PREVALENCE, INTENSITY AND PATHOLOGY OF ECTO AND HAEMOPARASITES INFECTIONS IN INDIGENOUS CHICKENS IN EASTERN PROVINCE OF KENYA

A THESIS SUBMITTED IN PARTIAL FULFILLMENT FOR AWARD OF THE DEGREE OF MASTER OF SCIENCE IN APPLIED VETERINARY PARASITOLOGY

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DECLARATION

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

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DEDICATION

Dedicated to my loving parents Benjamin Muchanja Sabuni and Agnes Indombo Lucheli, my brothers; Evans, Angatia and Eliud, and my sisters; Anne, Lilian and Sheilah.

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LIST OF ACRONYMS

ANOVA	Analysis of variance
DPX	Destrene 80 dibutylphthalate and xylene
EDTA	Ethylenediaminetetraacetic acid
IPM	Integrated pest management
KOH	Potassium hydroxide
LH1	Lower highland 1
LM5	Lower midland 5
MAFF	Ministry of Agriculture Food and Fisheries
NLPD	Nairobi Province Livestock Division
WP	Wet powder
S	Suspension
F	Firkin
D	Dram
Oz	Ounce
gal	gallons
Ib	Pounds
EC	Emulsion Concentration
sq ft	Square feet
qt	quart

ABSTRACT

Indigenous chickens constitute over 81% of poultry in Kenya and produce 71% of eggs and poultry meat. Ecto- and haemoparasites limit production of these birds in the rural areas. However, no previous studies have been carried out in Kenya to determine the prevalence and intensity of infection with these parasites and their effect on the host. The aim of this study was to determine the type and prevalences of ecto- and haemoparasites; and association, intensity and pathology caused by the ectoparasites affecting different ages and sex groups of free range indigenous chicken from two agro ecological zones: Lower highland 1 (LH1) in Embu District and Lower Midland 5 (LM5) in Mbeere District in Eastern Province, Kenya.

A total of 144 indigenous chickens with matching for age, sex and agro ecological zones were purposively randomly selected and purchased from smallholder farms and transported alive in cages to the laboratories at the University of Nairobi, Kabete for examination. Thorough physical and postmortem examination was performed on the birds with emphasis on the cutaneous system. Three blood smears were prepared from each bird, processed and examined for haemoparasites. Body, head and leg skins were examined and identified parasites quantified. Skin tissues were collected for histopathology, processed and examined for lesions. Data was managed using Ms excel and analyzed with Genstat® Statistical package.

One thirty eight chickens (95.8%) had one or more types of ectoparasites, namely; lice, mites, fleas and soft ticks. One thirty one birds had lice, 107 mites, 42 sticktight fleas and 8 had soft ticks. Of the 138 infested birds, 25 had single while 113 had mixed infestations. Lice were the most prevalent parasites. The study has documented *Epidermoptes* species, *Laminosioptes cysticola* and *Megninia* species for the first time in Africa as well as *Lipeurus caponis* and *Goniodes gigas* in Kenya. All adult birds were infected with ectoparasites followed by 97.7% grower and 89.6% chicks. Both male and female birds had the same prevalence (95.8%) of ectoparasites. Lower midland 5 had a slightly high prevalence of ectoparasites (98.6%) compared to LH1 (93.1%) ($p > 0.05$). Parasite intensity in chickens was significantly ($p < 0.05$) different among age groups and between agro-ecological zones, but not between sexes of birds.

Of the 144 birds examined, 79.2% were infected with haemoparasites, with 62.3% single and 37.7% mixed haemoparasitic infestations. *Plasmodium gallinaceum* was the most prevalent haemoparasite (53.5%) followed by *Leucocytozoon schoutedeni* (52.1%) and *Hemoproteus* spp., (3.5%). Grower birds had a prevalence of 83.3% for haemoparasites compared to 81.3% of adults, and 72.9% of chicks ($p > 0.05$). Male birds had 83.3% prevalence, while female birds had 75.0% ($p > 0.05$). LH1 was found to have a slightly high prevalence of 81.9% compared to LM5, 76.4% ($p > 0.05$). *Hemoproteus* spp were isolated in chickens from LH1 and but not from LM5.

Gross and microscopic lesions in the skin were observed in 94 and 129 birds, respectively. Gross lesions were observed on 24.3% chicken heads, 31.9% body and 43.8% leg skins. The gross lesions comprised of hyperemia, edema, skin desquamation, superficial necrotic wounds, pitting ulcers at the tip of skin nodules and feather loss. Microscopic lesions were observed in 36.1% of head skin, 89.6% of body skin and 55.6% of leg skin. These lesions were characterized by congestion, haemorrhages, pressure atrophy due to parasites, hyperkeratinization, parakeratosis, epidermal ruptures, cellular infiltrations with heterophils involving deeper layers of the skin and necrosis. Head lesions differed among the bird's age groups, between sexes and agro ecological zones ($p< 0.05$). Body lesions varied among chickens of different age groups and birds with lesions in different zones ($p< 0.05$). Gross leg lesion varied among age groups and between infected birds in different agro-ecological zones ($p< 0.05$).

In conclusion, there is a high prevalence of both ecto- and haemoparasites, as well as high intensity of ectoparasites in free range indigenous chickens in the study area. Severe ectoparasitic infestations was associated with significant pathology in the birds. Further study to determine the impact of infestation on the health and productivity of these birds, and evaluation of cost benefit of various control strategies need to be investigated.

CHAPTER ONE

1.0 INTRODUCTION

In Kenya, the livestock sector contributes 23% of the total Gross National Product, 10% of Gross Domestic Product and accounts for over 30% of farm gate value of agricultural commodities (Kiptarus, 2005). In view of the rapidly increasing human population in Kenya resulting in high demand for food and a decrease in land available for agriculture, food production and food security will remain priorities in the agricultural sector. To satisfy this rising demand, future development in this sector will be focused in those enterprises that require less land such as poultry production and those that result in products readily acceptable to the consumers (Kiptarus, 2005).

The most kept poultry are chickens (*Gallus spp*), ducks (*Carine spp*), geese (*Anser spp*) and turkeys (*Meleagris spp*) (Mbugua, 1990). The poultry industry in Kenya is characterized by a rapid expansion witnessed in commercial and backyard or free-range indigenous chickens production. In 1993, poultry population in the country was 21 million, which had increased to 29 million birds by 2001 and 34 million birds in 2006 (Nairobi Province Livestock Division, 2007). Of these, 81% are indigenous chicken (Njue, *et al.*, 2001; Maina, 2005).

Indigenous village chickens are always associated with free-range management systems in rural areas or as backyard flocks in urban and peri-urban areas of most developing countries. The types of feed used for this group of chickens and their feeding systems are also very typical to their group and different from those used for commercial breeds in intensive commercial farms. These chickens are however very important component in the

life of villagers or those living in the rural areas (Bebora *et al.*, 2005). In the olden days, poultry were kept for sporting, idol worshipping and sacrifices to gods, and for prestige in terms of numbers owned by the farmers. Nowadays poultry contribute to the rural employment, family nutrition ("poor man's meat") and income (sale of eggs and birds) (Maina, 2005). They also form part of cultural life of rural people in form of special dishes and are given out as gifts to visitors and relatives (Bebora *et al.*, 2005).

The overriding constraint to expansion and increased productivity of indigenous poultry is their frequent decimation by viral diseases especially Newcastle disease, ecto - endo - and haemoparasitic infections, predation, theft, other diseases (bacterial and fungal diseases) and low levels of animal health and husbandry practices resulting in high mortality rates especially in chicks. In addition, there is inadequate databases for planning, monitoring and evaluation of rural poultry programs, societal pressures that can interact in multiple ways influencing the ultimate productivity level and low knowledge base among the farmers (limited organizational abilities of smallholder farms) (Arends, 2003; Njunga, 2003).

Most studies on poultry have focused on viral diseases such as New castle disease, infectious bursal disease, fowl pox, avian influenza and marek's disease among others (Njunga, 2003). The extension messages that are developed on parasites are mainly for endoparasites while ecto- and haemoparasites have received less attention in most reports (Njunga, 2003). Pandey *et al.* (1992) reports that in an extensive management system where chicken have access to outdoor areas and are not confined, such birds do have a great

diversity of parasites. Some of the ectoparasites reported in chicken are mites, lice, ticks and fleas (Maina, 2005).

Studies carried out in Botswana (Binta *et al.,* 1996), Nigeria (Sadiq *et al.*, 2003), Malawi (Njunga, 2003) and Zimbabwe (Permin *et al.,* 2002) on free-range indigenous chicken have shown high prevalence in endo -, ecto - and haemoparasites. Adene and Dipeolu (1975) observed and recorded the association between the incidence of some blood parasites like *Aegyptinella pullorum, Plasmodium* spp and *Leucocytozoon* spp in chickens with the pressure of avian ectoparasites. These parasites are often overlooked although they are harmful to the host, as they suck blood, serve as carriers of poultry diseases and pathogens such as *Aegyptinella* spp., and *Plasmodium* spp, or act as intermediate host for a range of helminth infections such as *Heterakis gallinarum* (Permin *et al.*, 2002).

Although work on prevalence in ectoparasites has been done in Kenya (Maina, 2005; Mungube *et al.,* 2008), no studies on the intensity of ecto- and haemoparasites have previously been done in Kenya and their effect on the host has not been evaluated. It is therefore necessary to carry out a study on the intensity of ecto- and haemoparasites of indigenous chickens. Results from such studies are useful when making objective decision on control strategies to improve the health and productivity of these birds.

1.1 Objectives

1.1.1 General objective

The general objective of the study was to improve the control of ecto- and haemoparasites in indigenous chicken through establishment of the prevalence, intensity and pathology associated with ecto - and haemoparasites infections in indigenous chickens of different age and sex groups in two agro-ecological zones in Embu (Lower highland 1) and Mbeere (Lower midland 5) districts in Eastern province of Kenya.

1.1.2 Specific objectives:

The specific objectives of the study were to;

1. Determine the type and prevalences of ecto- and haemoparasites; and the intensity and pathology caused by the ectoparasites in free-range indigenous chickens in two agro-ecological zones in Mbeere and Embu districts.
2. Determine the gross, histological and clinical pathological changes associated with the ecto - and haemoparasites infections in the chickens.
3. To determine the association between age, sex and agro-ecological factors and prevalence, intensity of infection and pathology of ecto- and haemoparasites of indigenous chicken.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Poultry production in Kenya

The poultry population in Kenya is estimated to be 34 million birds. Over 81% of this population consisted of indigenous chickens, while the rest (19%) consisted of semi-commercial and commercial birds (Nairobi Province Livestock Division, 2007).

Poultry are raised under intensive production systems for exotic poultry (broilers and layers), semi - intensive production systems especially for the genetically improved birds such as crosses of local birds with Rhodes island red and light sussex; and free range system for most of family poultry (Maina, 2005). Free-range management system is common in rural areas and is the least capital-intensive production system of low input, low output farming system. Average flock size is 10-14 birds that consist of indigenous family birds (Mbugua, 1990). These birds are let free during the day and are only confined during the night. Indigenous family birds are harder than exotic breeds on free-range system where little or no food is supplemented. They have a great foraging ability, high feed conversion efficiency, but small size and low production (Bebora *et al.*, 2005). These birds are preferred because they have tasty meat and desirable egg quality, color and taste. Their products are also free from antibiotics, hormones and other harmful chemicals (Bebora *et al.*, 2005).

The local indigenous chicken produce 71% of both eggs and poultry meat, but only 10% and 40% of the eggs and poultry meat, respectively, is marketed through the open-air

market and retail shops. Marketing of these chicken produce faces constraints such as small size of output per household at irregular times, lack of market information and high marketing margins (Njue *et al.*, 2001).

2.2 Diseases and parasites of poultry

Despite its great potential and opportunities, family poultry production is precarious and permanently threatened by disease outbreaks which cause heavy mortalities. These include both infectious and parasitic diseases. Parasitic diseases appear to be a daily concern, causing little mortality but lower production. Newcastle disease occurs as outbreaks causing mortality as high as 100% (Njue *et al.*, 2001; Njagi, 2008).

2.2.1 Ectoparasites of poultry

Ectoparasites found on poultry are in the phylum *Arthropoda*, which is characterized by segmented bodies, jointed appendages and chitinous exoskeleton. The phylum is divided into two classes: the *Arachnida* with the order *Acarina* (ticks and mites) and the *Insecta* that includes the orders *Phthiraptera* (lice), *Siphonaptera* (fleas) and *Diptera* (flies and mosquitoes) (Permin and Hansen, 1998).

The *Arachnida* are characterized by having fused body segments, no antennae, three pairs of legs as larvae and four pairs of legs as nymphs or adults. Members of the class *Insecta* are characterized by a body that is divided into three regions (head, thorax and abdomen), one pair of antennae attached to the head, three pairs of legs attached to the thorax and trachea (air tubes) for breathing. Some adult insects have wings (Arends, 2003).

Ectoparasites are believed to be common in free-range systems, whereas they are usually controlled in commercial systems. These parasites may constitute a clinical problem; transmit a number of infectious diseases and can also act as transport/ intermediate hosts of a range of helminth parasites (Arends, 2003).

2.2.1.1 Insects affecting poultry

The insects that affect poultry are fleas, lice, mosquitoes and other flies.

2.2.1.1.1 Poultry lice

All species of lice that affect chicken have mouthparts adapted for chewing (*Mallophaga*). Many species of this sub order feed on the epithelial debris of the skin of the host, or on feathers of birds. In the species of the sub order *Mallophaga*, the meso- and metathorax are fused to form one piece in front of which the prothorax is a distinct and separate segment (Soulsby, 1982). Lice species affecting chicken are *Menacanthus stramineus, Menopon gallinae, Cuclotogaster heterographus, Lipeurus caponis, Goniodes gigas* and *Goniocoites gallinae.*

Menacanthus stramineus (*M. stramineus*) (body louse) is relatively large with adults about 3.5mm in length and occurs on those parts of the body which are not densely feathered like the breast, thigh and around the anus (vent). Its palps and four-segmented antennae are distinct. The abdominal segments have each two dorsal rows (dense covering) of medium-length setae (bristles). The eggs have filaments on the anterior half of the shell and on the operculum (Soulsby, 1982; Fabiyi, 1996). This louse has been reported in Nigeria (Biu *et*

al., 2007), Zimbabwe (Permin *et al.,* 2002) and Machakos in Kenya (Mungube *et al.,* 2008). It may be present in other regions of Kenya, although not documented.

Menopon gallinae (*M. gallinae*) (shaft louse) occurs largely on the body thigh and breast feathers. The adult is about 2mm in length and pale yellow in color. It has small palps and a pair of antennae, folded into grooves in the head. Its antennae have four segments and the abdomen has sparse covering of small to medium length setae (Walker, 1994; Fabiyi, 1996). It has been reported in Zambia (Lumbwe, 2002), Zimbabwe (Permin *et al.,* 2002), Nigeria (Sadiq *et al.*, 2003) and in market birds in Kenya (Maina, 2005). It is not well documented at farm level in rural areas.

Cuclotogaster heterographus (*C. heterographus*) (head louse) occurs on the head (Permin and Hansen, 1998). It has rounded body with a large round head. The adult is about 2.5mm in length. Three long bristles project from each side of the dorsal surface of the head. The abdomen is barrel-shaped in female and more elongate in the male (Smith, 2001; Fabiyi, 1996). This louse species has been reported in market birds in Kenya (Maina, 2005) and Nigeria (Sadiq *et al.*, 2003). There are no reports of it in birds at farm level in rural scavenging set ups.

Lipeurus caponis (*L. caponis*) (wing louse) is an elongated, narrow species, about 2.2mm in length and 0.3mm in width. It occurs on the underside of the large wing feathers and move about very little. The legs are narrow and, characteristically, the hind legs are about twice as long as the first two pairs. There are characteristic small angular projections on the head in

front of the antennae (Walker, 1994). *Lipeurus caponis* have been reported in Nigeria (Sadiq *et al.*, 2003). There are no reports of its occurrence in Kenya.

Goniodes gigas (*G. gigas*) are large lice, about 3mm in length and occurs on body feathers. They are brown in color. The head is concave posteriorly, producing marked angular corners at the posterior margins and carries two large bristles projecting from each side of its dorsal surface. Its antennae have five segments (Smith, 2001). *Goniodes gigas* have been reported in Nigeria (Sadiq *et al.*, 2003) and Zimbabwe (Permin *et al.*, 2002). This parasite has not been reported in Kenya.

Goniocoites gallinae (*G. gallinae*) (fluff louse) is the smallest lice found on poultry, with adult measuring 1 to 1.5mm in length. The head is rounded, carrying two large bristles that project from each side of its dorsal surface. The antennae have five segments (Walker, 1994). It has been reported in Zambia (Lumbwe, 2002) and in market birds in Kenya (Maina, 2005). Its occurrence among rural Kenya poultry is not well documented.

Life cycle of poultry lice

Lice are permanent ectoparasites, spending their entire lifecycle on their host and tend to remain on single host bird throughout their lives. They are able to survive for more than 1-2 days off their host. Eggs hatch in 5 to 7 days. Their life cycle from egg to adult is about 3 weeks (Jacob *et al.*, 2003). As many as 60 eggs are laid by adult female louse and are glued to the host feathers. A pair of lice may produce 120,000 descendants within a few months (Hogsette *et al.*, 2003).

Clinical signs and pathology

Lice while on host cause pruritus, scratching, skin excoriation, secondary feather damage (birds pluck their feathers) and irritation, which lead to self-wounding and resultant in formation of inflamed and scab covered skin. Chicken lice feed on dry scales, feathers, or scabs on the skin. As lice crawl over the bird, their mouthparts and sharp claws scratch the skin. This constant irritation causes the bird to become nervous and behave abnormally, causing a general unthriftness and unkempt appearance in the bird (Jacob *et al.*, 2003). Infestation in birds also leads to a drop in egg production, decreased hen weight; decrease clutch size and death in young birds. *Menacanthus stramineus* can cause anaemia by puncturing soft feather quills and feeding on the blood that oozes out (Jacob *et al.*, 2003). Lice are rarely linked to significant pathology. Heavy infestations may cause feather damage and irritation but more importantly, are a sign of debility and poor husbandry. They can move directly between hosts or may "hitch lifts" on hippoboscid flies (Smith, 2001).

2.2.1.1.2 Poultry fleas

Echidnophaga gallinacea (stick tight flea) is the only flea commonly affecting chicken. Adult fleas attach to the skin of the head, often around the eye in clusters of hundreds. The adult flea is small, 2mm in length and black to brown in color. Their head is sharply angled at the fronts (frons). There are no genal and pronotal ctenidia, and on the head behind antennae are two setae, and in female, a well developed occipital lobe. Thoracic segment is narrowed dorsally. Mouthparts appear large extending the length of the fore coxae and project from the head conspicuously. The maxillary laciniae are broad and coarse (Hogsette *et al.*, 2003; Wall and Shearer, 1997). They have been reported in Nigeria (Sadiq *et al.*,

2003), in market birds and some parts of Kenya (Maina, 2005; Mungube *et al.*, 2008) and Tanzania (Msanga and Tungaraza, 1985). Their distribution in different age and sex of birds; and different agro-ecological zones are not well documented at farm level in rural set-ups.

Life cycle of poultry flea

After fertilization, the female fleas burrow into the skin of the fowl, mainly on the comb, wattles and around the eyes of the birds, resulting in the formation of nodules in which eggs are laid. Hatching occurs within the nodules. The female lay up to 20 eggs at a time and about 400 – 500 during her lifetime. Larvae drop to the ground to develop in soil around chicken cages, pupating in 2 weeks. Two weeks later, adult fleas emerge from pupae and are free-living until breeding occurs. Female flea attaches herself mainly to the comb, wattles and around the eyes of birds and lay eggs to continue the cycle (Hogsette *et al.*, 2003).

Clinical signs and pathology due to flea infestation

The adult flea attaches to the skin around the face and head, causing severe irritation, nodular formation and in some cases, blindness (Jacob *et al.*, 2003). They cause blood loss, anemia and death (Hogsette *et al.*, 2003). The skin over the nodules often becomes ulcerated and young birds may die due to heavy infestations (Urquhart *et al.*, 1996).

2.2.1.1.3 Mosquitoes and flies affecting poultry

The order *Diptera* includes among others, the families *Culicidae* (mosquitoes), *Simuliidae* (black flies), *Ceratopogonidae* (midges) and *Muscidae* (house flies and stable flies). The majority irritates and sucks blood from hosts. Except for the annoyance and physical damage to setting hen and young birds, there is little clinical significance. Their great importance lies in their role as intermediate hosts or as mechanical vectors. Mosquitoes (*Aedes* spp, *Anopheles* spp, and *Culex* spp) may act as intermediate hosts for *Plasmodium* spp, but can also mechanically transfer fowl pox virus. Black and biting flies are intermediate hosts of the protozoa *Leucocytozoon* spp. Biting midges can also be vectors for fowl pox, avian infectious synovitis and *Haemoproteus* spp. The *Muscidae* may transfer Newcastle disease virus, *Heterakis gallinarum, Pasteurella multocida* and *Mycobacterium avium* to non-infected birds, and may also act as intermediate hosts for tapeworms such as *Choanotaenia infundibulum* and *Hymenolepis carioca* (Permin and Hansen, 1998).

2.2.1.2 Poultry ticks

Argas persicus (fowl tick) commonly affects chickens, turkeys, pigeons, ducks and geese in tropical and sub-tropical countries. They are found on the skin, but most of the time, the adult ticks hide in cracks or under the tree bark, away from the host. The unfed adult tick is pale yellow, turning reddish brown when fed. Female tick is about 8mm in length, while male one is 5mm. The margin of the body appears to be composed of irregular quadrangular plates or cells and the hypostome is notched at the tip (Hogsette *et al.*, 2003). *Argas persicus* have been reported in Nigeria (Sadiq *et al.*, 2003) and Zimbabwe (Permin *et al.*, 2002) and in market chicken in Kenya (Maina, 2005; Mungube *et al.*, 2008). However,

there is no documentation of a study on infestation with this tick in different chicken age group and between birds in various agro ecological zones.

