PREVALENCE, INTENSITY AND RISK FACTORS OF HELMINTHS AND HAEMOPARASITES INFECTIONS IN PIGS IN HOMABAY DISTRICT, KENYA

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DECLARATION

This thesis is my original work and has not been presented for the award of a degree in any other University

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DEDICATION

This thesis is dedicated to the memory of my late father Nicholas Mukanga, my mother Imelda Achieng', my sisters and brothers.

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LIST OF ABBREVIATIONS

AAT	ANIMAL AFRICAN TRYPANOSOMOSIS
EPG	EGG PER GRAM OF FAECES
FAO	FOOD AND AGRICULTURE ORGANIZATION
FTC	FARMERS TRAINING CENTRE
HAT	HUMAN AFRICAN TRYPANOSOMOSIS
KNBS	KENYA NATIONAL BUREAU OF STATISTICS
MOLD	MINISTRY OF LIVESTOCK DEVELOPMENT AND MARKETING
PATTEC	PAN AFRICAN TSETSE ERADICATION AND CONTROL
PCV	PACKED CELL VOLUME
PRRS	PORCINE REPRODUCTIVE AND RESPIRATORY SYNDROME
RPM	REVOLUTION PER MINUTE

ABSTRACT

A cross-sectional study was conducted to determine the prevalence, intensity and risk factors associated with the transmission of helminths and haemoparasites of pigs in Homabay District, Kenya. A questionnaire survey was carried out on 297 pig farmers to collect information on pig production and management practices, feeding, importance of worm infestation and aspects of parasite control. The questionnaire survey revealed that pigs were mostly kept for income generation (83.2%) with the majority of the farmers keeping non-descript type of pigs (98%). Tethering was the main system of confining pigs and was mostly done during crop planting (98.6%), growing (99.3%) and harvesting (99%) seasons. The most common feed given to pigs was a mixture of kitchen left overs and pastures (40.7%) with none of the farmers supplementing their pigs with commercial feeds. Deworming was done by 20.5% of the farmers with only 3.7% deworming their animals after every 3 months.

The prevalence and intensity of helminths was determined by the modified McMaster technique and post-mortem examinations. Out of 372 animals examined, three hundred and eight pigs (83%) were found to excrete nematode eggs. The nematode eggs encountered were those of Strongyles (75%), *Strongyloides* spp (26.6%), *Trichuris* spp (7.8%), *Ascaris* spp (5.4%) and *Metastrongylus* spp (0.3%). Coproculture of Strongyle-type nematode egg positive faecal samples revealed the presence of *Oesophagostomum* spp (74%), *Hyostrongylus rubidus* (22%) and *Trichostrongylus* spp (4%).

Post-mortem examination of 30 pigs revealed that 86.7% of the animals were infected with various helminthes which included; *Hyostrongylus rubidus, Physocephalus sexalatus,*

Trichostrongylus axei, *Ascaris suum*, *Oesophagostomun dentatum*, *Trichuris suis* and *Metastrongylus pudendodectus*. The highest prevalence with helminth infections was recorded in finishers (88%) and the lowest prevalence recorded in adults (79%). The highest mean epg with helminth infections was recorded in adults (1,735) while the lowest mean epg was recorded in piglets (526). Age had significant influence on the intensity of Strongyles ($p = 0.04$) with growers and finishers recording higher levels of infection than adults. Sex had significant effect on the prevalence of Strongyles ($p = 0.028$) and *Ascaris suum* ($p = 0.012$), with females recording higher levels of infection than males. Housing, feed type and frequency of deworming were not significantly ($p > 0.05$) associated with the prevalence of helminths.

Division of origin of pigs had significant influence on the prevalence of infection with *Ascaris suum* ($p = 0.000$) and Strongyles ($p = 0.000$) with the mean epgs for Riana, Ndhiwa and Rangwe divisions being significantly higher ($p <0.05$) than those of Pala Division. The highest prevalence of infections with helminths was recorded in Riana Division (91%) and the lowest prevalence (50%) recorded in Asego Division. Similarly, the highest mean epg of infection with helminths was recorded in pigs from Riana Division (1,109) while pigs from Asego Division recorded the lowest mean epg (100).

The prevalence of haemoparasites was determined by microscopic examination of Giemsa stained blood smears. Out of the 374 animals examined, 125 animals (33.4%) were positive for *Mycoplasma (Eperythrozoon)* spp with the most predominant species being *Mycoplasma suis* (54.4%) while *Eperythrozoon parvum* had a prevalence of 45.6%. The overall mean PCV was 41.5% with significantly higher mean PCVs being recorded in growers and finishers than in piglets (p = 0.039). Haemopoarasites infections did not have an effect on the mean PCV of the animals examined.

In conclusion, helminths were highly prevalent in pigs in the study area with low to moderate levels of infections. Pigs in the study area were infected by a wide variety of nematodes. The prevalence and levels of infection with helminths in the district was associated with age, sex and division of origin of pigs. Haemoparasites identified in the study area included *Mycoplasma suis* and *Eperythrozoon parvum.* There is need for control of helminths in the study area and control measures should integrate better nutrition with anthelmintic treatment.

CHAPTER ONE: INTRODUCTION

The livestock sector is growing more dynamically than any other agricultural sector with the growth in meat consumption in the developing world being greater than that of the developed countries (Lekule and Kyvsgaard, 2003). According to Delgado *et al.* (1999), the total meat consumption in the developing world increased by 70% between 1971 and 1995, while the consumption increased by 26% in the developed world. The most popular meat consumed in the world today is pork, with 44% of the world meat protein consumption being derived from pork and pork products (Lekule and Kyvsgaard, 2003).

In Kenya, pig farming plays an important role in the livelihood of many families (Mutua *et al.*, 2010). There is a growing popularity of local pig farming under free range systems popular in Nyanza and Western provinces of the country. The rising popularity of local pig farming may be explained by the fact that keeping pigs under the free range system requires minimum amount of input and the financial risk involved is small. Also, the local demand for pork is high and most of the pork produced is consumed locally (Mutua *et al.*, 2010). A part from African swine fever, helminthosis in domestic pigs has been reported to be the most common and important disease in tropical and subtropical countries (Permin *et al.*, 1999; Ng'ang'a *et al.*, 2008). These infections result in considerable economic losses due to reduced weight gains, decreased litter sizes, poor growth rates, visceral organ condemnation at slaughter and deaths (Stewart and Hale, 1988).

Several surveys have been conducted to determine the prevalence and intensity of helminths in domestic pigs in different countries (Roepstorff and Jorsal, 1990; Ajayi *et al.*, 1988; Yadav and Tandon, 1989; Esrony *et al.*, 1997; Permin *et al.*, 1999; Boes *et al.*, 2000; Nsoso *et al.*, 2000; Tamboura *et al.*, 2006; Nissen *et al.*, 2011). Studies have shown that poor hygienic conditions in most traditional systems allow a higher prevalence, burden and rate of helminths transmission while infection levels in the highly intensive production system are usually low and involve only a few species (Nansen and Roepstorff, 1999; Kagira *et al.*, 2002; Ng'ang'a *et al.*, 2008). The higher prevalence in the traditional system is associated with factors such as continuous exposure to infective stages of parasites in the external environment, scavenging behaviour of pigs and the presence of intermediate hosts and parasite vectors in the environment (Roepstorff and Nansen, 1994; Kagira, 2010).

Previous surveys on helminths infections in Kenyan pigs have shown the presence of *Ascaris suum, Strongyloides ransomi, Trichuris suis, Oesophagostomum dentatum, O. quadrispinalatum, Trichostrongylus colubriformis, T. axei, Hyostrongylus rubidus, Ascarops strongylina, Physocephalus sexalatus, Globocephalus urosubulatus* and *Metastrongylus* spp (Lagat,1999; Kagira *et al.*, 2002; Wabacha *et al.*, 2004; Ng'ang'a *et al.*, 2008; Kagira, 2010) and *Cysticercus cellulose* (Githigia *et al.*,2005; Mutua *et al.*,2007; Kagira *et al.*, 2010a)). Knowledge on the prevalence and intensity of helminths infections in pigs reared under the free range system is limited to the studies by Githigia *et al.* (2005), Mutua *et al.* (2007) and Kagira (2010). Githigia *et al.* (2005) studied the prevalence of *Cysticerci cellulosae* and the risk factors by lingual examination of 107 pigs in Funyula Division of Busia District while Mutua *et al.* (2007)

conducted a study to estimate the prevalence of palpable lingual cysts from 316 randomly selected small scale pig farmers in Western Kenya as possible indicator of cysticercosis. The study by Kagira (2010) was done to determine the prevalence and intensity of gastrointestinal and ectoparasites and *C. cellulosae* at both slaughter slab (37 pigs slaughtered) and on farm (135 farms, 306 pigs) levels in Busia District. No such study has previously been carried out in Homabay District where outdoor rearing of pigs is common. Such knowledge of the spectra of parasites present and their epidemiology is important in the formulation of effective parasite control measures.

Unlike ruminants whose blood parasites have been investigated, information on the status of blood parasites of pigs in Kenya is scanty. Furthermore, domestic pigs have been incriminated to play a role in the epidemiology of both human and animal trypanosomes where they have been shown to harbour *Trypanosoma brucei gambiense* in West Africa (Gibson *et al.*, 1978; Mehlitz *et al.*, 1982) and may be potential reservoirs of *Trypanosoma brucei rhodesiense* in East Africa (Ng'ayo *et al.*, 2005; Simo *et al.*, 2006). Only few data are available on the role played by the pig as reservoir hosts of *T. b. rhodesiense* in Kenya. No previous studies have been carried out to determine the haemoparasites occurring in outdoor reared pigs in Homabay District.

Infections with *Mycoplasma suis* is a common problem in countries where porcine reproduction and respiratory syndrome (PRRS) is present. If present, the most noticeable sign is yellow to white neonatal piglets. Sows can be affected by developing anaemia which can result in abortion and still births (Thacker, 2006).

1.1 Objectives

1.1.1 Overall objective

The overall objective of the study was to investigate the prevalence, intensity and risk factors of helminths and haemoparasites infection in pigs in Homabay, District, Kenya.

1.1.2 Specific objectives

1) To determine the prevalence, spectrum and intensity of helminths and haemoparasites of pigs in Homabay District. Kenya
2) To determine the potential risk factors associated with the transmission of helminths and haemoparasites of pigs in Homabay District

1.2 Justification of the study

Helminthosis and haemoparasite infections are some of the commonest and most important diseases of pigs in the tropics and subtropics. These infections are an important constraint to pig production which is emerging as an important livestock enterprise in Kenya as it requires less acreage and has a high potential for economic gain. The control of these infections is therefore often necessary. Effective parasite control measures are those based on a thorough knowledge of the spectra of parasites present and their epidemiology, which is lacking for small holder pig farms in Homabay District. Certain helminths that infect pigs are zoonotic and different species of the same parasite genus occurring in communities inhabited by both humans and pigs create the possibility of cross infection. The importance of parasitic infections varies greatly with time and between geographical locations and depending on the prevailing climatic conditions. There is currently very little information on the burden of helminthosis and haemoparasitic infections in pigs kept under the free range system in Kenya. Also, specific data on the most important risk factors under this type of production system are sparse.

CHAPTER TWO: LITERATURE REVIEW

2.1 Pig population and production in Kenya

In Kenya, the pig population is estimated at 334,689 (KNBS, 2009b) of which, 80% are reared under commercial enterprises mainly in Central, Rift Valley and Nairobi provinces (Ng'ang'a *et al.*, 2008). The remainder 66,937 is reared under small scale enterprises mostly with poor management practices, poor housing, and suboptimal feeding and without standard helmith control programmes (Githigia *et al.*, 2005; Ng'ang'a *et al.*, 2008). The small scale enterprises comprise the free range systems popular in Nyanza and Western provinces of Kenya.

2.2 Helminths of pigs

2.2.1 Nematodes of pigs

Nematode parasites constitute the most important group of the parasites of swine. The adult nematodes live in the intestines, feeding on the gut lining and ingesting particulate and liquid ingesta thus limiting nutrient uptake by the pigs. The damage caused by adult gastrointestinal nematodes includes haemorrhagic gastroenteritis and anaemia. Larval migration through tissues of the pigs results in the spread of infectious organisms from the gut as well as extensive tissue damage thus compromising organ function (Marufu *et al.*, 2008).

2.2.1.1 *Ascaris suum* (The large roundworm of the pig)

A. suum is a large white worm, 15-40cm in length found in the small intestines. It has a world wide distribution and is widespread throughout the tropics. Morphologically, *Ascaris suum* is identical to the species in human, *Ascaris lumbricoides* but they differ in their physiological requirements. Estimates of the daily *Ascaris suum* female egg production generally are in the range of 200,000 eggs. The eggs have a thick shell which is considerably resistant to environmental factors (Roepstorff and Murell, 1997). Embryonation and larval development are dependent on temperature (Nansen and Roepstorff, 1999). The life cycle is direct. The pigs become infected by ingesting embryonated infective eggs along with food and water. The eggs hatch in the small intestines (largely in the duodenum) under the influence of intestinal conditions especially partial pressure of carbon dioxide. The second stage larvae (L_2) penetrate the intestinal wall and are carried to the liver through the blood stream where they develop to L_3 and then to the lungs. The L_2 are reported to exclusively invade and penetrate the walls of the caecum and colon and not the small intestines (Murell *et al.*, 1997). The larvae are arrested in the capillaries and some may pass through and be carried by the circulating blood to other organs. The larvae in the lung capillaries may escape into the alveoli and pass up the trachea to the pharynx. They are then swallowed and pass down the esophagus into the stomach where they grow into adult worms and move into the small intestines.

In heavy infestation there may be vomiting, impaction of the bowel due to obstruction of intestinal lumen by worms, jaundice, anaemia, emaciation and pendulous abdomen. The presence of the larvae in the lungs may cause pneumonia which would be characterized by coughing with some exudation (Stewart and Hoyt, 2006). Growth is stunted and the animal is unthrifty. The young pigs may show neurological signs. At post-mortem examination, apart from the presence of adult worms in the intestines, pathological lesions are found in the liver and the lungs as white spots caused by the granulation tissue due to migration of the larvae. Adult Ascarids in moderate numbers are relatively non pathogenic but compete with their host for food and can therefore markedly reduce feed efficiency. Infections with *Ascaris suum* may stimulate the development of strong protective immunity which depends on the level and length of exposure period. In single infections, it has been shown that the number of established adult worms may be negatively correlated to the size of inoculated dose. In pigs heavily exposed over some months, incoming larvae may be killed by acquired immunity even before they reach the liver (Eriksen *et al.,* 1992). There is limited age resistance, as the larvae easily migrate and establish in parasite naive baconers and sows (Eriksen *et al.*, 1992).

2.2.1.2 *Oesophagostomum* species (Nodular worm of the pig)

The major characteristic of the parasites belonging to the genus *Oesophagostomum* is the cervical groove which is a transverse cuticular depression extending laterally for varying lengths. The eggs are typically thin shelled strongyle eggs which are segmented when laid. Experimentally the worm burden in the caecum and the colon of the infected pigs has been reported to range from 5000-15000 (Roepstorff and Nansen, 1994). The numbers of larvae present in the intestinal mucosa are higher than adults and infections with nodular worms stimulate limited immunity which moderates the intestinal worm burden (Nansen and Roepstorff, 1999). The females have higher fecundity and in heavily infected sows may have epgs of 3000-14000 without showing clinical signs (Nansen and Roepstorff, 1999). Once passed out in the feces, these eggs hatch and develop into infective third stage larvae. The latter can be ingested by the pigs with feed and water. Both the eggs and free living pre- infective larvae are sensitive to desiccation but the infective third stage larvae are resistant and may survive in temperate environment for approximately one year. After ingestion the larvae moult and burrow in the intestinal mucosa anywhere between the pylorus and the rectum. After 5-7 days the larvae moult to fourth stage larvae within the nodule and emerge into the small intestinal lumen where they mature to excrete eggs about 40-50 days after infection. Sows may have a periparturent rise in *Oesophagostomum* egg output which is an important source of infection in newborn piglets. Diarrhea, weight loss and anorexia may be observed in heavy infection. Apart from loss of condition, these may lead to secondary infections which may end up in death, hence considerable economic loss (Stewart and Hoyt, 2006). In severe infections, pseudomembranes may be shed and passed out in feces carrying with them large numbers of worms.

