3   LITERATURE REVIEW

3.1   Trypanosomosis

3.1.1   Introduction

Trypanosomosis is a disease of both man and livestock caused by protozoan parasites of the genus *Trypanosoma*. Of the different species, *Trypanosoma brucei rhodesiense* and *T.b. gambiense* infect man. The resultant human African trypanosomosis (HAT) leads to a protracted, debilitating and finally fatal disease in untreated cases. The disease is endemic in 36 countries of sub-Saharan Africa and approximately 60 million people are estimated to be at risk. The reported incidence is 25,000 new cases annually, and is associated with a breakdown in active case finding (Van Nieuwenhove, 1998). There has been a resurgence of the disease during the past decade in large portions of Central Africa, with 350,000 to 450,000 persons now estimated to be infected (Barrett, 1999; Denise *et al*., 1999; Hellenport and Pecoul, 2000; Seed, 2000). Currently, epidemics are being experienced in the Democratic Republic of Congo, Angola, Sudan and Uganda (Van Nieuwenhove, 1998).

African animal trypanosomosis (AAT) is considered a major constraint to livestock productivity in sub-Saharan Africa (SSA) (Leak *et al.,* 1988) and has profound effects on rural development over vast areas (Holmes, 1997). It is estimated that tsetse flies are distributed over approximately 11 million km^2 of Africa (Jordan, 1986), which is about 37% of the continent (FAO/WHO/OIE, 1982). Presently, out of the estimated 172 million head of cattle, approximately 44.7 million are at risk of trypanosomosis (Gilbert *et al.,* 2001). The economic losses attributed to AAT are due to decreased meat and milk production as a result of mortality, morbidity and infertility. When the impact on crop productivity due to reduced animal draught power and manure is considered, the true economic losses could be much higher (Budd, 1999).

The epidemiology of trypanosomosis is complicated by the fact that both the human and livestock infective trypanosomes circulate in wild animals and livestock (Onyango *et al.,* 1966; Hide *et al.,* 1996). In addition, the human-infective *T.b. rhodesiense* and non-human-infective

T.b. brucei are morphologically identical. However, recent development of a genetic marker based on the detection of a serum resistance associated (SRA) gene in *T.b. rhodesiense* (Welburn *et al.,* 2001; Gibson *et al.,* 2002; Tilley *et al.,* 2003) has enabled the differentiation of the two *T. brucei* sub-species.

3.1.2   Aetiology and transmission of AAT

The most important trypanosomes in terms of economic losses in livestock are the tsetse transmitted species: *Trypanosoma congolense, T. vivax* and *T. brucei* (Mulligan, 1970). However, *T. vivax* has been found outside the zone of *Glossina* infestation, where it is transmitted non-cyclically by other species of biting flies (Molyneux and Ashford, 1983; Abebe and Yobre, 1996). *Trypanosoma evansi* is also acyclically transmitted by biting flies of the genus *Tabanus* and *Stomoxys. Trypanosoma equiperdum* on the other hand is transmitted sexually, from host to host (Molyneux and Ashford, 1983).

3.1.3   Epidemiology

The epidemiology of trypanosomosis is dependent on the interactions between the parasite, vector and host factors. The severity of the disease depends on the species and strain of trypanosomes involved. It has been stated that *T. vivax* infections predominate in cattle in West Africa and are rapidly fatal whilst *T. congolense* causes a chronic disease. In contrast, *T. vivax* may be commonly encountered in East and Central Africa but causes a mild disease in cattle in comparison to *T. congolense.* There are exceptions to this rule: for example, the haemorrhagic *T. vivax* infections that occasionally break out in Kenya are rapidly fatal (Mwongela *et al.,* 1983; Murilla *et al.,* 1998; Stevenson and Okech, 1997; Leak, 1999).

The mammalian trypanosomes of the *Congolense, Vivax* and *Brucei* groups are normally restricted to the humid and sub-humid zone of Africa, roughly between latitudes 15° N and 25° S, which coincides with the area of distribution of their intermediate hosts, represented by *Glossina* (Hoare *et al.,* 1957). The disease transmitted by these flies (trypanosomosis) has proved difficult to control despite intensive efforts over most of the last century and attempts to achieve eradication have failed (Holmes, 1997). On the one hand, there has been over-dependency on

donor agents to finance tsetse control activities with little involvement of the communities since these communities have in the past viewed tsetse control as a public good (Eisler *et al.,* 2002). In addition, the fact that trypanosomes infect not only cattle but also wild animals, which constitute the reservoirs of the disease, make the epidemiology of trypanosomosis extremely complicated (Onyango *et al.,* 1966; Hide *et al.,* 1996). The problem is further compounded by the concurrent occurrence of trypanosomosis and tick-borne diseases in most of the tsetse infested zones of SSA (Latif and Jongejan, 2002).

3.1.4 Pathogenesis

Infected tsetse flies inoculate metacyclic trypanosomes into the skin of animals, where the trypanosomes grow for a few days and cause localized swellings (chancres). They enter lymph nodes, then the blood stream, where they divide rapidly by binary fission. In *T. congolense* infections, the organisms attach to endothelial cells and localize in capillaries and small blood vessels. *Trypanosoma brucei* and *T. vivax* invade tissues and result in tissue damage in several organs (Blood *et al*., 1989).

When an animal is infected with trypanosomes, antibodies against the surface coat are produced. However, trypanosomes have multiple genes, which code for different surface proteins; allowing organisms with new surface coat glycoproteins to elude the immune response. This process is referred to as 'antigenic variation' and results in the persistence of these organisms. Antigenic variation has thus far prevented development of a vaccine and permits re-infection when animals are exposed to tsetse carrying trypanosomes with surface coat glycoproteins of a new antigenic type (Blood *et al*., 1989).

The real cause that leads to the death of the animal is not fully understood. However, it is believed that the parasite releases toxic substances when it is destroyed within the circulatory system, and hence damages the lining of the blood vessels. In some cases the sudden release of large amounts of such toxins triggers a chain of reactions which produce a shock-like syndrome (Seifert, 1996). Therefore, the damage to the host does not depend on nutrients being depleted by the parasite but rather on the production of toxic substances (Mehlhorn and Piekarski, 1989).

With this theory, the typical symptoms of trypanosomosis, such as cachexia, oedema, anaemia and nervous symptoms can be explained.

Anaemia appears with progressing parasitaemia and there is lysis of large numbers of red blood cells resulting in a drop in PCV% (Coetzer *et al*., 1994). Metabolic disorders are observed in the host due to a trypanosome-induced hypothyroid status (Abebe and Eley, 1992) and pituitary dysfunction during trypanosomosis (Abebe *et al.*, 1993a; b). The ability of trypanosomes to change their surface-coat-antigen continuously leads to the exhaustion of the antibody production by the host leading to immunosuppression (Brown *et al.*, 1990; Hörchner, 1993). In addition, there is enlargement of lymph nodes and splenomegally associated with plasma cell hyperplasia and hypergammaglobulinaemia (Urquhart *et al.*, 1992). Acute infections associated with high parasitaemia may lead to the death of an animal still in good body condition. However, chronic trypanosomosis is associated with progressive emaciation and eventually, cachexia. This is usually accompanied by low levels of parasitaemia and death in untreated cases (Coetzer *et al.*, 1994).

3.1.5 Economic importance

In addition to the mortality that occurs in paracute and acute cases, trypanosomosis also leads to reproductive disorders (Ikede *et al.*, 1988). General reproductive failure and poor lactation performance of *Bos taurus* cattle introduced into high tsetse challenge areas was reported by Anene *et al.* (1991). A similar observation with up to 25% decline in milk yields was also reported by Agyemang *et al*. (1991). Disruption of oestrus cycles has been reported in trypanosome-infected Boran cows with most infected ones becoming acyclic (Luckins *et al.,* 1986). Long calving intervals and abortions or stillbirths are common in trypanosome infected cattle in the field. Other production losses due to trypanosomosis include neonatal mortality and poor growth rates. It has been shown that infected bulls were unfit for breeding due to poor quality of semen and lack of libido (Sekoni *et al.,* 1990). There may be many other losses attributed to trypanosomosis. Unfortunately, losses in food production from mixed crop-livestock production system as a result of reduced availability or lack of manure, draught power and cash income, are difficult to estimate (ILRAD, 1993). According to Budd (1999), African farmers

spend 35 million US dollars per year on trypanocidal drugs to protect and cure their cattle. Losses in meat production, milk yield, and traction power are estimated to cost approximately US$ 500 million annually and, if lost potential in livestock and crop production are also considered, then trypanosomosis may be costing Africa an estimated US$ 4.5 billion per year (Budd, 1999).

