J Parasit Dis (July-Dec 2013) 37(2):151–157
DOI 10.1007/s12639-012-0215-z

REVIEW ARTICLE

JPD

Internal parasite management in grazing livestock

Niranjan Kumar · Thakur Krishan Shankar Rao · Anju Varghese · Veer Singh Rathor

Received: 4 October 2012 / Accepted: 26 November 2012 / Published online: 11 December 2012

Abstract It is a challenging task to control internal parasites in grazing livestock even by applying multi label and multi directional approach. It is impossible to draw general recommendations to control parasitic diseases due to varied geo-climatic conditions and methods adopted for rearing the livestock in the country like India. In view of increasing incidence of anti-parasitic drug resistance in animals, there is an urgent need to design sustainable parasite control strategy which must include on the host as well as off the host control measures to harvest the maximum productivity from the animal for an indefinite period.

Keywords Parasites · Livestock · Grazing · Management

Introduction

The population of livestock in world is 3509.7 million, and most of the animals are kept on grazing based production system (FAOSTAT 2010). India, a developing country is a land of villages and more than 60 % of the human population still depends upon agriculture and livestock sector for their livelihood. According to the 18th livestock census, the total number of livestock population is 529.70 million in which the rural population is 504.96 million (95.33 %) while urban population is 24.73 million (4.67 %) and most of the rural livestock population is still reared on grazing based system (Animal Husbandry statistics series-12 2010).

The grazing animals are always exposed to parasites and are thus constantly being reinfected in chain reactions mode. Several world wide reports have suggested that the parasitic diseases inflict severe economic losses on the livestock industry and adversely affects the health, weight gain, feed conversion efficiency and reproduction of animals. Spithill et al. (1999) due to fasciolosis in livestock estimated significant economic loss at US $ 3.2 billion per annum worldwide, mainly due to condemnation of livers at abattoirs, mortality in infected flocks, persistently depressed growth and feed conversion efficiency, loss of productivity, impaired fertility and also the cost of treatment. Anti-parasitic drugs are effective to minimize the internal parasites in grazing herd. However, it does not able to provide a long term solution. Certain anti-parasitic drugs like benzimidazole, levamisole and ivermectin have developed resistance (FAO 2004; Terrill et al. 2001; Kaplan 2004). Therefore, an integrated approach (Wells 2002; Rahmann and Seip 2007) becomes obligatory to control internal parasites with objective to harvest the optimum productivity from grazing herds. The internal parasites include flukes, tape worms, round worms and protozoa, only a few of them account for the majority of problems for grazing animals.

Prevention and control measures

The various control strategies applied, on the host and off the host with or without chemicals will be useful for

N. Kumar (✉) · A. Varghese
Department of Parasitology, Vanbandhu College of Veterinary Science & A.H., NAU, Navsari 396450, Gujarat, India
e-mail: niruvet@gmail.com

T. K. S. Rao
Department of LPM, Vanbandhu College of Veterinary Science & A.H., NAU, Navsari 396450, Gujarat, India

V. S. Rathor
Department of Parasitology, College of Veterinary Science & A.H., Dantiwada, Palanpur, Gujarat, India

sustainable production of farm animals as per agro-climatic conditions.

Housing management

The animals having good living conditions resist or tolerate better against internal parasites as compared to animals kept under poor housing conditions. Animal shed must be well ventilated and lighted to maintain required humidity and air circulation (Madke et al. 2010). In high humidity and low light there will be accelerated growth of parasites population. Always keep optimum number of animals in the animal shed as overstocking in the animal shed causes large number of livestock population to have parasites at a time. The animal should not be fed on the ground. Feeders which cannot easily be contaminated with faeces should be utilized for grain, hay, and minerals feeding. Water should be clean and free from faecal matter and watering areas should be situated in well drained places with gravel or even cemented floors. Animals must be prevented from the access to parasite infected water bodies. Facilities of proper drainage in the animal shed reduce the chances of survival of the parasites. The newly introduced animals should be quarantined for 4–6 weeks and if required administer the anti-parasitic drugs. Always keep the manure by making heap so that eggs, larvae, cyst, or other stages of parasites are killed due to heat generated during composting (Williams and Warren 2004). The bedding material should be allowed to decompose along with manure for better control of parasites as it act as important source of various parasitic infections like winter coccidiosis. Application of nitrogen fertilizers like urea (1:25) to the surface of manure also eliminate the parasites (Howell et al. 1999).