Ornithodoros spp (the eyeless tampan) affects poultry and other domestic and wild animals. It causes anaemia, emaciation, weakness and slow growth. These tick species occurs in tropical and subtropical habitats. Its integument has wrinkled patterns that run continuously over the dorsal and ventral surfaces. There are no distinct lateral margins of the body, which appears sac-like. These parasites are known to transmit *Borrelia anserina* and *Aegyptinella pullorum* (Hoogstraal, 1967). There is no documentation of this tick in Kenya.

Life cycle of ticks

Female ticks lay eggs in the cracks and crevices they occupy, usually in batches of 30 to 100 or more. They lay several batches of eggs and produce an average of 700 to 800 eggs during their lifetime. A blood meal is needed to produce each batch of eggs. Eggs hatch in 2 to 4 weeks and 6-legged tick larvae appear. Larvae are active day or night and readily seek a host. Larvae attach to the host and feed for 5-6 days. After this time, they drop from the host, and molt to the nymphal stage. Nymphs, which have 8 legs, feed only at night and for short periods. After two more nymphal molts, the ticks reach the adult stage. Under favorable conditions, time from egg to adult is approximately 30 days. Adult ticks completely engorge on hosts in 30 to 45 minutes. Adults are extremely resistant to starvation, and can live more than a year without a blood meal (Hogsette *et al.,* 2003).

Clinical signs and pathology of tick infestation

Argas persicus causes severe blood loss, leading to progressive weakness and lowered production. The birds show ruffled feathers with poor appetite and diarrhea. It produces tick paralysis in chicken (Arends, 2003).

2.2.1.3 Poultry mites

In poultry, mites are found in different parts of the body and most species are either microscopic or less than 1mm in length (Soulsby, 1982). The common free-living ectoparasitic mites of poultry belong to the family *Dermanyssidae* and include the chicken mite, Northern fowl mite, and tropical fowl mite. These mites possess relatively well-sclerotized free dorsal and ventral plates, claws and caruncles on the tarsi, one lateroventral stigma near each third coxa, and small chelicerae on long-sheathed bases. Of lesser importance are members of many other mite families that bore into the skin or infect various internal passages and organs (Arends, 2003). These mites have not been documented among local family birds' ages and between birds in different agro- ecological zones. *Dermanyssus gallinae (D. gallinae), Ornithonyssus sylviarum (O. sylviarum)* and *Ornithonyssus bursa* (O. *bursa)* are the species found on the skin (Permin and Hansen, 1998). They affect chicken, turkey, ducks and other domestic and wild birds.

Dermanyssus gallinae (chicken mites) are quite small, but they can be seen with the naked eye. They can be identified by the shape of the dorsal plate and by the long whip-like chelicerae that appear to be stylets. The adult measures about 0.7x 0.4mm, varying in color from gray to deep red, depending on its blood content (Arends, 2003). *Dermanyssus*

gallinae is cosmopolitan in distribution and has been reported in Tanzania (Msanga and Tungaraza, 1985), Nigeria (Okaeme, 1988), Zambia (Lumbwe, 2002) and in Machakos in Kenya (Mungube *et al.,* 2008).

Ornithonyssus (Liponyssus) sylvarium, the northern fowl mite, is recognized as a serious pest in temperate countries and also extremely common in almost all types of production facilities. It is easily distinguished from *Dermanyssus gallinae* by possession of easily visible chelicerae, and the shape of dorsal and anal plate (DeVaney and Ziprin, 1980).

Ornithonyssus bursa (tropical fowl mite) is distributed throughout the warmer regions of the world and possibly replaces *O. sylviarum* in these regions. The hosts include poultry, pigeons, sparrows and humans. It closely resembles the Northern fowl mite but can be distinguished by the shape of the dorsal plate and the pattern of the setae (Arends, 2003). *Ornithornyssus bursa* occurs in the tropics and subtropics and has been reported in Zambia (Lumbwe, 2002), while O. *sylviarum* occurs in temperate regions (Sadiq *et al.,* 2003).

Cnemidocoptes gallinae (*C. gallinae*; feather mites or depluming mites) are the common mites observed in chicken. Females are rounded and about 400 microns long. Their legs are short and stubby and the anus is terminal. The dorsal surface is covered by faint striation. However, mid-dorsally the striations are unbroken. Body has no spines or scales. Stalked pulvilli are present on all legs of larvae and males but are absent in nymphal stages and female. Copulatory suckers are absent in male. These mites burrow into the epidermis at the

base of feather shafts and cause intense irritation and feather pulling in chickens, pheasants, pigeons, and geese (Wall and Shearer, 1997; Permin and Hansen, 1998).

Cnemidocoptes mutans (*C. mutans*; scaly-leg mite) lives under the scales on the feet and legs of birds, causing thickening that gives the impression that the scales are protruding outwards. It also attaches to the comb, wattles and neck. *Cnemidocoptes mutans* is characterized by short and stubby legs, the anus is terminal, and the dorsal surface is covered by faint striation. Mid-dorsally, pattern of dorsal striations is broken in a plate - or scale-like pattern. The body has no scales or spines (Wall and Shearer, 1997). *Cnemidocoptes mutans* has been reported in Zimbabwe (Permin *et al.,* 2002), Tanzania (Msanga and Tungaraza, 1985), Zambia (Lumbwe, 2002) and Kenya (Mungube *et al.,* 2008).

Cytodites nudus (*C. nudus*; airsac mites) is found in air passages and lungs of wild birds, and poultry. The mite is oval and about 500microns long, with smooth cuticle. The chelicerae are absent and palps are fused to form a soft, sucking organ, through which fluids are imbibed (Wall and Shearer, 1997). This mite has been reported in Kenya (Maina, 2005).

Life cycle of mites

Mites do not spend their entire life cycles on the host bird, except for *Cnemidocoptes mutans* and *Ornithonyssus* spp. Adult mites spend most of their lives on the host but will

wonder from the birds into crevices and cracks. Adult female mites complete egg laying in 2 days and the number of eggs laid average 2 to 5 per female (Hogsette *et al.*, 2003).

Dermanyssus gallinae (chicken mite) are gregarious and can be found in large numbers on poultry. The life cycle is fairly complicated, with a series of feeding and non-feeding immature stages. Eggs hatch in about 3 days, and the life cycle can be completed in 7 to 10 days under favorable conditions. Adults are resistant to starvation, and can live off the host for more than a month. This mite does not spend its entire life cycle on birds (Hogsette *et al.*, 2003).

Ornithonyssus sylvarium, breed continuously on the host bird and are a particular problem for caged birds. They spend their entire life cycles on the host. After laying eggs, normally on feathers in the cooler regions of the bird, the mites migrate to the neck area of bird. The eggs then hatch within a day, with larval and nymph stages completed in four days and the entire life cycle within a week (DeVaney and Ziprin, 1980).

Ornithonyssus bursa can pass its entire life cycle on chickens. Its biology and habits are similar to those of *Ornithonyssus sylvarium,* although a greater proportion of its eggs are laid in the nests (Arends, 2003).

Clinical signs and pathology of mite infestation

Dermanyssus gallinae are bloodsuckers and irritate poultry. Anemia occurs in heavily parasitized birds, reducing feed efficiency, egg production, and ability to withstand and

overcome diseases (Jacob *et al.*, 2003). Birds infected with some mites will have a change of behavior due to itching effect of the mites.

Inspection of birds heavily infested with *Ornithonyssus sylvarium,* reveals heavy deposits of mite eggs and faeces in the vent area. Parting of the feathers reveals the mite, eggs and excrement. The mites can also be seen crawling on chicken eggs. The Northern fowl mite is sometimes confused with the red mite, although, unlike the red mite, it can be found easily on birds in the day as well as night. Heavy infestations result in blackened feathers and scabby and cracked skin, particularly around the vent, and infested male birds can get discouraged from breeding (DeVaney and Ziprin, 1980). *Onithonyssus sylviarum* and *O. bursa* are associated with severe emaciation, droopiness and reddened scabby skin in chicken (Fabiyi, 1996).

Cnemidocoptes mutans cause inflammation with exudates and subsequent keratinization of the legs (Jacob *et al.*, 2003). Pathological findings include small yellowish- grey or reddish brown, wart-like skin proliferations that seem to begin on the soft parts of the planter side of the tarsus and spread along the digits and up the shanks to the hock. There is elevation of the scales and increased desquamation (Kirmse, 1966).

Cnemidocoptes gallinae, are also associated with severe emaciation, droopiness and reddened scabby skin in chicken (Fabiyi, 1996).

Small infestations with *Cytodites nudus* (air sac mites) may cause coughing and accumulation of mucus in trachea and bronchi. Balance of the bird may be affected (Wall and Shearer, 1997).

2.2.2 Haemoparasites affecting poultry

Haemoparasites are found in poultry in the tropical and temperate areas. The main ones includes; *Leucocytozoon spp, Plasmodium spp., Haemoproteus spp, Aegyptinella spp,* and *Trypanosoma spp.* (Arends, 1997). The lifecycles of haemoparasites require some arthropod vectors. These vectors include the mosquitoes, poultry soft tick (*Argas persicus*) and other flies. Haemoparasites cause anaemia and death by invading erythrocytes, which consequently are destroyed by the bird's immune system (Arends, 2003).

Unlike semi-wild and wild birds whose blood parasites have been investigated (Bennett and Herman, 1976), information on haemoparasitic infections in domestic chickens in Africa is limited. There is no documentation of these parasites in family poultry in Kenya.

2.2.2.1 *Plasmodium* species

Plasmodium gallinaceum and *P. juxtanucleare* are the two main species of the malaria parasites found in chickens. *Plasmodium gallinaceum* is found in Asia and Africa, whereas *P. juxtanucleare* occurs in South America, Africa and Asia. *Plasmodium* spp have been reported in Nigeria (Sadiq *et al.,* 2003). In *Plasmodium* spp. infections (avian malaria), merozoites or ring forms of the organism are usually more apparent within erythrocytes. The rings may be single or multiple. Microgametocytes and macrogametocytes also form

within erythrocytes in *Plasmodium* infections but are observed infrequently (Weisman, 2007).

Life cycle of *Plasmodium* species

Birds are infected with *Plasmodium* sporozoites, which are transferred from the mosquito salivary glands to the bloodstream. The parasites undergo schizogony in macrophages and fibroblasts and then liver cells producing merozoites. These merozoites enter erythrocytes, where they multiply by schizogony and finally form gametes, which are picked by mosquitoes (Soulsby, 1982). Both gametocytes and schizonts of *P. gallinaceum* can be round, oval or irregular in shape. The nucleus of host cells is displaced by the parasite during infection. The gametes are usually round or ovoid, but may be irregular or slightly elongated. Often the host cell is distorted when infected (Campbell, 1995).

Pathology due to *Plasmodium* species

Soulsby (1982) reported progressive emaciation, anaemia and enlargement of spleen; and liver in affected birds. Paralysis may be observed where there are massive numbers of erythrocytic forms in endothelial cells of the brain capillaries, and death in untreated cases.

2.2.2.2 *Leucocytozoon* species

There are two main species of *Leucocytozoon* commonly found in chicken: *L. caulleryi* and *L. sabrazesi*. *Leucocytozoon* spp., is most easily distinguished because of its large size and football-like distortion of infected cells with pointed ends. This parasite may infect erythrocytes or leukocyte cells (Weisman, 2007). *Leucocytozoon sabrazesi* have been

reported in Zimbabwe (Permin *et al.*, 2002) while *L. caulleryi* has been reported in Nigeria (Sadiq *et al.,* 2003). *Leucocytozoon scoutendeni* (a new species) has been reported in Uganda and Cameroon (Sehgal *et al.,* 2006).

Life cycle of *Leucocytozoon* species

The Leucocytozoidae are haemosporidian parasites of birds with indirect life cycles involving sporogony in arthropod vectors such as midges and blackflies. For most *Leucocytozoon* species, schizogony with the production of small schizonts and megaloschizonts occurs in hepatocytes, although schizogony can also occur in the vascular endothelium of other tissues (Fallis *et al.,* 1973). Gametocytes of the parasites are found in erythroblasts and mononuclear leucocytes as ovoid (10 by 15 microns) or elongated (24 by 4 microns) forms. The host cells with elongated gametocytes become spindle shaped with nuclei appearing as thin bands beside the parasite (Campbell, 1995).

Clinical signs and pathology due to *Leucocytozoon* species

Leucocytozoon caulleryi is the most virulent. Infected chickens frequently show signs of anorexia, thickened oral discharge, ataxia, anaemia and have difficulty breathing. They frequently die because of hemorrhages as a result of rapture of megalomeronts that may develop in all organs and tissues. In addition, birds may be susceptible to secondary infection that may increase mortality (Sehgal *et al.,* 2006).

2.2.2.3 *Haemoproteus* species

Haemoproteus spp. are intracellular, protozoan, hemotropic parasites that infect red blood cells of birds, turtles, and lizards. It is found worldwide and is capable of infecting a variety of birds including gamebirds (Galliformes), waterfowl (Anseriformes), raptors (Accipitriformes, Falconiformes, Strigiformes), pigeons, doves (Columbiformes), and perching birds or songbirds (Passeriformes). Organisms may appear similar to *Plasmodium*, but the pigment within the intraerythrocytic gametocytes is more dispersed. The gametocytes partially encircle the erythrocyte nucleus forming a "halter-shaped" appearance. *Haemoproteus* gametocytes often occupy over one-half of the erythrocyte cytoplasm with little displacement of the host cell nucleus. Both *Haemoproteus* and *Plasmodium* produce an insoluble pigment called hemozoin. This pigment is derived from the digestion of hemoglobin found within the host's erythrocytes and appears as refractile, yellow to brown granules within the host's erythrocyte (Weisman *et al.,* 2007).

Life cycle of *Haemoproteus* species

Haemoproteus is transmitted by blood sucking insects including mosquitoes, hippoboscid flies (house flies), and culicoides species (biting midges). Successful transmission depends on the presence of the vector, therefore infections occur more often in the warmer months of the year. The infective stage is the *sporozoite*, which is present in the salivary glands of the insect vector. Once the vector bites a new host, the sporozoites enter the blood stream and invade endothelial cells of blood vessels within various tissues including the lung, liver, and spleen. Within the endothelial cells, the sporozoites go through asexual reproduction to become *schizonts*, which then produce numerous *merozoites*. These merozoites penetrate

the erythrocytes and mature into either female gametocytes (*macrogametocytes*) or male gametocytes (*microgametocytes*). Another blood-sucking insect can then ingest gametocytes where they undergo sexual reproduction in the midgut of the insect to produce oocysts. The oocysts rupture and release numerous sporozoites that invade the salivary gland and serve as a focus of subsequent infection for another host once the insect takes its next blood meal (Campbell, 1995).

Pathogenesis and pathology of *Haemoproteus* infections

Infections with most *Haemoproteus* spp. do not result in significant clinical signs. Experimental infection of turkeys with *Haemoproteus meleagridis* (*H. meleagridis*) resulted in lameness, diarrhea, depression, emaciation, anorexia and occasionally anemia. Muscovy ducks infected with *H. nettionis* suffered lameness, dyspnea and sudden death. Pigeons infected with *H. columbae* had enlarged gizzards. In other avian species, anemia, anorexia, and depression have been reported occasionally, but *Haemoproteus* generally is considered non-pathogenic in most avian species. Post-mortem findings of infected birds include enlargement of the spleen, liver, and kidneys. These organs also may appear chocolate-brown due to hemozoin deposition. Cytologic imprints of these organs may reveal schizont-laden endothelial cells. Some species of *Haemoproteus* will also form large, cyst-like bodies within skeletal muscles that resemble those seen with *Sarcocystis* spp. infections (Weisman *et al.*, 2007). These parasites have been reported in Nigeria (Sadiq *et al.*, 2003). However, these parasites are of little importance in domestic chicken (Soulsby, 1982).

2.2.2.4 *Aegyptinella* species

The two species of *Aegyptinella* namely: *Aegyptinella pullorum (A. pullorum)* and *Aegyptinella mushkovskii (A. mushkovskii)* occur in chicken, turkey, ducks, geese and other birds in Africa, Asia and Southern Europe. They are transmitted by *A. persicus* and appear as small 0.5-1.0 microns, round to oval bodies within the erythrocytes (Permin and Hansen, 1998). *Aegyptinella pullorum* has been reported in Zimbabwe (Permin *et al.*, 2002) and Ghana (Poulsen *et al.*, 2000).

Life cycle, clinical signs and pathology of *Aegyptinella* species

The developmental cycle of *Aegyptinella* in the avian host consist of the formation of initial bodies, developmental forms and marginal bodies. Following feeding by an adult tick on an infected fowl, 25days or more is required before the organism is transmissible to another bird. *Aegyptinella pullorum* causes fever, diarrhea, anorexia and jaundice. At post-mortem there is anaemia, enlargement of the spleen and degeneration of the kidneys (Levine, 1985).

2.2.2.5 Other poultry haemoparasites

Trypanosoma avium (T. avium) occurs in a wide range of birds. The most common vectors of avian trypanosomes are arthropods belonging to *Hippoboscidae, Culicudae, Ceratopogonidae* and *Simuliidae*. In addition dermanyssid mites have been identified as avian trypanosome vectors (Soulsby, 1982). *Trypanosoma avium* has been reported in Zimbabwe (Permin *et al.*, 2002), Uganda and Cameroon (Sehgal *et al.*, 2006).

Borrelia anserina are transmitted by *Argas persicus*, *culex* mosquitoes and the red mites (Dickie and Barrera, 1963). Within 24-72 hours post infection with *Borrelia anserina*, spirochaetes appear in the bloodstream and there is marked temperature elevation. Affected birds are listless, have urates around the vent and manifest leg weakness (Dickie and Barrera, 1963). This parasite has been reported in Zimbabwe (Permin *et al.*, 2002).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area

Two agro-ecological zones in two neighbouring districts were purposively chosen for this study. The selection was based on the availability of an indigenous village rural poultry population with a free-range system practiced in the areas and the contrasting agro-ecological zones.

Of these two, one was a lower highland 1 (LH1) in Embu District. This is a high agricultural potential area where tea, maize, beans and various fruits are grown and free-range poultry and dairy cattle are kept. The area has a bimodal rainfall pattern of long rains between March and June, and short rains in October to December. It has an annual average rainfall of 1080mm. Altitude ranges from 1500 to 4500 meters above sea level. The temperatures range from 12 to 27°C (Onduru *et al.*, 2002) (**Figure 1**).

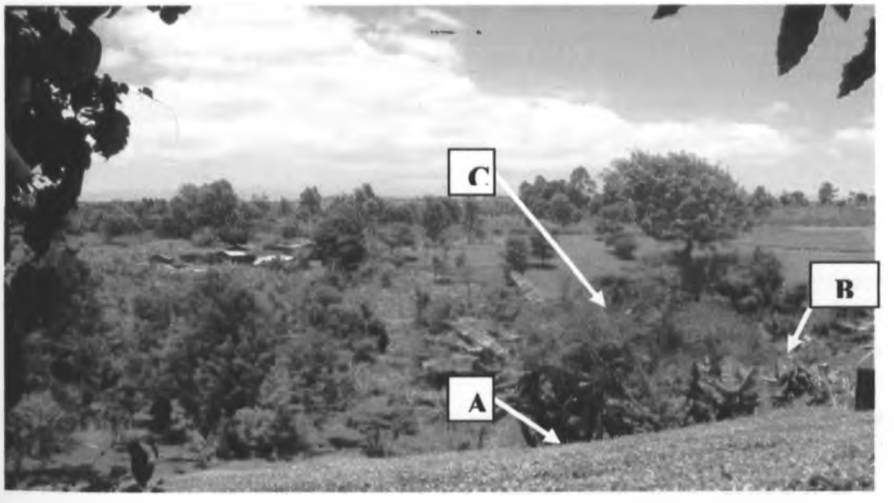

Figure 1. Lower highland zone 1, a high agricultural potential area showing tea (A) banana (B) plantations and fruit trees (C)

The other study area was the lower midland 5 (LM5) in Mbeere District. This is a semi-arid area with livestock (beef cattle, sheep and goats), poultry, millet and green gram as the main agricultural activities. It has a bimodal and erratic rainfall pattern with average annual rainfall of 180mm per year. Altitude is 1200m above sea level and temperatures range from 20-30°C (Onduru *et al.*, 2002) **(Figure 2)**.

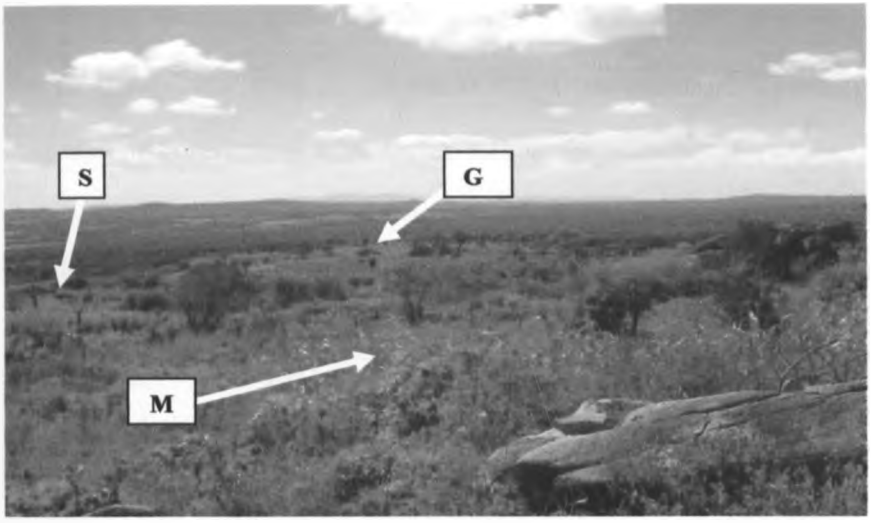

Figure 2. Lower midland zone 5 (semi arid area) shows open grasslands (G), shrubs (S) and scanty "katumani" maize crops (M).