2.2.1.3 *Trichuris suis* (Whipworm of Swine)

The male *Trichuris* has a single spicule and the testis is convoluted throughout its length. The female has a single ovary, uterus and the vulva opens at the junction of the anterior and posterior parts. The larvae develop within the resistant eggs in which they may remain infective for years (Nansen and Roepstorff, 1999). Infections occurs by ingesting infective eggs which are barrel shaped, thick shelled and dark brown in colour with a clear transparent plugs at either pole in feed, water or when rooting in contaminated soil. After being ingested, *Trichuris suis* larvae hatch and enter the intestinal wall and develop further to the second stage larvae and finally proceed to the large intestines for final maturation. The infection induces a strong immunity. Heavy infections may lead to the inflammation of the bowel wall leading to unthriftness, weakness and emaciation (Pitman *et al.*, 2010). During post-mortem, very little damage is usually observed. However in heavy infections, necrosis, oedema and hemorrhage of the mucosa may be seen. Ulcer like lesions may be present in the caecum and colon. There may be nodule formation which are granuloma like and contain the anterior portion of the worms, eggs and phagocytes. The mucosa of the large intestines may be replaced by a necrotic diphtheritic membrane (Stewart and Hoyt, 2006).

2.2.1.4 *Hyostrongylus rubidus* (The red stomach worm of the pig)

H. rubidus is found under heavy catarrhal exudates and produces lesions similar to those of *Ostertagia* species in ruminants except that hyperemia of the mucosa is more common. Inhibition of larvae during periods of adverse environmental conditions occurs. In sows, these inhibited larvae resume their development prior to parturition with the result that the environment of the piglets is contaminated. *H. rubidus* lay typical strongyle eggs which are passed out in faeces. The larvae become infective in pasture and soil in about 7 days. Pigs become infected by ingesting infective larvae (L_3) in feed or water. The L_3 enter pits of gastric glands where they remain for about 2 weeks as they go through 2 moults returning into the lumen as L_5 (Stewart and Hoyt, 2006). Heavy infections cause inflammation and thickening of the stomach wall leading to gastric upsets. Pigs become unthrifty and young ones may die. At post-mortem the hyperemic and ulcerative lesions are observed on the stomach wall (Kauffman, 1996).

2.2.1.5 *Ascarops strongylina* (Thick stomach worms)

A. strongylina are small red colored spirurod nematodes with narrow cuticular wings on the left side (Stewart and Hoyt, 2006). They live in the stomach of a wide range of domestic animals and are of worldwide distribution. They have an indirect life cycle with coprophagus bettles as intermediate hosts. Eggs are oval with thick shells and embryos are well developed before oviposition. The males have unequal spicules. In the females the vulva is anterior to middle of the body (Stewart and Hoyt, 2006). Eggs are passed out in feces where they are consumed by various species of coprophagus beetles. The larvae hatch and develop within a cyst to the third infective larval stage in the body cavity of beetles. Pigs become infected by eating the beetles and larvae develop to maturity in the stomach. Infected pigs do not exhibit any noticeable symptoms. However, at necropsy pseudomembranes may be formed at the pyloric end of the stomach where these worms are found attached to the wall. Red patches may be found around the pinprick openings made by the worms and there may be gastritis and small ulcerations (Soulsby, 1982).

2.2.1.6 *Strongyloides ransomi* (Intestinal threadworm of pigs)

S. ransomi has a direct life cycle that includes free-living adult males and females and parasitic parthogenetic females in the small intestines (Nansen and Roepstorff, 1999). The parasitic females are tiny and have a transverse vulva with protruding lips which lie posterior to the middle of the body (Stewart and Hoyt, 2006). The eggs are ellipsoidal, thin shelled and contain embryos when laid. The small embryonated eggs are passed in feces where they hatch and the resultant rhabditiform larvae may develop into filariform or infective larvae. The infective larvae are capable of penetrating the skin. Transmission of larvae in the colostrum is the most common route of infection of nursing piglets (Nansen and Roepstorff, 1999). They proceed to the alveoli of the lungs via the blood stream. From the alveoli of the lungs, they enter into the bronchi, oesophagus, stomach and then into the small intestines where they become adults. The adult worms which are exclusively female burrow into the intestinal wall and cause irritation and inflammation. The prepatent period is 6-9 weeks. Adult breeding stock may be infected with dormant larvae in their subcutaneous fat. Pregnancy and farrowing stimulate the re-emergence of these larvae which then may infect piglets via the colostrum. In only one week after birth piglets may pass eggs in their feces that can develop within 24 hours to infective larvae. Consequently, a quick rise in worm burdens is typical for threadworm infections. In heavy infections bloody diarrhea, anaemia, emaciation and sudden deaths especially in piglets may occur. During the migratory phase of infection, coughing, muscle soreness, abdominal pain and vomiting can be observed. At post-mortem, petecchial hemorrhages may be evident in the lungs, heart and intestinal mucosa (Soulsby, 1982).

2.2.1.7 *Physocephalus sexalatus*

P. sexalatus are small red colored spiruroid nematodes with trilobed lips. The head is marked off from the body by an inflated cuticular ending in a circular demarking margin just anterior to the posterior end of the pharynx (Soulsby, 1982). The entire male tail is twisted about three turns and the vulva in the female is posterior to the middle of the body. The eggs are oval and slightly flattened at the poles. Embryos are well developed in the shell prior to oviposition. These nematodes have an indirect life cycle where coprophagus beetles act as intermediate hosts (Nansen and Roepstorff, 1999). The worms cause unthriftiness and loss of condition hence an economic loss to the farmer.

2.2.1.8 *Globocephalus urosubulatus* (Pig hookworms)

G. urosubulatus adults are 6- 8mm long and a typical hookworm like buccal capsule to suck blood. The life cycle is direct. Eggs are passed in the faeces and develop to infective third stage larvae within 8-12 days. Infection occurs by ingesting third stage larvae or by transcutenous penetration. Migration of the larvae occurs through the heart, lungs, trachea, oesophagus and intestines. In heavy infections, anaemia, hypoproteinemia, progressive weight loss and emaciation may occur (Kauffman, 1996).

2.2.1.9 *Metastrongylus* species (Lungworms of pigs)

The important species are *Metastrongylus pudendodectus, M. apri* and *M. salmi.* The parasites are fairly long white worms. The adults live in the bronchi and bronchioles of the lungs. The adults apparently orient themselves with their heads down or facing the terminal branches of the trachea where they ingest inflammatory exudates as it is coughed up (Stewart and Hoyt, 2006). The thick shelled embryonated eggs are coughed up, swallowed and finally passed in the faeces. They are then ingested by earthworms where the infective L_3 larvae develop. Eggs in the soil and the infective larvae within the earthworms may remain viable for several years (Nansen and Roepstorff, 1999). The pigs become infected by ingesting earthworms containing the infective larvae. The larvae are then released and penetrate the intestinal wall. They enter the bloodstream via the lymphatic system and finally into the lungs where they enter into the air passages. Metastrongylosis is characterized by coughing, difficult breathing, loss of appetite and retarded growth with heavy infections causing bronchitis and pneumonia. *Metastrongylus* spp have been suspected to carry the virus of swine influenza (H_1N_1), classical swine fever and hog cholera

(Kauffman, 1996). Metastrongylosis has also been associated with purulent staphylococcal lung infections. During post-mortem, there may be wedge shaped area of vesicular emphysema accompanied by small irregular pale areas of consolidation along the ventral border of the diaphragmatic lobe of the lung.

2.2.1.10 *Stephanurus dentatus* (The kidney worm)

Adult *S. dentatus* are 2- 4cm long and about 2mm in diameter and are usually found in pairs within cysts up to 4cm in diameter in the kidney or perirenal fat. Immature larvae may be found in the liver and peritoneal cavity and occasionally in other tissues or organs. It is mainly a parasite of the pigs raised outdoors. Eggs pass out with the urine and hatch in 2 days. Infective third stage larvae develop within 4 days and may infect pigs percutenously or by being ingested. In addition, earthworms may ingest and accumulate larvae (Stewart and Hoyt, 2006). Consequently, pigs may acquire infections by eating earthworms. The larvae then migrate via blood vessels to the liver where they wander for 3 months or more. The larvae proceed to migrate through the peritoneum to the kidney where the cysts are formed. Eggs do not appear in the urine until 9-16 months after infection. Patent infections in piglets less than 5 months old are acquired prenatally. Female worms live as long as 3 years and produce up to 1 million eggs per day. Heavy infections result in reduced growth. Pleuritis and peritonitis are common. Other signs are inappetance, emaciation and ascitis due to cirrhosis. The principal economic loss results from condemnation of organs affected by migrating larvae. The liver is usually most severely affected, showing cirrhosis, scar formation and extensive thrombosis of the portal vessel. Kidney and lung damage is also common (Kauffman, 1996).

2.2.1.11 *Trichinella* species (The garbage worm)

Adult Trichinella worms are very small nematodes, 2- 4mm long and they occur in the small intestines. Encysted larvae are found in muscles. They have a worldwide distribution (Kauffman, 1996). A female produces several hundreds of larvae which penetrate the intestinal wall and migrate via the lymph and blood vessels to the muscles where they encyst and remain viable for years. Further development only occurs if the infected tissue is ingested by another host often a rat, man or pig. Swine may therefore be both intermediate and principal host for trichina worms. After ingestion of the trichina cysts the larvae are liberated and mature in several days. The adult worms copulate in the small intestines and the female penetrate the mucosa to produce larvae for 2 weeks. Trichinella are less pathogenic in swine than in man. The larvae accumulate in the diaphragm and jaw muscles of pigs. Adults cause few problems in swine whereas in man, they cause nausea, diarrhea and abdominal pain. Infection of muscles may cause myositis, muscle pain, stiffness, polypnea, oedema, and eosinophilia and in severe cases, death (Kauffman, 1996).

2.2.2 Acanthocephalids

2.2.2.1 *Macracanthorhycus hirudinaceous* (The thorny headed worm)

M. hirudinaceous belongs to the Phylum Acanthocephala, a group of parasitic worms closely allied to nematodes. They are of worldwide distribution where pigs are raised. Adults are 10-35cm long, with reddish transversely wrinkled bodies. The anterior end shows spiny, retractable proboscis (rostellum) which anchors each worm to the intestinal wall (Kauffman, 1996). They are mainly found in the small intestines of pigs, wild boars and occasionally dogs and monkeys. They occasionally infect humans where they may cause intestinal perforations (Radomyos *et al.*, 1989). The eggs contain larvae when laid and are passed out with feces. They are then eaten by beetle grubs in which infective larval stage develops. Pigs acquire the infection by ingesting these grubs containing the infective larvae. The latter develop and mature in the small intestines. The adult worms are normally found attached to the intestinal wall. The infected animals are asymptomatic but in heavy infections there may be unthriftiness. At post-mortem, inflammation of the mucosa at the site of attachment and wounds with caseous material may be seen. Perforation of the intestinal wall may occur and peritonitis caused by leakage of intestinal contents may be fatal (Kauffman, 1996).

2.2.3 Trematodes of the pig

2.2.3.1 *Fasciola hepatica*

F. hepatica flat, leaf-like worm which normally infects the bile ducts and in its immature form the liver parenchyma of ruminants but many other animals including the pig can also be affected (Kauffman,1996). Pigs acquire fasciola infections especially if they are grazing in swampy areas where the intermediate hosts are present. The intermediate hosts are the snails where the metacecariae leave and encyst on grass or other plants and pigs pick up the infection when they swallow this metacercariae encysted on grass. Fasciolosis in swine is generally asymptomatic. Losses occur by liver condemnation at slaughter (Kauffman, 1996).

2.2.3.2 *Fasciolopsis buski*

F. buski live in the small intestines of humans and pigs and they are of public health and economic importance. They are some of the largest trematodes found in humans and measure up to 80mm in length. Pigs serve as reservoir hosts. The worms produce eggs that are passed in the host's faeces (Sharma and Gogoi, 1986). The intermediate host is a snail and the cercariae that emerge from the snail encyst on vegetation. Humans are infected when they eat vegetables contaminated with metacercariae. Chronic infections with this parasite lead to inflammation, ulceration, hemorrhage and abscess of the small intestines (Soulsby, 1982).

2.2.3.3 *Dicrocoelium dendriticum* (The lancet fluke)

D. dendriticum small fluke with a rather elongated body being narrower anteriorly and broader posteriorly. It occurs in bile and pancreatic ducts of domestic animals. It is found in Europe and various other parts of the world and snails act as intermediate hosts (Soulsby, 1982).

2.2.3.4 *Schistosoma japonicum*

S. japonicum is an elongated fluke. The female is usually carried by the male in the gynacophoric canal (ventral groove). It is found in the portal and mesenteric blood vessels of the pig, other animals and man in Africa and Far East (Kauffman, 1996). The females lay eggs in the capillaries of the mucosa of the intestines. The eggs penetrate the intestinal lumen and are passed out in the faeces. They are taken up by the snails of the Oncomelena genus, which are the intermediate hosts. The pigs are infected by coming into contact with water containing the cercariae which penetrate the skin and gain access to the blood circulation

2.2.3.5 *Paragonimus kellicoti*

P. kellicoti is a fleshy, spinous worm of fairly large size living as an adult in the lungs of many different hosts. Pigs are probably accidental hosts and they acquire infections by ingesting the metacercarial stages found in the intermediate host which include cray fish and snails (Soulsby, 1982). The ingested metacercariae penetrate the intestinal wall and wander to the pleural cavity, enter the lungs and encyst. Large, brown, operculate eggs are coughed up and may be demonstrated at the sputum or faeces of definitive hosts. At post-mortem, there are adhesions, local inflammatory reaction and even fibrosis in the lungs.

2.2.3.6 *Paragonimus westermani* (The lung fluke)

P. westermi is a fluke having a fleshy body, concave ventrally and convex dorsally with a spiny cuticle. The parasites are found in the lungs and sometimes in the brain, spinal cord and other organs of the pig, other animals and man in America, China, Japan, Malaysia and Africa (Soulsby, 1982).

2.2.4 Cestodes

2.2.4.1 *Cysticerca cellulosae* (The pork "measles")

C. cellulosae are the larval stages of the cestode, *Taenia solium* with a world-wide distribution (Flisser, 1988). Cysts are white, 5-18mm in diameter and contain protoscolex with a hook collar. The cysts are found in the skeletal and cardiac muscles of pigs. Adult tapeworms (*T. solium*) are found in the small intestines of man who is the definitive host. Infections of pigs occur by ingesting gravid proglottids or eggs which are passed in the faeces of infected man. These proglottids contain embryophores. Oncospheres are released in the small intestines and migrate to skeletal muscle and the heart via the bloodstream. Cysticerci develop within 2-3 months after ingestion of the eggs and remain infective up to 2 years. Man acquires infection by eating infective *Cysticercus cellulosae* in pig muscle. Cysticerci are released in the human small intestines where the scolices evaginate and attach to the intestinal wall. The prepatent period is 7-8 weeks (Kauffman, 1996). Man can also act as an intermediate host after ingestion of *Taenia solium* eggs. Cysticerci develop in various organs and tissues especially brain and subcutenous tissue. Cysticercosis in swine is not associated with pathology or clinical disease. Pathology in man is related to the number and localization of cysticerci. When they occur in the brain, they lead to neurocysticercosis manifested by epilepsy and seizures. Neurocysticercosis in humans is a serious condition often with fatal consequences. Adult tapeworms produce no significant pathological changes in man (Kauffman, 1996).

