STUDIES ON THE POSSIBLE CAUSES OF LOSSES IN OSTRICH PRODUCTION IN SELECTED OSTRICH FARMS IN KENYA

CHEMIS VIOLA JELAGAT
(BVM, UNIVERSITY OF NAIROBI)

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DEPARTMENT OF VETERINARY PATHOLOGY, MICROBIOLOGY AND PARASITOLOGY

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DECLARATION

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

DR. CHEMIS VIOLA JELAGAT (BVM, UoN)

Signature.....Date 14/08/09

This thesis has been submitted with our approval as the University supervisors:

PROF. KANYARI, P.W.N. (Ph.D, M.Sc, BVM)
Department of Veterinary Pathology, Microbiology and Parasitology
University of Nairobi

Signature.....Date 20th August 2009

PROF. NGATIA, T.A. (Ph.D, Dip. P.V.M., M.Sc, BVM)
Department of Veterinary Pathology, Microbiology and Parasitology
University of Nairobi

Signature.....Date 18/8/2009

DR. P. MBAABU MATHIU. (Ph.D, BVM)
Department of Veterinary Anatomy and Physiology
University of Nairobi

Signature.....Date 26/08/2009

DEDICATION

This thesis is dedicated to my dear son Trevor Kipkirui and my parents Gideon and Rebecca Chemis for their support and patience. Above all to the glory of God for His day to day guidance and providing me with strength and perseverance I needed when carrying out this work.

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ABSTRACT

Commercial ostrich farming is rapidly becoming a desirable alternative source of profitable meat production among small holder farmers in Kenya. However ostrich farming in the country is severely constrained by high egg losses (up to 60%) and chick mortality rate (up to 40%). The overall aim of this study was to establish the possible causes of egg and chick losses in ostrich production in Kenya. The study was carried out in Maasai Ostrich Farm (MOF) in Kitengela and Ostree Ostrich Farm (OOF) in Naivasha. It involved i) examining the incubation parameters and egg weight losses during incubation, ii) performing post-mortem examinations on un-hatched embryos and dead chicks, iii) investigating parasitological status of the birds and iv) establishing the management practices at farm level regarding disease control, handling and incubation of eggs, management of newly hatched chicks and relating these to overall production performance.

Results of the study showed that optimum hygienic conditions were maintained within the incubation and hatchery facility at MOF. The average percentage egg weight loss during the incubation period was 10.2%. The automated incubator used was always set and maintained at a temperature of 36°C and 30% relative humidity. Abnormalities in the yolk were common phenomenon in the embryos (with poor embryo development and those dead in shell). Changes in the yolk included deviations in colour and consistency. The colours varied from yellowish brown, brownish, yellowish green, green and dark green, whereas the consistency was either semi-solid or solid. Other findings included

subcutaneous gelatinous oedema of embryos and chicks. An average of 62.5% of the adult birds' small intestines had tapeworm infection with *Houttuynia struthionis.* Out of those infested, 60% had severe haemorrhagic enteritis, while 20% had moderate and another 20% had mild haemorrhagic enteritis respectively. In addition, the small intestines observed histopathology showed atrophy of the villi, glandular distortion and inflammatory cell infiltration. The inflammatory cells observed were mainly lymphocytes and heterophils. Mites and flies collected from feathers of the slaughtered birds were identified as *Struthiopterolichus bicaudatus* and *pseudolynchia canariensis,* respectively. The ostrich quill mite cause irritation, leading to excessive preening, feather loss, reduction in leather quality and predisposition to secondary infection and gastrointestinal disorders. *Pseudolynchia canariensis* when in high numbers also irritate the birds, causing them to be restless hence interfere with their feeding and resting time.

The average egg weight loss during incubation at MOF was below the normal documented range and there was high prevalence of endoparasites and ectoparasites observed. Trained personnel and routine recordings of egg weights during incubation were recommended in keeping track of progressive egg weight loss at the farm. Routine treatments of the birds to prevent tapeworms and quill mites that will deprive off essential nutrients as well as interfere with the birds feeding time and comfort is important.

1. INTRODUCTION

Ostrich farming in Kenya started in 1989 as a response to global demand for ostrich products. Most of the ostrich farms in Kenya are located within a 200 kilometer radius from Nairobi. The largest of the farms is Maasai Ostrich Farm (MOF), which was established in 1991 (Shanawany and Dingle, 1999). In 1993 there were about 62 registered ostrich farms, varying in ostrich population from 4 to 1200 birds and this number decreased such that by the year 2000, there were about 17 ostrich farms in Kenya (Kithuka, Personal communication, 2006). Most farmers abandoned the business due to constraints in marketing the products, as most of the farmers were small scale holders (Kithuka, Personal communication). In addition, the decline is attributable to the unfavourable legal frame work which classifies ostriches as wildlife thus restricting trade in ostriches and ostrich products. Most farms are no longer in active production and appear to be waiting for the trade in ostrich products to be liberalized. The Kenyan ostrich industry is marketing good quality products as well as live birds.

European Union (EU) regulations exclude Kenya from their Third Country List, which effectively bans exports to Europe. Most products have to be sold locally and these include: meat in various forms (frozen, chilled, fresh, smoked, dried (biltong); feather articles such as dusters; salted skins; fat; egg shells (plain, painted and curved); and claws and feet as souvenirs.

It is notable that, demand for ostrich chicks is increasing and superceding the supply. In order to meet market demand, Kenyan farmers should be producing up to 4500-5000 birds annually; yet their capacity is currently only 1500-2000 birds annually. This is partly attributed to technical difficulties in production that the farms experience, such as high cost of acquiring, installing and running the incubators as well as unreliable electric power supply. The farms are also constrained by high egg losses and high chick mortality especially in the first three weeks of life.

Ostrich farming contributes to the Kenyan economy as it attracts tourists who not only watch the birds racing but can also participate in ostrich riding and consume its meat. Therefore, to help rural farmers gain a successful foothold in this potentially lucrative farming enterprise, the causes of egg/chick losses and hence decreased production should be identified and controlled.

1.1. HYPOTHESIS

Ostrich production in Kenya is constrained by poor egg hatchability and high chick losses especially in the first three weeks of life due to low egg weight loss during incubation, pathological and parasitological causes.

1.2. GOAL

To establish possible causes of loss in ostrich production in Kenya with emphasis on egg management and hatchability, chick rearing and grower management.

1.3. BROAD OBJECTIVE

To establish possible causes of poor egg hatchability, high chick mortality and poor performance of growers in commercial ostrich farms in Kenya.

1.4 SPECIFIC OBJECTIVES

The objectives of the study were:

i To determine the incubation parameters and egg weight losses during the period of incubation.

ii To study the pathological changes (gross and microscopic) on un-hatched embryos (those with poor embryo development and dead-in-shell) and dead chicks and other birds.

iii To investigate the parasitological status of the birds of different age groups.

iv To study the management practices at the farm level as regards disease control, handling and incubation of the eggs as well as management of the newly hatched chicks.

1.5 JUSTIFICATION

Ostrich farms are currently considered to be among the most profitable agricultural enterprises. Commercial ratite farming is rapidly becoming a desirable alternative source of profitable meat production among small holder farmers in Kenya. Ostrich farms are often referred to as "the farms of the future" because of the large variety of product outputs and hence the high profit potential. However, ratite ranching, especially ostrich production is severely constrained by very high egg losses (up to 60%) and chick mortality rate (up to 40%) in Kenya, (Kanyari *et al.*, 2005). Ostrich farmers incur losses of considerable magnitude from a wide range of causes. Losses are experienced right from the embryonic stages whereby eggs may be discarded due to infertility or embryos develop poorly causing death before hatching. Studies done by Kanyari *et al.*, (2005) established that hatchability on average, in USA was 72%, while in Kenya, it was only 56%. In Kenya, a high mortality rate is experienced in the early weeks of life, i.e. less than three weeks and was noted to be 27-40%. However, the factors affecting, influencing or contributing to such losses is still unknown. Therefore, to help farmers gain a successful foothold in this lucrative business, the causes of high egg and chick losses, hence decreased production should be identified and rectified.

2. LITERATURE REVIEW

2.1. DEFINITION, EXISTING FORMS AND DESCRIPTION OF RATITES

A ratite is any of a diverse group of large, flightless birds of Gondwanian origin, most of them now extinct. The species still in existence belong to the order *Struthioniformes*. Some extinct species belong to *Struthioniformes*, while some belong to *Aepyornithiformes*. Unlike other flightless birds, ratites have no keel on their sternum and lack a strong anchor for their wing muscles and therefore could not fly even if they were to develop suitable wings. The African Ostrich is the largest living ratite. A large member of this species can be 3 m tall, weigh 135 kg, and can outrun a horse (Yahoo Ratite Wikipeda encyclopedia). Of the living species, the Australian Emu is next in size and reaches up to 2 m tall and weighs about 60 kilograms (kg). Like the ostrich, it is a fast-running, powerful bird of the open plains and woodlands.

Ratites called Cassowaries are native to Australia and islands north of Australia. Cassowaries are shorter than Emus and are very solidly built. Cassowaries prefer thickly vegetated tropical forest. They can be very dangerous when surprised or cornered. In New Guinea, cassowary eggs are brought back to villages and the chicks raised for eating.

The smallest ratites are the six species of Kiwi from New Zealand. Kiwis are chicken-sized and shy. They nest in deep burrows and use a highly developed sense of smell to find small insects and grubs in the soil. Kiwis are notable for laying eggs that are very large in relation to their body size. A Kiwi egg may equal 15 to 20 percent of the body mass of a female Kiwi.

South America has two species of Rhea; these are mid-sized, fast-running birds of the pampas. The larger American Rhea grows to about 1.5 m tall and weighs 20 to 25 Kg. South America also has 73 species of the small and ground-dwelling but not flightless tinamou family, which is distantly related to the ratite group (Yahoo Ratite Wikipeda encyclopedia).

Of the extinct species *Aepyornis*, the "elephant bird" of Madagascar, was the largest bird ever known. Large *Aepyornis* could have weighed up to 450 kg. There were two species in Madagascar when humans arrived from Borneo and Africa, probably in the 1st century. Both species seem to have survived for some time: the smaller *Aepyornis mullerornis* probably disappearing first while the giant *Aepyornis maximus* may have existed until as late as 1600.

The extensive Moa family of New Zealand had ten different species until humans began arriving in numbers at about 1300. Like the cassowaries, Moa were mostly forest-dwellers without any mammalian predators. They are believed to have been brought to extinction by hunting within a few hundred years of human settlement. However, some believe small populations may have survived in isolated regions until more recent times (Yahoo Ratite Wikipeda encyclopedia).

The ostrich is the largest living bird in the world. Ostrich reach an adult height of over 2.1 meters (m) by 16 to 18 months of age. An adult male stands at 2.5m and may weigh up to 150 kg. They continue to increase in weight after this time with adult males reaching over 136.4 kg. The mature male is mostly black with white plumes on the wing and tail. The adult female is slightly smaller at 2m tall and up to 110 kg in weight and is mostly brown/grey in color. Ostrich become sexually mature at 2 years of age although males often mature later than females. It is common for hens to begin laying at 2 to 3 years of age while males may take as long as 4 to 5 years to be functionally mature. In captivity, females may lay as many as 100 eggs in a season, although 20 to 40 are more common (Shanawany and Dingle, 1999). Eggs are whitish in color, weigh about 900 to 2000 grams and are laid every other day. Eggs are typically laid in late afternoon. Although mating may occur numerous times during the day, it is believed that a single mating may be effective for up to a week. These birds are unable to fly due to their great body size, solid bones and reduced wing size. The wings are however used during mating and in aggressive display (Shanawany and Dingle, 1999).

In the wild, ostriches are mainly found in the plains of Africa where they intermingle with grazing wild ungulates. There is only one true species of ostrich (*Struthio camelus*) although several subspecies are recognized. They have a long neck, long bare legs and two toes. Their strong legs allow them to run at great speeds of up to 70 kilometers per hour when necessary but only for 15 minutes, with strides of up to 8 meters. Neck and thigh muscles are well developed and un-feathered. The head is small and has a short but rather wide bill (Shanawany and Dingle, 1999).

Ostriches are primarily grazing birds and survive on a variety of plant and brush material. In many instances, succulent plants and fruits also make up a large portion of their diet as do small insects and lizards. Ostriches travel vast distances to obtain sufficient food and water (Shanawany and Dingle, 1999).

Ostriches are equipped with many advantageous features including excellent eye sight, large external ear canals, and powerful legs. Because of these features, mortalities in adult ostrich are not thought to be common. By comparison, mortalities in chicks are usually related to predation, and are thought to be as high as 90% (Kocan, 2004).

Adult male ostrich are solid black in color with white wing tips while the smaller females are brownish gray. Male ostrich of East Africa have pink or red skin and are often referred to as "red necks", while others have blue skin and are referred to as "blue necks". The Maasai red necks were in nature distributed among the southern parts of East Africa whereas the Somali blue necks were found in the north eastern parts. The color of the neck is dependent on the presence of the male hormone testosterone. The color of the feathers is dependent on the presence or absence of the female hormone estrogen. Thus,

castrated males will have normal feather color but not the skin color and immature or spayed females will have black feathers (Shanawany and Dingle, 1999).

The mating behavior of the male is quite elaborate with the male sitting on his hocks, moving his wings up and down while throwing his head from side to side. During this time the male will usually make a thumping sound and will inflate his neck area and create a loud booming noise. The receptive female walks with her head down, popping her beak and shaking her wings ("clucking"). When approached, the female will sit, allowing the male to mount from the back (Shanawany and Dingle, 1999).

The male digs a depression in the ground by sitting and digging with his legs, pushing dirt backwards, forming the nest. Eggs are laid in these nests and the male usually sits on the eggs at night while the female incubates during the day. Wild clutches usually range from 8 to 14 eggs. Both parents are involved with the rearing of the young (Shanawany and Dingle, 1999).

2.2. CLASSIFICATION

Family: *Struthionidae*, ratite or running bird.

Order: *Struthioniformes*

Genus: *Struthio*

Species: *Camelus*

The ostrich is the only member of the genus *Struthio*. The species name *camelus* is due to the similarities of ostriches to camels such as the prominent eyes which are brown and with prominent third eyelids, thick black eyelashes, the large size and remarkable

tolerance to arid environment. They have very keen eyesight and may see clearly up to 12 kilometers away.

The native ostrich to Kenya is *Struthio camelus masaicus* (The Maasai, East African or Kenyan Red-neck). It occurs naturally only in Kenya and Tanzania. A few East African (Somali) Blue-neck ostriches naturally occur in north-eastern Kenya. The Kenyan Red-neck is a large bird, standing 2.3 meters high to the top of the upright head, although it can stretch higher. The Kenyan Red-neck male has a pink skin on the bare neck which becomes darker red in the breeding season. The scales in front of the legs and the upper and lower bill are pink (Shanawany and Dingle, 1999).

Commercially, ostrich subspecies have been classified as follows:

i Red-necked which includes the subspecies *Struthio camelus camelus* (found in North and West Africa) and *Struthio camelus masaicus* (found in East Africa).

ii Blue-necked referring to the subspecies *Struthio camelus molybdophanes* (found in East Africa) and *Struthio camelus australis* (found in Southern Africa).

The ostrich is adapted for running and possesses only two toes; one large and one small. The main toe is developed almost as a hoof which it can use as a weapon. This toe when used with the strong muscles can deliver lethal kicks capable of tearing a human body open. It is estimated that a kick may have a force of 225 kilograms. Due to this ostriches especially breeding males should be treated with great care and respect. Luckily these

birds can only kick forwards and when one is being chased by an ostrich the advice is to lie flat on the ground.

2.3. HISTORY OF COMMERCIAL OSTRICH FARMING

For a long time, ostriches have aroused people's interest. Apart from being hunted for their flesh and feathers, ostriches were kept in captivity and tamed. Attempts at domestication were done by the early Egyptians, Greeks and Romans. Egyptian and Roman women of noble birth used to ride ostriches (Siegfried, 1984). Feathers from the wild ostriches were used during early civilization for decoration of hats. The domestication of ostriches for commercial purposes was started at the Cape Province, South Africa in the 1700's. The first commercial ostrich farm was established in the Little Karroo in the Cape Province in 1863.

Ostrich farming may be divided into three eras. The first era revolved around the feather industry at the beginning of the sixteenth century. Ostrich feathers were used to decorate soldiers' helmets and ladies hats. Some ostriches were imported from Northern Nigeria to the Cape Province for these birds had the best feathers (Hallam, 1992). The demand for ostrich feathers was slowed down by the automobile industry because ladies hats were dislodged during journeys travelled at high speed.

The second era revolved around the ostrich skins/leather which were in great demand for their durability and attractiveness. The third era is set on the demand for ostrich meat.

Ostrich meat is tasty and is low in fat and cholesterol as compared to that of beef and chicken (Table 1). A high level of the two components in human blood has been associated with heart disease. Therefore, ostrich meat is preferred by the health conscious people mainly in the western world. Although the traditional markets for ostrich meat has been Europe and North America, the potential demand for ostrich meat globally is enormous.

Due to the great value of the ostrich products and the fact that enough could not be gathered in the wild, then the need for commercial ostrich farming arose.

Table 1: Comparison of the composition of meat from three different animal sources (Mushi, Chabo, Modisa and Binta, 1997).

SOURCE	PROTEIN (Grams/Kilogram)	FAT (Grams/Kilogram)	CHOLESTEROL (Miligrams/Kilogram)
OSTRICH	19.7	0.425	2.4
CHICKEN	27	3.0	73.0
BEEF	23	15.0	77.0

2.4. PRODUCTION SYSTEMS

Farming systems that are employed are: extensive, semi-intensive and intensive. In the extensive system birds are allowed to range over large areas of land mainly with natural vegetation cover. Birds mainly depend on the vegetation cover as source of feed. Supplementary feed is provided but at minimum quantities. It is the cheapest way of growing birds as feeding costs are very minimal but productivity will be dependent on the prevailing environmental conditions.

