanthium strumarium* (*Chhota Gokharu*) a gregarious weed distributed throughout tropical India possess anti- trypanosomal activity (Talakal *et al*. 1995a). Another plant *Parthenium hysterophorus* was found to significantly reduce parasitaemia and increase the survival time of *T. evansi* infected animals (Talakal *et al.* 1995b). Dwivedi (1997) screened 23 indigenous plants for antitrypanosomal activity. Of these, only the alcoholic extracts of three plants *X. strumarium* leaves, *Parthenium hysterophor*us flowers and *Nyclanthes arbortristis* leaves, were found effective both *in vivo* and *in vitro*. *Acacia* sp. was eminent among medicinal plants identified in Nigeria for trypanocidal activity (Adewunmi *et al*. 2001). Naphthalene derivatives from *Diospyros assimilis* roots were evaluated for antiprotozoal activity (Ganapaty *et al*. 2006), and dimene quinones 4 and 5 exhibited good activity against *Trypanosoma brucei* with IC_{50} of 1–12 and 8.82 µM. Due to limited choice of trypanocides available in the market, high cost, toxicity and emergence of drug resistance, search for alternatives from ethno-medicine gained momentum (Shaba *et al.* 2006). Several medicinal plants were found to possess trypanocidal activity against *T. evansi* in a series of *in vitro* studies which may hold the key to developing anti-*T. evansi* drugs for future: 1) *Plumbago zelanica* root (Shaba *et al*. 2007), 2) *Terminalia chebula* dried fruits (Shaba *et al.* 2009), 3) *T. bellirica* dried fruits (Shyaba *et al*. 2009), 4) *Calatropis gigantea* leaves (Shaba *et al*. 2011a), 5) *Quercus borealis* leaves, 6) *Zingiber officinale* roots (Shaba *et al*. 2011b), 7) *Camellia sinensis* or green tea leaves (Shaba *et al*. 2011c), 8) *Ageratum houstonionum* flowers (Shaba *et al*. 2011d), 9) *Khaya senegalensis* tree bark (Shaba *et al*. 2011e), 10) *Zanthoxylum alatum* leaves, and 11) *Eugenia caryophyllata* fruit buds (Shaba *et al*. 2012a), 12) *Piper nigrum* Black pepper (Shaba *et al*. 2012 b), 13) *Centella asiatica* leaves (Shaba *et al*. 2012c), 14) *Eupatorium adenophorum* leaves (Shaba *et al*. 2012d), and 15) *Picrorhiza kurroa* rhizomes (Shaba *et al.* 2012e). Of these, some like *K. senegalensis* and *T. bellirica* indicated high promise. Methanol and chloroform extracts of some common medicinal plants of Sudan were evaluated for *in vivo* activity against *T. evansi* (Abdelrahman 2011). Good trypanocidal effect was found in *Tinospora bakis, Argemone mexicana* and *Aristolochia bracteolata.*

Management of giardiasis (*Giardia lamblia*) by "Pippala Rasayana" an Indian Ayurvedic drug prepared from Palash (*Butea monosperma*) and Pippali (*Piper longum*) administered at 1g orally thrice daily for a period of 15 days (Agarwal *et al*. 1997) gave clinical and parasitological recovery in 23 of 25 patients. *In vitro* anti-giardial activity was documented in *Yucca schidigera* powder (Busatti *et al.* 2009). Against trichomoniasis of pigeons, 4 herbal and 5 commercial antiprotozoal drugs were evaluated (Biswas *et al*. 2010). Thankuni (*Centella asiatica*) 20% showed the highest efficacy *in vitro* and *in vivo* conditions but commercial drugs like metronidazole were more effective. Ethanol extracts of *Curcuma longa* (turmeric) rhizome contained antiprotozoal activity against *Entamoeba histolytica* (Chattopadhay *et al.* 2004). Sequiterpene lactone (Incompeteney A) from the leaves extract of *Decachaeta incompta* was found to be a potent antiamoebic and antigiardial compound (Calzada *et al.* 2009) with IC_{50} values of 2.6 μg/ml for *E. histolytica* and 18.1 μg/ml for *G. lamblia*. Piperine from *Piper longum* enhance the *in vivo* bioavailability of metronidazole when administered in combination to rabbits (Singh *et al.* 2010). Another herb *Berberis aristata* ('Daruharidra') containing berberine exhibited antiamoebic properties (Patel *et al.* 2012). In *in*