2.2.4.2 *Cysticercus tenuicollis* (The bladder worm)

The adult worm, *Taenia hydatigenia* lives in the intestines of dogs and other carnivores. The larval stage, *Cysticerca tenuicollis* is mostly found in the peritoneum of sheep and cattle but sometimes in pigs (Soulsby, 1982). Domestic animals acquire the infection by ingesting gravid proglotttids. The eggs hatch in the intestines and embryos find their way into the liver via the blood stream. In the liver, they burrow out and may be found on the surface of the liver or more commonly attached to the omentum or organs in the peritoneal cavity (Soulsby, 1982). The larvae are usually found in a cyst filled with fluid and may be very large measuring several inches in diameter when mature. Dogs become infected by ingesting the bladder worm.

2.3 Epidemiology of helminth infections

The epidemiology of parasitic infections is determined by a number of factors which are governed by parasite-host-environment interactions. The main risk factors can be classified as; environmental factors, management factors, host factors and parasite factors (Odoi *et al.*, 2007).

2.3.1 Environmental factors

Rainfall or moisture is the most important factor which influences the survival, development, dissemination and availability of free living stages of helminths (Kusiluka and Kambarage, 1996). Moisture facilitates horizontal and vertical migration of nematode larvae in the environment. Temperature also influences the development of nematode larvae with some nematode larvae being resistant to desiccation and this ability enables them to survive under extremely low or high temperatures.

2.3.2 Management factors

Poor nutrition lowers the resistance of the animal thus enhancing the establishment of worm burdens and increasing the pathogenicity of the parasites. Consequently, worm burdens tend to be higher in poorly fed than in well fed animals. Similarly, if animals are totally confined and fed on helminth free diet. the risk of helminthosis is reduced (Kusiluka and Kambarage, 1996). Management systems for the animals have a strong influence on the epidemiology of nematodes. High stocking density increases the contamination of the environment with nematode eggs or larvae and this makes the infective stages to be more accessible to susceptible animals (Ghanem *et al.*, 2009). Also. tethering animals during the wet season results in increased environmental contamination with the infective larvae and clinical disease. Anthelmintic treatment reduces the prevalence and severity of gastrointestinal nematode infection and may significantly influence their epidemiology (Nansen and Roepstorff, 1999; Kagira *et al.*, 2003; Nissen *et al.*, 2011).

2.3.3 Host factors

The incidence, rate and severity of infection with nematodes can be influenced by factors such as age, breed, nutrition, physiological state and the prescence or absence of intercurrent infection (Kusiluka and Kambarage, 1996). The prevalence of nematodes is generally thought to be higher in young animals than in adults (Bugg *et al.*, 1999; Wabacha, 2001; Kagira *et al.*, 2003)) and this is due to higher immunogenicity of helminths which is important in the generation of acquired immunity in older animals. The physiological status of the animal may influence its susceptibility to nematode infections. Hormonal changes during late pregnancy and lactation lower the resistance of the host to nematodes and consequently result in the establishment of higher worm burdens (Urquhart *et al.*, 1996). Intercurrent infections and other stress factors also enhance the establishment of higher worm burdens.

2.3.4 Parasite factors

The intrinsic multiplication rate of the nematode species determines the rate of establishment and size of the nematode burden in the host. The multiplication rate is determined by the fecundity of the adult worms, the pre-patent period and survival and development rate of the parasite in the environment (Kusiluka and Kambarage, 1996).

2.4 Worm distribution in pig population

Helminth infections in the different age groups of pigs in traditional herds are strongly associated with the immunogenicity of individual species. Two characteristics type of age distribution exist. In one type, the infections usually have a maximum in young pigs for parasites such as *Strongyloides ransomi* in piglets and *Ascaris suum* and *Trichuris suis* especially in young fatteners. This pattern of distribution is explained by the highly immunogenic properties of these three parasites. The other distribution type is characteristic for *Oesophagostomum* spp and *Hyostrongylus rubidus* which both show higher prevalence rates and intensities of infection in older animals (the breeding stock) which is a reflection of lower immunogenicity of these two parasites (Nansen and Roepstorff, 1999). Furthermore, the transmission pattern within a given pig production system has a profound influence on the levels of infection in the various age categories (Esrony *et al.*, 1997: Kagira *et al.*, 2002 ; Wabacha *et al.*, 2004).

2.5 Diagnosis of pig nematodes

The gastrointestinal nematodes infections are mainly diagnosed by coproscopy, using features described by various authors (Soulsby, 1982; MAFF, 1986). Pathological lesions caused by various worms and the morphology of various adult parasites can be used in the diagnosis at post-mortem. Several highly sensitive and specific techniques that rely on the demonstration of parasite nucleic acid sequences have been developed. These techniques depend either on the use of DNA probes or on the polymerase chain reaction or Random amplification of polymorphic DNA (RAPD-PCR) (Kauffman, 1996).

2.6 Haemoparasites of pigs

2.6.1 Protozoa

2.6.1.1 Trypanosomes

2.6.1.1.1 *Trypanosoma congolense simiae*

T. c. simiae is a polymorphic form resembling *Trypanosoma congolense*. Its' natural host is the warthog and it is highly pathogenic for the pig and camel (Kauffman, 1996). *Glossina brevipalpis* and *Glossina morsitans* introduce *T. congolense simiae* to domestic pigs but thereafter mechanical transmission by stomoxys species and tabanids is also possible. *T. congolense simiae* differs from *T. congolense* in that it is polymorphic instead of monomorphic. It is 12-24µm long. About 90% of its forms are long and stout with a conspicuous undulating membrane. A free flagellum is usually absent. *T. congolense simiae* is the most important trypanosome of domestic swine and causes very acute and fatal disease. The disease is characterized by disseminated intravascular coagulation, hemorrhage in the heart, lungs and meninges. It is found in Tropical East and Central Africa. Clinical signs in the affected animals include hyperthermia, inappetance, depression, polypnea and death within a few hours (Kauffman, 1996).

2.6.1.1.2 *Trypanosoma suis*

T. suis specific trypanosome is poorly known. It is monormophic, 14-19µm in length, stout and with a free flagellum. It is found in Central Africa and transmitted by *Glossina brevipalpis* and *Glossina vanhoofi*. *Trypanosoma suis* causes a chronic infection in adults and more acute disease with death in less than 2 months in young pigs. Clinical signs include fever, apathy, progressive weakness and death in suckling piglets and unthriftiness in adult pigs (Kauffman, 1996).

2.6.1.1.3 *Trypanosoma congolense*

T. congolense occurs in swine but may regress spontaneously. Once the disease sets in, it develops a chronic course associated with emaciation, progressive anaemia, weakness and ataxia. It is transmitted by *Glossina* species (Kauffman, 1996).

2.6.1.1.4 *Trypanosoma evansi*

T. evansi affects a wide range of hosts including pig. The most severe disease occurs in camels, horses and dogs. The transmission is mechanical by biting flies. *T. evansi* infections in pigs are chronic in nature and the clinical signs are non specific (apathy and weakness) and often overlooked (Kauffman, 1996).

2.6.1.1.5 *Trypanosoma brucei and Trypanosoma vivax*

T. brucei is not very pathogenic for pigs and develops as a chronic usually mild or asymptomatic disease. *Trypanosoma vivax* is generally non pathogenic for pigs (Kauffman, 1996).

Domestic pigs have been incriminated to play a role in the epidemiology of both human and animal trypanososmosis where they have been shown to harbour *Trypanosoma brucei gambiense* in West Africa (Gibson *et al.*, 1978) and may be potential reservoirs of *Trypanosoma brucei rhodosiense* in East Africa(Ng'ayo *et al.*, 2005).

2.6.1.2 Babesidae

2.6.1.2.1 *Babesia trautmani*

B. trautmani the large porcine *Babesia* species (2.5-4μm long and 1.5-2μm wide) characteristically long and narrow. It occurs frequently in pairs but the infected cells may also contain up to 6 organisms. Oval, amoebid and ring forms may occur. It occurs in Southern Europe and Equatorial Africa. Transmission is by *Rhipicephalus sinus, R. appendiculatus, R. sanguinus, Boophilus decoloratus* and *Dermacentor* species. Babesiosis of swine is seasonal according to the vector. Wild birds and warthogs may serve as natural reservoirs. Pigs of all ages may be affected and mortality may reach 50%. Clinical signs include fever, anaemia, haemoglobinuria, jaundice, oedema and incordination. Abortion may occur in pregnant sows (Kauffman, 1996).

2.6.1.2.2 *Babesia perroncitoi*

B. perroncitoi is the small porcine *Babesia* species, a small rounded form (0.7-2μm in diameter). Oval to pyriform forms may occur (1.2-2.6μm long and 0.7-1.9μm wide). It is found in the Mediterranean basin, West and Central Africa. It is transmitted by *Rhipicephalus sinus, R. appendiculatus, R. sanguineus* and *Dermacentor reticulatus*. Clinical signs include fever, anaemia, hemoglobinuria, jaundice, oedema and incordination. Abortion may occur in pregnant sows (Kauffman, 1996).

2.6.2 Rickettsiales

2.6.2.1 *Mycoplasma (Eperythrozoon)* species

2.6.2.1.1 *Mycoplasma suis*

M. suis occurs in pigs on the surface of erythrocytes. Severe cases occur in young pigs. *M. suis* is transmitted through several potential routes. *Haematopinus suis* and probably other arthropods may transmit the infection. Mechanical transmission by surgical instruments may occur. Transplacental transmission may occur. *M. suis* is generally not pathogenic but may assume significance together with other concomitant infections. It is found in America, Europe, Asia and Equatorial Africa. Clinical signs include varying degrees of hemolytic anaemia, icterus (yellow belly), fever, anorexia and weakness. Anaemia is the predominant clinical sign of *M. suis* infection in neonatal piglets (Kauffman, 1996; Guimaraes *et al.*, 2011).

2.6.2.1.2 *Eperythrozoon parvum*

E. parvum is smaller than *Mycoplasma suis* and non pathogenic. It also occurs on the surface of erythrocytes (Kauffman, 1996).

2.7 Diagnosis of pig haemoparasites

Diagnosis of haemoparasites in pigs is made by direct parasitological examination of wet, thin and thick films and buffy coat preparations. Indirect method involves the use of serological tests that detects specific antibodies against haemoparasites. Other sensitive and specific tests include the use of DNA probes and Polymerase chain reaction (PCR) that demonstrates the occurrence of sequences of nucleotides specific for haemoparasites (Kauffman, 1996).

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study area

3.1.1 Physical and agro-climatic condition

Homabay District (currently Homabay and Ndhiwa districts), Nyanza province has a geographical coverage of 1,160.4km^2 of which 84% is cultivable. The district has seven administrative divisions; Rangwe, Asego, Ndhiwa, Pala, Nyarongi, Riana and Kobama (Fig.1). Pala Division was curved out of Ndhiwa Division before the study started (2007) but at the time of this study, its' administrative boundaries had not been included on the map. After the study had started, the district was further subdivided into two districts namely, Homabay District with two divisions, Asego and Rangwe divisions and Ndhiwa District with five divisions, Riana, Pala, Kobama, Nyarongi and Ndhiwa divisions. However, for the purposes of this study, the two districts were regarded as Homabay. The climate of the district is inland equatorial with two distinct regions, the Lakeshore lowlands and the Uplands plateau. The Lakeshore lowlands lie between 1,143 to 1,220m above the sea level and mainly comprise of a narrow stretch bordering Lake Victoria on the Northern part of the district. At the end of the Lakeshore is a bay from which the district derives its name. The uplands plateau rises from 1,220 to 1,560m and has undulating terrain. The bay is skirted by a shoreline stretching about 16.5km covering parts of Asego and Rangwe divisions (FAO, 2007).

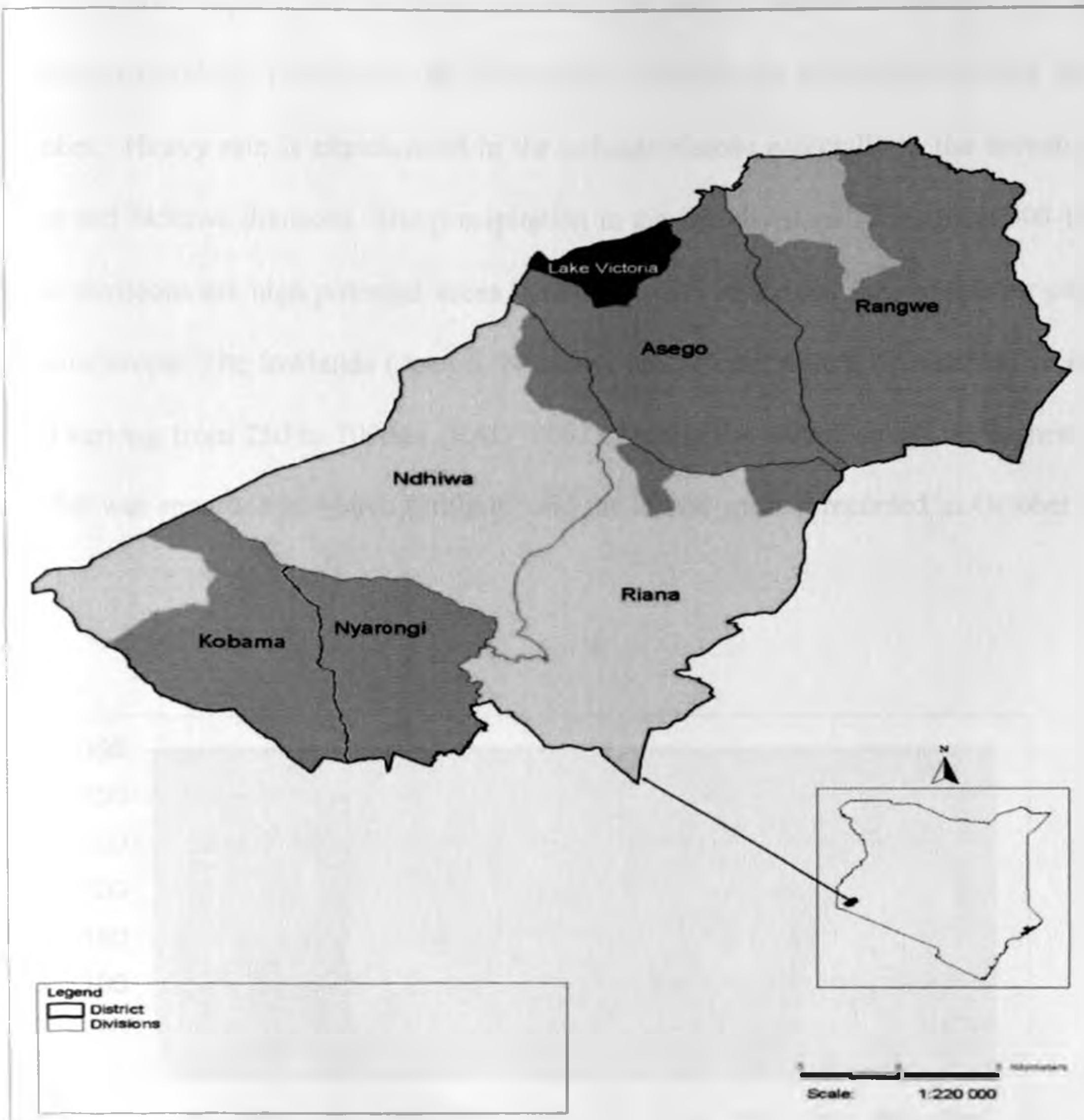


Fig 1. Map of Homabay District showing its administrative divisions (Adapted from FAO, 2007)

Homabay district experiences two rainy seasons. The rainfall pattern is bimodal with the long rain season extending from March to June while the short rain season occurs from August to November. Heavy rain is experienced in the uplands plateau especially in the eastern parts of Rangwe and Ndhiwa divisions. The precipitation in the two divisions varies from 500-1000mm. The two divisions are high potential areas in terms of agriculture and are suitable for production of various crops. The lowlands (Asego, Nyarongi and Western parts of Ndhiwa) receive low rainfall varying from 250 to 700mm (FAO, 2007). During the current study, the highest amount of rainfall was recorded in March (300mm) and the lowest amount recorded in October (33mm) (Fig. 2).