3.1.6 Diagnosis of trypanosomosis

Routine diagnosis of trypanosomosis in the field is undertaken via clinical signs and knowledge of the endemicity of the disease in the area (Blood *et al.,* 1989; Coetzer *et al*., 1994). However, other more accurate methods of diagnosis include: parasitology, serology and molecular biology.

Some of the parasitological methods currently in use are: thin stained blood films (Shute and Maryon, 1966), the buffy coat dark ground-phase contrast technique (BCT) (Murray *et al.,* 1977), the haematocrit centrifugation technique (HCT) (Woo, 1970) and the miniature-anion exchange centrifugation technique (mAECT) (Lumsden *et al.*, 1977). These methods are confirmatory since they depend on demonstration of trypanosomes. However, these parasitological detection methods have a limited analytical sensitivity (i.e. lower detection limit) and may lead to under-reporting of the prevalence of disease (Paris *et al*., 1982).

More sensitive diagnostic methods, including the detection of trypanosome-specific antibodies and antigens have been developed (Luckins and Mehlitz, 1976; Luckins, 1977; Nantulya *et al*., 1992). In their study of bovine trypanosomosis, Luckins and Mehlitz (1976) used a microplate-ELISA system and found that cattle developed positive ELISA values after infection, but it was not possible to differentiate between *T. vivax, T. congolense, T. brucei* or *T. rhodesiense.* For instance, the antigen-detecting enzyme-linked immunosorbent assay is extremely sensitive for the detection of trypanosomosis in cattle and goats (Trail *et al.,* 1991). Nevertheless, the serological tests in current use suffer from lack of well defined antigens necessary for designing simple and accurate tests that are easily adaptable for field use. In addition, the detection of anti-trypanosomal antibodies in serum cannot distinguish between an active infection and a cured

one. This is due to the fact that, in cattle, the length of time taken for antibodies to disappear from the circulation after a successful therapy may extend up to 9 months (Voller *et al.*, 1977).

Techniques in molecular biology have led to the development of DNA-based assays for detection of trypanosomal DNA. Species-specific DNA probes have been shown to detect simultaneous infection of cattle with *T. vivax*, *T. b. brucei*, and *T. congolense* when conventional methods revealed only single infections (Nyeko *et al.,* 1990). Consequently, PCR coupled with DNA probe hybridization could prove to be a highly sensitive tool for the diagnosis and assessment of therapeutic efficacy and disease progress especially in chronic trypanosomosis (Clausen *et al.,* 1999).

3.1.7 Control

3.1.7.1 Chemotherapy and chemoprophylaxis of AAT

Chemotherapy in livestock currently depends upon the salt of six compounds, several of which are chemically closely related. These groups are the phenanthridines, isometamidium and homidium, and the aromatic diamidine, diminazene. After the introduction of isometamidium in 1961 (Berg *et al.,* 1961) the development of new trypanocidal drugs has made little progress. The incidence of resistance to these drugs is apparently on the increase (Peregrine, 1994) and the main means of controlling the disease is therefore under threat.

3.1.7.2 Diminazene aceturate

Diminazene is probably the most commonly used therapeutic agent for trypanosomosis in livestock in SSA (Geerts and Holmes, 1998). Sensitive populations of *T. congolense* and *T. vivax* are eliminated by intramuscular treatment of the host with diminazene aceturate at a dose of 3.5 mg/kg bw. Diminazene aceturate was thought to have some prophylactic activity, providing protection against natural infection for up to 3 weeks when used at a dosage of 7 mg/kg bw (Van Hoeve and Cunningham, 1964). However, the drug is quickly excreted (Bauer, 1962; Karanja *et*

al., 2002) and is not used as a prophylactic. Treatment of domestic livestock with standard therapeutic doses of diminazene aceturate (3.5-7.0 mg/kg bw) rarely results in signs of toxicity. Since its therapeutic index in most animals is relatively large, cattle for instance can tolerate doses as high as 21 mg/kg bw without exhibiting signs of systemic toxicity (Fairclough, 1963). In camels, a single dose of 7.0 mg/kg bw can be highly toxic (Leach, 1961). Diminazene is also relatively toxic in dogs (Losos and Crockett, 1969).

3.1.7.3 Isometamidium chloride (ISMM)

Isometamidium (Berg *et al.,* 1961) is a phenanthridine-aromatic amidine marketed as both a therapeutic and prophylactic agent. In the prophylactic recommended dose (0.5-1.0 mg/kg bw), the compound has been successfully used to maintain the productivity of Zebu cattle exposed to tsetse challenge in both village and ranch management systems in East Africa (Moloo *et al.,* 1987). On Mkwaja ranch in Tanzania where there was a high tsetse challenge, cattle maintained under isometamidium prophylaxis were 80% as productive as high quality Boran cattle on a trypanosomosis-free ranch in Kenya (Trail *et al.,* 1985). This form of mass treatment exerts a strong selection pressure on the trypanosome population (Geerts and Holmes, 1998). As a result, multiple drug resistance later developed on this ranch (Fox *et al.,* 1993; Peregrine, 1994; Geerts and Holmes, 1998). There however, is considerable variation in the prophylactic activity of ISMM (2-22 weeks) even at a dose rate of 1.0mg/kg (Kirby, 1964; Pinder and Authie, 1984; Peregrine *et al.,* 1991). Variation in drug susceptibility between different trypanosome populations appears to be the major factor determining the duration of prophylaxis (Peregrine *et al.,* 1991). Reduction of the number of trypanocidal treatments by integrating drug treatment with other control measures may help alleviate the problem (Geerts and Holmes, 1998).

3.1.7.4 Homidium

Homidium (chloride salt: Novidium; bromide salt: Ethidium) is a phenanthridium whose antitrypanosomal activity was demonstrated more than 60 years ago (Browning *et al.,* 1938). Homidium was extensively used in the 1960s and 1970s but its usefulness has been greatly reduced due to widespread resistance (Scott and Pegram, 1974) and possible mutagenic effects. Over the years it has remained essentially a curative drug in the field, despite claims that the

13

drug has prophylactic properties (Dolan *et al*., 1990). Homidium is active against *T. congolense* and *T. vivax* infections and is recommended for im use at a dose of 1 mg/kg bw.

3.1.7.5 Trypanocidal resistance

There is growing concern that the future effectiveness of trypanocidal drugs may be severely curtailed by widespread drug resistance (Geerts and Holmes, 1998). This is compounded by the fact that no new drugs have been produced for treatment of animals over the last 40 years, except for melarsomine. The use of the same drugs over such long periods has resulted in the widespread development of drug-resistant strains of trypanosomes (Peregrine, 1994).

Resistance of trypanosomes to trypanocidal drugs has been reported in many parts of Africa (Jones, 1967; Garber, 1968; Authie 1984; d'Ieteren, 1988; Peregrine *et al*., 1988). In Kenya, drug resistant *T. congolense* (Gitatha, 1979) and *T. vivax* (Schönefeld *et al.,* 1987) have been described. Work carried out by Clausen *et al*. (1992) in Burkina Faso indicated that diminazene aceturate at 7.0 mg/kg bw cured infections of *T. vivax*, but was ineffective against *T. congolense* in 20 Zebu cattle that were naturally infected. Several reports from Southwest Ethiopia (Codjia *et al*., 1993; Leak *et al*., 1993; Rowlands *et al*., 1993) also indicated that there is a severe drug resistance problem to both diminazene aceturate and isometamidium chloride. Rowlands *et al*. (1993) demonstrated that in the Ghibe Valley in Ethiopia, the mean prevalence of diminazene-resistant infections increased significantly from 6% in 1986 to 14% in 1989. Codjia *et al*. (1993) subsequently determined the drug-resistance phenotype of trypanosome isolates from this site and confirmed the occurrence of drug-resistant populations. Furthermore, development of multiple-drug resistant strains of *T. congolense* isolates has been detected in several areas: in the Bobo-Dioulasso region of Burkina Faso (Authie, 1984; Sones *et al.,* 1988; Moloo and Kutuza, 1990; Clausen *et al.,* 1992) and Ethiopia (Codjia *et al.,* 1993; Mulugeta *et al.,* 1997; Afewerk *et al.,* 2000). This suggests that the concept of the sanative pairs might no longer be working in certain regions. The 'sanative pairs' of trypanocides are ones in which induction of resistance to one drug does not lead to resistance in the other (Whiteside, 1960). Examples of these pairs are: isometamidium and diminazene or homidium and diminazene. Thus, integration of tsetse and trypanosomosis control methods is deemed necessary (Holmes, 1997).