The Semi-intensive system involves keeping birds in medium-sized paddocks of up to 40 hectares. The stocking ratio is one male to one or two females in 20 hectares with a maximum of 40 breeding birds in the area. Objects such as tree stumps and large rocks should be removed as these may injure the birds. Ostriches prefer open spaces but some vegetation should be left to provide cover and protection. This is the most commonly practiced farming system in South Africa, Zimbabwe, Namibia and Botswana (Mushi *et al.*, 1997). MOF rears its birds under a semi-intensive production system on a 80 hectare farm.

Intensive farming system is basically a zero-grazing unit with all feed supplied. Pairs or trios (one male with two females) are kept in 50metres by 50metres paddocks. Vegetation should be taken into account and some trees are planted to provide for shade and protection. Stumps, large rocks and any objects that may injure the birds are removed. This system uses up limited land space.

2.5. DEVELOPMENTS IN THE OSTRICH INDUSTRY IN KENYA

The main criteria for a suitable location for ostrich farming are availability of reasonably priced land and proximity to the city/markets. Water is also a major consideration. The MOF has two boreholes that supply the farm with water throughout the year. Majority of the ostrich farms in Kenya are located in areas where agricultural cultivation is being done. There are no farms in the very dry northern parts of the country.

The Kenyan Ostrich Producers Association (KOPA) was formed in 1993 and the majority of ostrich producers are members. KOPA has unsuccessfully lobbied the government for assistance in gaining approval by the European Union (EU) for live birds and product exports which fulfil EU requirements, such as testing for Avian Influenza (AI) antibodies. The industry remains under the regulatory control of the Kenya Wildlife Service (KWS) (Shanawany and Dingle, 1999).

An ostrich management plan (OMP) has been developed by KOPA, KWS and the Government of Kenya, which specifies the conditions under which farmed ostriches should be kept in Kenya. The OMP covers: 1) the definition of farmed ostriches; 2) the collection of eggs and chicks from the wild; 3) the identification of birds; 4) controls on imports of live birds, fertile eggs and sperms; 5) licensing of farms; and 6) the marketing of products.

EU regulations exclude Kenya from their Third Country List, which effectively bans exports to Europe. Most products have to be sold locally and include: meat in various forms (frozen, chilled, fresh, smoked, dried (biltong); feather articles such as dusters; salted skins; fat; egg shells (plain, painted and curved); and Claws and feet as souvenirs. The meat is sold to some of the top hotels and restaurants in the country where there is a great demand. There is also a rise in the demand of live exports with markets as far as France, Holland, Pakistan, United Arab Emirates (UAE), South Africa and China (Kithuka, 2006). However, the local demand for these products has still not been met by the existing industry.

All ostrich farms must be registered with the Kenya Wildlife Service (KWS), who inspect and issue farming licenses as well as export and collection permits. It is still possible for farmers or institutions to obtain a permit from KWS to collect ostrich eggs from the wild.

The Kenyan ostrich industry is gradually breaking into new niche/markets for its birds and products. Overseas markets have yet to be fully exploited; but markets do exist in Europe and other parts of the world if the industry can comply with EU regulations.

Ostrich farming is important in that ostrich meat is low in fat and cholesterol (0.425grams and 2.4milligrams per 3 oz serving respectively). In addition to meat, there is also a high demand for other ostrich products. These include: skins/leather for making various designer items such as boots, wallets, handbags, belts among others ; feathers for static-

free dusters, fashion clothing, decoration, feather pillows and furniture stuffing ; toes for making souvenirs; fertile eggs or eggshells sold either as plain or decorated and bone and blood for incorporation into animal feeds (Shanawany and Dingle, 1999).

Besides the legislative setbacks, ostrich farming in Kenya has been limited by poor reproductive performance. Egg losses both before and during incubation, as well as high chick mortality rates among the newly hatched have been noted (Kanyari, Ngatia, Mathiu, Oyejide and Srivastava, 2005).

Before incubation, many of the eggs are discarded due to several factors such as cracked shells (due to poor handling), being too small or too large or even having deformities. These deformities may be associated with the age of the hen, nutritional deficiency diseases of the hens, or even genetic factors (Mushi *et al.,* 1997). After the eggs have been set and incubated, a high percentage is discarded at various stages of incubation due to lack of embryo development (infertility) and poor embryo development (PED). Some eggs fail to hatch and are regarded as dead in shells (DIS). Egg losses due to these problems have been observed to exceed 50% in Kenya (Kanyari *et al.,* 2005).

Studies done by Kanyari *et al.* (2005) established that hatchability on average in USA was 72%, while in Kenya it was only 56%. Ostrich eggs often have low hatchability rates because they probably do not lose sufficient water during incubation. There is a high incidence of death in fully developed embryos during the last several days of incubation and necropsy results reveal that a significant amount of this late embryonic mortality

appears to stem from suffocation in edematous embryos (Gonzalez, Satterlee, Moharer and Cadd, 1999). During hatching some chicks are too weak and are assisted to hatch by breaking the shell. Majority of these chicks die shortly thereafter. Chick losses may be quite high and in certain instances may reach 100% (Mushi *et al.*, 1997). Although the losses are encountered in the first three months, the highest death rates occur below three weeks of age. In Kenya, annual chick mortality rates for the years 1997-2000 were found to range from 49-55% (52.8% on average) (Ngatia, Kanyari, Mathiu, Wilson and Oyejide, 2004a). The highest chick losses (90.4%) occurred in the group aged one to three weeks while the other 9.6% occurred in the four to six weeks old chicks. Such losses are not unique to Kenya as they occur in many ostrich producing countries of the world (Foggin, 1992a; Huchzermeyer, 1994; Philbey, Button, Gestier, Munro, Glastonbury, Hindmarsh and Love, 1991; Shanawany and Dingle, 1999).

Hatching success of ostrich eggs in artificial incubators is considerably below that found in the wild (Betram and Burger, 1981), which suggests that the hatchability of artificially incubated ostrich eggs can be improved by identifying and altering factors inherent to eggs or associated with current incubation practices that preclude maximum hatchability. These factors include: length of egg storage, pre-incubation environmental conditions, egg size, shell thickness and porosity, and incubation criteria (e.g. temperature, humidity and frequency of egg turning) (Betram and Burger, 1981). From the literature it appears that the exact causes of the high egg losses and chick mortality have not been fully identified.

2.6. COLLECTION, HANDLING AND CARE OF EGGS

Collection and proper handling of eggs to prevent contamination are important for successful hatching. Many producers use disposable gloves to handle and gather eggs. Others use a similar idea by employing disposable plastic bags while still others simply wash and clean their hands thoroughly before handling eggs.

Studies have shown that storing eggs for a period of from 7 to 10 days generally results in better hatchability (Kocan, 2004). Eggs can be gathered daily and placed either on their side or upright, and maintained at between 18-21^{o}C. Eggs should be turned several times a day.

Eggs laid in wet weather are the most likely to become contaminated with wet soil and as a result soil bacteria may be taken into the egg while it is sitting in water or mud. Occasionally, reproductive tract infections in the hen can also result in bacterial contamination of the egg. A complete bacteriological examination by a veterinary diagnostic laboratory can provide insight into these problems and is strongly recommended when an abnormally large number of eggs are involved.

Many commercial products which sterilize the egg shell, the air or the working area in the incubator room are available to producers. The use of these products as a means of preventing potential contamination can be considered in any operation's biosecurity plan.

2.7. INCUBATION FACILITIES

Often, the facility in which the incubation equipment is kept is as critical as the equipment itself. Although there are no strict requirements that will ensure successful incubation, there are several factors that should be considered (Kocan, 2004). These include:

a) Facilities should be capable of being maintained at 15-20°C.

b) Outside fresh air exchange should be at least 20%.

c) Humidity should not exceed 45%

d) Traffic and personnel should be maintained at a minimum with as few people as possible entering the facility.

e) Floors and walls should be of such a construction as to allow daily cleaning and washing.

f) Additional air movement within the room should be supplied by portable fans or some similar mechanism.

2.8. CANDLING AND HATCHING

The development process in ostriches begins when the egg cell is expelled from the ovary of the hen. When the ovum passes into the oviduct of the female, it begins to mature and if spermatozoa are present, fertilization occurs. As the egg continues down the oviduct, the viscous albumin (egg white), papery shell membrane and hard outer shell are progressively secreted by the lining of the duct. Even before the egg is laid, the formation of a visible embryo has begun and appears as a whitish disk on the surface of the yolk. Additional development does not occur until incubation at the proper temperature. The egg is fully formed and ready to be laid about 24 hours after being discharged from the ovary.

The incubation period of ostrich eggs is about 42 days, the range being 39 to 45 days. In most farms candling is done at day 14, 28 and 35 of incubation. Candling is done to determine the amount of shadow (growth rate of the embryo) in the egg. The air cell becomes more pronounced as development proceeds. At day 14 eggs that appear clear as if there was no change, are assumed to be infertile. An infertile egg will begin to decompose and thus be potential source of infection to other eggs in the incubator. Infected eggs can be detected during candling, as the appearance of dark patches indicates infection of shell membranes (Cooper, 2001). Deeming (1995) demonstrated that during candling of ostrich eggs, there is progressive increase in dark shadowing within the egg as the embryo grows. The growing blood vessels inside the egg will become more prominent and may make the egg appear dark (Jeffrey, Martin and Fanguy,

2007). During candling eggs with signs of infertility or poor embryo development are discarded.

The optimum incubation temperature is not a constant, but varies with humidity of the air. Egg shells are porous because developing embryos need to breathe. Gaseous exchange across the egg shell takes place by diffusion through the pores. The presence of pores in the shell, however, means that eggs lose weight continuously after being laid because water escapes from the egg contents. Weight losses from eggs during incubation are ascribed solely to the loss of water because embryonic gas exchange involves no overall weight change (Shanawany and Dingle, 1999).

Humidity is important for an embryo to develop properly and to transform into a chick of normal size. For this to happen, water evaporates at an established rate (13-15%) (Shanawany and Dingle, 1999). If the rate of evaporation is high, the egg contents dry out too rapidly and the chick will be smaller than normal. On the other hand if evaporation is not fast enough, the chick will be oedematous. In either case, the embryo is weakened, resulting in reduced hatchability or poor quality chicks, or both. To control the rate by which egg contents are evaporated, moisture content in the air surrounding the egg must be controlled, as it is this outside moisture that determines water loss from the egg. Too little moisture in the early stages results in excessive shrinkage of the egg contents. In addition, the developing kidneys will have insufficient water to excrete the waste products. Most of the chicks will die at about the same time they are due to start respiration. Too much moisture results in a small air cell, excess amounts of albumin and an oedematous chick (Shanawany and Dingle, 1999).

2.9. DISEASES AND PARASITES AFFECTING OSTRICHES

2.9.1. VIRAL DISEASES

Newcastle disease: This is caused by a paramyxovirus and occurs commonly in poultry. There are different strains which vary in their pathogenicity and are classified accordingly into: lentogenic (mild), mesogenic (moderately pathogenic) and velogenic (highly pathogenic) strains. Mortality can vary from a few birds to more than 30% and all age groups are susceptible. However, often the outbreak is limited to one flock or camp. This probably is due to lack of respiratory involvement, which prevents the virus from becoming airborne. In addition to the proximity of susceptible or infected poultry, the injudicious moving of ostriches from farm to farm and from area to area can play a major role in spreading the disease. Gross changes at postmortem are minimal and non-specific, in some cases petechiae on serosal surfaces. Microscopic changes are non-specific and can include a lymphocytic pancreatitis, focal cardiomyopathy and oedema of the brain. The only reliable diagnostic tools are the isolation of the virus from brain, lung, liver and kidney and serological tests. Occasionally, less severely affected birds recover (Huchzermeyer, 1994).

Avian Influenza: This is caused by various strains of Influenza virus, which can be isolated in embryonated chicken eggs. An outbreak occurred in ostriches in the Eastern Cape, mainly in younger birds, which showed depression, green discoloration of the urine, air sacculitis and ocular discharge. In some groups, mortality was as high as 60%. The severity of symptoms and lesions depended on concurrent infection with *Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus* and *Aspergillus fumigatus*. The

virus was isolated and typed as H7N1 (Huchzermeyer, 1994). Avian nfluenza viruses are highly species-specific, but have on rare occasions, crossed the species barrier to infect humans (World Health Organization, 2005).

Fowl pox: This is caused by several strains of avipoxvirus and is usually transmitted by mosquitoes. The virus can be isolated in embryonated chicken eggs and produces typical cytoplasmic inclusions visible on histopathology. On the bird it produces small blisters which turn into brown crusty lesions 5 to 10 millimetres in diameter on the eyelids, in the corner of the beak and on other parts of the head. These can lead to blindness and also interfere with feeding (Huchzermeyer, 1994).

Coronaviral enteritis: Reported to have caused mortality in very young ostrich chicks in the USA. In the distal small intestine atrophied villi were found, with necrotic cells in the crypts and crypt collapse as well as eosinophilic inclusions in the apical cytoplasm of many enterocytes (Huchzermeyer, 1994)..

Crimean-congo haemorrhagic fever: This is not a disease of ostriches but of man, though ostriches have been found serologically positive for the virus. It is endemic in parts of South Africa and transmitted by tick-bite. In man it causes severe haemorrhagic fever and is fatal (Huchzermeyer, 1994).

Eastern equine encephalitis: This is transmitted by biting insects and causes severe disease in horses and man. Birds act as virus reservoirs (Huchzermeyer, 1994).

Borna disease: Outbreaks of paresis of suspected viral origin occurred in 2 to 6 week old ostrich chicks in Israel (Huchzermeyer, 1994). The virus was found in the brains of affected birds.

Wesselsbron virus: A flavivirus has been isolated from several cases of mortality in ostrich chicks and identified as wesselsbron virus (Huchzermeyer, 1994).

2.9.2. BACTERIAL DISEASES

Gram-negative bacterial enteritis and septicaemia are particularly common in young ostrich chicks, which may show diarrhea and depression. *Salmonella species, Escherichia coli* and *Pseudomonas aeruginosa* are the main infective agents (Foggin, 1992a). The liver may be swollen and may show multiple foci of necrosis. In cases of *E.coli* septicaemia lesions similar to those seen in poultry that is, fibrinous pericarditis and perihepatitis are sometimes seen. Prevention of infection by the application of strict hygiene is important (Huchzermeyer, 1994).

Clostridial enterotoxaemia has been reported in young ostriches on Lucerne pastures. Birds become weak and sometimes have diarrhea. On postmortem they are emaciated with empty proventriculus and gas in the intestines. *C. perfringens* types A and D have been isolated. *C. chauvoei* has been reported in two ostriches in Israel where it caused paralytic-like disease (Lublin, Mechani, Horowitz and Weisman, 1993). The birds were unable to stand and died after 8-13 days. On postmortem examination there was serous atrophy of the coronary fat, hyperemia and oedema of the lungs, prominent haemorrhages in the intestinal mucosa and necrotic foci in the liver.

C. colinum, which causes ulcerative enteritis in poultry, has been isolated from outbreaks of enteritis in ostriches in Israel (Huchzermeyer, 1994).

Anthrax: Two forms of the disease have been described; sudden death and anthrax fever. Both forms can occur simultaneously in a flock. Birds affected with anthrax fever become anorexic and somnolent but usually recover after some time. Anthrax bacilli cannot be found in blood smears of such birds. After sudden death, petechiae are found on the pleura and peritoneum and congestion of the intestines is present. The spleen may be either normal in size or somewhat enlarged with very dark pulp. The blood is very dark and on smears contains the typical *B. anthracis* (Huchzermeyer, 1994).

Mycobacteriosis is caused by *Mycobacterium avium*. It is contracted most frequently via the digestive tract and localizes in the liver, where it produces small hard white nodules. The disease has a chronic course, during which the birds lose weight and become emaciated (Huchzermeyer, 1994).

Chlamydiosis is caused by infection with *Chlamydia psittaci*, the agent of parrot disease. It causes a high mortality in young birds (Huchzermeyer, 1994).

Megabacterial gastritis occurs as an outbreak in young birds 10 days to 6 weeks old (Huchzermeyer, 1994). Prominent postmortem changes are: serous atrophy of the coronary fat, distension of the proventriculus, which is filled with loose food matter, and an almost empty gizzard. After removal of the contents and gentle washing of the gizzard and proventriculus a very soft folded lining is seen with erosions and ulcers of varying numbers and severity. The causative bacteria have not yet been specifically identified.

Upper respiratory infections are frequently seen in young ostriches stressed by cold and/or overcrowding. *Pseudomonas aeruginosa* and *Pasteurella haemolytica* are often isolated. *Bordetella avium, Mycoplasmas* and *Haemophilus species* have been associated with upper respiratory tract infections (Huchzermeyer, 1994).

Campylobacteriosis (vibrionic hepatitis) was described from an outbreak in young ostriches two weeks to four months old in Israel (Huchzermeyer, 1994). Clinically the birds were depressed, anorexic, dehydrated and produced green urine. Mortality was upto 40%. The pathology resembled that of vibrionic hepatitis of poultry. *Campylobacter jejuni* serotype 8 was isolated from the livers of affected birds.

Aegyptianellosis caused by *Aegyptianella pullorum* (an anaplasma-like rickettsia infecting red blood cells) affects young ostriches reared with infested poultry flocks. The disease is transmitted by fowl tampans, *Argas persicus* and in South Africa, *Argas walkerae* (Huchzermeyer, 1994).