3.2 Study chickens

Indigenous chickens were obtained from individual randomly selected homesteads and purposive sampling used. The calculated sample size was 144 birds which were purchased. The expected prevalence used in the sample size calculation was 50% and the maximum limits of error at 8.3% as per the following formula $n=1.96^2pq/L^2$ where n is the sample size, p the prevalence, $q=1-p$ and L the limits of error on the prevalence (Martin *et al.*, 1987).

The birds were categorized into three age groups as follows: Chicks (aged < 2 months), growers (2 to 8 months) and adult (aged > 8 months) according to Magwisha *et al.* (2002) with modification. A total of 72 birds were sampled per agro-ecological zone comprising 36 birds per sex group and 24 birds per age group (**Table 1**). All the birds from the two agro-ecological zones were purchased from January to February 2007 in a one month period. They were transported alive in cages to the Department of Veterinary Pathology, Microbiology and Parasitology laboratories, Kabete for examination.

Table 1. Indigenous chickens selected for the study by age, sex and agro-ecological zone

Chicken age and sex		**LH1**	**LM5**	**Totals**	
Chicks	Males	12	12	**24**	**48**
	Females	12	12	**24**	
Growers	Males	12	12	**24**	**48**
	Females	12	12	**24**	
Adults	Males	12	12	**24**	**48**
	Females	12	12	**24**	
Totals		**72**	**72**	**144 chickens**	

Key: LH1- Lower highland 1

LM5- Lower midland 5

3.3 Determination of chicken age

The ages were determined subjectively based on the size of crown, length of spur and flexibility of the xiphoid cartilage together with information from the farmers. The birds were classified as adults (cock or hen), growers (pullet or cockerel) and chicks (male and female) according to Magwisha *et al.* (2002) and Maina (2005).

3.4 Clinical examination, blood collection and necropsy of the chicken

Before slaughter, each chicken was subjected to a thorough clinical examination and observation recorded. The birds were then killed by dislocation of the atlanto-occipital joint, followed by severing of the carotid arteries and jugular veins using a scalpel blade. Blood was collected in universal bottles containing Ethylenediaminetetraacetic acid (EDTA) to prevent clotting. Three blood films were prepared from each bird namely: a fresh thin blood smear, blood smear from EDTA blood and a buffy coat smear. Blood films were air-dried within 5–10 seconds after preparation. Slides were fixed in methanol for 5 minutes and then stained with 10% Giemsa for 15 minutes, washed with tap water, blotted and examined under the microscope for haemoparasites (Nemi, 1986).

Post mortem examination of chicken was carried out as described by Charlton *et al.* (2006). Gross lesions on the skin were recorded. The whole skin together with feathers, head and legs were removed and stored in 70% alcohol. The air sacs were also examined and where mites were seen, these were removed and stored in 70% alcohol to await further examination (Nemi, 1986).

3.5 Examination of Giemsa stained blood smears

Examination of Giemsa stained blood smears and buffy coat smears was carried out as described by Nemi (1986). Blood films were examined for 10–15 minutes at low magnifications of X40, X63 and then 100 fields were studied at high magnification (X100). The haemoparasites detected were identified according to Soulsby (1982) and Valkiūnas (2005) and recorded.

3.6 Examination of skin of the body, legs and head skin for ectoparasites

Birds were skinned with all the feathers intact. Half of the body skin was examined and the total number of parasites multiplied by two to give the overall parasite intensity. The procedure for examination of these body parts and organs was carried out as described in the Ministry of agriculture food and fisheries (MAFF) (1986) manual.

3.7 Identification and scoring of parasite load

The ectoparasites were dehydrated first in 80%, then 90% and finally 100% alcohol before being cleared in xylene and mounted on a slide for final identification with light microscope. They were identified according to their morphological characteristics using entomological keys of Soulsby (1982), MAFF (1986), Wall and Shearer (1997) and Arends (2003).

The ticks were identified using tick identification keys available from different sources (Ruedisueli and Manship, 2006; Walker *et al.,* 2003). Important morphological features used in tick identification included size of the tick, position of head and mouthparts

(*capitulum*) relative to the thorax and abdomen on dorsal and ventral views and shape of the body.

Infestation with *Cnemidocoptes mutans* was classified on a clinical evaluation based on the presence of hypertrophic dermatitis on the legs as follows: + = no macroscopic changes, no visible sign of the mite infestation though mites were present on laboratory examination; ++ = minor scale formation only the distal parts of the legs; and +++ = massive hypertrophic dermatitis with involvement of the whole leg. Scrapings cleared with potassium hydroxide (KOH) were used to identify the developmental stages and adult parasites (Permin *et al.*, 2002).

3.8 Tissue processing for histological examination

Five skin samples were taken per bird together with sections with obvious gross lesions and examined for skin histopathology. They were taken from the head, leg and body skin (neck, back and cloacal area). They were fixed in 10% neutral formalin. The procedure of Luna, (1968) briefly described below was used to process all tissues collected for histological examination.

The formalin fixed tissues were trimmed to a thickness of 3mm and labeled with a tag. These tissues were then placed in an automatic tissue processor for the following treatments: (a) dehydration using 80% ethyl alcohol for 4 hours, 96% ethanol in 2 changes each for 2 hours and 100% isopropanol for 1.5 hours for 3 changes; (b) clearing of alcohol using amyl acetate for one hour and then through xylene in two changes for 2 and 2.5 hours

respectively; (c) in filling with molten paraffin wax at 60° C in two changes for three hours each followed by embedding in paper boats with molten wax.

After setting of molten wax to a solid cast, they were fixed onto a wooden block using a searing spatula. The specimens were cut to 5µm thickness using a microtome, floated on a water bath at 50° C to flatten it out, mounted on a labeled microscope slide and dried in an oven at 60° C for one hour. They were dewaxed in three changes of xylene, each for 5 minutes. Tissues were then rehydrated in preparation for staining using descending grades of alcohol in 2 stages to 90-80-70-50% alcohol and to distilled water for 5 minutes in each stage. The staining of histological sections was done using hematoxylin and counterstained using 1% eosin. Tissues were finally taken through dehydration using ascending grades of alcohol similar to those used in rehydration. Alcohol was cleared using two stages of xylene for 5 minutes in each stage. A cover slip was then applied using Destrene 80 dibutylphthalate and xylene (DPX) as a mountant and then left to dry before examination.

3.8.1 Examination of tissue sections

Examination of the tissue sections was done under (x4, x10 and x40) magnification using a light microscope. The lesions on the skin were scored as none, mild, moderate or severe.

3.8.2 Microscopic lesions scoring

Microscopic skin lesions induced by the ectoparasites were scored as none, mild, moderate or severe according to Mbuthia (2004) and Maina (2005) with modifications.

Head, body and leg skin lesions were scored on the basis of no lesion (-) = intact epidermis, no cellular infiltrations or skin tissue reaction or hyperkeratinization. Mild lesion (+) = hyperkeratinization combined with either; compression of epidermis and or dermis by parasites (present or absent), thickening of epidermis and or dermis, congestion of dermal blood vessels or parasite sections within the skin tissue. Moderate lesion (++) = hyperkeratinization and skin necrotic changes, combined with either parakeratosis, compression of epidermis and or dermis by parasites (present or absent), thickening of epidermis and or dermis, hemorrhage or congestion or parasite cross-sections within skin tissue, and severe lesions (+++): hyperkeratinization, parakeratosis and epidermal rupture combined with either of the following; necrosis, changes in blood vessels, pressure atrophy due to parasites (present or absent), hemorrhage, inflammatory changes involving deeper layers of the skin and parasite cross-sections within the skin tissue.

3.9 Data analysis

Data from the study were entered in Ms-Excel (Microsoft corporation, 2003), and later exported to Genstat® Discovery Edition 3 for descriptive statistic. The following were tested: parasite-specific prevalence and that between the ages, sexes and agro-ecological zones, the influence of age and sex groups, and agro-ecological zones on the parasite prevalence (Chi- square ($\chi 2$) test) and intensity (One-way analysis of variance) and the association between the presence of ectoparasites and severity of lesions on the skin (Chi-square ($\chi 2$) test).

The prevalence of parasites was defined as the total number of birds infested with a particular parasite group/ species divided by the number of chicken examined at a point in time (Margolis *et al.,* 1982). A critical probability of 0.05 was adopted throughout as a cut-off point for statistical significance between groups compared.

CHAPTER FOUR

4.0 RESULTS

4.1 Prevalence, intensity and identity of ectoparasites

A total of 144 indigenous village chickens of different age and sex groups, from two different agro ecological zones were examined for the presence of ecto- and haemoparasites. Of these, 138 had one or more species of ectoparasites, giving an overall prevalence rate of 95.8%. Four groups of ectoparasites, namely; lice, fleas, soft ticks and mites, were found in this study.

Of the 144 birds examined, 131 (91.0%) had lice, 107 (74.3%) mites, 42 (29.2%) sticktight fleas and 8 (5.6%) had soft ticks (**Table 2**). Of the 138 infested birds, 25 (18.1%) had single infestation, while 113 (81.9%) had mixed infestation. Twenty birds (14.5%) had lice alone, while 2 had fleas (1.5%); ticks 0 (0.0%), mites 3 (2.2%), lice and fleas 9 (6.5%): lice and mites 68 (49.3%); fleas and mites 2 (1.5%); lice, fleas and mites 26 (18.8%); lice, mites and ticks 4 (2.9%), while 4 (2.9%) birds had lice, fleas, ticks and mites. Lice were the most prevalent parasite as individual or together with other parasites infesting the indigenous chicken (**Table 3**).

Table 2. Type of ectoparasite observed, number of birds infested and percentage parasitic infestation rates

Type of ectoparasites	Number of birds infested	Number of birds without parasites	Prevalence (%) infestation
Lice	131	13	91.0
Fleas	42	102	29.2
Ticks	8	136	5.6
Mites	107	37	74.3

All four groups of ectoparasites were found in chicks, growers and adult birds, and in both male and female birds. They were also present on birds from LH5 (Mbeere), but ticks were not observed on birds from LH1 (Embu). In both zones lice were the most prevalent followed by mites.

Among the age groups, adult birds had a 100% (48/48) prevalence which was slightly higher than growers, 97.7% (47/48) and chicks, 89.6% (43/48). Both male and female birds had the same prevalence of 95.8% (69/72). Between the agro ecological zones, the LM5 had a slightly higher prevalence, 98.6% (71/72) compared to LH1, 93.1% (67/72). There was a statistical significance in occurrence of ectoparasites among age groups of birds ($p < 0.05$), while the differences between sexes and agro ecological zones were not statistically significant ($p > 0.05$).

The mean specific parasite intensity in chickens was significantly different among age groups (total lice, *M. gallinae* and *L. caponis*) (**Appendix 1**) and between agro ecological zones (total lice, *M. gallinae* and soft ticks) (**Appendix 3**). However, there was no significant difference in mean specific parasite intensity between the sexes (**Appendix 2**).

Table 3: Ectoparasite groups (single or mixed infestations), number of birds infested and percentage parasitic prevalence in indigenous village chickens

Ectoparasites groupings	Number of positive birds in the group (x)	Percentage parasitic prevalence (x/144)
Lice	20	14.5
Fleas	2	1.5
Ticks	0	0.0
Mites	3	2.2
Lice and Fleas	9	6.5
Lice and Mites	68	49.3
Fleas and Mites	2	1.5
Lice, Fleas and Mites	26	18.8
Lice, Mites and Ticks	4	2.9
Lice, Fleas, Ticks and Mites	4	2.9

Table 4: Prevalence rates of various ectoparasitic species found on indigenous chickens and their predilection sites

Ectoparasite	Common predilection site	Number of birds with parasite	Prevalence (%)
Lice		131/144	90.0
1. *Menopon gallinae*	Feather shafts and all over the body	128	97.7
2. *Lipeurus caponis*	Underside of the large wing feathers	83	63.4
3.*Goniodes gigas*	Body feathers	41	31.1
Mites		107/144	74.3
4. *Cnemidocoptes mutans*	Lower limbs (non-feathered areas)	71	66.4
5. *Dermanyssus gallinae*	Entire body of bird	8	7.5
6. *Epidermoptes species*	On the skin of birds	89	83.2
7. *Laminosioptes cysticola*	On subcutaneous tissue	2	1.9
8. *Megninia species*	On feathers (quills)	4	3.7
Stick tight flea		42/144	29.2
9. *Echidnophaga gallinacea*	Comb, wattles, eyes and around the ears	42	29.2
Soft tick		8/144	5.6
10. *Argas persicus*	Ventral abdominal area and below wings.	8	5.6

4.1.1 Lice infestation in chickens

A total of 131 (91.0%) birds had lice on their body surface, wings and feathers. The total lice count ranged from 0-178 parasites with a mean average of 29.3 lice per bird. Three species of lice namely: *Menopon gallinae, Lipeurus caponis* and *Goniodes gigas* were observed on birds from both agro-ecological zones (**Table 4**). These lice species occurred either singly, 41 (31.3%) or in various combinations, 90 (68.7%). Thirty eight (29.0%) birds had *M. gallinae*, 3 (2.3%) had *L. caponis*, 0 (0.0%) had *G. gigas* alone; while 49 (37.4%) had *M. gallinae* and *L. caponis*, 10 (7.6%) *M. gallinae* and *G. gigas*, 0 (0.0%) had *L. caponis* and *G. gigas*, and 31 (23.7%) had *M. gallinae*, *L. caponis* and *G. gigas* as mixed infestation (**Table 5**).

Table 5. Prevalence of lice species (singly or mixed infestation), encountered in indigenous village chickens

Lice species	Number of birds with lice (x)	Percentage prevalence (x/131)
Menopon gallinae	38	29.0
Lipeurus caponis	3	3.1
Goniodes gigas	0	0.0
Menopon gallinae and *Lipeurus caponis*	49	36.6
Menopon gallinae and *Goniodes gigas*	10	7.6
Lipeurus caponis and *Goniodes gigas*	0	0.0
Menopon gallinae, Lipeurus caponis and *Goniodes gigas*	31	23.7

Overall, the prevalence of lice was higher among adult and grower birds at 95.8% (46/48) both, compared to chicks, 81.2% (39/48). Between sexes, female birds had a slightly higher rate of 91.7% (66/72) than males, 90.3% (65/72). Lower midland zone 5 (Mbeere) experienced a slightly higher prevalence of 94.4% (68/72) compared to LH1 (Embu), 87.5% (63/72). There was a statistically significant difference in occurrence of lice among the bird age groups ($p< 0.05$), while that between the sexes and the two agro ecological zones was not significant ($p> 0.05$).

4.1.1.1 *Menopon gallinae*

Of the 131 indigenous chickens infested with lice, 128 (97.7%) had *M. gallinae*. The total count ranged between 0 and 103 lice, with a mean average of 21.3 parasites per bird. This lice species occurred on the body feathers and the adult louse was about 2mm in length and pale yellow in color. It had small palps and a pair of antennae, which was folded into grooves in the head. The antennae had four segments and the abdomen had sparse covering of small to medium length setae in a single row per abdominal segment dorsally (**Figure 3**).

Adult birds showed a higher rate of 95.8% (46/48) compared to growers and chicks, which had 89.6% (43/48) and 79.2% (38/48), respectively. Between sexes, females had slightly higher prevalence of 90.3% (65/72) compared to males 86.1% (62/72). Lower midland zone 5 showed a high prevalence of 95.83% (68/72) compared to LH1 81.94% (59/72). There was statistically significant difference in rate of occurrence of *M. gallinae* ($p< 0.05$) among bird ages (with chicks showing a lower prevalence compared to adults) and between the

two agro ecological zones. The difference between the sexes was not statistically significant.

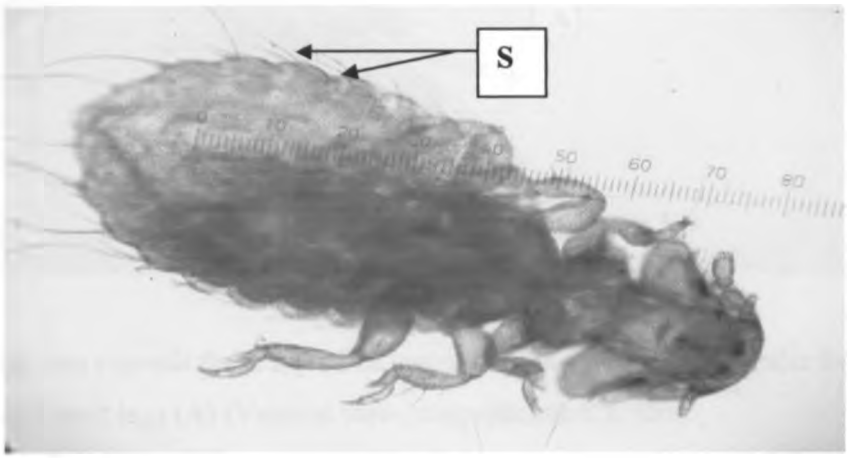

Figure 3. *Menopon gallinae* from a chicken in lower midland zone 5 showing a single row of medium to small setae (S) (Ventral view; magnification X 100)

4.1.1.2 *Lipeurus caponis*

A total of 83 birds out of the 131 infected with lice (63.4%) had *L caponis* on their wings. The parasite load for *Lipeurus caponis* ranged from 0- 80, with an average intensity of 5.6 parasites per bird. *Lipeurus caponis* (wing louse), had an elongated, narrow body measuring about 2.2 mm in length and 0.3 mm in width. The legs were narrow and characteristically, the hind legs were about twice as long as the first two pairs. The first segment of the antennae was considerably longer than following four segments. There were characteristic small angular projections on the head in front of the antennae (**Figure 4**).

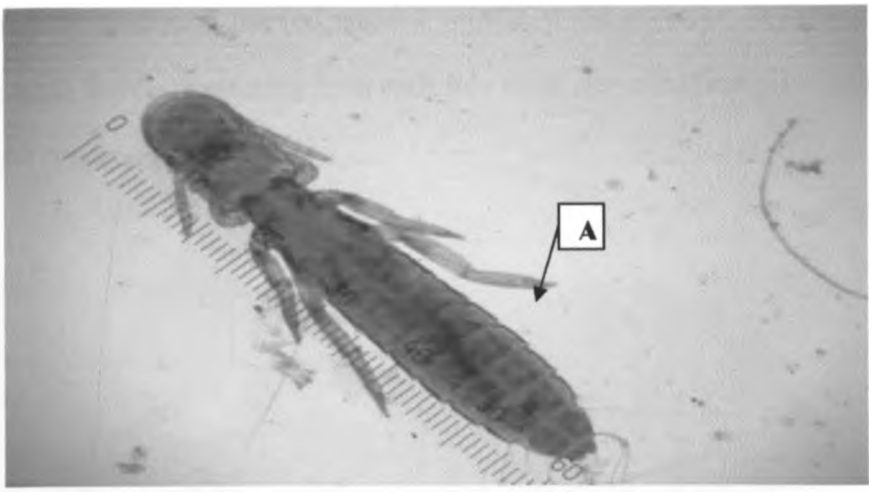

Figure 4. *Lipeurus caponis* from a bird in lower midland 5 showing slender body and long hind legs (A) (Ventral view, magnification X 100)

Among the age groups, *L. caponis* was prevalent among growers, 66.7% (32/48) and adults, 66.7% (32/48), than in chicks, 39.6% (19/48). Females had slightly higher prevalence of 59.7% (43/72) compared to male birds, 55.6% (40/72). Lower highland 1 (Embu) recorded a higher prevalence of *L. caponis,* 70.8% (51/72) than LM5 (Mbeere), 44.4% (32/72). There was a statistically significant difference in the occurrence of *L. caponis* among the bird age groups and between the two agro-ecological zones, but not between chicken sex groups.

4.1.1.3 *Goniodes gigas*

Out of 131 indigenous chickens, which had lice, *G. gigas* was found on body feathers of 41 (31.3%) bird. The total count ranged from 0- 58 lice, with an average parasite load of 1.9 lice per bird. These are large lice of about 3mm in length, brown in color and the head had

concave posterior producing marked angular corners at the posterior margins. The head carried two large bristles projecting from each side of its dorsal surface. The antennae had five segments (**Figure 5**).

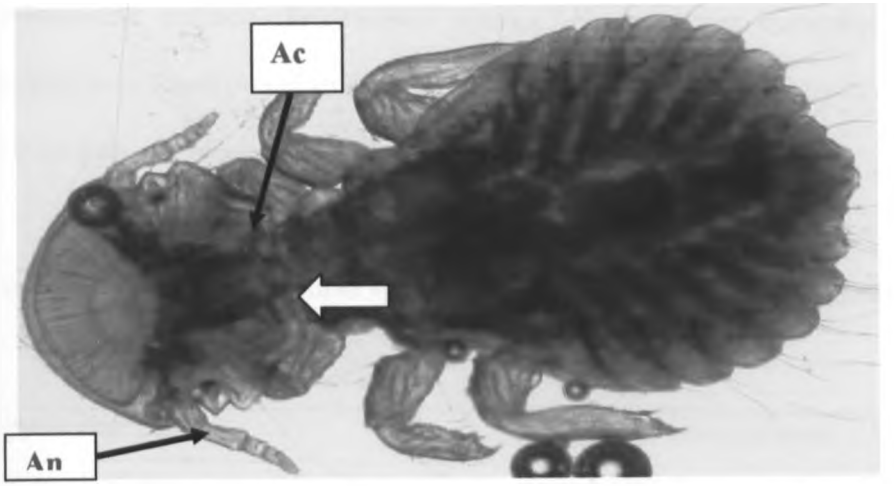

Figure 5. Ventral view of *Goniodes gigas* from a chicken in lower highland 1 showing the antennae with five segments (An), and concave posterior (Block arrow) with angular corners (Ac) (magnification X 100)

Grower birds showed a slightly higher rate of 33.3% (16/48) compared to adult birds, 31.3% (15/48) and chicks, 20.8% (10/48). Female birds had a slightly higher prevalence of 29.2% (21/72) than male ones, 27.8% (20/72). Lower highland 1 (Embu) showed a rate of 30.6% (22/72) which was slightly higher than in LH5 (Mbeere) 26.4% (19/72). Statistically, the rate of occurrence of *G. gigas* among the bird age groups, sexes and between agro ecological zones was not significant.

