Gastrointestinal parasites as a threat to grazing sheep

Z.M. RUANO[a], N. CAROLINO[b,c], T.L. MATEUS[a,d,e,f]

[a] Departamento de Medicina Veterinária, Escola Universitária Vasco da Gama, Av. José R. Sousa Fernandes, Campus Universitário - Bloco B, Lordemão, 3020-210 Coimbra, Portugal
[b] Instituto Nacional de Investigação Agrária e Veterinária, 2005-048 Vale de Santarém, Portugal
[c] CIISA - Faculdade de Medicina Veterinária, Universidade de Lisboa, 1300-477 Lisboa, Portugal
[d] Escola Superior Agrária de Ponte de Lima, Instituto Politécnico de Viana do Castelo, 4990-706 Ponte de Lima, Portugal
[e] Centro de Estudos em Ciência Animal e Veterinária, Universidade de Trás-os-montes e Alto Douro, Quinta dos Prados, 5000-801 Vila Real, Portugal
[f] ISPUP-EPIUnit, Universidade do Porto, Rua das Taipas, nº 135, 4050-600 Porto, Portugal

SUMMARY

Despite pressure to increase farm productivity, a tendency for animal-friendly production systems, like the one that includes grazing, is becoming more common due to an increased consumer awareness of animal welfare. Pasture is generally the main food source for these animals. Grazing sheep are therefore exposed to a huge diversity of parasites. These parasites impact greatly on animal health, welfare and productivity, and can be responsible for high economic losses due to delayed development of lambs and low productivity levels of adult sheep, which can be especially threatening in endangered breeds. Nematodes of the genera *Haemonchus*, *Trichostrongylus*, *Teladorsagia*, *Cooperia* and *Nematodirus* can cause serious health problems in sheep. *Haemonchus contortus* is responsible for the main health problems in sheep, and represents a significant cause of mortality worldwide. *Nematodirus battus* is a common cause of lamb diarrhoea. Some trematodes, besides affecting animal health, are zoonotic and may have health implications for farmers and local communities. Prophylaxis plans are essential in order to keep acceptable infection levels. A detailed knowledge of parasite species involved, as well as their burden and prevalence, is necessary. Pasture management should be a primary tool to control parasites. Integration of more than one measure like good farming practices, and appropriate biological control measures is essential to achieve the sustainable control on the parasites. Anti-parasitic drugs are still an important part of parasite control in grazing sheep. Consumers worry about the quality of meat as well as about the animal welfare, but studies of the effects of parasites are scarce, and there is a concern that grazing management systems increase the prevalence of parasites. The question is whether to choose less productive breeds but well adapted to the local environmental conditions (autochthonous breeds) and more resistant to parasites, or high productive breeds but not adapted to the local environment and its parasites. The aim of this review was to understand the current situation of the prevalence of gastrointestinal parasites in grazing sheep, and the consequences on sheep management and the effects on meat quality.

KEY WORDS

Grazing sheep; parasites; meat production; autochthonous breeds; animal welfare.

INTRODUCTION

In 2013 the sheep population amounted to approximately 1.2 billion worldwide. The continent with the highest percentage of sheep is Asia (46.9%), followed by Africa (24.5%), Europe (11.5%), Oceania (9.4%) and America (7.6%)[1]. Livestock farming, including sheep production, is central to the sustainability of rural communities around the world[2]. In some regions, sheep have a great socioeconomic value, particularly due to the fact that alternative economic activities are very scarce. However, there are obstacles to the livestock production, and parasitic diseases are one of the main ones[3,4]. Most sheep are kept in a grazing production system and are always exposed to various parasitic forms[5]. The level of parasitic infection is directly associated with the productive and reproductive performance of sheep[6,7], both among confined and grazing sheep[8-10]. Worldwide, the production system is generally extensive or semi-intensive[11], with flocks being kept on the poorest land of farms, spontaneous pastures or grazing in community pastures, with variable supplementation at critical times.

Modern animal farming involves the production of large quantities of high quality food, under conditions that provide for animal welfare and achieve economic sustainability[12,13]. It is expected that consumption of meat will increase, mostly in developing countries[12]. From 2010 to 2013, the production of sheep meat increased dramatically in the world, but in Europe, for example, it has been in decline since 2011. Europe contributes with only 13.2% of the sheep meat production in the world[14]. Therefore it is important to

Autore per la corrispondenza:
Zita Ruano (zita.ruano04@gmail.com).

increase production and efficiency of sheep without decreasing the sensory quality of meat[12].

Parasites and parasitic diseases have a major impact on farm profitability because they cause a significant decrease in the economic balance[2,15]. These economic losses are due to negative effects on productivity rates (growth delays, decrease in live weight gain or weight loss, reduction of reproductive rates such as fertility) and *post-mortem* rejections at slaughtering[16,17]. In general, most of the infected animals have lower production rates[17].

High levels of infection lead to an increase in energy and protein requirements, resulting in lower availability of nutrients for production[18,19]. They may also act as vehicles for the transmission of other infectious agents, serving as a gateway for subsequent infections[20].

The aim of this review was to understand the current knowledge and true impact of gastrointestinal parasites in grazing sheep and the consequences on sheep management and the effects on meat quality.

WHY IS IT IMPORTANT TO STUDY GASTROINTESTINAL PARASITES IN GRAZING SHEEP?

Influence on the animal, the environment and human health

Small ruminants in extensive or intensive production systems are extremely susceptible to a wide range of gastrointestinal parasites. Grazing sheep are frequently exposed to multiple parasites[21] and the knowledge of the parasite species present in areas where sheep farming is relevant for the local economy is important in order to plan control and treatment strategies. For successful livestock farming, especially under grazing conditions, control of parasites is crucial. The presence of parasitized sheep increases the costs of therapy and/or prophylaxis[15], and also promotes resistance to antiparasitic therapy[22]. There are a number of sheep gastrointestinal parasites, including nematodes, tapeworms, liver flukes and protozoa[23]. Gastrointestinal nematodes and liver flukes are the two major causes of lost productivity in ruminants[7]. The major economic impact of parasitism is due to sub-clinical infections causing production losses[2]. Charlier et al.[13] reported that gastrointestinal nematodes cause lower efficiency in the production, with a decrease in the production of milk, meat and wool. Parasites affect sheep of any gender and age, however lambs and ewes in the *peripartum* period are most affected by them[10].