vitro study antimalarial activity against *Plasmodium falciparum* was exhibited in phenylated chalcones isolated from *Crotalaria* genus (*C. anixensis*).Those from two other species *C. medicagenia* and *C. ramosissima* also exhibited similar activity when evaluated at three concentrations (50, 10 and 2 μg/ml). Compound 3 exhibited 100% inhibition of schizont maturation at 2 µg/ml concentration (Narendar *et al.* 2005). The authors opined that provision of scientific rationale for the antiprotozoal activity of plants used in ethnomedicine may pave the way to develop a potent synthetic antimalarial drug derivative. In the Indian medicinal herb *Salaginella bryopteris*, eleven biflavonoids containing amentoflavone and hinokiflavone derivatives (Kunert *et al.* 2008) were investigated using *in vitro* assay for antiprotozoal activity. Against K1 strain of *P. falciparum*, the highest activity was displayed by a methylamentoflavone with an IC_{50} of 0.26 µM. The chloroform extract of *Artemisia roxburghiana* showed good antiplasmodial activity (Dua *et al.* 2011) with IC_{50} value of 0.42 µg/ml and was regarded as most selective (SI = 78) extract among 5 traditional medicinal plants from the Garhwal region of Northwesteren Himalayas. *In vitro* antiplasmodial activity of significant levels was recorded in aqueous and ethanol extracts of *Diospyros melanoxylon* bark from Uttaranchal against chloroquine resistant and susceptible variety of *P. falciparum* (Saxena *et al.* 2011).

Artemisinin derivative from the plant *Artemisia* was reported to have therapeutic activity against *Babesia equi (Theleria equi)* (Kumar *et al.* 2003). Antibabesial activity in *Rhoicissus tridentata* extracts was ascribed to antioxidant compounds present in it (Naidoo *et al.* 2006). Bark extracts of 22 plants were evaluated for their anti-babesial activity against *Babesia gibsoni in vitro.* Of these, the extracts of *Calophyllum tetrapterum*, *Garcinia rigida*, *Lithocarpus* sp., *Sandoricum emarginatum* and *Shorea balangeran* were found effective. The results showed more than 90% inhibition of the parasite growth at a test concentration of 1000 µg/mL (Subeki *et al*. 2005). Bruceine A, a natural quassinoid compound extracted from the dried fruits of *Brucea javanica* was evaluated for its antibabesial activity *in vitro* and *in vivo* (Nakao *et al*. 2009). It was found to inhibit the *in vitro* growth of *Babesia gibsoni* in canine erythrocytes at lower concentration compared with the standard antibabesial drug and killed the parasites within 24 hr at a concentration of 25 nM. Oral administration of Bruceine A at a dosage of 6.4 mg/kg/day for 5 days resulted in clinical cure in dogs infected with *B. gibsoni*, but untreated dog developed typical acute babesiosis. Kazembe and Chinyuku (2012) showed that both the ethyl acetate and the methanol extracts of the root bark and pods of *Swartzia madagascarensis* were effective against *Babesia bigemina* and results of their fortification of chloroquine demonstrated that they might have a synergistic relationship with chloroquine. Herbal formulation prepared from extracts of *Nyctanthes abortristis,* '*Jagadrumis'* (local name in Orissa), *Soymida febrifusa, Lawsonia innermis* (root) and entire plant of *Vitex peduncularis* and *Combertum dacandrom* was administered I/v @ 1 ml 20 kg^{-1} body weight for 5 days along with 50 ml water extracts of herbal material with honey and ginger orally once for 7 days to five calves experimentally infected with *Theileria annulata.* Improvement after 24–48 h and clinical normalcy by 10^{th} day compared to five non-treated infected controls which died 20–25 days post-infection (Pradhan *et al.* 1998). Mirzaei (2007) treated 50 cattle naturally infected with *T. annulata* with the extract of the plant *Peganum harmala* @ 5 mg/kg per day for 5 days, and recorded a recovery of 78% in cattle, but 22% did not respond to the treatment and died. Further the comparative trials carried out (Durrani *et al.* 2009) with homogenized buds and flowers of herbal plant *Calotropis procera* and buparvaquone (Butalex) in crossbred cattle after experimental infection with *T. annulata* indicated that the efficacy of *C. procera* @ 0.3 mg/kg orally with 8 doses on alternate days was higher (92.5%) than buparvaquone @ 2.5 mg/kg body weight (b.w). on alternate days (75.0%) on 21 day post treatment (pt). Natural infection of malignant ovine theileriosis in Iranian fat-tailed sheep was clinically cured with I/v injection of 10 ml garlic (*Allium sativum)* extract, two injections at 48 hr interval (Nowroozi-Asi *et al*. 2010). Lambs were experimentally infected with *Theileria hirci* causative agent for malignant theileriosis through the bites of infected ticks *Hyalomma anatolicum anatolicum* and after development of disease they were treated with extract containing the alkaloids of *Peganum harmala* (wild rue). All treated animals recovered from infection while control sheep progressed with typical disease until their death (Derakhshanfar and Mirzaei, 2008). Investigations of *in vitro* activity of aqueous extract of *Gardenia ternifolia* fruit (Hayat *et al*. 2012) and *Tinospora bakis* root (Hayat *et al.* 2013) against *Theileria lestoquardi*, causative agent for malignant theileriosis in sheep. It was concluded that the plant extracts have high activity against this species.