Pasteuerellosis affects young ostriches, ten to twelve months old causing haemorrhagic septicaemia and sometimes death without any preceding clinical symptoms. *Pasteurella multocida* is the causative agent (Huchzermeyer, 1994).

Enterobacter species: This is a soil contaminant and is likely to affect eggs laid in open paddocks. Infection by this species has been suspected to play a role in yolk sac retention (Srivastava, Oyejide, Kanyari, Ngatia and Mathiu, 2002).

2.9.3. FUNGAL INFECTIONS

Fungal infections are seldom transmitted from bird to bird, but are usually contracted from moulds growing in the environment, particularly mouldy feed.

Respiratory mycosis is a problem in young ostriches, particularly when they suffer from debilitating conditions (e.g. malnutrition). Fungi (*Aspergillus species* and others) cause nodular lesions in the trachea, lungs and air sacs, as well as on the conjunctivae (Huchzermeyer, 1994).

Gastric mycosis, fungal gastritis: Infection with *Candida* species can cause a proventriculitis with a clinical and postmortem appearance similar to megabacterial gastritis. Other fungi such as *Mucor* species can also cause outbreaks of gastric mycosis. Fungal infections of the gizzard lining are often secondary to primary insults to the gizzard wall such as toxic gizzard erosion, foreign bodies and impaction. Fungal growth can be enhanced by prolonged antibacterial and /or anti-inflammatory treatment (Huchzermeyer, 1994).

Thrush is the fungal infection by yeasts, *Candida species,* of the buccal cavity, pharynx and upper eosophagus, often as a consequence to antibiotic treatment. Yellowish pseudo-membranes to which food particles may adhere are usually present (Huchzermeyer, 1994). In protracted cases necrotic lesions can develop in the upper beak leading to beak deformation.

2.9.4. PARASITIC INFECTIONS

Parasites that have been reported to infect ostriches include:, gastrointestinal nematodes, cestodes, trematodes, protozoa, and ectoparasites.

ENDOPARASITES:

Libyostrongylus douglassii, the wireworm is the most economically significant gastrointestinal parasite of ostriches. This nematode is the cause of the disease "vrotmaag" or rotten stomach in ostriches in South Africa where it may be responsible for mortality rates of up to 50% in juvenile birds (McKenna, 2004). *Libyostrongylus* is a small blood-sucking trichostrongylid nematode found under the mucosal lining of the proventriculus of ostriches. Three species that can be differentiated on the basis of adult worm morphology are known. These are *Libyostrongylus douglassii*, *L. magnus* and *L. dentatus.*

Although the occurrence of a prominent dorsal esophageal tooth is the best characteristic feature for differentiating *L. dentatus* from *L. douglassii* and *L. magnus*, there are a number of other morphological criteria that may be used to distinguish between them. These include, features relating to the structures of the dorsal rays and spicules of the male worms and to differences in the form of the tails and the lengths of the ovijectors in the females. In addition, *L. magnus* shows a marked sexual dimorphism with female worms being smaller than males; a feature that is not evident in either *L. dentatus* or *L. douglassii.*

Apart from these morphological differences, little is known about *L. magnus* and *L. dentatus*. Although it seems reasonable to assume that they share some similarities with *L. douglassii*, precise knowledge relating to their pathogenicity and life cycles, is lacking.

In addition to South Africa and North America, infections with *Libyostrongylus* species have been reported in ostriches from Australia, Spain, Belgium, Portugal, The Netherlands, Sweden and Scotland. There is also some strong circumstantial evidence for its occurrence in Greece where strongylate-type worm eggs, which are likely to have included those of *Libyostrongylus*, were found in 146 (43%) out of 336 ostrich fecal samples. In a number of these countries, infection appears to be widespread and common. In Australia, it has been detected in approximately one-quarter of the ostrich farms surveyed in New South Wales, farms in Western Australia as well as in Eastern Victoria and on 33% of 12 farms in Queensland. A relatively high prevalence of infection has also been reported in Sweden where *L. douglassii* was detected in fecal samples from ostriches on 28 (40%) of 45 investigated farms. In other European countries, but mainly involving ostriches raised in Spain, 20% prevalence has been recorded (McKenna, 2004).

The immature parasites penetrate deeply into the glands of the proventriculus while the adults live on the surface where they suck blood and cause severe inflammation. The invasion of the proventricular glands causes a diphtheritic proventriculitis with impaction and subsequent fermentation of the proventricular contents being common sequelae. Clinical signs of infection include general wasting, anorexia, anemia, and death. However, well fed mature ostriches may sustain considerable parasite burdens without exhibiting clinical signs.

The diagnosis of *Libyostrongylus* infection may be based on the presence of clinical signs and the detection of the eggs in feces or, on the demonstration of the worms in the proventriculus. The latter may be done histologically or by stripping the mucosal lining from the fresh organ to reveal the presence of the adult worms. In heavy infections these may be clearly visible to the naked eye. When present in lower numbers, however, microscopic examination of the sieved washings from this organ may be required. The adult worms are recognizable as delicate, 4-6 mm long nematodes that are often red in color when fresh. Confirmation of the identity of the recovered worms can be readily achieved by comparing them with published descriptions (McKenna, 2004).

The eggs of this parasite need to be differentiated from those of the largely non-pathogenic ostrich caecal worm, *Codiostomum struthionis*. This requires that the eggs be cultured to the third larval stage, by incubating the feces at 27^0C for approximately 7 days and then recovering the larvae by the Baermann procedure. Infective larvae of *L. douglassii* are, on average, about 830 microns long, possess 16 triangular intestinal cells and have a short to medium length tail sheath. They also have small 4 micron diameter knob at the end of the larval tail that is diagnostic. Infective larvae of *C. struthionis*, on the other hand, have a longer and whip like tail sheath, typical of strongylids.

For routine diagnostic purposes and on properties where *L. douglassii* is already known to be well established, fecal egg counts can be performed using the modified McMaster method to determine the eggs per gram concentrations. Where the primary purpose of fecal examination is to detect the presence of the parasite rather than to determine their infection levels, however, the use of a more sensitive testing procedure will be required.

For the latter task, a concentration floatation technique, based on that of Egwang and Slocombe (1982) with a detection level of around 1 egg per 3 grams of feces, is recommended.

This procedure should be used both for assessing the status of ostrich farms with apparently healthy birds, and in investigating cases from farm populations that may be exhibiting clinically suspicious symptoms. The same test may also be used as a pre-entry quarantine screen and as an appropriate testing procedure for conducting random farm surveys. While it might perhaps, also function as a slaughterhouse surveillance tool, the collection and laboratory examination of proventriculi for the presence of worms is likely to represent a better option in these circumstances. Not only would this permit a more accurate assessment of infection levels, it would also enable the detection of immature worms and allow for the possible speciation of the parasite. It also seems probable that the targeting of older rather than younger birds for sampling purposes may enhance the likelihood of detecting infections. Older ostriches are, after all, likely to have had greater opportunities to acquire and accumulate *Libyostrongylus* infections than younger birds especially given that the parasite may persist in the host for many years and possibly life (Barton and Seward, 1993).

A number of products have been tested and found to be efficacious against *L. douglassii.* These include fenbendazole at 15 mg/kg, levamisole at 30 mg/kg and ivermectin at 0.2mg/ kg (Aiello, 1998). However, levamisole is no longer fully effective against some populations *of L. douglassii* in South Africa due to the development of resistance (Malan, Gruss, Roper, Ashburner and DuPlessis, 1988). No such resistance has been reported

against fenbendazole which, at an oral dose rate of 15 mg/kg, was shown to be >99% and >82% effective against adult worms and fourth larval stages, respectively (Fockema, Malan and Cooper, 1985). Ivermectin was also found to be effective against *L. douglassii* in ostriches in Scotland (Pennycoat and Patterson, 2001). This drug may be given orally at 0.2 mg/kg, as a subcutaneous injection, at 0.3mg/kg. In addition to these three anthelmintics, moxidectin, at a dose rate of 0.5 mg/25kg (Cydectin I% injectable), has recently been launched by Bayer Animal Health in Africa as an intramuscular treatment against L. douglassii in ostriches.

Paronchocerca struthionis is a filaroid nematode recovered from the lungs of an ostrich in West Africa (Kocan, 2004). It was an incidental finding in a bird that died of other causes. Its pathogenicity is unknown.

Struthiofilaria megalocephala *is a* nematode that has been recovered from the body cavity of ostrich (McKenna, 2004).

Cestodes: The tapeworm *Houttuynia struthionis* inhabits the small intestine of the ostrich causing ill-health in young birds. Diagnosis is made at postmortem, although segments of the worm may be passed in the faeces and eggs identified by Flotation techniques such as Modified McMaster. The worm is white, segmented and grows up to 60 cm long. Fourie, Van, Michael and Putterill (1997) describes a scanning electron microscope of *H. struthionis* in which the scolex differed from other subfamilies in the family Davaineidae by lacking scale-like spines covering the base of the rostellum and replaced by small hooks. The worm develops to an immature stage possibly in an insect or mite living on

pasture. When the ostrich eats the intermediate host, it develops into an adult worm. Treatment can be achieved with Resorantel and Fenbendazole (Fockema *et al.*, 1985).

Trematode: *Philophthalmus gralli* (eye fluke) was reported to cause severe eye irritation and discharge in captive ostriches in Florida (McKenna, 2004).

Protozoa: A number of intestinal protozoa, including *Hexamita, Giardia, Trichomonas, Cryptosporidium,* and *Toxoplasma,* have been isolated from ostrich chicks (Aiello, 2005). Their pathogenicity is unknown and immunosuppression may be required for disease to develop. Treatment is achieved with metronidazole at 10mg/kg. Coccidiosis caused by *Isospora struthionis* was described from an ostrich in a Russian zoo. Unnamed Eimeria species have also been found in ostriches and rheas in North America (Huchzermeyer, 1994).

ECTOPARASITES:

Mites, lice and ticks: Infection by the ostrich quillmite *Pterolichus bicaudatus* and the biting louse *Struthioliperurus struthionis* are important for skin and leather quality as irritation from these ectoparasites may cause pruritis and/or excessive preening and feather loss (Foggin, 1992). Infestation with these parasites causes stress and predisposes birds to secondary infections and gastrointestinal disorders such as impaction (Cooper, 2005). The lice are seen on feather shafts. Treatment is done with 5% carbaryl dust at 14 days intervals (Aiello, 1998). Numerous ticks of various life stages infest ostriches, their main significance being disease vectors. Treatment for ticks and mites is by use of ivermectin at 0.2 mg/kg at 30 days intervals (Aiello, 1998; Cooper 2005).

The ostrich quill mite *Struthiopterolichus bicaudatus* (Gervis) = *Pterolichus bicaudatus* (Cooper) = *Gabucinia Bicaudata* (Andre) live in the rachis of the feather (Halliday, 2006). It appears to be a normal inhabitat of ostrich feathers, but can also cause economic losses in farmed birds. It has been reported to cause irritation to its host leading to excessive preening, feather loss, reduction in leather quality and predisposition to secondary infection and gastrointestinal disorders. It is usually confined to the ventral groove of the feather shaft, where it feeds on the gelatinous content of the feather. When its population builds up to high levels, it can spread to the skin of the bird and cause the reported symptoms (Halliday, 2006).The parasites appear as small, reddish, dust-like particles in the feather vein.

Struthiopterolichus bicaudatus is host specific with occasional transfer to other hosts when different bird species are kept close together in captivity. All pairs of legs are roughly similar in size and by pattern of ornamentation on the dorsal surface. In both the male and female the dorsal surface of the body is mostly covered by a large sclerotised posterior plate and a smaller anterior plate which bear a strong pattern of polygonal ornamentation. The sexes may be distinguished by the fact that the male has a pair of large posterior lobes that bear a conspicuous large setae and a pair of suckers. Males and females may often be found in copulating pairs with the posterior ends of their bodies attached together by means of these suckers (Halliday, 2006).

Adults of *S. bicaudatus* have a body length of about 550 micrometers. This makes them barely visible to the naked eye, so they may easily be overlooked or mistaken for dust and debris. It may be detected in the field by examination of the rachis of feathers with a hand lens or low power microscope. Effective control may be achieved by use of ivermectin at a rate of 0.2mg/kg per os at four weeks intervals for three treatments (Halliday, 2006).

2.9.5. NUTRITIONAL AND METABOLIC DISEASES

Vitamin E and selenium deficiencies have been reported in ostriches in South Africa (Huchzermeyer, 1994). Nutritional muscular dystrophy is caused by vitamin E and/or selenium deficiency and results in paresis and lameness when birds are fed imbalanced diets. This condition affects heart and gizzard muscles as well and may be accompanied

by steatitis and fat necrosis. Marginal selenium deficiency is also reported to cause ill-thrift and susceptibility to infectious disease (Foggin, 1992a). Prolonged recumbency in cases of gastric stasis can lead to muscle degeneration (rhabdomyolysis) in the legs and produce lesions similar to those of nutritional muscular dystrophy, but is more likely to affect individual birds only, while nutritional muscular dystrophy is more likely to be a flock problem.

Oedema (exudative diathesis) of varying degrees of severity has been encountered in ostriches of various age groups including: un-hatched embryos, chicks, juveniles and adults (Ngatia *et al.*, 2005). Oedema in embryos and newly hatched ostrich chicks has been associated with incubation inadequacies (Philbey *et al.*, 1991), others have associated it with nutritional inadequacies in the hens' diet, especially deficiencies of vitamin E, B12 and biotin, manganese and selenium (Foggin, 1992a). Inadequate hens' diet may lead to formation of yolks which are quantitatively and qualitatively inadequate, which in turn result in reduction in the chances of survival of the embryo and hatched chicks. Deficiency of vitamin E and or selenium are known to cause exudative diathesis and hemorrhages among other lesions (Shanawany and Dingle, 1999). Protein inadequacy can also lead to loss of body condition and exudative diathesis. Besides development of oedema, prolonged malnutrition leads to weakness (due to weakness of skeletal and cardiac muscles), inappetance and anorexia. Additional lesions reported include combinations of abdominal steatitis, hemorrhages and pneumonia (Ngatia *et al.*, 2005).

Oedema (exudative diathesis) is a disorder characterized by excessive accumulation of fluid in the intercellular spaces including body cavities. Localized oedema may occur in most organs and tissues depending upon local causes. Generalized oedema affects the body as a whole, but most of the fluid tends to accumulate in the lowest parts of the body. Besides mammals, oedema has been described in birds either as anasarca (subcutaneous oedema), ascites (hydroperitoneum), or hydropericardium (Jones and Hunt, 1983). Exudative dermatitis of the head is thought to be caused by vitamin B deficiency (pantothenic acid, niacin and biotin (Foggin, 1992a).

CONGENITAL DEFORMITIES:

Bone deformation: Twisted and bent legs, enlarged hocks, slipped tendons and leg weaknesses as well as bow leg syndrome are terms used to describe various manifestations of metabolic bone disease in ostriches. The common use of often unbalanced home-mixed rations encourages the occurrence of these bone deformities. Lucerne is low in phosphate and when limestone is given to ostrich chicks grazing on lucerne, this can lead to calcium: phosphorous imbalance (Huchzermeyer, 1994).

Curled toe syndrome: Riboflavin deficiency causes such a syndrome in ostriches as well as in other birds. The affected toes turn inwards, lying on their lateral surface and pointing medially. This should not be confused with twisting of the toes of birds kept on slippery surfaces, where the toes lie on their medial surfaces and point laterally (outwards) (Huchzermeyer, 1994).

Embryonic malformations of the head, neck and limbs as well as of the viscera are seen from time to time. Shortening of the lower beaks was found to be caused by manganese deficiency in the parents ration (Foggin, 1992a). Excessive humidity during incubation repeatedly caused anasarca and muscular degeneration in hatchlings (Philbey *et al.*, 1991).

2.10. OTHER FACTORS RELATED TO OSTRICH HEALTH

Poor hatchability must not be confused with infertility and should be investigated by opening un-hatched eggs. Early embryonic death is probably caused more often by overheating or poor egg storage conditions. Malpositioning could be caused by excessive turning. However, there are reports of successfully hatched emu and cassowary chicks which were in the upside-down position (Huchzermeyer, 1994). Dwarfing of embryos has been observed in several flocks and the cause remains unknown.

Hatchery hygiene consists of meticulous washing of incubators and all implements and their disinfection. Incubators should be fumigated before setting. Eggs can be fumigated before setting, preferably on the day of collection, but not during incubation. The eggs should be pre-warmed to 30°C for pre-incubation. Hatching success of ostrich eggs in artificial incubators is considerably below that found in wild ostriches (Betram and Burger, 1981), which suggests that hatchability of artificially incubated ostrich eggs can be improved by identifying and altering factors inherent to eggs or associated with current incubation practices that preclude maximum hatchability. These factors include:

length of egg storage, pre-incubation environmental conditions, egg size, shell thickness and porosity, and incubation criteria (temperature, humidity and frequency of egg turning). Hassan *et al.*, (2004) noted that the optimal incubation temperature for ostrich eggs appears to be less than 37°C as it improves hatchability. In addition, Sahan *et al.*, (2003) concluded that incubator humidity should be low (25%) to allow adequate weight loss from eggs during incubation.

A common problem for ostrich producers is an unacceptably high incidence of death in fully developed (dead in shell) embryos during the last several days of incubation (Gonzalez *et al.*, 1999). Necropsy results reveal that a significant amount of this late embryonic mortality appears to stem from suffocation in edematous embryos. Many ostrich producers are concerned that the length of pre-incubation egg storage might negatively affect hatchability. However, it has been found that storage for approximately eight days resulted in a numerical increase in hatchability over storage for approximately three days (Betram and Burger, 1981).