Nutritional management

Types of diet and availability of vitamins, minerals and other nutrients are directly related with susceptibility of animal to the parasites. Vitamin A, D and B complexes are essential in developing the immunity against parasites. Minerals like zinc, iron, cobalt, sodium, potassium, phosphorus, etc. are very essential for proper functioning of immunological phenomenon going inside the animal's body to develop functional immunity against the parasites (Hughes and Kelly 2006).

Vitamin A is essential to improve the intestinal epithelial integrity (Villamor and Fawzi 2005). Following deficiency in animals the intestinal immune system is disrupted, presumably weakening the host defense against intestinal parasites (Coop and Kyriazakis 1999). The profile of cytokine production by cells from vitamin A deficient animals is also altered substantially, leading to profound changes in the regulation of immune cell function. Vitamin A polarizes the immune response towards Th2 (Stephensen 2001; Stephensen et al. 2002) acting through principal oxidative metabolite retinoic acid.

The zinc deficient animals have impaired cell mediated cytotoxicity and T helper cell function. Scott and Koski (2000) using a zinc deficient nematode infected mouse model noted that parasites are better able to survive in the zinc deficient hosts than in well nourished hosts; that the production of interleukin-4 in the spleen of zinc deficient mice is depressed, leading to depressed levels of IgE, IgG1 and eosinophils; and that the function of T cells and antigen presenting cells is impaired by zinc deficiency as well as by energy restriction. Cook-Mills et al. (1990) while studying trypanosomosis recorded that NK cell function and phagocytosis by macrophages are impaired in zinc deficient animal, and this may be a consequence of reduced oxidative burst capacity. The deficiency reduces thymulin levels in blood, and thus reduces the CD4/CD8 ratio. Zinc deficiency also reduces the synthesis of Th1 cytokines IL-2 and IFN-γ, but not the Th2 cytokines IL-4, IL-6, and IL10 (Rink and Kirchner 2000).

Cobalt deficiency promotes parasitism as it is essential for vitamin B_{12} synthesis. Iron supplements are also very important, where animals are affected by blood sucking worms, like *Haemonchus* spp., *Bunostomum* spp. etc. The animals should always have access to mineral block and vitamin supplements to compensate for the mineral deficiencies in pastures. Animals on low protein diets are more susceptible to infection because they produce less immunoglobulin IgA. To avoid getting infection directly from the ground, the animals should be fed from feeders in the shed. The weaning age of young animals is an important factor with regard to the parasitic resistance. It has been observed that adequately milk fed calves are markedly less infected by *Haemonchus*, *Cooperia* and *Oesophagostomum* than early weaned calves (Geurden et al. 2008).

In short, nutrition level of the host could have the potential to affect how rapidly immunity is acquired and the effect would be expected to be seen best in internal parasite infections in which the rate of acquisition of immunity is relatively complex.

Pasture management

The scientific management of pasture is an effective way to control internal parasites in grazing livestock (Stuedemann et al. 2004). Ideally, the animals are allowed to graze clean or new pasture to fetch maximum productivity from them. The clean or new pastures are those pastures which have not been grazed since 6–12 months; pasture fields in which a hay or silage crop has been removed; pasture fields which have been rotated with field crops; and pastures that have been recently renovated by tillage. Regular burning of old or grazed pasture should always be practiced to obtain parasites free pasture land. The timing of insemination of female animals should be planned accordingly, so that the parturition period should tally with the period when risk of contamination is low in the pastures. In India, the winter season seems most appropriate when transmission of parasites is less as compared to rainy and summer season. Overstocking of animals in a small piece of land increases the concentration of parasites. So, allow optimum number of animals to graze in a given piece of land. It is estimated that parasite infections increases with the square of the animal load, per surface unit. Therefore, for a given piece of land, parasitic infestations become quadruples when animal density is doubled.