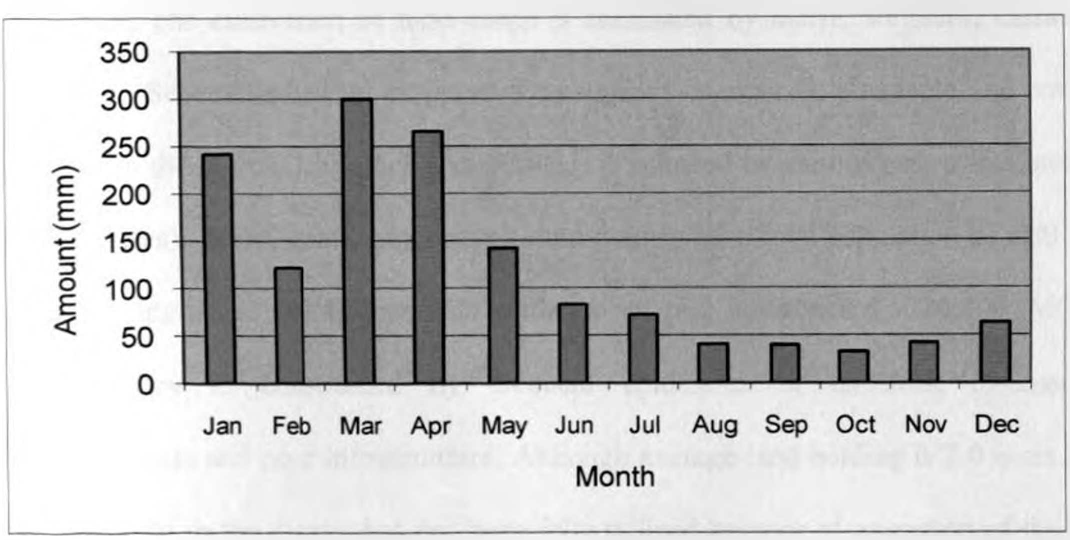


Fig.2 Rainfall distribution in the study area for the year 2010 (Source: FTC, Homabay)

3.1.2 Physical geography

Homabay has plenty of surface and underground water sources. Surface sources include Lake Victoria and several perennial rivers such as Kuja, Riana and Rangwe. There are also numerous dams found in the district providing water to households while some rely on roof catchments. Significant underground resources are wells and boreholes distributed throughout the district whereas springs supply water for domestic use in the hilly areas (FAO, 2007).

3.1.3 Livestock and crop production

Agriculture is the lifeline of the districts' economy employing over 50% of the residents. Small holder farming is the dominant land use practice accounting for about 86.8% of land cultivated in the district. The cultivation of food crops is dominated by maize, sorghum, cassava and bean production. Several industrial crops such as sugarcane, tobacco, pineapple and cotton are also produced in the region. Livestock production is dominated by various enterprises including cattle (Zebu crosses), sheep, goats, pigs, rabbits and poultry. The total population of cattle, sheep and goats is estimated at 589,400 animals while that of pigs is estimated at 20,800 (MOLD, 2007). This industry is constrained by frequent epidemics of livestock diseases including trypanosomosis and poor infrastructure. Although average land holding is 2.0 acres, agricultural land available in the district has not been fully utilized because of migration of the labourforce. Fishing is the other economic activity and it is practiced in Lake Victoria, rivers and ponds within the district (FAO, 2007).

3.1.4 Human population

The human population in Homabay was 963,794 with males comprising 462,454 while females comprise 501,349 of the population (KNBS, 2009a). The youth and labour force comprise 23% and 47.8% respectively while the dependency ratio is 100:109. The district has a mean density of 270 individuals per square kilometer but distribution within the district is influenced by availability of road infrastructure and climate. Asego Division hosts the district headquarters of Homabay town while Rangwe Division is the most populous. Kobama Division is the least populated division. Asego and Kobama have densities of 417 and 172 per square kilometer while Ndhiwa and Rangwe have densities of 242 and 424 per square kilometer respectively (FAO, 2007).

3.2 Selection of study farms

An estimation of the sample size of the pigs required for the study was done using the formula $n=Z\alpha^2pq/L^2$ (Martin *et al.*, 1987), where n is the required number of individuals to be examined (sample size), $Z\alpha$ is the standard normal deviate (1.96) at 5% level of significance, p is a known or estimated prevalence, $q = (1-p)$ and L is the allowable error (precision) of estimation. The sample size was based on estimated prevalence of 14% of *Cysticerci cellulosae* in Busia District, Western Kenya (Githigia *et al.*, 2005). With a desired absolute precision of 5% and a 95% level of confidence, faecal and blood samples were required from at least 185 pigs (Thrushfeld,1995) in order to obtain an accurate estimate of the helminths and haemoparasite prevalence in free range pigs. The study farms were selected with the assistance of field extension officers of the Ministry of Livestock Development and Marketing (MOLD) and local administration officials.

The sampling unit of interest was individual small holder farms and all the pig farms in the area were regarded as being small holder with herd sizes of less than 10 pigs. In the cross sectional survey used in the current study, a list of locations with the highest population of pigs in the seven divisions was made and two locations from each division were randomly selected for the study. Subsequently, a list of small scale farmers in the selected locations was established. In Kobama and Nyarongi divisions where there were few pig farmers, the sampling frame consisted of only villages with pigs. In Rangwe Division where the management system was semi-intensive, all the farmers with the semi-intensive system were included in the study (Fig. 3). At the village level, households with pigs were established with the help of Extension Officers and other farmers until all the selected farmers were covered.

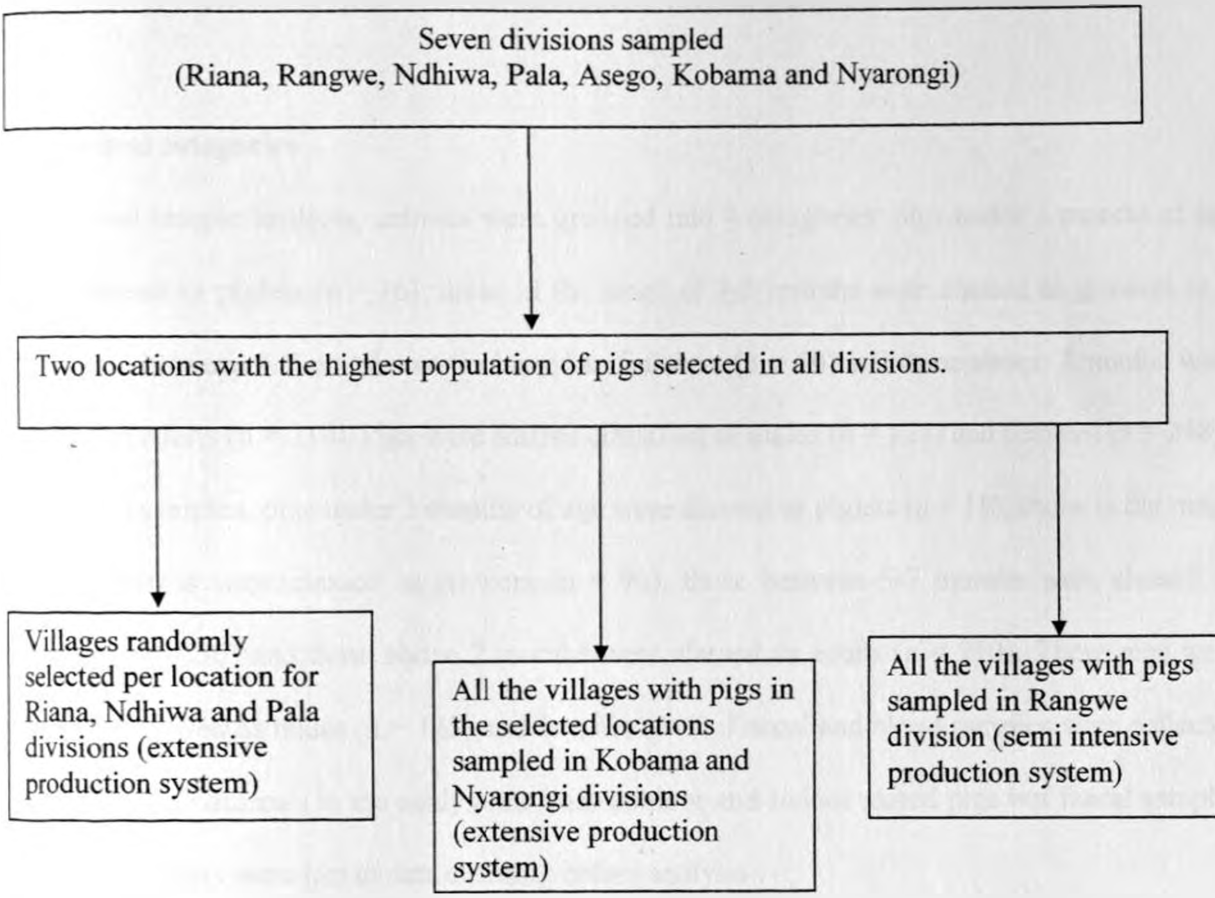


Fig 3. Sampling design used in Homabay District

3.3 Questionnaire survey

In order to achieve the desired number of pigs, 297 farmers were recruited. Structured questionnaire (Appendix I) aimed at determining the potential risk factors influencing the prevalence of helminths and haemoparasites in pigs in Homabay District were administered through face-to-face personal interviews. The questions were constructed in the English language but they were administered in the local dialect to improve on clarity of various issues. Specific data were collected on household information, pig production and management practices, type of feed given to pigs, importance of worm infestation, clinical signs and parasite control.

3.4 Animal categories

For faecal sample analysis, animals were grouped into 4 categories: pigs under 3 months of age were classed as piglets (n = 16), those in the range of 3-5 months were classed as growers (n = 96), those between 5-7 months were classed as finishers (n = 50) and those above 7 months were classed as adults (n = 210). Pigs were further classified as males (n = 124) and females (n = 248). For blood samples, pigs under 3 months of age were classed as piglets (n = 18), those in the range of 3-5 months were classed as growers (n = 96), those between 5-7 months were classed as finishers (n = 50) and those above 7 months were classed as adults (n = 210). These pigs were further classified as males (n = 125) and females (249). Faecal and blood samples were collected from the same animals in the study area from outdoor and indoor reared pigs but faecal samples from two piglets were lost to data cleaning before analysis .

3.5 Sampling

Faecal and blood samples were collected in the months of February, April and August (2010) in the morning hours (between 7.00 a.m and 12.00 p.m). Briefly, pigs were restrained and single faecal samples collected per rectum from individual pigs using clean, unused gloves. Blood samples were collected from the supra-orbital fossa using gauge 19 needle. From each animal, 1-2ml of blood was collected into vacutainer tubes containing heparin as the anticoagulant. All the samples were labeled individually and kept in a cool box containing ice packs during transportation to the laboratory where faecal samples were immediately processed or kept at 4 ^{0}C for a maximum of one day before processing. Blood samples were processed immediately upon arrival at the laboratory.

3.5.1 Faecal sample analysis

The number of nematode eggs in the faeces was determined using the modified McMaster Method (MAFF, 1986). Briefly, 2g of faeces was mixed in 28ml of saturated salt solution (360g of Sodium Chloride dissolved in 1000 ml of hot water) with thorough stirring. The mixture was then filtered using a sieve and solids discarded. Using a teat pipette, the McMaster chamber was filled with the solution and eggs examined and counted (in cm^2 of the slide) under low power objective lens (x10) of the microscope. The types of eggs were determined based on their morphological characteristics. An animal was considered infected with a parasite if at least one egg was detected in the McMaster chamber. The type of helminths eggs and the number of eggs per gramme of faeces (e.p.g) were recorded.

All Strongyle type-eggs positive faecal samples were pooled per farm and thoroughly mixed. They were cultured at 27 ^{0}C for 14-21 days and larvae were harvested using Baerman apparatus as described in the MAFF (1986) manual. For this procedure, a test-tube was filled at the end of the rubber tubing and a piece of cheesecloth placed in the sieve in the funnel. The funnel was filled with warm water until it raised about half above the layer of the cloth in the sieve and the water left to cool at about 35 ^{0}C – 45 ^{0}C. The cultured faecal sample was spread evenly over the cloth and allowed to stand overnight. The apparatus was clamped off at the rubber tubing, the clamp opened and contents withdrawn in to the test-tube. A drop of the sample was transferred from the test-tube to a slide, a drop of Lugols' iodine added to immobilize the larvae and a cover slip placed. One hundred nematode larvae were examined and identified according to the criteria described by Thiepont *et al.* (1986) in order to differentiate between *Oesophagostomum* spp, *Hyostrongylus rubidus*, *Trichostrongylus axei* and *Globocephalus urosubulatus.*

3.5.2 Post-mortem examination for helminth parasites

In order to determine the species of worms in Homabay District, post-mortem examinations were carried out on gastro-intestinal tracts of pigs which were at least seven months old. Due to logistic considerations, gastrointestinal tracts were obtained from thirty pigs only. The lungs, livers and gastrointestinal tracts (stomach, small and large intestines) were obtained from five pigs from two local slaughter houses in Homabay District; two from Riana Division and three from Asego Division. The rest of the gastro-intestinal tracts, liver and lungs were obtained from twenty five pigs purchased from different parts of Homabay District and transported for slaughter to Ndumbuini slaughter house on the outskirts of Nairobi. The pigs were slaughtered between August and October.

Post-mortem examination was carried out as per the procedure described by Roepstorff and Nansen (1998). Briefly, the trachea, bronchi and bronchioles were cut open using a pair of scissors and examined for lungworms. The liver surfaces were examined for milk spot lesions associated with larval ascarid migration. The stomach was cut open along the major curvature using a pair of scissors and the contents transferred to a bucket, sieved using a mesh (250µm) and macroscopically examined for stomach worms. The stomach wall was also inspected for worms attached to the gastric mucosa. The small intestines were sliced longitudinally using a pair of scissors, their contents sieved using a mesh (250µm) and examined macroscopically. The mucosa was inspected for worms attached to the intestinal wall. The large intestines was sliced longitudinally, its contents emptied in a bucket and intestinal wall washed with water. The sample was examined macroscopically for the presence of worms. The intestinal wall was inspected for the worms attached on the mucosa. The isolated worms were preserved in 70% ethanol, cleared with the use of lactic acid and identified using a light microscope according to Soulsby (1982) and Kauffman (1996).

3.5.3 Blood sample analysis

Blood samples were screened for trypanosomes and other haemoparasites using the microhematocrit centrifugation buffy coat examination (Murray *et al.*, 1977) and thin smear examination respectively (Bell-Sakyi *et al.*, 2004).

3.5.3.1 Packed Cell Volume (PCV) determination

Packed cell volume determination was done as per the procedure described by Kamani *et al.* (2010). Briefly, blood was drawn from heparinised vacutainer tube into heparinised capillary tube and one end of the capillary tube sealed with plastacene. The capillary tubes were placed in the hematocrit centrifuge with sealed end outermost and centrifuged at 4500 rpm for 5 minutes. The Packed Cell Volume (PCV) was read on PCV reader as a percentage of the packed blood cells to the total volume of whole blood.

3.5.3.2 Buffy coat examination

After PCV determination, the capillary tube was cut just below the buffy coat and the buffy coat together with the top layer of red blood cells transferred on to a clean slide, covered with a cover slip and the preparation examined under the microscope at 100 x magnification (Mbahin *et al.*, 2008).