Infertility can be caused by advanced age of the male(s), by genuinely infertile males or by incompatibility of mates. In cases of suspected infertility, semen of the suspect males should be collected and examined for the presence of sperm, its motility and possible morphological abnormalities (Betram and Burger, 1981).

Due to the wide spectrum of factors documented to affect ostrich production, the study was designed to address the situation in Kenya.

3.0 MATERIALS AND METHODS

3.1. STUDY AREA

The study was carried out in Maasai Ostrich Farm (MOF) in Kitengela and Ostree Ostrich Farm in Naivasha (OOF). MOF is located in the semi-arid plains of Kitengela about 45km south of Nairobi. Most of the year is cloudy, with temperatures of 25 degrees celcius and 47 % humidity. The farm had 1700 birds which included 205 breeders (80 males and 125 females). These birds were reared under semi-intensive production system on a 200 acre farm. OOF is located approximately 15 kilometres south of Naivasha town, at latitude 0°-47' 60 N and Longitude 36° 21' E. The farm had 33 birds (16 females and 17 males) which were also raised under semi-intensive production system (Potter H.L, Undated). MOF had the various age groups of birds and a wide range of facilities whereas OOF which was recently started had mainly adult birds.

3.2. INCUBATION STUDIES

This study was carried out at MOF only because OOF at the time of the study was still establishing the incubation facility. Incubation parameters namely temperature, humidity and turning rates were followed throughout the incubation period and recorded for comparison with other documented recordings. Egg weight losses (EWL) during incubation were determined by taking the weights of the eggs at different periods, that is:

1) When the eggs were collected from the pens, which is done within 12 hours of being laid (before storage),

2) Just before incubation (setting); 7 – 10 days old,

3) Day 14 of incubation (during 1st candling),

4) Day 28 of incubation (during 2nd candling),

5) Day 35 of incubation (during 3rd candling), and

6) Day 39/40 (during hatching).

Egg weight losses during incubation were calculated using the formula:

EWL (%) = (egg weight at day 1 – egg weight at day 39/40)/egg weight at day 1 × 100 (Gonzalez *et al*, 1999).

3.3. POST-MORTEM STUDIES ON UN-HATCHED EMBRYOS AND DEAD CHICKS

Dead chicks and un-hatched embryos collected from MOF were preserved in buckets containing 10% formalin solution and in the cold room respectively until collected for post-mortem examination. This was performed following the procedure described by Foggin (1992b). Weak dying birds on site were transported alive and post-mortem performed. Tissue samples with gross lesions were collected for histopathology and processed routinely as described by Luna (1968).

3.4. PARASITOLOGICAL STUDIES

3.4.1. FECAL SAMPLES

Faecal samples were randomly collected from 30 pens housing different age groups of birds. Every second fresh faecal sample in each of the pens housing chicks and growers was collected. Ten to fifteen samples were collected from each pen depending on availability of fresh faeces and stocking density of the birds. The samples were collected from different sites of each pen. However, in the breeder paddocks every fresh sample of faeces on site was collected. The assumption was that each faecal sample represented an individual bird.

Faecal samples (approximately 4 grams) were collected in clear plastic bags from the pens. Each sample was labelled indicating pen identification, date of collection and location using waterproof ink and masking tape. All the samples collected were gathered in larger black plastic bags. The samples were then packed in an insulating cooling box to keep them fresh and transported to the laboratory.

Once in the laboratory the samples were placed in a refrigerator (approximately 4 degrees Celsius) for intervals of one to seven days until processing was completed.

Faeces were examined visually for adult parasites, larval stages of insects (for example bots), and tapeworms segments. Modified McMaster egg-counting technique (as described by Soulsby, 1982) was done to reveal nematode, cestode and coccidian oocysts

present. To arrive at a specific diagnosis from the eggs, positive samples were cultured at 26 degrees Celsius for seven days (Soulsby, 1982) to characterize the larvae.

3.4.2. ECTOPARASITES

Ectoparasites that were recovered directly from the skin and feathers during slaughter at MOF were preserved in 70% ethanol in small plastic tubes that were clearly labelled to indicate farm of origin and date of collection. These were transported to the laboratory where identification was done following descriptions by Soulsby, (1982).

3.5. POST-MORTEM AND PARASITOLOGICAL STUDIES ON GASTROINTESTINAL TRACTS OF SLAUGHTERED BIRDS

MOF regularly slaughtered a group of birds and the gastrointestinal tracts of the carcasses were kindly donated for the study. The entire gastrointestinal systems of the slaughtered birds (growers) and dead chicks were examined for any endoparasites and gross pathological changes. Any visible endoparasites (nematodes and cestodes) were collected and stored in plastic containers containing 70% alcohol. Cestodes were collected with their scolices intact as these were of great importance for identification, fixed for permanent preparations in 70% alcohol with glycerin.

Any visible gross lesions on the gastrointestinal tract were sampled, fixed in 10% formalin and transported to the laboratory where they were processed for histopathology

(Luna, 1968). These were clearly labelled indicating the section of the gut from which they were recovered, date of slaughter and farm of origin.

The cestodes recovered were stained and processed as per the procedure recommended below in the International Institute of Parasitology manual (1994).

Preparation of stained whole mounts for processing cestodes:

a) Cestodes fixed in formalin were washed in running water while those preserved in 70% ethanol were washed with distilled water for several hours respectively.
b) Large cestodes were cut into approximately 5cm lengths.
c) Hydration stage: The samples were then taken through a graded series of alcohols, that is, 70% then to 50%, then to 30% (45minutes duration at each stage) and then to several changes of distilled water.
d) Staining: This was done overnight (17 hours) using aceto alum carmine.
e) Specimens were then washed in distilled water (5 times every 10 minutes) to remove excess stain.
f) Differentiation: 1% HCL in 70% ethanol was used. This was done carefully using light source from a stereomicroscope. The specimens were then washed in distilled water (5 times every ten minutes) to remove the differentiating solution.
g) Dehydration: Specimens were then taken through an ascending series of alcohols, that is, 30% to 50% to 70% to 80% to 90% to industrial methylated spirit then to absolute ethanol (30 minutes duration at each stage).
h) Clearing was done using clove oil and mounted using DPX.

Faecal samples were also collected from the rectum of the 40 slaughtered birds and examined as above (section 3.4.1).

3.6. OBSERVATION ON FARM MANAGEMENT PRACTICES

The farm management practices were assessed by observation and interactive interviews with the farm workers. Focus was on the disease control measures, standards of hygiene especially in the incubation facility, personal hygiene by the handlers of eggs or incubator, handling of eggs from collection through incubation period, and management of newly hatched chicks.

4. RESULTS

4.1. INCUBATION STUDIES

The incubation facility at MOF is maintained under strict quarantine. The incubator is automated, electrically controlled and set at 36°C and 30% temperature and relative humidity, respectively.

The total number of eggs weighed at the start of the incubation period was 43. However, this number decreased (because they were discarded for either poor embryo development or infertility) such that by day 14 of incubation, 42 eggs were weighed; on day 28 and 35, 22 eggs were weighed; on day 38, 15 eggs were weighed and on day 42, only 7 eggs were remaining.

The average egg weight loss was 10.2%. Out of 43 eggs present at the start of incubation (Appendix), 15 eggs (31.9%) were weighed on day 38/9 and 7 eggs (14.9%) weighed up to day 42 respectively. Figure 1 shows average egg weight loss at different stages of incubation. After day 38/39, only 7 eggs remained and therefore this sudden small sample size could be associated to the marked change of the mean egg weight on this day thus the skewed graph. Figure 2 shows progressive egg weight loss of the eggs that hatched.

Figure 1: Average egg weight changes (Grams) during incubation at MOF

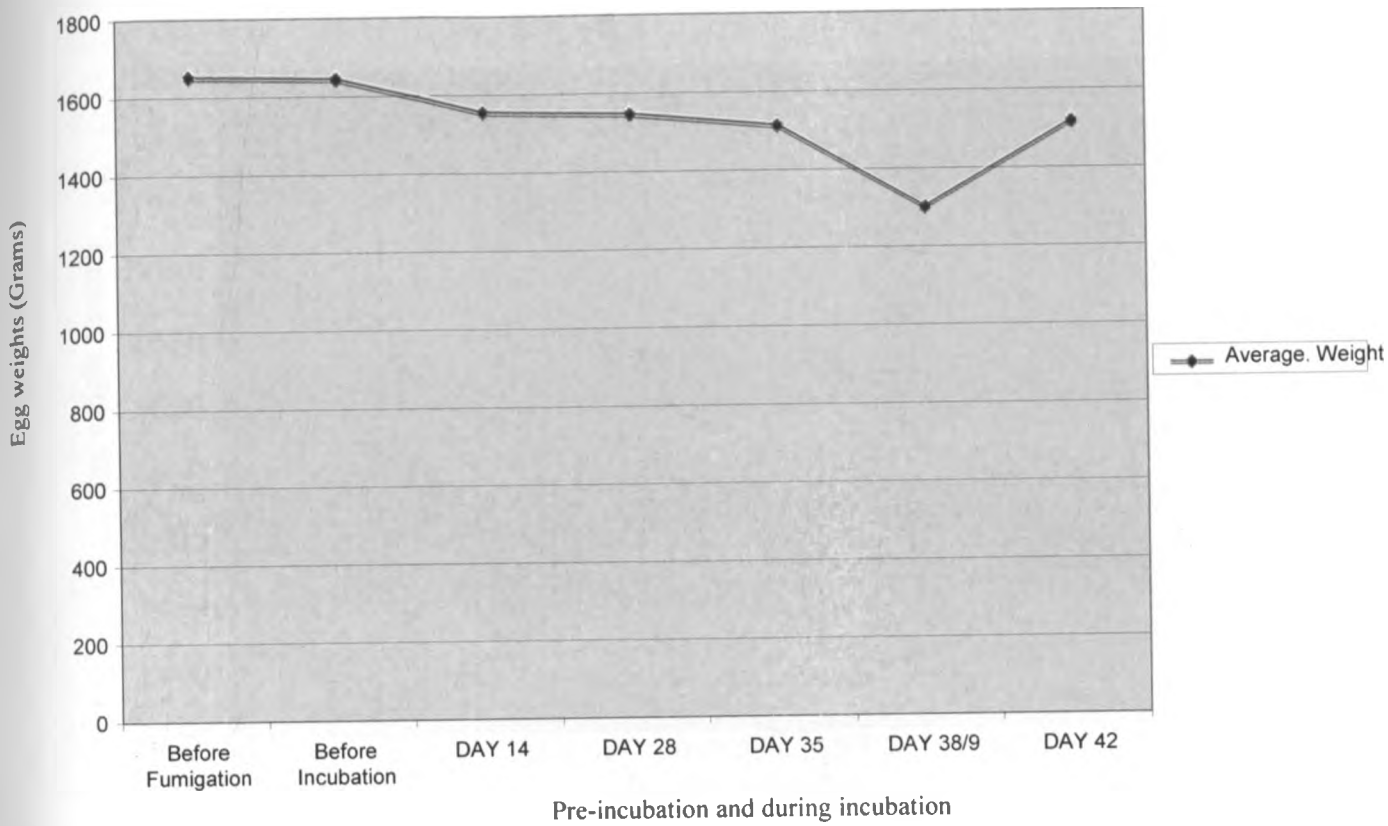
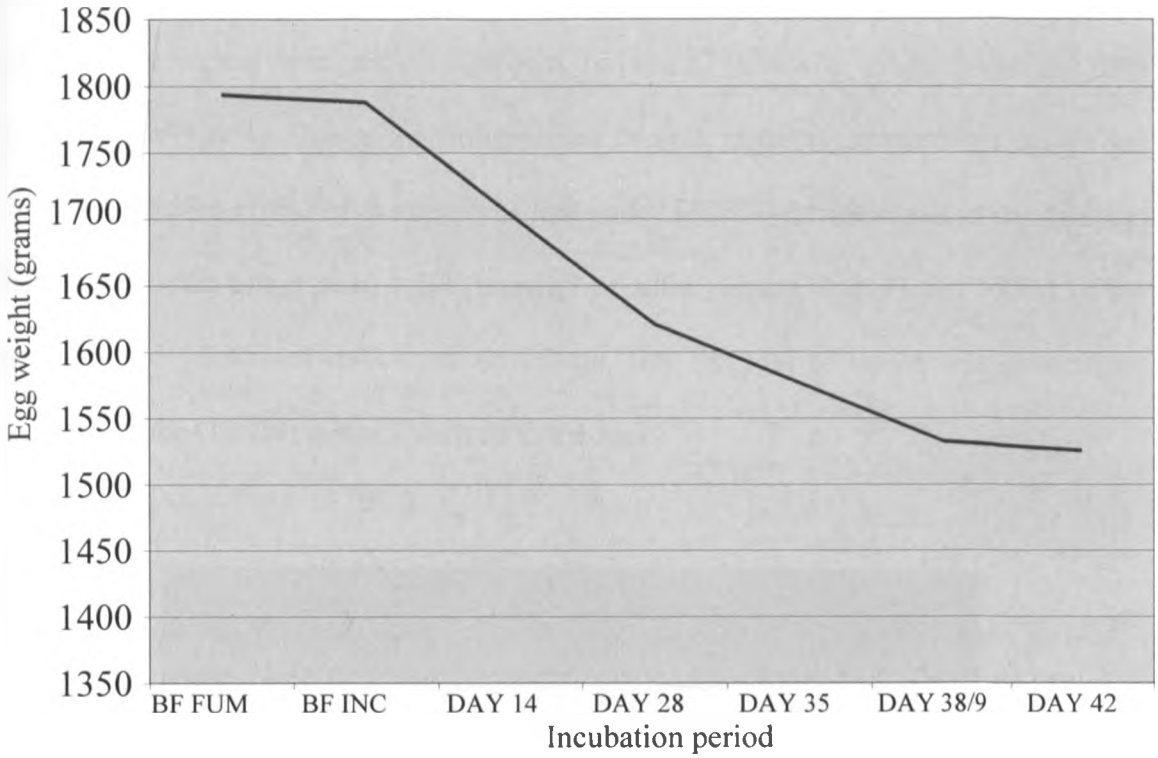


Figure 2: Egg weight loss for the eggs that were weighed up to day 42



KEY:

- BF = before
- FUM = fumigation
- INC = incubation

4.2. POST-MORTEM FINDINGS ON UN-HATCHED EMBRYOS

Embryos dying at different stages of development (dead in shells and those with poor embryo development) were examined post-mortem. Out of ten embryos examined, eight (80%) had yolks which were either completely or partly externalized or abnormal in color. These varied from yellowish brown, brownish, yellowish green, green and dark green (Figure 3 & 4). One of the embryos had its yolk material enclosed in a double sac (Figure 5). Seven (70%) of the embryos had yolks which were abnormal in consistency, that is they were either semi-solid (marshy) or solid (Figure 3 & 4). Six (60%) of the embryos had gelatinous sub-cutaneous edema, five (83.3%) of which was generalized whereas in one (16.7%) it was localized to the legs.

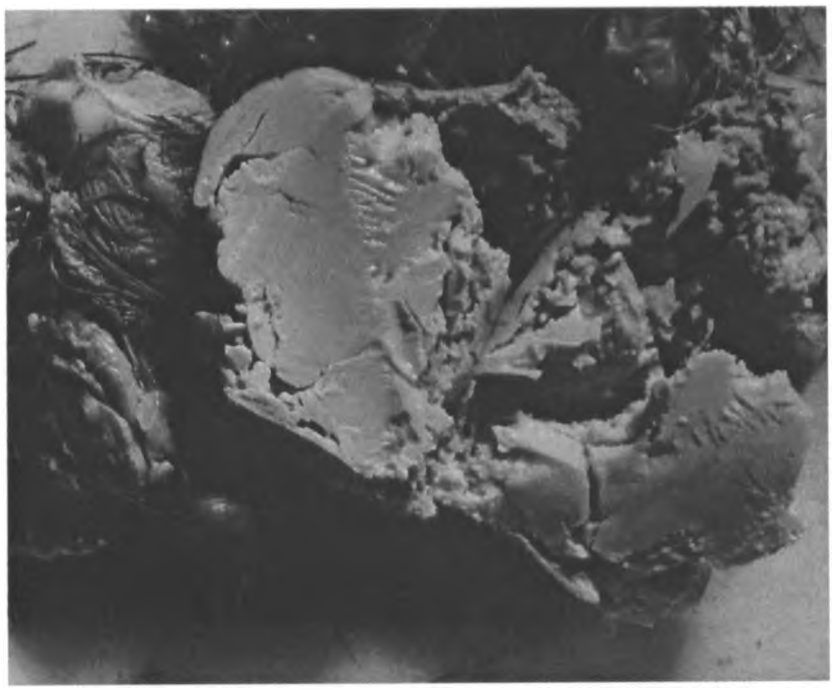


Figure 3: Section of an ostrich embryo with green marshy to solid yolk material.