Population pressure on the land and cheap labour which make other agricultural operations more profitable are the major factors which prevent assigning the land exclusively for pasture and fodder crop cultivation. Thus, in many countries especially developing ones there are only a few defined pasture lands and farmers usually allow their animals to graze in uncultivable ground like government land, road side land, crop field between two crops, etc (Fig.1). Almost the same measures as advised for the livestock exclusively reared on grazing can be applicable in these countries to achieve effective parasite control. An extensive research is now an urgent need in grazing perspective for designing effective and sustainable control measures against various parasites (Table 1).

Pasture rotation and rest

Pasture rotation, or intensive grazing is optimum use of grass by distributing the pastures into parcels of land of varying sizes called paddocks and frequently moving the livestock from one paddock to another (Wells 1999; Johns et al. 2004). The main objective of pasture rotation is not to put the animals back into the same field until the risk of infection has diminished. Theoretically this means that parasitism will decrease, if the number of parcels of land and rotation time is increased. Practically it appears difficult to diminish the parasitic load with intensive grazing. The lifespan of infective stage of parasites are usually greater than the time required between grazing periods for maximum grass use. A rest of 3–6 months is required for an infected pasture to return to a low level of infectivity.

The larvae of most parasites move to the tops of plants when intensity of light is low at sunrise, sunset and in overcast sky. Therefore, grazing should be avoided during these conditions. As the density of parasite is generally at a maximum in the rainy season and at a minimum in the summer/winter, it is preferable to limit grazing to the summer/winter months to diminish the level of ingestion. During fall, the animals should ideally be put in a new pasture. About 80 % of parasites live in the first 5 cm of vegetation. Parasite infection can be minimized by allowing the livestock to graze up to 10 cm from the ground in a field. The drier the grass, the more parasites will stay at the base of the plants. The risk of infection is greatly lowered by allowing animals to graze only dried grass and not to wet grass. Along with rotational grazing a sufficient pasture rest period is also required for a better pasture management. Animals would graze a pasture for a period of time (grazing period) then the pasture would rest for regrowth (pasture rest period). The length of the grazing period depends on condition of pasture, forage quantity and stocking density. It is commonly recommended that pastures are grazed from a couple of days to a couple of

Fig. 1 Animals grazing in uncultivated government field

Table 1 Different grazing management strategies (Younie et al. 2004)

Preventive strategies	Evasive strategies	Diluting strategies
Turning out parasite free animals on clean pastures	Worm challenge is evaded by moving animals from contaminated to clean pasture	Worm challenge is relieved by diluting pasture infectivity
✔ Delayed turnout	✔ Moving to safe pastures within the same season	✔ Avoid stocking rates close to carrying capacity of plant production
✔ Changing pastures between seasons	✔ Alternate grazing of different species	✔ Reduction of the general stocking rate
✔ Moving at weaning	✔ Hay/silage aftermaths	✔ Mixed grazing with other host species
✔ Late lambing	✔ New grass reseeds	✔ Alternate grazing with other host species
✔ Grass reseeds	✔ Cultivation of annual forage crops	✔ Mixed grazing with other age groups
✔ Cultivation of annual forge crops		
✔ Silage/hay aftermaths		
✔ Alternation of different host species		

weeks. The length of the rest period depends on the time needed to regrow specific forages, the weather, pasture quality and management. It is commonly recommended that pastures should be given a rest for 2–7 weeks. It should be noted that these forage management recommendations are generally excellent for improving nutritional status, but they will not improve parasite control. On the other hand, better nutrition provided by rotational grazing may offset the effects of higher parasite loads on the pasture. Accordingly, pasture rotation with optimum rest period is an important component to minimize internal parasites in grazing animals (Colvin et al. 2008).