3.5.3.3 Preparation of blood smears, fixing and staining

Thin smears were made as per the method described by Gadahi *et al.* (2008) and air dried. Briefly, a drop of blood was placed near one end of a clean glass slide using the capillary tube and another slide used to prepare the blood smear. The edge of the second slide, held at an angle was touched with the drop spreading it on either side. Then the slide was moved in a forward direction allowing the blood to spread as a thin layer on the surface of the slide. The smear was allowed to air dry. The dried blood smears were fixed in 99.0% methanol for 5 minutes and allowed to dry. Later the slides were immersed in coupling jars containing Giemsa stain at 1:5 dilutions for 15 minutes. The Giemsa stained blood smears were taken out and washed with water. After drying, the slides were examined systematically under a microscope (at 1000x oil immersion objective) for identification of various blood parasites (Urquhart *et al.*, 1996).

3.6 Data analysis

The data collected were entered into Microsoft Excel and exported to SPSS version 12.0 (Statistical package for Social Scientists, 2003) for statistical analysis. The prevalence (p) of the animal harboring each parasite was calculated as $p = d/n$ where d is the number of animals diagnosed as having a given parasite at that point in time and n is the number of animals at risk (examined) at that point in time (Thrushfeld, 1995). The EPG was described in terms of mean, minimum, maximum and standard deviation) was determined. Cross tables were used for Chi-square (χ^2) test to determine the association between parasitism and host and management factors. The differences in the mean egg counts (epgs) for different ages, sex and divisions were tested using One-way analysis of variance (ANOVA) based on logarithmically transformed egg counts i.e. $\log10$ (epg+1). An unpaired t-test was used to examine the differences in the mean PCVs between haemoparasite infected and non- infected animals while the differences in the mean PCVs for different divisions and ages were tested using One-way analysis of variance. The results were considered to be significantly different when $p < 0.05$.

CHAPTER FOUR: RESULTS

4.1 Prevalence and intensity of helminth infections (from farm survey)

Out of the 372 animals sampled, 83% (308) were shedding nematode eggs. The nematode eggs were; Strongyles (75%), *Strongyloides* spp (26.6%), *Trichuris* spp (7.8%), *Ascaris* spp (5.4%) and *Metastrongylus* spp (0.3%). From coprocultures of Strongyle positive faecal samples, *Oesophagostomum* spp comprised 74%, *Hyostrongylus rubidus* 22% and *Trichostrongylus* spp 4% of the larvae.

Table 1 shows the prevalence of helminths according to the age category of pigs. The highest prevalence with nematode eggs was recorded in finishers (88%) and the lowest prevalence recorded in adults (79%). Growers recorded the highest level of infection with Strongyles (84.4%), *Strongyloides* spp (55.2%), *Trichuris* spp (50%) and *Ascaris* spp (51%). No *Ascaris* spp was recorded in piglets.

Table 1. Prevalence of helminths according to the age category of the pigs in Homabay District

Age category	Prevalence for specific nematodes			
	Strongyles	*Strongyloides* spp	*Trichuris* spp	*Ascaris* spp
Adults (n = 210)	72.4%	33.3%	10.0%	9.1%
Growers (n = 96)	84.4%	55.2%	50.0%	51.0%
Finishers (n =50)	70.0%	14.0%	4.0%	6.0%
Piglets (n =16)	81.3%	12.5%	6.3%	0.0%

The prevalence of helminth infection varied from division to division. The highest prevalence was recorded in Riana (91%) and the lowest prevalence was recorded in Asego (50%). Also, Riana division recorded the highest prevalence of infection with Strongyles (84.9%), *Strongyloides* spp (30.1%) and *Trichuris* spp (10.2%). Rangwe division recorded the highest prevalence of infection with *Ascaris* spp (46.2%) but no infection with *Strongyloides* spp while Asego and Kobama divisions did not record infections with *Strongyloides* spp, *Trichuris* spp and *Ascaris* spp (Table 2). One adult pig was infected with *Metastrongylus* spp in Riana Division. The highest mean epg was recorded in pigs form Riana Division (1,109) and the lowest mean epg was recorded for pigs from Asego Division (100). Riana Division recorded the highest mean epgs for infection with Strongyles (623) and *Strongyloides* spp (428) while Rangwe Division recorded the highest mean epgs for infections with Ascaris spp(492) (Table 2).

Table 2. The prevalence and mean epgs of various nematodes eggs in pigs according to the division

Division	Percentage prevalence and mean epg for specific nematodes			
	Strongyles	*Strongyloides* spp	*Trichuris* spp	*Ascaris* spp
Riana (n =167)	84.9% (623)	30.1% (428)	10.2% (40)	4.8% (18)
Pala (n =123)	67.5% (317)	28.5% (153)	4.1% (7)	2.4% (10)
Ndhiwa (n = 45)	80.0% (570)	22.2% (104)	6.7% (13)	2.2% (2)
Nyarongi (n =15)	73.3% (207)	13.3% (33)	6.7% (7)	0% (0)
Rangwe (n =13)	15.4% (62)	0% (0)	7.7% (139)	46.2% (492)
Asego (n = 6)	50.0% (100)	0% (0)	0% (0)	0% (0)
Kobama (n = 3)	33.3% (333)	0% (0)	0% (0)	0% (0)

The mean epg and range for the nematodes for different age categories are shown in Table 3. The highest mean epg of infection with helminths was recorded in adults (1,175) while the lowest mean epg was recorded in piglets (526). Growers recorded the highest mean epg of infection with Strongyles (584) while the lowest mean epg of infection with Strongyles was recorded in piglets (43). The highest mean epg of infection with *Trichuris* spp was recorded in adults (146).

Table 3. Mean eggs per gram of faeces and range for different age categories of pigs in Homabay District

Age category	Overall mean epg	Range	Mean epg for specific nematodes			
			Strongyles	*Strongyloides* spp	*Trichuris* spp	*Ascaris* spp
Adults (n= 210)	1175	0-12,000	229	766	146	34
Growers (n= 96)	1106	0-15,000	584	480	20	22
Finishers (n=50)	734	0-2,900	506	147	57	24
Piglets (n=16)	526	0-4,700	43	473	10	0

Table 4 shows the mean eggs per gram of feaces according to the sex category of the pigs. Females recorded a higher overall mean epg (567) than males (416). Also, females recorded a higher mean epg of infections with Strongyles (362), *Trichuris* spp (32) and *Ascaris* spp (37) than males.

Table 4. Mean eggs per gram of faeces according to the sex category of pigs in Homabay District

Sex	Mean epg for specific nematodes				Overall mean epg
	Strongyles	*Strongyloides* spp	*Trichuris* spp	*Ascaris* spp	
Male (n= 124)	210	178	17	11	416
Female (n= 248)	362	136	32	37	567

A higher proportion (68%) of the animals was found to have low levels of infection (< 500 epg), 29% had moderate (500-2000 epg) and 3% had high levels of infections with Strongyles (2000-5000) (Fig. 4).

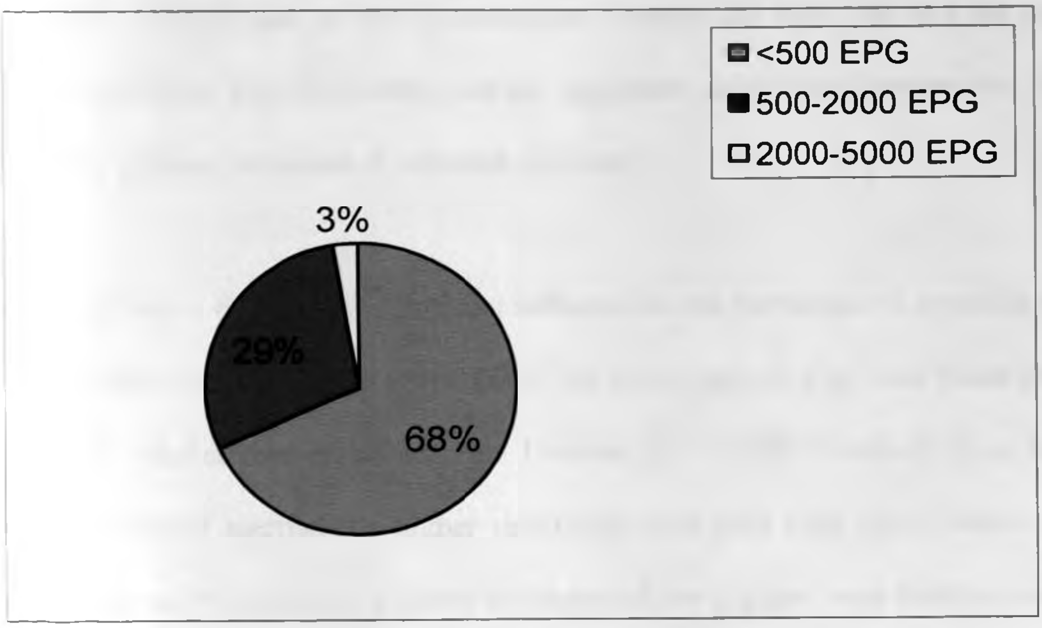


Fig 4. Levels of infections with Strongyle-type nematode eggs in pigs in Homabay District expressed as percentage.

Age had significant (ANOVA, $p = 0.042$) influence on intensity of infection with Strongyles, with significantly (ANOVA, $p = 0.007$) higher levels of infection being recorded in finishers than in adults. Also, growers recorded significantly (ANOVA, $p = 0.036$) higher levels of infection with Strongyles than adults. Sex of the pig had significant influence on the prevalence of infection with Strongyles ($p = 0.028$) and *Ascaris suum* ($p = 0.012$) with females recording higher levels of infection than males.

Sex of the pig was significantly associated with Strongyle infections ($p = 0.037$, df = 2, $\chi^2 = 6.5$). Age was also significantly associated with Strongyle infections ($p = 0.037$, df = 2, $\chi^2 = 13.4$). There was no significant ($p > 0.05$) association between the feed type and the prevalence of helminth parasites. Likewise, there was no significant association between the frequency of deworming and the prevalence of helminth parasites.

Division of origin of pigs had significant influence on the prevalence of infection with *Ascaris* spp ($p = 0.000$) and Strongyles ($p = 0.000$). The mean epgs for pigs from Riana Division were significantly higher than pigs from Pala Division ($p = 0.000$). Similarly, pigs from Ndhiwa Division recorded significantly higher mean epgs than pigs from Pala Division ($p = 0.04$). Asego, Rangwe, Nyarongi and Kobama divisions had few pigs and were therefore not included in the statistical analysis (ANOVA) due to small sample size to avoid bias. .

4.2 Worms isolated at Post-mortem examination (Slaughter- house survey)

Out of the 30 pigs examined, 26 (86.7%) had one or more helminth parasites. *Oesophagostomum dentatum* (Fig. 5 and Fig. 6) was isolated from the large intestines of 23 pigs while *Trichostrongylus axei* (Fig. 7) was isolated from the stomach of one pig. *Hyostrongylus rubidus* was isolated from the stomachs of 12 pigs while *Physocephalus sexalatus* (Fig. 8) was recovered from the stomachs of 10 pigs. The small intestines of 3 pigs harboured *Ascaris suum* while 4 pigs harboured *Trichuris suis* in the large intestines. *Metastrongylus pudendodectus* was recoverd from the lungs of 13 pigs. The highest mean burden of worms was recorded for *Physocephalus sexalatus* (85.06) while the lowest mean burden was recorded for *Ascaris suum* (0.13) (Table 5).

Table 5. Genus and species of worms recovered from pigs at post-mortem examination in Homabay district

Location	**Parasite**	**Number infected (%)**	**Mean burden**	**Range**
Stomach	*H. rubidus*	12 (40.0%)	60.73	0-587
	P. sexalatus	10 (33.3%)	85.06	0-460
	T. axei	1 (3.3%)	26.27	0-788
Small intestines	*A. suum*	3 (10.0%)	0.13	0-2
Large intestines	*O. dentatum*	23 (76.7%)	74.37	0-559
	T. suis	2 (6.7%)	1.33	0-18
Lungs	*M. pudendodectus*	13 (43.3%)	16.50	0-126

Key:

H-Hyostrongylus — *A- Ascaris* — *M- Metastrongylus*

P- Physocephalus — *O- Oesophagostomum*

T- Trichostrongylus — *T- Trichuris*

Postmortem examination revealed the presence of *Trichostrongylus axei* and *Physocephalus sexalatus* whose eggs were not detected through faecal examination. Also, *Metastrongylus pudendodectus* was recovered from the lungs of 13 pigs through post-mortem examination as compared to the faecal examination which detected the presence of *Metastrongylus* spp in one pig only.

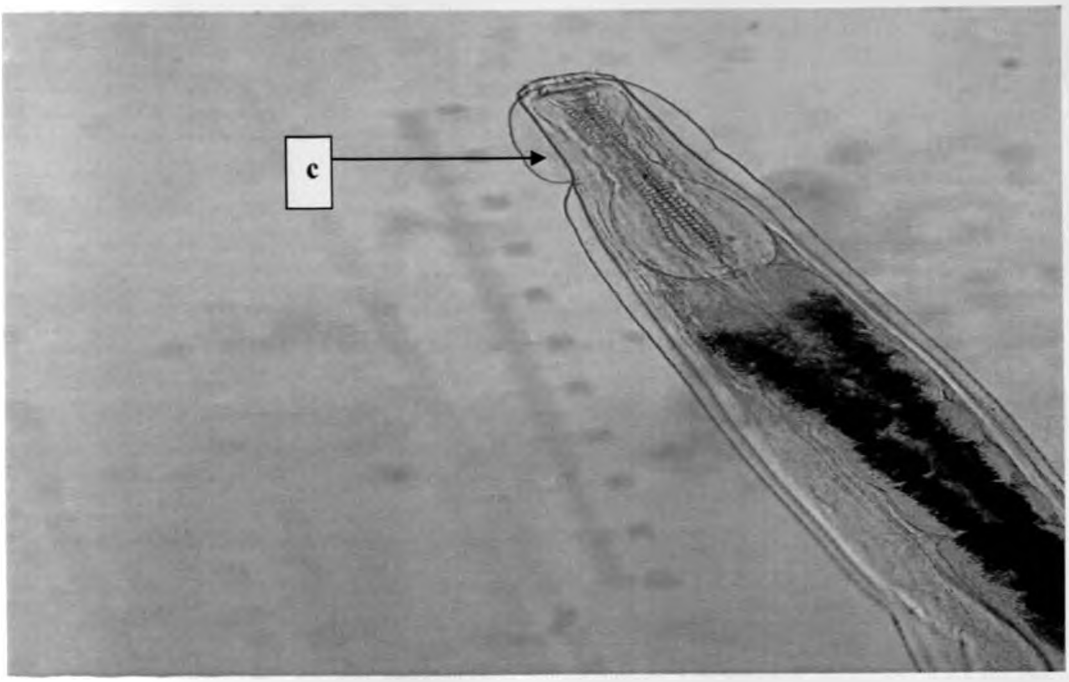


Figure 5. Anterior portion of *Oesophagostomum dentatum* showing oesophagial region and cephalic vesicle (c). Magnification: X100

