PRACTICAL ASPECTS AND CONSTRAINTS IN THE COMMERCIAL PRODUCTION OF OSTRICHES (*Struthio camelus*) AND EMUS (*Dromaius novaehollandiae*) IN SAUDI ARABIA

BY

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DEDICATION

THIS THESIS IS DEDICATED, PRIMARILY, TO MY BELOVED FAMILY FOR SUPPORT AND SACRIFICE AND, SECONDLY, TO ALL WHO CONTRIBUTED, IN ONE WAY OR ANOTHER, IN ITS PRODUCTION.

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ABSTRACT

This study was conducted to record, analyze and discuss the day-to-day practical aspects and constraints affecting the commercial production of ostriches *(Struthio camelus*) and emus (*Dromaius novaehollandiae*) in two ratite farms, A and B, in Al-Qassim area, Central Region of Saudi Arabia.

In Farm A, where the original ostrich breeders were imported from France the new breeders (breeders produced in the Farm) started egg laying at the age of 19 months while the new emu breeders in the same Farm started egg laying at 22 months old. Ostriches in the two farms laid most of their eggs (73.5% and 64.9%) during day time (before sunset) while emus laid most of their eggs (98.1%) during night. Both original breeders of ostriches and emus were found to be more persistent in egg laying (85.9% and 72.6%) than their descendant breeders. About 11% of the ostrich eggs laid in Farm A throughout three seasons were found to be defective whereas 6.7% of the eggs laid in Farm B were defective. In emus, however, the average of the defective eggs throughout four production seasons was found to be 8.9%.

The fertility of ostrich eggs in Farm A was found to be improving successively from season to another (32.4%, 55.6%, 60.7% and 61.2%) as well as with the progress of the single season before it drops at the end of the season (36.5%, 45.2%, 65%, 67% and 47%). Heat stress was found to reduce the fertility rate of ostriches. Emus were found to have higher overall mean fertility rates (70.3%) than ostriches in both Farms (52.5% and 58.4%). The overall mean hatchability rate of ostrich eggs (72.8%) was found to be higher than the overall mean fertility rate of ostrich eggs (52.5%) in four seasons. However, the overall mean hatchability rate of emu eggs (62.9%) was found to be lower than the overall mean fertility rate of emu eggs (70.3%) in three seasons.

Developing ostrich and emu embryos had higher late embryonic mortality (60% and 66.4%) compared to early embryonic mortality (40% and 33.6% respectively). Emu chicks had higher (19.4%) incidence of congenital deformities than ostrich chicks (4.1%). The total weekly body weight gain of ostrich chicks in Farm B at the end of the first 14 weeks of life was higher (18350 g) compared to that in Farm A ostrich chicks (2600 g). The mean weekly body weight gain per ostrich chick that was hatched during summer was found to be higher (657.5 g; $p<0.05$) than the mean weekly body weight gain in chicks that were hatched during winter (356.75 g).

The mortality rate of ostrich chicks during rearing phase (first 3 months of life) was 29% with non-consistent pattern throughout the season. The overall emu chick mortality rate during rearing phase (21.6%) was lower than that in ostrich chicks (29%), similarly, without specific pattern or behaviour.

The main causes of mortality in ostrich chicks in Farm A were leg deformities, fading chick syndrome (F C S), Newcastle disease (N C D) and enteritis whereas the main causes of mortality in Farm A ostrich growers were sand impaction, Newcastle disease, leg deformities and enteritis. In Farm A ostrich breeders, the main causes of mortality were septicaemic pasteurellosis, wound infections, accidents, particularly those terminated into broken necks, and peritonitis.

Causes of mortality in Farm B ostrich chicks included fading chick syndrome, leg deformities, enteritis and sand impaction. In Farm B growers, the main causes of mortality were leg deformities and septicaemic pasteurellosis whereas for Farm B breeders septicaemic pasteurellosis, accidents and fractures comprised the main causes of lethality. Leg deformities were the most common cause of mortality in Farm A emu chicks throughout the four seasons of study. There were no mortalities attributed to sand impaction or Newcastle disease in the emu chicks although these chicks were sharing the same premises with the ostrich chicks that suffered a severe NCD outbreak in Farm A in the year 2000. In emu growers, the main causes of mortality were leg deformities, suffocation and infected fighting wounds.

Escherichia coli was isolated from 35.5% of the samples cultured from dead ostrich chicks in Farm A whereas *Salmonella* sp. organisms were isolated from 12.9% of the cultured samples. However, 22.6% of the cultured samples did not reveal any bacterial growth. For the emus, *Escherichia coli* was isolated from 33.3% while

Salmonella species were isolated from 16.7% of the specimens (liver, yolk fluid and intestinal content) cultured from dead emu chicks.

Among the different forms of leg deformities terminating lethally, tibiotarsal rotation (84%) comprised the most common one in ostrich chicks followed by splayed legs (11.9%). In ostrich growers in Farm A, again tibiotarsal rotation was found to be the most common killing form of leg deformities (78.5%) followed by slipped tendon (14%). In emu chicks, tibiotarsal rotation (98.8%) was the most common killing form of leg deformities followed by splayed legs (1.2%) whereas in emu growers, tibiotarsal rotation (99.4%) was the most common killing form of leg deformity followed by valgus rotation (0.6%).

Introduction

The ratite family includes flightless birds with a flat breastbone. Ostriches (*Struhtio camelus*), emus (*Dromaius novaehollandiae*) and rheas (*Rhea americana*) are the ratites most commonly raised as livestock increasingly in many countries in the world. The commercial breeding of ratites has emerged as a viable and widely acceptable enterprise in the recent decades. Ratites produce red meat that is similar to beef or venison. Hides and leathers, particularly of ostriches, make fine leather products. Other significant ratite products include oils and fat as well as feathers. In many countries around the world an increasing number of citizens are realizing the value of ratite products and a growing market has been identified in Europe, America and the Middle-East. Both Sudan and Saudi Arabia are witnessing significant growth in the number of investors allocating money and efforts towards the establishment of ratite farms.

Many producers express their concerns around not well-known practical aspects of ratites management particularly feeding, breeding, hatching and rearing of chicks. Also, the diseases of ratites are known to be poorly understood.

However, the objectives of this thesis were to study the following:

1-Practical day-to-day management practices in artificial rearing of ostriches and emus from egg to maturity.

2-Disease and health problems in intensively kept ostriches and emus.

3-Factors affecting rearing and growth of young chicks.

4-Productivity and patterns of egg laying in new and original ostrich and emu breeders.
5-Factors affecting incubation, fertility and hatchability of ostrich and emu eggs.

6-Incidence and causes of ostrich and emu egg defects.
7-Incidence and types of congenital abnormalities in newly hatched chicks.
8-Incidence and causes of mortality in ostriches and emus in captivity.
9-Experimentation of natural incubation of ostrich eggs under Saudi conditions.
10-Performance of emus fed on low-cost feed alternatives.

CHAPTER I

LITERATURE REVIEW

1.1 Historical background

As long ago as 20 or even 60 million years, ostriches were found around the Mediterranean Sea in the West, China in the east and Mongolia in the north. It was only about a million years ago that they migrated south across Africa, together with many of the larger mammals. Detailed pictures of ostriches have been found in ancient Egyptian tombs. Arabs hunted the bird for sport and as a source of meat and income. Queen Elizabeth I of England and Marie Antoinette of France were the first to establish the use of ostrich feathers and plumes as articles of fashion in the western world (Holtzhausen and Kotze, 1990).

Modern ostrich farming began in South Africa as early as the middle of the nineteenth century following the domestication of the ostrich birds. The first incubator for ostrich eggs was assembled in 1869 leading to a giant step-forward in the ostrich farming industry.

Between the first and second world wars ostrich feather markets collapsed totally till the sixties when the industry expanded again and other new ostrich products such as meat, leather, skins and eggs were developed and got demand. Ostrich farming industry spread from South Africa to other countries and continents such as France, the United States, Canada, Australia, New Zealand, the United Kingdom and the

Middle-East as one of the younger and profitable agricultural industries (Huchzermeyer, 1998).

1.2 The ratites

Ratites are flightless running birds which lack a keel on the sternum and flight muscles on the breast. Their feathers also lack the typical inter-linked structure of the feathers of flying birds (Deeming and Angel, 1996). The main exploited species of ratites are the ostrich, the emu and the rhea.

1.3 Classification of ostriches

The ostrich is the largest living bird. In the wild, ostriches are restricted to southern and eastern Africa and are the only ratite species of which natural distribution extends north of the equator (Deeming, 1999).

The classification of ostriches is as follows:

Order :*Struthioniformes*.

Suborder :*Struthiones.*

Family :*Struthionidae*

Species : *Struthio camelus.*

There are six extant subspecies or races of ostriches and their nomenclature depends, mostly, on their geographical origin (Bertram, 1992). They differ from one another slightly in size, in skin colour of the bare thighs, head and neck and in the size and texture of their eggs. These subspecies are:

1-*Struthio camelus syriacus* (The Arabian ostrich): This Red Neck subspecies was formerly found in the Syrian Desert and north Arabia but was hunted to extinction by 1941 (Cramp *et al*., 1977). However, Cramp (1986) reported that the last recorded seeing of an Arabian ostrich was that of a dying bird reported following floods in south-east Jordan in February, 1966.

2-*Struthio camelus camelus.* This Red Neck is the North African subspecies. It was heavily persecuted during the 20th century and is considered to be threatened (Cramp *et al*., 1977; Brown *et al.*, 1982).

3-*Struthio camelus molybdophanes*. This Blue Neck is the most distinct race, although under artificial conditions it has produced fertile hybrids when cross-bred with *S. c. massaicus* (Brown *et al*., 1982). It is considered as the tallest ostrich living in the wild.

4-*Struthio camelus massaicus.* This was the wild bird inhabiting the eastern parts of Africa. It is the origin of the Red Neck ostriches which are used extensively for meat production at the present time.

5-*Struthio camelus australis.* This Blue Neck is possibly the heaviest and its adult males may weigh up to 150 kg. Its original range is South Africa.

6-*Struthio camelus spatzi.* It is confined to the northwest Africa. It is now merged with the North African ostrich and some researchers now do not recognize it as a distinct subspecies.

The hybrid of farmed ostriches in South Africa was described as *Struthio camelus* var *domesticus* (Swart, 1988) and it is commercially known as the black neck. The blue neck ostrich was derived from wild populations of *S. c. australis* although some birds may be derived from populations of *S. c. molybdophanes* (Deeming, 1999).

Ostriches have sometimes been split into two subspecies on the basis whether the crown is bold or feathered and on the colour of the neck. These two subspecies are:

1) The red necked ostriches which include the subspecies *S. c. camelus* and *S. c. massaicus* and,

2nd) The blue-necked ostriches which include *S. c. molybdophanes* and *S. c. australis.*

1.4 Classification of other ratites

1.4.1 The emu

The emu (*Dromaius novaehollandiae*) is an Australian ratite species. Beside the classical products of the ratites it produces an oil with alleged remarkable pharmacological properties. Emu farms are not widely spread as the case with ostrich, being confined to a few countries particularly Australia and France (Deeming, 1999).

1.4.2 The rhea

There are two rhea species, the greater rhea, *Rhea americana* and Darwin's rhea, *Pterocnemia pennata.* Both species are only found in South America.

1.4.3 The cassowaries

Cassowaries live in Australia and New Guinea. They are aggressive and difficult to domesticate and keep in captivity. There are three species of cassowaries:

1-Casuarius benetti.

2-Casuarius casuarius.

3-Casuarius unappendiculatus.

1.4.4 The kiwis

These are the smallest, chicken-sized ratites. They are confined to New Zealand. They have three species:

1-*Apteryx australis* or the brown kiwi.

2-*Apteryx haastii* or the great spotted kiwi.

3-*Apteryx owenii* or the little spotted kiwi.

1.5 Ostrich farming systems

There are basically three types of farming systems for ostrich production:

1-Extensive farming system: This system requires a large area of land as the major capital requirement. The birds are kept and raised as near as possible to their natural habitat, with minimum interference. The main advantage of this system is the reduced cost of production. On the other hand, the disadvantages which can easily outweigh the advantages include the difficulty of monitoring and identification of birds and eggs, difficulty of control over breeding conditions and high mortality particularly among chicks because of high degree of predation involved in this system.

2-Semi-intensive farming system: The birds in this system are kept in relatively smaller paddocks or territories than the extensive system, thus obtaining some of their nutritional requirements from the pasture. The advantages of this system include the relative ease of identifying good producing birds and collecting and transporting the eggs besides the savings in feed and fencing costs. However, the physical capture and handling of the birds remains a problem as is the extreme difficulty in maintaining any accurate breeding records.

3-Intensive farming system: The area required in this system is very small divided into small paddocks. The disadvantages of this system include the high feeding and fencing costs, thus a high capital investment is needed. The advantages, on the other hand, are numerous including the full control over breeding through keeping accurate and precise records of the number of eggs produced by each hen and their fertility and hatchability, thus selective breeding of quality birds can be performed. In this system, also, there are accurate feed consumption records and feeding control measures can easily be applied (Jarvis *et al.*, 1985).

1.6 Ostrich farm design and facilities

There are basically four types of facilities needed in intensive ostrich farms. These are breeding paddocks, a hatchery, brooding or rearing facilities and growing facilities. Before establishing and constructing an ostrich farm, the following points should be considered:

1-Farm location: The farm should be away from traffic and industrial areas to avoid disturbance caused by heavy traffic, airports, trains and factories.

2-The land topography: It should be flat and devoid of hilly, mountainous, sloping, rocky or steep ground. Sand soil is best for water drainage. The ground should be cleared of nails, screws, wires and holes.

3-Positioning of buildings: The buildings should be at right angles to the direction of the seasonal wind for efficient natural ventilation.

4-Design facilities: Facilities should be designed to allow ample room for maneuvering vehicles and for future expansion. Interior surfaces and fences should be free from any sharp objects and barbed wires should never be used for fencing of the paddocks (Shanawany and Dingle, 1999).

1.7 Management of ostriches

1.7.1 The breeding systems and breeding behavior

Ostriches are primarily seasonal breeders. Their breeding season lasts for six to eight months each year. However, the timing and duration of breeding vary with latitude and altitude. In the northern hemisphere, breeding commences in March and ends around August/September whereas in the southern hemisphere it commences around July and finishes by the end of March (Shanawany and Dingle, 1999). The light intensity and length of daily light period are known to produce biological influences associated with egg production. These responses are initiated by the action of light on the eye retina where its effect is relayed via the optic nerve to the hypothalamus resulting in an increase in the releasing of gonadotrophic hormone-releasing factors which influence egg production (Salih *et al*., 1998; Blache *et al*., 2001). However, ostrich reproduction increases when day length starts to increase, peaks coincide with the periods of maximum length of day light and decreases when the day length starts to decrease (Deeming, 1996; van Schalkwyk and Brand, 1977; Horbanezuk, 1998). Ostriches appear to be induced breeders, with egg production in females being stimulated by the presence of the male and on separation of the males from females an abrupt cessation of egg laying was noticed (Cloete *et al.,* 1998).

1.7.2 Sexual characteristics

In the wild, the ostrich is sexually mature at four to five years of age while the domesticated ostrich is mature at two to three years of age; the female becomes mature slightly earlier than the male. The male ostrich is polygamous and can mate with more than one female. Thus, in the modern farming systems ostriches, during the breeding season, are kept in pairs (one male to one female; i.e. male to female ratio at 1:1) or in trios (one male to two females ; i.e. 1:2 ratio). In some farms, more number of birds are kept together such as two males with six females (2:6 ratio) (Shanawany and Dingle, 1999).

1.7.3 Ratite eggs

The colour of ostrich eggs varies from white to yellowish white and their surface is hard, shiny and is pitted with superficial pores of various sizes and shapes. The average weight of an ostrich egg is 1454 gram with a range between 1 - 2 kilograms. The average yearly egg production per ostrich hen was found to be 55 eggs whereas the egg production performance (EPP), which is the number of eggs laid expressed as a percentage to the number of days on which eggs are laid, was found to be 46.1%. The EPP of the breeding birds increased from an initial value of 30% at 2 years of age to a peak of 60% at 9 years followed by a slow decline to around 45 – 50% at 17 years of age. The environmental stresses such as sudden rain or sudden heat spells can reduce egg laying temporarily (Anon, 1999). The laying season in ostriches varies widely according to the geography and climate of the area. Eggs are laid every other day in clutches of 20 - 24 eggs then the hen stops laying for 7 – 10 days after which it starts a new clutch again. High producing females can lay between 80-100 eggs during the breeding season. Usually the females come into season (start laying eggs) before the males, therefore, the early laid eggs are usually infertile. Egg laying usually takes place during the afternoon and a few eggs may be laid during the night. Ostrich eggs should be collected soon after laying so as to minimize the incidence of microbial contamination and other factors which reduce egg quality such as shell breakage (Shanawany and Dingle, 1999).