Coccidiosis, particularly avian coccidiosis, is responsible for enormous economic losses to poultry industry worldwide. Commercial coccidiostats incorporated in feed was a satisfactory practice till the emergence of resistance and undesirable residues in animal products, vitiated the routine. In the current scenario, search for sustainable alternative strategies has resulted in evaluation of botanicals for anticoccidial, immunomodulatory and probiotic activities worldwide (Table 1). Dietary supplementation with flaxseed whole or oil added in starter ration from day 1 of age was observed to reduce lesions resulting from challenge infection with *Eimeria tenella* (Allen *et al.* 1997a). In India some of the plants with proven antiprotozoan activity, as mentioned by Kirtikar and Basu (1975), like 'Kurchi' (*Holorrhena antidysentrica*), *Berberis* spp. and A*llium* spp. have formed part of proprietory anticoccidial formulations. Efficacy for some of these, like IHP-250C(Zycox) and AV/CPP/12, as per standard protocols in poultry floor pen trials (Mandal *et al.* 1994, Ashuma *et al*. 2005, Pangasa *et al.* 2007, Bal *et al.* 2008,

Table 1. Summary of some studies on plants/plant-based products for the control of coccidiosis

Name of plant	Part used	Preparation (active principle)	Activity	Coccidian species	Efficacy criteria	Reference
Melia azedarach (*Backain*)	Fruit	Extract	Anticoccidial	Natural *Eimeria* infection	Survival rate; oocyst excretion, Lesion score	Akhtar and Rifaat (1987)
Artemisia annua	Whole plant	Extract (Artemisinin)	Anticoccidial	*Eimeria tenella*	Lesion score, Body weight, oocyst count	Allen *et al.* (1997b)
Beta vulgaris		Glycine betane		*Eimeria tenella* (broilers)	Growth promotion, Body weight, Oocyst output	Augustine *et al*. (1997)
Sophora flavescens	Root	Extract (in drinking water 6–30 g /1000 ml)	Anticoccidial	*Eimeria tenella* (experimental infection)	Survival rate, Bloody diarrhea, Weight gains	Youn *et al.* (2001)
Azadirachta indica (Neem)	Fruit	Feed additive (Azadirachtin)	Anticoccidial	*Eimeria* spp. (broilers)	Faecal oocyst, Feed convertion ratio (FCR), Lesions	Tipu *et al*. (2002)
Echinacea purpurea		Dietary supplement	Immuno-therapeutic	*Eimeria* spp. (broilers)	Growth/Body weight, Oocyst output, Survival rate	Allen (2003)
Artemisia sieberi	Whole plant	Extract (Artemisinin: a sesquiterpene compound)	Anti-oxidant (anticoccidial)	*Eimeria* spp.(broiler chicken)	Faecal count	Arab *et al.* (2006)
Hops	Flower	(a prenylated chalcone xanthohumol)	Anti-oxidant (anticoccidial) (affects the intracellular replicative stages)	*Eimeria* spp. (broiler chicken)	Faecal count	Allen (2007)
Camellia sinensis (Green tea)	Leaf	Dietary supplement	Anti-oxidant Probiotic (contains polyphenolic compounds catechins)	*E. maxima* (broilers)	Reduced oocyst count	Jang *et al.* (2007)
Aegel marmelos (Bael)	Fruit rind	Extract (Marmelosin)	Anticoccidial	*Eimeria* spp. (Industrial broilers)	Faecal oocyst count	Khan *et al.* (2008)
Polygoum bistorta (Anjbar)		Extract	-do-	-do- -do-	-do-	-do-

(Contd...)

