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HELMINTHS AND PROTOZOA OF THE GASTROINTESTINAL TRACT OF RUMINANTS IN TANZANIA

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ABSTRACT

Tanzania has one of the largest populations of domestic ruminants in Africa. Their performance is less than their potential. Health, particularly disease due to gastrointestinal parasites, is a major constraint to improved productivity. Internal parasites also affect the country's very diverse and huge array of wild ruminants. This review is based on a thorough search of the formal and informal literature pertaining to gastrointestinal parasites of ruminants in Tanzania. The occurrence and geographical distribution of helminth (nematodes, trematodes and cestodes) and protozoan parasites are presented. Cattle, goat and sheep nematodirus (roundworm) infection usually comprises mixed infections of several taxa of which 13 species in nine genera have been recorded. A total of seven species of trematodes (flukes) in six genera have been found. Some six species of cestodes (flatworms) have been recorded, three being in the genus Taenia. The most prevalent species of protozoan parasites, of which seven have been identified in cattle and 18 in sheep and goats, belong to the genus Eimeria: four other species of protozoan parasites are also recorded. A general overview of the epidemiology of gastrointestinal parasites is provided and the main methods of control are discussed.

Contribution/Originality: Domestic ruminants are an important part of the Tanzania economy. They contribute to food security, biodiversity, household income and human welfare. This paper reviews with the aid of 74 published references the status and distribution of the main internal parasites of domestic ruminants in Tanzania.

1. INTRODUCTION

Livestock production is a major agricultural activity in Tanzania and provides livelihood support to 1 745 776 (or 37 per cent) of the 4 901 837 agricultural households in the country [1]. Domestic animals contribute to national food supply, convert rangeland resources into products suitable for human consumption, are a source of cash income and are an inflation proof store of value. Livestock production is predicated on a large resource base comprising various species, breeds and types and whose ownership and distribution differ from region to region. Commercial ranching, pastoralism and agropastoralism are the commonly distinguished systems in the rangeland areas. The first of these systems is very minor (2 per cent of the national cattle stock); the second -- pastoralism in which the main roles of livestock are subsistence, a store of wealth and a source of cash income -- is concentrated in the northern plains and is practised in traditional grazing areas where climate and soil conditions do not favour crop production; the third, agropastoralism comprises a range of combinations of crop cultivation with livestock keeping. There are also many animals in urban and periurban locations.

Livestock numbers are considered to have increased steadily for many years in line with human population growth. The country's ruminant livestock wealth in 2007/2008 – the third largest in Africa after Ethiopia and Sudan – comprised 21.3 million cattle, 13.1 million goats and 3.6 million sheep of which a massive 99 per cent were in the ownership of the traditional sector [1]. The livestock subsector contributes about 30 per cent of Agricultural Gross Domestic Product (GDP) of which about 40 per cent derives from beef production, 30 per cent from milk and 30 per cent from small ruminant and poultry production. In spite of these impressive figures, however, the subsector contributes far less than its underlying potential. Major constraints to improved productivity are related to management, nutrition and health.

Parasitic diseases have major adverse effects on productivity and performance of farm animals worldwide [2, 3]. They lower production efficiency, result in heavy mortality and are a potential danger to human health. Gastrointestinal helminth parasites (including nematodes, trematodes, and cestodes) together with protozoans in particular negatively affect animal productivity primarily through impairing nutritional efficiency [4].

This review presents information on the presence, epidemiology and control of gastrointestinal helminths and protozoans of ruminants reported in Tanzania. The various options recommended for their control are discussed. The studies reviewed in this paper, which is complementary to an earlier paper on pig pathology [5] are of great significance in the assessment of the gastrointestinal parasitic fauna of large and small ruminants in Tanzania.