3.1.7.6   Tsetse control

Control techniques that have previously been used include: vegetation clearing, ground and aerial insecticide spraying and selective game destruction. There are reports of reclamation of areas in Nigeria infested with *G.m. submorsitans, G.p. palpalis* and *G. tachnoides* by use of aerial spraying (Jordan, 1986). Vegetation clearing, ground and aerial spraying though, have been discouraged due to the high costs involved in addition to being environmentally unfriendly (FAO 1992). However, recent developments in the aerial application of synthetic pyrethroids (deltamethrin) as was used in the control of tsetse flies in northern Botswana (Okavango Delta), may effectively reduce the risk of pollution (Allsopp and Phillemon-Motsu, 2002). Deltamethrin was initially applied at a concentration of 0.3g/ha and thereafter at 0.26g/ha using a GPS system with an accuracy of 1.0m. The low concentrations of the deltamethrin coupled with the accuracy of application and high tropical temperatures (deltamethrin has a negative temperature coefficient of toxicity) are expected to result in minimal pollution of the environment.

The development of insecticide impregnated, odour-baited traps (Dransfield *et al.,* 1990) and targets (Vale *et al.,* 1988) and insecticide-treated cattle with pour-ons (Shereni, 1990; Bauer *et al.,* 1995; Bauer *et al.,* 1999) which attract and kill tsetse offer prospects for cheaper alternatives with less damage to the environment (Jordan, 1988). Development of synthetic pyrethroid pour-ons (SPs) that are effective against both ticks and tsetse flies is expected to change the tick and tsetse fly control policies in the infested countries. These pesticides are applied along the animal's body and spread through the sebum layer to the rest parts of the body. Flies pick lethal doses of the pesticide during feeding. Cattle therefore act as mobile targets. Successful use of SPs in the reduction of both the vector population and the risk of trypanosomosis has been reported in Burkina Faso (Bauer *et al*., 1995; Bauer *et al.,* 1999), Kenya (Löhr *et al*., 1991; Baylis and Stevenson; 1998; Kamau *et al*., 2000) and Ethiopia (Swallow *et al*., 1993; Leak *et al*., 1995). Baylis and Stevenson (1998) however concluded that reduction in vector population was at local levels and re-infestation was common if the applications were not sustained.

On the other hand, baits (traps, targets) are nowadays used widely to replace air and ground spraying of the insecticides (Vale, 1993). In addition, various trap designs have been used in many countries in the efforts to control tsetse. To control *G. pallidipes* and *G. longipennis* in

Kenya, Brightwell *et al*. (1991) reported that NGU traps baited with acetone, cow urine and octenol were used while biconical traps without any odours were employed for the control of *G. morsitans submorsitans* in Burkina Faso. Targets are usually more effective as a control method because they do not require the flies to enter (Vale, 1993). In Zimbabwe, Kenya, Ethiopia, Rwanda and Burkina Faso, insecticide-treated targets have been used for the control of both *G. pallidipes* and *G. morsitans submorsitans* (FAO, 1992). Work carried out in Nguruman, south-west Kenya, indicated that the populations of *G. pallidipes* and *G. longipennis* were reduced by 99.9% while using insecticide-impregnated targets (Dransfield *et al.,* 1990). In Zimbabwe, Vale *et al.* (1988) reported that the use of targets consisting of a black cloth and netting baited with octenol, acetone and impregnated with deltamethrin, reduced *G. pallidipes* and *G. m. morsitans* populations by 99.9%. In conclusion they indicated that targets offer a simple and ecologically clean method of controlling tsetse and preventing re-invasion. Clausen and co-workers (1992) indicated that efficient tsetse control will lead to a reduction in use of trypanocidal drugs and this will leave their role as efficient means of curing the disease in case of an outbreak.

3.2   Tick-borne diseases

Ticks are perhaps the most important pests in the livestock industry world-wide, causing losses estimated at US$ 7 billion per annum (Griffiths and McCosker, 1990). Although ticks are virtually present throughout the world, they are most prevalent and exert their greatest impact in the tropical and sub-tropical regions (Bram, 1983). The major tick-borne diseases of cattle include anaplasmosis, babesiosis, theileriosis and cowdriosis. Dermatophilosis, which is associated with the *Amblyomma variegatum* tick, is also of great economic importance in vast areas of SSA and the Caribbean region (Brown, 1997). In addition to disease transmission, tick infestation reduces productivity of cattle: damages hides and predisposes them to bacterial and fungal infections and screw-worm attack (Bram, 1983).

3.2.1   Anaplasmosis

The two most important Anaplasma parasites of cattle in Africa are *Anaplasma marginale* and *A. centrale*. These are rickettsia organisms which infect the red blood cells of cattle (Ristic, 1968).

Anaplasma marginale parasites are found near the margins of the erythrocytes while *A. centrale* parasites occupy a more central position. Susceptibility of cattle to anaplasmosis increases with age and adult cattle of any breed are susceptible. Although young animals are susceptible, they do not exhibit clinical signs of the disease (Ristic, 1968).

Anaplasmosis is an acute, sub-acute or chronic syndrome characterized by fever, progressive anaemia and jaundice. In chronic cases, debility and emaciation are common. In addition to other direct effects, pathogenicity of anaplasmosis is mainly related to loss of erythrocytes, lowered immunity and hence predisposing the animals to other disease conditions (Ristic, 1968).

Although *Boophilus decoloratus* ticks are incriminated as the main vectors for anaplasmosis, mechanical transmission through hypodermic needles and biting flies plays an important role. It has been observed that repeated use of hypodermic needles as in vaccination campaigns increases the risk of infection with *Anaplasma* parasites (Maloo, 1993).

Diagnosis of anaplasmosis is dependent on clinical signs, case history and microscopic detection of initial bodies in Giemsa stained thin blood smears. However, the clinical signs are not pathognomonic and hence knowledge of the micro-distribution of the disease is important.

Serological tests have also been developed and validated in laboratory and field studies. The main serological tests include card agglutination test, indirect haemagglutination assay (FAO, 1975) and ELISA (Katende, 1994; Nielsen *et al*., 1996). Use of DNA probes and PCR techniques on the epidemiology of anaplasmosis are increasingly gaining importance.

Anaplasmosis is routinely treated with oxytetracycline formulations. The success of treatment is however dependent on the stage and severity of the disease.

3.2.2   Babesiosis

Babesiosis is caused by intra-erythrocytic protozoan parasites which have a worldwide distribution. The occurrence of the disease is dependent on the distribution of the vector ticks.

The main species of *Babesia* that infect cattle in Africa are *Babesia bovis* and *B. bigemina*. The main vector tick for *B. bigemina* is *Boophilus decoloratus*. *Boophilus microplus* transmits both *B. bovis* and *B. bigemina*. The mode of transmission between the ticks and the hosts is transovarial where either the nymph or the adults can transmit the disease (Young *et al.,* 1988).

The clinical manifestation of bovine babesiosis varies from a very mild and often symptomless infection to acute and often fatal episode depending on the species of the babesia and the susceptibility of the host animal. The main signs of the acute form are anaemia, pyrexia, anorexia, depression, weakness and fall in milk yield. As a result of destruction of erythrocytes, haemoglobinuria and jaundice are common signs especially in terminal stages. In chronic cases, colic, tenesmus and diarrhea are other common signs. Nervous signs may be observed in chronic cases of *B. bovis* infections.

Diagnosis is routinely carried out through clinical signs, especially haemoglobinuria, anaemia and jaundice. Examination of Giemsa-stained thin blood smears from suspected animals is essential for confirmation. The complement fixation test (CFT) was the most commonly applied serological test in assessment of exposure of animals to the disease before the development of ELISA tests (Nielsen *et al*., 1996). Card and capillary tube agglutination tests have been developed but their specificities are low. ELISA techniques have been improved and validated and standardized methods are available for the detection of antibodies to *B. bigemina* (Katende, 1994). There is also increasingly use of DNA probes in the diagnosis of babesia infections (Bose *et al*., 1995).