Grazing by age group

As susceptibility of animals against parasites varies with age, it is reasonable to graze different age group animals in different fields.

Multispecies grazing

Several parasite species cannot infect two different animal species. Sheep and goats are generally not affected by the same internal parasites (Christensen 2005); similar is the condition with cattle and horses. Consequently, pastures grazed by large ruminant and horses are safer for sheep (Greiner 1998; Hartwig 2000; Scoggins 2000) or and goats (Luginbuhl 1998) and conversely. Sheep or goat can be co-grazed with bovine and/or horses. Pastures can be alternated between sheep and cattle and/or horses. This can help to break the parasite's life cycles. There are numerous other benefits to multi-species grazing. Each species has different grazing behavior that complements one another. For example, sheep prefer to eat weeds (Whittier et al. 2003), short tender grasses and clover, while cattle prefer to eat taller grasses thus allowing the sun light to reach the ground to kill many parasites.

Zero grazing

Zero grazing means keeping the animal in captivity to reduce the parasitic load. During confinement the animal should be fed off the ground in feeders and watering containers should be kept free from faecal matter.

Alternative forages

The pasture plants containing condensed tannins have anthelmintic properties (Min et al. 2004). Research has shown that animals grazing tannin rich forages have lower faecal egg counts than animals grazing traditional grass pastures. The tannin may also decrease the hatching rate of parasite eggs and larval development in faeces. Forage plant species (Marley et al. 2003) which contain high levels of condensed tannins include sericea lespedeza (warm season legume), birds foot trefoil (perennial legume) and chicory (leafy perennial). Tropical legumes contain more condensed tannins than temperate legumes. Normally trees and shrubs contain higher levels of tannins than pasture grasses (Niezen et al. 1998).

Genetics of animals

Genetics is probably the best long term weapon against internal parasites in animals. Some animal breeds are more resistant and resilient to internal parasites. Extensive research all over the world is going on to identify parasite resistant gene(s) containing animal breeds. On the basis of faecal egg output a parasite resistant or susceptible breed can be identified. Following molecular test, the parasite resistant gene can be identified and by animal cloning or by selective breeding a parasite resistant breed of animal can be created.

Biological control

Biological control may be defined as the use of one living organism to achieve control over the targeted organism like parasite, and thus reducing the population of pathogen below a threshold level where it can not causes clinical problems and/or economic losses in the animals. This is quite a new area and needs extensive research to know its merits and demerits before implementing it as a weapon against the parasites.

The biological control with nematophagous fungi are well documented all over the world. The fungus *Duddingtonia flagrans* is relatively easy to culture and can be released in the environment against the targeted parasites in a controlled fashion (FAO 2002; Waller and Thamsborg 2004). So, it is widely used to control gastro-intestinal parasites of grazing animals by reducing pasture load (Waller et al. 2006; Sanyal et al. 2008). In the future the nematode destroying fungi, either as a single species or a mixture of species and types (trapping and egg parasitic), can be effectively and environment compatibly used to control economically important gastro-intestinal parasites. In spite of various merits, impediment in the adoption of nematophagous fungi in practical control schemes include lack of suitable application systems, assessment of long term environmental effects and finally, acceptance in principle by the farmers. The natural plough, ‘earthworm’ can ingest worm eggs and larvae during its normal feeding process thus destroying the egg in the gut or carrying them below the soil surface. Dung beetles ingest manure, thus killing eggs and larvae of various parasites.

Anti-parasitic drugs management strategies

Anti-parasitic drugs are still an important part of parasite control in the grazing livestock. As per Indian climatic conditions the grazing animals must be dosed at least twice in year at the onset (May end) and offset of monsoon (September end). However, strategic use of anti-parasitic drugs is necessary to ensure effectiveness of treatment and to slow down the rate of drug resistance development.