Name of plant	Part used	Preparation (active principle)	Activity	Coccidian species	Efficacy criteria	Reference
Prunus salicina (oriental plum)	Fruit	Dietary supplement	Immuno-modulatory	*E. aceruvulina* (challenge)	Weight gains, Faecal oocysts, Increased level of mRNAs	Lee *et al.* (2008)
Tulbaghia violacea	Whole plant	Acetone extract (35mg/kg b. w.)	Antioxidant	*E. tenella*	Feed convertion ratio (FCR), Oocyst output	Naidoo *et al.* (2008)
Ageratum conyzoides (Billy goat weed)	Whole plant	Ethanol extract (500-1000 mg /kg b. w.)	Anticoccidial	*E. tenella*	Faecal oocysts, Body weight	Nweze and Obiwulu (2009)
Pinus radiata (Pine)	bark	Aqueous extract (condensed tannins) in drinking water	Anticoccidial	Three *Eimeria* spp. (including *E. tenella*)	Decreased sporulation	Molan *et al.* (2009)
Curcuma longa (Turmeric)	rhizome	,,	Anticoccidial	*Eimeria* spp.	Weight gain, FCR, Reduced mortality, Lesion score	Abbas *et al.* (2010)
Fraxinus ornus (Manna-ash tree)	Leaves & little stem	Decotion in water Dietary supplement	Anticoccidial (growth promoter)	*E. tenella* (experimentally infected broilers)	Faecal oocysts, Body weight	Papazahariadou *et al.* (2010)
Musa paradisiaca	root	Methanolic extract	Anticoccidial	-do-	-do-	Anosa and Okoro (2011)
Saccharum officinarum (Sugarcane)	Whole plant	Extract Dietary supplement	Immuno-therapeutic Neutroceutical	-do-	Weight gain, Faecal oocysts, Lesion score	Awais *et al.* (2011)
Leucaena leucocephala (Subabul)	Seed	Extract (Mimosin)Feed additive 10% concentration	Anticoccidial (growth promoter)	*E. tenella* (experimentally infected broilers)	Body weight gains (Moderately effective)	Bal *et al.* (2011)
Carica papaya (Papaya)	Leaves powder	Feed supplement 15g/kg, 7g/kg	Anticoccidial Immuno-modulatory	*E. tenella* (experimentally infected broilers)	Weight gain, FCR, Oocyst count, Lesion scores 1gY levels	Hadimani and Gupta (2011)
Azadirachta indica	Leaves powder	”	”			

Combination of two (*C. papaya* and *A. indica*) appeared to work as antagonist and beneficial effects were reduced as compared to single bio-agent.

(Contd...)

(Concluded Table 1.)

Name of plant	Part used	Preparation (active principle)	Activity	Coccidian species	Efficacy criteria	Reference
Eclipta alba	aerial parts	Extracts (coumestans) Phytotherapy in feed 120ppm	Anticoccidial Immuno-modulatory (Therapy & prophylaxis)	*E. tenella* (experimental infection)	Faecal oocytes, Body weight	Michels *et al.* (2011)
Anona senegalensis (*Gwandan daji* in local language)	Stem bark	Aqueous extract Orally or intra-peritoneally	Anticoccidial (Inhibition of oocyst production and sporulation)	*Eimeria* spp. (avian coccidiosis)	Faecal oocysts	Nwosu *et al.* (2011)
Khaya senegalensis (Kadanya)	Stembark	Aqueous extract Orally or intra-peritoneally	Anticoccidial (Inhibition of oocyst production and sporulation)	*Eimeria* spp.(avian coccidiosis)	Faecal oocysts	Nwosu *et al.* (2011)
Aloe vera (Medicinal aloe)	Leaves pulp	Aqueous extractEthanol extractDietary supplement	Probiotic, Immuno-therapeutic (poetentiates cellular and humoral immune responses)	Mixed (*Eimeria* spp. *E. tenella* *E. nexatrix* *E. aceruvulina*)	Weight gain, Oocysts per gram, Lesions score	Akhtar *et al.* (2012 a)
Triticum aestivum (Wheat)	Bran-derived Polysaccharides & Arabino-xylans	Extract Dietary supplement	Immuno modulatory (Coccidia protective)	Experimental mixed *E.maxima*	Body weight, Development of lymphoid organis	Akhtar *et al.* (2012 b)
Artemisia annua	Leaves (dried)	Feed supplement	Coccidiostat	Mixed natural in free-range broilers	Faecal oocys tscounts	de Almeida*et al.* (2012)
Argeratum conyzoides (goat weed)	Whole leaf	Aqueous extract Oral (10% concentration of whole extract	Anticoccidial (useful as handy first line of control)	*E. tenella*	Faecal oocyst count	Annan-Prah *et al.* (2012)
Artemisa absinthum	Whole plant (dried)	Aqueous extractm Oral graded doses 1,2, & 3mg/kg/day (3mg/kg gave best result)	Anticoccidial	*E. tenella* (experimental in broilers)	Bloody diarrhea	Kostadinovic *et al.* (2012)
Echinaceae purpurea	Whole plant	Extract & cinnam-ald ehyde (alone or as adjuvant) Dietary supplement	Anticoccidial (moderately effective)	*E. aceruvulina*	Performance, Oocyst excretion, Lesion scores	Orengo *et al.* (2012)
Cinnamon	Bark	Volatie oil (cinnamaldehyde)	Anticoccidial (moderately effective)	*E.aceruvulina* (experimental)	Performance lesion scores (grass and microscopic)	Orengo *et al.* (2012)