There are two main compounds available for the treatment of babesiosis in cattle. These are diminazene aceturate which is used at a dosage of between 3.5-8.0mg/kg bw im and imidocarb dipropionate at a dosage of 1.2mg/kg bw sc (Steuber and Kroker, 1997).

3.2.3　Theileriosis-East Coast Fever (ECF)

3.2.3.1　Aetiology

Theileriosis is an infection caused by several protozoan parasites of the genus *Theileria*. It is speculated that theileriosis in cattle originated from buffalo populations in Eastern and Central Africa (Young, 1981; Grootenhuis *et al.,* 1987). Various studies (Levine *et al*., 1980; Irvin, 1987) have resulted in the proper taxonomic placement of the parasite in the genus *Theileria* since it was previously classified with *Babesia*. The main species of the genus *Theileria* that infect cattle include:

Theileria annulata (Dschunkowsky and Luhs, 1904)

Theileria mutans (Theiler, 1906)

Theileria buffeli (Neveu-Lemaire, 1912)

Theileria parva (Theiler, 1904)

Theileria taurotragi (Martin and Brocklesby, 1960)

Theileria velifera (Uilenberg, 1964)

The above classification is as cited by Norval *et al*. (1992).

Theileria parva causes the classical syndrome referred to as East Coast fever (ECF) in Kenya and is the most economically important. East Coast fever was first reported in Kenya in 1904 (Norval *et al.,* 1992). Reports indicate that ECF spread fast from the two initial main foci: the Lake Victoria basin and the coastal strip, as ox transport increased (Norval *et al.,* 1992). The economic impact of the disease escalated as the more susceptible *Bos taurus* cattle continued to be kept in endemic areas by the white settlers.

Until recently, *Theileria parva* was thought to exist in three sub-species namely *T. parva parva, T. parva lawrencei* and *T. parva bovis* causing ECF, Corridor disease and January disease, respectively (Lawrence *et al.,* 1994). However, new findings using monoclonal antibodies (Minami *et al.,* 1983; Conrad *et al.,* 1987a) and DNA characterization (Allsopp and Allsopp, 1988; Conrad *et al.,* 1987b and 1989; Allsopp *et al.,* 1993) have shown that these three species are not genetically different. Therefore, the parasite is classified as either cattle or buffalo-derived *T. parva*.

3.2.3.2 Transmission

The main vector for ECF is the three host tick *Rhipicephalus appendiculatus*, commonly referred to as the brown ear tick. Transmission of *T. parva* by the tick is transstadial by passage from larvae, nymphs and adults as they moult. After ingestion of infected blood by the vector tick, the erythrocytes are lysed leading to release of the piroplasms. The piroplasms undergo sexual development in the mid gut of the ticks leading to the formation of macro-gametes and micro-gametes which then undergo syngamy to form kinetes (Mehlhorn *et al.,* 1978). The kinetes develop further into motile forms which then infect the salivary gland epithelium (Young *et al.,* 1983). Feeding by the tick triggers the process of sporogony where kinetes develop into the infective sporozoites within 3-4 days of feeding (Fawcett *et al.,* 1985).

Following a bite by an infected tick, *T. parva* sporozoites are injected with the tick's saliva, enter the host's lymphoid cells and initiate a reversible transformation of the infected cells (Ole-Moi Yoi, 1989). This leads to a rapid and exponential clonal increase of infected cells which then infiltrate all lymphoid and other tissues (Irvin *et al.,* 1982). The sporozoites then develop into schizonts and later into merozoites leading to the destruction of the lymphoid cells 12-14 days post infection. The merozoites are then released and infect the erythrocytes. In the erythrocytes, merozoites develop into comma, ring or bar-shaped piroplasms (Young *et al.,* 1978).

3.2.3.3 Clinical syndrome

The main clinical signs of ECF include fever, lymphadenopathy, pulmonary and subcutaneous oedema, petechial hemorrhages and corneal opacity (review by Norval *et al.* (1992), Kiptoon *et al*. (1983) and Irvin and Mwamachi (1983)). In acute cases, there is sudden loss of weight while complete blindness is common in chronic cases (Maloo, 1993). In terminal cases, recumbency, cachexia, hypothermia and nervous signs are observed.

3.2.3.4 Diagnosis

Due to inadequate laboratory services, diagnosis of ECF relies mainly on clinical signs. Presence of the *R. appendiculatus* ticks, knowledge of the distribution and occurrence of the disease

contribute towards the diagnosis. Confirmation of the diagnosis is achieved by examination of Giemsa-stained thin blood smears and lymph node aspirates (FAO, 1984).

Application of immunological and molecular diagnostic tools for the diagnosis of ECF is on the increase. The enzyme-linked immunosorbent assay (ELISA) using a recombinant polymorphic immunodominant molecule specific to *T. parva* (Toye *et al.,* 1996) has demonstrated a sensitivity of over 99% and a specificity of between 94 and 98% in experimental and field sera (Katende *et al.,* 1998). This may be the most reliable serological test for *T. parva* to date. Other molecular diagnostic tools for the detection of the parasite's DNA and RNA in both vectors and hosts have been developed (Allsopp *et al.,* 1993; Bishop *et al.*, 1993; Shayan *et al.,* 1998).

3.2.3.5   Chemotherapy

Treatment of ECF was previously difficult until naphthaquinone menoctone was shown to have antitheilerial activity (McHardy *et al.,* 1976). Further development of this compound through laboratory evaluation and field studies (McHardy *et al.,* 1976; Dolan *et al.,* 1984; McHardy and Morgan, 1985; Chema *et al.*, 1986) culminated in the launching of the first and widely used drug for ECF, parvaquone (Clexon®, Wellcome Pharmaceutical Ltd, UK). Another naphthaquinone, buparvaquone (Butalex®, Schering-plough Animal Health, UK), has been developed (McHardy *et al.,* 1985) and extensively evaluated (Dolan *et al.*, 1992; Thaiya *et al.*, 1993; Wanjohi *et al.*, 1995) and is currently available for treatment of ECF. Halofuginone (Terit®, Hoechst Pharmaceutical, Germany) is also used for the management of ECF but at a lower scale (Dolan *et al.*, 1986a). A second type of parvaquone (Parvexon®, Bimeda Export Ltd, Ireland), was developed recently and initial field evaluations indicated that its efficacy is comparable to that of Butalex® (Muraguri *et al.,* 1999). This drug is also available in the market now. The efficacy and reliability of these compounds are however dependent on early diagnosis and administration of full therapeutic doses (McHardy, 1989). Unfortunately, the prohibitively high costs of these drugs have resulted in their limited use by smallholder farmers. In addition, Dolan (1986b) demonstrated that there was a high prevalence of carrier state of *T. parva* in cattle treated with these drugs.

3.2.4   Epidemiology of tick-borne diseases

Although the epidemiology of ECF is well documented (Norval *et al.,* 1992), only a few epidemiological studies on anaplasmosis and babesiosis have been undertaken. Therefore, most concepts developed during the study of the epidemiology of ECF were also speculated to apply for other TBDs. Perhaps the variable economic impacts of these diseases have led to the disproportionate emphasis in favour of ECF.

The concept of endemic stability (Perry *et al.,* 1992) has been applied to describe the epidemiological states of TBDs with a view of developing appropriate and cost-effective control strategies. Endemic stability describes the situation where, as a result of high and continuous challenge by ticks and TBDs, the incidence of clinical disease and resultant mortality rates are low and restricted mainly to younger animals (Perry *et al.,* 1992; Perry and Young, 1995). This situation was initially associated with high and continuous challenge of *Bos indicus* calves early in age and hence development of immunity against the disease (Moll *et al.,* 1984; Moll, 1986; Norval *et al.,* 1992). In such conditions, the majority of calves are expected to have sero-converted by six months of age. O'Callaghan (1998) reported that endemic stability may also exist as a result of protection of calves by maternal antibodies. In endemically unstable conditions, the antibody prevalence is low and the disease incidence is normally high and distributed in all age groups (Norval *et al*., 1992; Perry *et al*., 1992). This condition normally exists where susceptible animals are kept under low levels of tick challenge. Smallholder dairy farming is normally carried out under conditions of endemic instability and thus appropriate tick and TBD control strategies are required.