Reduce use of anti-parasitic drugs

Injudicious use of anthelmintics leads to faster rate of development of drug resistance (Stear et al. 2007) than when used judiciously. Drug use should be minimized to 2 or 3 times per year or on the basis of epidemiology of parasitic infection. Frequent dosing of same anthelmintics must be avoided. According to modern concept treat only those animals that essentially need to be dewormed and do not give anthelmintics to those which are not in urgent need.

Use of full dose of anti-parasitic drugs

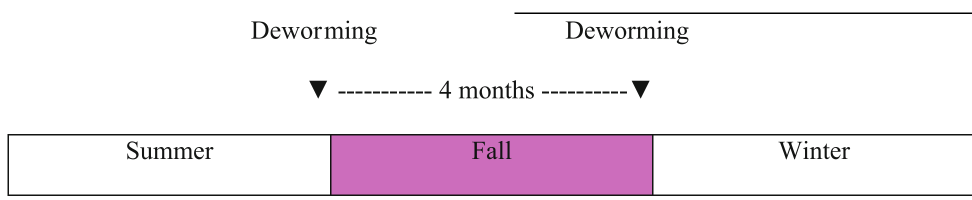
Selection pressure produced due to under-dosing favors the survival of resistant parasite population. Herd should be divided into groups for anti-parasitic drug dosing and drug dose should be decided from the body weight of heaviest animals. The anti-parasitic drug dose rate should be as per the species of animals, the same dose rate for different species must be avoided. Such as goat takes higher dose of drugs to reach the same pharmacological effects as in cattle and sheep, as goat metabolism is physiologically different from cattle and sheep (Toutain et al. 2010). The thumb rule is that goat needs twice the drug dosage than sheep or cattle.

Alternate the type of anti-parasitic drugs

Anti-parasitic drugs should be alternated on an annual basis but frequent change at every deworming is also not recommended. The frequent changes may enhance the chances of development of resistance against a group of anthelmintics.

Alternative dewormers

Now, various natural products have been identified which are having anthelmintics properties and can be used as an alternative to chemical control of parasites. Such products include herbal dewormers, charcoal and diatomaceous earth. Copper oxide particles (administered as a bolus) have been shown to reduce worm infections in ruminant (Burke et al. 2005). Some common botanical dewormers include garlic (Worku et al. 2009); wormwood (*Artemisia* spp.); wild ginger or snakeroot; goosefoot; conifers (pine, spruce,



or fir); mustard and castor oil (Manthri et al. 2011); squash or pumpkin seeds; carrot and fennel seeds; pyrethrum (plant extract from *Chrysanthemum*) (Athanasiadou et al. 2007) etc. can be successfully used to eliminate the internal parasites but extensive research is warranted.

Conclusions

The internal parasite is limiting factors for profitable livestock farming by affecting the animal's performance. In most of parasitism, the economic losses are actually not attributable to mortality but due to impaired productivity of animals. The proper management of internal parasites is extremely important for successful livestock farming especially in the grazing conditions. None of the single control measures will give long term solution. Integration of more than one measure like good farming practices, best breeding strategies, appropriate biological control measures, scientific utilization of biotechnological tools and techniques and appropriate chemical control measures is essential to achieve the sustainable control on the parasites.

