Epidemiology and Control Measures of Helminth Parasites in Small Ruminants

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Article History

Manuscript No. 335
Received in 5th July, 2012
Received in revised form 21st April, 2013
Accepted in final form 4th June, 2013

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Keywords

Ruminants, Helminth parasites, epidemiology, control

Abstract

Epidemiology of parasitic disease is very important for control as well as preventive measures in small ruminants. The precipitating factor of environment and host parasite plays a very important role for prevalence and occurrence of parasites in population. Hence, a systematic approach and judicious use of anthelmintic will not only help in substantial control of parasite in population but also increase productivity of animals. However, recent advancement of biological control and immunological control will be promising hope for reduce morbidity and mortality due to gastrointestinal parasites. The elucidation of parasitic antigen will be of great help in developing of successful vaccine in near future.

1. Introduction

Parasitic disease is one of the major causes of mortality and morbidity in small ruminants. The direct causes of economic loss due to parasitic infestations are acute illness, death and premature slaughter. In addition, another cause of economic loss to small animal ruminant farmers is rejection of edible parts of infested animals during meat inspection. The indirect losses are due to decrease potentiality in terms of production performances like weight loss, decrease growth rate in growing animals and decreased reproductive potentiality in adult animals. In animals, parasitic infections can occur in either clinical or sub clinical form. However, the later is being the most common and important from economic point of view. The sub-clinical infection is directly related to reproductive performance of the animal. However, the clinical form of parasitic infestation has received considerable attention as it causes mortality in animals. The epidemiology of helminthes diseases is determined by several factors that are governed by the environment and host-parasite interactions. This article presents an overview of epidemiology of helminthes parasites in small ruminants and the factors affecting prevalence of helminthes parasites. In addition, the effective measures to control and prevent helminthes parasites in small ruminants are discussed in detail.

2. Epidemiology of Helminth Parasites

2.1. Gastrointestinal (GI) nematodes

In sheep and goats, the gastrointestinal nematode species that have been identified as most virulent are *Haemonchus contortus*, *Trichostrongylus colubriformis*, *Oesophagostomum columbianum* and *Gaigeria pachycelis* (Fabiyi, 1970; Allonby and Urquhart, 1975; Eysker and Ogunsusi, 1980). In addition, the small ruminants have also been reported to be infected with nematodes like *Bunustomum* spp. and *Cooperia* spp. Several reports are available on frequent occurrence of *Nematodirus* spp, *Pseudomarshallagia* (*Longistrongylus) elongata* and lungworms, specifically *Dictyocaulus filaria* infestations in small ruminants of temperate and tropical highlands.

2.2. Factors affecting parasitic life cycle

The climatic and environmental factors like temperature, humidity and precipitation influences the various stages of parasitic life cycle i.e. development, survival and transmission of eggs and infective larvae. These factors lead to seasonal fluctuation in the availability of infective larvae and subsequently prevalence of parasitic infection in the host. The seasonal variation in parasite population dynamics have been studied extensively in sheep and goats in the tropics (Allonby and Urquhart, 1975; Cheijina et al., 1989). In general, active development of parasites occurs during the rainy season when grazing animals harbour a variable and significant number of worms. In areas with distinct rainy and dry seasons, the majority of third stage larvae (L3) undergo arrested development at the end of the rainy season. In contrast, during the dry season the faecal egg counts decline and remain consistently low. However, at the onset of the rainy season as pasture larval challenge and intake of infective larvae are high; there is a sharp increase in egg output. In the humid tropics of Africa, Latin America and Southeast Asia, the climatic conditions permit development of eggs and larval stages throughout the year. In general, it is anticipated that a higher animal density may facilitate transmission and cause higher parasitic infection in animals (Nansen, 1991). In extensive grazing areas, where temperature is high and humidity is low, the association between animal density and worm burden may be less or sometimes variable. The larvae of some genera of nematodes are able to delay maturation from larvae to adult stage (a phenomenon known as *hypobiosis*) if the environment is incompatible. Their development resumes in concurrence with rainy season. Rainy season is considered as the most favorable period for development and transmission of larvae.