1.7.4 Factors affecting egg productivity

Many factors can influence the number of eggs produced and these factors include:

1-Inheritance or genetics: The genetic make-up of the hen plays a major role in egg production as the different subspecies attain sexual maturity at different ages. Genetics also influences the duration of breeding and laying persistency.

2-Age: Egg production in ostriches is also affected by the age of the breeding hen. The production is usually low in the first breeding season but it increases as the birds get older.

3-Environment: Severe weather or climatic fluctuations such as heavy rains or sudden cold spells are known to affect the level of egg production.

4-Nutrition: Marked deficiency in the ostrich feed nutrients will affect the egg production. The level of calcium in the diet must be increased before the onset of the breeding season to allow for normal egg production and proper shell formation. Obesity in the birds also results in decreased egg production.

5-Health: Diseases reduce the ability of the hen for egg production. Prolapse of the vagina or oviduct is sometimes associated with young females in their first production season.

6-Psychological factors: Stressful conditions should be avoided as they affect the bird egg production. Therefore, birds should be transferred to their breeding paddocks sometime before the onset of laying. Moving of the birds during the laying season should be avoided as it reduces egg production.

1.7.5 Incubation and hatching of ratite eggs

1.7.5.1 Natural incubation

Nests are generally prepared during the dry season while hatching occurs during the rainy season allowing for growth of vegetation as a source of food for the chicks (Brown *et al*., 1982). In nature, the major female which builds the nest contributes between 8 and 12 eggs while the minor females contribute the remaining eggs in the clutch which contains from 16 to 32 eggs (Bertram, 1992). The nest is attended and later incubated by the female during daylight hours while the males attend during night hours carrying the bulk of the incubation activity (61 – 70%). Excessive exposure to the sun and attack of aerial predators such as the Egyptian vulture (*Neophron percnopterus*) affect seriously the viability and survival of the eggs. The central temperature of naturally incubated eggs is maintained at 34° - 36°C with a nest humidity of around 42%. (Bertram and Burger, 1981). Males were found to maintain higher nest air temperature than females (Siegfried and Frost, 1974). Hatching, in natural incubation, occurs after an average incubation duration of 42 – 43 days and over 4 – 5 days (Sauer and Sauer, 1966; Bertram, 1992) with hatching success reaching a maximum of 100% for central eggs in many nests. During incubation, the incubating birds turn the eggs inside the nest periodically, pushing some to the outside and bringing others to the centre (Bertram, 1992).

1.7.5.2 Artificial incubation

1.7.5.3 Fertility of ostrich eggs

Results of fertility of ostrich eggs artificially incubated in different countries are highly variable (Deeming and Ar, 1999). Fertility ranges from poor (less than 50%) through to good (above 85%). However, these average values are considered low compared to other poultry species. In an experimental station in South Africa, fertility of ostrich eggs averaged 82.9% (Cloete *et al.,* 1998) whereas in Australia the average fertility in 38 farms was found to be 51.3% (More, 1996c). In a British farm, however, the average weekly fertility rate during 1995 season was found to be 74.8% (Deeming, 1996). Within each breeding season, fertility increases to reach a maximum around the middle of each laying cycle after which it declines gradually (Deeming and Ar, 1999). At the beginning of each breeding season, fertility is usually low but it increases as the season advances. This is probably due to the fact that females come into production earlier than the males and, secondly, due to the slow increase in production of the luteinizing hormone (LH) and delayed increase in male plasma testosterone concentration which results in low fertility of eggs collected at the beginning of the season (Murton and Westwood, 1977).

1.7.5.3.1 Factors affecting fertility of ostrich eggs (Shanawany and Dingle, 1999)

1-Male:female ratio: The ratio of one male to one female is ideal for highest fertility if compatible pairing is successful. Satisfactory fertility rates could also be achieved at ratios of 1:3 and 1:4. Higher ratios may give higher number of infertile eggs.

2-Age of breeding birds: Very young males may be unable to mate successfully and frequently. Generally the fertility for the whole season increases as the birds get older till a maximum plateau is reached and remains so for a number of years after which it gradually declines due to loss of vigour, reduced mating frequency and decline in the number of sperms produced.

3-Inheritance: Ostrich subspecies differ greatly in their inherent fertility. The males of the red-neck ostriches are more virile, aggressive and dominant and, therefore, have higher fertility rates than other subspecies such as the South African blue-neck.

4-Nutrition and Health: Gross or marginal deficiencies in either the quantity or quality of feed can adversely affect fertility. On the other hand, sick or diseased birds will have poor breeding activity, thus fertility will be reduced. Injuries to the feet, wings or head can prevent successful mating and therefore affect fertility of eggs.

1.7.5.4 Hatchability of ostrich eggs

The hatchability of incubated eggs is poor with maximum values at around 60% while hatchability of fertile eggs is generally higher but again at best around 70%. There is considerable variation in hatchability between farms and between laying seasons (Philbey *et al*., 1991). However, hatchability of ostrich eggs is reported to drop as the breeding season progresses and it was found that the hatchability is directly proportional to the number of eggs particularly at the beginning and end of the season. This could, possibly, be due to low rates of fertility or due to the unfavourable conditions in partially empty incubators (Deeming, 1996). The incidence and causes of malformations and other developmental abnormalities in the ostrich are poorly documented in the literature. However, the hatchability of extra large and small eggs are 28% and 14%, respectively, lower than average eggs besides the effect of the abnormal egg size on egg positioning within the tray in the incubator (Deeming and Ar, 1999). It was found that selection and removal of abnormal eggs, cracked or deformed, will increase the success rate of incubated eggs. Malpositioning is a common finding in dead-in-shell embryos. It was found to be 36.9% of the dead-in-shell embryos examined by Deeming, 1997. The incidence of malpositioning in ostrich eggs was attributed to the improper turning and errors in positioning the eggs in the incubator because of difficulties in identifying the blunt end of the egg (Deeming *et al.,* 1993).

Factors affecting commercial hatchability of ostrich eggs include microbial contamination, pre-incubation storage, the incubator temperature, exchange of water vapour, oxygen and carbon dioxide exchange, egg turning in the incubator and hatcher management. In South Africa, bacterial contamination was observed in 13.4% of the eggs examined and the organisms isolated were typical of soil and faecal environments (Brown *et al*., 1996). Fungal contamination was found to be higher in eggs in which the embryo had survived to the end of development. An average rate of microbial contamination of 18 - 20% was found in eggs from a variety of sources (Deeming, 1996). The properties of the shell are very important factors in determining the risk of microbial contamination. Shells with high conductance values have a higher risk of contamination and had higher average percentage mass loss values compared to uncontaminated eggs (Deeming, 1996). Sanitation programmes for ostrich eggs are based on procedures employed for poultry eggs and vary from simple brushing off of soil through to egg washing (Deeming, 1997). However, the washing disinfection procedures were noticed to depress hatchability by 6 – 10% due to increased early mortality (van Schalkwyk *et al*., 1998). Severely contaminated eggs can be washed but this procedure will reduce hatchability due to the removal of outer protective cuticle. Immersion in a disinfectant solution may facilitate penetration of bacteria through the pores of the shell. However, eggs can be dipped for 30 – 45 seconds in a freshly prepared solution of an approved phenolic or quaternary ammonium disinfectant warmed to 100° F. It is advised that eggs should not be immersed in an antibiotic solution as a routine as this practice may lead to development of drug resistant strains of pathogens (Tully and Shane, 1996a).

The storage of ostrich eggs prior to incubation is highly recommended due to the seasonal nature of egg laying in ostriches, particularly in the beginning and at the peak of the laying season to overcome incubator capacity problems (Ar, 1996). Ostrich eggs storage at temperatures of 18°C – 23°C for 10 days was found to have no negative effect on the hatchability of ostrich eggs whereas storage for up to 14 days showed little decrease in viability (Gonzalez *et al.,* 1999). However, storage for longer periods was found to cause a significant depression in hatchability (Swart, 1988). van Schalkwyk *et al*. (1998) showed that storage temperature was a key factor in determining embryonic viability. Embryonic mortality was found to be lower at a storage temperature of 17°C than at 25°C.

1.7.6 Hatchery management of ostrich eggs

Incubation of ostrich eggs at a variety of temperatures ranging from 36°C to 36.7°C has shown that incubation at 36.4°C allowed 50% of all chicks to hatch at 42 days which indicated that the duration of incubation is primarily a function of incubator temperature (Ar *et. al*., 1996). A higher starting temperature such as 37°C reduced the average incubation period by almost three days over a constant temperature of 36°C (Deeming *et al.,* 1993). The optimum incubation temperature of 36.4°C produces an incubation period of 42 days which represents a compromise between the high temperature permitted during early development and the lower temperature for egg cooling during the last third of incubation (Deeming and Ar, 1999). However, recently Hassan *et al*. (2004) found that incubating fertile ostrich eggs at 36.5ºC increased hatchability and incubation period compared to higher temperatures. It is recommended that the set point temperature should be dropped to 0.5 ºC lower than the set point of incubator when ratite eggs are transferred to the hatcher (Horbanezuk and Sales, 1998). In South Africa and Australia, improved hatchability was found with a humidity of 34% – 37% at a recommended incubator temperature of 36ºC (Horbanezuk and Sales, 1998). The rate of water loss from eggs incubated artificially was found to be lower than the loss observed in eggs in the nest which was considered as a significant problem contributing to lower hatchability in artificial incubation. Moreover, low mass loss usually results in oedemic hatchlings or dead-in-shell embryos (Ley *et al.,* 1986). Generally, it is observed that between 8% and 18% water loss hatchability was relatively high whereas for eggs of both lower and higher water loss mortality was usually close to 100% (Deeming and Ar, 1999). Therefore matching the humidity of the incubator to the shell conductance is a way to optimize weight loss of individual eggs. On the other hand, insufficient water loss was found to produce a small air cell which may bring about difficulties in the hatching process leading to late embryonic mortality due to suffocation (Ley *et al.,* 1986). However, Horbanezuk and Sales (1998) mentioned that the acceptable range of humidity during the incubation of ostrich eggs is 25% – 40%, although 40% humidity gives a loss of only 11% of the initial egg weight. Therefore, Sahan *et al*. (2003) recommended that incubator humidity should be low (25%) to allow enough mass loss from the eggs during incubation while hatcher humidity was advised to be around 80%.

Egg turning was found to have a very significant role during development and promoting normal growth of the embryo and is essential during incubation up to transfer to the hatcher. It was found that turning through 30 – 45 degrees at hourly intervals satisfies normal embryonic development. However, van Schalkwyk *et al.* (1998) showed that as the angle of hourly rotation increased, the level of both early and late embryonic mortality decreased. The orientation of the egg during incubation also appears to have an influence since eggs incubated with their long axis set horizontally for 2 – 3 weeks and then repositioned with their long axis set vertical for the rest of the incubation period yielded higher hatchability results (Smith *et al.*, 1995; van Schalkwyk *et al.*, 2000). Some researchers, however, reported the low significance of egg turning frequency in hatchability results such as Wilson and Eldred (1997) who showed that hatchability of eggs turned eight times a day was not significantly different from that of eggs turned 24 times a day.

1.7.7 Hatchery management of emu eggs

Emu eggs are generally produced during the winter at 3-day intervals and are laid after sundown. Therefore eggs should be collected as soon as possible to avoid being incubated by the male. If eggs are pre-incubated for longer than 8 hours, embryonic development will be initiated and if these pre-incubated eggs are cooled for storage the embryo will die (Shane, 1996).

Incubation temperature for emu eggs should be ranging from 36.1°C to 36.3°C and a relative humidity of 25 – 30% resulting in an incubation period of 51 days. Emu eggs should lose 15% of the original setting weight by the time of pipping and limiting the amount of evaporative water loss from the egg will result in an oedematous chick with reduced viability (Shane, 1996). Emu eggs should be positioned vertically in the incubator with the air cell uppermost and eggs should be turned through 180° at 4 – 8 hours interval during the setting phase which is 48 – 49 days in duration.

Infrared candling is used to monitor embryo development in emu eggs by observing vascularity of the chorioalantoic membrane. Emu eggs are transferred to the hatcher compartment 1 – 3 days before anticipated hatch date. The hatchers are operated at 35.5°C and a relative humidity ranging between 25 – 35%. Premature and aggressive intervention for assistance during hatching will result into high neonatal mortalities due to omphalitis, septicaemia, and devitalization caused by anoxia and oedema.

It is highly recommended that new hatchlings should be transferred within 24 hours to the brooders so as to avoid pathogens, including bacteria and fungi, from spreading within the hatcher and infecting later emerging embryos. Therefore, the navel should be treated with a suitable antiseptic and the open umbilicus should be protected with a clean dressing (Shane, 1996).

1.7.8 Rearing of ostrich chicks

Ostrich farming was originally developed in South Africa and is practiced over an extremely wide range of geographical and climatic conditions. Three phases of rearing from hatch to slaughter are described (Verwoerd *et al.,* 1999b):

1.7.8.1 Post-hatch management rearing (Brooding)

Immediately post-hatch, chicks are usually kept inside a building in groups of 20-30 birds in small areas delimited by a circle of plastic crates or hard board. The temperature of the room is controlled above 30°C maintained by suspending a heat lamp over the brooder. However, in colder climates optimal chick survival and growth will be ensured if there is correct temperature regulation with regard to the size of the bird as suggested by the schedule of Deeming *et al.*(1996). Ostrich chicks have little subcutaneous fat and appear to be particularly susceptible to cold (Jensen *et al.*, 1992). Hypothermia is a stress that predisposes chicks to diseases and other ailments and usually results in mortality (Brown and Prior, 1998). Thus, the required room temperature should be reduced from 32°C at day one to 20°C at three months old or till the ambient temperature of 21° – 23°C is reached at about four weeks of age (Shanawany and Dingle, 1999). Ventilation must be passive for efficient removal of noxious gases, mainly ammonia especially in cold climates. Concentration of ammonia higher than 20 parts per million (ppm) is reported to cause irritation in the mucous membranes of the respiratory tract, sinuses and conjunctiva. Consequently, this will result in increased incidence of respiratory and ocular diseases and, eventually, high chick mortality. Excessive noise should be prevented to maintain a stress-free environment (Deeming *et al.*, 1996). The walls can be of solid wooden or stainless material to facilitate cleaning and disinfection (Kocan and Crawford, 1994). The space requirement is 0.16 m^2 per chick (i.e. about 5 – 6 chicks per square meter) which should be extended by 10% weekly. Ostrich chicks need plenty of exercise which helps to reduce impaction of the digestive tract by increasing its motility, enhances blood circulation and promotes correct muscle and bone formation and development. Therefore, long runs attached to the chicks quarters are most suitable to enable the chicks to practice exercise. The floor can be rough concrete or galvanized steel crates on a frame and wheels to allow for taking the crates outside during pleasant weather conditions (Verwoerd *et al*., 1997). Ease of cleaning of the floor is an essential factor; therefore plastic slatted flooring, rubber mats or straw (under a wire mesh) are possible alternatives. Feed should be available from the start otherwise poor starter problems arise. The chicks remain in this area for 2 – 7 days. All-in all-out operation is indicated for the rearing of birds up to 12 weeks of age. Single groups of birds, usually hatched in one week, are kept together and mixing of different ages is prohibited (Wade, 1995). Fresh clean drinking water should be provided at least twice daily and some feed should be available at all times although the yolk sac continues to supply the chick with necessary nutrients after hatching. However, feed restriction programmes can be applied after the first week to avoid gastric impaction with feed. Continuous or near continuous light should be provided to enable the chicks to see their surroundings and where to find feed and water. Then after, a specific light programme can be implemented depending on the purpose of production (Shanawany and Dingle, 1999).