2. MATERIALS AND METHODS

This review focuses on the literature on gastrointestinal parasites of ruminants in Tanzania. Systematic searches were made in electronic and non-electronic databases. The electronic databases were CAB Abstracts, PubMed, Science direct and Web of Science. Firstly, titles and abstracts of all retrieved articles were searched to identify articles that were missed by electronic search. Secondly, references of all relevant articles were searched to identify articles that were missed by electronic search. Thirdly, all relevant articles were reviewed and pertinent information extracted and compiled in a searchable data base. A relevant article was defined as one that contained information on the subject of interest – meaning endo-parasites of large and small ruminants. Types of documents included in the search were research articles, review articles, short surveys, short communications, correspondences, letters and book reviews.

Different search terms were used for different search engines. CAB Abstracts -- (*indigenous cattle, goats, sheep* or small scale* or large scale**) and (*gastro-intestinal* or endo* or parasites**) and (*Tanzania**); PubMed – (*small scale*or large scale*, indigenous cattle* or goats* or sheep**) and (*gastro-intestinal * or endo** and (*Tanzania**); Science Direct – (*small scale* or indigenous cattle**) or (*gastro-intestinal*, or endo** and (*Tanzania*)*. An iterative process combining different key words was used to arrive at the final search terms. Specific search engines for journals such as Livestock Research for Rural Development were used to retrieve information relevant to Tanzania and to other areas with similar environmental conditions. Unpublished records and reports from government and non government bodies and dissertations and theses from Sokoine University of Agriculture were retrieved and reviewed for additional information.

3. RESULTS

3.1. Nematodes

Gastrointestinal nematodes or roundworms exert different pathogenic effects [6]. It is therefore important to establish the broad groups that are present in an animal unit, area, country or region. Knowledge of the different development times and stages outside and inside the definitive host is also important for implementation of effective control measures. Most nematodes, often considered as the primary pathogens, are found in the abomasum, with those in the intestine playing a lesser but synergistic role. Parasitic gastroenteritis in Tanzanian cattle, goats and sheep is caused by mixed infections of several nematode species of which 13 species in nine genera have been recorded (Table 1).

Table-1. Nematode species infecting large and small ruminants in Tanzania

Genus and species	Host	Distribution	Reference
Strongyles	Goat, (pig)		[7, 8]
Trichuris ovis	Goat, sheep	Less prevalent	[9]
Oesophagostomum columbianum	Goat, sheep, cattle	Most prevalent	[8-11]
Oesophagostomum. radiatum	Traditional, small and large scale dairy; slaughter cattle, sheep, goat	Most prevalent; Iringa, Mwanza, Morogoro	[8, 12-14]
Bunostomum trigonocephalum	Dairy goat, sheep	Most prevalent; Morogoro	[9-11]
Strongyloides papillosus	Dairy goat	Most prevalent; Morogoro	[9, 11]
Cooperia pectinata	Traditional, small and large scale dairy; dairy goat	Prevalent; Iringa, Morogoro	[11, 12]
Cooperia punctata	Traditional, small and large scale dairy; dairy goat	Prevalent; Iringa, Morogoro	[11, 12]
Trichostrongylus colubriformis	Traditional, small and large scale dairy; dairy goat	Prevalent; Iringa, Morogoro	[12]
Haemonchus contortus	Sheep, goat	Intensive and extensive systems; slaughter stock	[8-11]; [15-17]
Haemonchus placei	Traditional, small and large scale dairy cattle, sheep, goat	Most prevalent	[12]
Haemonchus similis	Traditional, small and large scale dairy, sheep, goat	Prevalent	[12]
Dictyocaulus. viviparus	Cattle	All highland areas	[18]