The phenomenon of periparturient rise in faecal egg count is very significant in the epidemiology of gastrointestinal nematodes in ruminants. This has been extensively reported under tropical conditions. In cattle, there are few instances of periparturient rise in nematode egg counts as early as two weeks prior to calving and it persisted up to eight weeks after calving till there is end of the humid season. Thus, pregnant and lactating animals act as the major sources of infection for the neonates. Generally, sheep and goats are infected with similar type of helminth parasites, but former has been found to suffer with heavier worm infestations due to their different grazing habit. Sheep rely entirely on grazing, while goats prefer to browse trees and shrubs and this considerably reduces the intake of infective larvae. Another factor that increases the worm burden in sheep is that it trends to graze much closer to the ground, invariably picking up more numbers of infective larvae.

2.3. Trematode and cestode

Among trematodes, predominantly fascioliasis, schistosomiasis and amphistomiasis plays a vital role in loss of million dollars in throughout the globes. They not only are causing morbidity in animals but also cause mortality by immature stages of worms.

The prevalence of trematodes parasites is always based on availability of intermediate host i.e. snails. In recent days, due to construction of dams due to new irrigation scheme has influence the increase population of snails, i.e. intermediate host. However, there is considerable fluctuation of snail population in different seasons of the year. During the raining season, due to congenial temperature, precipitation and humidity favors their completion of their life cycle. However, there was drastic reduction of snail population during dry period. The infective stage of metacercariae may survive up to 10 months in wet tropics. However, the longevity of metacercariae has been reported to vary from few weeks to 3-4 months in hot and dry conditions (Njau and Scholtens, 1991). The prevalence of suitable conditions required for egg production by adult flukes determines the extent of pasture contamination and this subsequently affects the epidemiology of the disease. In a chronic form of infection in sheep, the flukes may survive in the liver for many years and continue to produce eggs. The epidemiology of liver fluke infection is determined by the grazing habit and the management of animals.

The cestode infestation is one of the most common problems faced by the small ruminant industry in the world. The species of *Moniezia expansa*, *M. benedeni* and *Thysanosoma actinoids* not only impairs the digestive function but also reduce the productivity of the animals. The occurrence of tapeworms is greatly influenced by the epidemiology of parasites and also of environmental factors. The cysticercoids, infective stage of tapeworms in oribatid mite, which initiates the infection after ingestion by the animals along with grass.

3. **Sustainable Parasite Control Measures**

3.1. Use of anthelmintics

There are a wide range of commercial anthelmintic formulations available in the market under different brand names. However, a limited numbers of effective anthelmintics are available to treat worm infestation. The fact is that there are different chemicals within a group having similar mode of action. One has to be aware of the possibilities of side effects and resistance within anthelmintics with similar mode of action. Hence, for adopting practical measures to prevent anthelmintic resistance one must know the mode of action of a particular anthelmintic. However, of the factors to be considered before administering an anthelmintic are health condition of the animal, type of parasitic infestation, dose and route of drug administration. The different drugs which are commonly used in small ruminants are shown in the Table 1.

3.*1.1. Anthelmintic resistance*

Indiscriminate use of anthelmintic results in development of resistance against parasites. This is one of the major problems faced by the veterinarians during sustainable parasite control programme (Taylor, 1991). Anthelmintic resistance increases the cost of treatment, reduces production efficiency and increases the risk of environmental contamination. Anthelmintic resistance can be compared as regional problem

Table 1: List of commonly used Anthelmintics

Sl. no.	Anthelmintic	Used against	Dose (mg or ml kg^{-1} body wt.)	Route
1	Tetramisole	Round worm	7.5 mg	S/C ly
2	Levamisole	Round worm	7.5 mg	S/C ly
3	Pyrantel	Tapeworm	10 mg	Orally
4	Morantel	Broad spectrum	10-20 mg	Orally
5	Benzimidazole group	Broad spectrum	7-15 mg	Orally
6	Niclosamide	Fluke infestation	90 mg	S/C ly
7	Oxyclozanide	Fasciolosis Amphistomiasis	10 mg	S/C ly
8	Triclabendazole	Fasciolosis	9 mg	S/C ly
9	Ivermectin	Broad spectrum	0.02 ml	S/C ly
10	Doramectin	Broad spectrum	0.02 ml	S/C ly