Shameem *et al*. 2010) has been claimed. A herbal anticoccidial powder containing *Embelia ribes* seeds and *H. antidysentrica* with or without soda bicarb (to increase the pH of intestinal contents) was evaluated in experimentally infected broiler chicks (Singh *et al*. 2008). Supplemented group showed significant effect on growth performance, parasitological and haematological parameters. Soda bicarb as feed additive was highly effective against moderate mixed coccidial infections. Another proprietary formulation 'Coxynil' with composition of *Allium sativum* 15%, *Cinnamonum camphora* 15%, *Elephantopus scaber* 15%, *Valeriana wallichi* 15%, sulphur dioxide 25% and sodium chloride 15%, was evaluated in experimentally induced (Kurkure *et al*. 2006) and against natural clinical coccidiosis in broiler flock (Raut *et al*. 2012). Efficacy was indicated by recovery of birds post treatment, faecal oocyst counts and oocyst sporulation. A herbal complex containing A*llium sativum*, *Salvia officinalis*, *Echinacea purpurea*, *Thymus vulgaris* and *Origanum vulgare,* was also found effective against many species of *Eimeria* in broiler chickens, in reducing oocyst output (Arczewska-Wlosek and Swiatkiewicz 2012). Most of the ingredients have compounds with reported antioxidant properties indicative of the current trends in management of coccidiosis. Plant-expressed coccidial antigens as potential vaccine candidates in protecting chickens against coccidiosis (Sathish *et al*. 2012) is another potential plant-based alternative approach. Coccidiosis near weaning is a major cause of diarrhea, ill thrift and impaired performance in small ruminants. Markovics *et al.* (2012) reported that coccidiosis in young weaned kids could be alleviated by feeding them the tannin-rich foliage of *Pistacia lentiscus* L (lentisk) or by tethering them close to lentisk bushes which they browse on. The positive effect is associated with intake of tannins. Most recently, in naturally infected goats (Iqbal *et al*. 2013), *Artemisia absinthium* at 2g/kg-^{1} single treatment proved moderately effective in comparison to conventional standard treatment with either amprolium or toltrazuril.

CONCLUSION

Phytotherapy as component of integrated control of parasites is emerging as a realistic and sustainable measure. As such, there is need for large-scale experimental trials to establish the efficacy of alternative agents. However, critical appraisal and standardization of methods currently used for validation of antiparasitic activity is imperative. Since *in vivo* findings may not necessarily correlate with *in vitro* efficacy, more weightage should be given to *in vitro* field screening and replicability of studies. As a measure of confidence, evaluation of plants/bioactive compounds for anticoccidial activity, protocols should be formulated on the basis of standard procedures as described in the guidelines of the World Association for Advancement of Veterinary Parasitology-WAAVP (Holdsworth *et al*. 2004). The adjunct role of botanicals for enhancing and extending the efficacy - life span of existing anti-trypanosoma and anticoccidials, should be explored. Neutroceuticals, immunomodulants and probiotics sourced from plants are a new class which should be promoted with the twin objectives of providing protection from parasitism as well as improved performance.

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