1.7.8.2 Artificial or foster rearing phase

Foster rearing of young ostriches is practiced in traditional ostrich farming areas in South Africa. Foster parents are used for the rearing of young chicks which are cared for by breeder pairs or by yearling females (de Kock, 1996). In artificial rearing practice it is recommended to provide room temperature of 30°C with a gradual drop of 0.5°C daily until a stable temperature of 26°C is reached. Optimal group sizes at this phase are 30-50 chicks with stocking rate of 2-3 chicks per square meter with concrete-floored outside runs that may extend on to sand/soil or into small lucerne paddocks. The runs measure 2 - 3 X 10 - 15 meter for this age group (up to 4 - 6 months). During mild weather, chicks are grazed on short lucerne fields and care should be taken to avoid ingestion of roots or long stalks which may lead to trauma or impaction. Movable fences and enclosures are used to allow for rotational grazing. In desert or semi-desert areas where there are limited grazing opportunities sand runs are used. Under these latter circumstances preventive measures, including provision of high fibre levels or sterilized crushed bones in the ration, should be adopted to avoid displacement behaviour such as sand eating and feather pecking (Verwoerd *et al.*, 1999b). Ostriches show a propensity to sit out in rainy weather rather than seeking a shelter and could thus be adversely affected by wetting during cold weather. Therefore it is strongly recommended that ostriches, particularly juveniles, be brought into shelter during prolonged periods of rain (Deeming, 1997).

1.7.8.3 Grow-out phase

In this phase the birds spend around 7-8 months either grazing on lucerne besides supplementation with grower ration at 1 kg per bird per day or confined to feedlots with zero-grazing. At 5-6 months (@ 65 kg body weight), growers are subjected to selective feather plucking so as to promote uniform new feather growth, which is finally harvested at slaughter when the birds are 14 months old. Prior to slaughter birds should be quarantined for 30 days on a zero-grazing feedlot with rodent control and acaricide treatment in order to exclude the presence of Crimean-Congo haemorrhagic fever (CCHF) (Swanepoel *et al.,* 1998). In this finishing phase all of the compulsory regulations against Newcastle disease (NCD) and CCHF as required by the veterinary authorities need to be followed. Also towards the end of this phase birds are put on a very high-fibre diet (30-50%) to prevent excess fat deposition (Verwoerd *et al.,* 1999b).

1.7.9 Chick quality

Ostrich chick rearing is directly influenced by both parental condition and incubation. The ideal range of chick weight at day one is 780 - 975 gram with little sign of generalized oedema or dehydration. At least 80% of any group of chicks should be uniform in mass, an observation which persists with growth. The bird should be alert with clear, round eyes and should be free from any anatomical defects of the legs, feet and beak. The navel should be completely closed and dry. With good chick quality, mortality at 14 days post-hatch should be less than 10% (Verwoerd *et al.,* 1999b). Prolonged periods in the hatcher can dehydrate the chicks due to excessive moisture loss. Oedema or anasarca, on the other hand, results due to insufficient mass loss and is characterized by gel-like deposits under the skin and within the muscle tissue leading to splay leg conditions (Philbey *et al.,* 1991).

1.7.10 The residual yolk sac

The yolk sac forms above 50% of the total body mass of the hatchling and provides nutrition as well as passive immunological protection. It should be absorbed within 7 – 10 days post-hatch (Guittin, 1987; Jensen *et al.,* 1992), or 2 - 3 weeks (Smith, 1963). Therefore, for better chick survival, some authors advised withholding feed and water during the first 3 – 5 or 6 – 8 days post hatch so that chicks can absorb the yolk sac faster (Kocan and Crawford, 1994). On the other hand, some researchers recommend immediate provision of feed and water to the chicks to allow for functional development of the digestive tract as soon as possible and to avoid the so-called "fading chick syndrome" at the end of the yolk-dependent phase (Verwoerd *et al.,* 1999a). In domestic fowl, consumption of feed increases the rate of yolk utilization (Noy *et al.,* 1996). In ostriches, however, the persistence of a large yolk sac in a growing ratite chick is a symptom of an underlying problem within the rearing environment (Deeming, 1995a).

Yolk sac infection is a significant cause of early chick mortality with most birds dying within 14 – 21 days of hatching. The organisms involved in yolk sac infection include *Escherichia coli*, *Pseudomonas spp., Staphylococcus aureus, Proteus spp.* and *Streptococcus spp*. (Grilli *et al*., 1996). Yolk sac infection is commonly attributed to poor hatcher hygiene or post-hatch navel infection or infections of the yolk from gastrointestinal pathogens (Deeming, 1995a).

1.7.11 Growth rates of ratites

Immediately after hatching chicks lose up to around 20% of their weight within 5 – 7 days before beginning a steady climb in weight. This decline is greater and more prolonged in sick birds (Deeming and Ayres, 1994). Thereafter the birds gain weight at an increasingly faster rate and by three months of age they should have a weight of 35 – 40 kg and an adult weight of around 100 kg is attained at around 12 months of age (Degen *et al.,* 1991).

Practically the growth rate of some birds is far from this typical pattern. This leads to considerable variability in chick mass during the first three months of age with chicks often not attaining normal rates of growth (Deeming *et al.*, 1993). Factors affecting the normal rates of growth of chicks and consequently their sizes include protein content in the diet, social grouping and diseases (Deeming *et al.,* 1993). The time of year affects the rate of growth of ostriches especially in outdoor enclosures where the rate was found to be faster in the summer than in the winter. More energy is needed for keeping warmth for the bird during the winter and the number of feeding hours is increased during the summer which explain the faster growth rate during summer seasons. Other factors affecting variations in growth rate include genetics, feed quality and management practices (Jarvis, 1998). The maximal rate of growth was found to be between 70 and 98 days of life in Indiana (USA) farms (Angel, 1996) whereas in some African countries it was found to occur between 115 and 121 days and between 92 and 114 days (Verwoerd *et al.,* 1999b).

1.7.12 Chick survivability and mortality

Ostrich chick survivability is low in the wild compared to the rate obtained under intensive farming environments (Hurxthal, 1979). Typical chick mortality was found to be 40 - 50% up to three months of age and 10% from 3 – 6 months of age in South Africa (Smith *et al.,* 1995). Under quarantine conditions in Britain the mortality rate was found to be 21.7% and 33.3% in two batches of three month old ostrich chicks (Deeming et al., 1993). However, mortality of chicks that received assistance during hatching was found to be higher (75%) than chicks hatched without assistance (9.8%) (Deeming and Ayres, 1994). In the Middle-East, ostrich mortality rate was found to range between 15 and 50%. The mortality was lower at the beginning of the summer season (March - June) and increased sharply during the peak of summer (June - July) when ambient temperatures averaged 39° – 41° C. However, a lower mortality rate was experienced in a farm where a semi-intensive rearing method was adopted with chicks reared on lucerne pasture (*Medicago sativa*) (Verwoerd *et al.,* 1999b).

1.7.13 Nutrition of the ostrich

Inadequately fed ostriches will rapidly reflect deficiencies through a decline in growth rate, production of eggs, fertility, hatchability and general performance. Ostrich feed must contain the following essential classes of nutrients to satisfy their needs (Shanawany and Dingle, 1999):

1-Water: It should be provided continuously and be easily accessible to all birds. It should be free of excess minerals and salts, free of high bacterial contamination and generally of a quality suitable for human consumption.

2-Protein: Proteins in the ostrich feed should be of good quality and their amino acids content should be available from the feed stuffs. Animal protein sources such as meat, blood and fish meals should be incorporated in the feed to ensure adequate supply of certain essential amino acids such as methionine and lysine which are not provided by plant materials (Huchzermeyer, 1998). Feed conversion ratio in ostrich chicks was found best at protein percentage of 18% (Gandini *et al.,* 1986).

3-Energy: Carbohydrates, mainly grains such as yellow maize, wheat and barley, are the primary source of energy for the ostriches. High energy values are also available in lipids (fats and oils) but their added level should not exceed 5% so that the feed does not lose its optimum flow characteristics (Shanawany and Dingle, 1999).

4-Minerals and vitamins: Although most minerals are important for the ostrich, calcium and phosphorus are of particular importance since they are used in bone and eggshell formation. Vitamins, both fat and water soluble, are required to allow various organs and tissues to perform their functions properly.

5-Fibre: Due to their hindgut fermentation ability, ostriches are able to digest more fibre than other domestic birds. Therefore, it is necessary, particularly for adult ostriches, to provide certain amount of bulk in the diet, in the form of fibre. This fibre is useful for efficient digestion and physical consistency and movement of feed materials through the long digestive tract of ostriches. Moreover, this fibre is effective in controlling some bad vices such as cannibalism and feather pecking among ostriches in quarantine confinement. Chopped green alfalfa, grain hulls and corn cobs are good sources of dietary fibre for ostriches (Shanawany and Dingle, 1999).

1.7.13.1 Nutritional requirements of growing ostriches

Young male ostriches grow faster than the females. Therefore, they may be raised separately to ensure having higher supply of protein in their diet and make use of their high efficiency as feed converters. Thus, juvenile male ostriches attain marketable body weight earlier then their female partners (Shanawany and Dingle, 1999).

1.7.13.1.1 From one to three months

Since the newly hatched chick can feed on its yolk material for the first seven to ten days, some workers recommend to withhold the feed for two to three days after hatching. It is also indicated to control the initial growth of ostrich chicks, through feed restriction, to avoid problems associated with fast growth such as leg and skeletal disorders. However, the energy content of feed ranging between 9 and 10 MJ of metabolizable energy per kilogram of feed is sufficient to control body growth for young ostrich chicks. Since the ability of juvenile ostriches to digest fibre increases after four months of age to reach 58%, it is important not to feed diets containing more than 5% fibre during the vital first few weeks of the chicks life (Huchzermeyer, 1998).

1.7.13.1.2 From three months to one year

In this phase emphasis should be placed towards increasing both the energy and fibre contents and reducing the crude protein value of the feed. The dietary fibre can be up to 11% for birds around 5 months old as it helps in feather development. Moreover, the caloric value of the feed should be increased to around 10 - 10.5 MJ/Kg of feed while the crude protein level can be reduced to 18%. For this age group there should be a balance between calcium and available phosphorus which should be maintained at 1.8:2.1 (Preeze and Preeze, 1991).

1.7.13.2 Nutritional requirements of breeding ostriches

At around one year of age ostriches reach about 95% of their full bodyweight after which there will be very little increase in metabolic size and all major metabolic changes are mainly geared towards the development of the sex organs. From one year up to breeding age birds should be maintained in prime condition avoiding both obesity and starvation or underfeeding which delays sexual maturation. Dietary fibre can be increased up to 15% while protein and energy levels should be reduced except during cold weather spells when high energy rich sources can be added. Birds should be prepared for breeding after attaining 18 months of age by offering them a breeder ration which should be relatively high in energy and protein and low in fibre. As calcium is the main constituent in the ostrich egg shell, the calcium and available phosphorus levels should be increased at the onset of breeding to at least 40 gram of calcium and 4.2 gram of available phosphorus per kilogram of feed. Low or imbalanced dietary levels of calcium and phosphorus may prevent egg laying altogether or result in poor rates of egg production, hatchability of fertile eggs and increased production of soft-shell or shell-less eggs (Shanawany and Dingle, 1999).

1.8 Management diseases and health problems of ratites

1.8.1 Leg problems of ratite chicks

Ratite chicks, particularly ostriches, are very prone to leg problems due to their fast growth. Most of these problems are multifactorial. Gonzalez (1992) found that high protein levels in starter feeds have been reported to cause leg deformities since the fast growth rate of ostrich chicks, when associated with existing mineral imbalance problems, aggravates the problem by putting excessive body mass on the incompletely ossified legs (Guittin, 1986). High calcium levels in plants and water in California soils (USA) induced malabsorption of manganese and zinc leading to leg problems in ostriches (Frank and Carpenter, 1992). Several mycotoxins were claimed to influence calcium/phosphorus and vitamin D metabolism, thus contributing in the aetiology of ostrich leg deformities (Bissinger, 1998). The leg deformities in ostriches can be classified as:

1.8.1.1 Splayed legs

It is the case when both legs spread out sideways particularly when the new hatched ostrich chicks are kept on slippery surface or when the chick has an overlarge yolk sac which pushes the two legs apart (Jones, 1994).

1.8.1.2 Twisted toes

It is attributed to nutritional deficiencies in the breeding stock or when the chicks are reared on hard surfaces or due to injuries. The toes in this condition either turn inwards or outwards (Wallach, 1970).

1.8.1.3 Tibiotarsal rotation

The tibiotarsal bone in this condition rotates on itself above the hock joint turning the foot to the outside. When the condition progresses, affected birds cannot stand and injure the hock joint by rubbing it on the concrete floor while attempting to stand up. Deformed birds find difficulty to reach food and water troughs and die of starvation or wound infection. It has been suggested that poor bone mineralization and reactive osteoid formation take place in some cases due to increased serum zinc and decreased serum calcium and phosphorus levels (Bezuidenhout *et al.,* 1994).

1.8.1.4 Valgus rotation

This condition involves the tarsometatarsal bone below the hock causing twisting of the whole foot (Jones, 1994).

1.8.1.5 Slipped tendons

It is the dislocation of the gastrocnemius tendon from the condyles of the hock joint leading oftenly to a compound dislocation with an open wound. It can be unilateral or bilateral. Manganese deficiency was suspected as a possible cause of this condition (Dick and Deeming, 1996).

1.8.1.6 Osteomalacia

It is the bending or fracture of bones due to calcium deficiency. Other ratite species including emus and rheas were also affected (Huchzermeyer, 1998).

1.8.1.7 Rickets

This condition results into leg abnormalities due to disturbance in calcium metabolism following vitamin D deficiency or imbalance of calcium:phosphorus (Ca:P) ratio in growing birds (Huchzermeyer, 1998).

1.8.1.8 Arthritis

Usually caused by trauma, open injuries affecting the tibiotarsal-tarsometatarsal joint (the hock joint) and thorn punctures penetrating the digital joints. It leads to severe lameness (Huchzermeyer, 1998).

1.8.2 Congenital deformities

Congenital deformities of the head, neck and limbs are seen possibly due to nutritional deficiencies in the parents, faulty incubation or due to genetics (Huchzermeyer, 1998). These deformities include:

1.8.2.1 Cross-beak

It is a genetic defect where the lower beak stands out sideways at an angle to the upper beak and the affected chick finds difficulty in feeding. It is advised to stop breeding from parents producing crossbeak chicks (Huchzermeyer, 1998).

1.8.2.2 Shortened lower beak

It is attributed to manganese deficiency in the parents ration (Foggin, 1992).

1.8.2.3 Clubbed feet

It is a rare condition where the feet take the shape of a tennis ball club. The cause is unknown (Huchzermeyer, 1998).

1.8.2.4 Anasarca – oedematous chicks

It occurs due to excessive humidity during incubation or due to certain nutritional imbalances including high potassium content in the alfalfa feed of the parents diet. It results into muscular degeneration in the newly hatched chicks (Philbey *et al.,* 1991).

1.8.2.5 Shortened legs

It is presumed to be a genetic defect. Chicks, otherwise, develop normally except for this defect.

1.8.3 Viral diseases of ratites

1.8.3.1 Newcastle disease (NCD)

Newcastle disease (NCD) is a highly contagious avian disease that causes severe economic losses in poultry industry throughout the world. It is caused by avian paramyxovirus serotype 1 (APMV-1) viruses (Alexander, 2000). The disease was first reported in zoo ostriches in the 1950s in South Africa (Placidi and Santucci, 1954) and in Palestine it was reported in 1989 (Samberg *et al.,* 1989). The disease was spread during the 1990s from commercial domestic fowl to ostriches severely affecting the ostrich industry in South Africa. The disease spreads slowly through affected ostrich flocks and the clinical signs and mortality rates vary considerably with age (Samberg *et* *al.*, 1989). Transmission of NCD in ostriches takes place mainly via the oral route and a high infective dose is required to establish infection (Huchzermeyer, 1998). The virus can be carried to ostrich farms on shoes and clothes of people particularly from adjacent infected chicken farms. Wild birds act as reservoirs of infection especially for the free ranging and outdoor reared susceptible ostrich chicks. Infection of other ratites with NCD virus is rare. However, Kaleta and Baldauf (1988) reported infection of rheas with NCD virus while Heckert *et al.* (1999) described the disease following experimental infection of two emus with a mesogenic strain of NCD virus. Huchzermeyer (1998) suggested that other ratite species are more resistant to NCD, while Estudillo (1972) described an outbreak of NCD in an avian collection where rheas and cassowaries were affected.

1.8.3.1.1 Clinical signs and postmortem findings

The clinical signs of NCD in ostriches vary considerably with age and route of infection. In birds less than 6 months old, natural infection with virrulent NCD virus usually results in peracute death, with nervous signs seen in some birds and mortality can be as high as 85% while in adult birds both morbidity and mortality are low (Allwright, 1996). Huchzermeyer (1996) reported more consistent nervous signs in infected ostrich chicks with oedema of the head being the only consistent postmortem feature. The same author reported extremely slow spread of the disease through infected flocks while the disease did not occur in birds separated by a wire fence from infected birds. The macroscopic postmortem lesions of NCD were minimal and nonspecific. There was oedema of the upper neck and head region and in some cases petechial haemorrhages were found on serosal surfaces particularly in the small intestines (Huchzermeyer, 1998).