in contrast to the global importance of pesticide resistance in arthropods. The problem of anthelmintic resistance is worldwide in distribution. There have been reports of anthelmintic resistance from countries like South Africa, Latin America, Fiji, Malaysia, South Africa, Australia, New Zealand, Indonesia as well as India. However, the type of anthelmintic resistance varies between and within the countries according to variations in farming conditions. There have been reports of resistance in *Cooperia* spp., against anthelmintic drugs like bezimidazole, imidazole and Ivermectin (Cole, 1998). There is also a report of albendazole resistance against larval *Echcinococcus granulosus* in sheep, which was diagnosed in experimental infection. Yadav and Singh (2011) have also reported anthelmintics resistance in sheep and goat from India. Bezimidazole resistance has been recorded in *Cooperia punctata*, *Ostertagia ostertagi* and *Haemonchus placei* in cattle in Argentina (Mejia et al., 2003) and also in *Cooperia oncophora* in New Zealand (Winterrowd et al., 2003). The main alarming situation is that India is also slowly and steadily emerging as the epicenter of anthelmintic resistance in South Asia (Sanyal, 1998). There is also possibility of emergence of clinical cases due to s development of such resistance (Morris and Taylor, 1990).

3.1.2. Managemental strategies for anthelmintic resistance

The managemental strategies for practicing effective deworming schedule are routine faecal count reduction test for monitoring the effectiveness of particular anthelmintic, rotational administration of anthelmintic in a herd or flock, using right brand and dose of anthelmintic and use of herbal drugs instead of synthetic drugs.

3.2. Herbal anthelmintics

The plant based anthelmintic remedies were widely employed prior to the beginning of synthetic drug era. There are many plant derived therapeutic agents that are available in the market at present. In view of emerging resistance to synthetic anthelmintic therapy, there is a need for effective alternative anthelmintic (Yadav and Singh, 2011). Unlike synthetic anthelmintic drugs, which leaves residues in faeces after treatment leading to deleterious effect on the environment, plant derived anthelmintics are easily biodegradable, ecofriendly and potentially sustainable. The most commonly known plants for their anthelmintic principle are mentioned in Table 2.

3.3. Grazing management

Looking at the present scenario of anthelmintic resistance in animals, one cannot deny a future possibility of development of such resistance in a much severe form rendering all chemical families of anthelmintics ineffective. This may lead to a serious problem for escalation of efforts to develop sustainable helminth control technologies. A relatively simple and rapid solution for improving helminth control and reducing anthelmintic usage is grazing management. The grazing management also offers a formidable solution for organic animal production in near future.

The different practices associated with management of animal production are based on geographic location, choice of production system and specific objective for reducing parasitism. All practices associated with the management of grazing livestock have some influence on parasite epidemiology. The effects of managemental variables such as stocking rate, timing of parturition and weaning, usage of fodder crops, fodder conservation and choice of pasture species have been reviewed elsewhere (Morley and Donald, 1980). Michel (1985) classified such managemental strategies as preventive, evasive or diluting. Preventive strategies are those that rely on putting worm free animals on a clean pasture or by suppressing egg output by anthelmintic treatment in the early part of the grazing season until the initial population of infective larvae on pasture declines to safe level. Under the evasive strategies before the development of parasitic larvae in the grazing land the livestock are moved to another paddock. On the contrary,

Table 2: List of different plant based Anthelmintic

Scientific Name	Family	Part used as anthemintic
Allium sativum	Amaryllidaceae	Bulb
Anacardium occidentale (cashew)	Anacardiaceae	Skin of fruit
Ananas comosus L. Merr (pineapple)	Bromoliaceae	Fruit/juice of fruit
Antidesma bunius	Euphorbiaceae	Leaves
Areca catechu	Arecaceae	Seeds
Bamubusa	Graminea	Shoots
Carica papaya	Caricaceae	latex
Codiaeum variegatum	Euphorbiaceae	Leaves
Cucurbita domestica	Cucurbitaceae	Rhizome
Nicotiana tabacum	Solanaceae	Leaves
Morinda citrifolia	Rubiaceae	Fruit
Piper nigrum	Piperaceae	Seeds
Leucaena leucocephala	Fabaceae	Seeds

diluting strategies exploit the grazing of the susceptible animals with resistant animals of same or different species in order to reduce herbage infestation resulting from their combined faecal output of worm eggs. The application of these three measures in small ruminants is discussed below in detail.