The current financial and agricultural losses caused by parasites have a substantial impact on agricultural profitability[15,24,25], making it necessary to implement control programs against these infections[26,27]. In order to achieve this, a detailed knowledge about the diversity of parasites, their parasitic loads and their prevalence is required.

Sheep production systems are very variable between and within countries, but sheep are often reared in small areas, which results in overpopulation. This tends to generate higher concentrations of larvae in pasture, turning it into a source of infection[5]. Under these production systems, seasonal fluctuations in forage quantity and quality can negatively affect sheep welfare and grazing sheep are usually subjected to a temporary nutritional stress[28].

Contaminated pastures with parasite eggs and larval forms acts as a reservoir of infection[7,8]. The climatic conditions in each region act as a variable that influences the development of free-living stages[24]. The temperature, environmental humidity and overstocking are conditions that determine the amount of larvae on pasture during the different seasons, as well as their viability or infective capacity. Gastrointestinal nematodes are most observed in temperate and humid climates[23]. Traditionally, the amount of infective larvae on pasture in cool temperate climates is lower during the winter months, whereas in warm climates it is lower during the summer, so warmth and extreme cold are damaging to development and survival of free-living stages[10,29]. The optimum temperature for larval development for most species of nematode is 26-27ºC, and the relative humidity is 70-100%[17,23].

Infection is initiated by ingestion of infective larvae on pasture[30,31] and sheep are thus constantly being reinfected[5]. Ibrahim et al.[32] showed that grazing animals have higher infection prevalence and mean burden than those which feeds on mixed food, which can be explained by the fact that the transmission of most parasites is by ingestion of infectious larvae in contaminated pasture. Over stocking of sheep increases the concentration of parasites. Therefore, for a given piece of land, parasitic infestations become quadruples when animal density is doubled[5].

When sheep are raised extensively and pastures are shared with other species, the problems associated with parasitism are sporadic[5]. At certain times, such as winter or spring, the correlation between the *peripartum* period and poor pasture conditions becomes very evident[9,33,34].

Finally, some studies have shown that some of the sheep gastrointestinal parasites are of public health importance and they have been incriminated as zoonoses transmitted to humans either by direct contact with sheep manure or indirectly through ingestion of contaminated food or water[35-37].

Influence on the quality of meat

The consumption of meat is a source of protein in the human diet[12] and consumers are increasingly worried about its quality[13]. However, there are few studies related to gastrointestinal parasites and the quality of meat[38]. Meat quality includes safety and palatability[39]. The colour of meat is important for consumers; quantity and quality of lipids play an important role in the quality of meat[40].

Animal nutrition influences meat quality as it can change the flavour depending on the fatty acid ratios[39]. Arsenos et al.[38] assessed to what extent the performance of growing lambs, meat quality and composition of fatty acids in muscle may be affected by gastrointestinal nematodes. They concluded that there should be no significant differences between the presence of parasites and the fatty acid composition.

In Arsenos et al.[38], sixty lambs were divided into three groups (the control group, a group of animals that received anthelmintic drugs, and another group that received protein supplements). It was concluded that there were no significant differences in carcass weights between the lambs of the three groups, but there were significant differences in the colour of the meat. The meat of the control group was lean, whereas the meat of the group that had received protein supplements had a greater amount of intramuscular fat. The meat of the group that received anthelmintic drugs presented higher pH value.

The effect of gastrointestinal nematodes on live weight and carcass weight in lambs is not yet well described[41]. Consequences of larval intake on sheep meat productivity warrant further investigation as reductions in live weight gain, nutrient utilisation, soft tissue deposition and skeletal growth are the most important production deficits usually attributable to nematode infection and grazing of pastures contaminated with nematode larvae[19]. In infected animals, fat deposition is reduced because available energy is reduced as well[38]. Changes in live weight may not accurately describe differences in carcass productivity; there are different factors, including body composition (particularly fatness) and weight of the gastrointestinal tract contents, as well as a number of other factors such as time of feed and diet, which affect the relationship between live weight and carcass weight[19].

WHAT ARE THE MOST PREVALENT AND PATHOGENIC GASTROINTESTINAL PARASITES IN GRAZING SHEEP?

Prevalence surveys

The first step in the investigation of infections with gastrointestinal parasites is to establish which species are present in the country or region, and the host species[21,42,43]. Even though such research has already been conducted, it is important to note that the dominant parasites in a given geographical area may change, particularly when changes occur in livestock production practices[9,27]. Further studies of parasite populations are necessary, and the data may need updates. As various parasite species have several pathogenic effects and different development times, it is important to know their prevalence in order to take effective control measures[21].

Faecal egg counts in faeces of small ruminants have become a routine veterinary practice[44], but have low sensitivity[34,44]. Atlija et al.[34] used grazing ewes and confirmed that all ewes were infected with *Teladorsagia circumcincta*, but in 64% of faecal samples no eggs were detected.

Parasitic infections are usually mixed[10,21,31]. The most important parasitic infections of livestock in temperate climates include the nematodes *Haemonchus contortus*, *Teladorsagia circumcincta, Nematodirus battus* and the trematode *Fasciola hepatica*[3].

Helminths

According to Bowman[17] there is a huge diversity of gastrointestinal nematodes, mostly strongyle-type that are commonly found in sheep, namely in the abomasum (genera *Trichostrongylus* spp., *Haemonchus* spp. and *Teladorsagia* spp.), in the small intestine (*Trichostrongylus* spp., *Nematodirus* spp., *Cooperia* spp., *Bunostomum* spp., *Strongyloides* spp. and *Chabertia* spp.) and in the large intestine (*Oesophagostomum* spp., *Trichuris* spp. and *Capillaria* spp.). The most harmful gastrointestinal nematodes belong to the genera *Haemonchus* spp., *Trichostrongylus* spp., *Teladorsagia* spp., *Cooperia* spp. and *Nematodirus* spp.[10,27]. The main lesions observed in flocks are caused by *H. contortus* infections[7,21]. *H. contortus* is highly pathogenic because adult worms attach to the abomasal mucosa and feed on the blood[17], which has a negative influence on sheep health, welfare and productivity.