1.8.3.1.2 Diagnosis of the disease

The only reliable method of diagnosis is the isolation of the virus from brain, lung, liver and kidney in embryonated chicken eggs besides the use of serological test methods. The serological tests include the haemagglutination inhibition test (HI) and the enzyme-linked immunosorbent assay (ELISA). However, some workers reported poor results using the HI test for ostrich sera and recommended a microneutralization test or a standard ELISA test (Allwright, 1996). Thus, estimation of antibodies to NCD virus in the sera of ostriches and other ratites is not as straight forward as in other poultry species (Huchzermeyer, 1998).

1.8.3.1.3 Control and vaccination against NCD

Little is known about the immune response of ostriches to NCD vaccines. However, several authors have reported the successful use of vaccines in protecting ostriches against experimental challenge. Allwright (1996) reported the efficacy of NCD vaccines in ostriches and recorded some adverse reactions with adjuvant oil-based vaccines where large swellings were developed at the injection sites. To overcome the problem of adverse local reactions some workers recommended the use of inactivated aluminium hydroxide adsorbed vaccines. Huchzermeyer (1994) recommended the following vaccination regime for NCD: a primary live vaccine administration by eye drop at one-day old followed by a dose of an inactivated oil emulsion vaccine, intramuscularly or subcutaneously, three weeks later and another dose after six months and then annually for the breeding stock. However, Madeiros (1997) recommended more frequent vaccination in the NCD high risk areas and considered the presence of maternal antibodies to affect the effectiveness of vaccination. Therefore, where there is no maternal immunity in the hatchlings the recommended programme is to give the first dose at two weeks old using a live vaccine followed by an inactivated oil emulsion vaccine at one month old, then the same vaccine at two months old, six months, 12 months and then, annually. The use of live vaccines via the ocular route at early ages was recommended because of the fact that vaccination via this route is known to confer a good mucosal immunity that does not interact with the maternal immunity (Blignaut *et al.,* 2000). The response of ostriches to the parenterally administered inactivated vaccine was found to be dose-dependent and the risk of transmission of NCD virus by such vaccinated birds and their products would be extremely low (Schaetz *et al.,* 1998). Thus, the export of ostrich meat and other products from endemic countries to NCD free regions could not transmit velogenic strains of this disease. However, meat export regulations in South

Africa stipulate that all feedlot birds be vaccinated one month before slaughter. Because of their size, natural environment and extensive rearing practices programmes aimed at controlling NCD infection among ostriches are met with little chances of success before achieving their ultimate goals (Huchzermeyer, 1998).

1.8.3.2 Avian influenza

Avian influenza is caused by various strains of influenza virus. Outbreaks of this disease have occurred in young ostriches in South Africa (Allwright, 1992). Clinically affected birds show depression, green discoloration of urine, respiratory signs and ocular discharge. The mortality rate can be as high as 70% and the severity of symptoms and lesions depends on age and concurrent secondary infection. Certain influenza virus strains, namely HPAI virus of ratite origin, did not cause significant clinical diseases or mortality (Clavijo *et al.,* 2003). Postmortem lesions consist of enlarged, mottled and friable livers and congested proximal small intestine filled with mucoid contents. There is a vaccine that can protect against infection but the most important preventive measure is the reduction of contact with wild birds (Huchzermeyer, 1998).

1.8.3.3 Avian pox

Avian pox is reported in several ostrich keeping countries. The disease is caused by different strains of avipoxvirus (Huchzermeyer, 1998) although it has similar antigenic, genetic and biological properties to fowlpox virus (Shivaprasad *et al.,* 2002). The virus is transmitted by mosquitoes. Clinically the disease has two forms. The cutaneous form affects the skin around the beak and eyes forming brown crusty lesions. The other form is the mucosal form which produces inflammation in the buccal cavity, larynx and trachea leading, in severe cases, to respiratory distress. Mortality in ostriches is usually low (15%). A commercial poultry fowl pox vaccine is available and it gives good protection in ostriches (Huchzermeyer, 1998; Shanawany and Dingle, 1999).

1.8.3.4 Crimean-Congo haemorrhagic fever (CCHF)

The disease occurs in many parts of Africa where it is transmitted by ticks of the genus *Hyalomma*. It causes very short, symptomless viraemia in sheep, cattle and ostriches. Fatal human infections are contracted through the bite of infected ticks or through direct contact with the blood of a viraemic animal or through handling tick-infested slaughtered ostriches and their tissues (Shepherd *et al.,* 1987). However, there are no reports of infection through consumption of meat from an infected animal. Keeping birds free of ticks for 14 days before slaughter is thought to prevent infection at abattoirs (Verwoerd *et al.,* 1999b).

1.8.4 Bacterial diseases of ratites

1.8.4.1 Yolk sac infection

That is a major cause of death of chicks before and after hatching and it is caused mainly by *Escherichia coli* organisms. When the infection is localized in the navel or umbilical area it causes omphalitis. These conditions are characterized by inflammation of the navel and incomplete resorption of the yolk leading to yolk sac retention. The most common source of infection is the contamination of hatching eggs with bacteria which penetrate the egg shell. These infections result in either death of the embryos before hatching, usually late in the incubation period, or the chicks die suddenly short after hatching in the acute form. In the chronic form affected chicks show retarded growth accompanied by dehydration with deaths occurring up to three or four weeks after hatching (Huchzermayer, 1998).

1.8.4.2 Necrotic or ulcerative enteritis (Enterotoxaemia)

It is caused by *Clostridium perfringens* type C when the ostriches, particularly young chicks, are subjected to severe stress or sudden change of nutrition. Clinical signs include sudden depression, anorexia and death within 48 hours. Mortality in chicks may approach 100%. The uncontrolled multiplication of the causative agent produces toxins which might be absorbed in the circulation causing enterotoxaemia (Huchzermeyer, 1998).

1.8.4.3 Anthrax

Ostriches are the only birds that are susceptible to anthrax possibly due to their lower body temperature. Two forms of the disease have been described, sudden death and anthrax fever. Symptoms include fever, weakness, swelling of the throat. Death occurs quickly with blood oozing from the cloaca and nostrils. No recent outbreaks have been described. The ordinary cattle anthrax vaccine can be used to protect the ostriches (Theiler, 1912).

1.8.4.4 Campylobacteriosis

It is a semi-acute or chronic disease that affect young chicks, between ten days to four months, resulting in high mortalities. Symptoms include loss of appetite, production of green-stained urine, depression, anorexia and progressive weakness followed by death within a few days (Shanawany and Dingle, 1999).

1.8.4.5 Respiratory infections

The upper respiratory tract infections affect the nasal passages, sinuses, larynx, trachea and the conjunctivae. Young ostriches are frequently affected particularly when stressed by cold or overcrowding. The microbial agents mostly incriminated in these conditions include *Pasteurella haemolytica, Pseudomonas aerogenosa, Bordetella avium* and *Bordetella bronchiseptica* (Clubb *et al.,* 1994). Mycoplasma spp. have also been isolated. Pneumonia, on the other hand, is relatively rare in ostriches due to the construction of the avian lung in which the inhaled air by-passes the gas exchange tissue which reduces the risk of direct contamination (Huchzermeyer, 1998).

1.8.5 Fungal infections in ratites

1.8.5.1 Aspergillosis

It is a fungal infection of the respiratory tract caused by the fungus *Aspergillus fumigatus*. Spores are transmitted through contaminated litter or feed or through inhalation of spores in contaminated hatcheries. Young ostriches are more susceptible to infection and clinical signs include depression, anorexia, stunting and death (Shanawany and Dingle, 1999; Perez *et al*. 2003).

1.8.5.2 Candidiasis

It is caused by the fungus *Candida moniliformis.* The infection is related to long-term treatment with antibiotics or when the birds are subjected to stress conditions. As the fungus affects the mucous membranes of the mouth and oesophagus, affected birds show anorexia, dehydration and death (Shanawany and

Dingle, 1999). When infection affects the proventriculus, it causes gastric mycosis or fungal gastritis with clinical and postmortem manifestations similar to megabacterial gastritis. A mixed infection of proliferative ventriculitis in an ostrich caused by *Aspergillus* and *Candida sp.* was described by Perelman (1993).

1.8.6 Parasitic diseases

1.8.6.1 Worms

The wireworm *Libyostrongylus douglassii* is found in the openings of the deep proventricular glands and under the koilin layer of the proventriculus and gizzard. In heavy infestations it causes impaction of the proventriculus and may lead to a high mortality rate particularly in chicks. *Codiostomum struthionis* is a relatively harmless roundworm that inhabits the upper rectum. *Houttuynia struthionis* is a large tapeworm which inhabits the small intestine of ostriches causing ill-thriftiness in young ostriches and the intermediate host of which is not known. It is common in pasture-raised ostriches particularly in South Africa (Huchzermeyer, 1999). Verminous encephalitis (Kazacos *et al.,* 1982; Kwiecien *et al.,* 1993) and cerebrospinal nematodiasis (Kazacos *et al.,* 1991) caused by the migrating larvae of the nematode *Baylisascaris* sp. were described in adult ostriches and emus manifesting fatal nervous signs. The source of infection was postulated to be racoons seen on the premises.

1.8.6.2 Protozoa

Coccidiosis has been recognized in ostriches in many parts of North America and Europe particularly where young ostrich chicks are raised indoors. However, in a natural reserve in Botswana, Mushi *et al.* (2003) demonstrated seasonal prevalence of strongyle eggs in ostrich faecal samples while failed to demonstrate neither helminth eggs in samples collected from chicks nor coccidia oocysts from any of the ostriches. Symptoms are usually minimal in affected ostriches which may show loss of appetite, weakness, ruffled feathers and bloody droppings. An unidentified *Cryptosporidium* species has been shown to infect the bursa, the rectum and the pancreas of the ostrich chicks. It causes outbreaks of cloacal prolapse sometimes with severe losses (Allwright and Wessels, 1993). The flagellate *Histomonas meleagridis* can infect ostriches in close contact with turkeys and other gallinaceous birds and cause inflammation of caeca and liver (Borst and Lambers, 1985).

1.8.6.3 Arthropods

Feather lice, *Struthiolipeurus struthionis,* feed on feathers sometimes causing considerable damage and irritation (Huchzeremyer, 1998). The hippoboscid fly, *Struthiobosca struthionis,* sucks blood and causes considerable irritation. *Gabucinia spp*. are the ostrich quill mites that live in the ventral groove of feather shafts where they feed on the gelatinous contents in growing feathers and sometimes they attack the skin causing mange-like lesions (Sambraus, 1995).

1.8.7 Multifactorial diseases

1.8.7.1 Gastric stasis

It is a complex disease mainly of young chicks but can affect older birds. It occurs when the contractions of the gizzard cease and the food does not move from the proventriculus leading to starvation, loss of weight and eventually death of the bird. The causes for this condition include excessive fibrous matter in the feed, excessive sand, presence of foreign bodies in the stomach and lack of stones leading to impaction. Other contributing factors include cold, excessive heat, stress due to parents desertion and disorientation. Microbes such as megabacteria, fungi, and viruses besides helminths also are involved. Clinically the growth of affected birds slows down and they begin to lose weight and finally become unable to stand before death ensues (Huchzermeyer, 1998).

1.8.7.2 Enteritis

It is a major cause of mortality in intensively reared ostrich chicks and is almost absent in chicks reared on pasture. Factors influencing this condition include nutrition, intestinal flora, environmental factors and pathogens. The failure to establish normal gut flora or the destruction of these normal flora by excessive use of antibiotics drastically lowers the birds' defense mechanism and paves the way for pathogens to cause enteritis. The inclusion of enough amount of fiber, avoidance of excessive proteins in the chick diets and smooth and gradual change of rations are essential measures for producing healthy chicks and preventing enteritis. Stress and cold weather reduce the activity of the immune system and consequently affect the ability of chicks to combat infectious agents. The infectious pathogens involved in enteritis of ostrich chicks include paramyxoviruses, avian influenza virus, reovirus, retrovirus, different species of bacteria particularly *Escherichia coli* (Henton, 1998) and some protozoan agents including *Cryptosporidium, Histomonas* and *Toxoplasma* (Huchzermeyer, 1998).

1.8.8 Disturbed behaviour and miscellaneous conditions

1.8.8.1 Feather pecking

It is an acquired vice following stress conditions such as transference into bare land and the feeding of compounded rations (Sambraus, 1995). The condition is rare in ranging ostriches. This vice can lead to downgrading of hides (Huchzermeyer, 1998).

1.8.8.2 Toe and face pecking

This vice is directed towards the face and toes of group mates resulting into loss of the eyelids, and wounds on the toes (Huchzermeyer, 1998).

1.8.8.3 Sand impaction

It is caused by the excessive ingestion of sand from soil or litter. It is mainly a disturbed behaviour and there is no evidence of pica due to mineral deficiency causing this problem. The sand first accumulates in the proventriculus and then passes through and fills the small intestine and caeca leading to blockage which results in starvation and death (Huchzermeyer, 1998).

1.8.8.4 Foreign bodies

The ingestion of foreign bodies such as thorns, sticks, nails, or pieces of wire causes obstructions or penetrates the wall of the proventriculus or gizzard causing peritonitis or pleuritis (Swart, 1980). Causes for ingestion of foreign bodies include insufficient grazing, insufficient energy intake and lack of enough fibre in the ration. Transferring of ostriches into new pens without removal of harmful foreign objects encourages them to ingest these materials (Huchzermeyer, 1998).

1.8.8.5 Epidermolysis bullosa

The condition has been described in normally hatched chicks which a few days later developed vesicular lesions followed by complete loss of feathers (Perelman *et al.,* 1995).

1.8.8.6 Baldness

It occurs as a consequence of prolonged exposure of young chicks to infrared light (Huchzermeyer, 1998).

1.8.8.7 Injuries and fractures

Traumatic injuries occur most often when ostriches are chased or become frightened and run into fences and other obstacles. Traumas also occur when birds are transported under unsuitable conditions or when handled roughly or when subjected to attacks of stray dogs and foxes. Fractures, on the other hand, occur in young chicks when their feed is deficient of calcium. The most commonly affected long bones in ostriches are the femur, tibiotarsus and the tarsometatarsus (Huchzermeyer, 1998).

1.8.8.8 Conjunctivitis

It is often caused by dust particles lodging under the eyelids. The dust comes either from the feed troughs or from the ground where faecal bacteria may complicate the condition (Huchzermeyer, 1998).

1.8.8.9 Neoplasms

A few neoplasms have been reported from ostriches and other ratites. These neoplasms included squamous cell carcinoma, papilliform mesotheliosarcoma in an aged female cassowary and another one in a female ostrich and a lymphoma in a three year old ostrich hen (van Der Heyden *et al.,* 1992; Reece, 1992; Neumann *et al.,* 1970).

1.8.8.10 Intestinal intussusception

The condition has been reported occasionally in ostriches leading to the occlusion of the intestinal lumen and the compression of the affected mesenteric vessels. The affected bird manifests signs of acute discomfort. The condition occurs due to disturbed peristaltic movements which might be provoked by local irritation of the gut mucosa as a result of a parasitic infection such as *Cyptosporidium* sp. or presence of foreign objects (Drenowatz, 1995; Huchzermeyer, 1998).

1.8.8.11 Stunted growth

Stunted growth in ostrich chicks can be caused by many subclinical conditions that affect the flock resulting into earlier mortality. However, the most common cause of stunting is partial gastric impaction (Huchzermeyer, 1998).

Chapter II
Materials and methods

2.1 Study farms

2.1.1 Farm A

Farm A is located in Al-Qassim area, Central region of Saudi Arabia, near Buraydah town (Fig. 1).

2.1.1.1 History of the Farm

The construction work of the farm was completed in October, 1997 and the birds were received in December, 1997. The initial stock of the flock, composed of 400 ostriches (*Struthio camelus*) and 400 emus *(Dromaius novaehollandiae)*, was imported from a French company (France Autruche, Lyon, France). The male to female ratio of the ostrich stock was 1:2 (i.e. 133 males and 267 females) while the ratio for the emus was 1:1 (i.e. 200 males and 200 females).