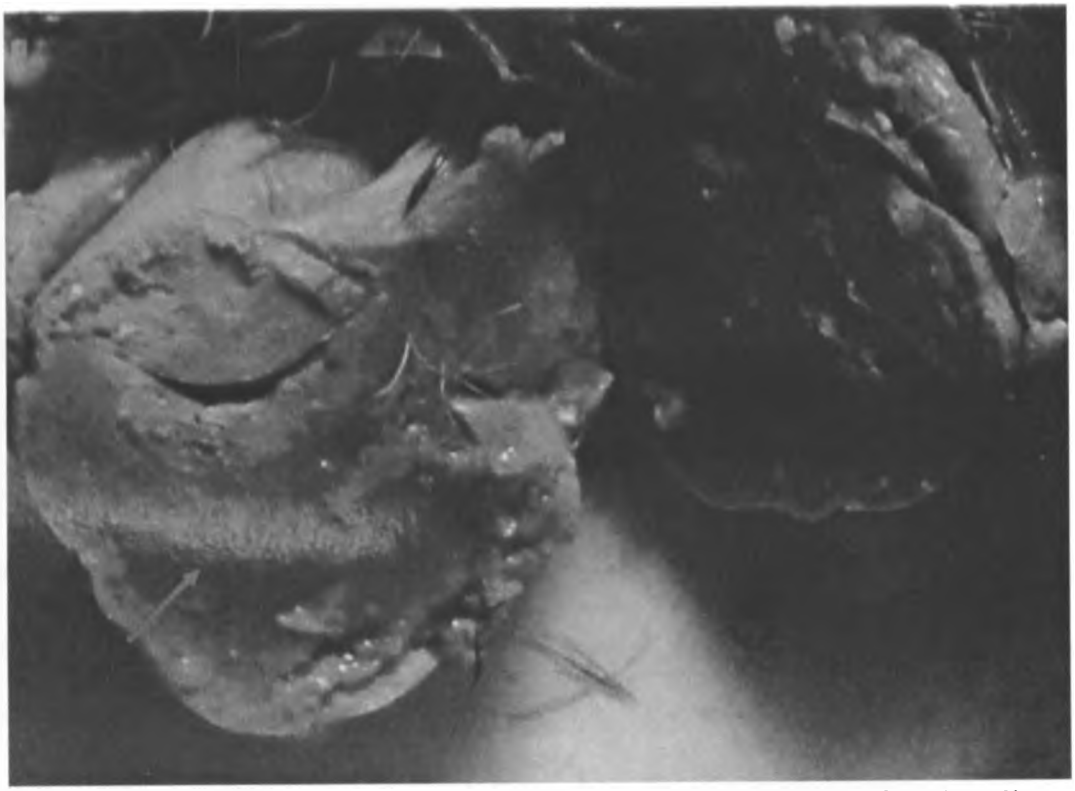


Figure 4: Cross section of an ostrich embryo yolk with mixture of dark yellow and green color.

Figure 5: Double sac egg yolk with fluid-like dark yellowish contents.

4.3. POST-MORTEM FINDINGS ON DEAD CHICKS

Dead chicks stored in 10% formalin were collected from the brooders and pens. Of the ten dead chicks examined, eight had unresorbed yolks. Seven (87.5%) of the residual yolks were abnormal in color and consistency. Colors varied from light brown, brownish black, yellowish green to green and were either semi-solid (marshy) to solid in consistency. One (10%) of the carcasses which was the oldest of those examined, aged 20 days had completely reabsorbed its yolk, had splay legs and very thin pale muscles of the breast and thigh. In addition, five (50%) of the chicks had gelatinous sub-cutaneous edema which was generalized in one (20%) carcass, localized to the legs and head in three of them (60%) and in the peritoneal cavity in one (20%) of them. One (10%) of the chick had deformed legs.

4.4. PATHOLOGICAL AND PARASITOLOGICAL FINDINGS ON GASTROINTESTINAL TRACTS OF SLAUGHTERED BIRDS

Twenty five (62.5%) gastrointestinal tracts had tapeworms in the small intestines. The degree of infection varied from mild in 5 (20%) of the tracts (Figure 6 and 7), moderate in 5 (20%) of the cases (Figure 8) while severe enteritis in 15 (60%) of the cases examined (Figure 9). The degree of infestation was dependent on the degree of haemorrhage and the extent of gastrointestinal tract lumen occupied by the parasites, *Houttuynia struthionis*. For the severe cases, the tapeworms had extended almost the entire jejunum and in some cases even part of the ileum (Figure 10). The intestinal lumen was partially obstructed in these areas where the parasites were.

For quantitative purposes, when collected in 200 ml containers, the parasites exceeded 100 ml volume for the severe forms of infection and the scolex count was ≥ 15 (when counted on a tray). For the moderately infected birds, the tapeworms occupied almost half the jejunal length and when collected in 200 ml containers did not exceed 100 ml volume and their scolex count ranged from 8-14. The mildly infected intestines had few tapeworms in their small intestines which when collected were barely 30 ml in volume and their scolex count ranged from 1-7.

However there was one exception to this method of categorizing infection by tapeworms. One gastrointestinal tract had up to 222 very tiny entire worms, (that is, with their scolices intact), most of which had a length of 0.3cm; which when collected barely exceeded 30ml in volume. These worms did not grossly occupy a large portion of the small intestinal lumen but due to the physical damage seen as severe enteritis on the affected gastrointestinal tract; this was categorized as severe infection.

Table 2: Summary of gross pathological findings on the gastrointestinal tracts of the slaughtered birds:

Description	Number of birds affected	Percentage affected (%)
Mild haemorrhagic inflammation with scattered foci of petechiae	2	5
Moderate haemorrhagic inflammation with widespread petechiae and ecchymotic haemorrhages	1	2.5
Severe haemorrhagic inflammation, with varied diffuse, linear, ecchymotic and petechiae haemorrhages over entire sections of duodenum and jejunum	25	62.5
Mild catarrhal and haemorrhagic inflammation	2	5
Moderate catarrhal and haemorrhagic inflammation	2	5
Severe catarrhal and haemorrhagic inflammation	6	15
None	2	5

Figure 6: Duodenum of *Struthio camelus* showing mild infection with *Houttuynia struthionis* (yellow arrows).

Note: There are multiple raised focal areas with petechiae and ecchymotic haemorrhages in the mucosa (blue arrows).

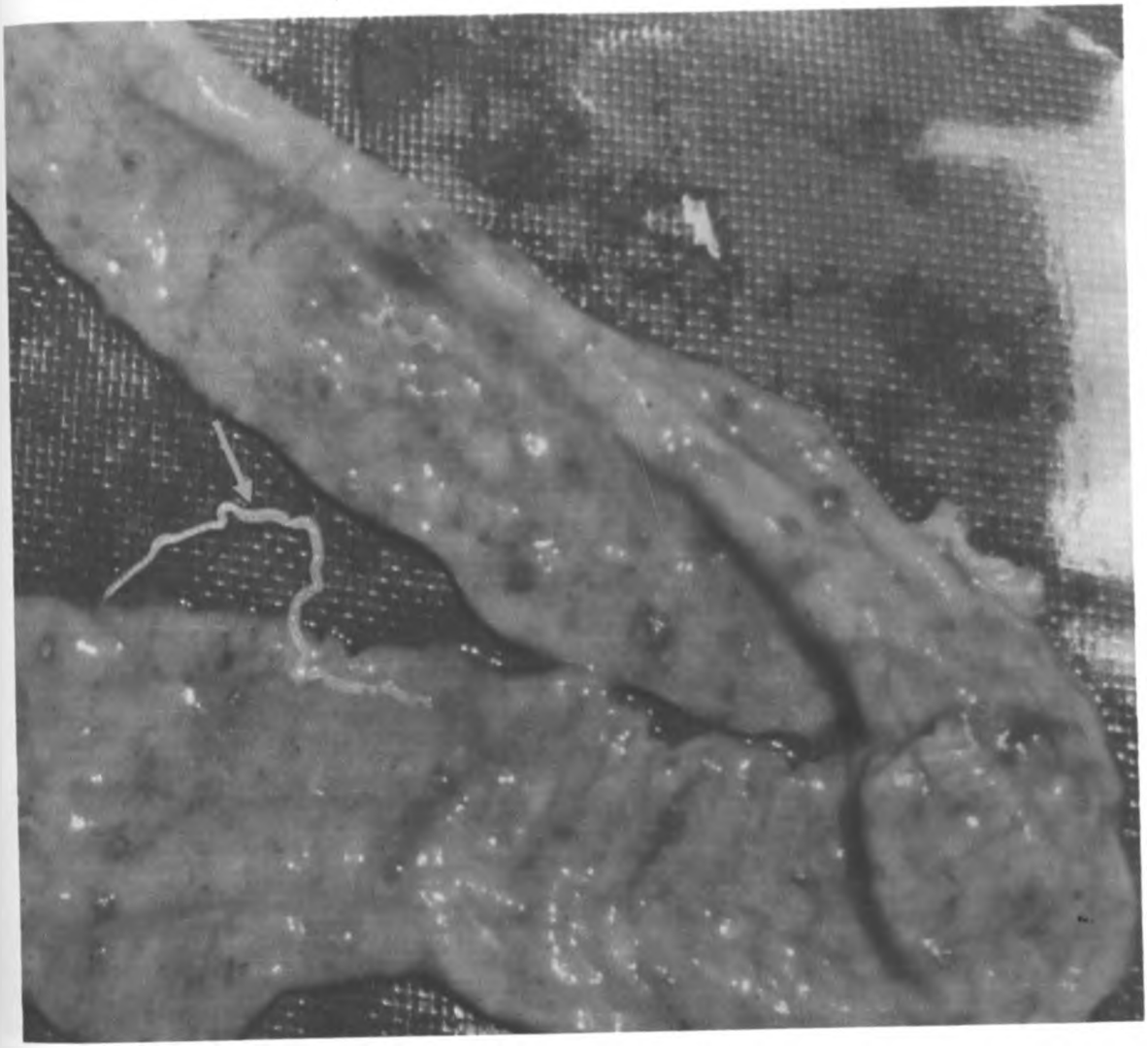


Figure 7: A section of duodenum of *Struthio camelus* showing mild enteritis and widespread petechiae and ecchymotic hemorrhages.

Note: Tapeworm embedded in the lumen (Blue arrow).

Figure 8: A section of duodenum of *Struthio camelus* showing focal nodular lesions and diffuse haemorrhage (green arrow). Light blue arrow indicating an embedded tapeworm.

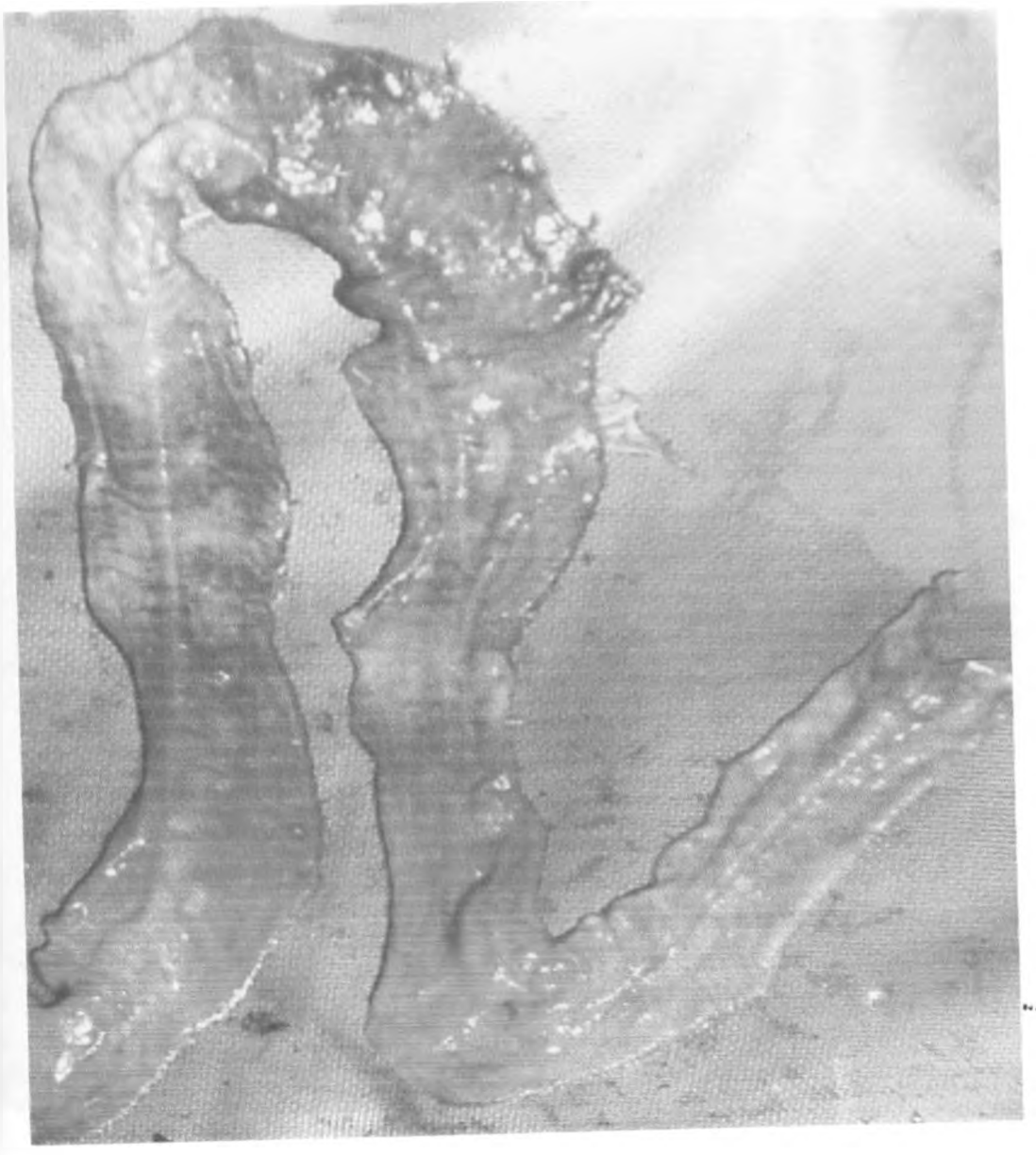


Figure 9: A section of duodenum of *Struthio camelus* showing severe hemorrhagic enteritis.

Note: Entire right half and lower left sides have diffuse hemorrhage.

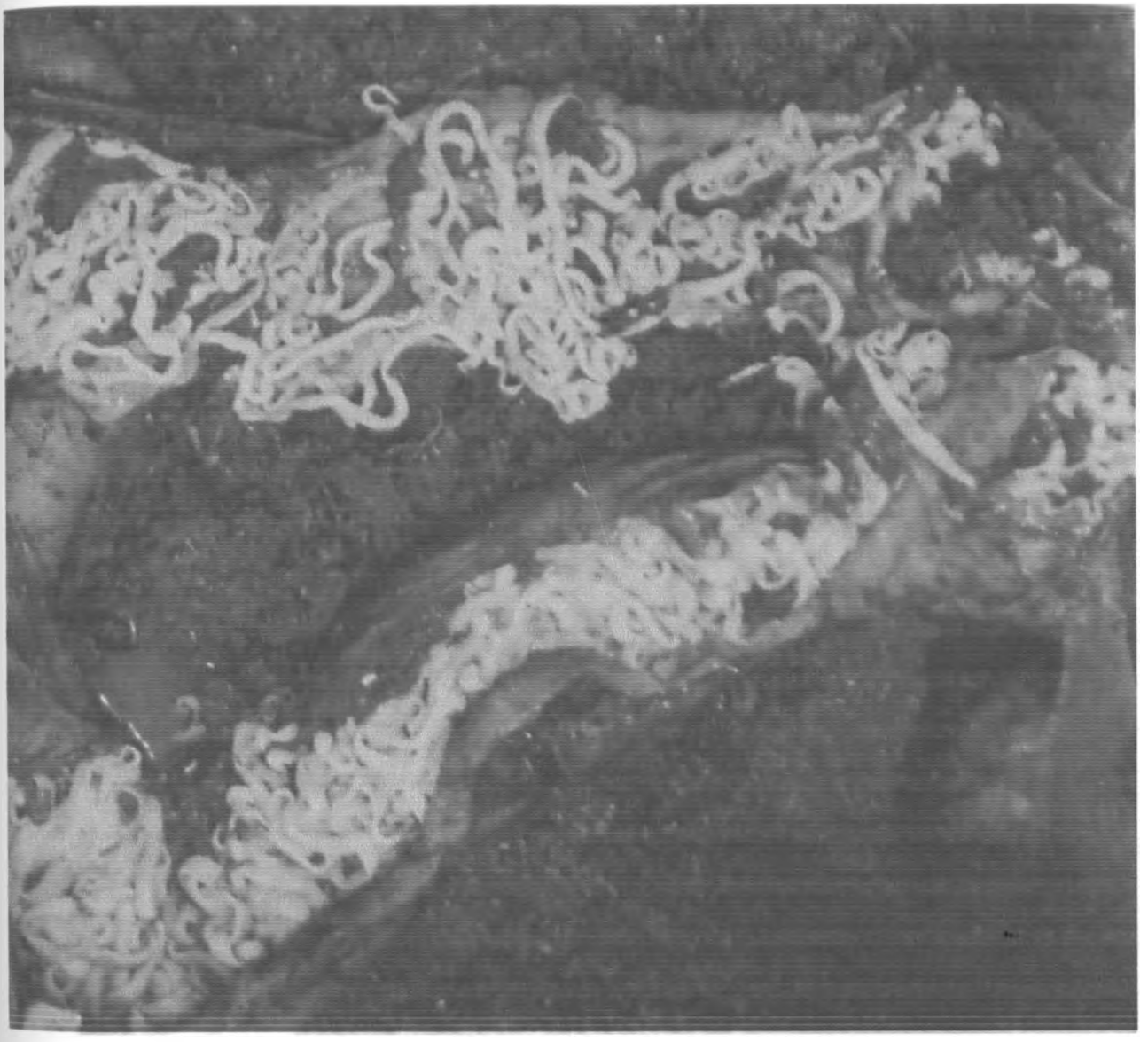


Figure 10: A section of the small intestines of *Struthio camelus* showing severe infection by *Houttuynia struthionis* (Tapeworms are white in color). The entire lumen was filled with parasites and very little intestinal contents.