On the other hand, most of the species of *Nematodirus* do not usually cause clinical disease, but in some parts of the world *Nematodirus battus* causes diarrhoea in lambs[23].

Sheep, when infected, may exhibit signs such as diarrhoea, dry and brittle coat and weight loss, but in most cases the infection is subclinical. However, infected animals ingest less food[17,30], and parasites may affect the performance parameters that are important for livestock production. Jacobson et al.[41] investigation, the authors concluded that there were trends for increased average daily gains in sheep without larval exposure compared to sheep that were exposed to larval stages of *Teladorsagia circumcincta* and *T. colubriformis*. They also stated that the effect of gastrointestinal nematodes on live weight in lambs was not well described.

Moniezia spp. are seen relatively frequently in grazing sheep and are seasonal, related to periods of higher activity of the intermediate host, the oribatid pasture mites. The two most important species are *Moniezia expansa* and *Moniezia benedeni*[23]. The clinical signs go unnoticed when it comes to a lower parasite burden in the gastrointestinal tract of adult ruminants. The pathogenic condition occurs more frequently in young hosts, because sheep have the ability to develop some immunity to parasites, like *Moniezia* spp.[23], Alade and Bwala[48] reports that the mean of *Moniezia* egg count was significantly higher in young animals, with 27.5±60.0, that the adults, with 20.7±45.6. Also Mazid et al.[49] showed the occurrence of *M. expansa* and *M. benedeni* in younger and old sheep, in younger lambs (<1 year) the prevalence of *M. expansa* and *M. benedeni* was 100% and 71.4%, respectively, while in sheep between 1 and 2 years the prevalence was 23.9% and 0%, respectively, and in older sheep (>2 years) was 0% for both species. Chronic intestinal inflammation is accompanied by anaemia, pallor of the mucous membranes and skin, progressive and delays in growth[17].

Adult trematodes, like *Fasciola* spp. and *Dicrocoelium* spp. can be found mainly in the bile ducts, while *Paramphistomum* spp. in the reticulum and rumen[23]. Liver flukes can infect all grazing sheep[9]. In sheep infected with *Fasciola* spp., liver abscesses are not uncommon (18.5%)[50], suggesting that the flukes can spread highly pathogenic bacteria. Infections with *Clostridium novyi* can cause high sheep mortality rate[17]. In many parts of the world liver fluke disease is caused by *Fasciola hepatica. Dicrocoelium dendriticum* is also present in many parts of Europe, like Spain, that has a Mediterranean climate with continental and Atlantic influences characterized by cold winters and warm summers, or Greece, with a temperate Mediterranean environment characterized by dry summers and wet winters[9,33,34]. A characteristic clinical sign of chronical fasciolosis is a submandibular oedema[23].

The prevalence of helminths found in sheep faecal samples worldwide is presented in Table 1.

Protozoa

Gastrointestinal diseases are often caused by protozoan parasites, mainly *Eimeria* spp., *Cryptosporidium* spp. and *Giardia* spp.[23]. *Cryptosporidium* spp. and *Giardia* spp. are transmitted by direct faecal/oral contact or by the ingestion of contaminated food or water and have a zoonotic potential[17]. Quílez et al.[51] isolated *Cryptosporidium parvum* from lambs in Northeastern Spain. Clinical coccidiosis continues to be a serious threat to animal health due to the associated morbidity, mortality, cost of treatment and control[52]. It is a sig-

Table 1 - Overall prevalence (%) of helminths found in sheep faecal samples (N) worldwide.

Country	N	Nematoda	%	Cestoda	%	Trematoda	%	References
Bangladesh	190	*Bunostomum* spp. Strongyle-type *Strongyloides* spp. *Trichuris* spp.	19.0 62.6 9.5 2.1	n.i.	–	*Fasciola gigantica* *Paramphistomum* spp. *Schistosoma indicum*	8.4 44.2 3.7	(70)
Egypt	224	*Nematodirus* spp. Strongyle-type *Strongyloides papillosus* *Trichuris* spp.	0.5 19.2 4.0 2.7	*Moniezia* spp.	0.9	*Paramphistomum* spp.	9.4	(71)
Ethiopia	384	*Nematodirus* spp. Strongyle-type *Strongyloides* spp. *Trichuris* spp.	11.1 45.0 10.5 12.8	*Moniezia* spp.	13.7	*Fasciola* spp.	6.8	(31)
Ethiopia	384	Strongyle-type *Strongyloides* spp. *Trichuris* spp.	39.8 17.5 7.8	*Moniezia* spp.	9.1	*Fasciola* spp. *Paramphistomum* spp.	1.8 0.8	(72)
Ghana	110	Strongyle-type *Strongyloides* spp.	94.5 27.3	n.i.	–	n.i.	-	(73)
Greece	557	*Nematodirus* spp. Strongyle-type *Trichuris* spp.	1.1 3.4 2.9	n.i.	–	*Dicrocoelium dendriticum* *Fasciola hepatica*	0.2 0.5	(33)
India	1200	*Chabertia* spp. *Haemonchus* spp. *Nematodirus* spp. *Oesophagostomum* spp. *Teladorsagia* spp. *Strongyloides* spp. *Trichostrongylus* spp. *Trichuris* spp.	6.7 55.0 57.8 9.2 11.7 1.7 17.5 1.5	*Moniezia* spp.	7.9	*Dicrocoelium* spp. *Fasciola* spp. *Paramphistomum* spp.	11.6 3.6 4.8	(74)
India	1533	*Bunostomum trigonocephalum* *Chabertia ovina* *Haemonchus contortus* *Marshallagia marshalli* *Nematodirus spathiger* *Oesophagostomum columbianum* *Teladorsagia circumcincta* *Trichostrongylus* spp. *Trichuris ovis*	37.7 37.7 59.6 22.1 29.4 28.4 38.0 33.9 23.5	n.i.	–	n.i.	–	(8)
Italy	72	*Bunostomum trigonocephalum* *Chabertia ovina* *Cooperia curticei* *Cooperia oncophora* *Cooperia punctata* *Haemonchus contortus* *Nematodirus battus* *Nematodirus filicollis* *Nematodirus spathiger* *Teladorsagia circumcincta* *Teladorsagia ostertagi* *Trichostrongylus axei* *Trichuris ovis*	40.0 45.0 3.0 6.0 3.0 14.0 11.0 34.0 40.0 94.0 2.0 49.0 100	n.i.	–	n.i.	–	(25)
Nigeria	63	*Haemonchus* spp. *Strongyloides* spp. *Trichuris* spp.	10.9 9.2 11.8	*Taenia* spp.	14.3	n.i.	–	(75)
Pakistan	500	*Bunostomum phlebotomum* *Chabertia ovina* *Cooperia* spp. *H. contortus* *Haemonchus placei* *O. columbianum* *Oesophagostomum radiatum* *T. circumcincta* *T. ostertagi* *S. papillosus* *T. axei* *Trichostrongylus colubriformis* *Trichuris ovis*	1.4 0.4 0.2 13.8 0.2 2.0 1.4 1.2 3.0 1.2 4.6 1.2 4.0	*Echinococcus granulosus* *Moniezia benedeni* *Moniezia expansa*	0.6 0.2 1.2	*Dicrocoelium dendriticum* *Fasciola gigantica* *Fasciola hepatica* *Paramphistomum cervi*	0.4 0.8 2.2 4.2	(76)