4.1.2 Poultry mites

One hundred and seven (74.3%) birds were found to have mites on the body surface, subcutaneous tissue or the legs. Five genera and species of mites (*Cnemidocoptes mutans, Dermanyssus gallinae, Epidemoptes* species, *Laminosioptes cysticola* and *Megninia* species) were found on the study chickens. They occurred either singly in 48.6% (52/107) or more than one species per bird at 51.4% (55/107) (**Table 6**).

Table 6. Prevalence of the mite species occurring singly or in mixed groups in chickens in the study areas

Type of mite species	Number of birds infested with mites	Prevalence (%)
Cnemidocoptes mutans	19	17.8
Dermanyssus gallinae	0	0.0
Epidemoptes species	33	30.8
Cnemidocoptes mutans and *Dermanyssus gallinae*	1	0.9
Cnemidocoptes mutans and *Epidemoptes* species	47	43.9
Dermanyssus gallinae and *Epidemoptes* species	3	2.8
Cnemidocoptes mutans, D. gallinae and *Epidemoptes* species	4	3.7

The occurrence of mites was higher in adult birds, 77% (37/48) compared to grower birds, 75% (36/48) and chicks 70.8% (34/48). Males had a higher frequency of occurrence (80.56% prevalence) than females (72.22%). Lower midland 5 (Mbeere) had a higher

prevalence of 88.9% (64/72) than LH1 (Embu) 59.7% (43/72). The difference in occurrence among bird age groups and sexes was not statistically significant ($p > 0.05$) while that between agro ecological zones was statistically significant ($p < 0.05$) in occurrence of mites.

4.1.2.1 *Cnemidocoptes mutans*

Figure 6 shows *Cnemidocoptes mutans* from chicken from Lower Midland zone 5. Of 107 birds that showed mite infestation, *C. mutans* occurred in 71 (66.4%) birds. *Cnemidocoptes mutans* was found to infest feet causing characteristic scaly lesions varying from mild to severe encrustations. It had short and stubby legs with claw-like tarsi. Females did not have suckers and setae. In males, all legs had one of the setae longer than the sucker, which was found on the second pair of legs, whereas they were less distinct in the third and fourth pairs of legs. The anal aperture was terminal with a dorsal slit. The body had no scales or spines. Setae were short except for one long pair on the posterior margin of the mite, and the dorsal body surface was covered with faint striation.

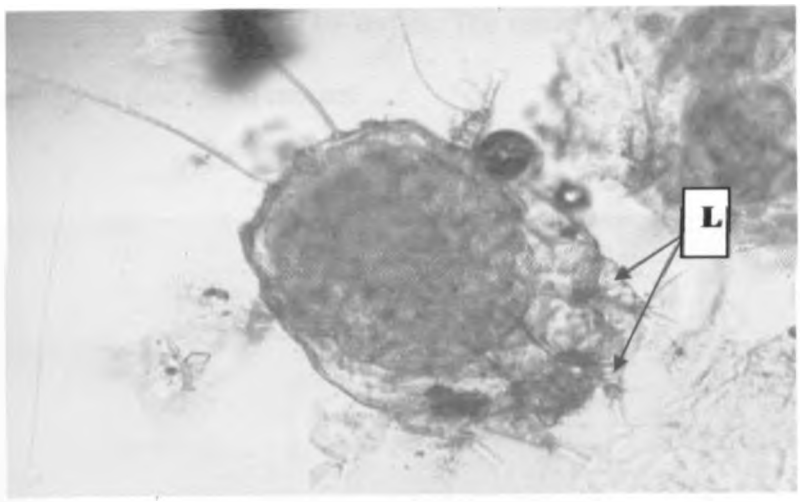

Figure 6. Male *Cnemidocoptes mutans* found in a chicken from Lower midland 5 showing short and stubby legs (L) (magnification X 400).

Cnemidocoptes mutans was slightly more prevalent among adult birds, 54.2% (26/48) compared to growers, 52.1% (25/48) and chicks 41.7% (20/48). Between sexes, male birds had a slightly high prevalence of mite 50% (36/72), compared to females, 48.6% (35/72). Lower midland 5 (Mbeere) was found to experience a higher occurrence of 69.4% (50/72) compared to LH1 (Embu) 29.2% (21/72). The differences in occurrence of *C. mutans* among age groups and sexes of birds were not statistically significant, while that between the two agro ecological zones was statistically significant ($p < 0.05$).

4.1.2.2 *Dermanyssus gallinae*

Dermanyssus gallinae, "the red mite" (**Figure 7**) was found to occur on 8 (7.5%) of 107 birds that had mite infestations. They were found on body feathers. *Dermanyssus gallinae* were quite small (but they could be seen with the naked eye), egg shaped with a unique non-segmented body and were identified by the shape of the dorsal plate and their long

whip-like chelicerae that appeared to be stylets. The adults varied in color from gray to deep red, depending on their blood content.

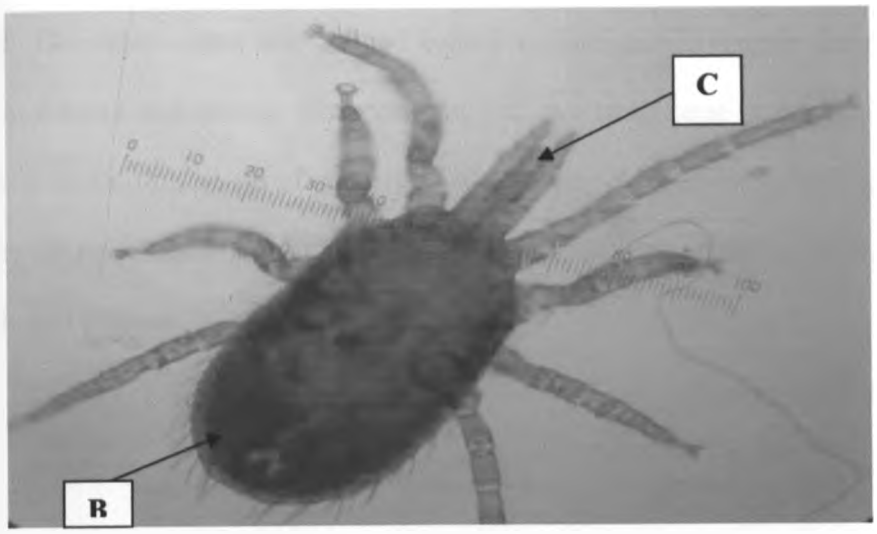

Figure 7. *Dermanyssus gallinae* isolated from chicken obtained from lower highland 1 showing egg shaped non-segmented body (B) and long whip-like chelicerae (C). (Ventral view, magnification X400)

This mite was found to occur among growers at a rate of 12.5% (6/48) and adults 4.2% (2/48). None was recovered from chicks. Between sex groups, males had a slightly higher prevalence 6.9% (5/72) than female 4.2% (3/72) birds. Lower midland 5 had a prevalence rate of 6.9%, which was slightly higher than in LH1 (4.2%). There was a statistical significance ($p< 0.05$) in occurrence of *D. gallinae* among age groups of birds, while the differences between sexes and agro ecological zones were not statistically significant ($p> 0.05$).

4.1.2.3 *Epidermoptes* species

This group of mites was found in 89 (83.2%) of 107 birds, which were found to be infested with mites. These mites were brownish white in color and nearly one and a half time long as broad. The opisthosoma was splitted behind to form two diverging abdominal lobes pointed at the end and bearing incrassate long and two small setae at the tip. All the tarsi were round at the tip, devoid of any claw, each bearing an ambulatory sucker with short unsegmented stalk. Their pre-tarsi were short while the sucker-like pulvillus was more funnel-shaped (**Figure 8**).

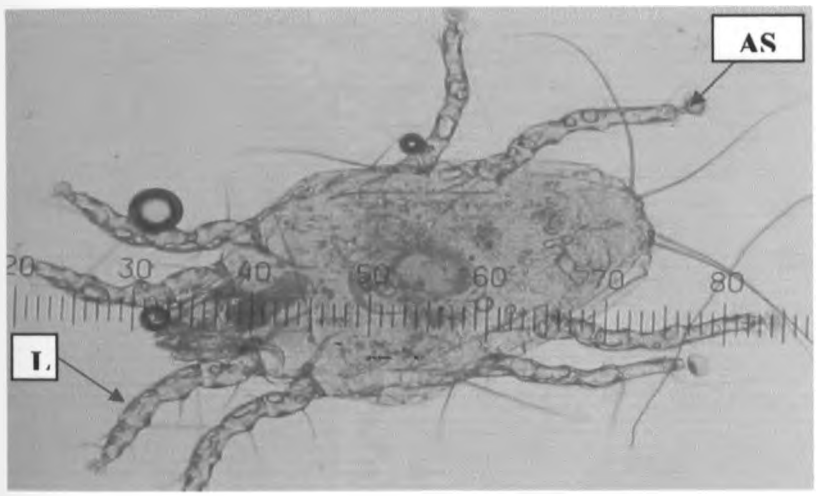

Figure 8. Male *Epidemoptes* species obtained from a chicken from lower midland 5 showing the first pair of legs (L) which is slightly thicker and ambulatory sucker with short unsegmented stalk (AS) (magnification X40)

Grower and adult birds both had the same prevalence of 64.6% (31/48) which was slightly higher compared to chicks 56.3% (27/48). Female birds had a higher prevalence of 63.9% (46/72) compared to males, 59.7% (43/72). Lower midland zone 5 (Mbeere) was found to

have a higher prevalence of 76.4% (55/72) compared to Lower highland zone 1 (Embu), 52.9% (38/72). The difference in occurrence between the age and sex groups was not statistically significant, while that between the two agro-ecological zones was statistically significant ($p > 0.05$).

4.1.2.4 *Laminosioptes cysticola*

This mite was found in 2 (1.9%) of the 107 birds infested with mites. This mite was characterized by long body (female mite measuring 0.3 by 0.1mm). The body had a few setae and two pairs of long setae on the posterior body margin (**Figure 9**).

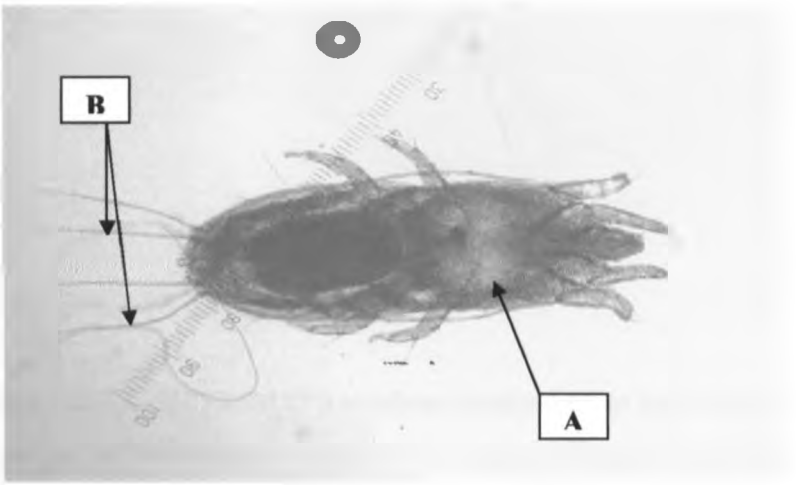

Figure 9. *Laminosioptes cysticola* found in chicken from lower midland zone 5 showing a long body (A) with two pairs of long setae (B) on the posterior body margin (magnification X 400).

This mite only occurred in grower male birds at a prevalence of 4.2% (2/44) obtained from lower highland zone 1 (Embu district) at a rate of 2.8% (2/72).

4.1.2.5 *Megninia species*

Megninia species was found on 4 (3.7%) of 107 chicken that were infested with mites. This mite was elongated in size. The third pair of legs was characteristically long. The legs had short pre-tarsi, while the sucker-like pulvillus was more funnel-shaped. It had tibial spurs on legs 1 and 2 and shallow incised terminal lobes (**Figure 10**).

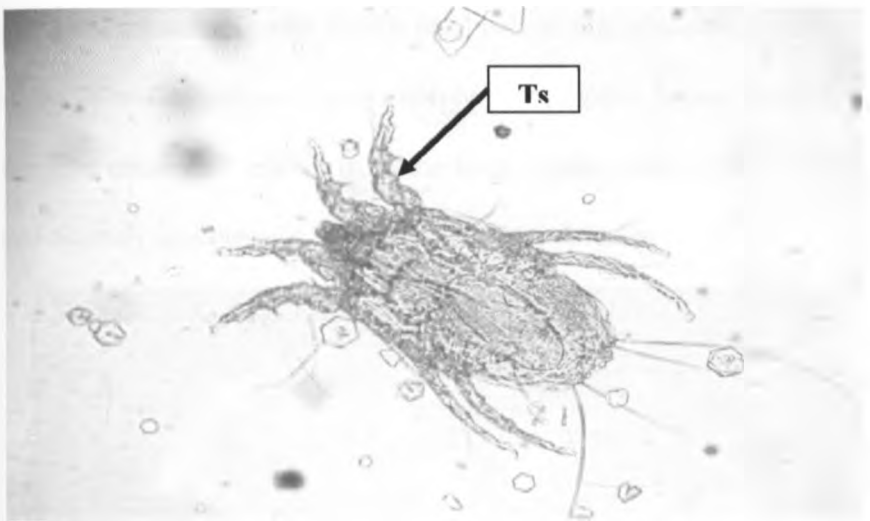

Figure 10. ***Megninia*** **species found in a chicken obtained from lower midland 5, showing the tibial spurs on the first two pairs of legs (Ts) (magnification X400).**

This mite genus was found among growers, 6.3% (3/48) and chicks, 2.1% (1/48) while none was found among adults, 0.0% (0/48). Between sexes, there was an equal occurrence between male and female birds at a rate of 2.8% (2/72). Lower midland zone 5 had a higher rate of 4.2% (3/72) compared to lower highland zone 1, 1.4% (1/72). The difference among age groups and between sexes and agro ecological zones was not statistically significant.

4.1.3 Poultry fleas

Echidnophaga gallinacea (E. gallinacea), the stick tight flea of poultry (**Figure 11**) was observed in 42 (29.2%) of the 144 birds examined in this study (**Table 2**). The flea occurred on the comb, wattles, eyelids and around the ears. The total fleas count ranged from 0 to 113, with an average of 3.8 fleas per bird. The adult flea was small, measuring about 2mm in length and black to brown in color. The head was sharply angled at the fronts (frons) with no genal and pronotal ctenidia. On the head behind the antennae, there were two setae and in females, a well developed occipital lobe. Mouthparts appear large extending the length of the fore coxae and project from the head conspicuously. The maxillary laciniae are broad and coarsely and thoracic segments narrowed dorsally.

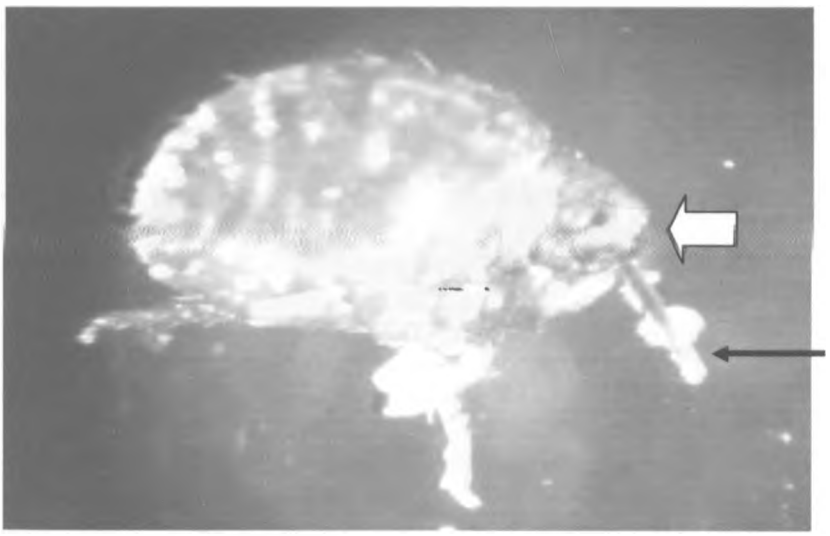

Figure 11. ***Echidnophaga gallinacea*** **found in a chicken from lower highland zone 1 showing head sharply angled at the frons (thick arrow); large mouth parts extending the length of fore coxae and projecting from the head conspicuously (narrow arrow) (magnification X 10)**

The occurrence of the fleas was almost the same among the three age groups of birds 31.3% (15/48) in growers, 29.2% (14/48) in adults and 27.1% (14/48) in chicks. Similarly, the differences in prevalence of the *E. gallinacea* between male birds 33.3% (24/72) and female birds 25% (18/72), and for birds from LH1 31.9% (23/72) and LM5 26.4% (19/72) agro ecological zones was very minimal. Hence, difference in occurrence of the *E. gallinacea* among age groups and sexes, and agro ecological zones was not significant ($P > 0.05$).

4.1.4 Poultry soft ticks

Argas persicus (A. persicus) (**Figure 12**) was the only genus and species of soft tick found in chicken in the study area. Out of the 144 birds examined, 8 (5.6%) had soft ticks (*A. persicus*) on their body (**Table 2**), attached to the unfeathered areas of the body skin. These ticks were also found in the poultry house. The tick load ranged from 0 to 28 ticks per bird, with an average tick load of 0.9 ticks per bird. The unfed adult tick was pale yellow, turning reddish brown when fed. The female tick was about 8mm in length, and the male's 5mm. The margin of the body appeared to be composed of irregular quadrangular plates or cells and the hypostome was notched at the tip. The scutum or festoons were absent, and the legs were unarmed.

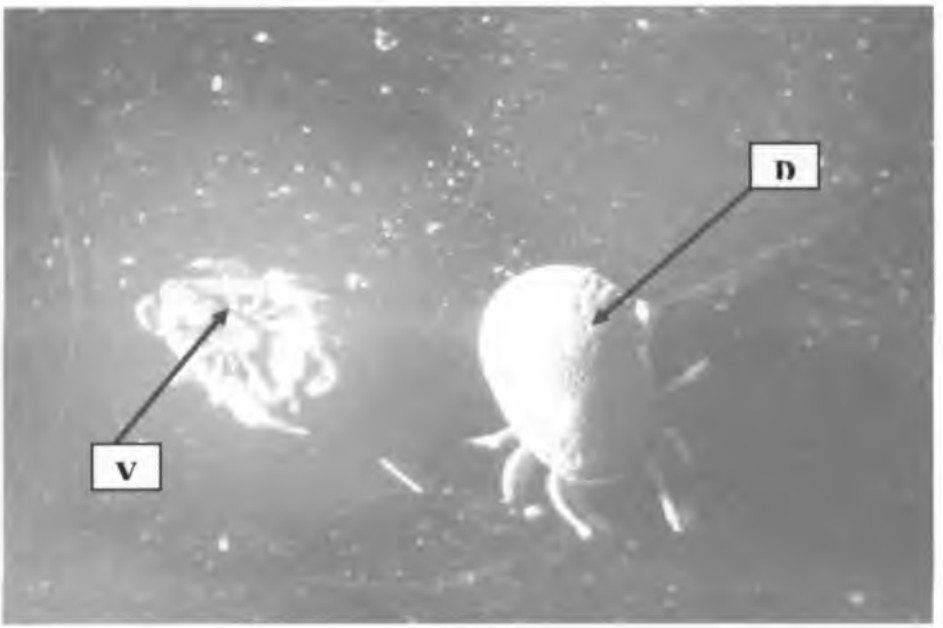

Figure 12. Ventral (V) and dorsal (D) views of *Argas persicus* nymphs found on a chicken from lower midland 5 (magnification X 10)

Chicks and growers both had a rate of 6.3% (3/48), while adult birds had 4.2% (2/48). Females had a slightly higher prevalence of 10.4% (5/48) than males 6.25% (3/48) birds. The parasite was only observed on chicken from Lower midland zone 5 (Mbeere) with an overall prevalence of 11.1%. The difference in occurrence among the age groups and between sexes was not significant statistically ($p > 0.05$), while that between the agro ecological zones was significant ($p < 0.05$).

4.2 Hemoparasite infections in indigenous chickens

Out of 144 birds examined, 114 (79.2%) were infected with haemoparasites. Three species of haemoparasites were found during this study. These were *Plasmodium* spp., *Leucocytozoon* spp., and *Haemoproteus* spp.

Plasmodium gallinaceum, 53.7% (77/144) was the most prevalent haemoparasite, followed closely by *Leucocytozoon schoutedeni,* 52.1% (75/144) and lastly *Haemoproteus* spp., 3.5% (5/144). Of the 114 infected birds, 71 (62.3%) had single infection, while 43 (37.7%) had more than one genera of haemoparasites (**Table 7**).