Nematode infections in cattle in Tanzania have been reported in the formal literature by various authors [12, 15, 19-25] and there are many unpublished records from the national State Central Veterinary Laboratory at Temeke, Tanzania. The most important and widely prevalent nematodes belong to the Family Trichostrongylidae comprising the genera *Cooperia*, *Haemonchus*, *Trichostrongylus* and *Ostertagia* and to the Family Chabertiidae comprising the single genus *Oesophagostomum*. The genera *Bunostomum* (Ancylostomatidae), Nematodirus (Trychostrongylidae), *Strongyloides* (Strongyloididae), *Toxocara* (Toxocaridae) and *Trichuris* (Trichuridae) are of lesser frequency [20, 21]. *Dictyocaulus viviparus* (Dictyocaulidae), a nematode of the trachea and larger bronchi is responsible for parasitic bronchitis in cattle and has been recorded from Iringa District in the Southern Highlands and Lushoto District in the northeast of the country [18]. Most of the foregoing genera including *Trichostrongylus*, *Oesophagostomum*, *Strongyloides*, *Bunostomum*, *Ostertagia* and *Toxocara* have been shown to be present at various levels of prevalence in wild African buffalo *Syncerus caffer* in Ngorongoro and Arusha National Parks [26]. The nematode genera found in Tanzania have been reported in previous studies in neighbouring countries including *Haemonchus*, *Trichostrongylus*, *Cooperia* and *Oesophagostomum* in small ruminants in Kenya [27, 28].

3.1.1. Cooperia Spp

Cooperia spatulata is the most common species in cattle in the tropics [29] but it is unexpectedly absent in Tanzania [12, 30]. *Cooperia pectinata* and *C. punctata* are usually less prevalent but they have been found in cattle in the lower areas of the Southern Highlands and in the Eastern Region at Morogoro [11, 12]: although they occur in the small intestines of a wide range of ruminant species world-wide they seem to be more important in cattle. Unless infected by massive doses (300 000 L3 or more during a 10-day period) clinical signs are seldom seen. In severe infestations there is a fluid foetid diarrhoea, selective anorexia, bottle jaw and eventually death which results from starvation, dehydration and exhaustion [4]. There are no documented reports of any *Cooperia* spp. in sheep and goats in Tanzania.

3.1.2. Haemonchus Spp

The most prevalent of the three *Haemonchus* species found in Tanzania is *H. placei* which has been recorded in the lower areas of the Southern Highlands and in the Eastern Region [12]. Both *H. placei* and *H. similis* are more adapted to cattle whereas *H. contortus* is more adapted to sheep and goats [31]. The heaviest burdens in Tanzania occur at the end of the rainy and the beginning of the dry season whereas the lowest burdens are seen at the end of the dry and at the beginning of the rainy season [12]. Worm burdens are more pronounced in immature (<3 years) than mature animals. *H. contortus* is widely distributed in Tanzania and is reported in sheep and goats from Mtwara Region in the south, Mwanza and Kigoma Regions in the west, Morogoro and Coast Regions in the east, Dodoma Region in the centre and Arusha and Kilimanjaro Regions in the north [8, 10, 11, 13-30, 32]. Cross-infection of *H. contortus* between cattle, goats and sheep has not been investigated in Tanzania although studies from other countries have shown cross-infection between domestic stock and wildlife [33].

3.1.3. Trichostrongylus Spp

The most frequent species is *Trichostrongylus colubriformis* but there are some reports of *T. axei* [12]. *T. colubriformis* is a parasite of sheep and its presence in cattle is likely to be due to cross-infection [29]. With the exception of *T. axei*, however, this genus is not considered to be important in cattle [29]. *T. colubriformis* was the predominant species in traditionally managed cattle in the Southern Highlands of Tanzania but the genus is also prevalent in dairy goats and their crosses reared in intensive and semi-intensive systems in Tanzania [11]. *Trichostrongylus* spp. have also been recorded in African buffalo in Ngorongoro and Arusha National Parks [26]. *T. colubriformis*, with a direct life cycle and a developmental period of 18-20 days, tends to occur in the first 7 metres of the small intestine and is found less often in the abomasum. Manifestation of infestation occurs from acute (rarely seen) to chronic (when 100 000 larvae are ingested) forms. In acute cases the pain caused by the parasite results in anorexia, closure of the pyloric sphincter and retention of food in the abomasum and rumen. Sheep become listless, signs of sub-mandibular oedema develop and there is yellow foetid diarrhoea followed by death 16-17 days after infection.