3.2.5   Economic importance of TBDs

Although ticks and TBDs are known to result in severe economic losses, only a few reports on their direct effects on productivity are available. There is evidence that tick infestation leads to reduction in body weight gains and milk production, however, the available data have not been verified through long-term observational studies (Gitau *et al.,* 1999). It has been hypothesized that reduction in live-weight gains and milk production in tick infested cattle results from decreased appetite or reduced intake due to irritation. Norval *et al.* (1989) demonstrated that in

Zimbabwe, *Amblyomma hebraeum* caused daily reduction of weight of 9-19g for each engorging tick while *R. appendiculatus* caused a reduction of 3-8g. In Zambia, Pegram *et al.* (1991) estimated the damage coefficient caused by every engorging female of *A. variegatum* to be 45-60g. However, data on the direct effects of tick infestation on milk yields is virtually unavailable (Gitau *et al.,* 1999).

Tick-borne diseases are considered to have important direct economic effects. They lead to drastic reduction in milk production, weight loss and death in untreated cases (Norval *et al.,* 1992). The mortality rate due to ECF varies from 0-50% in endemically stable conditions (Staak, 1981; Moll *et al.,* 1986). In endemically unstable conditions, ECF mortality may be as high as 80-100% (Julla, 1985). Although not fully quantified, milk production and draught power decreases significantly during the course of the disease. Perhaps most of the expenditures in Kenya are attributed to costs for the control of TBDs. Importation of acaricides remains a big drain on foreign exchange. Annual expenditure on ticks and TBD control services by the GoK was in excess of US$ 10 million (Young *et al.,* 1988) although this figure may have decreased following the more recent policy of tick control as a private good.

In the smallholder production system, epidemiological studies have been undertaken mainly in the Central medium-high potential and Coastal areas. These studies were carried out in Kiambu District (Gitau *et al.,* 1994a, 1994b and 1994c), the Coastal lowlands (Deem *et al.,* 1993; Maloo, 1993) and Muranga District (Gitau, 1998). However, there seems to be virtually no epidemiological work carried out on the prevalence of TBDs in Western Kenya and especially Busia District. It is therefore imperative that epidemiological data be collected for the assessment of the situation of TBDs and their importance in productivity of cattle in this region.

3.2.6 Control of ticks and TBDs

For a control method of ticks and TBDs to achieve its goals, it needs to match the problem, be economically justifiable, socially acceptable in the production system and environmentally friendly.

3.2.6.1 Acaricides

Various compounds have been used in the past for tick control and these include: chlorinated hydrocarbons (CHCs), organo-phosphoric acid esters (OPAEs), carbamates, cyclic amidins and synthetic pyrethroids (Seifert, 1996). Some of these compounds have already ceased to be used because of development of resistance while others are still in use.

3.2.6.1.1 Chlorinated hydrocarbons (CHCs)

The CHCs are aromatic, ring shaped compounds whose basic skeleton is derived from the benzene ring. The compounds are very stable in the environment, and their catabolism within the organism is rather slow. The biological activity of CHCs is to target and destroy the nervous system of organisms (Seifert, 1996).

While CHCs are not used any more in industrialized countries, these compounds are still applied in third world countries. An example is Toxaphene which has been in use for more than 30 years and is still used as an acaricide in Africa. In Kenya, *Boophilus* and *Rhipicephalus* species of ticks are reported to have developed resistance to Toxaphene (Georghiou and Lagunes-Tejeda, 1991).

The other CHC is hexachlorcyclohexane (Hexachloran, Lindane) which was developed in 1942 and introduced in the market in 1949. Currently, a wide spectrum of ticks have developed resistance to his compound by catabolizing it into non-toxic substances (Seifert, 1996). *Boophilus, Rhipicephalus, Amblyomma* and *Dermacentor* species of ticks have developed resistance to this compound and its use was consequently restricted (Georghiou and Lagunes-Tejeda, 1991).

3.2.6.1.2 Organo-phosphoric acid esters (OPAEs)

Organo-phosphoric acid esters are phosphates, phosphonates, phosphothionates, phosphothiolates and phosphodithiolates. They inhibit the enzyme cholinesterase, which splits acetylcholine into acetate and choline. These compounds affect the nervous system of arthropods

and mammals. They are metabolized quickly and have a short residual effect with the exception of Fenthion. Consequently, they have a lesser tendency to develop resistance to ticks, in comparison to CHCs (Seifert, 1996).

Some examples in this group include chlorphenviphos, chlorpyriphos, coumaphos, diazinon, dioxathion, dicrotophos and malathion. Resistance by ticks to OPAEs has been reported in Kenya against chlorphenviphos and dioxathion by *Rhipicephalus* and *Hyalomma* species (Georghiou and Lagunes-Tejeda, 1991). However, chlorphenviphos is still in use in Kenya and is marketed as Steladone[®] by Ultravetis, East Africa.

3.2.6.1.3 Carbamates

Carbamates are esters from carbaminic acid consisting of three basic groups, namely: dimethylcarbamates, monomethylcarbamates from phenols and monomethylcarbamates from oximes. Biologically, carbamates also inhibit cholinesterase. They bind with the active centre of cholinesterase and block the hydrolysis of acetylcholine.

In this group, Promacyl was initially used as an acaricide in Australia against *Boophilus*. However, the compound is excreted in milk and therefore not allowed in lactating animals. Consequently, its production has been discontinued (Seifert, 1996).

3.2.6.1.4 Cyclic amidins

Cyclic amidins are compounds commonly known as detaching agents. They work in three pathways: 1) interfere with the metabolism of ticks by reducing the glycogen and glucose levels and hence blocking the development of the ova; 2) interfere with the respiratory enzyme system of the arthropods by blocking the NADH-fumarat-reductase; 3) cause a neuromuscular blockage in the ticks. Ticks exposed to amidins drop off the animal a few days later (Seifert, 1996).

Among the three common amidin-compounds (Amitraz, Chlordimeform and Cymiazole), Amitraz (Taktic, Triatix, Triatox) is the most widely used. It is used to control one-, two- and three-host ticks as a 0.25% dip or spray preparation. The compound is unstable in dips. However, stability can be improved by addition of lime to adjust the pH to 12. A long period of use of amidins has resulted in development of resistance in some ticks as was the case in Australia. However, Amitraz is still one of the most widely used acaricides in Africa (Seifert, 1996).

3.2.6.1.5 Pyrethroids

Pyrethroids are etheric oils and are synthetic esters of Chrysanthemum acid or its derivatives. The most important pyrethrins are Pyrethrin I and II and Cinerin I and II. Once ticks come into contact with pyrethroids, the ion-exchange at the axon of nerves is blocked causing an interruption of nervous transmission. This is an irreversible action and leads to a quick knock-down effect. Even with a low dose of a pyrethroid, a tick's oviposition is inhibited (Stendel and Hamel, 1990). One advantage of the pyrethroids is their potency on ticks that are resistant to OPAEs. In addition, pyrethroids have a low toxicity to vertebrate animals. Consideration should however be taken to avoid contamination of water masses due to the high toxicity of these compounds to crustaceans, fish and reptiles.

Various active molecules have been derived from pyrethrins and these include: cyfluthrin, cypermethrin, deltamethrin, flumethrin, permethrin and cyhalothrin. Among these, cypermethrin, permethrin, deltamethrin and flumethrin have been widely used as acaricides either as sprays or as pour-ons. The simultaneous control of tsetse flies and ticks in tsetse infested areas of Africa, using pyrethroids, leads to maximum benefits (Meyer, 1990). However, care should be taken to avoid development of resistance in these compounds as has been the case with other acaricides.

3.2.6.2 Methods of application

The methods used for the application of acaricides include plunge dipping (currently being phased out), hand spraying and hand dressing. The principal objective of tick control is to kill the infesting ticks in order to break the life cycle and to ensure total coverage of all predilection sites of the various tick species. However, intensive tick control using acaricides has many inherent

problems including high costs (Kariuki, 1990), increased environmental pollution (de Castro, 1997), residues in meat, milk and other products and eventual development of resistance.