Table 7. Prevalence of haemoparasites in birds (single or mixed infection)

Haemoparasite occurrence in birds	**Number of birds infected with haemoparasites (x)**	**Percentage prevalence rate (x/144)**
***Plasmodium* species**	34	29.8
***Leucocytozoon* species**	36	31.6
***Haemoproteus* species**	1	0.9
***Plasmodium* species and *Leucocytozoon* species**	39	34.2
***Plasmodium* species and *Hemoproteus* species**	4	3.5
***Leucocytozoon* species and *Hemoproteus* species**	0	0.0

Among the age groups, grower birds showed a slightly higher rate of occurrence of 83.3% (40/48) compared to adults, 81.3% (39/48) and chicks, 72.9% (35/48). Male birds had a slightly higher rate of 83.3% (60/72) than female birds, 75.0% (54/72). Between the two agro ecological zones, LH1 (Embu) was found to have a higher prevalence rate of 81.9% (59/72) compared to LM5 (Mbeere), 76.4% (55/72). The rate of occurrence among bird age groups and sexes and between the agro ecological zones was not statistically significant.

4.2.1 *Plasmodium gallinaceum*

Plasmodium was found to infect 77 (67.5%) of the 114 birds infected with haemoparasites. *Plasmodium* gametocytes were observed in erythrocytes. They appeared as yellow, brown or black intra-cytoplasmic inclusions. The gametocytes were round to irregular, relatively small, and parasites tended to be in contact with the host cell nucleus. The merozoites had a "signet-ring" appearance due to a large vacuole that forced the parasite nucleus to one pole (**Figures 13** and **14**).

The occurrence rate of *Plasmodium* was the same (56.3%) in adult and grower birds, but slightly lower in chicks (47.9%). Males had a slightly higher rate of infection with *Plasmodium* (56.9%) compared to female birds, 50% (36/72). Between the agro ecological zones, Lower highland 1 was found to have a slightly higher rate of infection. 61.1% (44/72) than the Lower midland zone 5, 45.8% (33/72). The difference in the rate of occurrence of *Plasmodium gallinaceum* among the bird age groups and sexes, and between the agro ecological zones was not statistically significant.

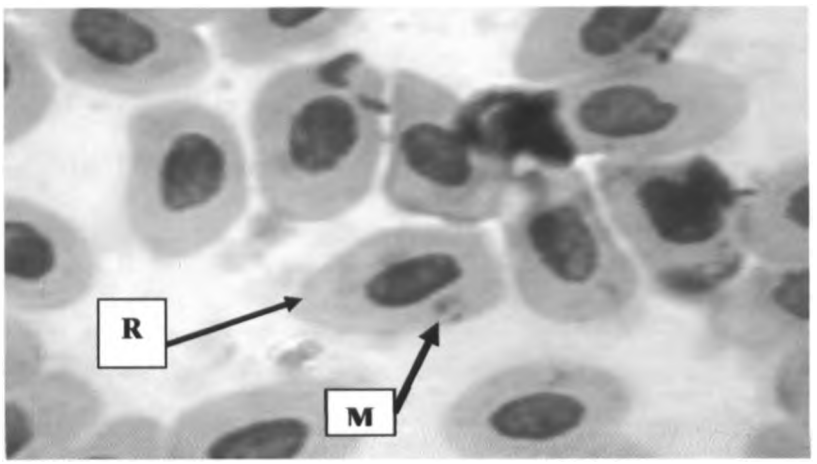

Figure 13. Blood smear showing a red blood cell (R) infected with a "signet-ring" merozoites (M) of *Plasmodium gallinaceum* (Giemsa stain, magnification X 1000).

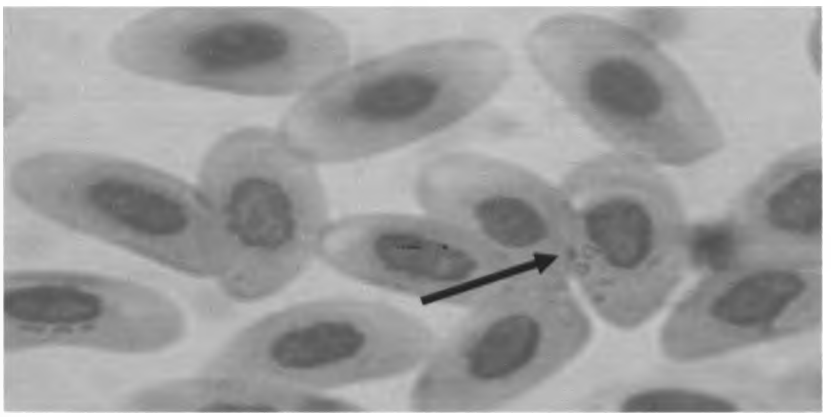

Figure 14. Blood smear showing a red blood cell infected with *Plasmodium gallinaceum* (arrow) (Giemsa-stained, Magnification X 1000).

4.2.2 *Leucocytozoon schoutedeni*

Out of the 114 birds infected with haemoparasites, 75 (65.8%) had *L. schoutedeni.* This parasite was found to infect the leukocytes. The parasites were spherical, ovoid or spindle-

shaped containing one to four elongated deeply staining structures called host cell nucleus or lateral bars. Gametocytes caused marked enlargement and distortion of the infected cell producing a football-like appearance (**Figure 15** and **16**). The nucleus of the host cell was elongate and formed a long thin dark crescent along one side of parasitized cell (**Figure 17**). Macrogamete stained dark blue with Giemsa stain, and the nucleus was compact and had several vacuoles occurring in darkly stained cytoplasm. The microgametes were slightly smaller than macrogametes, their cytoplasm stained less deeply, usually pale blue in color, and the nucleus was diffuse and stained pale pink.

This parasite showed an increase in prevalence rate with increase in age of the chicken. The adult birds had a slightly higher prevalence of 58.3% (28/48) compared to growers, 50.0% (24/48) and chicks 47.9% (23/48). Male birds had a higher prevalence 54.2% (39/72) than in females, 50% (36/72). There was a slight difference in occurrence of *L. schoutedeni* between Lower LM5 (Mbeere) 52.8% (38/72) and LH1 (Embu), 51.4 (37/72). The rate of *L. schoutedeni* occurrence among bird age groups and sexes, and between the agro ecological zones was not statistically significant.

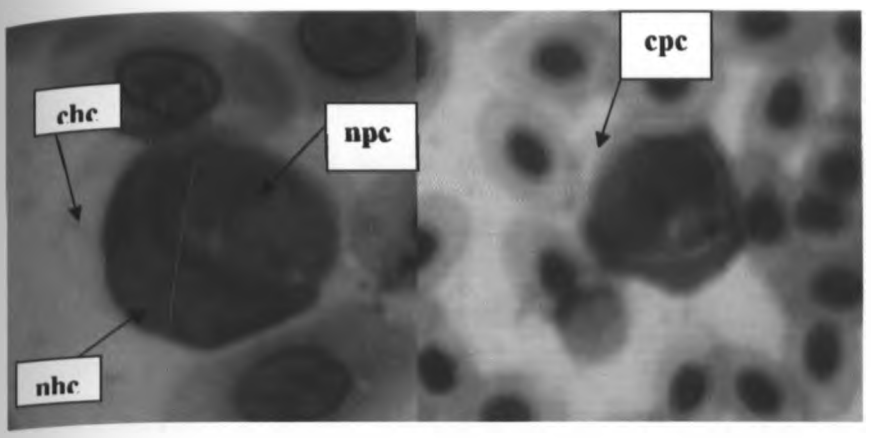

Figure 15 Figure 16

Figure 15 and 16. Chicken blood smears showing football-like *Leucocytozoon schoutedeni* (cytoplasm of host cell- chc; nucleus of host cell-nhc; cytoplasm of parasite cell- cpc; nucleus of parasite- npc) (Giemsa-stained, magnification X1000)

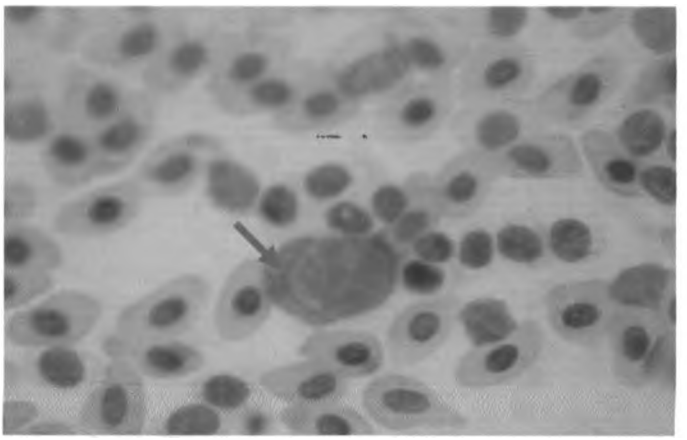

Figure 17. A Chicken blood smear showing an elongated host cell nucleus (arrow) forming a long thin dark crescent band along one side of parasitized cell (Giemsa stained, magnification X 1000).

4.2.3 *Haemoproteus* species

Out of 114 birds that had haemoparasites, 5 (4.4%) had *Haemoproteus* spp., occurring either singly or with mixed infections (**Table 7**). In Giemsa stained blood smears, the gametocytes of *Haemoproteus* spp., appeared elongate, sometimes horseshoe shaped cells embracing the erythrocyte nucleus. Cytoplasm of gametocyte contained pigment granules accumulating as result of incomplete digestion of hemoglobin.

Among age groups, this parasite was found in chicks 6.3% (3/48) and grower birds 4.2% (2/48), with no cases isolated from the adult birds. Between sexes, the female birds had a slightly higher prevalence, 4.2% (3/72) compared to males, 2.8% (2/72). This parasite was only found in chickens obtained from Lower highland zone 1 (Embu), 6.9% (5/72). The difference in rate of occurrence of *Haemoproteus* spp., among age groups and sexes was not significant statistically ($p>0.05$), while that between the agro ecological zones was statistically significant.

4.3 Gross and microscopic lesions of the skin in indigenous chickens

Out of 144 chickens that were examined for skin pathology, 94 (65.3%) had gross and 129 (89.3%) microscopic lesions.

4.3.1 Lesions on the head

Thirty five (24.3%) of the 144 heads examined had gross lesions (**Table 8**). These were edema and hyperemia around the eye (on the eye lids); pox-like lesions, and necrotic wounds especially on the comb, which were most likely due to trauma.

Microscopically, 52 (36.1%) birds had lesions (**Table 9**) that ranged from mild (51.9%) to moderate (48.1%) ones. Sixty per cent of the heads examined had no lesions and no parasites, 25% had both lesion and parasite, 11% had lesion alone and 4% had parasite alone (**Figure 18**). Of those that had lesions, 36 (69.2%) of these were attributed to *Echidnophaga gallinacea*, while 16 (30.8%) were not. Those due to parasite were necrosis, pressure atrophy due to parasites (present or absent); hemorrhage, hyperkeratinization, parakeratosis, epidermal breakages resulting to parasitic tracks in the epidermal and dermal tissues (**Figure 19**); inflammatory changes involving deeper layers of the skin characterized by plasma cells and heterophilic granulocytic infiltrations; and parasite cross-sections within the epidermal skin tissue (**Figure 20**).

Ninety two (63.3%) head skin sections had no lesion, 27 (18.7%) had mild lesions, 25 (17.4%) had moderate lesions, and there were no severe lesions. There was an association ($p< 0.001$) between the gross head lesions and the presence of *Echidnophaga gallinacea*

among the study chickens (**Appendix 4a**), and a strong association between presence of microscopic lesion and occurrence of *E. gallinacea* (**Appendix 5a**).

Table 8. Number of chickens with gross head lesions and the percentage prevalence rates among chicken age groups, sexes and agro ecological zones

Chicken groups, sexes and agro ecological zones		**Number of chickens with gross head lesions**	**Percentage prevalences**
Total positive chickens		35	24.3
Age groups	Chicks	8	22.9
	Growers	12	34.3
	Adults	15	42.8
Sexes	Females	21	60.0
	Males	14	40.0
Agro ecological zones	LH1	11	31.4
	LM5	24	68.6

Table 9. Number of chickens with microscopic lesions on the head skins and percentage prevalence rates among chicken age groups, sexes and agro ecological zones

Chicken groups, sexes and agro ecological zones		Number of chickens with histopathological lesions	Percentage prevalences
Total positive chickens		52	36.1
Age groups	Chicks	9	17.3
	Growers	18	34.6
	Adults	25	48.1
Sexes	Females	29	55.8
	Males	23	44.2
Agro ecological zones	LH1	20	38.5
	LM5	32	61.5

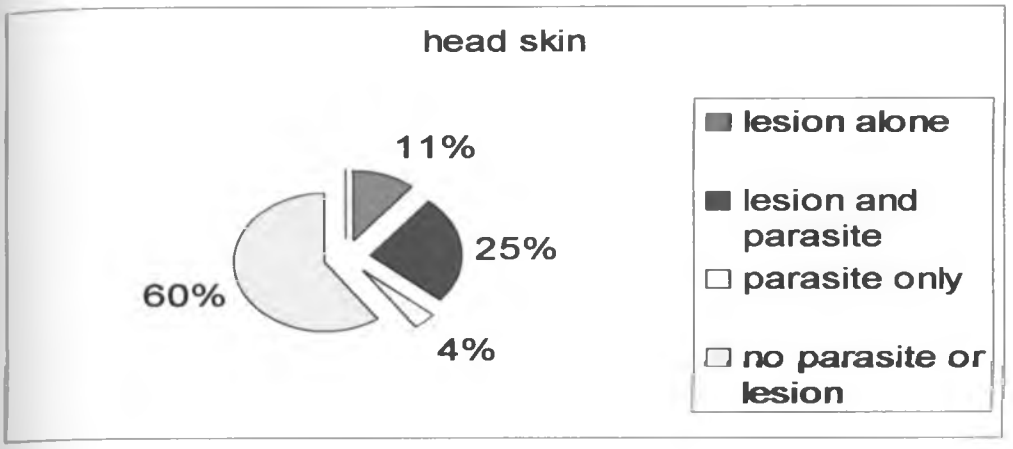

Figure 18. A pie chart showing microscopic lesions on the head, with or without presence of *Echidnophaga gallinacea*

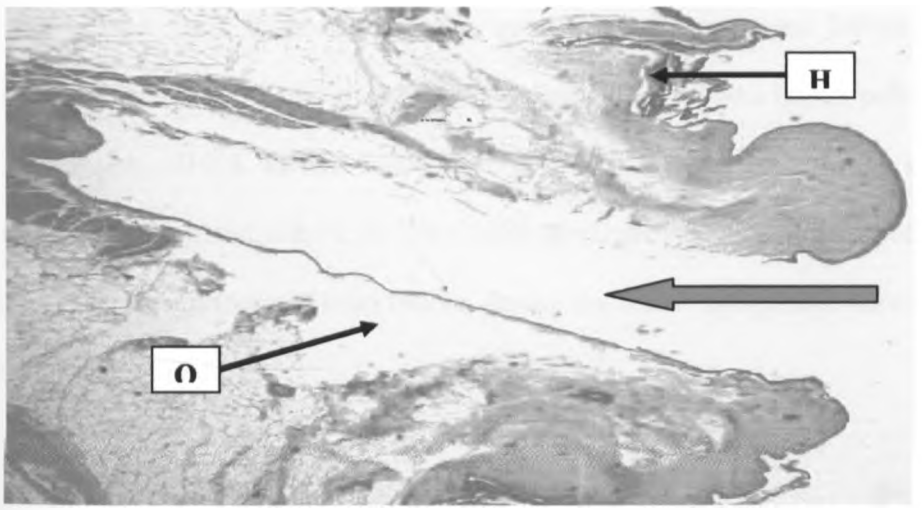

Figure 19. A section of the head skin (comb) showing parasitic track caused by *Echidnophaga gallinacea* (thick arrow), oedema/ loose tissue (O) and hyperkeratosis (H) (magnification X100, H.E stain)

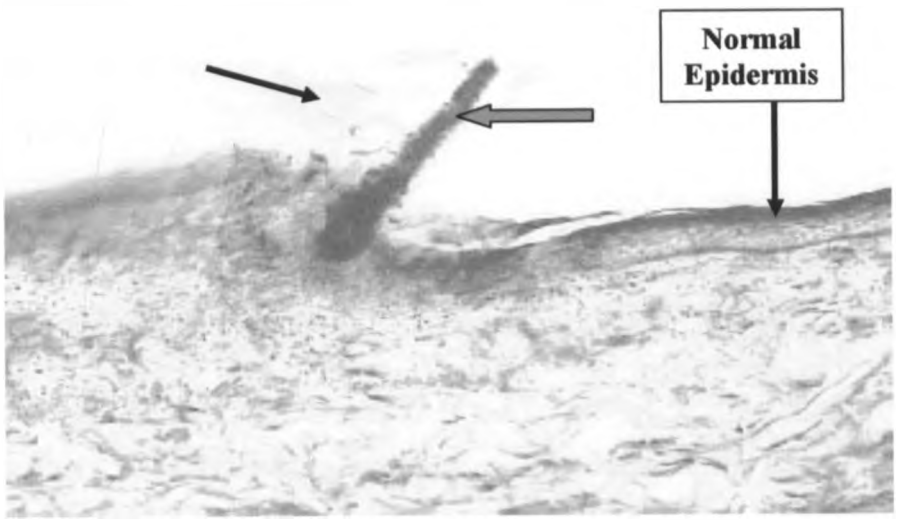

Figure 20. A head skin section showing mouth parts of *Echidnophaga gallinacea* inserted into the epidermis (thick arrow) surrounded by epidermal debris (thin arrow) (magnification X 100, H.E stain)

Among age groups, adult birds had a higher prevalence of gross head lesions (42.8%) compared to growers (34.3%) and chicks (22.9%). Female birds had a higher prevalence of 60.0% than males, 40.0%. Lower midland zone 5 had a higher prevalence of 68.6% compared to lower highland zone 1, 31.4% (**Table 8**). There was statistical significant ($p< 0.05$) difference in occurrence of head lesions among the birds' age groups, between sexes and agro ecological zones.

Adult chickens showed a higher prevalence in occurrence of microscopic lesions (48.1%) than growers (34.6%) and chicks (17.3%). Between sexes, female birds had a higher rate of 55.8% (29/52) compared to male ones, 44.2% (23/52). In the study zones, there were more occurrences of these lesions on birds from LM5 (61.5%) than those from LH1 (38.5%)

(**Table 9**). There was a statistical significant difference in occurrence of microscopic lesions among chicken age groups, between the birds from LH1 and LM5, but not between chicken sexes.

4.3.2 Lesions on the chicken legs

Gross leg lesions were observed in 63 (43.8%) chicken examined (**Table 10**). In the early stages mild lesions observed were small yellowish- grey or reddish- brown, wart like skin proliferations; minor scale formation, beginning on the soft parts of the planter side of the tarsus and the shanks and later spread along the digits to the hock. In severe cases, there was a massive hypertrophic dermatitis with the whole leg showing massive skin proliferations (**Figure 21**). There were hyperemic areas along the groove on the shanks of the leg. This groove had pathological materials ranging from powdery dandruff to heavy encrustations; elevated scales and increased desquamation. Feathered parts of the legs were not involved, nor were there any lesions seen around the beak. There was no loss of toes, although in some cases, there were overgrown toe nails. Other lesions included: wounds, swollen hock joints and bumble foot. Chicks and growers had lesions ranging from mild to moderate with majority of birds showing no gross lesions, while adult birds had lesions ranging from mild to severe leg skin lesions (**Figure 22**).

Microscopic examination revealed that 80 (55.6%) chicken (**Table 11**) had leg lesions. Sixty two (77.5%) of these, were attributed to *Cnemidocoptes mutans* while 18 (22.5%) were due to other causes (**Figure 23**). Lesions were characterized by hyperkeratinization (proliferated stratum corneum), parakeratosis, inflammatory and cellular changes,

congestion of the dermal blood vessels and pouches or burrows caused by mites. Some pouches had sections of mites (**Figure 24**) while others were empty, probably due to loss of mites during the processing or because the mites had penetrated more deeply.

Sixty four (44.4%) of the leg skin sections examined for histopathology had no lesion, 19 (13.2%) had mild lesions, 50 (34.7%) had moderate lesion, while 11 (7.6%) had severe lesion. There was an association between the occurrence of leg gross and microscopic lesion and the presence of *Cnemidocoptes mutans* (**Appendix 4b; Appendix 5b**).