3.1.4. Oesophagostomum Radiatum

Oesophagostomum radiatum, the nodular worm of cattle, occurs in the colon. It is distributed world-wide from temperate to tropical climes. It is reported in traditional herds in Tanzania's Southern Highlands which has a relatively cool climate [12] but does not occur in arid, non-seasonal rainfall areas. The direct life cycle has a developmental period of 32-34 days. Wet, warm weather, overgrazed rangelands and unhygienic pens are risk factors for calves which are the main class of stock affected. Clinical signs of affected animals are pain, anorexia, loss of body mass, hypoproteinaemia, anaemia and diarrhoea that is often foetid and blood-stained. Cattle constantly exposed tend to develop a strong immunity from 8-12 months of age. Studies in the higher rainfall areas of the Southern Highlands around Iringa showed low numbers of *Oesophagostomum radiatum* and *Trichuris globulosa* [12]. This contrasts with *Bunostomum trigonocephalum* which was found to be prevalent with occurrence being relatively high in goats and sheep [9].

3.1.5. Strongyloididae and Trichuridae

Documented species in the families Strongyloididae and Trichuridae in Tanzania are *Strongyloides papillosus* and *Trichuris ovis*. *S. papillosus* is reported in goats in extensive and semi-intensive production systems around Morogoro [9, 11] with kids being more susceptible than adults. The source of infection for very young kids is the reservoir of larvae in the tissues of their dams. Adult worms cause anorexia, diarrhoea or constipation, sunken eyes with a purulent discharge, a frothy mucous discharge from the nose, muscular atrophy and paresis just before death. Warm moist weather favours worm development and survival and allows the accumulation of large numbers of infective larvae. *Trichuris ovis* which is commonly found in the caecum and colon is less prevalent but has been detected in Tanzanian goats [9]. *T. ovis* eggs are resistant to desiccation and survive in a temperature range of – 20° C to 50° C. The larval stages cause haemorrhages and local oedema when they penetrate the intestinal wall and these injuries can result in secondary bacterial infection. The adult worms are not pathogenic unless present in large numbers when they may cause abdominal pains, mucoid diarrhoea, anaemia, loss of body mass and, rarely, death.

3.2. Trematodes

There are an estimated 18 000 to 24 000 species of trematodes or flukes in the world. These include *Fasciola hepatica*, *F. gigantica* and species of *Dicrocoelium*, *Schistosoma* and *Paramphistomum* among others (Table 2). The most significant trematodes from a clinical point of view are the blood flukes, *Schistosoma mansoni*, *S. japonicum* and *S. hematobium*. Other trematodes of significance are the intestinal fluke *Fasciolopsis buski*, liver fluke *Clonorchis sinensis* and lung fluke *Paragonimus westermani*. Trematodes often live in the bile ducts or small intestine and may also affect the lungs. Some are ingested but some burrow into the skin to gain access to their host [18]. Their eggs are passed with the faeces of the host. Trematodes usually require an intermediate host in their life cycle with vertebrates being the definitive host. Larval stages may occur in either invertebrate or vertebrate hosts [34, 35].

Table-2. Trematode species infecting large and small ruminants in Tanzania

Genus and species	Host	Distribution	Reference
Fasciola gigantica	Cattle, goat	Country wide, Mwanza, Arusha	[7, 8, 19, 23, 24, 36-39]
Fasciola hepatica	Cattle		[35]
Paramphistomum species	Cattle, goat	Iringa, Mwanza, Arusha	[7, 23, 40]
Schistosoma bovis	Cattle	Iringa/Meru	[20, 39, 41]
Dicrocoelium hospes	Cattle	Iringa	[40]
Calicophoron microbothrium	Cattle	Iringa	[22]
Cotylophoron jacksoni	Cattle	Iringa	[22]

Symptoms of trematode infestation include watery diarrhoea, weakness, weight loss, decreased milk production, reduced product quality, mortality and secondary infections [2]. Fasciolosis is now recognized as an emerging human disease [42].