Table 1 (cont.) - Overall prevalence (%) of helminths found in sheep faecal samples (N) worldwide.

Country	N	Nematoda	%	Cestoda	%	Trematoda	%	References
Portugal	145	Strongyle-type *Nematodirus* spp. *Trichuris* spp. *Skrjabinema* spp.	88.3 25.5 3.5 0.7	*Moniezia benedeni*	1.4	*Dicrocoelium* spp.	3.5	(77)
Portugal	80	Strongyle-type *Nematodirus* spp. *Trichuris* spp. *Strongyloides* spp.	100 56.3 1.3 96.3	*Moniezia benedeni* *Moniezia expansa*	21.3 12.5	*Fasciola* spp.	3.8	(78)
Spain	529	*Cooperia* spp. *Nematodirus* spp. *T. circumcincta* *Trichostrongylus* spp. *Trichuris* spp.	0.7 1.4 48.6 49.3 2.9	*Moniezia* spp.	0.9	*Dicrocoelium dendriticum*	13.3	(34)
Spain	1710	*Chabertia* spp. *Cooperia* spp. *Nematodirus* spp. *Haemonchus* spp. *Oesophagostomum* spp. *Teladorsagia* spp. *Trichostrongylus* spp. *Trichuris* spp.	100	n.i.	–	n.i.	–	(79)

n.i.: not identified

nificant problem, particularly in intensive sheep production systems with increased stocking density, and reduced or limited availability of pasture, where principally young animals are affected[53]. The prevalence of protozoa found in sheep faecal samples worldwide is presented in Table 2.

HOW TO PREVENT PARASITIC INFECTIONS?

Pasture management

It is estimated that approximately 95% of the parasitic burdens are in pasture and 5% in the host[17]. Therefore, it is of great importance to conduct studies on the influence of temperature, humidity and rainfall on the development and survival of free-living stages. Pasture management is an important tool for decreasing parasite exposure. The pasture rotation can optimize grazing areas. It is frequently referred to as one of the ways of reducing parasitic forms in pastures. This practice, associated with high temperatures, accelerates the development and death of the parasite population[5,8-10,31]. Kumar et al.[5] indicate that a pasture rotation period should be between 3-6 months in order to reduce the level of infectivity. However, in many cases that period is too short for a significant reduction in pasture contamination since some infective larvae can survive for several weeks or months in the environment. For example, *Nematodirus* spp. eggs under optimal environmental conditions can survive more than one year[17,23].
Generally, larvae move to the top of herbage when intensity of light is low[17]. The shorter the grazing period, the lesser the possibility of a serious accumulation of infective larvae and ensures maximum pasture utilization[54].

Paddock hygiene and nutritional management

The period in a paddock is crucial to reduce a build-up of infective larvae[54], but under poor hygienic and overcrowded conditions, it may result in the development of higher burden of infection[17]. While in a paddock, sheep require energy and protein in order to increase their resistance to parasitic infections[19,32,55]. Whenever economically feasible, correct flock supplementation reduces the degree of infection. Nutrition greatly influences the development and consequences of parasitism. High protein diets contribute to an immune response generated by animals in response to parasitic infection, providing a satisfactory performance of susceptible breeds[38]. Sheep with low protein diets are more susceptible to infection because they do not produce enough Immunoglobulin A[5]. Sheep with good indoor living conditions resist and better tolerate parasites in comparison to animals kept under poor conditions[5]. In addition to the potential influence of grazing behaviour, the host immune response plays a crucial role in transmission dynamics[30]. Equally, the use of bioactive plants, that posses certain metabolites or secondary compounds, like tannins, seems promising to reduce infection rates in animals. Various species of plants, in particular those containing tannins, for example *Calluna vulgaris*, have been studied due to their anthelmintic effect in different species of ruminants[56].

Breeds susceptibility

One of the factors which should be taken into consideration when it comes to susceptibility to gastrointestinal parasites is the lack of understanding of the characteristics of each breed. Breeds adapted to the local environment may have a similar performance compared to crossbreeds because losses of adjustment exceed the benefit of heterosis[57]. According to Paim et al.[6], autochthonous breeds do not differ in growth when compared with crossbreeds or breeds selected for greater weight gain and meat quality. On the other hand, Amarante et al.[58] affirms that autochthonous breeds crossed with other breeds result in increased production maintaining the high level of resistance to parasites, especially against *H. contortus* and *T. colubriformis*.

Table 2 - Overall prevalence (%) of protozoa found in sheep faecal samples (N) worldwide.