The original stock which was composed of ostrich and emu breeders was housed in communal pens with dimensions of 100 X 200 meters. Each pen had two shaded areas of 10 X 20 meters, eight drinkers and four feeders made of concrete. The stocking density ranged from 60 – 70 birds per pen for the ostriches and from 80 – 100 for the emus (i.e. 285 – 333 m^2 for the ostrich bird and 200 – 250 m^2 for the emu bird). The ostrich breeders continued in this communal system of housing throughout the study period (1998 - 2002) except for eight couples (male:female sex ratio at 1:1) which were transferred to eight separate pens with dimensions of 10 X 30 meters. The emu breeders, on the other hand, were transferred after one year to couple pens with dimensions of 10 X 30 meters. Each pen had a shaded area and a plastic feeder while each two pens were sharing one concrete drinker. The fence for all pens was made of Cyclone® wire net (McArthur Cyclone, Bristol, England).

Farm A had a hatchery section composed of five incubators and three hatchers which were also purchased from a French company (Mayenne Eclosion, St. Jean Sur Mayenne, France). The chick rearing section, in which the birds were kept up to three months of age, was composed of 24 rooms of varying sizes ranging from 9 to 32 m^2 each. Attached to each room there was an outside exercise area for the chicks with total area ranging from 30 to 120 m^2. One third of each exercise area was shaded while the rest was left open. The floor area for the rooms was made of concrete while the floor for the exercise area was composed of compacted gravel in the beginning of the project but later on was changed to concrete. Each room was supplied with one or more air-conditioner with cooling and heating abilities. For the grower birds section there were several pens of varying sizes, ranging in dimensions from 20 X 30 meter to 100 X 200 meter. All grower pens were supplied by shades, feeders and drinkers.

Feed in Farm A was manufactured in the farm by feed mills originally installed for the poultry section owned by the same company.

2.1.1.2 Daily production and operation routine in Farm A

Eggs were usually removed from inside the parents communal pens either late in the afternoon (before end of duty hours) or early in the morning. Then eggs were collected in steel trays by the farm supervisor, labeled with date and pen number on the egg shell and then transported to the hatchery where they were inspected for incubation suitability. Non-defective good eggs were cleaned by tissue papers, fumigated by potassium permanganate and formaldehyde mixture (80 gram potassium permanganate in 130 ml 40% formaldehyde solution per cubic meter for 20 minutes, Horbanezuk and Sales, 1998). Then eggs were stored in a special storage room at 18ºC and 60% – 70% relative humidity for a period ranging from 2 to 6 days. During this initial storage period eggs were turned hourly at an angle of 180 degrees. Defective eggs, such as those oversized, undersized elongated or damaged eggs were removed and discarded. During this storage period eggs were positioned vertically with the air cell upper most until the day of transference to the incubator. Twelve hours before transfer to the incubator, eggs were again fumigated and then preheated to 25ºC.

In a fixed day every week, usually Saturday, eggs were transferred to the incubator where they were positioned vertically with the air cell to the top. The incubation temperature for ostrich eggs was set at 36.2ºC and the relative humidity was usually below 20% so that the loss in ostrich egg mass would be around 15% of the initial weight at the end of incubation period. The incubation temperature for emu eggs, on the other hand, was adjusted at 35.5ºC while the relative humidity was 25%. After two weeks of incubation for ostrich eggs and three weeks for emu eggs, ostrich eggs were candled for fertility assessment using a simple illuminator while emu eggs were candled using a special candling apparatus (Emu Vision, Minnedosa, Manitoba, Canada).

After candling, fertile eggs were returned to the incubator to continue incubation while the non-fertile eggs were removed. At day 39 for the ostrich and 49 for the emu, eggs were candled again to ascertain embryonic viability before being transferred to hatcher for hatching at a temperature of 35.9ºC and relative humidity of 33% for ostrich eggs and a temperature of 35.2ºC and relative humidity of 33% for emu eggs. Eggs in the hatcher were checked four times daily to monitor the hatching process and to give necessary assistance to weak chicks which started the pipping but became unable to finish successfully the hatching process and need to be assisted. At day 42 for the ostrich and 52 for the emu, all non-hatched eggs were opened to investigate the causes of hatching failure. The navels of successfully hatched chicks were disinfected using any suitable disinfectant then chicks were delivered to the chick rearing section.

In the rearing section chicks were received on raised beds for one week before being put down on the floor. Immediately upon arrival to the rearing section starter mash feed and water were provided to the chicks together with the initial vaccination doses against Newcastle and infectious bronchitis diseases which were administered via aerosol spraying.

Young chicks were followed closely and monitored daily for any deviation in health and vitality. Dead chicks were necropsied to diagnose the cause of mortality. Pathological samples were obtained and sent to the farm diagnostic unit for further investigation and confirmation of the initial tentative diagnosis. Upon prompt diagnosis medication and other necessary actions and precautions were undertaken accordingly.

During this rearing phase, mash starter feed, was given *ad libitum* and vitamins were provided via drinking water or feed. The second and third vaccinal doses against Newcastle disease and infectious bronchitis were administered at days 21 and at three months of age, respectively. Avian pox vaccine, on the other hand, was administered by scratching the upper thigh muscles at the age of three months.

Chicks were transferred to the growers section after attaining the age of three months, where they were provided with growers pelleted feed. At six months and one year of age, ostrich and emu growers receive the fourth and fifth doses of immunization against Newcastle disease and infectious bronchitis, respectively.

Table 1. Vaccination schedule for ostriches and emus

Doses	**Disease and age of vaccination**		
	Newcastle disease	**Infectious bronchitis**	**Avian pox**

First dose	day one	day one	3 month
Second dose	21 days	21 days	annually
Third dose	3 months	3 months	-
Forth dose	6 months	6 months	-
Fifth dose	one year	one year	-
Sixth dose	annually	annually	-

2.1.2 Farm B

Farm B was also located in Al-Qassim area, Central region of Saudi Arabia, near Al Badayaa town.

2.1.2.1 History of the Farm

The farm was established in the year 1999. The parent stock was composed of three groups. Group I was composed of parents which were purchased as one day old chicks from a commercial farm in Riyadh area, Saudi Arabia, and raised in the farm up to maturity. Group II were parents purchased from the same source in Riyadh as growers at 8 months old. Group III was composed of parents which were purchased from the same source in Riyadh area as mature breeders at point of lay.

The parent stock was of the breed *Struthio camelus* var *domesticus* and their grandparent stock was originally imported from The Republic of South Africa (Elandspoort Stud Ostriches, George 6530, South Africa). The system of housing for the breeders was that of single couple system with male to female sex ratio of 1:1. Few pens had the ratio of 1:2. Pens measured 15X50 meters and each pen was supplied with a feeder and a water trough.

The hatchery section consisted of five incubators and three hatchers (NatureForm Inc., Jacksonville, Florida, USA).

The chick rearing section was divided into two parts. The first section was annexed to the hatchery building where the chicks were kept for the first three weeks of life. Chicks were then transferred to the second section which was composed of five rooms each of 36 m^2 and outside exercise areas ranging from 90 to 150 m^2. The floor for rooms and exercise area in this rearing section was made of pure sand, without concrete. Each room was supplied with a heater.

The growers section was made of numerous pens of varying size ranging from 320 m^2 to 6000 m^2. Each pen was shaded and supplied with drinkers and feeders. A large number of date palms provided additional shading in most of the pens in both rearing and grower sections of this farm. The fencing material in Farm B was made of Al Watania Fencing Wirenet (Al Watania Group, Riyadh, Saudi Arabia).

The source of the feed for this farm was a commercial feed supplier in Riyadh area.

2.1.2.2 Daily production and operation routine in Farm B

The daily routine in Farm B differed from that in Farm A in the following activities:

1- Eggs collected in the afternoon were delivered immediately to the hatchery while similarly collected eggs in Farm A were delivered to the hatchery in the next morning.
2- Due to the system of ostrich management, namely the single pair method of breeders housing, fertility and hatchability results could be traced back to the individual female (or male) bird unlike Farm A where the communal system of housing was applied.
3- Newly hatched chicks were kept within the hatchery building for the first three weeks of life.
4- The flooring of the chick rearing sections was made of sand in Farm B while it was concreted in Farm A.

2.2 Methods of data collection

The following methods were followed in order to fulfill the study objectives

2.2.1 Egg production

Daily egg production was recorded for both study farms. In Farm A, eggs produced by both the original breeders and the locally produced breeders were recorded in Form number 01 (Appendix I) while for Farm B, only the eggs produced by the original breeders were included. The pattern of egg laying was followed by recording the eggs laid in the afternoon, which were collected before sunset, compared to the eggs laid during the night which were collected in the next morning (Form number 02; Appendix II).

2.2.2 Hatchery procedure and records

Upon arrival of eggs to the hatchery, defective eggs were recorded in Form number 03 (Appendix III).

Results of candling (fertility assessment) were recorded in Form number 04 (Appendix IV).

The incidence of the different types of chick deformities were recorded (Form number 05; Appendix V) and were summarized for the whole production season in Form number 06 (Appendix VI).

The condition and status of hatched chicks and dead embryos were recorded after full completion of the incubation and hatching operation (Form number 07; Appendix VII).

A final hatchery report that recorded and summerized the whole hatching operations throughout the season was used. These data included total number of incubated eggs, fertility rate, embryonic mortality, hatchability rate and number of hatched chicks (Form number 08; Appendix VIII).

2.2.3 Mortality and follow-up records

Chicks which died during the rearing phase (up to three months of age) were recorded in Form number 09 (Appendix IX) and results were summarized in Form number 10 (Appendix X).

The types of leg deformities that lead to death of the birds were recorded in Form number 11 (Appendix XI).

Causes of mortality in ostrich and emu chicks, ostrich and emu growers and ostrich and emu breeders were recorded in Forms number 12, 13 and 14, respectively (Appendices XII, XIII and XIV, repectively). A daily flock control chart was used for monitoring the daily mortality and cause of that mortality in each pen or room (Form number 15; Appendix XV).

2.2.4 Body weight monitoring in ostrich and emu chicks

2.2.4.1 Daily body weight gain of ostrich chicks in Farm A

Seven, one-day old ostrich chicks were randomly selected in Farm A for monitoring the daily weight gain and weight changes. The initial body weight of the chicks was recorded when received from the hatchery and then on daily basis for a period of 10 days.

2.2.4.2 Weekly body weight gain of ostrich chicks in Farm A and B

Five, one-day old ostrich chicks from both Farms, A and B, were randomly selected to monitor and compare their body weight gain during the first fourteen weeks of life. The initial body weight, when the chicks were received from the hatchery (day-one), was recorded and then the weekly weight was followed and recorded up to the end of the first 14 weeks of life.

2.2.4.3 Weekly body weight gain of ostriches in different ambient temperatures

Two groups (I and II), each of four newly hatched ostrich chicks, were randomly selected in Farm A for monitoring the body weight gain in different ambient temperatues. Group I birds were hatched in the summer (August) while Group II birds were hatched in the early winter (November). The birds were weighed on the day they were received from the hatchery (one day old), then weighed on weekly basis up to ten weeks of age.

2.2.4.4 Weekly body weight gain of emu chicks

Seven, one day old emu chicks in Farm A were randomly selected and weighed on day one, then weekly for a period of 15 weeks in order to monitor and compare the gain in body weight of emu chicks with that of ostriches.

2.2.5 Investigation of causes of mortality

All dead birds were necropsied to investigate the causes of death. Samples from internal organs of young chicks that died within their first month of life were taken to the laboratory for bacteriological investigation with special emphasis on the involvement of enterobacteriae in the aetiology of these mortalities.

2.2.5.1 Bacteriological methods

Blood and MacConkey agar media were used for inoculation of specimens from the livers of dead chicks while MacConkey agar was used for inoculation from selenite broth liquid media after 24 hours of incubation of inocula from the intestines. Identification of bacteria was done according to the conventional identification methods including culture and growth characteristics, Gram's staining reaction, bacterial morphology, motility test, primary identification tests (catalase, oxidase and urease tests) and finally by the use of biochemical tests for satisfactory identification of bacteria (Cowan and Steel, 1985).

2.2.6 Serum biochemical profile in leg-deformed ostrich chicks

Serum samples were collected from ostrich chicks manifesting tibiotarsal leg deformities. Sera were analyzed for the concentration of calcium, phosphorus, magnesium, manganese, copper, protein, cholesterol and for the activities of the enzymes alanine aminotransferase (ALT) and creatinine kinase (CK) using commercial test kits (Rhone-Merieux, Lyon, France).

2.2.7 Response of emus to low-cost feed alternatives

This experiment was carried out in Farm A to monitor the response of emus (*Dromaius novaehollandiae*), as judged by the change in body weight, when fed on low-cost feeds. Fifteen emu birds of nine months old were randomly selected and divided into three groups of five birds each. The birds in Group A were fed on pure lucerne (*Medicago sativa*) pellets while birds in group B were fed on pellets made of mixed grasses and shrubs that have grown haphazardly in the ostrich Farm A premises. Birds in Group C were fed on pellets made of a mixture of equal amounts of lucerne (50%) and mixed grasses and shrubs (50%, Group B feed). All birds were fed to appetite till the end of the experiment. The Birds were weighed at the beginning of the experiment and then on weekly basis for three months. The nutritional analysis of the three types of feeds is shown in Table 2.

An electronic balance (Bosch, PE 620) was used for weighing birds up to 3 kgs body weight whereas for heavier weights another weighing scale (Fulgor Co., Italy) of 500 kilogram capacity was used.

2.2.8 Natural ostrich eggs incubation trial

Five production units of ostriches, namely A1, B5, B20, C20 and D2, were selected in Farm B for natural incubation experiment. The main criteria for selection was the high egg fertility rate recorded for the eggs that originated from these units.

For A1 unit, after the female has laid four eggs in its original unshaded nest, a special triangular shade made of branches of date palm trees was erected inside the unit and the four eggs were transferred to the new nest.

For B5 unit, no special shade was made as nest because the female already laid five eggs under the original shade of the unit.

Table 2. Nutritional analysis of the three types of feeds

Content (%)	Pure lucerne pellets	Mixed grasses and shrubs pellets	Mixture of lucerne and grasses pellets
Crude protein	23.00	07.5	15.08
Moisture	08.50	06.07	09.31
Crude fibre	18.39	33.25	27.89
Ash	11.84	13.07	10.18
Crude fat	02.64	02.84	01.91
N.F.E.	35.63	37.27	34.91
Calcium	01.68	01.80	01.36
Total phosphorus	0.38	0.15	0.28
Chloride	01.20	0.99	01.02

For B20 unit, a special triangular shade was erected over the natural unshaded nest which was holding nine eggs laid over 20 days. Then the parents started alternating the incubation till hatching started. Non hatched eggs were opened and examined to investigate the causes of hatching failure.

For C20 unit, the nest shade was erected over the ten eggs laid by the female which kept all the time moving and rolling the eggs on the ground in and outside the shade till the end of the incubation period.

For D2 unit, four eggs were laid and the female stopped laying more eggs till the end of the observation period.

2.2.9 Drugs used for treatment and prophylaxis

Different drugs and vaccines were used in both farms during the study period to treat sick birds or to immunize susceptible ones (Appendix XVI). Selection was made according to availability in the local market together with the manufacturer's claim and guarantee for the therapeutic efficacy of the drug or immunogenecity of the vaccine.

Table 3. Average temperature and humidity in Al-Qassim Region during the period August, 1999 to July, 2000.

Month	**Temperature**	**Average relative humidity**
	Max (°C) – Min (°C)	**(%)**
August, 1999	45.0 -- 26.5	11
September	42.8 -- 25.2	14
October	37.6 -- 18.1	18
November	29.0 -- 13.6	33
December	22.7 -- 6.5	43
January, 2000	19.5 -- 5.8	46
February	22.5 -- 6.7	30
March	27.5 -- 10.0	21
April	36.4 -- 19.5	21
May	39.7 -- 22.7	16
June	43.2 -- 24.3	10
July	45.5 -- 28.1	11

Source: Al-Qassim Meteorological Station. LAT: 26 18 28N LONG: 43 46 03E

Elevation: 646.71 meter, Meteorology and Environmental Protection Administration, Kingdom of Saudi Arabia.

CHAPTER III

RESULTS

3.1 Ostrich egg production

Ostrich egg production in Farm A, as from January 1998 up to the end of the season 2002, is shown in Table 4 and Fig 2. Eggs produced in the 1998, 1999 and 2000 seasons were all laid by the original breeders (N= 268) while eggs produced in the 2001 and 2002 seasons included eggs laid by new breeders that were hatched in the farm. In the first three seasons, 1998, 1999 and 2000, the mean egg production was found to be 1.2, 7 and 23 eggs per female, respectively. The new breeders started egg laying as early as 19 months old with an average egg production of 12 eggs per female in the first season (2001).

Table 4. Ostrich egg production in Farms A and B.