Trematode infections of cattle and small ruminants in Tanzania are widespread and severe. They cause significant economic losses due to reduction in production efficiency by 5 per cent in mild infestations to 10 per cent in more severe ones and in weight loss and abattoir condemnations [21, 41, 43-48]. The most prevalent species in Tanzania are *Fasciola gigantica* and *F. hepatica* [35, 39, 41]. Several researchers using slaughterhouse surveys have studied the infection rates of trematodes in domestic animals [19, 36, 38, 48]. Slaughter house surveys carried out from 1965-1984 covering different eco-climatic regions in the Lake Zone (Mwanza), Northern Zone (Arusha), the Southern Highlands (Iringa and Mbeya) and the Usambara Mountains (Lushoto) showed variable rates of infestation ranging from 6.5-71.0 per cent in cattle, 8-26 per cent in sheep and 12-23 per cent in goats [49, 50]. The stomach flukes *Calicophoron microbothrium* and *Cotylophoron jacksoni* have been reported from Iringa [22]. Other trematode parasites include *Schistosoma bovis* from Iringa and Meru [20, 39, 41, 51] amphistomes [37]

Paramphistomum species and *Dicrocoelium hospes* in Iringa [40]. Trematodes reported in African buffalo include *Fasciola*, *Paramphistomum*, *Gastrothylax*, *Ornithobilharzia* and *Fischoederius* [26].

3.3. Cestodes

Cestodes or tapeworms (also sometimes known as flatworms) that mature and live in the gut are acquired by ingesting contaminated food or water and have major negative effects on the health and well-being of the animal. These tapeworms have an indirect life cycle and require pasture mites to complete it. Eggs and larvae are often excreted in the faeces and live in the soil [52]. In almost all cases there are separate sexes with sexual reproduction occurring in the definitive host in parasitic species. The most common symptoms are gastrointestinal but cestodes may also cause allergic reactions, lung and heart symptoms. Large clumps of worms cause intestinal blockage followed by distention and abdominal pains similar to food poisoning. This group (Table 3) includes species of the cosmopolitan *Moniezia* and *Stilesia* [8, 19] which are commonly found in ruminants [29].

Table-3. Cestode species infecting large and small ruminants in Tanzania

Genus and species	Host	Distribution	Reference
Moniezia expansa	Goat, sheep	Less prevalent; Morogoro	[9, 14]
Stilesia hepatica	Cattle, sheep, goat	Country wide, slaughter stock; Mwanza, Arusha	[8, 24, 38]
Echinococcus granulosus	Cattle, sheep, goat slaughter stock	Most prevalent; Mwanza, Mbeya, Ngorongoro	[8, 53, 54]
Taenia multiceps (Coenurus cerebralist)[a]	Sheep, goat	Wildlife/livestock interface area (Arusha)	[55]
Taenia hydatigenea (Cysticercus tenuicollis)	Sheep, goat	Most prevalent, slaughter stock; Mbeya, Arusha, Dodoma	[8, 24, 25, 38]
Taenia ovis (Cysticercus ovis)	Sheep	Prevalent	[8]

Note: a) names in brackets refer to metacestode stage, commonly known as hydatid cysts