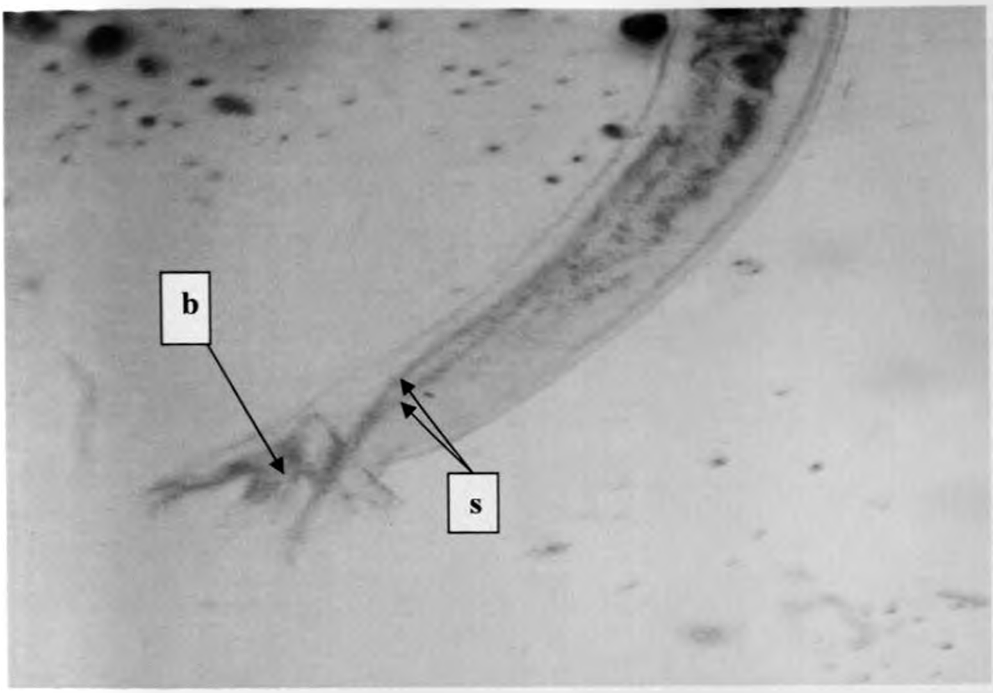


Figure 6. Posterior portion of *Oesophagostomum dentatum* showing long spicules (s) and bursa (b). Magnification: X100

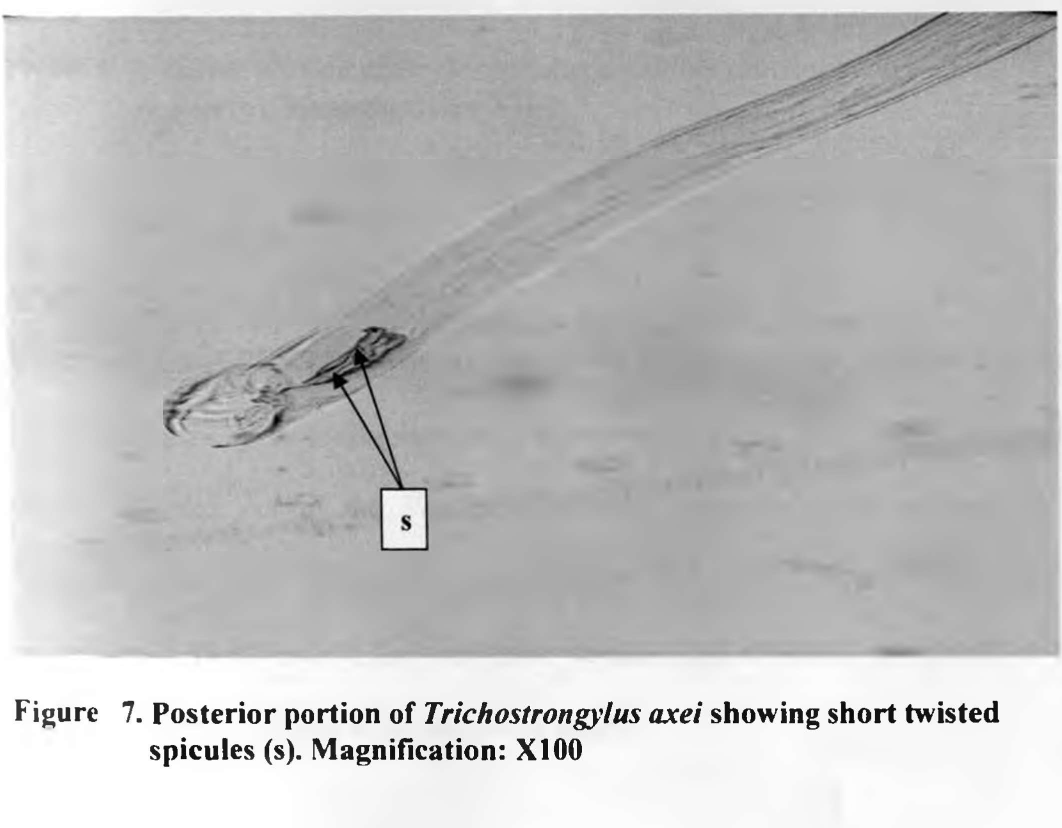


Figure 7. Posterior portion of *Trichostrongylus axei* showing short twisted spicules (s). Magnification: X100

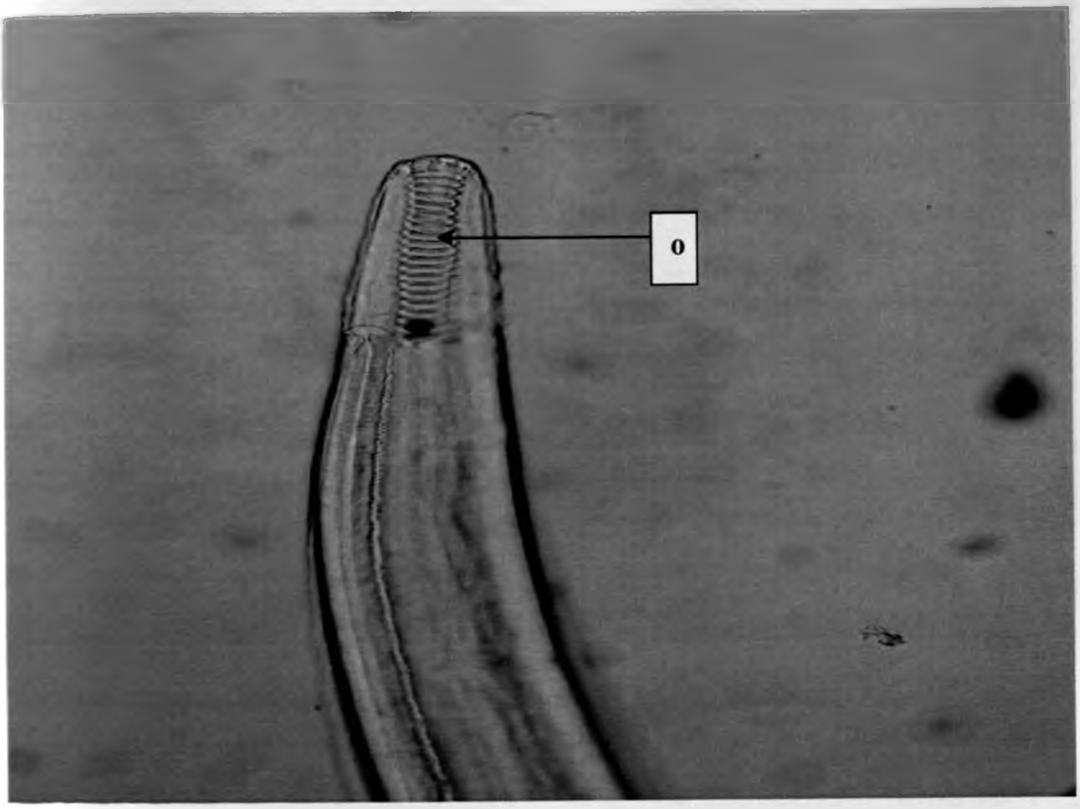


Figure 8. Anterior portion of *Physocephalus sexalatus* showing pharyngeal region (o). Magnification: X100

4.3 Blood examination

The overall mean PCV of the pigs examined was 41.5% and it ranged from 24 -70%. The mean PCVs for piglets, growers, finishers and adults were 38.8 40.5, 42.0 and 42.1 respectively. A total of 125 samples out of the 374 blood samples examined were positive for *Mycoplasma (Eperythrozoon)* spp thus giving a prevalence of 33.4%. *Mycoplasma suis* (Fig. 9) had prevalence of 18.2 % while *Eperythrozoon parvum* (Fig. 10) had a prevalence of 15.2 %. There were no parasites detected at the buffy coat region.

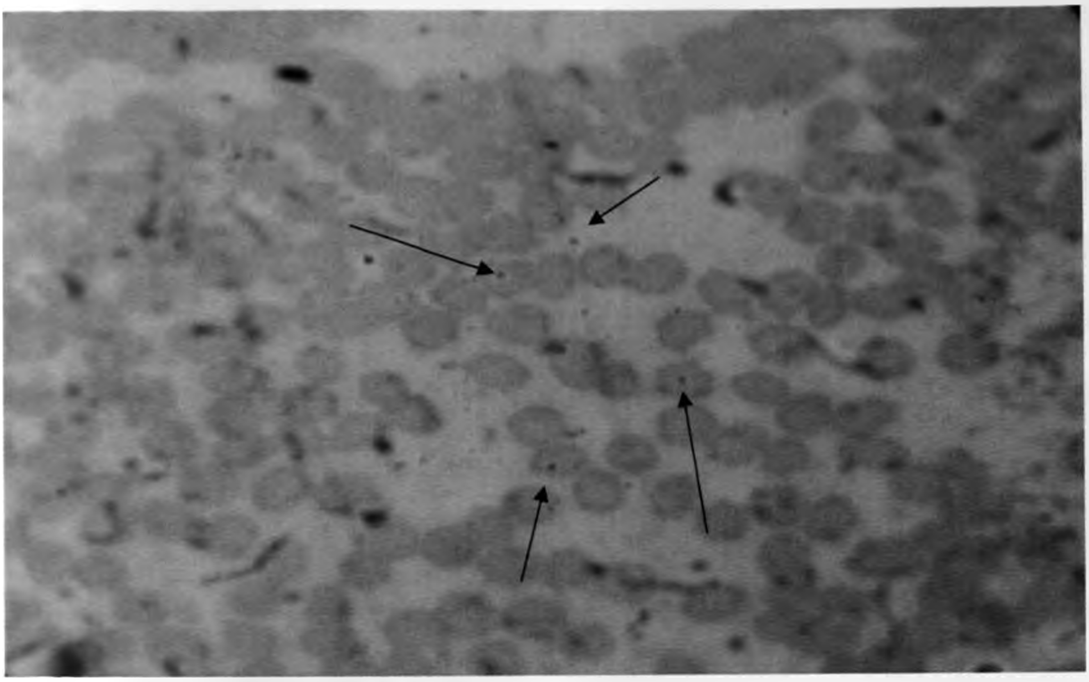


Figure 9. Giemsa stained blood smear showing *Mycoplasma suis* organisms in red blood cells and free in plasma (arrows). Magnification: X1000

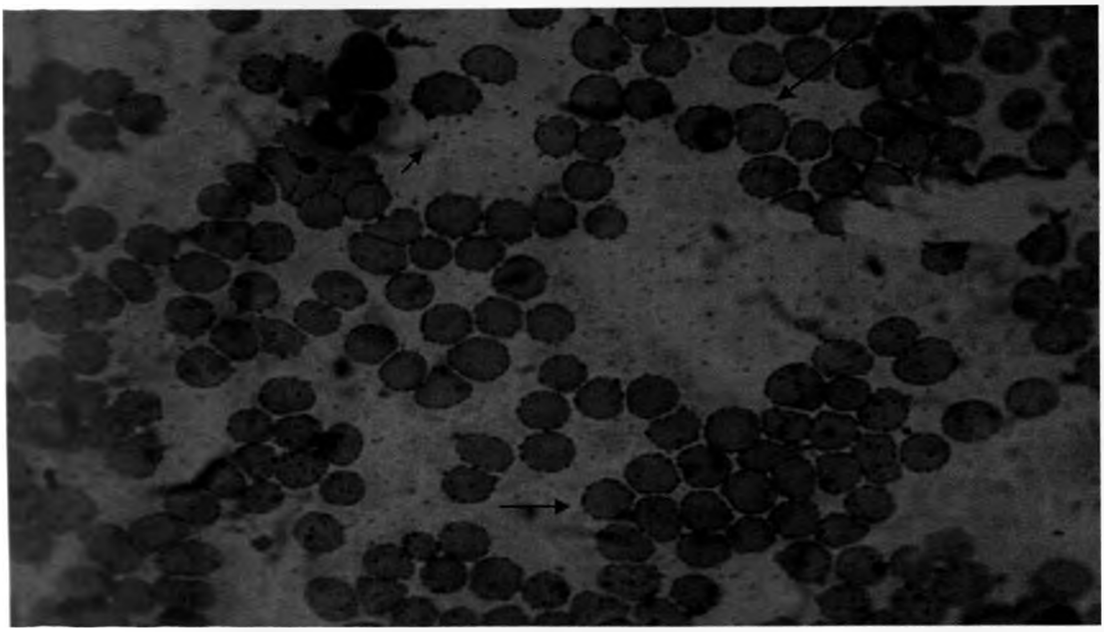


Figure 10. Giemsa stained blood smear showing *Eperythrozoon parvum* organisms on the surface of red blood cells and free in the plasma (arrows). Magnification: X1000

Animals parasitized with *Mycoplasma* (*Eperythrozoon)* spp recorded a lower mean PCV (41.1%) than non parasitized animals (41.7%) but no significant ($p > 0.05$) difference was noted between the mean PCVs of parasitized and non parasitized animals. For the animals infected with *Mycoplasma* (*Eperythrozoon)* spp, piglets recorded the lowest mean PCV (38.3%) while the highest mean PCV was recorded in finishers (41.5%) and adults (41.5%) (Table 6). Significantly higher mean PCV was recorded in growers than in piglets ($p = 0.039$). Similarly, significantly higher mean PCV was recorded in finishers than in piglets ($p = 0.039$).

Table 6. Mean PCV per age category for *Mycoplasma* (*Eperythroozoon)* spp infected and non- infected pigs in Homabay District

Age category	*Mycoplasma(Eperythrozoon)* spp	Number examined	Mean PCV (%)
Piglets	Infected	2	38.3
	Non-infected	16	43.0
Growers	Infected	29	40.1
	Non-infected	67	41.0
Finishers	Infected	22	41.5
	Non-infected	28	42.5
Adults	Infected	72	41.5
	Non-infected	138	42.5

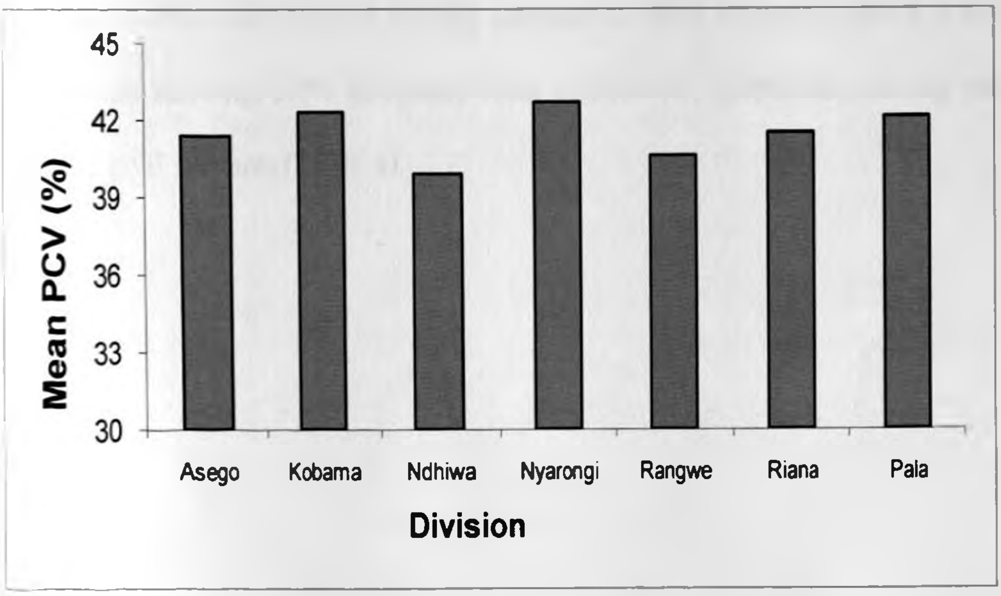
Females recorded lower mean PCV (41.4%) than males (41.6%). Also, females infected with *Mycoplasma* (*Eperythrozoon)* spp recorded lower mean PCV (41.0%) than males (41.7%) (Table 7). No significant ($p > 0.05$) difference was noted between the mean PCVs of males and females.