4.5. HISTOPATHOLOGY OF POST-MORTEM SECTIONS FROM SLAUGHTERED BIRDS

Sections from the duodenum of the slaughtered birds that were infested with the tapeworm *Houttuynia struthionis* on gross examination, had atrophy and matting of the villi. There was also glandular degeneration and distortion (Figure 11). In addition, there were widespread foci of haemorrhages, infiltration by lymphocytes, heterophils, and macrophages (Figure 12, 13 and 14). Similar changes were observed in histopathological sections taken from the ileum.

Section from the large intestines had little foci of haemorrhages and fewer scattered heterophils and lymphocytes.

In summary these findings emphasize haemorrhage and inflammation of the small intestines which extended into the large intestines. There was also degeneration of the intestinal cells/villi and glandular distortion and degeneration.

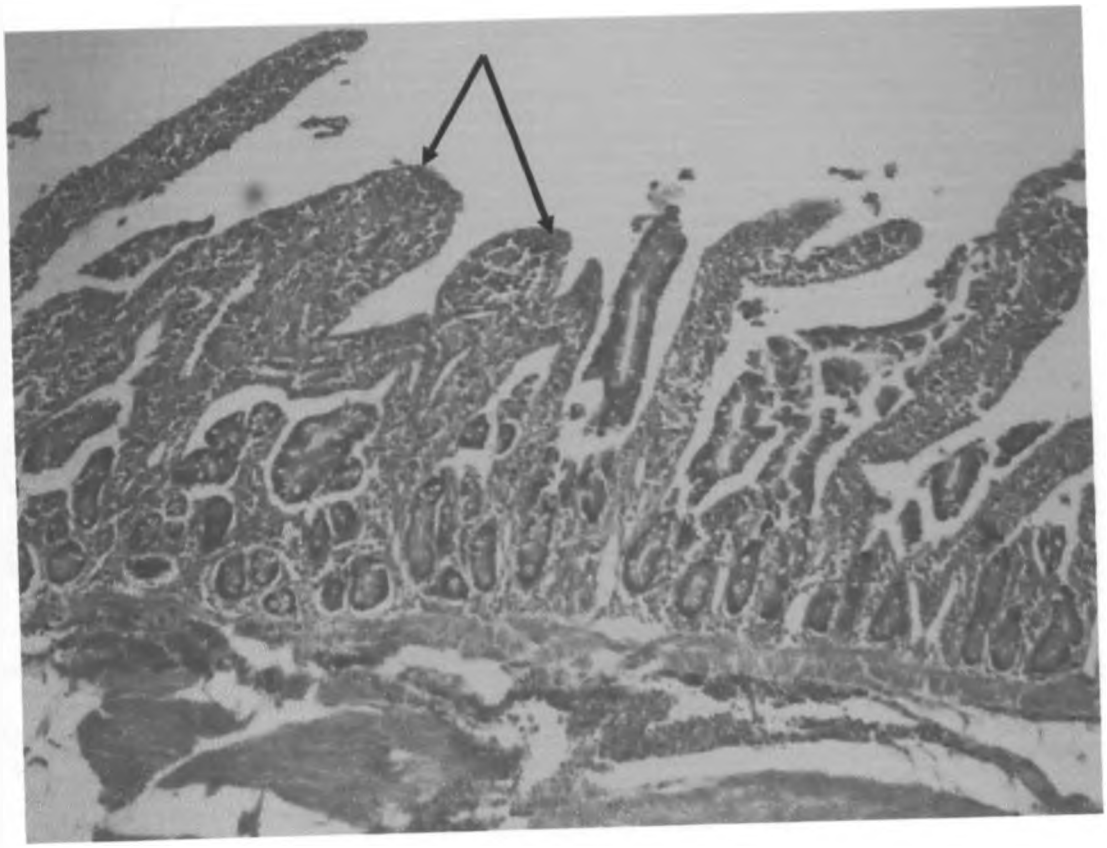


Figure 11: A section of duodenum from *Struthio camelus* infested with *Houttuynia struthionis* showing matting, disintegration and atrophy of the villi (arrows) and glandular degeneration. (H&E; X100).

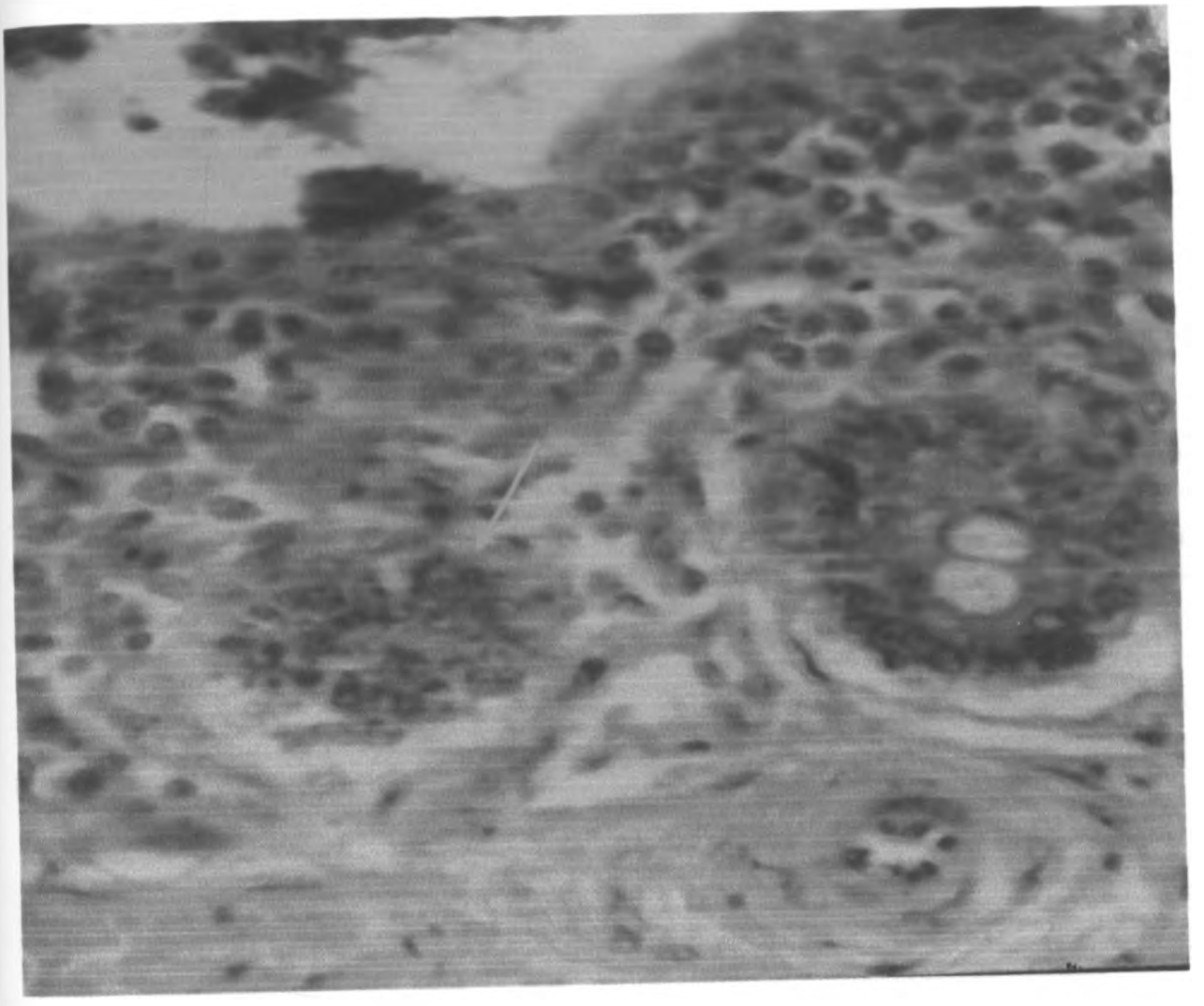


Figure 12: A section from the luminal side of duodenum of *Struthio camelus* with cellular infiltration and glandular distortion (Blue arrow) (H&E; X400).

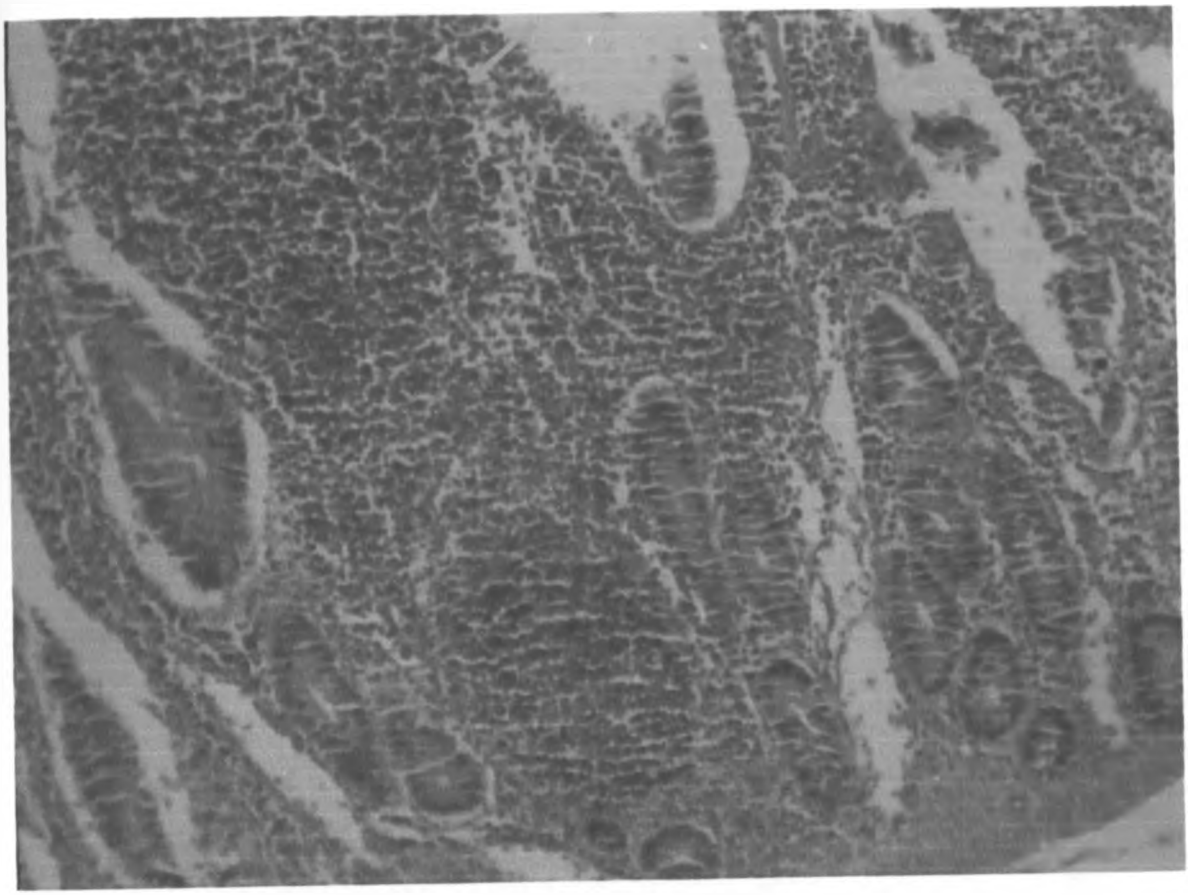


Figure 13: A section of duodenum (luminal side) from a *Struthio camelus* infested with *Houttuynia struthionis.* Note the lymphocyte aggregations (arrow) suspected to be a reaction due to chronic infection with the parasites (H&E; X400).

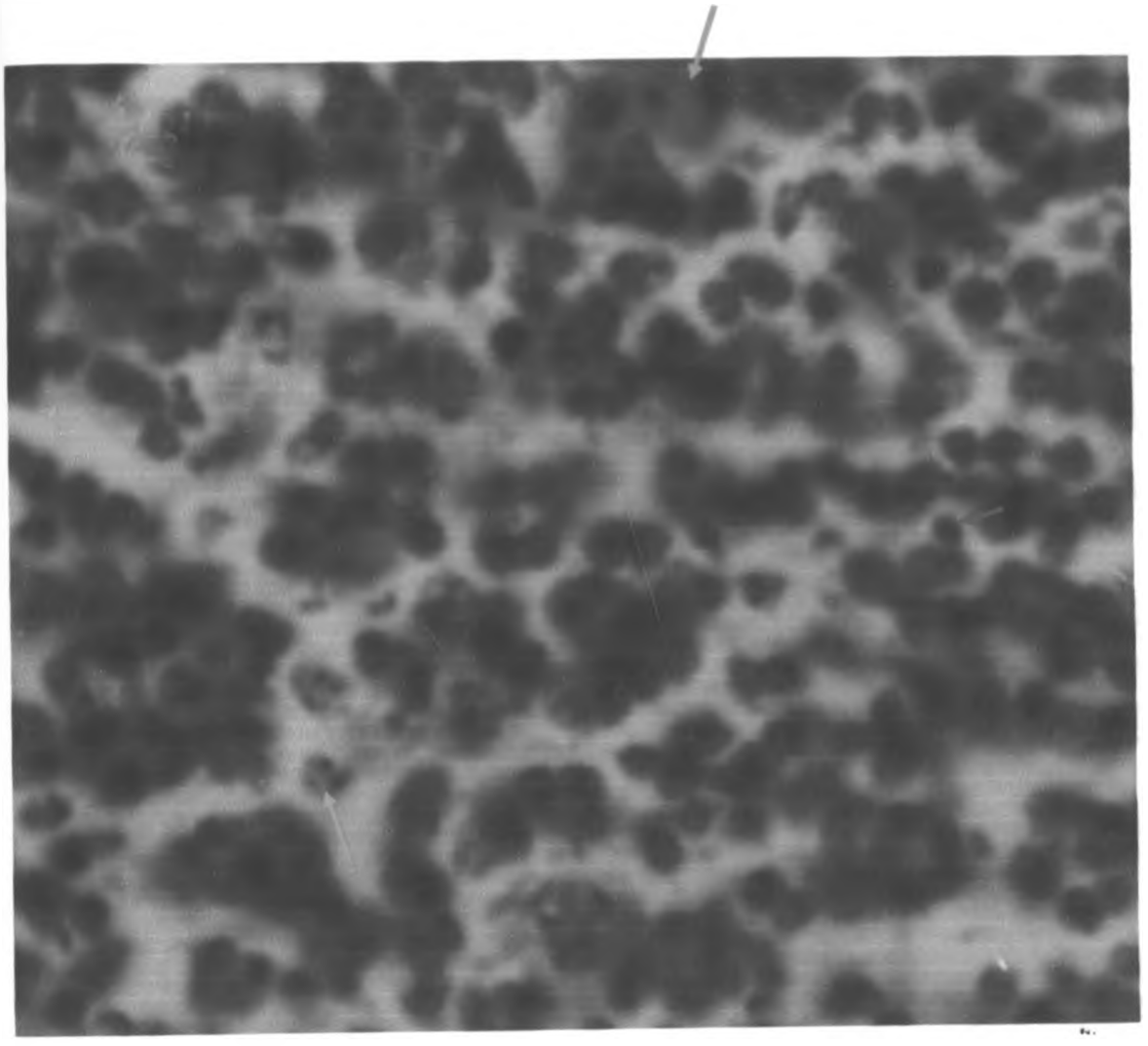


Figure 14: A section of the luminal side of the duodenum of *Struthio camelus* with infiltration by different inflammatory cell types; mainly heterophils (light blue arrow) and lymphocytes (dark blue arrow) (H&E; X400).

4.6. PARASITOLOGICAL FINDINGS

A total of 259 faecal samples were collected from Maasai Ostrich Farm (MOF). The various age groups involved from MOF were as follows: breeders 70, growers 30, chicks 3 to 6 months old 88 samples and chicks less than 3 months old 72 samples. Thirty three samples were collected from OOF, all being from breeders.

Most of the faecal samples were negative with only one (0.5%) from a breeder group collected from MOF being positive for strongyle eggs. The sample which was cultured at 27°C for 10 days hatched a trichostrongylid larva.

4.6.1. ECTOPARASITES

There were flies which were observed to be bothering the birds in the paddocks. These biting flies were collected from feathers of slaughtered birds, stored in 70% alcohol and identified in the laboratory as *Pseudolynchia canariensis* (Figure 15). They are commonly known as pigeon fly and are of the Phylum Arthropoda, Class Hexapoda, Order Diptera and Family hippoboscidae.

Mites were also collected from feathers of slaughtered birds which occurred in high numbers (Figure 16). The mites were identified as *Struthiopterolichus bicaudatus* (Figure 17). They are host specific with occasional transfer to other hosts when different bird species are kept close together in captivity. All pairs of legs are roughly similar in size

and by pattern of ornamentation on the dorsal surface. In both the male and female the dorsal surface of the body is mostly covered by a large sclerotised posterior plate and a smaller anterior plate which bear a strong pattern of polygonal ornamentation. The sexes may be distinguished by the fact that the male has a pair of large posterior lobes that bear a conspicuous large setae and a pair of suckers.

Figure 15: *Pseudolynchia canariensis* are dark brown biting flies with a pair of transparent, tapering wings collected from MOF.