References

Animal Husbandry statistics series-12 (2010) Govt. of India, Ministry of Agriculture, Department of Animal Husbandry Dairying and Fisheries, Krishi Bhawan, New Delhi

Athanasiadou S, Githiori J, Kyriazakis I (2007) Medicinal plants for helminth parasite control: facts and fiction. Animal 1(9):1392–1400

Burke JM, Miller JE, Larsen M, Terrill TH (2005) Interaction between copper oxide wire particles and *Duddingtonia flagrans* in lambs. Vet Parasitol 134:141–146

Christensen K (2005) Internal parasites of the goat. Scientific Animation and Illustration, Oklahoma

Colvin AF, Walkden-Brown SW, Knox MR, Scott JM (2008) Intensive rotational grazing assists control of gastrointestinal *Nematodirus* of sheep in a cool temperate environment with summer-dominant rainfall. Vet Parasitol 153:108–120

Cook-Mills JM, Wirth JJ, Fraker PJ (1990) Possible roles for zinc in destruction of *Trypanosoma cruzi* by toxic oxygen metabolites produced by mononuclear phagocytes. Adv Exp Med Biol 262:111–121

Coop RL, Kyriazakis I (1999) Nutrition-parasite interaction. Vet Parasitol 84:187–204

Food and Agriculture Organization (2010) FAOSTAT, electronic database. http://www.faostat.fao.org. Accessed 2 Sept 2010

Food and Agriculture Organization, Rome (2002) Biological control of nematode parasites of small ruminants in Asia. In: Final proceedings of FAO technical co-operation project in Malaysia TCP/MAL/0065 (T)

Food and Agriculture Organization, Rome, Animal Production and Health Division Agriculture Department (2004) Guidelines resistance management and integrated parasite control in ruminants

Geurden T, Somers R, Thanh NTG, Vien LV, Nga VT, Giang HH, Dorny P, Giao HK, Vercruyssea J (2008) Parasitic infections in dairy cattle around Hanoi, northern Vietnam. Vet Parasitol 153(3–4):384–388

Greiner SP (1998) Control of internal parasites in sheep. Virginia Cooperative Extension, Blacksburg

Hartwig N (2000) Control of internal parasites of sheep. Iowa State University, Ames

Howell JM, Luginbuhl JM, Grice MJ, Anderson KL, Arasu P, Flowers JR (1999) Control of gastrointestinal parasite larvae of ruminant using nitrogen fertilizer, limestone and sodium hypochlorite solutions. Small Rumin Res 32:197–204

Hughes S, Kelly P (2006) Interactions of malnutrition and immune impairment, with specific reference to immunity against parasites. Parasite Immunol 28:577–588

Johns H, Johnson K, Turner L (2004) Rotational grazing. University of Kentucky Coop. Ext. Serv. ID-143, Lexington

Kaplan RM (2004) Responding to the Emergence of Multiple-Drug Resistant *Haemonchus contortus*: Smart Drenching and FAMACHA©. College of Veterinary Medicine, University of Georgia, Department of Medical Microbiology and Parasitology, Athens

Luginbuhl JM (1998) Gastrointestinal parasite management of meat goats. North Carolina State University, Raleigh

Madke PK, Lathwal SS, Singh Y, Kumar A, Kaushik V (2010) Study of behavioural and physiological changes of crossbred cows under different shelter management practices. Indian J Anim Sci 80(8):771–774

Manthri S, Sravanthi KC, Sidagonde S (2011) Anthelmintic activity of castor oil and mustard oil. J Phytol 3(3):12–14

Marley CL, Cook R, Keatinge J, Barrett NH, Lampkin (2003) The effect of birdsfoot trefoil (*Lotus corniculatus*) and chicory (*Cichorium intybus*) on parasite intensities and performance of lambs naturally infected with helminth parasites. Vet Parasitol 112:147–155

Min BR, Pomroy WE, Hart SP, Sahlu T (2004) The effect of short-term consumption of a forage containing condensed tannins on gastro-intestinal nematode parasite infections in grazing wether goats. Small Rumin Res. P.279–P.283

Niezen JH, Charleston WAG, Hodgson J, Miller CM, Waghorn TS, Robertson HA (1998) The effect of plant species on the larvae of gastrointestinal nematodes which parasitize sheep. Int J Parasitol 28:791–803