№ of ostrich eggs							Month
Farm B		Farm A					
2003	2002	2002	2001	2000	1999	1998	
93	0	208	504	8	55	2	January
261	34	242	371	86	152	13	February
876	122	931	791	545	329	26	March
1737	332	1514	1102	1043	360	75	April
1716	609	1920	1329	1230	437	105	May
1095	425	990	962	822	134	53	June
931	582	293	553	511	175	25	July
526	440	424	102	269	95	0	August
689	302	526	382	410	34	6	September

0	276	291	651	339	6	7	October
0	0	1246	207	143	0	3	November
0	0	1770	53	342	1	7	December
7924	**3122**	**10355**	**7007**	**5748**	**1778**	**322**	Total

Ostrich eggs produced in Farm B throughout the 2002 and 2003 production seasons are also shown in Table 4 and Fig.2. It can be seen that with a less number of female breeders (N=225), egg production showed a sharp increase (153.8%) in the third production season of the farm (2003) with an average of 35.2 egg per female compared to the second season (2002) in which the average egg production was 13.5 egg per female (N=231). However, the 2003 season was intentionally terminated by the end of September, 2003. Egg production records for the first season (2001) were not available.

3.2 Emu egg production

Emu eggs produced in Farm A are shown in Table 5. Eggs produced during 1998/1999 and 1999/2000 seasons were laid by the same original breeders (N=200), while eggs produced in the following seasons included eggs produced by the new breeders that were hatched in the same farm. It can be noticed that, the emu breeders had an average egg production of 10 eggs per female in their first season in Saudi

Table 5. Emu egg production in Farm A. (1998/1999 – 2001/2002).

№ of emu eggs				**Month**
2001/2002	**2000/2001**	**1999/2000**	**1998/1999**	
14	6	0	0	September
360	191	47	30	October
2316	1164	364	208	November
3718	2261	805	619	December
2347	1823	936	686	January

431	517	294	348	February
149	103	69	96	March
17	31	20	16	April
0	0	0	0	May
0	0	0	0	June
0	0	0	0	July
0	0	0	0	August
9352	6096	2535	2003	Total

Arabia (1998/1999) compared to 13 eggs per female in the second season (1999/2000). It is noticeable that the majority (94.3%) of emu eggs were laid during November - February period coinciding with the winter months in Saudi Arabia whereas the production season extended from September to April which covered the coolest months of the year. The new emu breeders started egg laying at 22 months old with an average egg production of 6 eggs per female in the first season (2000/2001).

3.3 Pattern of egg laying

3.3.1 Pattern of ostrich egg laying

The diurnal pattern of ostrich egg laying in Farms A and B is shown in Table 6 and Table 7, respectively and also in Fig. 3. In both farms the majority of eggs were laid during the afternoon period, before sunset (diurnal pattern).

Table 6. Diurnal pattern of ostrich egg laying in Farm A (April – May, 2002).

Eggs laid during night		Eggs laid before sunset		Total № of recorded eggs	Month
%	№	%	№		
22.1	335	77.9	1179	1514	April
30	575	70.1	1345	1920	May
910 (26.5%)		2524 (73.5%)		3434	Total

Table 7. Diurnal pattern of ostrich egg laying in Farm B (January–February, 2003).

Eggs laid during night		Eggs laid before sunset		Total № of recorded eggs	*Month*
%	№	%	№		
20.4	19	79.6	74	93	January
40.2	105	59.8	156	261	February
124 (35%)		230 (65%)		354	Total

3.3.2 Pattern of emu egg laying

Table 8 and Fig. 3 show the pattern of emu egg laying. Unlike the ostriches, most of the emu eggs were laid during the night (i.e. nocturnal pattern) while very few were laid in the afternoon (before sunset).

3.4 Persistency of egg laying

3.4.1 Persistency of egg laying in ostriches

Table 9 and Fig. 4 show a comparison between the original ostrich breeders and new breeders on the persistency and continuity of egg laying from May to the end of the season (December, 2001). The original breeders showed sustained level of egg production that continued for a longer duration while their descendents, the new breeders, showed unsustained and non-persistent pattern of egg productivity. In both original and new ostrich breeders, August witnessed the lowest egg production after which there was a slight increase in egg laying before it dropped again at the end of the season in December.

Table 8. Nocturnal Pattern of emu egg laying in Farm A (October – November, 2001).

Eggs laid during night		Eggs laid before sunset		Total № of eggs	Month
%	№	%	№		
98.1	353	1.9	7	360	October
98.1	2273	1.9	43	2316	November

2626 (98.1%)	50 (1.9%)	2676	Total

3.4.2 Persistency of egg laying in emus

Table 10 and Fig. 5 show the persistency and sustainability of egg laying in original and new emu breeders. As in the ostriches, original emu breeders were more persistent and sustainable in egg laying compared to their descendants which stopped egg laying after a relatively shorter period.

Table 9. Persistency of egg laying in ostriches in Farm A (May, 2001 – December, 2001).

New breeders		Original breeders		Total egg production	Month
%	№	%	№		
7.9	105	92.1	1223	1328	May
13.2	127	86.8	835	962	June
12.3	67	87.8	480	547	July
19.6	20	80.4	82	102	August
5.5	21	94.5	362	383	September
4.3	28	95.7	621	649	October
0.5	1	99.5	206	207	November
2	1	98.0	50	51	December
370 (8.7%)		3859 (91.3%)		4229	Total

Table 10. Persistency of egg laying in emus (September, 2000 – May, 2001).

Eggs laid by new breeders		Eggs laid by original breeders		Total egg production	Month
%	№	%	№		
0	0	100	8	8	September

0	0	100	191	191	October
25.3	294	74.7	870	1164	November
34.3	775	65.7	1486	2261	December
31.3	570	68.7	1253	1823	January
6.6	34	93.4	483	517	February
0	0	100	103	103	March
0	0	100	23	23	April
0	0	100	5	5	May
1673 (27.4%)		4422 (72.6%)		6095	Total

3.5 Defective ratite eggs

3.5.1 Defective ostrich eggs

Table 11 shows the number and percentage of defective ostrich eggs in Farm A during three hatching seasons with an overall percentage of 11%. On the other hand, Table 12 shows the defective ostrich eggs in Farm B during the 2003 hatching season with a percentage of 6.7%.

3.5.2 Defective emu eggs

Defective emu eggs throughout four hatching seasons are presented in Table 13. As more eggs were laid, the percentage of defective eggs also increased. There were more defective eggs in the last two production seasons than the first two seasons.

Table 11. Defective ostrich eggs in Farm A.

%	№ of defective eggs	№ of laid eggs	Season
4.6	81	1779	1999
7.8	451	5751	2000
15.2	1065	7007	2001
11	1597	14537	Total

Table 12. Defective ostrich eggs in Farm B (January – September, 2003).

%	№ of defective eggs	№ of recorded eggs	Season
6.7	447	6684	2003

Table 13. Defective emu eggs in Farm A (1998/1999 – 2001/2002).

%	№ of defective eggs	№ of recorded eggs	Season
4.8	96	2003	1998/1999
1.8	46	2535	1999/2000
10.4	632	6094	2000/2001
18.5	1726	9343	2001/2002
12.5	2500	19975	Total

The different causes of egg defects in ostriches and emus in both Farms, A and B, are shown in Table 14 and Fig. 6. For the ostriches of Farm A, most of the defective eggs were undersized (34.5%) whereas for Farm B ostriches and Farm A emus, most had holes (44% and 24.9%, respectively). A higher percentage of emu eggs (19.9%) was rejected due to dirt compared to the ostrich eggs of both farms (7.5% and 7.0%, respectively).

3.6 Fertility of ratite eggs

3.6.1 Fertility of ostrich eggs

Fertility of ostrich eggs in Farms A and B, as judged by the percentage of fertile eggs, is shown in Table 15 while Fig. 7 shows the fertility pattern in ostrich eggs in Farm A. It can be seen that there was low mean fertility rate in Farm A ostrich eggs in the 1999 season (32.4%) compared to the rate in the following seasons which showed relatively higher fertility rates (55.6%, 60.7% and 61.2% respectively). It can also be noticed that the fertility rate of the incubated eggs was usually low (36.5%) at the beginning of the breeding season, then it improved with the progress of the season (67.6%) before it dropped again (47.7%) at the end of the season (2000 season). It is also notable that mean fertility and hatchability were lowest (59.2% and 63.5%, respectively) in eggs laid during July when compared to eggs laid during June and

August (Fig. 8). In Farm B, it can be observed that the mean fertility rate for the 2003 season (66.6%) was generally higher than that for the 2002 season (50.2%). The overall mean fertility rate in Farm B ostriches (58.4%) was generally higher than that in Farm A ostriches (52.5%).

3.6.2 Fertility of emu eggs

Fertility rate of emu eggs is shown in Table 16 and Fig. 9. The mean fertility rate in the first season (1998/1999) was higher (77.4%) than the fertility in the subsequent seasons (65.7% and 67.7%). The overall mean fertility rate of emu eggs in the three production seasons (70.3%) was generally higher than those means recorded for the ostrich eggs in Farms A and B (52.5% and 58.4%, respectively) (Table 15).

Table 14. The relative frequency of types of ostrich and emu egg defects.

Types of defect	**(%)**		
	Farm A ostrich eggs	**Farm B ostrich eggs**	**Farm A emu eggs**
Holes	26.9	44	24.9
Undersize	34.5	4.5	24
Chalky eggs	16.3	10.6	3.0
Cracks	8.0	8.3	14.9
Dirty shell	7.5	7.0	19.9
Rough shell	2.8	24.6	1.4
Oversize	2.1	0	11.8
Elongated eggs	2	1.0	0.1

3.7 Hatchability of ratite eggs

3.7.1 Hatchability of ostrich eggs

Hatchability rate of ostrich eggs in Farms A and B is shown in Table 17 and Fig. 10. It can be noticed that ostriches in Farm A had a lower annual mean fertility rate (52.5%) for the four seasons when compared to the overall mean hatchability rate of the fertile eggs (72.8%) throughout the four hatching seasons under study. It can also be observed that the hatchability pattern of ostrich eggs usually declines towards the middle and end of the production season compared to the hatchability at the beginning of the season (Fig. 10). The overall mean hatchability rate of ostrich eggs in Farm A (72.8%) was higher than that for Farm B (67.3%).

3.7.2 Hatchability of emu eggs

Table 18 and Fig. 11 show the hatchability rate of emu eggs throughout three hatching seasons. The hatchability pattern in emu eggs declined towards the end of the season compared to the pattern in the beginning of the season in two (1998/1999 and 1999/2000) out of three production seasons. It can be observed that the overall mean hatchability rate of emu eggs in the three seasons (62.9%) was relatively lower than the overall mean fertility rate of the emu eggs (70.3%) (Table 16) throughout three production seasons (Fig. 12).

3.8 Ratite chick production

3.8.1 Ostrich chick production

Ostrich chicks hatched in Farm A throughout the five production seasons from 1998 to 2002 were shown in Table 19 and Fig. 13. The chicks hatched in the seasons 1998, 1999 and 2000 were produced by the same original breeders (N=268) while those hatched in the seasons 2001 and 2002 included chicks originated from new

Table 15. Fertility rates of ostrich eggs in Farms A and B.

Fertility rates (%)						Month
Farm B		Farm A				
2003	2002	2002	2001	2000	1999	
No eggs	No eggs	54.0	49.7	No eggs	14.3	January
No eggs	No eggs	47.9	53.7	36.5	21.7	February
No eggs	No eggs	50.9	52.6	42.2	27.1	March
70.3	39.2	57.5	57.1	45.2	35.1	April

79.6	50.9	60.0	61.9	56.7	37.2	**May**
66.8	50.8	68.1	62.6	64.4	47	June
62.2	50.7	65.9	69.3	65.0	42.2	July
60.7	54.8	68.5	61.3	67.6	51.2	August
60.2	52.7	72.0	65.9	65.2	15.6	September
No eggs	52.5	66.7	60.5	63.3	No eggs	October
No eggs	No eggs	No eggs	66.2	57.9	No eggs	November
No eggs	No eggs	No eggs	67.4	47.7	No eggs	December
66.6	50.2	61.2	60.7	55.6	32.4	Mean (%)
58.4 %		52.5 %				Overall mean Fertility (%)

breeders. It is noticeable that the majority of chicks were hatched during April - August period (72.7%) while hatching extended throughout the whole season particularly during the last two seasons (2001 and 2002).

Ostrich chicks hatched in Farm B during the seasons 2002 and 2003 are also presented in Table 19 and Fig. 13. There is a proportional increase in the number of chicks hatched in the season 2003 with the number of eggs laid in that season compared to the season 2002.

3.8.2 Emu chick production

Emu chicks hatched in Farm A are shown in Table 20 and Fig. 14. In the first two seasons (1998/1999 – 1999/2000) there was a proportional increase in chick production together with the improvement that happened in the number of eggs laid by the original breeders. However, chicks produced in the following seasons included those hatched from eggs laid by the new breeders.

Table 16. Fertility rates of emu eggs in Farm A (1998/1999 – 2000/2001).

Fertility rates (%)			**Month**
2000/2001	**1999/2000**	**1998/1999**	

No eggs	No eggs	No eggs	September
60.0	No eggs	No eggs	October
71.7	84.0	58.5	November
70.1	80.7	91.7	December
71.1	75.2	93.4	January
62.8	66.1	91.6	February
70.6	34.9	71.4	March
No eggs	53.3	57.9	April
67.7	65.7	77.4	Mean (%)
70.3%			Overall mean fertility (%)

3.9 Embryonic mortality

3.9.1 Embryonic mortality in ostrich eggs

The incidence of early embryonic mortality and late embryonic mortality in Farm A ostrich eggs is shown in Table 21. The majority of embryonic mortality in ostrich eggs (59.9%) was in late developmental stages during the last two weeks of incubation whereas 40.1% were mortalities happened during early embryonic development in the first four weeks of incubation as indicated by the dead embryo size.

Table 17. Hatchability rates of ostrich eggs in Farms A and B.

Hatchability rates (%)						**Month**
Farm B		**Farm A**				
2003	**2002**	**2002**	**2001**	**2000**	**1999**	
No eggs	No eggs	81.1	78.2	No eggs	83.3	January
No eggs	No eggs	84.1	86.3	78.1	70.0	February
75.5	No eggs	83.3	90.2	91.9	74.1	March
81.0	83.1	83.8	75.1	90.9	80.9	April
78.0	80.7	84.2	61.6	84.7	75.0	May
72.0	80.1	87.5	59.9	79.7	57	June
47.1	73.2	80.2	44.3	76.5	59.7	July

54.0	61.0	84.5	63.2	92.8	50.8	August
60.8	45.9	81.6	51.7	94.5	60.0	September
No eggs	49	54.8	65.2	93.1	No eggs	October
No eggs	No eggs	No eggs	51.0	87.1	No eggs	November
No eggs	No eggs	No eggs	48.5	88.2	No eggs	December
66.9	67.6	80.5	64.6	87.1	67.9	Mean (%)
67.3%		72.8%				Overall mean hatchability (%)

3.9.2 Embryonic mortality in emu eggs

Table 22 shows the embryonic mortality in emu eggs. As in the ostriches, embryonic mortality in emu eggs was mostly (66.4%) of the late type compared to early type (33.6%).

3.10 Chick congenital deformity

Table 23 shows the incidence of ostrich and emu chick congenital deformities. Emu chicks had higher (19.4%) incidence of congenital deformities than ostrich chicks (4.1%). Table 24 shows the relative frequencies and types of congenital deformities recorded in ostrich chicks arranged in descending order while Table 25 shows the types of congenital deformities in emu chicks arranged in the same order.

Table 18. Hatchability rates of emu eggs in Farm A (1998/1999 – 2000/2001).

Hatchability (%)			**Month**
2000/2001	**1999/2000**	**1998/1999**	
67.9	No eggs	No eggs	October
55.5	73.7	60.5	November
64.2	75.2	47.9	December
60.4	77.6	55.3	January
60.2	76.7	52.9	February
71.7	72.7	51.3	March
No eggs	62.5	45.5	April

63.3	73.1	52.2	Mean (%)
62.9%			Overall mean hatchability (%)

Table 19. Monthly frequency of ostrich chicks hatched in Farms A and B.

№ of ostrich chicks							Month
Farm B		Farm A					
2003	**2002**	**2002**	**2001**	**2000**	**1999**	**1998**	
0	0	21	81	0	0	0	January
0	0	39	146	0	3	0	February
0	0	48	153	10	10	9	March
0	0	169	171	71	41	7	April
485	19	427	412	255	82	13	May
555	254	667	449	419	102	15	June
628	188	785	596	555	74	10	July
200	207	311	394	395	32	3	August
144	152	45	146	129	44	1	September
112	119	249	71	155	5	0	October
19	80	141	274	216	0	0	November
0	19	37	248	141	0	0	December
2143	1038	2939	3141	2346	393	58	Total

Table 20. Monthly frequency of emu chicks hatched in Farm A (1998/1999 - 2001/2002).