Table 7. Mean PCV per the sex category for *Mycoplasma* (*Eperythrozoon)* spp infected and non-infected pigs in Homabay District

Sex	***Mycoplasma(Eperythrozoon)* spp**	**Number examined**	**Mean PCV (%)**
Male	Infected	39	41.5
	Non-infected	86	41.7
Female	Infected	86	41.0
	Non-infected	163	41.7

Nyarongi Division recorded the highest mean PCV (42.7%) while Ndhiwa Division recorded the least mean PCV (39.9%) (Fig. 11). Due to great variation in the number of animals sampled in the divisions, further statistical evaluation of the divisions was not carried out.

Fig 11. Overall mean PCVs of pigs in various divisions of Homabay District



4.4 Questionnaire Survey

4.4.1 Household information

Out of the 297 farmers interviewed, 65.3% were females while 34.7% were males. The mean age of the farmers was 40.78 years with a range of 12-88 years. Formal education had been attained by 78.1% of the farmers. The level of education for the majority was low with 67.7% of the farmers having only gone to primary school, 9.4% having attained secondary school education while only 1.0% had obtained college education. Most of the farmers (79.8%) obtained their income from farming, 5.4% had some form of business, 2.4% both farming and business while 0.7% was civil servants (Table 8).

Table 8. Household information of the pig farmers in Homabay District

Variable	Number	Percentage
Gender		
Male	103	34.7%
Female	194	65.3%
Level of education		
None	65	21.9%
Primary School	201	67.7%
High School	28	9.4%
College level	3	1.0%
Occupation		
Farmer	237	79.8%
Business	16	5.3%
Farming and business	7	2.4%
Civil servant	2	0.7%
Others	35	11.8%

4.4.2 Pig production and management practices

Table 9 shows the pig production and management practices by farmers in Homabay District. Most of the farmers (56.2%) had kept pigs for less than 1 year, 24.2% had kept pigs between 1 to 5 years and 19.5% of the farmers had kept pigs for more than 5 years. Majority (98.0%) of the farmers kept non-descript types of pigs (Fig. 12) with only 2.0% keeping cross-breed (mainly local breeds and land race or large white) types of pigs

Fig 12. Some types of pigs kept by farmers in Homabay District

Pigs were mostly kept for the purposes of sale for slaughter at the butchery (83.2%), with 9.4% being kept for slaughter and breeding and 6.1% for slaughter and home consumption. Only 0.7% of the farmers kept pigs for breeding. The main system of rearing pigs was tethering and was mostly done during the crop planting (98.6%), growing (99.3%), harvesting (99.0%) and fallowing (86.5%) seasons. Pigs were tethered around the homesteads. The tether ropes were weak and had formed wounds on the legs of the tethered pigs. Only 0.7% of the farmers confined their pigs in a pen while 12.8% allowed their pigs to free range during the fallowing season.

Table 9. Pig production and management practices by farmers in Homabay District

Variable	Number	Percentage
Kept pigs		
Less than 1 year	167	56.2%
1-5 years	72	24.2%
More than 5 years	58	19.6%
Type of pigs		
Cross breed	6	2.0%
Non-descript	291	98.0%
Reasons for keeping pigs		
Home slaughter for consumption	2	0.7%
Sale for slaughter	247	83.2%
Breeding	2	0.7%
Sale and slaughter for home consumption	18	6.1%
Sale and breeding	28	9.3%
How pigs are kept		
Planting season		
In a pen	2	0.7%
Free range	2	0.7%
Tethering	293	98.6%
Growing season		
In a pen	2	0.7%
Free range	0	0.0%
Tethering	295	99.3%
Harvesting season		
In a pen	2	0.7%
Free range	1	0.3%
Tethering	294	99.0%
Fallowing season		
In a pen	2	0.7%
Free range	38	12.8%
Tethering	257	86.5%

4.4.3 Types of feed given to pigs

Table 10 shows the types of feed given to pigs by farmers in Homabay District. The most common type of feed given to pigs was a mixture of kitchen leftover and pastures (40.7%). Pastures included various grasses, weeds and shrubs. The remainder of the feeds included mixtures of Machicha (brewers waste), cooked sweet potato tubers, sweet potato vines, flour (unga), guavas, pawpaw and cassava. None of the farmers supplemented their pigs with commercial feeds.

Table 10. Types of feed given to pigs by farmers in Homabay District

Feed type	Number	Percentage
Kitchen left over + Pasture	121	40.7%
Kitchen left over + Pasture + Sweet Potato tubers	98	33.0%
Kitchen left over + Pasture + Guavas	20	6.8%
Kitchen left over + Pasture + Sweet potato vines +Guavas	19	6.4%
Kitchen left over + Pasture + Sweet potato +Sweet potato vines	10	3.4%
Kitchen left over + Pasture + Sweet potato vines	8	2.7%
Kitchen left over	6	2.0%
Kitchen left over + Pasture + Machicha	4	1.3%
Pasture + Sweet potato tubers + Guavas + Cassava tubers	4	1.3%
Kitchen left over + Pasture + Flour	2	0.7%
Kitchen left over + Pasture + Pawpaw	2	0.7%
Pasture + Flour (left over from posho mill)	2	0.7%
Kitchen left over + Sweet potato tubers + Flour	1	0.3%

4.4.4 Importance of worms infestation and clinical signs in pigs

Intestinal worms infestation was considered to be of importance by 34% of the farmers (Table 11) while 66% of the farmers did not know that intestinal worms infestation was of importance. Most of the farmers (79.1%) could not recognize pigs infected with intestinal worms. A few farmers (14.5%) could identify worm infestation by observing poor growth rate while 6.4% based their observation on distended abdomen. Most of the farmers (81.8%) did not seek advice on pig farming while only 16.0% sought advice from extension officers.

Table 11. Importance of worm infestation, clinical signs and source of advice on pig farming

Variable	Number	Percentage
Importance of intestinal worm infection		
Important	101	34%
Not important	196	66%
Clinical signs of worm infection		
Do not know	235	79.1%
Distended abdomen	19	6.4%
Poor body condition	43	14.5%
Source of information on pig farming		
Other farmers	4	1.3%
Extension officers	48	16.2%
Others	2	0.7%
None	243	81.8%

4.4.5 Parasite control

Few farmers (20.5%) dewormed their animals with 11.4% preferring to use piperazine, 8.8 % using levamisole while 0.3% used herbal medicine (concotions of different plants). With regard to the frequency of deworming, 7.7% of all the farmers dewormed their animals irregularly, 6.7% every one month, 3.7% after every 3 months and 2.4% after 1-2 months (Table 12).

Table 12. Parasite control strategies in pigs by farmers in Homabay District

Treatment for worms	Number	Percentage
Yes	61	20.5%
No	236	79.5%
Drugs used for deworming		
Piperazine	34	11.4%
Levamisole	26	8.8%
Others(herbal)	1	0.3%
None	236	79.5%
Frequency of deworming		
None	236	79.5%
Every 1 month	20	6.7%
Every 1-2 months	7	2.4%
Once every three months	11	3.7%
Irregular	23	7.7%

CHAPTER FIVE: DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion

This study indicated a high prevalence and low to moderate levels of infections with helminths of pigs in Homabay District. The overall prevalence (83%) reported in this study is comparable to the 84.2% reported by Kagira (2010) in free range pigs in Busia District in Western Province of Kenya which neighbours Nyanza Province. However, the prevalence recorded in the present study is higher than that reported previously in the country by Ng'ang'a *et al.* (2008) on the outskirts of Nairobi, Wabacha *et al.* (2004) in Kiambu District and Kagira *et al.* (2002) in Thika District who reported prevalence's of 67.8%, 43.5% and 39.0% respectively. The higher prevalence recorded in this study may be due to the fact that it was based on outdoor pigs in which poor management and husbandry is associated with higher prevalence of helminths as compared to their studies which were mainly based on indoor pigs in which improved management is associated with lower helminth prevalence (Roepstorff and Nansen, 1998). The high prevalence recorded in this study is in agreement with reports from outdoor pigs in Nigeria (Ajayi *et al.*, 1988), Ghana (Permin *et al.*, 1999), China (Boes *et al.*, 2000), Burkina Faso (Tamboura *et al.*, 2006) and Uganda (Nissen *et al.*, 2011) in which prevalence's of 97%, 91%, 95.9%, 93% and 91% were respectively reported. In outdoor pigs kept in India (Yadav and Tandon, 1989), Botswana (Nsoso *et al.*, 2000) and Zimbabwe (Marufu *et al.*, 2008) and indoor pigs kept in Tanzania (Esrony *et al.*,1997), lower prevalence's of 68.4%, 52%, 58.7% and 53% were respectively reported. The differences in the prevalence's may be due to the differences in climatic conditions and management systems in the study regions. Results from the present study and those of Kagira (2010) indicate that helminths are highly prevalent in pigs kept under the free range system in Kenya.

Most of the animals examined were found to excrete low to moderate number of eggs. This indicates sub-clinical infections which are the most important form of infection since they are associated with economic losses such as decreased litter sizes, poor growth rates and reduced weight gain (Marufu *et al.*, 2008; Adebisi, 2008). The results therefore mean that nematode infections may be one of the contributing factors to low productivity of pigs in the study area.

The species spectrum of worms identified in this study has been reported before in indoor and outdoor reared pigs in Kenya (Langat, 1999; Kagira *et al.*, 2002; Wabacha *et al.*, 2004; Ng'ang'a *et al.*, 2008) and Kagira, (2010). However, *Oesophagostomum quadrispinalatum*, *Trichostrongylus colubriformis* and *Ascarops strongylina* which were reported by Ng'ang'a *et al.* (2008) and *Globocephalus urosubulatus* reported by Kagira (2010) were not identified in this study. This may be attributed to different bionomic characteristics of these helminth species.

Most of the pigs examined were infected with Strongyles (Family *Trichostrongylidae*) of which 74% were infected with *Oesophagostomum* spp. This finding is in agreement with other reports which have found *Oesophagostomum* spp to be the most common in most pig farms (Esrony *et al.*, 1997; Boes *et al.*, 2000; Marufu *et al.*, 2008; Ng'ang'a *et al.*, 2008; Kagira, 2010; Nissen *et al.*, 2011). The prevalence of *Oesophagostomum* spp reported in this study is comparable to

74.8% reported by Kagira (2010) in Busia District, Western Kenya but higher than 70% reported in outdoor reared pigs in Nigeria (Ajayi *et al.*,1988), 60.6 % in Ghana (Permin *et al.*,1999) and 54.6% in Zimbabwe (Marufu *et al.*, 2008). This prevalence is lower than 79.8% reported in indoor reared pigs in Denmark (Roepstorff and Jorsal, 1990) and 86.7% reported in outdoor reared pigs in China (Boes *et al.*, 2000). The differences in the prevalence in these studies may be attributed to the differences in the production systems which has significant influence on the environment and hence the development and survival of the free living stages. In pigs kept under the intensive indoor conditions, improved husbandry conditions such as high levels of hygiene and aggressive chemotherapy reduce the levels of infection with helminths. On the other hand, there is high parasite prevalence in pigs kept under the traditional production system where poor husbandry allows for the continuous proliferation of parasites in the environment. The high prevalence of *Oesophagostomum* spp is attributed to the fact that its transmission is favoured by the high egg excretion rate of the parasite and humid and unhygienic conditions which are common under the outdoor production system (Nansen and Roepstorff, 1999; Ng'ang'a *et al.*, 2008; Nissen *et al.*, 2011). Heavy infections with this parasite has been associated with diarrhoea, weight loss, anorexia and secondary infections that may even lead to death hence economic loss (Corwin *et al.*,1986).

Ascaris suum had a prevalence of 5.4% with the highest prevalence of infection being recorded in Rangwe Division. This prevalence is lower than 12% reported in indoor reared pigs by Esrony *et al.* (1997) and 12.7% (Permin *et al.*, 1999), 36.7% (Boes *et al.*, 2000), 17.6% (Kagira, 2010) and 40% (Nissen *et al.*, 2011) recorded in outdoor reared pigs. The highest prevalence recorded in

Rangwe Division may be due to the high rainfall in this division compared to other parts of the district. Re-infection levels of *Ascaris* spp have been found to be strongly corelated with the amount of rainfall, temperature as well as the number of wet days (Gunawardena *et al.*, 2004). Another probable reason for the high prevalence in this division is that most of the pigs sampled were growers and *A. suum* is known to mostly affect growers (Roepstorff and Nansen, 1998). In this study, growers recorded the highest prevalence of infection with *A. suum* and piglets did not record any infections with this parasite. This is contrary to the report by Kagira (2010) in which piglets recorded the highest prevalence of infection with *A. suum* while growers recorded the least prevalence. This could be explained by variations in the age of the piglets sampled. In the study by Kagira (2010), the piglets could have been quite old, thus allowing *A. suum* to complete the life cycle and start laying eggs. Low levels of infection with *A. suum* have been found to depress feed intake with concomitant increase in maintenance cost and at higher levels of infection, depression in feed conversion has been reported (Stewart and Hoyt, 2006). Losses from condemnation of organs at slaughter and lowered performance in pigs have also been reported (Stewart and Hale, 1988).

Trichuris suis was observed to have a prevalence of 7.8%. This is comparable to 7% reported in outdoor reared pigs by Kagira (2010) in Busia district, Kenya but higher than 4.6% reported in Ghana (Permin *et al.*, 1999) and 4.2% in Zimbabwe (Marufu *et al.*, 2008). A higher prevalence of 15.8% and 17% were reported by Boes *et al.* (2000) and Nissen *et al.* (2011) in outdoor reared pigs in China and Uganda respectively. This variability in the prevalence may be explained by the effect of environmental conditions on the development of *T. suis* eggs. The eggs are more susceptible to dehydration and high temperature thus many eggs are killed during the dry period (Pittman *et al*., 2010). Infections with *T. suis* can cause diarrhoea, anorexia, anaemia, poor growth, emaciation and dehydration but severity is usually related to the infective dose or concurrent bacterial infections (Pittman *et al*., 2010).

Strongyloides ransomi recorded a prevalence of 26.6% which is lower than 35.7% reported in indoor reared pigs in USA (Morris *et al*., 1984) and 36.6% in outdoor reared pigs in Busia district, Western Kenya (Kagira, 2010). This prevalence is higher than 9% reported in indoor reared pigs in Tanzania (Esrony *et a*l., 1997) and 2.3% in Kenya (Kagira, 2001) and 1.7% in outdoor reared pigs in Ghana (Permin *et al*., 1999)). The differences in the prevalence may be attributed to the differences in climatic conditions of the study areas since the survival of *Strongyloides* larvae depends on the environmental temperature and moisture. The larvae of these species are susceptible to desiccation with the dry areas providing unfavourable environment for survival of *S. ransomi* larvae ((Marufu *et al*., 2008). Even though *S. ransomi* was reported in faecal examination, it was not recovered during post mortem examination. This could be attributed to the fact that *S. ransomi* mostly affects piglets (Roepstorff and Nansen, 1994) and post-mortem examination was done in adult pigs.

The prevalence of *Metastrongylus* spp in this study was 0.3%. This is lower than 9.8% prevalence reported in outdoor reared pigs in Kenya (Kagira, 2010), 19.3% in Ghana (Permin *et al*., 1999) and 65.7% (Ajayi *et al*., 1988) in Nigeria. Although only one pig was found to excrete *Metastrongylus* spp eggs, most of the pigs were found to be infected with this parasite at postmortem. Lungworms are known to produce relatively fewer eggs and thus it is sometimes difficult to find the eggs in faeces when using the regular detection methods (Roepstorff and Nansen, 1994; Stewart and Hoyt, 2006; Kagira, 2010).