The presence of other cestodes such as *Echinococcus granulosus*, *Taenia multiceps* (whose metacestode stage is *Coenorus cerebralis*) and *Taenia hydatigena* (metacestode, *Cysticercus tenuicollis*) and *Taenia ovis* (metacestode *C. ovis*) in tissues or organs leads to them being condemned as unfit for human consumption. The migration of *C. cerabralis* through the brain can cause meningo-encephalitis and the presence of many hydatid cysts in the lungs may be associated with respiratory problems. *C. cerebralis* was found to be the most prevalent metacestode in the livestock-wildlife interface ecosystem of Ngorongoro and Serengeti [55]. Lack of knowledge in the community on how coenurosis occurs, free access of dogs to carcasses and offal of small ruminants and inadequate animal health services for dogs especially worm control were speculated to be major factors in the continuance of coenurosis [55] . The prevalence of echinococcosis (hydatidosis) reported in Ngorongoro District in cattle was 48.7 per cent, for goats was 34.7 per cent and for sheep was 63.8 per cent [53]. In an earlier study in a Masai community in northern Tanzania a prevalence of 1.4 per cent was found [56]. Recent postmortem slaughter slab surveys in Mbeya Region indicated prevalences of41.7 per cent in goats and 51.9 per cent in sheep [54].

3.4. Protozoa

3.4.1. Eimeria spp

Eimeria species are single-cell protozoa that cause coccidiosis in animals and damage the lining of the small intestine. Species are host-specific. Transmission of coccidiosis is facilitated by warm and wet environmental conditions. Research has shown that cattle, sheep and goats in intensive grazing areas and feedlots are at greatest risk [57]. Stress from weaning often induces outbreaks of coccidiosis. Clinical signs include diarrhoea (sometimes containing blood or mucous), dehydration, fever, weight loss, inappetance, anaemia, and death. Research in various agroecological zones of Tanzania has demonstrated the presence of at least seven species of *Eimeria* in cattle [14, 58] and 18 species in sheep and goats [59] (Table 4). The most prevalent species in cattle are *Eimeria zuernii* and *E. bovis* whereas in goats and sheep the main species is *E. arloingi*. The presence of pathogenic species including *E. alijevi*, *E. arloingi*, *E. ninakohlyakimovae* and *E. christenseni* in goats *E. ovinoidalis* and *E. ahsata* in sheep is a clear indication that coccidiosis is a major contributor to the enteric syndromes affecting small ruminants in Tanzania [59, 60].

3.4.2. Protozoan Species Other Than Eimeria

Other protozoan species found in ruminants in Tanzania include species of *Cryptosporidium*, *Giardia* [30, 59-61] *Balantidium* and *Entamoebae* [7].

Cryptosporidium oocysts are often detected in animals suffering or not from diarrhoea. Bovine faecal samples screened in villages in Dodoma Rural and Bagamoyo Districts showed 0.5 per cent infection with *Cryptosporidium parvum* in 942 cattle examined in three villages in Dodoma and 1.5 per cent of 202 cattle infected with *Giardia lamblia* in one village in Bagamoyo [61]. Other studies in the highland and semiarid areas of Iringa, Morogoro, Dodoma and coastal Tanga have shown varied levels of prevalence of *Cryptosporidium* in both dairy and traditional cattle [63-67]. In all these studies young stock were more affected than adults. These results highlight the possible public health risks associated with the keeping of livestock and the shared use of water sources by humans and animals. Other *Cryptosporidium spp* oocysts have been reported in wildlife including African buffalo, zebra and wildebeest [64]. The ciliate protozoa *Balantidium coli* was detected in slaughtered small ruminants in Mwanza [68]. The parasite lives in the caecum and colon of goats and sheep where it is asymptomatic. It is, however, associated with the zoonotic disease balantidiasis which is acquired by people via the faeco-oral route from the normal goat or sheep host. The parasite is not readily transmissible from one species to another because it requires a period of time to adjust to the symbiotic flora of the new host. Frequently existing as commensal parasite in pigs, *Entamoebae coli* has been reported in slaughtered goats and sheep in Mwanza [68]. Its pathogenic role in Tanzania is not clearly known.

4. EPIDEMIOLOGY OF GASTROINTESTINAL PARASITE INFECTIONS

The epidemiology of gastrointestinal parasites is influenced by predisposing factors. These include those related to the host and to the parasite, climate, management system, pasture management, grazing habits, nutritional status, immunological status, vector, presence of intermediate host and the number of infective larvae and eggs in the environment [4]. Cestodes have indirect life cycles, the intermediate hosts being soil-inhabiting oribatid mites [69]. Birds may also be involved in the dissemination of tapeworm eggs. The effect of helminth infections is determined by a combination of factors, of which the varying susceptibility of the host species, the pathogenicity of the parasite species, the host/parasite interaction, and the infective dose are the most important [4].