3.4. Preventive strategies

In most of the developed countries, the most common preventive managemental strategies for control of helminth parasites are the short, intensive treatment programme using controlled-release devices or careful application of conventional anthelmintic treatments in the first half of the grazing season for one year old calves. Controlled-release devices and conventional treatments are commonly given at turnout i.e. at eight weeks and again at 13 weeks respectively (Taylor et al., 1985). An extreme form of preventive strategy is to alter the host species, like sheep and then cattle and vis-a-vis over the same pasture. By this, the parasitic contamination is prevented both by anthelmintic treatment as well as by exploiting host specificity. In general, parasite species that are pathogenic in one host species may be non-pathogenic to the other host. Typical procedures involve alternation of the separate host species at intervals from two to six months usually along with anthelmintic treatment at time of alternation (Donald et al., 1987).

3.4.1. Evasive strategies

The evasive strategy can be defined as the removal of a moderate existing infection in animals by anthelmintic treatment and then moving the treated animals to a safe pasture, just before the population of infective larvae on the original pasture rose to dangerously high concentration (Michel, 1976; Thomas, 1982). The anthelmintic treatment helps to get rid of the existing worm population in the calves or lambs that might otherwise have contaminated the safe pasture. Generally, in temperate climates rotational grazing systems have been found to be ineffective for controlling parasitic nematodes, as the survival times of infective larvae on pasture is very long. However, in wet tropical climates, the warm, wet conditions favour rapid and continuous egg hatching and larval development. This is accompanied by occurrence of high death rates of infective larvae on pasture (Barger et al., 1994). Larvae can be first detected on pasture as early as four days after eggs are being deposited and this has been observed for most of the major nematode species *like Haemonchus contortus, Trichostrongylus colubriformis and Oesophagostomum columbianum*. It was observed that in rotationally grazed egg counts in goats were less than 50% as compared to goats maintained on an adjacent paddock with similar stocking density. Moreover, the later herd of goat maintained on the single pasture also required nearly three and half times more anthelmintic treatments as compared to rotationally grazed goats in a year.

3.4.2. Diluting strategies

Under the diluting strategy, the susceptible animals are allowed to graze with greater number of non susceptible animals so that the average rate of contamination of pasture with worm eggs will get reduce drastically over a period of time. This further reduces the uptake of parasitic eggs by susceptible animals. The rare incidence of clinical parasitism in pre-weaned calves may be another example of diluting effect. Mixed grazing of cattle and sheep has been studied in relation to productivity and effect on parasite transmission. There was decrease numbers of parasites like *Ostertagia circumcincta* and *Nematodirus spathiger* in sheep that might be the result of counter balance by an increase in burdens of parasitic species like *Trichostrongylus axei* and *Cooperia oncophora* that were associated with cattle. The effect of mixed grazing in ewes and lambs with cows and calves, resulted in reduced parasitism in sheep and increased production performance in lambs.

3.4.3. The farmacha system

This is a novel techniques used against *H. contortus* infection, which was tested and validated in South Africa. This assay is based on colour charts consisting of five colour categories to depict the degree of anemia. The chart colures are compared with the colour of mucous membrane of sheep and accordingly animal is scored as severely anemic (pale), anemic or non anemic (red). This assay system is now under the process of extensive field evaluation and further refinement in free range sheep farming in South Africa. This system has been found to be effective throughout the tropics and sub tropics where haemonchosis is endemic.