Table 10. Occurrence of gross leg lesions among chickens by age group, sex and agro-ecological zones

Chicken groups, sexes and agro ecological zones		**Number of chickens with gross leg lesions**	**Prevalence (%)**
Total positive chickens		63	43.8
Age groups	Chicks	13	20.6
	Growers	20	31.7
	Adults	30	47.6
Sexes	Females	35	55.6
	Males	28	44.4
Agro ecological zones	LH1	23	36.5
	LM5	40	63.5

Table 11. Occurrence of microscopic leg lesions among chickens by age group, sex and agro-ecological zones

Chicken groups, sexes and agro ecological zones		Number of chickens with histopathological lesions	Prevalence (%)
Total positive chickens		80	55.6
Age groups	Chicks	15	18.8
	Growers	32	40.0
	Adults	33	41.3
Sexes	Females	43	53.8
	Males	37	46.2
Agro ecological zones	LH1	29	36.3
	LM5	51	63.7

Figure 21. Legs of a chicken infested with *Cnemidocoptes mutans* showing heavy encrustation (C) with scaly formation on the plantar surface of the digits

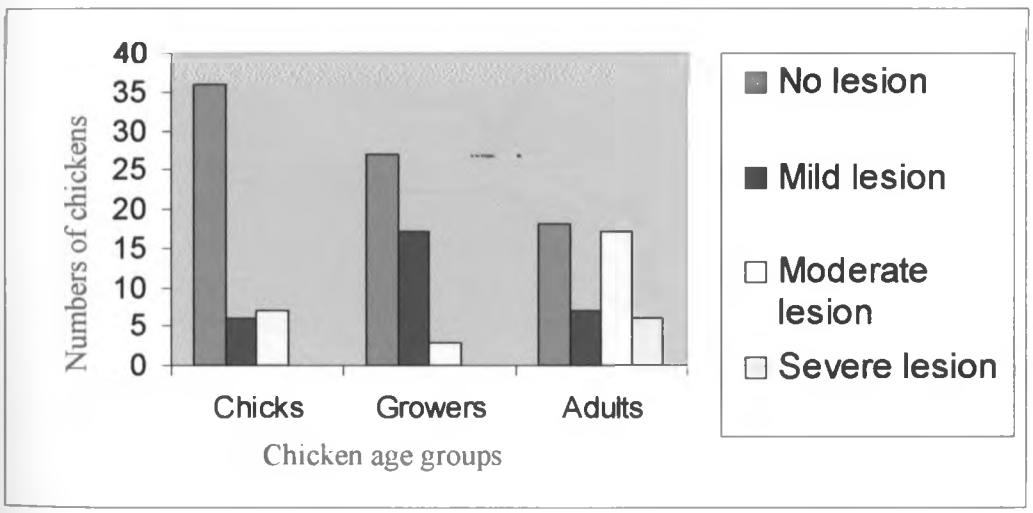

Figure 22. Distribution of gross leg lesions by severity among chicken age groups from LH1 and LM5 agro ecological zones

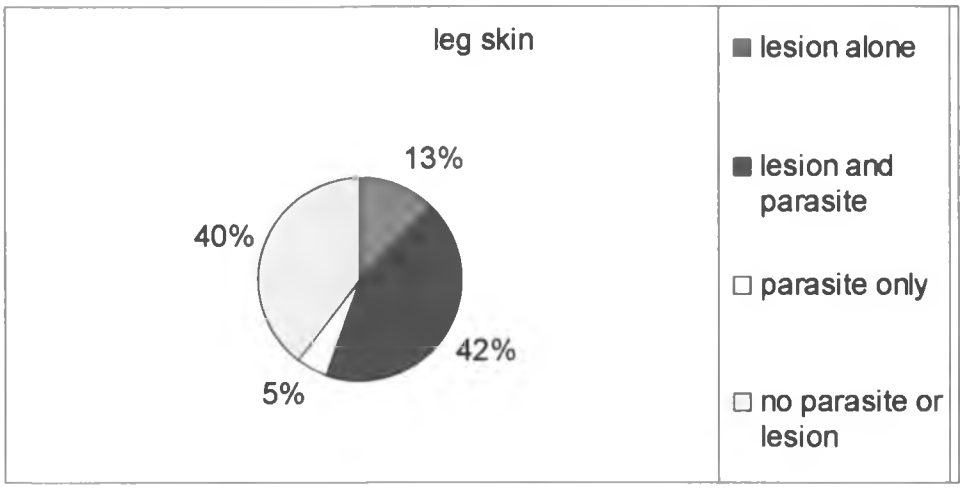

Figure 23. A pie chart showing the presence or absence of microscopic lesions on the leg skins, with or without *Cnemidocoptes mutans*

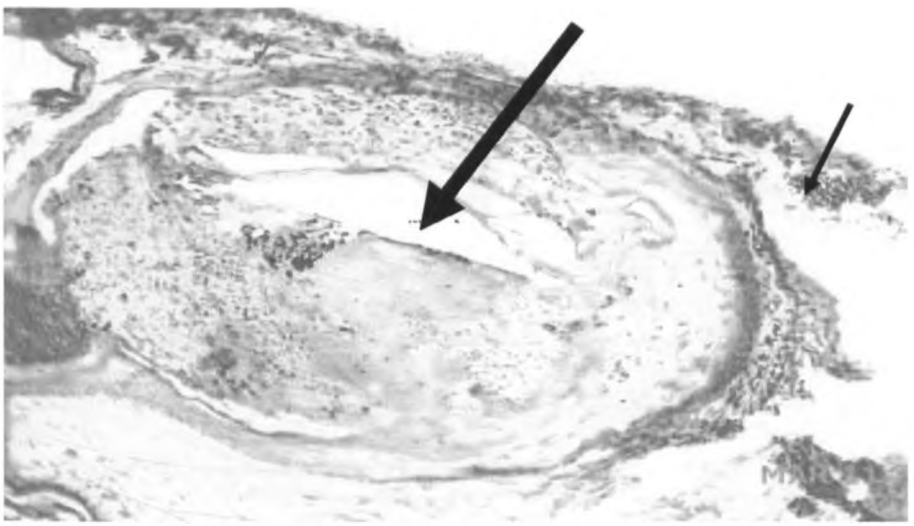

Figure 24. A histological section of the leg skin showing a cross section of *Cnemidocoptes mutans* (thick arrow) in a pouch, covered by highly proliferative stratum corneum (parakeratosis; thin arrow) (magnification X 100, H.E stain)

Among the age groups, adult birds had a higher rate (47.6%) of gross leg lesions compared to growers (31.7%) and chicks (20.6%). Females had a slightly higher rate of 55.6% compared to male birds (44.4%) (**Table 10**). Between ago ecological zones, lower midland zone 5 had a high rate (63.5%) than lower highland zone 1 (36.5%). There was a significant difference in occurrence of gross leg lesions among age groups and between agro ecological zones, but not between chicken sexes.

For the microscopic lesions, adult birds had a slightly higher rate of occurrence (41.2%) compared to grower (40.0%) and chicks (18.8%). Between sexes, female birds had a high rate of 53.8% (43/80) than male ones 46.2% (37/80). Chicken from LM5 had a higher prevalence of occurrence of leg lesions (63.7%) than those from LH1 (36.3%) (**Table 11**). The difference in rate of occurrence of the microscopic lesions of the leg skin among chicken age groups and between agro ecological zones was statistically significant ($p < 0.05$), while that between the sexes was not ($p > 0.05$).

4.3.3 Lesions on the rest of the chicken body

Gross examination of the body skins revealed that 46 (31.9%) chickens had macroscopic lesions (**Table 12**). Lesions observed were skin desquamation leading to dandruff formation; superficial necrotic wounds common around the abdominal area; feather loss, hyperemia and thickened skin especially around the neck area. Areas infested by ticks were characterized by pitting ulcer formations (**Figure 25**), and/ or nodular skin formation due to inflammatory reactions.

Microscopic lesions were observed in 129 (89.6%) chicken skins (**Table 13**). Of these, 96.1% (124/129) were due to lice, mites and ticks, while 3.9% (5/129) were due to other causes (**Figure 26**). The lesions were characterized by hyperkeratinization (acanthosis) (**Figure 27**), parakeratosis, sections showing thinning and thickening of the epidermis and dermis; mononuclear cells infiltration and parasite cross-sections within the epidermal skin tissue.

Fifteen (10.4%) chicken body skin sections had no lesions, 27 (18.7%) had mild lesions, 93 (64.6%) had moderate lesion, while nine (6.3%) had severe lesion. Association between presence of lice, body mites and ticks, and occurrence of gross lesions was not statistically significant ($p > 0.05$; **Appendix 4c**), while that of microscopic lesions was statistically significant ($p < 0.05$; **Appendix 5c**).

Table 12. Occurrence of gross body lesions among chickens by age group, sex and agro-ecological zones

Chicken groups, sexes and Agro ecological zones		Number of chickens with gross body lesions	Prevalence (%)
Total positive chickens		46	31.9
Age groups	Chicks	8	22.9
	Growers	15	32.6
	Adults	23	50.0
Sexes	Females	20	43.5
	Males	26	56.5
Agro ecological zones	LH1	18	39.1
	LM5	28	63.5

Table 13. Occurrence of microscopic body lesions among chickens by age group, sex and agro ecological zones

Chicken groups, sexes and Agro ecological zones		Number of chickens with histopathological lesions	Prevalence (%)
Total positive chickens		129	89.6
Age groups	Chicks	37	28.7
	Growers	45	34.9
	Adults	47	36.4
Sexes	Females	61	47.3
	Males	68	52.7
Agro ecological zones	LH1	58	45
	LM5	71	55

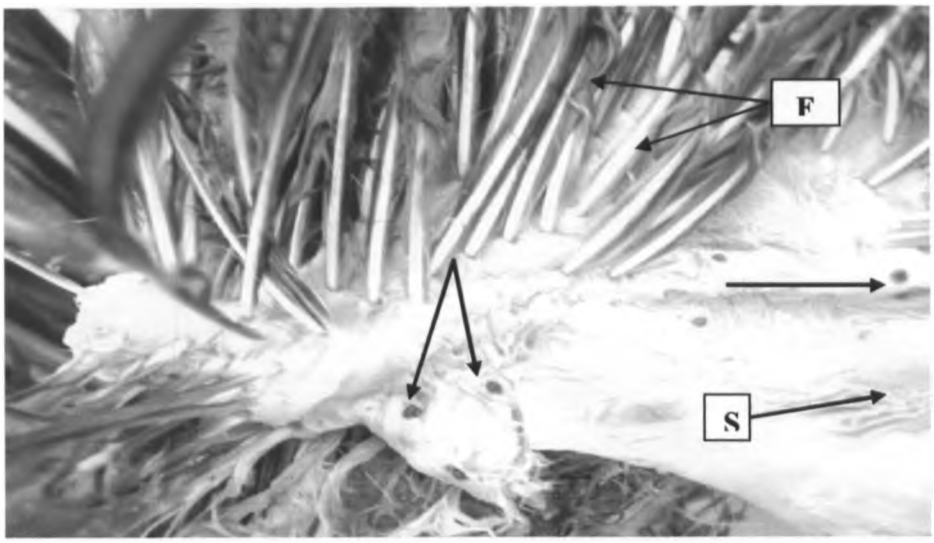

Figure 25. A section of body skin (abdominal area) showing pitting ulcers (brownish red areas) on the skin (S) between feathers (F) where larvae and nymphs of *Argas persicus* were attached (arrows)

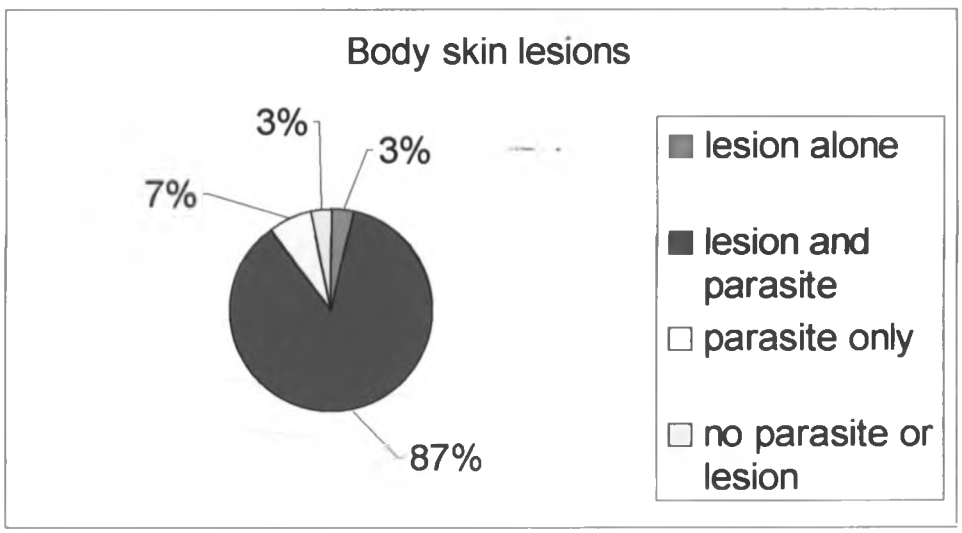

Figure 26. A pie chart showing microscopic lesions on the body skin, due to ectoparasites (lice, body mites and ticks)

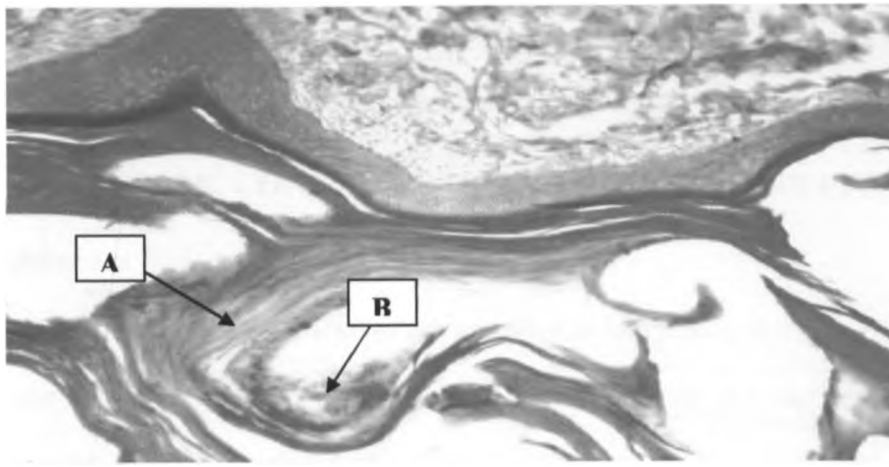

Figure 27. A section of the body skin showing heavy hyperkeratinization (A) and cross section of a parasite in the stratum corneum (B) (magnification X 100, H.E stain)

Adult chicken had a higher occurrence of gross body lesions (50.0%) than growers (32.6%) and chicks (17.4%). Males had a higher rate (56.5%) than females (43.5%), while birds from LM5 showed a high rate of gross lesions occurrence of 60.9% compared to those from LH1 (**Table 12**). There was a significant difference in occurrence of body lesion among age groups and between agro ecological zones ($p < 0.05$), but not between sexes.

Adult birds had a higher rate of occurrence of microscopic lesions of 36.4% (47/129) than grower birds, 34.9% (45/129), and 28.7% (37/129) in chicks. Between sexes, the male birds had a higher prevalence at, 52.7% than female birds (47.3%). Lower midland zone 5 had a high rate (55.0%) than LH1 (45.0%) (**Table 13**). The difference in rate of occurrence of microscopic lesions of the body among age groups and between agro ecological zones were significant statistically, but not between the sexes of birds ($p > 0.05$).

CHAPTER FIVE

5.0 DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion

This study showed that ectoparasites are prevalent in indigenous chicken in Embu (lower highland zone 1) and Mbeere (lower midland zone 5) districts, at a rate of 95.8%. Similar observations of high prevalence of ectoparasites in chickens have been reported in other tropical African countries such as Nigeria (Sadiq *et al.,* 2003), Ethiopia (Abebe *et al.,* 1997), Zimbabwe (Permin *et al.,* 2002), Malawi (Njunga, 2003) and Kenya (Maina, 2005 and Mungube *et al.,* 2008). Such high prevalences could be due to the free-range system practiced in the study areas, which exposes the birds to poor hygiene on the farm and chicken houses thus, enabling them to contract a wide range of harmful ectoparasites. The free-range system provides a more sustainable environment for the parasites. Mungube *et al.* (2008) reported that lack of control measures towards these parasites was a possible factor contributing to the high prevalence of the parasites.

Ectoparasites damage feathers, irritate and cause skin lesions, resulting in reduced performance of adult chickens and direct harm to young chicks (Arends, 2003). The importance of these ectoparasites transcends the direct impact on poultry production limiting the protein available to humans. Some of these parasites encountered in this study (*Argas persicus* and *Dermanyssus gallinae*) are reported either to infest man or cause annoyance especially in rural areas where there is close association between man and domestic fowls. *Argas persicus* is known to infest man especially children (Arends, 2003; Sadiq *et al.*, 2003).

The adult birds had a 100% overall prevalence of ectoparasite, which was slightly higher than that of growers (97.7%) and chicks (89.6%). These findings are in agreement with those from studies in Zimbabwe (Permin *et al.,* 2002) and Nigeria (Biu *et al.,* 2007), in which adult birds were compared to young birds. Comparisons of prevalence of ectoparasites among all three chicken age groups of birds (chicks, growers and adults) have previously not been reported in other tropical countries. Adult and grower chicken had a higher intensity of lice (overall), *Menopon gallinae* and *Lipeurus caponis,* when compared to chicks. Older birds maybe are exposed longer to the infested environment than the chicks, hence a higher prevalence and intensity rates. Previous studies on ectoparasites have not reported intensities as in this study.

Both male and female birds had the same prevalence of 95.8%. Mungube *et al.* (2008) reported that males had a slightly higher rate of occurrence of ectoparasites compared to females, while in Nigeria, Biu *et al.* (2007) found that female chickens had a higher prevalence of ectoparasites (15.4%), than male birds (14.7%). In both studies, the differences were not significant statistically. There are conflicting reports on the impact of host sex on prevalence of avian lice. It has been stated that lice are more prevalent on male birds in case of sparrows (Woodman and Dicke, 1954). However, no difference in louse prevalence with respect to host sex has been noted in domestic hens (in case of *M. gallinae*) (Saxena *et al.,* 1995). During the present studies, sex related differences in the prevalence were not found to be significant. However, some have stated that a number of host factors may occasionally cause variation in louse prevalence in some cases (Saxena *et al.,* 1995), but generally there is no significant difference in prevalence with respect to host sex. These

findings suggest that sex is not an influential factor on the prevalence rates of ectoparasites in poultry.

Lower midland zone 5 was found to have a slightly higher prevalence (98.6%) compared to LH1 (93.1%). There was a significant difference in intensities of lice (overall) and *Menopon gallinae* between the agro ecological zones, with LM5 having a higher intensity than LH1, probably due to agro climatic variation. Lower midland 5 is a semi-arid area with lots of shrubs, high temperatures and lower altitude. This provides a suitable ecological environment for productive parasite lifecycles. Warmer temperatures lead to higher parasite prevalence and/ or intensities (Fabiyi, 1996). However, LH1, in Embu district is a wet agricultural area with high rainfall, high altitude and lower temperatures. Although these conditions interfere with parasite life cycles, the vegetation is usually dense to provide amble-breeding place for these ectoparasites. Also, due to cold weather experienced in LH1 agro ecological zone, this tends to modify the behavior of chicken by encouraging confinement, which in turn facilitates the transfer of parasites from infested to non-infested chicken. This may explain the slight difference in prevalence between the agro ecological zones despite their varying agro climatic condition. The difference in intensity rates can possibly explain a better adaptability of lice (overall) and *M. gallinae* to lower midland zone 5, compared to lower highland zone 1.

Lice were the most prevalent (91.0%) ectoparasites encountered, followed by mites (74.3%), sticktight fleas (29.2%), and soft ticks (5.6%). This is in contrast to findings in previous studies in Kenya (Maina, 2005 and Mungube *et al.*, 2008) in which the stick tight

flea *Echidnophaga gallinacea* was reported to be the most prevalent ectoparasite. The prevalence rates for the parasite from those studies were 56% (Maina, 2005) and 76.7% (Mungube *et al.,* 2008). However, the report by Njunga (2003) indicated that *Cnemidocoptes mutans* was the most prevalent from a study carried out in Malawi, while Biu *et al.* (2007) reported *Argas persicus* to be the most prevalent ectoparasite encountered during their studies in Nigeria. Differences in type and prevalence of the most commonly encountered ectoparasites may be due to a variation in agro-climatic and topographic conditions and species adaptability.

Three species of lice were recovered during the present study. These were *Menopon gallinae*, *Lipeurus caponis* and *Goniodes gigas. Menopon gallinae* was the most prevalent lice species encountered. Similar observations were made by Maina, (2005) in Kenya and Sadiq *et al.* (2003) in Nigeria. *Lipeurus caponis* and Gonioides *gigas* have not been reported in Kenya before. May be they are not wide spread but found in some parts of the country. Maina (2005) found *Cuclotogaster heterographus* and *Goniocoites gallinae*, while Mungube *et al.* (2008) found *Menacanthus stramineus* in their studies, which were not encountered during this study.

The effects of lice on host stem from the vicious cycle started by irritation on the host. Birds become restless, do not sleep or feed well, have self-inflicted injury and damaged feathers. In laying birds with heavy infestation, egg production may fall (Soulsby, 1982). These effects are more pronounced in young chicks which become unthrifty, susceptible to various poultry diseases and may eventually die (Sadiq *et al.*, 2003).

Five mite (*Cnemidocoptes mutans*, *Dermanyssus gallinae*, *Epidemoptes* spp, *Laminosioptes cysticola* and *Megninia species*) species were found during the present study. *Cnemidocoptes mutans* was the most prevalent followed by *D. gallinae*. In previous studies, Permin *et al.* (2002) found *C. mutans* in their study in Zimbabwe. In Nigeria, Sadiq *et al.* (2003) found *D. gallinae*; in Kenya, Maina (2005) reported *C. mutans* while Mungube *et al.* (2008) found *C. mutans* and *D. gallinae*, in their studies. This study found three mites (*Epidemoptes* spp, *Laminosioptes cysticola* and *Megninia species*) species that had not been previously reported in previous studies in Africa. The differences in species identified in various studies may be due to variation of agro climatic zones where these studies were done.

Cnemidocoptes mutans was found to infest 66.4% of 144 birds examined. This prevalence was high compared to findings by Permin *et al.* (2002) who reported low prevalence rates of 6% and 32% in young and adult chickens, respectively; Maina (2005) (24%) and Mungube *et al.* (2008) (13.3%). The variation in prevalence of *C. mutans* is likely to be due to agro climatic differences between the study areas, season of study and control measure (local) instigated against *C. mutans* in these chickens. There was no difference in occurrence of *C. mutans* among chicken age groups and between sexes; however, there was a difference in occurrence between agro ecological zones with LM5 (warm) showing a higher prevalence than LH1 (cool), which could be due to difference in geographical and climatic factors exhibited by these agro ecological zones.