4.1. Host Factors

Age, breed, nutrition, physiological status and presence or absence of intercurrent infection are known to influence the rate and severity of infection. The number of infective stages present in the host environment at any time is related to the number of worm eggs excreted. This largely determines the number of parasites potentially capable of being established in a susceptible host [70]. Calves, kids and lambs are relatively more susceptible than mature stock. Some breeds, such as the Galla and Small East African goats [71] and the Red Masai sheep [72] are known to have greater resistant to *Haemonchus contortus* than other types. Poor nutrition, hormonal change during late pregnancy and lactation lower the resistance of the host to nematodes and consequently result in the establishment of higher worm burdens.

Table-4. Protozoan species infecting large and small ruminants in Tanzania

Genus	Host	Distribution	Reference
Eimeria zuernii	Large and small scale dairy, cattle	Country wide	[58]
Eimeria bovis	Large and small scale dairy, cattle	Country wide	[58]
Eimeria ellipsoidalis	Large and small scale dairy, cattle	Country wide	[58]
Eimeria cylindrica	Large and small scale dairy, cattle	Country wide	[58]
Eimeria aubernensis	Large and small scale dairy, cattle	Country wide	[58]
Eimeria alabamensis	Large and small scale dairy, cattle	Country wide	[58]
Eimeria subspherica	Large and small scale dairy, cattle	Country wide,	[58]
Eimeria arloingi	Small scale dairy, dairy goat, sheep	Tropical highland and semiarid areas of Morogoro	[14, 59, 60, 62]
Eimeria alijavi	Small scale dairy, dairy goat	Tropical highland and semiarid areas of Morogoro	[59, 60, 62]
Eimeria ninkohlyakimovae	Small scale dairy, dairy goat	Tropical highland and semiarid areas of Morogoro	[59, 60]
Eimeria christenseni	Small scale dairy, dairy goat, sheep	Tropical highland and semiarid areas of Morogoro	[14, 59, 60]
Eimeria caprovina	Small scale dairy, dairy goat	Tropical highland and semiarid areas of Morogoro	[59, 60]
Eimeria hirci	Small scale dairy, dairy goat	Tropical highland and semiarid areas of Morogoro	[59, 60]
Eimeria pallida	Small scale dairy, dairy goat	Tropical highland and semiarid areas of Morogoro	[60]
Eimeria caprina	Smallscale traditional, dairy goat, sheep	Morogoro	[14, 59]
Eimeria crandallis	Smallscale traditional, dairy goat	Morogoro	[59]
Eimeria parva	Smallscale traditional, dairy goat, sheep	Morogoro	[14, 59]
Eimeria ovinoidalis	Smallscale traditional, dairy goat, sheep	Morogoro	[14, 59]
Eimeria bakuensis	Smallscale traditional, dairy goat	Morogoro	[59]
Eimeria faurei	Smallscale traditional, dairy goat	Morogoro	[59]
Eimeria ahsata	Smallscale traditional, dairy goat	Morogoro	[59]
Eimeria granulosa	Smallscale traditional, dairy goat, sheep	Morogoro	[59]
Eimeria marsica	Smallscale traditional, dairy goat, sheep	Morogoro	[14]
Eimeria jolchijevi	Smallscale dairy, dairy goat	Tropical highland and semiarid areas of Morogoro	[59]
Eimeria aspheronika	Smallscale dairy; dairy goat	Tropical highland and semiarid areas of Morogoro	[59]
Cryptosporidium parvum	Extensive traditional cattle, dairy; wildlife (zebra, buffalo, wildebeest)	Central and coastal Tanzania and Southern Highlands	[61, 63-67]
Giardia lamblia	Extensive traditional cattle	Central and coastal Tanzania	[61]
Balantidium coli	Goat	Urban Mwanza	[68]
Entamoebae coli	Goat	Urban Mwanza	[68]

4.2 Parasite factors

The factors that determine the rate of establishment and size of the nematode burden in the host are the fecundity of the adult worms, the pre-patent period and the survival and development rate of the parasite in the environment.