2.4. Biological control

The biological control of parasites in animals has been found effective in most parts of the Southeast Asia as humidity and temperature are most congenial for the germination of fungal spores and simultaneously also have favorable climate for completion of parasitic life cycle. In India, Sri Lanka, Malaysia, Indonesia and China, nematophagous fungi have been isolated. The results in experimental conditions have indicated the potentiality of using fungi in reducing nematode infections in ruminants. In Indonesia, the use of nematophagous fungi, *Arthrobotrys oligospora,* as a biological control agent against *H. contortus* has been successful. Biological control of *fasciolosis* can be targeted for the intermediate host of *Fasciola*, the snail (*Lymnaea* spp), or at the la*rvae of Fasciola* that lives in the snail. Studie*s of Echinostoma revolutum* larvae as an agent for bi*ological control of F. gigantica* have been conducted by the Research Institute for Veterinary Science, Indonesia. In Malaysia, research on biological control of parasites using nematophagous fungi is in developmental stage. Studies on the use of nematophagous fungi to control worms in small ruminants in Fiji was initiated during 1996; but till today, Nematophagous fungi surveys were unable to identify *D. flagrans* in Fiji. Nevertheless, people were successful in trial conducted against the preparasitic stages of nematode by feeding of fungal spore to cattle (Gronvold et al., 1993), horses (Fernandez et al., 1997), pigs (Nansen et al., 1996) and sheep (Githigia et al., 1997). Pilot scale trials have been conducted successfully by using *D. flagrans* chlamydospores through feed supplement, feed blocks (Waller, 1997) and slow release devices (Waller, 1997).

India is still in infantile stage in regards to biological control against nematode parasite. Two species of nematode trapping fungi, viz., *A. oligospora* and *D. flagrans* and two species of egg parasitic fungi, viz., *Paecilomyces lilacinus* and *Verticillium chlamydosporium* were isolated from organic environment of Gujarat and Chhattisgarh (Sanyal, 2005). Those were subjected to stringent screening for their suitability as bio-control agents against nematode parasites of ruminants by applying growth assay, predatory activity, germination potential and ability to survive ruminant gut passage. A strategy was formulated for application of nematode-trapping fungi to control gastrointestinal nematodiasis in ruminants (Sanyal et al., 2008). It was observed that chlamydospores of these fungi able to survive during gastrointestinal transit in grazing animals and thereby it will effective in reducing pasture contamination.

It is one of the promising breakthroughs in biological science, in which nematode helminth parasites are control by predacious micro organism. The life cycle of gastro-intestinal nematodes of livestock consists of a parasitic stage within the host and a free-living or pre-parasitic stage on pasture. The pre-parasitic stages on the pasture are potentially vulnerable to attack by biological control agents. A number of organisms have been identified that can exploit the free-living stages of parasites as food sources and these are likely to be commercially exploited in near future. These organisms include micro-arthropods, protozoa, predacious nematodes, virus, bacteria and fungi. Although all these organisms are of academic interest as biological control agent for parasites, which could be a strong arm for integrated parasite control in near future. This renders a great scope for commercial exploitation of fungal delivery devices in future integrated parasite control programmes. However, the success and development of bio-control product for controlling and preventing nematode parasites in livestock have promising for integrated parasite control in near future.

2.4.1. Fungi as biological control tool

Several fungi have been known for a long time that exhibit anti-nematode properties. These consists of numerous species consisting special characters like ability to capture and exploit nematodes either as the main source of nutrients or supplementary to a saprophytic existence. However, these fungi are divided into three major groups based on their morphology and types of nematode-destroying apparatus (Barron, 1997; Nordbring-Hertz, 1988). They are predacious, endo-parasitic and egg-parasitic fungi.