Postmortem examination revealed the presence of *Trichostrongylus axei* and *Physocephalus sexalatus* whose eggs were not detected through faecal examination. Comparing the faecal examination with the postmortem examination reveals the natural reasons differences in some parasite species and their prevalence. It is well known that coprological examinations are less sensitive compared to postmortem examination and some parasites only produce a small number of eggs (Roepstorff and Nansen, 1998; Permin *et al.*, 1999 ; Ng'anga' *et al.*, 2008). Furthermore, there is no clear correlations between egg output and worm burdens (Ng'ang'a *et al.*, 2008).

The analysis of mean Strongyle-type epg indicated that a higher percentage of pigs (68%) were excreting low epg and 29% were excreting moderate epg. Only 3% of the pigs were found to excrete high epg meaning that the overall high prevalence of nematode infection was not associated with high mean epg. This is similar to the observations of Permin *et al.* (1999) in Ghana and Tamboura *et al.* (2006) in Burkina Faso in outdoor reared pigs. In the current study, the highest level of infections with helminths was recorded in adults and the lowest level of infection recorded in pig. This may be explained by the fact that scavenging sow being exposed for a long time to nematode infestation might transfer passive immunity to their offsprings (Tamboura *et al.*, 2006). The high prevalence of parasites in adults than in piglets is due to the fact that a huge percentage of the parasite was *Oesophagostomum* spp whose prevalence is highest in adults. Prevalence rates as well as the infection intensities of the most common helminth species in different age groups of pigs in traditional herds are strongly influenced by the immunogenicity of individual helminth species (Roepstorff and Nansen, 1994). Adults recorded the highest intensity of infection with *Ascaris suum. Ascaris suum* has been shown to be the most prevalent in growing pigs but adult pigs have the highest intensity of infection (Nansen and Roepstorff, 1999). On the other hand, piglets recorded the least mean epg of infections with Strongyles which could be explained by the fact that infections with *Oesophagostomum* spp and *Hyostrongylus rubidus* are maximal in the breeding stock which is a reflection of the lower immunogenicity of these two parasites (Nansen and Roepstorff, 1999).

Age was found to have an influence on the prevalence of infection with helminths parasites in Homabay District. The lowest prevalence of helminths was recorded in adults. This may be explained by the higher immunogenicity of helminth parasites which is considered to be important in the generation of acquired immunity in older animals (Wakelin, 1984). Adult animals may acquire immunity to the parasite through frequent challenges and expel the ingested parasite before they establish infections. Infections with helminths such as *A. suum* and *Trichuris suis* usually stimulate the development of rather strong protective immune reactions so that older animals have low worm burdens (Nansen and Roepstorff, 1999; Thamsborg *et al.*, 1999; Ng'ang'a *et al.*, 2008). The findings of this study are also in agreement with those of Wabacha *et al.* (2004) in which the prevalence of Strongyles was found to differ among the age groups with the growers recording the highest prevalence and weaners recording the highest prevalence with *A. suum*. Similar observations on the influence of age on the prevalence of helminth parasites have been made by Esrony *et al.* (1997) and Kagira *et al.* (2002). However, the findings of this study contrast with those of Marufu *et al.* (2008) in which pig class did not have an influence on the prevalence of helminth parasites in pigs.

The effect of sex on the prevalence of gastrointestinal nematodes in this study was evident for Strongyles and *A. suum* with female pigs recording a higher prevalence than the males. Sex is believed to influence the level of parasitism with females being more prone to parasitism during pregnancy and peri-parturient period. This may be due to the physiological changes during this period of time that result into stress and decreased immune status (Wakelin, 1984). The results of this study contrasts with those of Yadov and Tandon (1989) in which no sex related incidence on the prevalence of parasites was observed. It also contrasts with Kagira (2010), where male pigs had higher prevalences than females.

Riana and Ndhiwa Divisions recorded higher intensity of infections with helminths than Pala Division. This may be attributed to the effect of climate on the survival and development of infective stages of parasites (Esrony *et al.*, 1997). Riana and Ndhiwa divisions receive a higher amount of rainfall which may have provided suitable conditions for the eggs to hatch and develop to L_3 hence increased levels of infection. In contrast, Pala division receives a low amount of rainfall. This may have made the helminth eggs in this division susceptible to desiccation and fail to hatch to L_3. The differences in the prevalences in the divisions could also be due to the differences in the number of pigs sampled in these divisions.

There was no association between housing, deworming frequency and the type of feed and the prevalence of parasites in the study area. This is contrary to reports by Roepstorff and Jorsal (1990) and Kagira (2001) in which the prevalence of parasites in indoor kept pigs was associated with management factors such as dewoming frequency. The lack of association between these factors and the prevalence of helminths may be explained by lack of protein supplementation, lack of housing in most of the farms visited and the low number of farmers deworming their animals which is common under the extensive production system (Esrony *et al.*, 1997).

Information on the status of haemoparasites in pigs in Africa is rather limited but the findings of this study are in agreement with those of Dipeolu *et al.* (1982) in Nigeria in which *Mycoplasma suis* was found to be the most predominant species. However, *Babesia* spp which was reported in the Nigerian study was not recorded in this study. The overall prevalence reported in this study is lower than that reported in outdoor and indoor reared pigs in Nigeria (81%) by Dipeolu *et al.* (1982) but higher than that reported in outdoor reared pigs in Ghana (23.3%) by Permin *et al.* (1999). The differences in the prevalence in these studies may be explained by differences in the management systems and eco-climate (Kokan, 1995).

The haematological reference ranges for domestic pigs are variable and provide limited information about differences associated with breed, sex, age and reproductive status of the pigs. In this study, piglets recorded the lowest mean PCV with the difference in the mean PCV being significantly lower than in growers and finishers. This may be attributed to the severity of infection with *M. suis* in piglets. *Mycoplasma suis* adheres to the outer membrane of red blood cells, deforming and damaging them. Damaged red blood cells are subsequently removed from the circulation or may undergo intravascular lysis resulting in anaemia and the effects are more severe in piglets (Kauffman, 1996). Chronic infections in animals with low or undetectable numbers of parasites result in unthriftiness, pallor and occasionally hypersensitivity. Chronic infections have also been associated with decreased reproduction resulting in sows with anestrus, delayed estrus, early embryonic deaths and abortions (Guimaraes *et al.*, 2011). In all cases, secondary bacterial infection or viral infections, poor management including overcrowding, poor environmental conditions and the presence of parasites contribute to the severity of the disease associated with *E. parvum* (Thacker, 2006). Treatment of *M. suis* involves the detection of carriers and injection of sick pigs with drugs such as long-acting oxytetracycline. Control measures involve adequate control of ectoparasites such as *Haematopinus suis* by application of therapeutic agents in the form of sprays, pour-ons and dusting powders to the pigs (Jiansan *et al.*, 2006).

Homabay District is an area known to be endemic for both Human African Trypanosomiasis (HAT) and Animal African Trypanosomiasis (AAT) and the presence tsetse vectors for *Trypanosoma brucei rhodosiense* and other trypanosoma agents for AAT have been reported (Grady *et al.*, 2011) but trypanosomes were not detected in this study. This may be attributed to the low sensitivity of the parasitological methods used in the current study for detection of trypanosomes. A discussion with the relevant veterinary authorities (Dr. Wafula, Personal communication) revealed that Homabay District is under the Pan African Tsetse and Trypanosomiasis Eradication and Control (PATTEC) Kenya National programme which is involved in the control and eradication of tsetse flies in Trypanosomiasis endemic areas and that cases of animal trypanosomosis were on the decline. This may be another reason as to why trypanosomes were not detected in this study since even in the neighboring Western province, a low prevalence of trypanosomes of 21.3% (Ng'ayo *et al.*, 2005) and 0.3% (Kagira, 2010) was reported in Busia District (also under the PATTEC programme) using the polymerase chain reaction (PCR) method which is more sensitive than the parasitological method used in this study.

In the present study, majority of the pig farmers (65.3%) were females with the rest of the farmers being males. This is similar to the findings of Mutua *et al.* (2010) in Kakamega District and Kagira *et al.* (2010b) in Busia District, Western Kenya in which women were identified to take the leading role in the management of the family pig. The results of this study are also consistent with the findings of Nsoso *et al.* (2006) in Ramotswa village, Botswana in which most of the pig farmers (75%) were females. However, the results of the current study contrast with the findings of Nsoso *et al.* (2004) in southern Botswana in which 75.6% of the farmers were males. Women play important roles in both domestic and economic life (Mutua *et al.*, 2010). Men rarely stay at home and cannot therefore be entrusted with the intensive responsibility of managing the pigs. The level of education for the majority of the farmers was low with 67.7% of the farmers having only gone up to primary school. The low level of education is of concern because it could limit the awareness of the farmers on aspects of pig production and management. Gender and level of education would be important considerations in any projects involving technology transfer in pig production in the district.

Tethering was the most preferred way of confining pigs and was mostly done during the crop planting, growing and harvesting seasons to protect the crops from the scavenging and rooting behaviour of the pigs. This was consistent with the findings of other studies in Ghana (Permin *et al*., 1999) and Western Kenya (Githigia *et al*., 2005; Kagira *et al*., 2010) but contrast with the findings of Mutua *et al*. (2010) in Western Kenya where farmers were reluctant to tether their pigs because of the belief that tethering denies pigs exercise which was believed to be crucial for pigs' healthy development. Most of the farmers did not house their pigs in pens. These findings are consistent with those Nsoso *et al*. (2004) and Githigia *et al*. (2005) where a similar phenomenon was reported. Pigs which are not housed are in constant contact with soil because of their rooting behaviour which increases the uptake of infective parasite eggs and larvae as well as intermediate hosts hence increased worm burdens. Although the pigs' scavenging behaviour has been shown to have clear nutritional benefits (Lekule and Kyvsgaard, 2003), housing should be encouraged to increase productivity and safeguard the public from diseases of public health importance and African swine fever.

In the current study, pigs were mostly fed on kitchen left over and pasture (grass, weeds and shrubs) with no supplementation. Pigs kept under the traditional management systems which are characterized by low inputs are poorly supplemented or they are not supplemented with commercial feeds (Nsoso *et al*., 2006; Kagira, 2010; Nissen *et al*., 2011). This has been linked to the high cost of feeds (Wabacha, 2001; Kagira, 2001) with the farmers resorting to giving pigs locally available and cheap feeds. Studies have shown that feeding pigs on different kinds of residues under the free range system is more viable than supplementation with commercial feeds under the intensive system (Lekule and Kyvsgaard, 2003). Poor nutrition lowers the resistance of the animal to infections thus enhancing the establishment of worm burdens and increasing their pathogenicity. Consequently, worm burdens tend to be higher in poorly fed than in well fed animals. Therefore, information on the quality and use of locally available feed materials in the study area needs further exploration.

Most of the farmers in the current study did not seek advice on pig management and production and majority did not know the importance of worm infestation. These findings are in agreement with those of Mutua *et al.* (2010) in Kakamega District, Western Kenya where farmers were not aware that pigs could be treated and could not identify common pig diseases. Also, in the current study, few farmers dewormed their pigs and for those who did, only 3.7% dewormed after every three months. This may be explained by the low level of education which limits the awareness of the farmers on the need to improve on management and increased productivity of the pigs. The findings of this study contrasts with those of Kagira *et al.* (2010) in Busia District in which farmers appeared to have a relatively good knowledge of clinical signs associated with worm infestation. The relatively good knowledge of worm infestation reported by Kagira *et al.* (2010) may be attributed to the awareness created by earlier research projects in Busia District. Deworming, even in the 3.7% did not have an effect on prevalence (epg). This may be due to underdosing of the animals by the farmers. Anthelmintic treatment reduces the prevalence and severity of helminth infections and may significantly influence their epidemiology. Consequently, worm burdens tend to be higher in animals under the free range system with no anthelmintic treatment than in animals treated routinely with anthelmintics. Routine deworming of free range pigs is essential to avoid parasite build up.

5.2 Conclusions

1. Helminths are highly prevalent in free range pigs in Homabay District with low to moderate levels of infection.
2. Pigs in the study area are infected by a wide variety of nematodes that include; *Oesophagostomum dentatum, Hyostrongylus rubidus, Trichostrongylus axei, Strongyloides ransomi, Ascaris suum, Trichuris suis, Metastrongylus pudendodectus,* and *Physocephalus sexalatus.*
3. Prevalence and levels of infection with helminths in the district was associated with age, sex and division of origin of the pigs.
4. Haemoparasites identified in pigs in the district include *Mycoplasma suis* and *Eperythrozoon parvum.*

5.3 Recommendations

1. Farmers should be encouraged to improve on management, husbandry practices and productivity of pigs in the study area.
2. There is need for control of helminths and control measures should integrate better nutrition with anthelmintic treatment.

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Appendix 1

QUESTIONNAIRE FORMAT USED IN THE STUDY

Last name: ____________________ First name: ______________________________
Questionnaire number: _____________________
District: ________________________________ Division: ___________________________
Location: ______________________________ Sublocation _____________________
Village ______________________ Hut (House) number: ______________________
How long have you lived in this village? _____ Yrs

1. How old are you? _________ years

1.1. Sex = Male = Female

1.2. What is the highest schooling grade you have completed?

= None = Primary School

= College level = High School

1.3. What is your occupation? _____________

= Farming = Business = Farming & business = Civil servant = Others

2. Have you ever owned pigs? (If they answer "yes", ask when they owned the pigs)

= Less than 1 year = Yes 1 to 5 years ago

= Yes more than 5 years ago = No

2.1. What kind of pigs were they?

= Cross breed = Non descript

= Both cross breed and Non descript = I don't know

2.2. Of the pigs that you have, how many are for? (*Read each choice and record the number*)

Home slaughter for consumption____________ Sale for slaughter_____________

Breeding_________________ Sale and slaughter for home consumption______

Sale and breeding______________

2.3. Other animals owned by the household

Cattle: ____ Poultry (specify):_______ Sheep: ______

Goats: _____ Donkeys: _____ Others (specify):_______

3. Where do you get your drinking water?

= River = Bore-hole

= Well = Other (please specify) __________

3.1 Do you boil your drinking water?

= Always = Almost always

= Sometimes = Never

4. What clinical signs do pigs have when they are infected with intestinal worms?

= Do not know = Distended stomach = Poor body condition

5. Where do you get information on pig keeping?

= Other farmers = Extension officers = Others = None

6. Do you treat pigs for worms?

= Yes = No

7. If yes, which drugs are used?

= Piperazine = Levamisole = Benzimidazoles = Herbal = Others

8. How often do you deworm the animals?

= Every one month = every 1- 2 months = Once every 3 months = irregularly = None

9. What is the main economic activity?

= Farming__________ = Trading_______ = Fishing______ = Others (specify) ___________

THIS IS THE END OF THE INTERVIEW. THANK YOU VERY MUCH FOR YOUR CO-OPERATION!

INTERVIEWER: ___________________________DATE OF INTERVIEW: ________________

Appendix II

a) Actual egg counts in various age groups and sex of pigs from Homabay District

	Age group				**Sex**	
Parasite	Adults (n = 210)	Growers (n = 96)	Finishers (n =50)	Piglets (n = 16)	Male (n = 124)	Female (n =248)
Strongyles	48,000	56,100	25,300	700	26,000	89,700
***Strongyloides* spp**	160,800	46,100	7,300	7,500	22,000	33,700
***Trichuris* spp**	30,600	1,900	2,800	200	2,100	4,200
***Ascaris* spp**	7,100	2,100	1,200	0	1,300	14,0600

b) Actual egg counts for pigs from various divisions of Homabay District

Division	Parasite			
	Strongyles	*Strongyloides* spp	*Trichuris* spp	*Ascaris* spp
Riana	104.000	71.500	6,700	2,900
Rangwe	800	0	1,800	6.400
Ndhiwa	25,700	4,700	600	100
Pala	39,000	18.800	800	1,200
Kobama	1,000	0	0	0
Nyarongi	3,100	500	100	0
Asego	600	0	0	0