3.2.6.3 Other methods of control

The other methods of control of ticks and TBDs that have been practiced include manual removal, pasture spelling, rotational burning of pastures, using tick repelling grasses (Mwase *et al*., 1990), use of tick vaccines (Willadsen *et al*., 1995) and restriction of livestock movement. Confinement of animals in zero-grazing management systems also reduces the levels of tick challenge (Gitau, 1998).

3.2.6.4 Integrated control of ticks and TBDs

Total eradication of ticks in Africa is likely to be unachievable (Young *et al*., 1988). While the various tick control methods exhibit varying degrees of efficacy, it is speculated that adoption of integrated control strategies will lead to efficient and sustainable solutions to the ticks and TBDs problem in Africa (Tatchell, 1987; de Castro, 1997). The concepts of integrated tick control emphasize the importance of animal management, tick ecology and epizootiology and economic assessments. Specifically, integrated ticks and TBD control programmes must include:

- ➢ Quantification of direct and indirect economic impact of tick infestations.
- ➢ Economic assessments of control programmes against enterprise outputs.
- ➢ Appropriate legislation.
- ➢ Correct vector and disease control extension messages.
- ➢ Enhancement of endemic stability of TBDs (especially by immunizations).
- ➢ Considerations of innate breed resistance to ticks and TBDs.
- ➢ Varying intensity of acaricide application according to seasonal abundance of tick infestations.
- ➢ Consideration of cattle production systems (e.g. zero-grazing, free grazing and tethering).

Evaluation of the impact of applying integrated control strategies for the control of ticks and TBDs in Africa is minimal. Pioneer work in Zambia (Pegram *et al*., 1991) and Zimbabwe (Pegram *et al*., 1996) showed that integrated tick and TBD control was a feasible option in areas

of high challenge. More recently, Minjauw *et al*. (1999) showed that a combination of strategic tick control and immunisation against ECF was an economically viable option in traditionally managed indigenous herds in Zambia.

3.3   Helminthosis

3.3.1   Nematodes

The class Nematoda consists of parasites that are cylindrical, taper at both ends and covered by a cuticle (Urquhart *et al.,* 1996). There are several species of nematodes of economic importance to cattle in the East African region. The greatest impact is however experienced in calves and young animals. In adults, inapparent infections are common but even when production losses are incurred, little association is made with helminth infections (Kaufmann, 1996).

The important species of nematodes infecting cattle can be classified as follows (Bowman, 1999):
Strongyloides papillosus (intestinal threadworm) belongs to the order *Rhabditida* and genera *Strongyloides*. In this order, only *S. papillosus* is important to cattle and infects mainly calves via colostrums. Experimentally, prenatal transmission has also been reported. Although this parasite is almost universally prevalent in cattle, it rarely causes detectable illness. However, heavily infected animals show respiratory signs assumed to be induced by migratory larvae. Coughing, pneumonia and fever may be followed by secondary infections especially in calves kept in poor conditions.

From the order *Strongylida*, the superfamily *Trichostrongyloidea* represents important nematodes of cattle. *Trichostrongylus axei* and *T. colubriformis* (black scours worms) parasitize the abomasums of cattle and may produce protracted and debilitating watery diarrhea in stressed animals or when they occur in large numbers. *Ostertagia ostertagi* (brown stomach worms) is the other member of *Trichostrongyloidea* important for cattle. It causes chronic abomasitis in young cattle, a disease marked by profuse watery diarrhea, anaemia and hypoproteinaemia manifested clinically as sub-maxillary oedema. *Haemonchus contortus* (barber pole worm; large

stomach worm) is also an important *Trichostrongyloidea* in cattle although the severest of clinical signs are manifest mostly in sheep and goats. This nematode leads to severe anaemia and hypoproteinaemia and oedema (bottle jaw), progressive emaciation and death in young animals. The importance of *Cooperia* spp. (cattle bankrupt worms) in cattle depends on the level of burden and nutritional status of the animals. Heavy parasitism leads to production of disease while light infections go unnoticed. *Dictyocaulus viviparus* (cattle lungworm) is another nematode in the superfamily *Trichostrongyloidea.* This nematode is quite important in calves when it occurs in large numbers. Heavy infection leads to partial or complete obstruction of the air passages leading to severe coughing, harsh bronchial sounds, emphysema, pneumonia and death in some cases.

From the order *Strongylida*, superfamily *Strongyloidea*, worms of the species *Oesophagostomum* are the important nematodes of cattle from the subfamily *Oesophagostominae*. These worms are referred to as "nodular worms" because their parasitic larvae tend to become encapsulated by a somewhat excessive reactive inflammation on the part of the previously sensitized host. Acute inflammation may lead to clinical disease characterized by fetid diarrhea that may be fatal.

Toxocara vitulorum (large cattle roundworm) is a nematode of cattle in the order *Ascaridida*. Larvae in adult cows migrate to several tissues including the uterus and mammary glands. *Toxocara* infections are more important in calves where transmission is usually via the transmammary route and presumably also through the transplacental route. However, infected calves eventually rid-off the infection with age, due to development of resistance (Urquhart *et al.,* 1996; Fall *et al.,* 1999).

3.3.1.1   Life cycle of nematodes (Urquhart *et al.,* 1996)

During the developmental cycle of nematodes, the parasite undergoes four moults that result in five successive larval stages; L1, L2, L3, L4 and L5 (immature adult). Nematodes exhibit either a direct or indirect life cycle.

In the direct life cycle, eggs are laid and hatch on the ground to give rise to L1 larvae. These free living larvae undergo two moults and infection is by ingestion of the infective L3 (e.g. *Trichostrongylus, Haemonchus and Cooperia*).

During the indirect life cycle, adult worms lay eggs that are shed on the ground with faeces. Intermediate hosts are then infected by taking up L1 or eggs containing L1. The first two moults usually take place in the intermediate host and infection of the host is by ingestion of the intermediate host or by inoculation of the L3 during feeding (e.g. *Protostrongylus* and *Muellerius*). After infection of the definitive host in both the direct or indirect cycles, two further moults take place to produce an L5 which is the immature adult. Following copulation, another life cycle is initiated.

3.3.2 Cestodes

Parasites in this class have a tapering body with no alimentary canal. The body is segmented and each segment contains one or sometimes two sets of male and female reproductive organs. The adult cestode consists of a head or scolex and a chain of segments. The chain is known as a strobila and each segment as a proglottid. Two orders of class Cestoda are import in veterinary practice: Pseudophyllidea and Cyclophyllidea. The order Pseudophyllidea is represented by two genera of importance: *Diphyllobothrium* and *Spirometra*. Cyclophyllidea contains five families of veterinary importance: Taeniidae, Mesocestoididae, Anoplocephalidae, Dipylidiidae and Hymenolepididae (Bowman, 1999).

Cestodes living in the gastrointestinal tract of cattle are rarely of economic importance. However, infection of ruminants with *Moniezia expansa* (sheep) and *M. benedeni* (mainly cattle) is a common occurrence. Heavy infection in calves can result to reduced weight gains and obstruction of the intestines (Kaufmann, 1996).

Of importance is the occurrence of cysticerci (larval stages; metacestodes) in the muscles of cattle. *Cysticercus bovis* (beef measles), the metacestodes of *Taenia saginata* are found in the striated and non-striated muscles of cattle. The adult tapeworm (*Taenia saginata*) is found in the

small intestines of man. Cysticercosis in cattle is usually inapparent, except when vital organs are involved (heart, diaphragm). However, losses are incurred when carcasses containing beef measles are condemned at slaughter, because of the potential of transmission of the larvae to man in inadequately cooked meat. Occurrence of hydatid cysts of *Echinococcus granulosus* also leads to the condemnation of cattle offals (liver and lungs) at slaughter. Although the presence of the hydatid cysts in these animals rarely causes any clinical signs in cattle, it is of public health importance due to the potential of continuation of the cycle in dogs which may be followed by clinical hydatidosis in man (Urquhart *et al.,* 1996).