4.3 Climate factors

Most studies on gastrointestinal nematode ecology in cattle have concluded that climatic conditions are extremely important in the survival and transmission of parasite eggs and larvae [73]. Epidemiological studies in Tanzania showed seasonal differences with respect to helminth infections. Liver fluke transmission is dependent on the presence of its snail intermediate host so distribution of the parasite is limited to geographic areas where the appropriate snail species is present [39]. A high prevalence of fasciolosis has been shown towards the end of the dry season and the early part of the rainy season [21, 41]. This seasonality is in agreement with other investigators who suggested that heavy mortality as a result of fasciolosis occurred during the dry season [49, 51]. Cattle grazing in irrigation areas are most susceptible to infection [39].

Temperature influences the development of nematode larvae: the optimal temperature for development of most trichostrongylid larvae is 22-30° C. Some trichstrongylid larvae such as *T. colubriformis* and *O. columbianum* are known to be resistant to desiccation, an ability that enables them to survive under extremely low or high temperatures [27, 28]. Temperature and moisture are the main environmental variables that determine survival and development of coccidial oocyst to the infective stage.

4.4. Management Factors

Management systems also influence egg developments and the free living stages of helminth larvae. Heavy stocking densities increase the contamination of the environment with nematode eggs or larvae and thus render the infective stages more accessible to susceptible animals. Concentration of animals at watering points, particularly during the dry season may result in massive contamination of pastures with eggs or larvae leading to outbreaks of parasitic gastroenteritis. Tethering of goats and sheep during the wet season, which is common in many agropastoral parts of the country, is reported to result in increased environmental contamination with infective larvae and the incidence of clinical disease [59, 61]. Anthelmintic treatment may reduce the worm load but indiscriminate use of helminthic preparations of unproven quality and undefined doses may result in development of resistant strains of nematodes – a problem of increasing importance in Tanzania [10].

Over stocking and poor hygiene favour rapid transmission and build-up of coccidial infections whereas stress factors, confinement, weaning, inclement weather and inter-current disease precipitate the occurrence of clinical disease. Animals acquire *Cryptosporidium* infection by ingestion of contaminated feed and water.

5. CONTROL OF INFECTIONS

Effective control of gastrointestinal parasite infections is dependent on a comprehensive understanding of the epidemiology of the disease in both the host and the environment [73]. Control should be designed to, at best, eliminate or, at worst, reduce the prevalence of the parasites. Eradication of helminth diseases is not, however, a simple matter and it is important to make a correct assessment of the costs and the associated benefits of any control method. Control by the use of anthelmintics depends to a large extent on their proven quality under field conditions, the frequency of treatment and the correct dosage. It should be determined by the epidemiology and biology of the dominant parasite, the stocking rates of the particular area and the benefit accrued from the adopted control regime.

Control through management should aim at reducing the contact of susceptible animals with infective larvae. Control of helminth diseases by good management is likely to be more sustainable than the use of anthelmintics.

This method may be the most practical one in smallholder production systems when drugs are expensive (and in many cases may be of dubious efficacy). Rotational grazing, separation of animals according to age group, alternate grazing by different host species, adjusting stocking rates, improved nutrition and better housing systems are the common management practices employed as control measures against helminthosis in most countries.

Control by breeding resistant stocks and control by immunization has been applied in some countries although progress has been slow and variable although there are some encouraging prospects. In general, however, the ideal approach towards effective control of helminths is the integration of several methods because each method has its own advantages and disadvantages [4, 74].

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