№ of emu chicks				**Month**
2001/2002	**2000/2001**	**1999/2000**	**1998/1999**	
0	0	0	0	August
0	0	0	0	September
0	0	0	0	October
0	0	0	0	November
205	104	0	0	December

830	376	202	151	January
503	810	400	321	February
463	556	559	278	March
167	42	116	153	April
25	38	14	22	May
0	0	5	3	June
0	0	0	0	July
2193	1926	1296	928	Total

Table 21. Embryonic mortality in ostrich eggs in Farm A (1999 - 2002).

Late mortality		**Early mortality**		**Total dead embryos**	**Season**
%	**№**	**%**	**№**		
52.7	97	47.3	87	184	1999
63.3	243	36.7	141	384	2000
56.4	190	43.6	147	337	2001
67.2	391	32.8	191	582	2002
921 (59.9%)		566 (40.1%)		1487	Total

Table 22. Embryonic mortality in emu eggs in Farm A.

Late mortality		**Early mortality**		**Total dead embryos**	**Season**
%	**№**	**%**	**№**		
71.1	560	28.9	228	788	1998/1999
70.3	317	29.7	134	451	1999/2000

61.7	807	38.4	502	1309	2000/2001
67.2	706	32.8	345	1051	2001/2002
2390 (66.4%)		1209 (33.6%)		3599	Total

Among ostrich chicks, the most common type of congenital deformities were the open navel conditions (approximately 40%) followed by leg deformities (22%), oedematous chicks (21%) and then chicks with head between legs (10%). Other recorded deformities were minor and included chicks with star gazing attitude, head deformity, beak and eye abnormality and finally chicks with extra finger.

Table 23. Incidence of congenital deformities in ostrich and emu chicks in Farm A.

Particular	Ostrich	Emu
Number of batches followed	44	23
Production season	2001	2001
Total number of hatched chicks	2793	2193
Total number of deformed chicks	114	426
Percentage of deformed chicks	4.1%	19.4%

In emu chicks, on the other hand, the predominant congenital abnormalities were leg deformities and open navels (25%, each), followed by chicks with nervous circling manifestations (circling chicks) (16%) and then oedematous chicks (approximately 12%). Other recorded deformities included star gazing attitude, eye abnormality, neck deformity, head between legs, deformed beak and, finally, chicks with head deformity.

Table 24. The relative frequencies and types of congenital deformities in ostrich chicks in Farm A (N = 114).

Serial №	Description of the deformity	№ affected	%
1	Open navel	45	39.5
2	Leg abnormality	25	21.9

3	Oedematous chicks	24	21.1
4	Head between legs	11	9.7
5	Star-gazing attitude	3	2.6
6	Head deformity	3	2.6
7	Beak abnormality	1	0.9
8	Eye abnormality	1	0.9
9	Extra finger	1	0.9
Total		114	100

Table 25. The relative frequencies and types of congenital deformities in emu chicks in Farm A (N = 426).

Serial №	Description of the deformity	№ affected	%
1	Leg abnormality	107	25.1
2	Open navel	107	25.1
3	Nervous conditions	69	16.2
4	Oedematous chicks	51	12
5	Star gazing attitude	24	5.6
6	Eye abnormality	23	5.4
7	Neck deformity	20	4.7
8	Head between legs	17	4
9	Beak abnormality	5	1.2
10	Head deformity	3	0.7
Total		426	100

3.11 Daily body weight gain of ostrich chicks

Table 26 shows the daily body weight records of seven ostrich chicks in Farm A for ten days. The daily weight gain of each of the seven chicks up to the 10th day and the mean of the total daily weight gain of the seven chicks are presented in Table 27. Young ostrich chicks gained very little body weight in the first two to three days compared to the following days which showed higher and accelerated daily weight gain. The increase in weight gain was found to be non-consistent and did not follow a stable and specific pattern. Moreover, the mean of the total daily body weight gain for the seven chicks was found to be negative (-14.8 grams) in the 8th day (Fig.15).

3.12 Weekly body weight gain of ostriches in both Farms.

The weekly body weight and total weekly body weight gain in ostrich chicks during the first 14 weeks of life are presented in Table 28 for Farm A and in Table 29 for Farm B. It can be noticed that the total body weight gain of the five ostriches in Farm B was negative (-10 grams) at the end of the first week while it was 580 grams in Farm A. The total weekly body weight gain of the five birds at week 14 was 2600 grams in Farm A while it was 18350 grams in Farm B. The total body weight of the five birds in Farm A at week 14 was 54130 grams while it was 159650 grams in Farm B. The faster growth pattern in Farm B ostriches compared to Farm A is presented in Fig. 16. Proximate analysis of the starter feed used in feeding the experimental birds in the two farms is shown in Table 30.

3.13 Weekly ostrich body weight gain in different ambient temperatures

Table 31 shows the individual and total body weight and weight gain of the four birds in Group I which was hatched on mid of the summer season (August, 2002) while Table 32 shows the same data for Group II which was hatched on the beginning of the winter season (November, 2001), both in Farm A. The growth rate of ostrich chicks hatched during the summer (Group I) was better, more stable and less fluctuating than that of the chicks hatched during the winter (Fig. 17). Both groups had similar growth rates for the first six weeks, but started to manifest remarkably different growth rates from week 8 onwards. Winter hatched chicks (Group II) had a net negative weight gain by the 10th week when the experiment was terminated.

Table 30. Proximate analysis of starter feeds used in Farms A and B.

Farm	Moisture (%)	Dry matter (%)	Crude protein (%)	Crude fibre (%)	Ether extract (%)	Ash (%)	Nitrogen free extract (%)	Phosphorus (%)
A	4.30	95.70	24.26	14.80	4.90	9.40	42.34	1.40
B	4.00	96.00	23.18	15.50	4.70	16.5	36.12	1.30

The total gain in body weight of the four chicks in Group I was 26300 grams while it was 14270 grams for the ostriches in Group II. The mean weight gain was 6575 and 3567.5 grams per chick in 10 weeks for the ostriches in Groups I and II, respectively.

3.14 Weekly body weight gain in emu chicks.

Table 33 shows the weekly weight records of the seven emu chicks up to the age of 15 weeks. Table 34 shows the weekly individual and total weight gain records besides the mean weekly weight gain of the seven emu chicks. As in ostrich chicks, the weight gain in emu chicks was also fluctuating and did not follow a stable and specific pattern (Fig. 18). However, the degree of fluctuation in weight gain of emu chicks was less than that in the ostrich chicks. Moreover, the pattern of weight gain in emu chicks for the first fourteen weeks of life showed a positive pattern unlike the case in ostrich chicks which showed a negative pattern (Table 27 and Fig. 15).

3.15 Mortality in ostrich and emu chicks during rearing phase

3.15.1 Mortality in Farm A ostrich chicks during rearing phase

Ostrich chick mortality during rearing phase (up to three months old) in Farm A throughout the 2000 season is shown in Table 35 and Fig. 19. The overall average mortality rate during this period was found to be 29.1%. High mortality rates (> 30%) were recorded during January, March, May and June. Similar high mortality rates were also recorded in November and December. The pattern of the mortality was also fluctuating and non-consistent.

The ostrich chick mortality during rearing phase in chicks that were hatched in Farm A during May, 2000 was found to be 47.8% whereas the mortality in ostrich chicks that were hatched in Farm B during May, 2003, was found to be 57.6%. These mortality rates are, however, higher than the overall average chick mortality rate during the rearing phase in Farm A throughout one year (29.1%) (Table 35).

Table 35. Ostrich chick mortality during rearing phase in Farm A (2000).

Mortality		№ of followed chicks	Month of hatch
%	№		
32.1	26	81	January
26.0	38	146	February
41.2	63	153	March
23.9	17	71	April
47.8	122	255	May
38.4	161	419	June
22.3	124	555	July
14.4	57	395	August
25.6	33	129	September
17.4	27	155	October
36.6	79	216	November
29.8	42	141	December
29.1%	789	2716	Total

3.15.2 Mortality in emu chicks during rearing phase

The mortality in emu chicks during rearing phase for the season 2000/2001 is presented in Table 36. It can be noticed that the overall mortality in emu chicks during rearing phase for the whole season (21.6%) is lower than the mortality in ostrich chicks (29.1%). Fig. 20 compares the mortality in emu chicks during rearing phase in two production seasons (1999/2000 and 2000/2001). It can be noticed that there was no specific pattern of mortality throughout the two seasons.

3.16 Causes of mortality

3.16.1 Causes of mortality in ostriches

The causes of mortality in Farm A ostrich chicks throughout the four years (1998 – 2001) are presented in Table 37. Leg deformities were found to be the main cause of mortality (33.7%) followed by fading chick syndrome (FCS) (19.4%). Other notable causes of mortality included Newcastle disease (NCD) (17.7%) and enteritis (15%).

Table 36. Emu chick mortality during rearing phase in Farm A.

Mortality		№ of followed chicks	Month of hatch
%	№		
20.19	21	104	December
42.02	158	376	January
15.06	122	810	February
17.27	96	556	March
21.43	9	42	April
26.32	10	38	May
21.6%	416	1926	Total

The causes of mortality in ostrich growers in Farm A throughout the same four production years are shown in Table 38. Sand impaction was found to be the main cause of mortality (55.3%) while NCD, leg deformity and enteritis were other notable causes.

Regarding the ostrich breeders, the causes of mortality in Farm A throughout the four years of study are shown in Table 39. Septicaemic pasteurellosis (67.7%) was found to be the most killing problem in ostrich breeders. All mortalities due to septicaemic pasteurellosis took place during the summer seasons when the ambient temperatures were at the maximum. Other important causes of mortality included wounds and accidents inflicted during fights leading to broken necks, wound infections and peritonitis.

For comparison, the causes of mortality in Farm B ostrich chicks, growers and breeders during one year (October, 2002 - September, 2003) are presented in Tables 40, 41 and 42, respectively. In contrast to Farm A, fading chick syndrome (FCS) was the leading cause of death in Farm B ostrich chicks (approximately 58 %) followed by leg deformity (13%), enteritis (12%), sand impaction (4.6%) and suffocation (4%). It is notable that NCD was not incriminated as a cause of mortality in Farm B ostriches during the period of study (October 2002 – September, 2003).

Regarding Farm B ostrich growers, leg deformities and septicaemic pasteurellosis were the main causes of mortality (51.0% and 20.4%, respectively).

The infectious disease, septicaemic pasteurellosis, was the main cause of mortality in Farm B ostrich breeders (38.5%) followed by accidents and fractures as secondary notable causes of death.

Table 40. Causes of mortality in ostrich chicks in Farm B (N = 878) (October, 2002 - September, 2003).

(%)	№	Causes of mortality
57.9	508	Fading chick syndrome
13	114	Leg deformity
12.1	106	Enteritis
4.6	40	Sand impaction
4.1	36	Suffocation
3.8	33	Yolk sac retention/infection
1.6	14	Accidents
1.3	11	Congenital deformity
1.1	10	Drowned in a drinker
0.6	5	Killed by cats (predation)
0.1	1	Others
100 %	878	Total

3.16.1.1 Causes of mortality in Farm B ostrich chicks in two production seasons

Table 43 and Fig. 21 compare the causes of mortality in Farm B ostrich chicks during two production seasons, namely 2002 and 2003. It can be seen that there was no mortality due to sand impaction in 2003. Deaths due to fading chick syndrome and enteritis were increased from 36.6% and 3.5% in 2002 season to 62.5% and 13.9% in 2003 season, respectively.

Table 41. Causes of mortality in ostrich growers in Farm B (N=49) (October, 2002 - September, 2003).

(%)	№	Causes of mortality
51.0	25	Leg deformity
20.4	10	Septicaemic pasteurellosis
10.2	5	Enteritis
4.1	2	Broken neck
4.1	2	Broken leg
10.2	5	Others
100 %	49	Total

Table 42. Causes of mortality in ostrich breeders in Farm B (N = 13) (October, 2002 - September, 2003).

(%)	№	Causes of mortality
38.5	5	Septicaemic pasteurellosis
30.8	4	Accidents
15.4	2	Broken leg
7.7	1	Arthritis
7.7	1	Snake bite
100%	13	Total

3.16.2 Causes of mortality in emus

The causes of mortality in emu chicks in Farm A throughout four years (1998 – 2001) are shown in Table 44. Leg deformities were the most common cause of mortality (37.1%) followed by suffocation (31.1%). It is notable that no mortalities in emu chicks were attributed to sand impaction or Newcastle disease throughout the whole study period.

The causes of mortality in emu growers in Farm A during the same four years are presented in Table 45. Leg deformities (45.4%) were the main cause of mortality in emu growers followed by suffocation and infected wounds inflicted during fighting (14.6%, each). It is notable that, unlike the case in ostrich growers, emu growers had no mortalities due to sand impaction, Newcastle disease (NCD) or intestinal torsion. Foxes were found to be the main predators attacking emu growers during nights.

Table 46 shows the causes of mortality in emu breeders in Farm A during the four years of study. Egg peritonitis (27.8%) was the main mortality factor among emu breeders followed by accidents involving the neck (22.2%).

3.16.3 Comparison of causes of mortality in ostriches and emus

Table 47 shows the causes of mortality and percentages affected in ostrich and emu chicks in Farm A. It can be noticed that leg deformities comprised the most common cause of mortality in both species. Also we can notice that enteritis was more common in ostriches than in emus (15% versus 0.7%, respectively). There were no mortalities in emus due to Newcastle disease or due to sand impaction.

Table 48 shows the causes of mortality and percentages affected in ostrich and emu growers in Farm A. In ostrich growers, sand impaction and Newcastle disease still were the main causes of mortality whereas emu growers were not affected by these two causes. Also it can be noticed that emus were more affected by accidents of the leg and neck regions besides the fighting wounds and suffocation which resulted from huddling during cold nights.

The causes of mortality and percentages of affected ostrich and emu breeders are presented in Table 49. Ostrich breeders were more affected by septicaemic pasteurellosis than emus. Emu breeders, on the other hand, had more mortality rate due to enteritis, egg peritonitis, accidents on the neck region and infected fighting wounds.

3.17 Bacterial isolation

3.17.1 Bacterial isolation from dead ostrich chicks

Table 50 shows the results of bacteriological investigation on Farm A dead ostrich chicks. It can be noticed that *Escherichia coli* was isolated from 35.5% of the cultured samples while *Salmonella sp*. was isolated from 12.9% of the samples. A considerable percentage of the cultured samples (22.6%) revealed no bacterial growth.

3.17.2 Bacterial isolation from dead emu chicks

The results of bacteriological investigation on dead emu chicks are shown in Table 51. *Escherichia coli* was the main identified bacterial pathogen (33.3 %) while *Salmonella sp.* was isolated from 16.7 % of the samples. Other unidentified bacterial growths had a significant percentage (33.3 %).

The isolation of *Salmonella* species from dead ostriches and emus was a noticeable finding.

3.18 Mortality due to leg deformities

3.18.1 Mortality due to leg deformities in ostriches

Mortality due to leg deformities in Farm A ostrich chicks is shown in Table 52. Tibiotarsal rotation (84.1%) comprised the main lethal form of leg deformities in ostrich chicks followed by splayed legs (11.9%). The right leg was more often affected by tibiotarsal rotation than the left leg and the age of 2 to 4 weeks old showed the highest incidence of this problem.

Table 47. Causes and relative frequencies of mortality in ostrich and emu chicks in Farm A (N=8877; N=6343).

(%)		Causes of mortality
Emus	**Ostriches**	
37.1	33.7	Leg deformity
19.9	19.4	Fading chick syndrome
0	17.7	Newcastle disease
0.6	15	Enteritis
3.2	5	Yolk sac retention / infection
0	3.4	Sand impaction
31.1	1.1	Suffocation
0	2.3	Cold stress
6.6	0.7	Congenital deformity
0	0.2	Intestinal torsion
0.4	0.7	Drowned in a drinker
0	0.2	Eye problem
0.2	0.1	Accidents
0.8	0.5	Unidentified causes

Table 53 shows mortality due to leg deformities in ostrich growers in Farm A. Similarly, tibiotarsal rotation was found to be the most common lethal form of leg deformities in ostrich growers (78.5%) followed by slipped tendon (14%).

3.18.2 Mortality due to leg deformities in emus

Table 54 shows the different types of leg deformities which induced mortalities in Farm A emu chicks in the period 1998 - 2001. Tibiotarsal rotation (98.8%) was the most common lethal form of leg deformities in emu chicks followed by splayed legs (1.2%).