Country	N	Protozoa	%	References
Egypt	224	*Balantidium coli* *Eimeria* spp. *Entamoeba* spp. *Giardia duodenalis*	1.8 26.8 10.3 0.5	(71)
Ghana	110	*Eimeria* spp.	51.8	(73)
Greece	557	*Eimeria* spp.	6.5	(33)
Iceland	n.i.	*Eimeria ovinoidalis* *Eimeria ahsata* *Eimeria crandallis* *Eimeria bakuensis* *Eimeria faurei* *Eimeria parva* *Eimeria granulosa* *Eimeria intricata* *Eimeria weybridgensis* *Eimeria pallida*	40.7 5.6 1.4 18.9 4.2 6.7 8.2 1.6 11.1 1.6	(80)
Nigeria	63	*Eimeria* spp.	31.1	(75)
Pakistan	500	*Eimeria* spp.	0.4	(76)
Pakistan	486	*Eimeria ovinoidalis* *Eimeria ahsata* *Eimeria faurei* *Eimeria parva* *Eimeria intricata*	48.3 45.5 19.1 24.2 28.7	(81)
Portugal	145	*Eimeria* spp. *Eimeria intricata*	76.6 5.5	(77)
Portugal	80	*Eimeria* spp.	85.0	(78)
Spain	1882	*Eimeria ovinoidalis* *Eimeria ahsata* *Eimeria crandallis* *Eimeria bakuensis* *Eimeria faurei* *Eimeria parva* *Eimeria granulosa* *Eimeria intricata* *Eimeria marsica*	74.0 71.0 64.0 59.0 59.0 36.0 18.0 15.0 3.0	(82)
United Kingdom	64	*Giardia duodenalis*	43.7	(83)
n.i.: not identified				

It is important to promote autochthonous breeds because adaptation and genetic resources can be used for controlling parasites and the products are provided with better commercial quality carcass and meat because improves weight gain, conformation, performance and enables better fat distribution[59].

Pharmacological treatment

Treatment of sheep parasitic diseases involves the use of an effective anthelmintic. In livestock, anthelmintics are frequently used to control gastrointestinal parasites[60] generally by using a broad-spectrum anthelmintic[61]. However, Ploeger et al.[62] argue that the dependence on anthelmintic drugs should be minimized in order to maintain at least some effectiveness of the drugs. The indiscriminate use of drugs over the years has led to the development of resistant parasites[9,22,63].

Taylor et al.[16] describes anthelmintics recommended for sheep, that are presented in Table 3.

The broad spectrum anthelmintic families commonly used to control gastrointestinal parasites are: macrocyclic lactones (e.g. ivermectin), benzimidazole (e.g., albendazole), imidazothiazole (e.g. levamisole) and tetrahydropyrimidines (e.g. morantel)[61,64-66]. Macrocyclic lactones currently play a central role in the control of parasites because they have a broad action spectrum against endo and ectoparasites[64,65]. Amino-acetonitrile derivates and spiroindoles are the most recent additions to the anthelmintic range and parasites that are resistant to them are extremely rare, resulting in the current high effectiveness[64]. Diclazuril and toltrazuril are used against *Eimeria* spp. infections[16]. Feed additives, e.g. amprolium, are also used for the prevention of coccidiosis in lambs[24].

Heredia et al.[67] determined the effect of levamisole, closantel sodium, ivermectin, ivermectin/clorsulon and closantel/albendazole on the parasite load in sheep and they concluded that ivermectin/clorsulon was more effective in decreasing the number of eggs in faeces than other anthelmintics used, especially in *Haemonchus* spp. Puspitasari et al.[61] compared the anthelmintic efficacy of ivermectin and albendazole giv-

Table 3 - Recommended anthelmintics for sheep [Adapted from Taylor et al., (16)].

Anthelmintic	Molecules	Activity against		
		Nematode	Cestode	Trematode
Benzimidazoles	Albendazole Fenbendazole Mebendazole Oxfendazole Oxibendazole Triclabendazole	✓ ✓ ✓ ✓ ✓ 	✓	✓ *Dicrocoelium* spp. ✓
Imidazothiazoles	Tetramisole Levamisole	✓ ✓		
Tetrahydropyrimidines	Morantel Pyrantel tartrate	✓ ✓		
Macrocycliclactones	Ivermectin Doramectin Moxidectin	✓ ✓ ✓		
Amino-acetonitrile derivates	Monepantel	✓		
Spiroindoles	Derquantel	✓		
Salicylanilides	Closantel	*H. contortus*		✓
Quinoline-pyrazine	Praziquantel		✓	*Dicrocoelium* spp.

en separately to sheep naturally infected with *H. contortus* and concluded that the combination of ivermectin and albendazole was more effective than albendazole alone. The use of combinations serves to maintain nematode under control in the presence of anthelmintic resistance[68].

Some vaccines are based on antigens of the parasite stage that adheres to the gut wall. These antigens induce immune responses that interfere with successful attachment in the gut[69]. In 2014, for example, a new vaccine against *H. contortus* was made commercially available[69].

CONCLUSIONS

Gastrointestinal parasitic infections greatly impact on sheep production worldwide. The greatest concern is the high prevalence of the genus *Haemonchus* spp. and *Trichostrongylus* spp. affecting sheep of all ages. The study of the environment, parasite fauna and hosts will generate epidemiological data vital for the development of new control strategies and prophylaxis of gastrointestinal parasites in sheep. The goal is not to eradicate parasites, but to keep the infection at reasonable level, resulting in reduced mortality, better feed conversion rates and therefore greater weight gain and increased fertility. Parasite control in extensive systems involves an implementation of nutritional supplementation and selection of genetically resistant animals, providing a safe and sustainable method for controlling gastrointestinal parasites. Improvement of immune function contributes to the reduction of parasite burdens, reduces susceptibility to reinfection and indirectly reduces pasture contamination. The acquisition and maintenance of immunity to gastrointestinal parasites is slow and costly, with the resulting benefits emerging primarily long term. A good anti-parasite treatment consists of choosing the right product and way of delivering it, thus ensuring an optimum sheep performance at the least cost.

ACKNOWLEDGMENT

The authors would like to thank to Prof. Ivona Hansman for the english review of the manuscript.