3.3.2.1 Life cycle of cestodes (Bowman, 1999)

Cestodes of the order Cyclophyllidea have a typical indirect life cycle with one intermediate host. With few exceptions, the adult worm is found in the small intestines of the definitive host. Gravid taeniid segments are shed and exit from the definitive host. The segments crawl about on the pelage of the host or surface of faecal mass, emptying themselves of their eggs in the process. If ingested by a suitable vertebrate intermediate host, the eggs hatch and the hexacanth embryo grows, cavitates, and differentiates to form the second-stage larvae, which is infective to the definitive host. The fully developed second-stage larva of the family *Taeniidae* consists of a fluid-filled bladder with one or more scolices (often called a bladder worm) and is surrounded by a connective tissue capsule formed by the vertebrate intermediate host. When a metacestode is ingested by a suitable definitive host, the bladder is digested away, the scolex embeds itself in the mucosa of the small intestines, and the neck begins to bud off segments to form the strobila.

There are four basic kinds of taeniid second-stage larvae (metacestodes) important in livestock: the cysticercus (e.g. *Cysticercus bovis*) which is a fluid-filled cyst with an attached single invaginated scolex called a protoscolex. Coenurus is a fluid-filled cyst with numerous attached invaginated scolices (e.g. *Coenurus cerebralis*). Hydatid is a large fluid-filled cyst lined with germinal epithelium which produces invaginated scolices that lie free or in bunches, surrounded by germinal epithelium. The contents of the cyst other than the fluid, i.e. scolices and brood capsules are referred to as 'hydatid sand'. If the wall of the cyst raptures exogenously, daughter

cysts that are complete with cuticle and germinal layer are formed endogenously (metacestodes of *Echinococcus granulosus* and *E. multilocularis*).

3.3.3 Trematodes

The class Trematoda contains three orders: Monogenea, Aspidogastrea, and Digenea. Monogeneans and most Aspidogastreans undergo direct development and are parasites of aquatic and amphibious animals. The trematodes of veterinary importance are the digenetic trematodes (Bowman, 1999).

Fasciola gigantica and *F. hepatica* are the most important flukes infecting cattle. The clinical signs exhibited depend on the number of metacercariae ingested. Chronic fasciolosis is the most common disease feature and is associated with hepatic fibrosis and hyperplastic cholangitis. Anaemia, hypoproteinaemia, oedema (bottle jaw), digestive disturbances and cachexia develop gradually. Acute fasciolosis is not common but when it occurs, it is associated with hepatitis caused by the simultaneous migration of large numbers of immature flukes and can result in sudden death of animals under stress, especially in sheep (Kaufmann, 1996). Other losses due to fasciolosis are as a result of condemnation of livers at slaughter.

3.3.3.1 Life cycle of trematodes (Bowman, 1999)

The adult worms of *Fasciola* spp. live in the bile ducts of ruminant and other mammalian hosts. Their eggs are initially carried to the lumen of the bowel with the bile and then are shed with faeces. When deposited, each of these eggs consists of a fertilized ovum and a cluster of vitelline cells enclosed in an operculated capsule. Only if the egg falls into water will a ciliated larva called a miracidium develop inside it. The miracidium is completely covered with cilia and has a conical papilla at its anterior end for boring into the snail (intermediate host). It also has a pair of eye spots, a brain, a rudimentary excretory system, and a cluster of germinal cells, the progenitors of the next generation of larvae.

The miracidium, which is fully developed and ready to hatch after two to four weeks, escapes from the egg capsule by pushing aside the operculum, and swims about in search of a suitable

species of snail (e.g. *Lymnaea truncatula*). If it fails to find such a snail in 24 hours, the miracidium exhausts its energy reserves and dies. If it locates a host, it bores into the snail's body, loses its ciliated covering, migrates to the gonads or digestive gland and forms a sporocyst. Each germinal cell becomes a germinal ball through growth and repeated divisions and each germinal ball becomes a redia. The rediae grow until they burst the sporocyst wall and are thus liberated into the tissue of the snail. Each germinal ball of the second generation rediae develops a third kind of larva, the cercaria. The cercaria is a tadpole-like larva with a discoidal body and a long tail for swimming. When fully developed in a month or two, the cercaria leaves the redia through a birth pore and makes its way out through the snail's tissues and into the surrounding water. After a brief swim, the cercaria migrates a short distance above the water level on the surface of some plant and encysts, losing its tail in the process to become a metacercaria, the infective stage.

When ingested, the metacercarial cyst is digested in the host's small intestines. The young fluke, now called a marita, penetrates the wall of the intestines and crosses the peritoneal space to the liver, which it penetrates. After several weeks of boring about in the hepatic parenchyma, the maritas enter the bile ducts, mature into adult flukes, and begin laying eggs at about a month and a half after infection. The complete life cycle of *Fasciola* spp. thus encompasses three or four months under favourable conditions. Therefore, exposure to this parasite and patent infection tend to be rather more widely separated in time than is the case of most ruminant parasitism.

3.3.4   Epidemiology of helminthosis

Helminths have a world-wide distribution and often all animals in a herd are exposed to these parasites. Work carried out by Kaufmann and Pfister (1990) in the Gambia, West Africa, indicated that almost all village cattle carried gastrointestinal nematodes and the most prevalent species were *Haemonchus contortus, Oesophagostomum radiatum* and *Bunostomum phlebotomum*. One to four-year old cattle represent the most susceptible group of animals (Kaufmann and Pfister, 1990; Zinsstag *et al.,* 1992).

According to the findings of Chiejina *et al.* (1989), Kaufmann and Pfister (1990) and Ankers *et al.* (1992), pastures in the sub-Sahelian areas are free of infective trichostrongylid larvae and re-infections of cattle and sheep are thus negligible during the dry season. Consequently, during the dry season, trichostrongyles survive in their hosts only as hypometabolic adults or arrested larvae. It would therefore seem logical that, in isolated areas, trichostrongyle populations could be significantly reduced or even eliminated by treating the animals with a single dose of a larvicidal anthelmintic during the dry season. Findings by Zinsstag *et al.* (1994) in The Gambia indicated that there was a worm population build-up, enhanced by favourable climatic conditions during the rainy season; eventually, the egg excretion by treated animals reaching levels of untreated animals. The authors concluded that a single treatment during the dry season can not therefore eliminate nematode population at the village level. However, an early dry season treatment with a larvicidal anthelmintic can be used as part of a metaphylactic control strategy against gastrointestinal nematodes (Zinsstag *et al.,* 1994).

3.3.5 Interaction of helminth- and trypanosome-infection

Although single parasitic infections in a host are not uncommon in nature, mixed infections with various species or with several different types of parasites is the rule (Sharma *et al.,* 2000). In mixed infections, the presence of a pathogen may enhance the effect of the other in the host. This is more likely to occur when the first infection has an immunosuppressive effect on the host, thus making the latter more vulnerable to other parasites to which it would otherwise be resistant. This interaction between two or more parasites is an inevitable situation which may lead to significant physiological and biochemical changes in tissues and fluids, which cannot be attributed to either of these parasites individually (Sharma *et al.,* 2000).

In tsetse-infested areas, anaemia is predominantly associated with trypanosomosis. However, there are other equally potent and highly prevalent anaemia causing pathogens of ruminants. One of these is gastrointestinal helminth infections (Chiejina, 1986; Kaufmann and Pfister, 1990). Weaned calves infected with helminths are usually weak with rough coats and accompanied by severe anaemia, emaciation and hypoproteinaemia (Kaufmann *et al.,* 1989). The findings of Kaufmann *et al.* (1992) in The Gambia when investigating the interaction of *T. congolense* and *Haemonchus contortus* infection in N'Dama cattle were: a remarkably reduced prepatent period

of *H. contortus* infection from the usual 3 weeks to 2 weeks and increased pathogenecity (as judged by faecal egg counts, PCV and albumin values, body weight changes and mortality rates) of this infection when superimposed on a patent *T. congolense* infection. Conversely, a *T. congolense* infection superimposed on a patent *H. contortus* infection drastically aggravated the disease process caused by *H. contortus*. The authors observed increased output of faecal eggs, a reduced prepatent period, rapid decreasing PCV and albumin levels, and also drastically increasing weight loss and mortality in cases where animals were initially infected with the trypanosome. This is a confirmation of observations by Griffin *et al.* (1981) who reported that *T. congolense* suppressed normal innate resistance of goats to *H. contortus* infection and the fact that immunosuppression and chronic anaemia are features of bovine trypanosomosis caused by *T. congolense* (Murray and Dexter, 1988). In addition, Catley *et al.* (2001) reported that it was likely that pathology due to *Fasciola*, Haemonchus species and *Schistosoma* would be exacerbated in cattle that were also infected with *T. congolense*.