Dermanyssus gallinae (red poultry mite) was found at a rate of 7.5% between the two study areas. This rate was lower compared to studies done by Mungube *et al.,* (2008), who found 60.0% prevalence. *Dermanyssus gallinae* was found on grower and adult birds only. This is most likely a confirmation that *D. gallinae* hides in densely feathered skin areas, away from possible light (nocturnal behavior). The prevalence rate found is presumably lower than the actual prevalence due to its nocturnal behavior and a possible limiting collection strategy used, that excludes other parasites feeding only briefly on chickens such as mosquitoes and other flies. The difference in rate of occurrence between the current and previous studies is likely to be due to a difference in geographical and climatic factors between the study areas. This mite was not found on chicks, this may be as a result of poor feather cover, hence chicks did not provide suitable hiding place for *D. gallinae.* Male birds had a higher prevalence (6.9%) when compared to female ones (4.2%), this was however in contrast to reports by Mungube *et al.* (2008), who found females to have a slightly higher prevalence compared to males. The reasons for such differences remained unknown and calls for further research. In both studies, the differences between sexes were statistically insignificant. The occurrence of *D. gallinae* between agro ecological zones was not significant and no previous reports comparing the prevalence between agro ecological zones. This parasite is responsible for egg abandonment in brooding hens. Where chickens share the same house with humans, its presence is a big problem to people as well.

Epidermoptes species was found in 83.2% of the 107 chicken that harbored mites. This rate was so high considering the fact that this mite has not been reported in Africa. This high prevalence greatly reflects to the resultant pathologic lesions, as these skin mites causes pityriasis. When lesions are produced, they consist of a fine scaly dermatitis, followed by

formation of thick, brownish, sharply edged scabs (Arends, 2003). In this study, there was a significant difference in occurrence between LM5 and LH1. This may be linked to the agro climatic variation between the two study areas. The differences in prevalence rates among age groups and sexes were not significant.

Megninia species was found to infest 2.8% of chicken examined. The mites were found on the contour feathers. This mite has not been reported in Africa though they cause significant pathological lesion which in turn reduce the productivity of these birds. *Megninia* spp (feather mite) in chicken causes severe scratching and a 10% drop in egg laying rate in chicken (Philips, 1997).

Laminisioptes cysticola was found on 1.4% of the 107 birds infested with mites. This mite has also not been reported in previous studies in tropical countries. Arends (2003) reported that *L. cysticola* (fowl cyst mite) do not appear to influence the health of infested birds although the lesion may make carcasses unpalatable as food for human hence condemned on inspection.

One species of chicken flea (*Echidnophaga gallinacea,* stick tight flea) was found in the present study, at a rate of 29.2%. These findings were lower compared to the previous studies done in Kenya, 56.0% prevalence (Maina, 2005) and 76.7%, (Mungube *et al.*, 2008) and in Zimbabwe, 76.7% (Permin *et al.*, 2002). The variation in prevalence is likely to be due to agro climatic differences between the study areas, age of study birds and season of study, and control measure (local) instigated against *E. gallinacea* in these chickens. There

was evidence of control measures put in place in our study areas. *Echidnophaga gallinacea* has been reported in a number of hosts including chickens, turkeys, wild birds, humans, mice, cats and dogs (Mungube *et al.,* 2008). The range of sticktight flea is widespread in tropical and subtropical regions (Permin *et al.,* 2002). In this study, the flea infestation did not vary in different chicken sex and age groups and between the agro ecological zones.

Their intensity rates were 3.8 fleas per bird with a range of 0- 113. Direct effects of sticktight flea infestation in poultry may include weight loss, decreased egg production, irritation, blood loss, and possibly death in young birds. Signs of anemia as a result of the blood loss are frequently seen in infected chicken. Sticktight fleas are generally found in clusters on the head, particularly the comb, wattle, and around the eyes, preferring areas with few feathers. This observation by Gustafson *et al.* (1997) was consistent with our findings. Sticktight fleas do not completely burrow into the host as does the human fleas, but they do attach to the skin by burying mouthparts or fascicles. The mouthparts are embedded into the host's skin, making it difficult to dislodge (Gustafson *et al.*, 1997). Ulcerations form at the site of attachment and serve as a site for egg deposition (Hogsette *et al.*, 2003). There was no difference in occurrence of *E. gallinacea* among bird's age group, between sexes and agro- ecological zones. This has not been reported in previous studies and may be due to free range nature of this system which allows birds of different ages and sexes to interact. However, the similarity in occurrence between agro ecological zones is not well understood and hence could warrant further investigation. There are no previous reports on the same.

Argas persicus, the poultry soft tick was reported at a rate of 5.6%. This rate was lower compared to previous studies done in Zimbabwe (6% and 14% in young and adult chicken respectively) (Permin *et al.,* 2002); and Kenya (29.3%) (Maina, 2005) and (11.1%) (Mungube *et al.*, 2008).

Argas persicus is probably a limiting factor of successful poultry production in the tropical and subtropical areas (Reid, 1956). Ticks transmit bacterial, rickettsial, viral, and parasitic and spirochaetal diseases in poultry. *Argas persicus* transmits *Mycoplasma gallisepticum, Mycoplasma meleagridis* (Soliman *et al.,* 1988), *Salmonella gallinarum* (Gyurov, 1983), *Aegyptinella pullorum,* avian encephalomyelitis, Leucocytozoonosis (Permin and Hansen, 1998), and *Borrelia anserina* (Durden *et al.,* 2001). *Argas persicus* harbors different types of bacteria including those of genus *Salmonella, Aerobacter, Escherichia, Proteus, Staphylococcus, Flavobacterium, Bacillus, Pseudomonas* and *Streptococcus* (Buriro, 1983). *Argas persicus* infestation causes paralysis in birds (Soulsby, 1982), and their larvae have been responsible for simultaneous occurrence of infectious bursal disease and Spirochaetosis (Abdu, 1987).

The difference in geographical and climatic factors could probably be the reason for the differences observed between the present study and the previous studies; however, the true prevalence of *A. persicus* is presumably higher than reported here because of its nocturnal behavior. The larval and nymphal stages were encountered only in the LM5, and there was no difference in infestation between different chicken age and sex group. Its intensity was 0.9 ticks per bird with a range of 0- 28 ticks.

In general, this study revealed that multiple infestations (81.9%) were common as opposed to single ectoparasite infestation (18.1%) hence a possible synergistic potential between these ectoparasitic groups in causing the pathology of the skin as it was observed in both gross and histopathological skin lesion.

The results obtained from examination of blood smear revealed the presence of three haemoparasites (*Plasmodium* spp, *Leucocytozoon* spp and *Haemoproteus* spp) that were found to infect poultry in the study zones. Mixed infections with two of these haemoparasites were encountered. The findings of this study are consistent with the study by Sadiq *et al.* (2003) in Ibadan, Nigeria, who reported the same three haemoparasites (*Plasmodium* spp, *Leucocytozoon* spp and *Haemoproteus* spp) during their study. In other studies in Malawi, Njunga (2003) reported the occurrence of *Plasmodium gallinaceum, P. juxtanucleare* and *Aegyptinella pullorum.* However, observation on haemoparasitism indicated that the indigenous chicken samples examined in this study lacked *Aegyptinella* spp., which is frequently encountered in birds in Africa (Poulsen *et al.*, 2000, Permin *et al.*, 2002 and Njunga, 2003).

The prevalence of haemoparasites in birds in this study was found to be 79.2%. This high prevalence of blood parasites is comparable to the studies done by Valkiūnas *et al.* (2005) who reported that the prevalence of avian blood parasites in Uganda was 61.9%, while Njunga (2003) in Malawi found the prevalence of haemoparasites in chicken to be 71.0%. There were no differences in occurrences among bird age groups, and across sexes and agro ecological zones. The findings between age groups were consistent with the findings of

Permin *et al.* (2002), who compared the prevalences between young and adult free range birds. All infected chickens in Zimbabwe (Permin *et al.*, 2002) had a low parasitaemia (<1% of erythrocytes were infected). However, there were no documented studies on the comparisons between sexes, and agro ecological zones. The reason similar prevalences between bird's age groups and across sexes and agro ecological zones were not clear hence should be studied further.

Plasmodium gallinaceum occurred in 77 of 144 birds (53.7%) examined and was the most prevalent haemoparasite encountered during our study. This high prevalence was in contrast to results found in a study in Zimbabwe where, 14 of 94 chickens (14.9%) harbored *Plasmodium gallinaceum* (Permin *et al.*, 2002), and that in Ghana where 27 of 100 birds (27.0%) harbored *Plasmodium juxtanucleare* (Poulsen *et al.,* 2000). This variation can be adequately attributed to variation between agro climatic conditions. Fallis *et al.* (1973), Adene and Dipeolu, (1975) and Permin *et al.* (2002) indicated that *Leucocytozoon* spp. may be the most common hematozoan in these birds in Africa. This was however in contrast to the findings of the current study and that by Sadiq *et al.* (2003), where *Plasmodium* spp., was found to be the most prevalent.

Of the three haemoparasites encountered, *Plasmodium gallinaceum* is the most pathogenic. Soulsby (1982) cited progressive emaciation, anaemia, enlargement of spleen and liver. Paralysis may be observed where there are massive numbers of exoerythrocytic forms in the endothelia cells of the brain capillaries and death in untreated cases. In Zimbabwe, Permin *et al.* (2002) found that the differences in prevalence of *Plasmodium gallinaceum*

were not significantly different between the bird's ages (young and adult). This report was similar to our findings. However, there were no previous reports on comparison of occurrences of *Plasmodium* spp. between bird's sexes and agro ecological zones. The differences in prevalence of *Plasmodium* spp. in this study is most likely connected to abundance and variations in appearance of vectors (Permin *et al.*, 2002).

Leucocytozoon schoutedeni was found in 75 (52.1%) of 144 birds examined. This prevalence was comparable to studies by Fallis *et al.* (1973) who reported that of 150 chickens tested in Tanzania, more than 50% were infected with *L. schoutedeni.* Seghal *et al.* (2006) in their studies in Uganda found that the prevalence of *L. schoutedeni* was 31.0%, a prevalence that was lower than these findings. In Zimbabwe, 4 of 94 (4.3%) chickens' harbored *Leucocytozoon sabrazesi*, but in Ghana, no *Leucocytozoon* infection was detected (Poulsen *et al.*, 2000). Earlier studies showed *Leucocytozoon* spp. infected 55 of 163 (34%) examined chickens in Ibadan, Nigeria (Adene and Dipeolu, 1975). This variation in prevalence and distribution of various *Leucocytozoon* spp. can be attributed to agro climatic variation which affects vector distribution and adaptation of the *Leucocytozoon* spp., in different agro climatic zones. *Leucocytozoon* spp infection causes anaemia, thickened oral discharge and paralysis of legs (Sadiq *et al.*, 2003).

There were no differences in occurrences among bird age groups, sexes and agro ecological zones. The findings between age groups were consistent with the findings of Permin *et al.* (2002), who compared the prevalences between young and adult free range birds. All infected chickens in Zimbabwe (Permin *et al.*, 2002) had a low parasitaemia (<1% of

erythrocytes were infected). The reason for such prevalence between age groups, and across sexes and agro ecological zones was not clear hence calls for further investigation.

On the other hand, *Haemoproteus* was the least found haemoparasite during this study. This haemoparasite was found to infect birds from LH1 zone only, and has not been recently reported in other African countries. The variation in prevalence between LH1 and LM5 is likely due to a difference in geographical and climatic factors between the study areas. *Haemoproteus* infection is not particularly pathogenic in domestic chicken (Soulsby, 1982).

In all, 65.3% and 89.3% of chickens examined for pathology of the skin had gross and microscopic lesions, respectively. These lesions varied from mild to severe. These skin lesions accompanied ectoparasitic infestation, although in some cases, the presence of these parasites did not associate well with the occurrence of skin lesions in chicken. More lesions were seen microscopically than macroscopically.

Macroscopic study of head skin with stick tight flea (*Echidnophaga gallinacea*) infestation, showed, edema and hyperemia around the eye (on the eye lids) and necrotic wounds on the comb. Microscopic lesions were characterized by necrosis, congestion of dermal blood vessels, pressure atrophy due to parasites (present or absent), petechial hemorrhages; hyperkeratinization, parakeratosis, epidermal breakages and inflammatory changes involving deeper layers of the skin.

Of the ectoparasites, lice, ticks and mites were found on the body. The gross lesions on the body skin included: skin desquamation, superficial necrotic wounds commonly around the abdominal area, areas showing feather loss, hyperemia and obvious thickening of the skin around the neck area. Areas infested by ticks were characterized by pitting ulcer formation, and/ or nodular skin formation as a result of inflammatory reactions. Microscopic lesions included: acanthosis, parakeratosis, haemosiderosis, sections showing pressure atrophy and fibroplasias due to ectoparasites, mononuclear cells infiltration and parasite cross-sections within the epidermal skin tissue. Such pathological changes have been reported previously by various authors and could not be linked to specific parasites except the gross lesions caused by *A. persicus*, owing to the diversity of parasites isolated on the body skin. Arends (2003) noted that areas of the skin where soft ticks had just fed showed red spot (haemorrhages), while Prezovol *et al.* (2006) found shapeless areas with lack of feathers on the skin in the region of the cloaca, the abdomen and breast with haemorrhages, superficial wounds and brownish scabs with size of millet and corn seeds (1-5 mm) on chicken experimentally infested with poultry biting lice. These findings were to some extend comparable with the findings of this study.

Gross lesions on the legs were characterized by small yellowish- grey or reddish- brown, wart like skin proliferations/ minor scale formation, which seemed to begin on the soft parts of the planter side of the tarsus and the shanks and later spread along the digits to the hock in early cases. In severe cases, there was a massive hypertrophic dermatitis with the whole leg showing massive skin proliferations. There were hyperemia, heavy encrustations and increased desquamation. Feathered parts of the legs were not involved. These findings were

comparable to those described by Jordan, (1990), Rupley, (1997), Permin and Hansen (1998) and Arends (2003). In our study, no lesions were found around the beak and the lesion was more advanced (moderate to severe) in older birds than chicks, probably due to allergic sensitization due to re-infestation by these parasites. Microscopic lesions included hyperkeratinization (proliferated stratum corneum), parakeratosis, inflammatory and cellular changes and pouches or burrows caused by mites. Arends (2003) described these parasites to cause tunnels into the epithelium, causing proliferation and formation of scales and crusts. Kirmse (1966) in his study on cnemidocoptic infestation in wild birds described the microscopic lesion as pouches or burrows by mites found in the cornified epithelium. He described a striking honeycomb pattern of the skin where proliferation of stratum corneum had taken place. These finding were not encountered during this study and is likely to be due to intensity of infestation, which in this study was low compared to findings by Kirmse (1966). However, the study has described the gross and microscopic picture of lesion due to natural ectoparasitic infestation in indigenous chicken previously not documented.

5.2 Control of ectoparasites in indigenous chicken

5.2.1 Control options available

Control of ectoparasites in indigenous chicken is perceived as a major impediment to rural farmers since their scavenging habits and constant contact with contaminated environment make them an easy prey to parasitic infestations. Isolating poultry flocks from other animals to reduce the opportunity for disease transmission; isolating young from older birds if more than one age group is present on the farm and keeping wild birds, rodents, insects and pets

away from poultry is almost impossible due to the nature of their production system (free range system).

When the pests are discovered and identified, effective control will entail collective alternatives. This control can be approach as on-host and/ or off-host treatment. A number of techniques have been used in control of these ectoparasites. These include: management changes such as modification of poultry housing by eliminating, minimizing or sealing cracks and crevices required by these pests for shelter in current or planned housing. Entry of wild birds and rodents can be prevented with screen and other barriers.

Cultural methods like paraffin use in control of fleas (*Echidnophaga gallinacea*) and petroleum jelly applied on scaly legs (*Cnemidocoptes mutans*); and traditional herbs like neem (Mwarubaini) leaves and bark have been employed in control of ectoparasites in indigenous family chicken. In the treatment of scaly mites, neem (Mwarubaini) mixed with residue from soaked and filtered ash and a little water is made into paste and smeared on the scaly legs (Okitoi *et al.*, 2007). The commonly used insecticides include permethrins, cabaryl compounds, coumaphos, tetrachlorvinphos and/ or tetrachlorvinphos and dichlorvos combination, applied as a spray (or bird dipping) and dust treatments (Beyer and Mock, 1999; Gaydon, 2004; **Appendix 6a and 6b**).

Control mites by treating their hiding places. Treat roosts, walls, litter, and equipment by painting, spraying, or dusting. Treat all cracks, crevices, and rough spots. As a general practice, even in the absence of a known infestation of insects or mites, the poultry house

should be treated at least twice a year. The treatment should include a thorough cleaning of the house and an insecticide application (Campbell, 2006). Northern fowl mites (*Ornithonyssus sylviarum*) specifically infest the vent area, although males tend to have a more scattered infestation. Caged layers should be sprayed or dusted from underneath the cage in order to penetrate the vent feathers. For an effective treatment, spray two times with half doses, thirty minutes apart, to ensure that the vent region has been thoroughly saturated with the appropriate pesticide. Floor birds with northern fowl mite infestations can be bunched into a corner and treated with the same spray techniques, again, aimed at the vent area. For very small flocks, simply dipping each bird in a tank of the full dose spray mixture can be very effective. Treatment of *Dermanyssus gallinae* involves cleaning and disinfecting the poultry house. Mites can be located along cracks and crevices of the roost areas and poultry house, and eliminated by spraying pesticides in these infested areas two or three times for several weeks. Spray roosts and other equipment in the house. Remove nesting material and spray nest boxes inside and out. Allow time for drying before adding new nesting material (Beyer and Mock, 1999).

Control of poultry lice requires treating the birds since lice remain on the bird throughout its life. Treat by dipping, dusting, or spraying the birds, and be careful to avoid contaminating eggs, feed and water. Treatment is easiest at night when birds are quiet. For best results, split treatments with half of the recommended amount of insecticide applied initially, and the second half applied soon after the first, since the wet feathers retain more active ingredient. Applying liquid sprays to dry feathers often results in loss of some of the insecticide due to runoff (Campbell, 2006).

5.2.2 Integrated poultry pest management

Poultry integrated pest management (IPM) is based on applied ecology – understanding the pest biology and behavior in the habitat. Pest control in poultry facilities requires a judicious meshing of the cultural, biological, and chemical methods described previously. Biosecurity is always a primary element for preventing as much as possible the introduction of disease organism and pests into the operation. Optimal flock, housing, and waste management procedures should be continuously practiced to assist in suppressing pest populations and to encourage natural control factors, including moisture control, fly parasites and fly predators. When monitoring indicates unacceptable pest levels, additional actions are required to improve the implementation of the management practices (Axtell, 1999).

In addition, chemical applications may be necessary. The timing of insecticide applications must be meshed with the poultry management practices. Very often this restricts applications to between flocks in a house when thorough cleaning and spraying is possible as for beetle, chicken mite, and bedbug control. Chemical applications for fly control by residual spraying, insecticide–bait mixtures and occasional misting are sometimes necessary to bring the adult fly population down to an acceptable level (Axtell, 1999). However, those applications must be made with minimal contamination of the manure to preserve the natural populations of fly parasites and predators (Wills *et al.*, 1990).

5.3 Conclusions and recommendations

1. Four ectoparasites (lice, mites, fleas and ticks) and three haemoparasites (*Plasmodium* spp, *Leucocytozoon* spp. and *Haemoproteus* spp) were observed in indigenous chickens at a high prevalence rate but at moderate infestation intensities.
2. Three lice (*Menopon gallinae, Lipeurus caponis* and *Goniodes gigas*) species, five mite (*Cnemidocoptes mutans*, *Dermanyssus gallinae*, *Epidemoptes* spp, *Laminosioptes cysticola* and *Megninia species*) species, the flea *Echidnophaga gallinacea* and the tick *Argas persicus* were diagnosed in this study. Of these, lice (especially *Menopon gallinae*) were the most prevalent ectoparasite group.
3. *Plasmodium gallinaceum, Leucocytozoon schoutedeni* and *Haemoproteus* spp occurred in indigenous chicken with *P. gallinaceum* being the most prevalent haemoparasite.
4. Multiple infestations were common as opposed to single ectoparasite infestations, while with haemoparasites; single infection was common compared to mixed ones.
5. There were marginal differences between ectoparasite (more LM5) infestations and haemoparasitic (more in LH1) infestations in the two agro ecological zones.
6. There was significant difference for some parasitic infestation between chicken age groups (lice) and between agro ecological zones (lice, mites and ticks) but equal prevalences between sexes of birds
7. Ectoparasites caused considerable damage to the skin of indigenous chicken with more lesions seen microscopically than grossly in the apparently healthy birds. These lesions varied significantly between chicken age and sex group; and between the LM5 and LH1. These effects may play a role in lowering the productivity of these birds.

8. Some mites (*Epidermoptes* species *Laminosioptes cysticola* and *Megninia* species) are documented in indigenous chickens in Africa for the first time, while *L. caponis* and *G. gigas* are reported in Kenya for the first time.
9. Further study to determine the impact of infestation on the health and productivity of these birds, and evaluation of cost benefit of various control strategies need to be investigated.

CHAPTER SIX

7.0 REFERENCES

Abebe, W., Asfaw, T., Genete, B., Kassa, B. and Dorchies, P. H. (1997). Comparative studies of external parasites and gastrointestinal helminthes of chicken kept under different management systems in and around Addis Ababa (Ethiopia) *Review of Medicine and Veterinary*, **148**: 497-500.

Abdu, P. A. (1987). Infectious bursal disease in pullet chicks. *Avian Diseases*, **31**: 204–205.

Adene, D. F. and Dipeolu, O. O. (1975). Survey of blood and ectoparasites of domestic fowls in Ibadan, Western State of Nigeria. *Bulletin of Animal Health and production in Africa*, **23**: 333-335.

Arends, J. J. (2003). External parasites and, poultry pests. In: Diseases of poultry. 11th edition. Edited by Calnek, W. B., with Barnes, John, H., Beard, W. C., McDougald, L. R. and Saif, Y. M. Iowa State Press, Blackwell Publishing Company, Ames, Iowa. P 905- 930.

Axtell, R. C. (1999). Poultry integrated pest management: Status and future. *Integrated Pest Management Reviews* **4**: 53–73.

Bebora, L. C., Mbuthia, P. G., Macharia, J. N., Mwaniki, G., Njagi, L. W. and Nyaga, P. N. (2005). Appraisal of Indigenous chicken's potential in egg production. *The Kenya Veterinarian*, **29**: 10-13.