References

1. FAOSTAT. Online Statistical Service (Live Animal datasets). (2016) [cited 2016 Jul 9]. Available from: http://faostat3.fao.org/browse/Q/QA/E
2. Morgan ER, Charlier J, Hendrickx G, Biggeri A, Catalan D, Samson-Himmelstjerna G von, et al. (2013). Global Change and Helminth Infections in Grazing Ruminants in Europe: Impacts, Trends and Sustainable Solutions. Agriculture. 3:484-502.
3. Fox NJ, Marion G, Davidson RS, White PCL, Hutchings MR. (2012). Livestock helminths in a changing climate: Approaches and restrictions to meaningful predictions. Animals. 2(1):93-107.
4. Whitley NC, Oh SH, Lee SJ, Schoenian S, Kaplan RM, Storey B, et al. (2014). Impact of integrated gastrointestinal nematode management training for U.S. goat and sheep producers. Vet Parasitol. 200(3-4):271-5.
5. Kumar N, Rao TKS, Varghese A, Rathor VS. (2013) Internal parasite management in grazing livestock. J Parasit Dis. 37(2):151-7.
6. Paim T do P, Da Silva AF, Martins RFS, Borges BO, Lima P de MT, Cardoso CC, et al. (2013). Performance, survivability and carcass traits of crossbred lambs from five paternal breeds with local hair breed Santa Inês ewes. Small Rumin Res. Elsevier B.V.; 112(1-3):28-34. Available from: http://dx.doi.org/10.1016/j.smallrumres.2012.12.024
7. Rinaldi L, Catelan D, Musella V, Cecconi L, Hertzberg H, Torgerson PR, et al. (2015). Haemonchus contortus: Spatial risk distribution for infection in sheep in Europe. Geospat Health. 9(2):325-31.
8. Tariq KA, Chishti MZ, Ahmad F, Shawl AS. (2008). Epidemiology of gastrointestinal nematodes of sheep managed under traditional husbandry system in Kashmir valley. Vet Parasitol. 158(1-2):138-43.
9. Taylor MA. (2012). Emerging parasitic diseases of sheep. Vet Parasitol. Elsevier B.V.; 189(1):2-7. Available from: http://dx.doi.org/10.1016/j.vetpar.2012.03.027
10. Morgan ER, van Dijk J. (2012). Climate and the epidemiology of gastrointestinal nematode infections of sheep in Europe. Vet Parasitol. Elsevier B.V. 189(1):8-14. Available from: http://dx.doi.org/10.1016/j.vetpar.2012.03.028
11. DGAV. (2013). Raças Autóctones Portuguesas. Direção-Geral de Alimentação e Veterinária. 161-164 p.
12. Montossi F, Font-i-Furnols M, Campo M del, Julián RS, Brito G, Sañudo C. (2013). Sustainable sheep production and consumer preference trends: Compatibilities, contradictions, and unresolved dilemmas. Meat Sci. 95(4):772-89. Available from: http://dx.doi.org/10.1016/j.meatsci.2013.04.048
13. Charlier J, van der Voort M, Kenyon F, Skuce P, Vercruysse J. (2014). Chasing helminths and their economic impact on farmed ruminants. Trends Parasitol. Elsevier Ltd; 30(7):361-7. Available from: http://dx.doi.org/10.1016/j.pt.2014.04.009
14. FAOSTAT. Online Statistical Service (Livestock Primary datasets) (2016) [cited 2016 Jul 9]. Available from: http://faostat3.fao.org/browse/Q/QL/E
15. Roeber F, Jex AR, Gasser RB. (2013). Impact of gastrointestinal parasitic nematodes of sheep, and the role of advanced molecular tools for exploring epidemiology and drug resistance - an Australian perspective. Parasit Vectors. 6(1):1.
16. Taylor M, Coop R, Wall R. (2007). Veterinary Parasitology. 3rd ed. Blackwell Publishing. 398-571 p.
17. Bowman D. (2014). Georgis' Parasitology for Veterinarians. 10th ed. Elsevier Inc. 122-227 p.
18. Coop RL, Sykes AR. (2001). Interaction between nutrition and gastrointestinal parasitism in sheep. N Z Vet J. 49(6):222-6.
19. Greer AW. (2008). Trade-offs and benefits: Implications of promoting a strong immunity to gastrointestinal parasites in sheep. Parasite Immunol. 30(2):123-32.
20. Lacharme-Lora L, Salisbury V, Humphrey TJ, Stafford K, Perkins SE. (2009) Bacteria isolated from parasitic nematodes - a potential novel vector of pathogens? Environ Health. 8 Suppl 1(DECEMBER):S17.
21. Rinaldi L, Hendrickx G, Cringoli G, Biggeri A, Ducheyne E, Catelan D, et al. (2015). Mapping and modelling helminth infections in ruminants in Europe: Experience from GLOWORM. Geospat Health. 9(2):257-9.
22. Martínez-Valladares M, Geurden T, Bartram DJ, Martínez-Pérez JM, Robles-Pérez D, Bohórquez A, et al. (2015). Resistance of gastrointestinal nematodes to the most commonly used anthelmintics in sheep, cattle and horses in Spain. Vet Parasitol. Elsevier B.V. 211(3-4):228-33.
23. Zajac AM, Conboy GA. (2012). Veterinary Clinical Parasitology. 8th ed. West Sussex, UK: Willey Blackwell. 4-13 p.
24. Torina A, Ferrantelli V, Sparagano OAE, Reale S, Vitale F, Caracappa S. (2004). Climatic conditions and gastrointestinal nematode egg production: Observations in breeding sheep and goats. In: Annals of the New York Academy of Sciences. p. 203-9.
25. Torina A, Dara S, Marino AMF, Sparagano OAE, Vitale F, Reale S, et al. (2004). Study of gastrointestinal nematodes in sicilian sheep and goats. Ann N Y Acad Sci. 1026:187-94.
26. 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. Landbauforsch Völkenrode. 2007(57):75-88.
27. Bukhari S, Sanyal PK. (2011). Epidemiological intelligence for grazing management in strategic control of parasitic gastroenteritis in small ruminants in India - A Review. Vet World. 4(2):92-6.
28. Nardone A, Zervas G, Ronchi B. (2004). Sustainability of small ruminant organic systems of production. Livest Prod Sci. 90(1):27-39.
29. Martínez-Valladares M, Robles-Pérez D, Martínez-Pérez JM, Cordero-Pérez C, Famularo MDR, Fernández-Pato N, et al. (2013). Prevalence of gastrointestinal nematodes and Fasciola hepatica in sheep in the northwest of Spain: relation to climatic conditions and/or man-made environmental modifications. Parasit Vectors. 6(1):282.
30. Fox NJ, Marion G, Davidson RS, White PCL, Hutchings MR. (2013). Modelling parasite transmission in a grazing system: The importance of host behaviour and immunity. PLoS One. 8(11).
31. Kelemework S, Tilahun A, Benalfew E, Getachew A. (2016). A study on prevalence of gastrointestinal helminthiasis of sheep and goats in and around Dire Dawa, Eastern Ethiopia. J Parasitol Vector Biol. 8(10):107-13.