Rahmann G, Seip H (2007) Alternative management strategies to prevent and control endo-parasite diseases in sheep and goat farming systems—a review of the recent scientific knowledge. Landbauforschung Völkenrode 57:75–88

Rink L, Kirchner H (2000) Zinc-altered immune function and cytokine production. J Nutr 130:1411S–1470S

Sanyal PK, Sarkar AK, Patel NK, Mandal SC, Pal S (2008) Formulation of a strategy for the application of *Duddingtonia flagrans* to control caprine parasitic gastroenteritis. J Helminthol 82(2):169–174

Scoggins RD (2000) Control of internal parasites in sheep. University of Illinois Extension, Urbana

Scott ME, Koski KG (2000) Zinc Deficiency Impairs Immune Responses against Parasitic Nematode Infections at Intestinal and Systemic Sites. J Nutr 130:1412S–1420S

Spithill TW, Smooker PM, Coperman D (1999) *Fasciola gigantica*: epidemiology, control, immunology and molecular biology. In: Dalton JP (ed) Fasiolosis. Oxworth, Commonwealth Agricultural Bureau International, Mussoorie, pp 465–525

Stear MJ, Doligalska M, Donskow-Schmelter K (2007) Alternatives to anthelmintics for the control of nematodes in livestock. Parasitol 134:139–151

Stephensen CB (2001) Vitamin A, infection and immune function. Annu Rev Nutr 21:167–192

Stephensen CB, Rasooly R, Jian X, Ceddia MA, Weaver CT, Chandraratna RA, Bucy RP (2002) Vitamin A enhances in vitro

Th2 development via retinoid X receptor pathway. J Immunol 168(9):4495–4503
Stuedemann JA, Kaplan RM, Ciordia H, Franzluebbers AJ, Stewart TB, Seman DH (2004) Bermudagrass management in the Southern Piedmont USA V: gastrointestinal parasite control in cattle. Vet Parasitol 126:375–385
Terrill T, Kaplan R, Larsen M, Samples O, Miller J, Gelaye S (2001) Anthelmintic resistance on goat farms in Georgia: efficacy of anthelmintics against gastrointestinal nematodes in two selected goat herds. Vet Parasitol 97:261–268
Toutain PL, Aude Ferran A, Bousquet-Me'lou A (2010) Species differences in pharmacokinetics and pharmacodynamics. In: Cunningham F, Elliot J, Lees P (eds) Comparative and veterinary pharmacology. Springer, Heidelberg, pp 19–48, Springer-Verlag, Berlin Heidelberg
Villamor E, Fawzi WW (2005) Effects of vitamin a supplementation on immune responses and correlation with clinical outcomes. Clin Microbiol Rev 18:446–464
Waller PJ, Thamsborg SM (2004) Nematode control in 'green' ruminant production systems. Trends Parasitol 20(10):493–497
Waller PJ, Ljungström BL, Schwan O, Rudby Martin L, Morrison DA, Rydzik A (2006) Biological control of sheep parasites using *Duddingtonia flagrans*: trials on commercial farms in Sweden. Acta Vet Scand 47:23–32
Wells A (1999) Integrated parasite management for livestock. ATTRA, Fayetteville
Wells A (2002) Integrated parasite management for livestock. ATTRA, University of Pretoria, Pretoria
Whittier WD, Zajac A, Umberger SH (2003) Control of internal parasites in sheep. Virginia State University, St. Petersburg
Williams B, Warren J (2004) Effects of spatial distribution on the decomposition of sheep faeces in different vegetation types. Agric Ecosyst Environ 103:237–243
Worku M, Franco R, Baldwin K (2009) Efficacy of garlic as an anthelmintic in adult boer goats. Arch Biol Sci Belgrade 61(1):135–140
Younie D, Thamsborg SM, Ambrosini F, Roderick S (2004) Grassland management and parasite control. In: Vaarst M (ed) Animal health and welfare in organic agriculture. CABI, Wallingford, pp 309–324