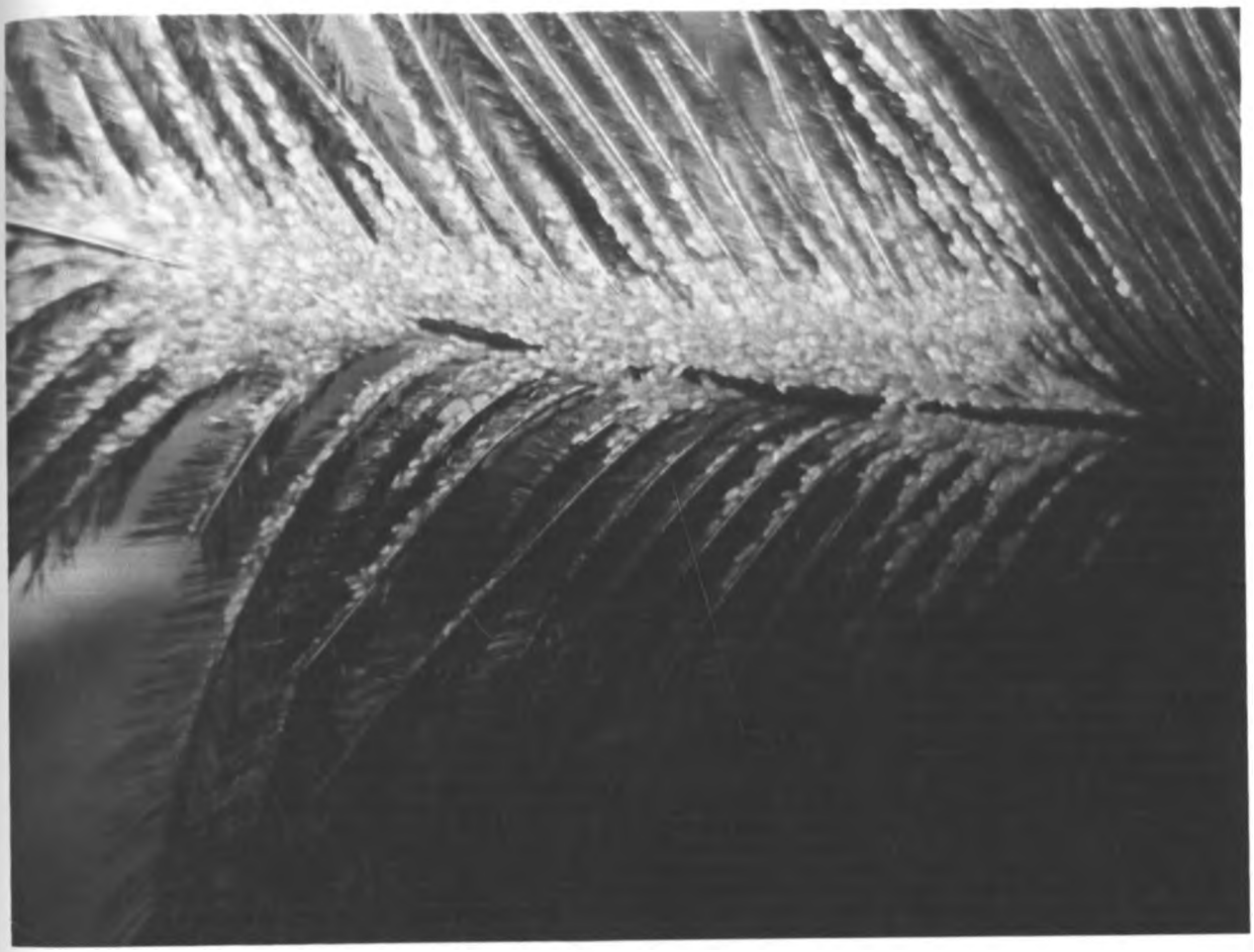


Figure 16: Ostrich feather with high mite (*Struthiopterolichus bicaudatus*) infestation appearing as concentrated dust-like particles or debris along the feather rachis.

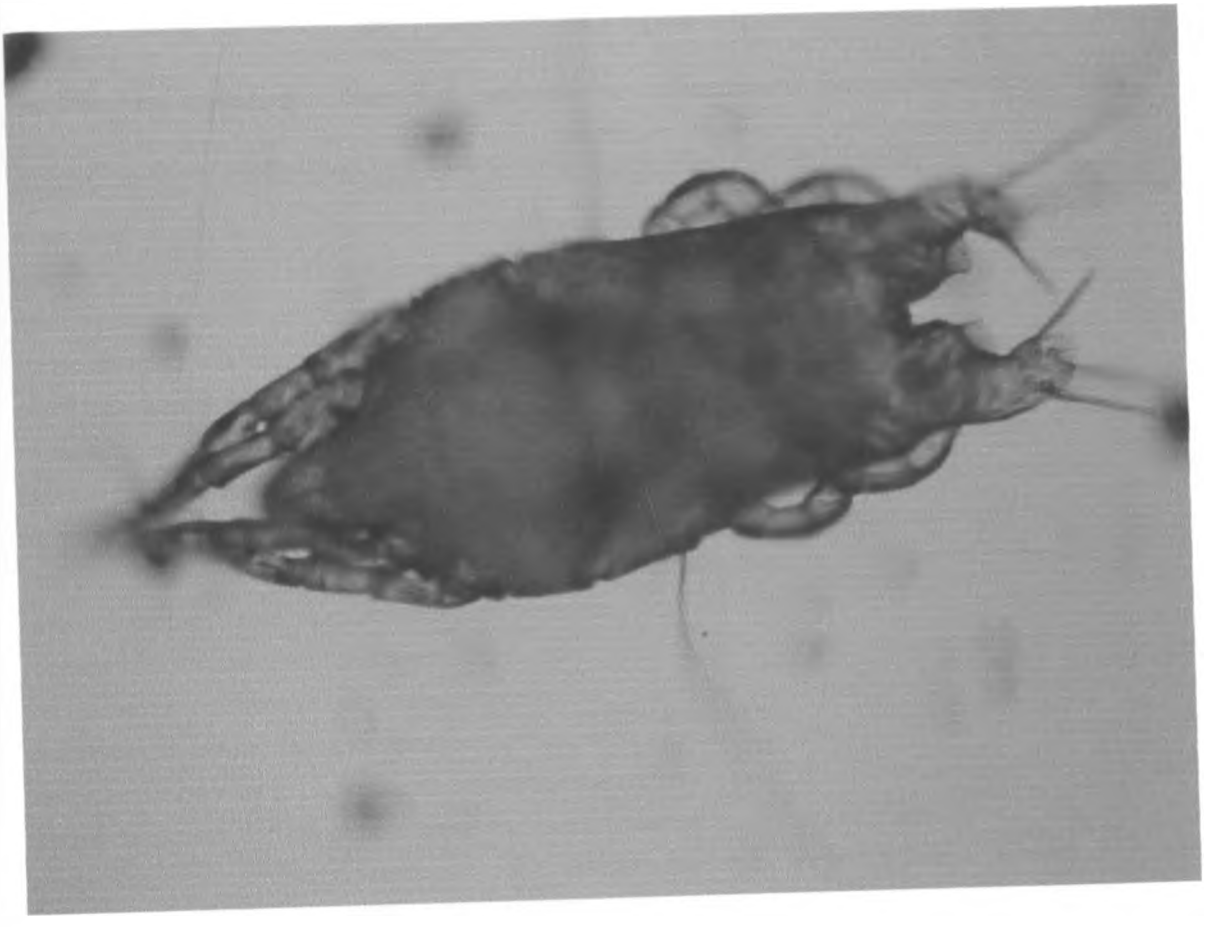


Figure 17: *Struthiopterolichus bicaudatus* (feather mite) recovered from an ostrich feather (X 400).

4.6.2. GASTRO-INTESTINAL ENDOPARASITES

The cestodes collected from the 25 gastrointestinal tracts of the slaughtered birds were white in color, segmented and some were as long as 105cm (extended length) and the thickest was as wide as 1.2cm. The bases of the scolices were covered with small hooks describing the ostrich tapeworm, *Houttuynia struthionis* (Figure 18 and 19).

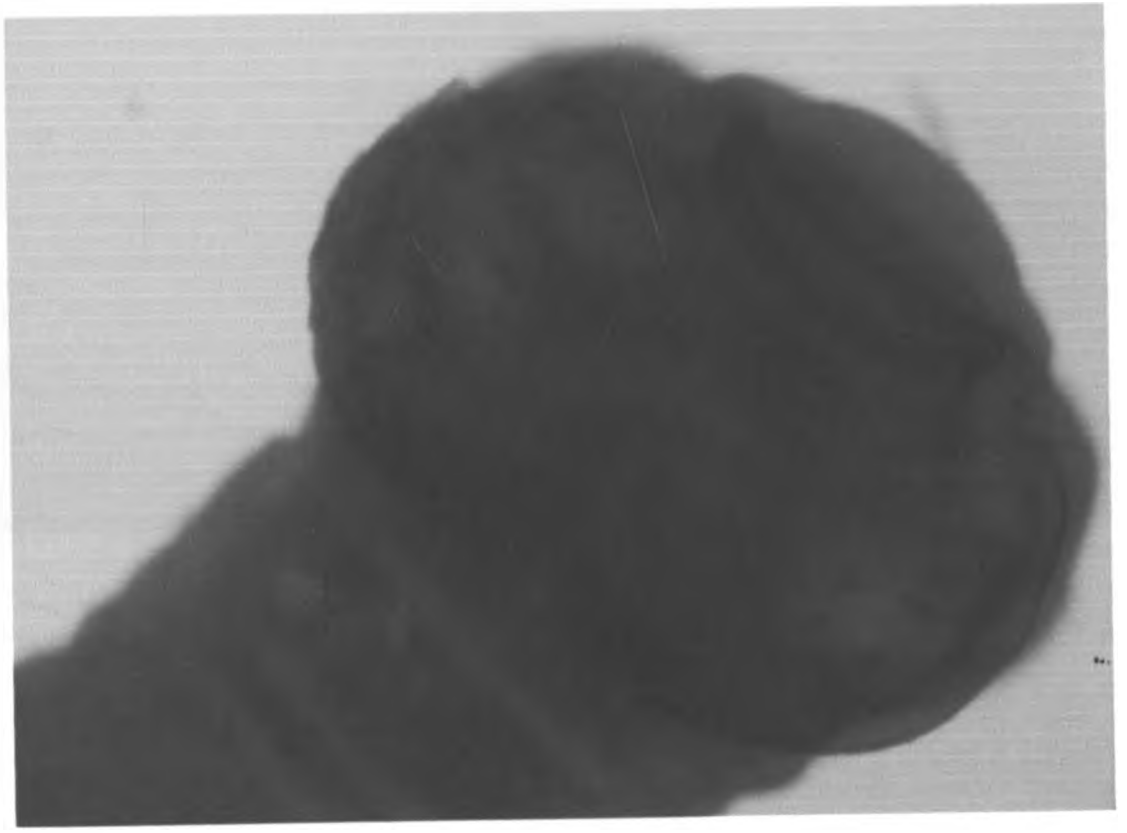


Figure 18: Stained scolex of ostrich tapeworm (*Houttuynia struthionis)* (X100).

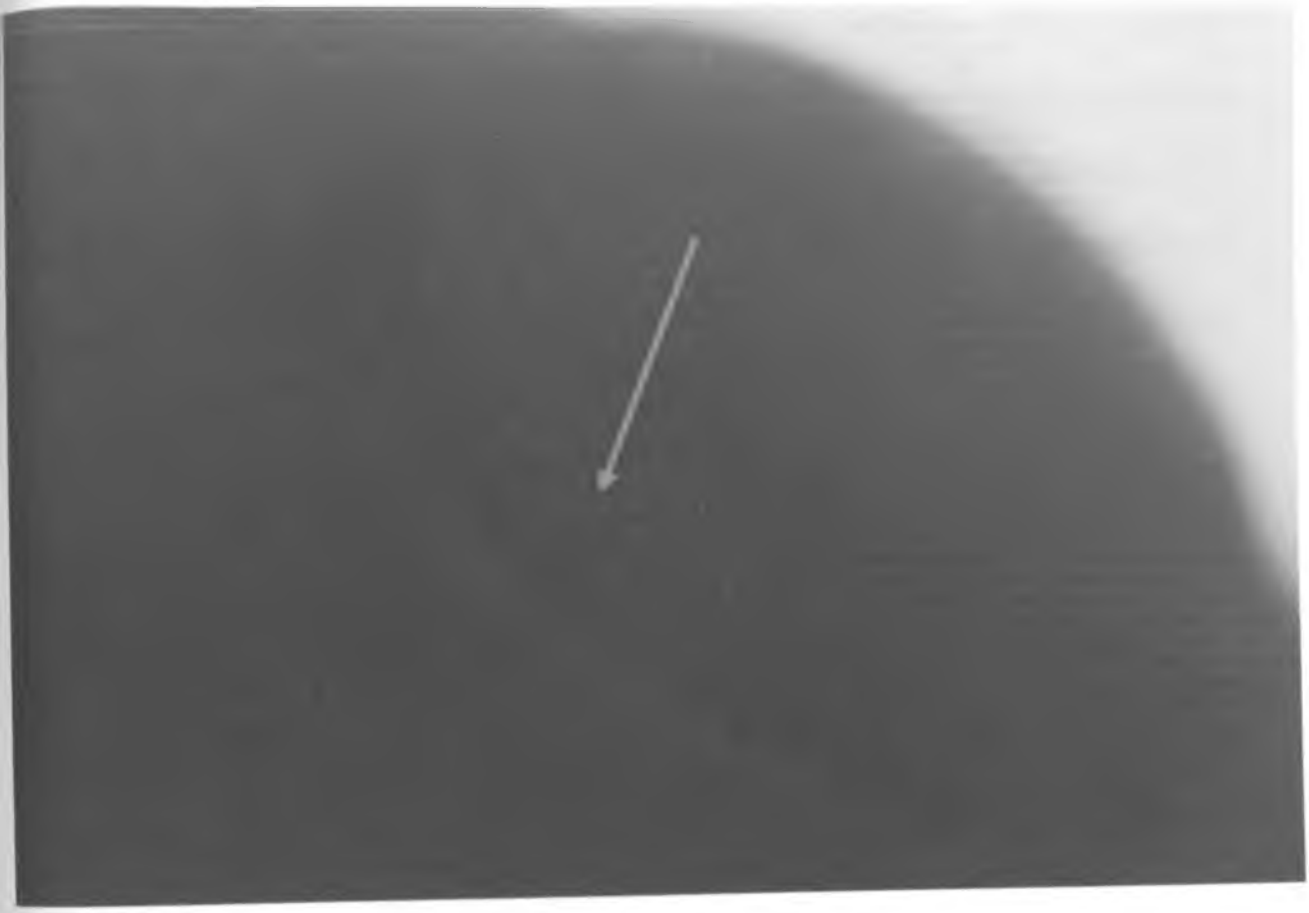


Figure 19: Section of a stained scolex of ostrich tapeworm *(Houttuynia struthionis)* showing the double row of hooks (arrow) (X400).

4.7. FARM MANAGEMENT PRACTICES

Maasai ostrich farm had 1700 birds which included 205 breeders (80 males and 125 females). The breeders were raised under semi-intensive system on a 200 acre farm thus allowing the ostriches to be kept under the most natural environment conditions and feed sources as much as possible. However, chicks up to the growers' age (8 – 9 months) were raised on an intensive system. Sufficient locally manufactured feed (whose details are guarded by the farm management) and cleaned drinking water was provided daily in containers in each pen and paddock.

Breeding females were changed from a maintenance diet to a breeder diet as from April or May (at least four months before the breeding season). Initially they were given 1.5 kg of breeder meal and that was increased after a few weeks to 2.5 to 3.0kg per bird. Chopped fresh green lucerne was mixed with the breeder's diet to increase palatability. The chicks were fed adlib high quality starter mash that was mixed with finely chopped lucerne leaves. Fresh water was supplied twice a day and containers scrubbed each day. Vitamins (commercially available) were added in the diet each day at the rate of 5 grams per bird.

The diseases that had previously been encountered in the farm were mainly bacterial infections. The species that had been isolated following various infections included: *Escherichia coli, Klebsiella pneumonia*, *Salmonella species*, *Streptococcus species* and

Staphylococcus aureus. The farm did not have a laid out parasite control regime but they occasionally treated the birds against endoparasites and ectoparasites.

Eggs for artificial incubation were collected using gloves and wiped with a disinfectant. The eggs were also wiped with a cloth soaked in potassium permanganate solution and fumigated with a reaction of 20 grams potassium permanganate in 20ml formalin prior to storage. Eggs were usually stored for 10 days at 15°C by placing them on a shelf of plastic foam in a dark cold room that was maintained at 55% relative humidity. Prior to being placed in the incubator the eggs were pre-warmed to incubation temperature. In the incubator, the eggs were turned slowly and gently through 90° once an hour.

An electrically controlled automatic incubator was used in the farm and the incubation temperature was set at 36°C and 30% relative humidity. Sanitation within the incubation facility was optimum and only the farm personnel were allowed in after disinfecting their feet in a footbath at the entrance.

The eggs were placed on racks in the hatching room on day 42, and when the shell was pipped they were placed on foam mats on the floor. Chicks were not assisted from the egg after breaking through the shell; however the shell was often broken to enable fresh air to penetrate the air sac of a hatching chick. If an egg had taken two days to hatch, the chick may have been helped out and the umbilical cord tied to prevent haemorrhage. After hatching, each chick was labelled with a cardboard strip stapled around the neck to identify its breeding pen and its navel disinfected with iodine.

Brooding took place in cement floored timber sheds. Newly hatched chicks were placed in heated brooders which were lit by incandescent bulbs and were fed vitamins mixed in water only for two days. Rubber and foam mats were used on all cement floors to prevent feet from slipping and any splayed legs were taped together. All mats and floors were cleaned and dried each day. After two days, if the weather was dull and wet, mash feed was placed on the mats and water made available in trays during the night. On sunny days feed and water were placed in the outside yard, and the birds allowed plenty of running space.