32. Ibrahim MM, Ghamdi M, Gahmdi M. (2008). Helminths community of veterinary importance of livestock in relation to some ecological and biological factors. Türkiye Parazitoloji Derg. 32(1):42-7.
33. Kantzoura V. (2012). Prevalence and Risk Factors of Gastrointestinal Parasitic Infections in Small Ruminants in the Greek Temperate Mediterranean Environment. Open J Vet Med. 2(1):25-33.
34. Atlija M, Prada JM, Gutiérrez-Gil B, Rojo-Vázquez FA, Stear MJ, Arranz JJ, et al. (2016). Implementation of an extended ZINB model in the study of low levels of natural gastrointestinal nematode infections in adult sheep. BMC Vet Res. 12(1):97.
35. Ralph A, O'Sullivan M, Sangester N, Walker J. (2006). Abdominal pain and eosinophilia in suburban goat keepers -trichostrongylosis. Med J Aust. 184(9):467-9.
36. Ella O, Mohammad A. (2015). Dicrocoelium dendriticum infection in a patient with chronic Schistosomiasis haematobium. J Egypt Soc Parasitol. 45(3):1-30.
37. Schweiger F, Kuhn M. (2008). Dicrocoelium dendriticum infection in a patient with Crohn's disease. Can J Gastroenterol. 22(6):571-3.
38. Arsenos G, Fortomaris P, Papadopoulos E, Kufidis D, Stamataris C, Zygoyiannis D. (2007). Meat quality of lambs of indigenous dairy Greek breeds as influenced by dietary protein and gastrointestinal nematode challenge. Meat Sci. 76(4):779-86.
39. Casey NH, Webb EC. (2010). Managing goat production for meat quality. Small Rumin Res. 89(2-3):218-24.
40. Arsenos G, Banos G, Fortomaris P, Katsaounis N, Stamataris C, Tsaras L, et al. (2002). Eating quality of lamb meat: Effects of breed, sex, degree of maturity and nutritional management. Meat Sci. 60(4):379-87.
41. Jacobson C, Pluske J, Besier RB, Bell K, Pethick D. (2009). Associations between nematode larval challenge and gastrointestinal tract size that affect carcass productivity in sheep. Vet Parasitol. 161(3-4):248-54.
42. Haven J, Park AW. (2013). Superinfection reconciles host-parasite association and cross-species transmission. Theor Popul Biol. Elsevier Inc. 90:129-34.
43. Patrelle C, Ferté H, Jouet D. (2014). Identification of Chabertiidae (Nematoda, Strongylida) by PCR-RFLP based method: A new diagnostic tool for cross transmission investigation between domestic and wild ruminants in France. Infect Genet Evol. 28:15-20.
44. Sargison ND. (2013). Understanding the epidemiology of gastrointestinal parasitic infections in sheep: What does a faecal helminth egg count tell us? Small Rumin Res. Elsevier B.V. 110(2-3):78-81.
45. Watt KA, Nussey DH, Maclellan R, Pilkington JG, McNeilly TN. (2016). Fecal antibody levels as a noninvasive method for measuring immunity to gastrointestinal nematodes in ecological studies. Ecol Evol. 6(1):56-67.
46. Mavrot F, Hertzberg H, Torgerson P. (2015). Effect of gastro-intestinal nematode infection on sheep performance: a systematic review and meta-analysis. Parasit Vectors. 8(1):557.
47. Dever ML, Kahn LP, Doyle EK. (2015). Persistent challenge with Trichostrongylus colubriformis and Haemonchus contortus larvae does not affect growth of meat-breed lambs suppressively treated with anthelmintics when grazing. Vet Parasitol. Elsevier B.V. 209(1-2):76-83.
48. Alade NK, Bwala MD. (2015). Gastrointestinal-parasites infestation in Yankasa sheep in a semi-arid environment. Livest Res Rural Dev. 27(6).
49. Mazid MA, Bhattacharjee J, Begum N, Rahman MH. (2006). Helminth parasites of the digestive system of sheep in Mymensingh, Bangladesh. Bangl J Vet Med. 4(2):117-22.
50. Degheidy NS, Sharaf EM, Al-Malki JS. (2013). The incidence of Fascioolasis and some types of bacteria incurred causing lack meat and livers quality of slaughtered animals at Al-Taif, KSA. Assiut Vet Med J. 59(139):136-41.
51. Quílez J, Vergara-Castiblanco C, Monteagudo L, Cacho E del, Sánchez-Acedo C. (2013). Host association of Cryptosporidium parvum populations infecting domestic ruminants in Spain. Appl Environ Microbiol. 79(17):5363-71.
52. Chartier C, Paraud C. (2012). Coccidiosis due to Eimeria in sheep and goats, a review. Small Rumin Res. Elsevier B.V. 103:84-92.
53. Taylor MA. (2013). Parasite control in sheep: A risky business. Small Rumin Res. Elsevier B.V. 110(2-3):88-92.
54. Bath GF. (2014). The "BIG FIVE" - A South African perspective on sustainable holistic internal parasite management in sheep and goats. Small Rumin Res. Elsevier B.V. 118(1-3):48-55.
55. Hughes S, Kelly P. (2006). Interactions of malnutrition and immune impairment, with specific reference to immunity against parasites. Parasite Immunol. 28(11):577-88.
56. Hoste H, Jackson F, Athanasiadou S, Thamsborg SM, Hoskin SO. (2006). The effects of tannin-rich plants on parasitic nematodes in ruminants. Trends Parasitol. 22(6):253-61.
57. Amarante AFT do. (2014). Os parasitas de ovinos. São Paulo: Editora Unesp. 36-37 p.