2.4.1.1. Predacious fungi

The idea of these fungi to control animal parasites was begin since 1930. By means of adhesive knobs, networks, rings on mycelium capture the nematode parasites and they are not parasites specific. The most commonly *Arthobotrys* spp. (*Arthobotrys oligospora)* and *Monacrosporium* spp. a *Duddingtoni flagrans* has been using for parasites control. The trapping activity of the fungus was influenced by the motility of the infective larvae and there was no specificity for the parasitic species (Nansen et al., 1996). The growth of predacious fungi is strongly influenced by temperature (Fernandez et al., 1999). A high dose (between of 470 and 680 gm of fungal material on millet) of one of the three different fungal species (*A. musiformis*, *A. tortur*, *Dactylaria candida*) was fed to lambs, harboring a mono infection of either *H. contortus or O. circumcincta*. The study showed a level high of *A. tortur* in the GI tract and this was enough to significantly reduce the *H. contortus* population in faecal cultures of treated lambs. The plot trials of *Duddingtoni flagrans,* another predacious fungus have shown good reduction of free living larval stages of nematodes in cattle (Gronvold et al. 1993), sheep (Peloille, 1991) and horses (Fernandez et al., 1997; 1999). These daily feeding of fungal spores to grazing animals prevents build-up of infective larvae on the pasture to a dangerous levels.

2.4.1.2. Endo-parasitic fungi

The endoparasitic fungi are obligate parasite of nematodes, which ingest the parasitic nematodes either by penetration of cuticle from sticky spores adhering to the nematode cuticle and always are of density dependant (Jaffe et al., 1993.*Drechmeria coniospora* is a fungus producing sticky drops on very small conidia, which adhere to the cuticle of the nematode, penetrate the cuticle and destroy the victim. Another endoparasitic fungus, *Harposporium anguillulae* produce very small, half moon shaped conidia which lodge in the digestive tract of the feeding nematode and after germination totally digest the victim before finally breaking through the cuticle to produce new conidia on the short conidiophores. A dose of 3 lakhs conidia/gm faeces could significantly reduce the number of *H. contortus* larvae recovery as per recent study (Charles et al., 1996).

2.4.1.3. Egg-parasitic fungi

The egg-parasitic fungi generally attacked that nematode which has long survival time in outside environment of the host (*Ascaris* spp., *Fasciola* spp., *Amphistomes* spp.). The fungus of *Verticillium chlamydosporium*, other *Verticillium* spp. has also shown the ability to degrade the parasitic egg shell enzymatically and could subsequently infect the eggs (Lysek and Krajci, 1987). It was also well documented that short exposure to high temperature or UV irradiation rendered the parasitic eggs more susceptible to fungal attack. It has also been shown that *V. chlamydosporium* fungi could attack and destroy the eggs of *Ascaridia galli* and *Parascaris equorum* whereas not effective against *Trichuris suis* eggs.

3.5. Role of nutrition on gastrointestinal parasites

Role of nutrition on host body response against the parasite is indicated by rise in immune response. The two important nutritional functions are maintenance of blood homeostasis and in associated with pathophysiological process that are responsible for expelling of parasite from host body. To summarize, an improvement in host nutrition can enhance the host resistance i.e. its aptitude to regulate the worm populations as well as the host resilience, i.e. its ability to withstand the negative effects of nematode infections. The majority of the pathophysiological studies have impact on protein metabolism is much more disturbed by the presence of gastrointestinal nematodes than any other nutrients. Moreover, in temperate conditions, proteins are usually the main limiting factor in the diet. Some advanced studies has shown some natural compounds that are present in the animal diet like plant secondary metabolites have shown direct or indirect effects on prevalence of nematode infection.

3.5.1. The role of protein supplementation and secondary metabolites of tanniferous plant

Protein plays an important role in improving the host response against nematode infection by increasing immunity. In general 13% protein supplementation is essential for resistance in the form of reduces egg per gram (EPG) count and reduce periparturient rise in pregnant animals. Recent studies indicate that nutrition can affect parasitic infestation through quantitative variations of different diet components and also by the presence of some qualitative compounds in plants particularly secondary metabolites consumed by the herbivores (Athanasiadou et al., 2003). In addition, as mentioned earlier feeding behavior of animals also affect the type and severity of parasite infection. Goats ingest secondary toxic metabolite by browsing and this feeding habit has negative impact on parasite biology (Silanikove et al., 1996). Several *in vivo* studies conducted by inducing infections experimentally could confirm the hypothesis of a possible impact of plant secondary metabolites on worms. Using quebracho, extracted from *Schinopsis* species, as a source of tannins, Paolini et al. (2003) showed that the presence of 5 to 6% tannins in the diet resulted in significant variations in the biology of nematode populations. The main affect observed in adult worms was decline in female fertility, whereas, concomitant distribution of quebracho during the initial larval infection resulted in reduction in worm population. Moreover, screening of bioactive anti-parasitic action in extracts of different legume forages (*Lotus pedonculatus*, *L. corniculatus*, *Hedysarum coronarium*, *Onobrychis viciifoliae*) have shown secondary compounds affecting different stages of the parasites. A recent study confirmed that secondary metabolite in the plant could interfere the development process of both third stage larvae and adult worms (Paolini et al., 2004).