At about one month old the birds were moved from the brooders to the pens that were less enclosed, but like the brooders had roofed shelter and bigger roaming space. The birds were moved according to their ages and numbers (split into several groups if too many for one pen) from pen to pen until when they became growers that were either slaughtered or moved to paddocks where they were then selected as replacement breeders. The brooder which was fenced with chain link had only one entrance which had a footbath with disinfectant and was located about 500 metres from the other pens. The pens were aligned in series and the younger chicks were placed furthest from the older birds paddocks and the group of birds regularly (monthly) kept being moved according to their ages from pen to pen until they were growers, whose paddock was nearest the breeder's.

5.0 DISCUSSION

In this study the average percentage egg weight loss was 10.2% in an incubator where hygiene was strictly observed. This is below the quoted 13 – 15% weight loss of initial egg mass described by Shanawany and Dingle (1999) and Hassan, Siam, Mady and Cartwright, (2004) for artificial incubation. Several factors affect the relationship between egg weight loss and hatchability namely temperature, relative humidity, albumin quality, egg weight, shell porosity, and breed (Hassan, Siam, Mady and Cartwright, 2005). Low hatchability may be attributed to the eggs not losing sufficient weight/water during incubation (Gonzalez *et al.* 1999; Hassan *et al.* 2005). In this study the incubator was automated and constantly maintained at 36°C and 30% relative humidity, respectively.

Though this study did not determine the egg shell thickness and porosity, these have been shown to greatly influence egg shell conductance of water vapour which serves as an estimate of the functional ability of an egg shell to resist water vapour passage (which predicts egg weight loss in the form of water during incubation) and to permit embryonic respiration (Gonzalez *et al.* 1999). Deeming (1995) and Gonzalez *et al.* (1999) found that decreased egg weight loss or reduced enhancement of egg shell conductance was associated with increased embryonic mortality. The above authors attributed embryonic mortality to reduction of surface-to-volume ratio leading to increased egg weight, thereby interfering with gas and heat exchange. These eggs tend to overheat, retain more water and adsorb less oxygen (Hassan *et al.*, 2005). Deeming, (1993) found that low egg weight loss reduces oxygen uptake and calcium metabolism and causes edema in chicks.

The low egg weight loss recorded in this study (10.2%) was probably due to reduced egg shell conductance leading to high chick mortality from hypoxia hence low hatchability rate. The low egg weight loss may have been associated with excess relative humidity, causing reduction in loss of moisture from the egg leading to development of anarsarca in chicks.

This hypothesis is supported by Nahm (2001), who demonstrated that hatchability was high when egg weight loss was between 10 and 20% but was low in eggs with lower (mortality from hypoxia) or higher (mortality from dehydration) water losses. He also reported that hatchability was negatively affected by weight loss (presumably water loss) greater than 20% during incubation. Christensen et al. (1996) stated that the optimal incubator humidity for ostrich eggs must be less than 25% so that 15% loss of egg weight occurs during a 45 day incubation period. Deeming (1993) recommended 15% ostrich egg weight loss during incubation to maximize hatchability.

The results in this study show that yolk abnormalities were a common finding in the embryos of various ages (those with poor embryo development and dead in shell). Changes in the yolk included deviations in color and consistency from normal. The changes in consistency of the yolk may be attributed to chemical changes within the yolk possibly as a result of high temperature or excess cooling during storage as previously documented by Foggin (1992a). The causes of yolk discolorations are not known. However it was hypothesized by Ngatia *et al.,* (2004a) that some type of yolk discolorations may be caused by deficiencies of vitamins and minerals in the hens' diet.

It is possible that such yolk abnormalities may have interfered with absorption of the yolk hence the residual yolks seen in the dead chicks. Ostrich chicks use the yolk as the main source of nutrients for up to 14 days after hatching (Deeming, 1995) and therefore lack of absorption would mean that the chick was in a state of malnutrition. Yolk sac retention or failure to absorb yolk is common in recently hatched chicks and is one of the major causes of mortality in the first two weeks after hatching (Cooper 2001; Dzoma and Dorrestein, 2001; Ngatia *et al.*, 2004a). Furthermore, it is known that in chicken, any qualitative or quantitative inadequacies of the yolk may lead to a reduction in the chances of survival of the embryo (Ngatia *et al.*, 2004b).

The occurrence of oedema in embryos and chicks as observed in this study has been reported previously (Philbey *et al.*, 1991; Terzich and Vanhooser., 1993; Ngatia *et al.*, 2004; Ngatia *et al.*, 2005). While some investigators have associated oedema in embryos and newly hatched chicks to incubation inadequacies (especially high relative humidity in the incubators) (Philbey *et al.*, 1991; Terzich and Vanhooser., 1993), others have associated it with nutritional inadequacies in the hens' diet, especially deficiencies of vitamins E, B12 and biotin, manganese and selenium (Foggin, 1992a; Shanawany and Dingle, 1999). Inadequate hens' diet may lead to formation of yolks which are qualitatively and quantitatively inadequate, which would in turn result in reduction of the chances of survival of the embryo and hatched chicks (Ngatia *et al.*, 2005). Diseases of the hen such as bacterial salpingitis or metritis may also affect the egg and range from abnormal shells to no egg production at all. Affected hens generally have a history of

erratic egg production, malformed or odoriferous eggs, or a sudden stop in production (Aiello, 1998).

The flies, *Pseudolynchia canarensis* reported in this study are known to move through the feathers of the birds, sucking blood and causing painful wounds (Soulsby, 1982). When in high numbers, they irritate the birds and cause them to be restless hence interfere with their feeding and resting period. Organophosphate dusts or sprays containing coumaphos or carbaryl are reported to be effective against *pseudolynchia canariensis* (Soulsby, 1982).

The ostrich quill mite *Struthiopterolichus bicaudatus* appears to be a common inhabitat of ostrich feathers, but can also cause economic losses in farmed birds. It has been reported to cause irritation to its host, leading to excessive preening, feather loss, reduction in leather quality and predisposition to secondary infection and gastrointestinal disorders. It is usually confined to the ventral groove of the feather shaft, where it feeds on the gelatinous content of the feather, but when its populations build up to high levels, it can spread to the skin of the bird and cause the reported symptoms (Halliday, 2006). Effective control of ostrich quill mites may be achieved by use of ivermectin at a rate of 0.2mg/kg per os at four weeks intervals for three treatments (Halliday, 2006).

The results in this study indicate that 25 (62.5%) of the adult birds' gastrointestinal tracts examined post-mortem had tapeworm infection (*Houttuynia struthionis*). Cooper (2005) reported its occurrence to be common in Africa and sporadically in the USA. The worm

develops to an immature stage possibly in an insect or mite living on pasture and when an ostrich eats the intermediate host, it develops into an adult worm (Cooper, 2005). The birds slaughtered at MOF were fed in pens and therefore chances that they ate the intermediate hosts were high. The tapeworms recovered from these birds feed by absorbing nutrients through their body wall and also attach onto the intestinal lining with their hooks, therefore depriving the birds' essential nutrients leading to emaciation and destruction of their mucosal lining. The tapeworms attach to the intestinal lining with their scolices injuring the blood vessels to such an extent that haemorrhage results. This is a violent reaction on the intestinal lining based on the fact that the scolex of *Houttuynia struthionis* has a double row of hooks. More scolices attaching means more severe inflammation. High infection of ostrich chicks is detrimental and lead to loss of body condition, and anaemia (Cooper, 2005). Severe infestation also causes intestinal obstruction leading to malnutrition and decreasing the survival ability of birds.

In the present study, the eggs of *Houttuynia struthionis* were not detected in the faecal samples. This may be because the test used (Modified McMaster technique) was not sensitive enough or the adult worms had a low fecundity level. It is suggested that the egg counts are not correlated with the actual worm burden.

Treatment of the birds with fenbendazole at a dosage rate of 15mg per kilogram body mass orally is effective against *Houttuynia struthionis* (Fockema *et al.* 1985; Aiello, 1998). For prophylaxis and treatment Cooper (2005) recommends either of the following

oral treatments every 6 weeks: niclosamide at 100 mg per kilogram, fenbendazole at 25 mg per kilogram, oxfendazole at 5 mg per kilogram or resorantel at 130 mg per kilogram.

The birds at MOF are fed on locally formulated rations. Breeding females are changed from a maintenance diet to a breeder diet. Legumes are added to the breeder's diet to increase palatability. The chicks ration is mixed with finely chopped lucerne leaves. Though this study did not identify the nutritional value and quality of the feed, it is imperative that breeder nutrition is a key element of good fertility and hatchability. Egg laying hens require higher concentration of total calcium for the formation of the shell and shell membranes of the egg. Adequate amounts of macronutrients and micronutrients especially vitamins E, B12 and biotin, manganese and selenium should be provided in the diet (Shanawany and Dingle, 1999).

6.0 CONCLUSIONS

The optimum egg weight loss for ostriches during incubation is still unknown. The egg weight loss recorded from MOF (10.2%) was low compared to that documented by Hassan *et al.*, (2004), Shanawany and Dingle (1999), Christensen et al., (1996) and Deeming (1993). However, it is thought that a weight loss between 13 – 20% increases hatchability. It is reported that temperature and relative humidity during incubation (36 to 36.5°C and 20 to 30% respectively) should be maintained within narrowly defined limits so as to maximize production.

However, it has been documented that several factors affect the relationship between egg weight loss and hatchability and these include: temperature, relative humidity, albumin quality, egg weight, egg shell porosity, shell thickness and breed. Optimal levels of interaction between these factors that will increase the egg weight loss and hence improved hatchability rates need to be investigated.

Abnormalities in colour of the yolk were a common finding in embryos and chicks observed at post-mortem. This may be attributed to inadequacies in the hen's diet. Breeder nutrition is a key element of good fertility and hatchability. Egg laying hens require twice the concentration of total calcium for the formation of the shell and shell membranes of the egg. Adequate amounts of macronutrients and micronutrients especially vitamins E, B12 and biotin, manganese and selenium should be provided in the diet.

Infection by *Houttuynia struthionis* was only observed in the slaughtered birds. However, there was a probability that the intermediate hosts moved from pen to pen leading to spread of the infection. Therefore, the parasitic infection was probably more widespread than was reported in this study. This implies that the birds were being deprived of essential nutrients and the effects will most likely be passed on to the egg quality, embryos and chicks.

7.0 RECOMMENDATIONS

- Trained personnel and routine recordings of egg weights during incubation may be helpful in keeping track of egg weight loss at the farm. It will also be useful for the farm if a controlled research was done to determine the levels at which these parameters should be maintained to increase the egg weight loss hence improve hatchability.

- Routine treatment of the birds to prevent effects of both endoparasites and ectoparasites. Such a regime will help control cestodes that will deprive the birds off essential nutrients. Effective control of P*seudolynchia canariensis* and the ostrich quill mites is also important.

- Good nutrition is required as it ensures good quality egg production and improved hatchability, an increase in healthy embryos, survival ability of hatched chicks, earlier breeding, higher fertility rates, better shell quality and porosity and higher egg yolk nutrient reserves.

- Additional research is necessary to determine the factors contributing to embryonic death at each stage of development and post hatching. Little is also known about the interaction of factors intrinsic to the ostrich egg and those of artificial incubation. It is also important to identify contributing factors from the parents and rest of the flock.

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9.0. APPENDIX: OSTRICH EGG WEIGHT RECORDS OF MAASAI OSTRICH FARM

	CODE	BF FUM	BF INC	DAY 14	DAY 28	DAY 35	DAY 38/9	DAY 42	EWT L	EWT L(%)
22/9/05	C31/44/1055	1520.36	1513.19	1442.53	0	0	0	0	**77.83**	**5.1**
22/9/05	C39/25/1062	1635.64	1626.63	1544.23	1463.52	1420.27	1377.12	1370.7	**264.94**	**16.2**
23/9/05	C11/24/1063	1765.76	1755.68	1655.09	0	0	0	0	**110.67**	**6.3**
23/9/05	C26/39/1068	2000.74	1991.93	1905.01	1819.17	1772.98	1726.19	1718.04	**282.7**	**14.1**
23/9/05	C33/15/1074	1465.69	1458.93	1393.68	0	0	0	0	**72.01**	**4.9**
24/9/05	C31/49/1082	1658.1	1651.14	1583.08	0	0	0	0	**75.02**	**4.5**
25/9/05	C8/29/1087	1553.46	1548.13	1481.98	1417.56	1381.12	1344.55	0	**208.91**	**13.4**
25/9/05	C14/16/1092	1330.53	1324.07	1256.18	0	0	0	0	**74.35**	**5.6**
25/9/05	C29/52/1094	1731.88	1723.43	1631.02	1540.1	1491.91	1443.84	0	**288.04**	**16.6**
26/9/05	3C/31/1105	1762.11	1755.04	1660.33	0	0	0	0	**101.78**	**5.8**
26/9/05	C20/74/1116	1832.95	1827.21	1750.2	1674.52	1634.81	1594.16	1587.83	**245.12**	**13.4**
27/9/05	C13/34/1139	1533.07	1527.68	1451.93	1377.69	1338.63	1299.97	1293.29	**239.78**	**15.6**
27/9/05	C26/39/1145	1999.02	1993.46	1908.23	1824.92	1780.75	1736.41	1728.51	**270.51**	**13.5**
28/9/05	C17/09/1161	1911.4	1907.51	1833.43	1759.81	1722.61	0	0	**188.79**	**9.9**
29/9/05	C26/41/1184	1977.08	1973.31	1895.46	1818.59	1778.23	1737.97	1730.96	**266.12**	**13.5**
29/9/05	2B/17/1174	1263.68	1260.77	1196.4	0	0	0	0	**67.28**	**5.3**
30/9/05	3C/35/1194	1778.21	1775.23	1683.82	0	0	0	0	**94.39**	**5.3**
30/9/05	C17/11/1203	1890.96	1888.1	1810.2	1733.7	1695.03	0	0	**195.93**	**10.4**
1/10/2005	2B/18/1215	1184.05	1183.06	1124.88	0	0	0	0	**59.17**	**5**
1/10/2005	C11/30/1217	1578.99	1577.17	1470.85	1366.73	1310.61	1255.04	1245.72	**333.27**	**21.1**
1/10/2005	C34/02/1254	1691.33	1690.4	0	0	0	0	0	**0.93**	**0.05**
1/10/2005	C3A/26/2215	1702.64	1692.13	1597.89	1499.8	1475.35	1448.58	0	**254.06**	**14.9**
1/10/2005	C26/85/2221	1951.14	1938.18	1822.19	1701.12	1672.7	0	0	**278.44**	**14.3**
1/10/2005	C29/97/2222	1682.24	1671.2	1579.55	0	0	0	0	**102.69**	**6.1**
1/10/2005	C9/50/2227	1292.16	1280.8	1180.69	1081.14	1058.08	0	0	**234.08**	**18.1**
1/10/2005	*C25/53/2230*	*1515.52*	*1507.01*	*1423.31*	*1336*	*1315.42*	*0*	*0*	**200.1**	**13.2**
1/10/2005	C13/78/2240	1618.1	1605.37	1455.52	0	0	0	0	**162.58**	**10**
1/10/2005	C17/43/2243	1779.8	1771.34	1688.72	1604.78	1583.05	1559.27	0	**220.53**	**12.4**
1/10/2005	C31/141/2250	1597.1	1587.7	1485.17	0	0	0	0	**111.93**	**7**

1/10/2005	C34/44/2254	1648.85	1640.69	1559.03	1477.08
1/10/2005	C35/10/2256	1380.05	1379.73	1305.91	0
1/10/2005	C12/66/2264	1668.84	1661.27	1570.11	0
1/10/2005	C16/41/2265	1638.13	1630.8	1555.16	0
1/10/2005	C31/142/2267	1682.86	1654.58	1542.51	0
1/10/2005	C24/47/2275	1828.4	1820.77	1702.08	1579.81
1/10/2005	C15/61/2272	1540.72	1532.94	1430.17	1323.8
1/10/2005	C26/90/2297	1932.37	1926.9	1821.69	1714.47
1/10/2005	C17/45/2284	1970.27	1965.45	1874.31	1782.06
1/10/2005	C10/56/2320	1632.54	1628.51	1539.73	0
1/10/2005	C25/62/2322	1528.73	1525.14	1427.3	1325.56
1/10/2005	C37/41/2336	1563.56	1561	1461.01	0
1/10/2005	C34/48/2318	1504.58	1500.7	1409.95	0
1/10/2005	3C/63/2306	1783.81	1778.9	1639.13	0

KEY:

EWL: Egg weight loss

EWL %: Percentage egg weight loss

SUMMARY TABLE FOR EGG WEIGHTS

	BF FUM	BF INC.	DAY 14	DAY 28	DAY 35
EWT SUM	71507.42	71212.18	65749.66	34221.93	33485.66
AV. EWT	1662.963	1656.097	1565.468	1555.542	1522.075
n	43	43	42	22	22

1457.26	1435.25	0	**213.6**	**12.95**
0	0	0	**74.14**	**5.4**
0	0	0	**98.73**	**5.9**
0	0	0	**82.97**	**5.1**
0	0	0	**140.35**	**8.3**
1550.9	1519.9	0	**308.5**	**16.9**
1298.75	0	0	**241.97**	**15.7**
1687.25	1658	0	**274.37**	**14.2**
1760.32	0	0	**209.95**	**10.7**
0	0	0	**92.81**	**5.7**
1299.63	1271.42	0	**257.31**	**16.8**
0	0	0	**102.55**	**6.6**
0	0	0	**94.63**	**6.3**
0	0	0	**144.68**	**8.1**

DAY 38/9	DAY 42
19643.25	10675.05
1309.55	1525.007
15	7