58. Amarante AF, Susin I, Rocha RA, Silva MB, Mendes CQ, Pires A V. (2009). Resistance of Santa Ines and crossbred ewes to naturally acquired gastrointestinal nematode infections. Vet Parasitol. 165(3-4):273-80.
59. Abdulkhaliq AM, Meyer HH, Busboom JR, Thompson JM. (2007). Growth, carcass and cooked meat characteristics of lambs sired by Dorset rams heterozygous for the Callipyge gene and Suffolk and Texel rams. Small Rumin Res. 71(1-3):92-7.
60. Eichberg C, Wohde M, Muller K, Rausch A, Scherrmann C, Scheuren T, et al. (2016). The anthelmintic ingredient moxidectin negatively affects seed germination of three temperate grassland species. PLoS One. 11(11):1-13.
61. Puspitasari S, Farajallah A, Sulistiawati E, Muladno. (2016). Effectiveness of ivermectin and albendazole against Haemonchus contortus in sheep in west Java, Indonesia. Trop Life Sci Res. 27(1):135-44.
62. Ploeger HW, Antonis AFG, Verkaik JC, Vellema P, Bokma-Bakker MH. (2016). Perceptions and actions of Dutch sheep farmers concerning worm infections. Vet Parasitol. Elsevier B.V. 229:150-8.
63. Greer AW, Hamie JC. (2016). Relative maturity and the development of immunity to gastrointestinal nematodes in sheep: An overlooked paradigm? Parasite Immunol. 38(5):263-72.
64. Scott PR. (2015). Sheep Medicine. 2nd Editio. CRC Press. 347-370 p.
65. Sargison ND. (2012). Pharmaceutical treatments of gastrointestinal nematode infections of sheep - Future of anthelmintic drugs. Vet Parasitol. Elsevier B.V. 189(1):79-84.
66. Taylor MA, Coop R, Wall R. (2015). Veterinary Parasitology. 4th ed. Willey Blackwell.
67. Heredia R, Aguilar E, Romero C, Bautista L, Mendoza G. (2016). Evaluation of five treatments to control intestinal parasites in sheep in Ayapango, state of Mexico. Vet world. 9(11):1233-7.
68. Bartram DJ, Leathwick DM, Taylor MA, Geurden T, Maeder SJ. (2012). The role of combination anthelmintic formulations in the sustainable control of sheep nematodes. Vet Parasitol. Elsevier B.V. 186(3-4):151-8.
69. Zvinorova PI, Halimani TE, Muchadeyi FC, Matika O, Riggio V, Dzama K. (2016). Breeding for resistance to gastrointestinal nematodes - the potential in low-input/output small ruminant production systems. Vet Parasitol. 225:19-28.
70. Sangma A, Begum N, Roy BC, Gani MO. (2012). Prevalence of helminth parasites in sheep (Ovis aries) in Tangail district, Bangladesh. J Bangladesh Agric Univ. 10(2):235-44.
71. Sultan K, Elmonir W, Hegazy Y. (2016). Gastrointestinal parasites of sheep in Kafrelsheikh governorate, Egypt: Prevalence, control and public health implications. Beni-Suef Univ J Basic Appl Sci. Elsevier B.V. 5(1):79-84.
72. Zeryehun T. (2012). Helminthosis of sheep and goats in and around Haramaya, Southeastern Ethiopia. J Vet Med Anim Heal. 4(3):48-55.
73. Owusu M, Sekyere JO, Adzitey F. (2016). Prevalence and burden of gastrointestinal parasites of Djallonke sheep in Ayeduase, Kumasi, Ghana. Vet World. 9(4):361-4.
74. Tramboo SR, Shahardar RA, Allaie IM, Wani ZA, Bushra MS. (2015). Prevalence of gastrointestinal helminth infections in ovine population of Kashmir Valley. Vet World. 8(10):1199-204.
75. Solomon-Wisdom G. (2014). Prevalence of Intestinal helminth in sheep and goat reared for slaughtering in Gwagwalada Abattoir, Abuja - Nigeria. J Glob Pharm Sci. 2(1):12-9.
76. Raza MA, Younas M, Schlecht E. (2014). Prevalence of gastrointestinal helminths in pastoral sheep and goat flocks in the cholistan desert of Pakistan. J Anim Plant Sci. 24(1):127-34.
77. Ruano Z, Cortinhas A, Carolino N, Mateus T. (2016). Ovinos da Raça Churra Galega Mirandesa - Que parasitas gastrointestinais. In: II Simpósio de Ovinos e Caprinos. Vila Real; Portugal.
78. Rodrigues T, Crespo M V., Morgado M, Rosa F. (2004). Levantamento parasitológico em ovinos de carne e leite do concelho de Mafra - dados preliminares. Acta Parasitológica Port. 11(1-2):37-40.
79. Pedreira J, Paz-Silva A, Sánchez-Andrade R, Suárez JL, Arias M, Lomba C, et al. (2006). Prevalences of gastrointestinal parasites in sheep and parasite-control practices in NW Spain. Prev Vet Med. 75(1-2):56-62.
80. Skirnisson K. (2007). Eimeria spp. (Coccidia, Protozoa) infections in a flock of sheep in Iceland: Species composition and seasonal abundance. Icel Agric Sci. 20:73-80.
81. Khan MN, Rehman T, Iqbal Z, Sajid MS, Ahmad M, Riaz M, et al. (2011). Prevalence and Associated Risk Factors of Eimeria in Sheep of Punjab, Pakistan. World Acad Sci. 55(7):443-7.
82. Díaz P, Painceira A, Dacal V, Vázquez L, Cienfuegos S, Arias MS, et al. (2010). Eimeria infections in wild (Capreolus capreolus) and extensive-reared domestic ruminants from Galicia (NW Spain). RevIbero-LatinoamParasitol. 69(1):83-9.
83. Minetti C, Taweenan W, Hogg R, Featherstone C, Randle N, Latham SM, et al. (2014). Occurrence and Diversity of Giardia duodenalis Assemblages in Livestock in the UK. Transbound Emerg Dis. 61:e60-7.