Bennett, G. F. and Herman, C. M. (1976). Blood parasites of some birds from Kenya, Tanzania and Zaire. *Journal of Wildlife Diseases* **12**: 59–65.

Beyer, R. S. and Mock, D. (1999). Eliminating mites in poultry flocks. Kansas State University. http://www.oznet.ksu.edu Last visited on 29th October 2008.

Binta, M. G., Mushi E. Z., Adom, E. K. and Diteko, T. (1996). Diseases of chicken in Botswana. 1985-1994. *Bulletin of Animal Health and Production Africa.* **44**: 216-218.

Biu, A. A., Agbede, R. I., and Peace, P. (2007). Studies on ectoparasites of poultry in Maiduguri, Nigeria. *Nigerian Journal of Parasitology*, **28**: 69-72

Buriro, S. N. (1983). Relative abundance of different species of bacteria isolated from *Argas persicus. Pakistan Veterinary Journal*, **3**: 126–128.

Campbell, T. W. (1995). Avian haematology and cytology, 2nd Edition. Iowa State University Press, Ames.

Campbell, J. B. (2006). A guide for managing poultry insects. University of Nebraska–Lincoln Extension educational programs, http://www.elkhorn.unl.edu last visited on 29th October 2008.

Charlton, B. R., Bermudez, A. J., Boulianne, M., Halvoson, D. A., Schrader, J. S., Newman, L. J., Sander J. E. and Wakenell P. S. (2006). Necropsy of the fowl. In, Avian disease manual. 6th edition. American Association of avian Pathologist. Athens, Georgia. P 232-233.

DeVaney, J. A. and Ziprin, R. L. (1980). Acquired immune response of white leghorn hens to population of northern fowl mite, *Ornithonyssus sylviarum* (Canestrini and Fanzago) *Poultry science*, **59**: 1742- 1744

Dickie, W. C. and Barrera, J. (1963). A study on the carrier state of avian spirochetosis in chicken. *California Department of Agriculture, Livestock and Poultry Pathology Laboratory*, Fresno, California. P 191-195.

Durden, L. A., Oliver Jr, J. H. and Kinsey, A. A. (2001). Ticks (Acari: Ixodidae) and spirochetes (spirochaetaceae: spirochaetales) recovered from birds on a Georgia Barrier Island. *Journal of Medical Entomology*, **38**: 231–236.

Fabiyi, J. P. (1996). Association between duration of humid season and geographical distribution of patterns of different species of chewing lice (Mallophaga: Insecta) infesting domestic chickens in Nigeria. *Journal of Parasitology*, **82**: 1034-1036.

Fallis, A. M., Jacobson, R. L. and Raybould, J. N. (1973). Haematozoa in domestic chickens and guinea fowl in Tanzania and transmission of *Leucocytozoon neavei* and *Leucocytozoon schoutedeni*. *Journal of Protozoology*, **20**: 438–442.

Gustafson, C. R., Bickford, A. A., Cooper, G. L. and Charlton, B. R. (1997). Sticktight fleas associated with fowl pox in a backyard chicken flock in California. *Avian Diseases*, **41**: 1006-1009.

Gaydon, D. M. (2004).External parasites of poultry. *Mississippi State University Extension Service.* Information Sheet 331 http://msucares.com/pubs/infosheets/is0331.htm last visited on 29th October 2008.

Gyurov, B. (1983). Role of *Argas persicus* in the epidemiology of fowl typhoid. *Veterinarna Sbirka*, **81**: 22–24.

Hogsette, J. A., Jacobs R. D. and Jacob, J. P. (2003). Common continuous external parasites of poultry. *Institute of food and agricultural sciences extension.* University of Florida. Fact sheet PS-10.

Hoogstraal, H. (1967). Ticks in relation to human diseases caused by viruses. *Animal Review of Entomology*, **11**: 261-306.

Jacob J. P., Wilson, H. R., Miles, R. D., Butcher, G. D. and Mather, F. B. (2003). Factors affecting egg production in backyard chicken flocks. *Institute of food and agricultural sciences (IFAS) extension.* University of Florida. Fact sheet PS-35.

Jordan, F. T. W. (1990). Poultry diseases. 3rd edition. Bailliere Tindall, Philadelphia. P 251-252.

Kiptarus, J. K. (2005). Focus on Livestock sector: Supply policy framework strategies, status and links with value addition. *Workshop on value Assess food and export investment.* Held at Grand Regency hotel, Nairobi, Kenya. 3rd March 2005.

Kirmse, P. (1966). Cnemidocoptic mite infestations in wild birds. *Bulletin of Wildlife Disease Association,* **2**: 86-99

Levine, N. D. (1985). Veterinary Protozoology, 1st Edition. Iowa State University Press, Ames, I A.

Lumbwe, H. (2002). The occurrence of ectoparasites on indigenous chickens among smallholder farmers in Chongwe district of Zambia. MSc thesis. University of Malawi, Lilongwe.

Luna, L. G. (1968). Manual of the histological staining methods of the Armed Forces Institute of Pathology. 3rd edition, McGraw Hill, New York.

Magwisha, H. B., Kassuku, A. A., Kvysgaard, N. C. and Permin, A. (2002). A comparison of the prevalence and burdens of helminth infections in growers and adult free-range chickens *Tropical Animal Health and Production*, **34**: 205-214.

Maina, A. N. (2005). Prevalence, intensity and lesion associated with gastrointestinal parasites of indigenous chicken in Kenya. MSc thesis. University of Nairobi.

Margolis, L., Esch, G. W., Holmer, J. C., Kuns, A. M. and Schad, G. A. (1982). The use of ecological terms in parasitology. (Report of an Ad HOC committee of American Society of Parasitologists). *Journal of Parasitology*, **68**: 131- 133.

Martin, S. W., Meek, A. H. and Willberg, P. (1987). Veterinary Epidemiology, *Principles and Methods*, Iowa State University Press, Ames, Iowa. P 32

Mbugua, P. N. (1990). Rural smallholder poultry production in Kenya. In *Proceedings of International CTA- Seminar on rural smallholder production.* October 1-5th, 1990. Thesaloniki, Greece.

Mbuthia, P. G. (2004). *Pasteurella multocida* in indigenous chicken and ducks in Kenya. A study of carrier status, susceptibility, molecular diagnosis and pathogenesis. PhD thesis, University of Nairobi, Kenya.

Ministry of Agriculture, Fisheries and Food (MAFF) (1986). *Manual of veterinary parasitological techniques. Technical Bulletin.* No. **18.** HMSO. London. P 118-124.

Msanga, J. F. and Tungaraza, R. (1985). The incidence of external and internal parasites of indigenous poultry in Mwanza municipality, Tanzania. *Tanzania Veterinary Bulletin*, **7:** 11-13.

Mungube, E. O., Bauni, S. M., Tenhagen, B. A., Wamae, L. W., Nzioka, S. M., Muhammed, L. and Nginyi, J. M. (2008). Prevalence of parasites of the local scavenging chicken in a selected semi-arid zone of Eastern Kenya. *Tropical Animal and Health Production Bulletin* **40**: 101-109

Nairobi Province Livestock Division (2007). Ministry of Livestock and Fisheries, Kenya, *Annual Report*

Nemi, C. J. (1986). *Schalms* Veterinary hematology. 4th Edition. Lea and Febiger, Philadelphia. P 21-62.

Njagi, L. W. (2008). Endemicity of Newcastle disease virus in village indigenous chicken and the role of carrier ducks. PhD thesis, University of Nairobi, Kenya.

Njue, S. W., Kasiiti J. L., Macharia, J. M., Gacheru S. G. and Mbugua, H. C. W. (2001). A survey of the disease status of village chicken in Kenya. *In proceedings of the 10th Conference of Association for Tropical Veterinary Medicine, Copenhagen, Denmark.*

Njunga, G. R. (2003). Ecto- and haemoparasites of chicken in Malawi with emphasis on the effects of the chicken louse, *Menacanthus cornutus*. MSc thesis, *Royal Veterinary and Agriculture University, Denmark.*

Okaeme, A.N. (1988). Ectoparasites of guinea fowl (*Numida meleagris galeata pallas*) and local domestic chicken (*Gallus gallus*) in Southern Guinea Savana, Nigeria. *Veterinary research communications,* **12**: 270-280.

Okitoi, L. O., Ondwasy, H. O., Siamba, D. N. and Nkurumah, D. (2007). Traditional herbal preparations for indigenous poultry health management in Western Kenya. *Livestock research for rural development*, **19** (5) Article 72.

Onduru, D. D., Gachimbi, L., Maina, F., Muchena, F. N. and A. der Jager, (2002). Sustaining Agricultural Production in Semi Arid area of Eastern Kenya. *A case study of Mbeere District. INMASP R*eport No. Ke-03.

Pandey, V. S., Demey, F. and Verhust, A. (1992). Parasitic diseases; A neglected problem in village poultry production in Africa. In: Pandey, V. S., and Demey, F. (Eds) Village poultry production in Africa. Rabat, Morocco. P 136-141.

Permin, A., Esmann J. B., Hoj C. H., Hove T. and Mukatirwa, S. (2002). Ecto-, Endo- and Haemoparasites in free range chicken in the Gomoronzi District in Zimbabwe. *Preventive Veterinary Medicine,* **54**: 213-224.

Permin, A. and Hansen J. (1998). Epidemiology, diagnosis, and control of poultry parasites. *Food and Agriculture Organization of the United Nations*, Rome. Italy. P 1-157.

Philips, J. R. (1997) Avian Mites. In: *Practical Avian Medicine* Veterinary Learning Systems, Trenton, NJ. (This is an updated version of an article originally published in Compendium on Continuing Education for the Practicing Veterinarian, Volume **15**, No. 5, May 1993).

Poulsen, J., Permin, A., Hinbsbo, O., Yelifari, L., Nansen, P. and Bloch, P. (2000). Prevalence and distribution of gastro-intestinal helminths and haemoparasites in young scavenging chickens in upper eastern region of Ghana, West Africa. *Preventive Veterinary Medicine*, **45**: 237-245.

Prelezov, P. N., Groseva, N. I. and Goundasheva, D. I. (2006). Pathomorphological changes in the tissues of chickens, experimentally infected with biting lice (Insecta: Phthiraptera). *Veterinary Archive,* **76:** 207-215.

Reid, W. M. (1956) Incidence and economic importance of poultry parasites under different ecological and geographical situations in Egypt. *Poultry Science*, **35**: 926–933.

Ruedisueli, F. L. and Manship, B. (2006) Tick identification key. University of Lincoln. Available on-line at http://webpages.lincoln.ac.uk/fruedisueli/FR-webpages/parasitology/Ticks/TIK/tick-key/softticks_adult.htm. Last visited on 6th march 2008.

Rupley, A. E. (1997). Manual of avian practice. 1st edition, Saunders, Philadelphia. P 254-263.

Sadiq, N. A., Adejinmi, J. O., Adedokun, O. A., Fashanu, S. O., Alimi, A. A. and Sofunmade, Y. T. (2003). Ectoparasites and haemoparasites of indigenous chicken (*Gallus domesticus*) in Ibadan and environs. *Tropical Veterinarian,* **21**: 187-191.

Saxena, A. K., Kumar, A., Surman and Singh, S. K. (1995). Prevalence of Menopon gallinae Linne. (Phthiraptera : Amblycera) on poultry birds of Garhwal. *Journal of Parasitic Diseases*, **19**: 69-72.

Sehgal, R. N. M., Gediminas, V., Tatjana, A. L. and Smith, T. B. (2006). Blood parasites of chickens in Uganda and Cameroon with molecular description of *Leucocytozoon schoutendeni* and *Trypanosoma gallinarum. Journal of Parasitology,* **92**: 1336-1343.

Smith, V. S. (2001) Avian Louse Phylogeny (*Phiraptera: Ischnocera*): A cladistic based morphology. *Zoo Journal of the Linnean Society* **132**: 81-144.

Soliman, A. M., Mousa, S. A., Gad, N., Desouky, U. and Sokkar, I. M. (1988). Rodents and ticks, as a reservoir of Mycoplasma in poultry farms. *Assiut Veterinary Medical Journal*, **9**: 184–190.

Soulsby, E. J. L. (1982). *Helminths, Arthropods and Protozoa of Domestic Animals.* 7th Edition. London: Bailliere and Tindall, East Sussex, UK.

Urquhart, G. M., Armour, J., Duncan, J. L., Dunn, A. M., and Jennings, F. W. (1996). Veterinary Parasitology. 2nd edition. Blackwell Science, p 180.

Valkiûnas, G. (2005). Avian malaria parasites and other haemosporidia. CRC Press, Boca Raton, Florida, P 936.

Walker, A. (1994). The arthropods of human and domestic animals. 1st edition. Chapman and Hall, London.

Walker, A. R, Bonattour, A., Camicas, J., Estrada-Pena, J., Harok, I. G., Latif, A. A., Pegram, R. G. and Presto, P. M. (2003). Ticks of Domestic animals in Africa: A guide to identification of species. Newsletter on ticks and tick borne diseases of livestock in the tropics version 29 February 2006, Available on-line at http://www.icttd.nl/ Last visited 6th march 2008.

Wall, R. and Shearer, D. (1997). Veterinary entomology. 1st edition. Chapman and Hall, London. P 43-95.

Weisman, J., LeRoy, B. E. and Latimer, K. S. (2007). *Haemoproteus* infection in avian species. *Veterinary Clinical Pathology Clerkship Program*, University of Georgia College of Veterinary Medicine, Athens, GA 30602-7388.

Wills, L. E., Mullens, B. A. and Mandeville, J. D. (1990) Effects of pesticides on filth fly predators (*Coleoptera, Histeridae, Staphylinidae, acarina, Macrochelidae, Uropodidae*) in caged layer poultry manure. *Journal of Economic Entomology*, **83**: 451–457.

Woodman W. L and Dicke R. J. (1954). Population fluctuation of the mallophagan parasite *Brueelia vulgata* (Kellogg) upon the sparrow. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters*, **43**: 133-135.

8.0 APPENDICES

Appendix 1. Kruskal Wallis one way ANOVA tables of intensities of various ectoparasite groups/ species among age groups

Variables		Age Groups	
		H- Value (adjusted)	P- Value
Lice	Overall (Total)	25.16	0.001*
	Menopon gallinae	18.98	0.001*
	Lipeurus caponis	18.35	0.001*
	Goniodes gigas	4.835	0.089 (ns)
Fleas (*Echidnophaga gallinacea*)		0.529	0.768 (ns)
Ticks (*Argas persicus*)		0.263	0.877 (ns)

Key; * statistically significant ($p < 0.05$)

ns- Not significant ($p > 0.05$)

Appendix 2. Kruskal Wallis one way ANOVA tables of intensities of various ectoparasite groups/ species between sexes

Variables		Sex	
		H- Value (adjusted)	P- Value
Lice	Overall (Total)	0.649	0.420 (ns)
	Menopon gallinae	0.7397	0.390 (ns)
	Lipeurus caponis	0.1831	0.669 (ns)
	Goniodes gigas	0.0005	0.982 (ns)
Fleas (*Echidnophaga gallinacea*)		2.646	0.104 (ns)
Ticks (*Argas persicus*)		0.562	0.453 (ns)

Key; * statistically significant ($p < 0.05$)

ns- Not significant ($p > 0.05$)

Appendix 3. Kruskal Wallis one way ANOVA tables of intensities of various ectoparasite groups/ species between agro ecological zones

Variables		Agro Ecological Zones	
		H- Value (adjusted)	P- Value
Lice	Overall (Total)	5.757	0.016 *
	Menopon gallinae	13.44	0.001*
	Lipeurus caponis	1.222	0.269 (ns)
	Goniodes gigas	0.237	0.626 (ns)
Fleas (*Echidnophaga gallinacea*)		1.222	0.269 (ns)
Ticks (*Argas persicus*)		8.403	0.004*

Key; * statistically significant ($p < 0.05$)

ns- Not significant ($p > 0.05$)

Appendix 4. Two by two Chi-square tables of association

a) Gross head skin lesions

	Parasite positive	Parasite negative	Total
Lesion positive	19	16	35
Lesion negative	23	86	109
Totals	42	102	144

Pearson chi-square value is 14.12: degree of freedom (df) 1; Probability level (under null hypothesis) $p < 0.001$

b) Gross leg skin lesions

	Parasite positive	Parasite negative	Total
Lesion positive	52	11	63
Lesion negative	20	61	81
Totals	72	72	144

Pearson chi-square value is 47.44: degree of freedom (df) 1; probability level (under null hypothesis) $p < 0.001$

c) Gross body skin lesions

	Parasite positive	Parasite negative	Total
Lesion positive	44	2	46
Lesion negative	89	9	98
Totals	133	11	144

Pearson chi-square value is 1.04: degree of freedom (df) 1; probability level (under null hypothesis) $p = 0.308$

Appendix 5. Chi square test for heterogeneity or independence

a) Microscopic head skin lesions

Lesion	Frequency type	Parasite positive	Parasite negative	Totals
No lesion	Observed	7	85	92
	Expected	26.8	65.2	
	Cell Chi	10.5	6.0	
Mild lesion	Observed	17	10	27
	Expected	7.9	19.1	
	Cell Chi	10.5	4.3	
Moderate lesion	Observed	18	7	25
	Expected	7.3	17.7	
	Cell Chi	15.7	6.5	
Severe lesion	Observed	0	0	0
	Expected	0	0	
	Cell Chi	0.0	0.0	
Totals		42	102	144

Pearson chi-square value is 57.83 with 3 df.

Probability level (under null hypothesis) $p < 0.001$

Appendix 5. Chi square test for heterogeneity or independence (continues)

b) Microscopic leg skin lesions

Lesion	Frequency type	Parasite positive	Parasite negative	Totals
No lesion	Observed	55	9	64
	Expected	32	32	
	Cell Chi	16.53	16.53	
Mild lesion	Observed	11	8	19
	Expected	9.5	9.5	
	Cell Chi	0.24	0.24	
Moderate lesion	Observed	6	44	50
	Expected	25	25	
	Cell Chi	14.44	14.44	
Severe lesion	Observed	0	11	11
	Expected	5.5	5.5	
	Cell Chi	5.5	5.5	
Totals		72	72	144

Pearson chi-square value is 73.42 with 3 df.

Probability level (under null hypothesis) $p < 0.001$

Appendix 5. Chi square test for heterogeneity or independence (continues)

c) Microscopic body skin lesions

Lesion	Frequency type	Parasite positive	Parasite negative	Totals
No lesion	Observed	9	6	15
	Expected	13.1	1.9	
	Cell Chi	1.28	8.84	
Mild lesion	Observed	26	1	27
	Expected	23.6	3.4	
	Cell Chi	0.24	1.69	
Moderate lesion	Observed	82	11	93
	Expected	81.4	11.6	
	Cell Chi	0.004	0.03	
Severe lesion	Observed	9	0	9
	Expected	7.9	1.1	
	Cell Chi	− 0.15	1.10	
Totals		126	18	144

Pearson chi-square value is 13.61 with 3 df.

Probability level (under null hypothesis) p = 0.003

Appendix 6. Ectoparasite control recommendations in poultry

a) Bird Treatment

Pests	Material and formulation	Mixing directions	Amount per bird	Days to slaughter	Remarks
a) Northern fowl mite b) Chicken mite c) Depluming mite d) Lice	Carbaryl (Sevin) 50% WP 80% S 43% F 5% D	10 oz/gal water 6 oz/gal water 10 oz/gal water ready to use	1 1/2 gal/100 birds 1 lb/100 birds	7	Do not spray nests, eggs, feed, or water. Do not treat within 10 days of vaccination or other stress.
	Tetrachlorvinphos & dichlorvos (Ravap) 23% & 5.7%	1 pint/6 gal water	1 gal/100 birds	0	Do not treat more often than every 14 days.
	Tetrachlorvinphos (Rabon) 50% WP	2 lb/25 gal water	1 gal/100 birds	0	Do not treat more often than every 14 days.
	Permethrin 10% EC 5.7% EC 25% WP .25% D	1 qt/50 gal water 1 qt/25 gal water 6 oz/11 gal water ready to use	1 to 2 oz/bird 1 gal/100 birds 1 to 2 oz/bird 1 lb/100 birds	0	Cover or remove feed and water. Do not treat more often than every 14 days.

Appendix 6. Ectoparasite control recommendations in poultry (continuation)

b) Premises Treatment

Pests	Material and formulation	Mixing directions	Amount per area	Remarks
a) Northern fowl mite b) Chicken mite c) Depluming mite d) Lice	carbaryl (Sevin) 50% WP 80% S 43% F 5% D	2 lb/25 gal water 1 1/2 lb/25 gal water 1 qt/25 gal water ready to use	1 gal/700 sq ft 1 gal/700 sq ft 1 gal/700 sq ft 1 lb/40 sq ft	Avoid contamination of eggs, feed, and water. Repeat as needed.
	permethrin 25% WP	6 oz/34 gal water	1 gal/700 sq ft	-
	tetrachlorvinphos (Rabon) 50% WP 3% D	2 lb/25 gal water ready to use	1 gal/100 sq ft 1 lb/100 sq ft	-
	tetrachlorvinphos & dichlorvos (Ravap) 23% & 5.7% EC	1 qt/12 gal water	1 gal/700 sq ft	-
Bedbugs	carbaryl (Sevin) 50% WP 80% S 43% F 5% D	2 lb/25 gal water 1 1/2 lb/25 gal water 1 qt/25 gal water ready to use	1 gal/700 sq ft 1 gal/700 sq ft 1 gal/700 sq ft 1 lb/40 sq ft	Do not apply directly to poultry, nests, or eggs. Repeat as needed.
	cyfluthrin(Tempo) 20% WP	19 gram/2 gal water	1 gal/500 sq ft	Do not apply with birds in the building. Allow spray to dry before placing birds

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