3.6. Medicated blocks

The concept of using feed supplements to deliver anthelmintics and other antibiotics has been existing for some time and was applied with varying degree of success. Prichard et al. (1978) showed that prolonged presence of low level of benzimidazole chemicals can efficiently control nematode parasites. This principle has been successfully applied through the development of intra-ruminal controlled release devices (CRD) which enable prolonged low level administration of benzimidazole anthelmintics. Barger (1999) has demonstrated the effectiveness of this technology in areas where resistant parasite strains have been identified. This increased efficacy is thought to be due to the continued presence of the anthelmintic preventing the establishment of incoming larvae, decreasing the viability and fecundity of mature worms and having an ovicidal effect on any worm eggs that are produced.

3.7. Evolving resistant breed

Tremendous success has been achieved in the field of breeding by evolving animal breed with parasitic resistance.

Breed variation in animals against parasitic resistance has been established by workers from different countries (Hupp and Deller, 1983). The Caribbean sheep breed St. Croix has been able to show resistant to endoparasites under different managemental condition in Indonesia. Whereas as compared to St croix, Indonesian thin tail sheep was found more resistant against Fasciolosis, but at the same time later was not resistant against *Haemonchosis* (Subandriyo et al., 1996; Raadsma et al., 2002). Interestingly the Carribean St. Croix sheep that originated from West Africa is related to the West African Djallonke sheep (Hupp and Deller, 1983).There is also some preliminary evidence regarding Boer goats in Philippines possessing some resistant against endoparasite. Studies on parasitic resistance in Red Maasai breed in East Africa were reveal that the Red Maasai breed is resistant and resilient to endoparasites, specifically to *H. contortus*. Studies on parasitic resistance in Barbados Blackbelly crosses were carried out by the International Livestock Research Institute in a comprehensive manner (Baker et al., 1999; 2002; 2003). The West African Djallonke sheep and the Indian Garole sheep are reported to be resistant to both endoparasites and trypanosomiasis (Baker, 1995; Ghalsasi et al., 1994). An investigation was conducted in Maharashtra, India, where several sheep breeds like Bannur, Deccani, F_1 Garole crossbred lambs as well as 50% Bannur+50% Deccani lambs were compared for their resistance against *H. contortus* . According to this study the breed with 50% Garole genes followed by 50%≥Bannur genes were found to be significantly resistant than the other breeds (Nimbkar et al., 2003). The interesting fact is that the Japanese Thin Tail and the Garole is said to be related genetically as both carry the FecB (Booroola) gene for prolificacy.

3.8. Immunological approach to control helminth parasite

Recent development of molecular techniques has not only assisted in disease diagnosis, but it has also opened up a new chapter in the area of immunoparasitology. There is a strong argument in support of developing vaccines for parasitic diseases. The most significant advantage of using vaccine over chemotherapy is that a single treatment gives lifelong protection. It could be a promising solution for parasite control measure in near future since long time drug treatment is expensive and there is every possibility of development of drug resistance. Nevertheless, recently some effort has been made for production of X-irradiated larval lung worm vaccine for cattle. A commercial vaccine prepared by X-irradiated larvae is available under the brand name ‘Dictol’ in Europe. Moreover, India has also produced vaccine under the brand name ‘Difil’ that is effective against the lung worm *Dictyocaulus filarial* in sheep.