3.3.6 Economic importance

The effects of gastrointestinal helminths on cattle productivity are estimated to be £45 million annually for the United Kingdom (Bain and Urquhart, 1986). In Africa, such estimates are not available, but the losses are expected to be even higher due to poor nutrition, which substantially enhances the pathogenic effect of parasites (Vassiliades, 1978; Fabiyi, 1987; Holmes, 1991). For instance, it is estimated that fasciolosis alone in Kenya leads to losses estimated at £7 million annually, through a combination of poor productivity, death of stock, condemnation of infected livers and reduction in carcass quality (Harrison, 1996).

Results of on-station and on-farm trials on improved productivity of Gambian N'Dama cattle through strategic control of helminthosis showed that 2- to 3-year old N'Dama increased their annual live-weight gains by 4% and 33% when treated, once and twice respectively, with fenbendazole (Panacur®, Hoechst, Germany) during the rainy season (Zinsstag *et al.,* 1992). One annual fenbendazole treatment had no significant effect on live weights, whereas two annual treatments significantly increased live weights of the age group 12-24 and 24-36 months by 9.4%, and 17.5% respectively (Zinsstag *et al.,* 1997a).

3.3.7 Diagnosis

In the absence of laboratories, clinical signs are relied upon when diagnosing helminthosis in animals. In general, heavy helminth infection in animals is characterized by anaemia, diarrhoea, soiling of the hind quarters, submandibular oedema, ascites, lethargy, inappetance, staring hair coats and progressive weight loss in chronic cases. In case of heavy infection by tapeworms, pieces of proglottids may be observed on the faecal pat. However, the other signs are not pathognomonic for helminthosis.

Quantitative methods have been developed for the diagnosis of helminthosis. Approximately 5g of faeces should be collected from the rectum using plastic gloves and examined fresh. Since eggs embryonate rapidly, the faeces should be stored in a refrigerator unless the examination is carried out within a day of collection (Urquhart *et al.,* 1996). These coprological methods involve concentration of faecal worm eggs for detection and quantification and they include: the flotation technique and the sedimentation technique (Thienpont *et al.,* 1990) and the McMaster method (Ministry of Agriculture, Fisheries and Food, U.K., 1986).

3.3.8 Control of helminthosis

3.3.8.1 Anthelmintics

Various anthelmintics are available for use in the treatment and prophylaxis of helminthosis. A brief description is given for the anthelmintics used against nematodes (Table 1), cestodes and fasciolicides used against *Fasciola* infection (Table 2) in cattle.

Table 1: The spectrum and activity of anthelmintics used against important nematodes of cattle

Compound	Dose (mg/kg bw)	Appl-ication	Ostert-agia	Haemo-nchus	Trichost-rongylus	Coop-eria	Strongy-loides	Toxocara	Oesophago-stomum	Dictyo-caulus
Benzimidazole										
Albendazole	7.5	Po	+++	+++	+++	+++	-		+++	+++
Febantel	7.5	Po	+++	+++	+++	+++	++	++	+++	+++
Fenbendazole	7.5	Po	+++	+++	+++	+++	+++	+++	+++	+++
Netobimin	7.5	Po	+++	+++	+++	+++		+++	+++	+++
Oxfendazole	4.5	Po	+++	+++	+++	+++	+		+++	+++
Ozibendazole	10.0	Po	++(+)	+++		+++				
Macrocyclic Lactones										
Abamectin	0.2	Sc	+++	+++	+++	++(+)	+++		+++	+++
Doramectin	0.2	Sc	+++	+++	+++	++(+)	+++		+++	+++
	0.5	pour-on	+++	+++	+++	++			+++	+++
Eprinomectin	0.5	pour-on	+++	+++	+++	++(+)	+++		+++	+++
Ivermectin	0.2	Sc	+++	+++	+++	+++	+++		+++	+++
	0.5	pour-on	+++	+++	+++	++			+++	+++
Moxidectin	0.2	Sc	+++	+++	+++	++(+)	+++		+++	+++
	0.5	pour-on	+++	+++	+++	++(+)	+++		+++	+++
Other substances										
Levamisole	7.5	Po	+++	+++	+++	+++	+++	+++	+++	++
	0.5	Im	++	+++	+++	+++	+	+++	++	++
	10.0	pour-on								
Pyrantel-tartrate	12.5	Po	++(+)	+++	+++	++(+)	+	++	++	-

+++: Highly potent; ++: potent; +: Partially potent. -: No sufficient effect. po: *Per os*; sc: Subcutaneous; im: Intramuscular
Source: Rommel *et al.* (2000)

37

The anthelmintics used against economically relevant cestodes for cattle (*Moniezia* spp.) are usually applied at higher doses than those required for nematode infections. These compounds and their dosage rates are as follows: albendazole (10 mg/kg bw, po), fenbendazole (15 mg/kg bw, po), mebendazole (10-20 mg/kg bw, po), oxfendazole (5 mg/kg bw, po) and the drug of choice, praziquantel (3.5 mg/kg bw, po) (Rommel *et al.,* 2000).

Table 2. The spectrum of activity of fasciolicides used against *Fasciola* spp. in cattle

Compound	Dose (mg/kg bw)	Application	Young immature	Old immature	Adults
Albendazole	10.0	po			++
Netobimin	20.0	po			++
Triclabendazole	12.0	po	++	++(+)	+++
Closantel	10.0	po			+++
Clorsulon plus	2.0	sc			++

+++: Highly potent; ++: potent; +: Partially potent: po: *Per os*; sc: Subcutaneous.

Source: Rommel *et al.* (2000).

3.3.8.2 Control of nematodes

Control of nematodes can be achieved through various methods. Prophylaxis against nematodes using slow or pulse release compounds has been in use for quite some time (Urquhart *et al.,* 1996). Use of prophylaxis has the advantage that animals can be grazed throughout the year on the same pastures. However, there is evidence to suggest that protected animals become more susceptible to infection in the following season and there is risk of establishment of drug resistance (KARI/DFID, 1999). The report indicates that at the onset of rains in subtropical Africa, initial treatment of all animals in a herd followed by another treatment 4-6 weeks later into the rain season will significantly reduce the worm-load and consequent pasture contamination. In addition, due to the presence of *Toxocara,* it is important to deworm pregnant cows before delivery (Urquhart *et al.,* 1996).

Rotational grazing of cattle, sheep, and goats is important but applicable only to farms with a high proportion of land suitable for cropping or grass conservation but less so for marginal areas and smallholder farmers. The drawback of this system is that it imposes a rigorous and inflexible regimen on the use of land which the farmer may find impractical (Semenye *et al.,* 1992).

Rotational grazing of adult and young stock is a system in which the susceptible younger animals are grazed ahead of the more resistant adults (Urquhart *et al.,* 1996). The success of this system depends on having sufficient fenced paddocks available to prevent over-grazing and the adults must have a good acquired immunity (Simenye *et al.,* 1992). These authors also observed that the method is costly in terms of fencing and requires careful supervision and hence is impractical for smallholder farmers.

3.3.8.3   Control of cestodes and metacestodes

Control of parasites within this genus depends more on high standards of sanitation for both man and animals. General practice of meat inspection and cooking meat thoroughly (thermal death of cysticercus is 57º C) is required. The use of human excreta as manure should be restricted to cultivated fields and not where animals graze. In the case of echinococcosis (hydatidosis), regular treatment of dogs to eliminate the adult worm is important. Denying dogs access to abattoirs and proper disposal of infected offals from sheep and cattle is advised (Kaufmann, 1996).

3.3.8.4   Control of fasciolosis

Control of *Fasciola* spp. can be undertaken in two ways; by reducing the populations of the intermediate hosts (snails) or by use of fasciolicides. Theoretically, aquatic snails can be controlled by draining swamps or by treating snail-infested waters with molluscicides. However, the continued existence of flukes where they have always been indicates that snail control measures are impracticable in many cases. Areas connected by streams are not amenable to snail control measures using molluscicides due to environmental pollution (Mukhebi *et al.,* 1985; Bowman, 1999). That notwithstanding, when the snail habitats are not expansive, the areas could be fenced off and treated annually with molluscicides (Urquhart *et al.,* 1996).