3.8.1. Vaccines against cysticercosis and hydatid disease

Hydatid disease caused by *Echinococcus granulose* which is very important from animal health point of view. Treatment of animal infected with *Echinococcus granulosus* is difficult due to absence of predominant clinical signs. The hydatidosis and cysticercosis are major concern in the developing countries because of their zoonotic nature. There are two vaccines i.e. EG95 and 45W that can be used against the oncospheres that hatch from parasitic eggs and migrate to a suitable tissue. Following vaccination, the antigens (Ag) are expressed on the surface of the oncospheres and protection is induced by antibody (Ab) and complement-mediated lysis of the cysts (Lightowlers et al., 2000). However, these two vaccines i.e. EG95 and 45W are the vaccines against hydatid and cysticercosis that have the potentiality to prevent human infections either indirectly by vaccinating intermediate hosts or directly by vaccinating humans. But so far these types of vaccines are not popular enough for more commercialization (Rickard et al., 1995). The recombinant Ag EG95 against *E. granulosus* has shown remarkable success by showing a protection level of 96-100%, whereas 45W used against *Taenia ovis*, could induce 92% protection in sheep and goat. The cocktail of recombinant protein of *T. ovis* 45W, To18 and To16 could provide protection against *Taenia solium* infection in pigs (Lightowlers et al., 2000).

3.8.2. Vaccines against fasciolosis in sheep

A reduction of 42-69% fluke burdens could be achieved by vaccination with Cathepsin L_1 and Cathepsin L_2 protease. In purified form, the Cathepsin L_1 and L_2 vaccination has resulted 60% reduction in faecal egg counts and when it was combined with Leucine aminopeptidase its activity was enhanced up to 79% in sheep (Piacenza et al., 1999). However, recombinant form of FABP was not found satisfactory in providing suitable protection level in rabbits

3.8.3. Vaccines against gastrointestinal worms

H11 is the most potent vaccine candidate against *H. contortus* infection which was isolated by lectin and anion exchange chromatography (Graham et al., 1993). The H11 is expressed in nematode microvilli that are involved in digestion of blood meal (Smith, 1999). H11 is disrupt the feeding activity of fourth stage larvae and adult stage by binding with Ab and provides 90% protection in lamb. The immunity conferred by this Ag, transferred to newborn lambs through placental barrier and colostrums. However, it also reduces EPG count in periparturient rise in pregnant mothers. Another vaccine candidate, H-gal-GP protein has been found to reduce worm burdens up to 72% and egg output by 93% whereas beta cysteine protease has been found to reduce worm burden by 47% and egg output by 77%. The purified fraction of 35kDa enzyme induced significant protection (Boisvenue et al 1992). Jasmer et al. (1996) have characterized the three proteins namely, p46^{GA1}, p52^{GA1} and p100^{GA1} that have been processed from a single protein i.e. *H. contortus* polyprotein (p100^{GA1}) whose induce 60% worm reduction and 50% reduction in EPG count. The characterization of three microvillar Con A-binding peptides i.e. P45, P49 and P53 showed similar activity with GAI protein (Smith et al., 1993). These peptides partial immunity against *H. contortus* infection by reducing 38% female worm and 20% males worms and then 69% reduction in faecal egg counts (Knox and Smith, 2001). Another HcsL3 when delivered in the Th2-inducing adjuvant alum hydroxide, it induces protection level of 55% worm reduction and 69% EPG reduction (Newton and Munn, 1999). The homologues of H11, H-gal-GP and TSBP from *O. ostertagi* and *T. circumcinta* were provides positive result against these non-blood-feeding nematodes (Knox et al., 2001).

4. Conclusions

The strategies for controlling gastrointestinal helminth parasites have to be followed depending on the variations in the epidemiology of helminth parasites. Looking into the present scenario as well as the future possibility, the herbal drug therapy may be considered as another promising option instead of synthetic or chemical anthelmintics. Immunological approach is the new concept based on recent advancement in the area of molecular biology. The major challenge in antiparasitic vaccine production is to find a suitable approach to distil the various identified vaccine components into a single component or few molecules that are capable of delivering cross-protection. The second challenge is to produce vaccines in a commercially viable manner using recombinant DNA technology.

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