Table 48. Causes of mortality and percentage affected in ostrich and emu growers in Farm A.

(%)		Causes of mortality
Emus	**Ostriches**	
45.4	12.9	Leg deformity
0	55.3	Sand impaction
0	14	Newcastle disease
0.6	4.2	Enteritis
14.6	2.2	Suffocation
10.9	3.32	Broken leg
14.6	0.3	Infected fighting wounds
8.6	1.1	Broken neck
4.6	1.9	Killed by fox (predation)
0	1.8	Intestinal torsion
0.9	3.1	Unidentified causes

Table 49. Causes of mortality and percentages affected in ostrich and emu breeders in Farm A.

(%)		Causes of mortality
Emu	**Ostrich**	

8.3	67.7	Septicaemic pasteurellosis
11.1	2.1	Enteritis
0	1	Sand impaction
27.8	3.1	Egg peritonitis
22.2	7.3	Broken neck
2.8	9.4	Drowned in a drinker
13.9	0	Infected fighting wounds
2.8	6.3	Traumatic peritonitis
2.8	0	Snake bite
8.3	3.1	Unidentified causes

Table 50. Bacterial isolations from dead ostrich chicks in Farm A.

Bacterial isolation					**Cultured organ**	**Case history and necropsy findings**
No growth	**Other types of bacteria**	***E. coli* + *Salmonella* sp.**	***Salmonella* sp. (alone)**	***E. coli* (alone)**		
1	1	1	3	6	Liver and yolk fluid	Sudden death, retained yolk, Fatty liver
2	0	1	1	3	Liver and abdominal fluid	Sudden death, Fatty liver, accumulated abdominal fluid
0	2	1	0	1	Liver and intestinal content	Weakness, yellow liver, enteritis
4	3	0	0	1	Liver	Fatty liver

7	6	3	4	11	Total
22.6	19.4	9.7	12.9	35.5	Percentage (%)

Mortality due to leg deformities in emu growers is presented in Table 55. Tibiotarsal rotation (99.4%) still comprises the main lethal form of leg deformities in emu growers followed by valgus rotation (0.6%).

3.19 Response of emus to low-cost feed alternatives

Table 56 and Fig. 22 show the results of feeding emus low-cost three feed alternatives (pure lucerne pellets "Group A", pellets made of grasses and shrubs "Group B", and thirdly, "Group C" pellets which are made of a mixture of lucerne, "Group A", and grasses and shrubs "Group B"). It can be noticed that birds of Groups

A and C showed an almost similar pattern of total body weight gain. There was a preliminary up-rise in the total body weights of the birds in these two groups whereas birds of Group B showed a steady drop in total body weight in the first few weeks followed by an increase in the total body weight at the end of the fifth week when the feed was changed.

Table 51. Bacterial isolation from dead emu chicks in Farm A.

Bacterial isolation					**Cultured organ**	**Case history and necropsy findings**
No growth	**Other types of bacteria**	***E. coli* + *Salmonella* sp.**	***Salmonella* sp. (alone)**	***E. coli* (alone)**		

0	1	0	0	1	Liver, yolk fluid	Sudden death, fatty degeneration in the liver, retained yolk.
0	0	0	0	1	Liver, intestinal content	Sudden death, enteritis, Focal liver necrosis
2	0	0	1	0	Liver	Sudden death, pale visceral organs, yellow liver.
2	1	0	1	2	Total	
33.3	16.7	0	16.7	33.3	Percentage (%)	

Table 52. Mortality due to leg deformities in ostrich chicks in Farm A (1998 – 2001).

Type of leg deformity						Total № of mortality	Year
Osteo-malacia	**Twisted toes**	***Spalyed* legs**	**Valgus rotation**	**Slipped tendon**	**Tibiotarsal rotation**		
0	0	6(26.1)	0	0	17(73.9)	23	1998
2(1.9)	0	11(10.7)	0	3(2.9)	87(84.5)	103	1999
3(1.5)	0	30(14.6)	2(1	5(2.4)	165(80.5)	205	2000
3(0.8)	0	37(9.9)	3(0.8)	7(1.9	323(86.6)	373	2001
8(1.1)	0	84(11.9)	5(0.7)	15(2.1)	592(84.1)	704	Total

Figures between brackets are percentages.

Table 53. Mortality due to leg deformities in ostrich growers in Farm A (1998 – 2001).

Type of leg deformity						Total № of mortality	Year
Osteo-malacia	**Twisted toes**	**Splayed legs**	**Valgus rotation**	**Slipped tendon**	**Tibiotarsal rotation**		
0	0	0	0	1(33.3)	2(66.7)	3	1998
0	0	2(8.7)	1(4.1)	4(17.4)	16(69.6)	23	1999
1(1.9)	0	1(1.9)	2(3.8)	6(11.3)	43(81.1)	53	2000
0	0	0	0	2(14.3)	12(85.7)	14	2001
1(1.1)	0	3(3.2)	3(3.2)	13(14)	73(78.5)	93	Total

Figures between brackets are percentages.

Table 54. Mortality due to leg deformities in emu chicks in Farm A.

Type of leg deformity						Total № of mortality	Year
Osteo-malacia	**Twisted toes**	**Spalyed legs**	**Valgus Rotation**	**Slipped tendon**	**Tibiotarsal rotation**		
0	0	0	0	0	0	0	1998
0	0	1 (1.2)	0	0	84 (98.8)	85	1999
0	0	2 (2.2)	0	0	90 (97.8)	92	2000
0	0	1 (0.6)	0	0	166 (99.4)	167	2001

0	0	4(1.2)	0	0	340 (98.8)	344	Total

Figures between brackets are percentages.

Table 55. Mortality due to leg deformities in emu growers in Farm A.

Type of leg deformity						Total № of mortality	Year
Osteo-malacia	Twisted toes	Splayed legs	Valgus rotation	Slipped tendon	Tibiotarsal rotation		
0	0	0	0	0	0	0	1998
0	0	0	0	0	30(100)	30	1999
0	0	0	1(1.6)	0	61(98.4)	62	2000
0	0	0	0	0	67(100)	67	2001
0	0	0	1(0.6)	0	158(99.4)	159	Total

Figures between brackets are percentages.

3.20 Serum biochemical profile in ostrich chicks affected with tibiotarsal rotation

Table 57 shows the serum biochemical profile of ostrich chicks affected and non-affected with tibiotarsal rotation. As can be seen, no differences were detected in the concentration of serum calcium, phosphorus, magnesium, manganese and copper ($P>0.05$). No significant differences were also detected in the concentration of protein, cholesterol and creatinine kinase enzyme (CK) ($P>0.05$). However, there was significant difference ($P<0.05$) in the concentration of alanine aminotransferase enzyme (ALT) between affected and control ostrich chicks. Calcium:phosphorus (C:P) ratios of both affected and control chicks were similar with range of 1:3.5 and 1:3.7 respectively.

Table 57. Serum biochemical profile in ostrich chicks in Farm A .

Parameter	Affected chicks		Non-affected control chicks	
	Mean ± SD	**Range**	**Mean ± SD**	**Range**
Calcium (mmol/L)	2.46 ± 0.58	(1.15 - 4.45)	2.54 ± 1.15	(1.77-3.22)
Phosphorus (m/dl)	8.4 ± 6.27	(4.0 – 15.5)	9.12 ± 4.22	(5.5 – 18.5)
Magnesium (mmol/L)	0.88 ± 0.3	(0.32 - 1.82)	0.80 ± 0.48	(0.41-1.14)
Manganese (ppm)	6.28 ± 2.11	(3.7 – 12.8)	8.37 ± 2.13	(4.1 – 15.9)
Copper (ppm)	63 ± 12.36	(52 – 79)	58 ± 4.91	(41.3 – 75)
Protein (g/L)	35.39 ± 2.56	(27.4 – 40.12)	35.96 ± 4.73	(34.25 – 39.6)
Cholesterol (mg/100 ml)	124 ± 9.59	(109.1 – 147.8)	118.2 ± 14.79	(109.1 – 128)
A L T (I.U.)	228.9 ± 25.67*	(160 – 298)	275.5 ± 45.06	(243 – 298)
C K (I.U.)	1063.9 ± 793	(527 – 2206)	1243.3 ± 569.15	(645 – 2400)

* Denotes mean value significant (P<0.05).

3.21 Ostrich eggs natural incubation trial

Table 58 shows the results of natural ostrich eggs incubation trials. It can be noticed that three out of the five females (60%) did not incubate the eggs leading to failure of the hatching process. However, one (B20) of the two other females which incubated their eggs, yielded a relatively successful result giving four healthy chicks.

Table 58. Ostrich eggs natural incubation trial.

Possible causes of incubation and/or hatching failure	Outcome of incubation	№ of hatched chicks	Type of brooding shade	№ of laid eggs	Unit
1-Human interference and transferring the eggs to the special triangular shade. 2-The location of the unit being near the traffic road.	Eggs were not Incubated	0	Special brooding shade	4	A1
No obvious reason for not incubating the eggs.	Eggs were not Incubated	0	No special Brooding shade	5	B5
Remaining eggs showed early embryonic mortality possibly due to the high ambient temperature prevailing at the time (> 45˚C).	Eggs were incubated with relatively good results	4	Special brooding shade	9	B20
1-High prevailing ambient temperature (45- 46.5˚C) resulted in early embryonic mortality. 2-Frequent moving and rolling of the eggs in and outside the nest.	Eggs were incubated but hatching failed.	0	Special brooding shade	10	C20
1-No obvious reason for not incubating the eggs. 2-All the eggs were defective (porous shell).	Eggs were not incubated	0	Special brooding shade	4	D2

CHAPTER IV

DISCUSSION

Ostrich production is a fairly new mode of animal production practices in Saudi Arabia in particular and in the Middle East in general. The history of ostrich production in Saudi Arabia is backdated to 1995 when the first ostrich farm was established (Al Bukhary, 1998). Currently, there are more than twenty ostrich farms in Saudi Arabia holding a parent stock population ranging between 50 to 1100 breeder birds in each farm. Also there are many smaller ostrich holdings located in rest houses and backyard farms for recreational and fun purposes. Although there has been a world-wide increase in the number of farm-raised ratites over the past decade (Tully and Shane, 1996), ostriches (*Struthio camelus*) represent the main ratite species raised in Saudi Arabia followed by the emus (*Dromaius novaehollandiae*) which are kept mainly in two farms in Al-Qassim region. To our knowledge, very little research, if any, has been done on the commercial production and health performance of ratites in Saudi Arabia although ostriches were native to the Arabian Peninsula for fairly a long time ago (Cramp, 1986). This study presents basic data on the practical aspects of management, productivity and health performance of ostriches and emus in two farms in Al-Qassim region of Saudi Arabia.

The successive improvement in egg production of Farm A ostriches throughout the first three seasons since the arrival of the parent stock from France might indicate the need for the breeding stock to adapt to the new environment. This is particularly so, since the birds were imported from a distant area with major climatic and ecological variations between the two habitats (Sauer and Sauer, 1966). In this study 19 months was recorded as the age at which new ostrich breeders could start egg laying in Saudi Arabia yielding a mean of 12 eggs in their first production season. Shanawany and Dingle (1999) reported a later age (two years) for maturity and the start of laying by new ostrich breeders. The sharp increase in egg production in the third season compared to the second season in Farm B shows the gradual progress towards full maturity and full productivity by the new breeders during their first few years of production life. In their study of the seasonal plasma level of luteinizing and steroid hormones together with egg productivity in ostriches, Degen *et al.* (1994) reported that egg laying in the northern hemisphere occurred between March and September with peak numbers of eggs laid in May and June. The concentrations of plasma luteinizing hormone increased in February in both sexes and plasma testosterone concentrations in males increased in April (Degen *et al.,* 1994). These findings might also explain the seasonal pattern of egg laying in ostriches in Saudi Arabia. The temporary drop in egg laying during the period of high ambient temperature in this study (July and August) indicates the negative influence of excess heat on egg productivity of ostriches (Anon, 1999). This hypothesis is further supported by the fact that egg production has been noticed to resume its seasonal increase in the following relatively cooler months (September and October). Therefore, a better strategy should be adopted to allow for starting the production season earlier during the cooler months (November/December) instead of January/February. The higher ostrich egg production in the third season in Farm B (35.2 egg/female) by breeders produced locally in Saudi Arabia, compared to egg production in the third season since the arrival of Farm A breeders (23 egg/female) which were imported as mature birds, indicates that the local breeders performed better than the imported ones possibly due to better adaptation. In this regard, the merits of importing mature stock at the point of lay should be weighed against the expected better performance of locally grown stock. Inheritance or genetics, however, are also known to affect egg production (Shanawany and Dingle, 1999).

The more persistency and sustainability in egg laying of both ostrich and emu original breeders compared to their descendents, the new breeders, might be attributed to the full development of their reproductive system (Deeming and Angel, 1996). On the other hand, the short breeding cycle of ostrich and emu new breeders could be attributed to the immediate drop in gonadotrophins secretion to levels that are insufficient to support the reproductive hormonal requirements (Blache *et al*., 2001). The negative and passive influence of high ambient temperature on the egg laying persistency was prominent and manifested by the lowest number of ostrich egg laid during August months in all seasons (Anon, 1999).

The diurnal pattern of ostrich egg laying in both farms and the nocturnal pattern of the emus were in accordance with the patterns of egg laying by these two species in other parts of the world (Sauer and Sauer, 1966; Deeming, 1996). The advantage of the diurnal egg laying is that laid eggs could be collected and transferred to the hatchery section for storage before sunset, particularly during periods of high ambient temperature, in order to prevent development of the embryo when eggs were left in the pens during nights. Moreover, diurnal egg laying and immediate collection of the laid eggs would minimize the incidence of microbial contamination and other factors which reduce egg quality such as rolling of eggs on the ground or picking by other ostriches when eggs were left inside the pens for a longer period. Therefore, diurnal egg laying would definitely reduce the percentage of eggs rejected due to defects (Shanawany and Dingle, 1999).

The egg production season of emus, which usually starts in September and ends in March/April, was alternating with that of the ostriches because emus are short-day breeders and most of their eggs were laid during the winter. In emus plasma concentrations of luteinizing hormone and testosterone increase during short photoperiod days while their plasma prolactin level decreases (Malecki *et al*., 1998; Blache *et al.,* 2001). Since the production season of emus alternates with that of ostriches, the latter being long-day breeders, both ratite species were integrated in Farm A in order to maximize the utilization of land, farm capacities and labour. However, the new emu breeders were late maturing when compared to ostrich breeders (22 months versus 19 months) and were fewer egg layers in their first production season (6 eggs/female versus 12 eggs/female).

The higher percentage of defective ostrich eggs in Farm A compared to Farm B could be attributed to the husbandry system. Breeders in Farm A were kept on communal pens and laid eggs were more subjected to rough handling by other birds unlike Farm B breeders which were kept as couples in separate pens. The higher percentage of defective emu eggs during 2000/2001 and 2001/2002 seasons compared to the previous seasons could be attributed to the fact that the new breeders, unlike their ancestors which had a significant contribution in the laid eggs, were kept in communal pens. It is possible that eggs laid in communal pens were more prone to damage and soiling compared to eggs laid in couple pens. The identification and removal of abnormal or defective eggs is essential due to the reduced hatchability of these malformed eggs (Deeming and Ar, 1999; Gonzalez *et al*. 1999). The higher incidence of undersized ostrich eggs in Farm A compared to Farm B might be due to genetic reasons as these breeders were originated in France. The higher incidence of holes in Farm B ostrich eggs could be attributed to the rocky nature of the farm soil whereas the higher incidence of holes in defective emu eggs, compared to ostrich eggs, was possibly due to the relatively thin emu egg shell. The noticeable high tendency for defecation in emus might be a reason for the increased percentage of dirty and faecal-soiled emu eggs.

The high variability in fertility of ostrich eggs in different ostrich breeding countries is well documented in the literature (More, 1996a; More, 1996b; Cloete *et al.,* 1998; Deeming and Ar, 1999). Factors affecting fertility of ostrich eggs include male: female ratio, age, nutrition and health of breeding birds and inheritance (Shanawany and Dingle, 1999; Cabassi *et al.,* 2004). The proportional successive improvement of fertility rates in Farm A ostrich eggs through the different seasons could be due to the better adaptation of the birds to local environmental conditions besides the faster maturity attained by the breeders (Deeming and Ar, 1999). Ostriches in this farm had an average initial fertility rate of 32.4% in 1999 season, rising to 55.6%, 60.7% and 61.2% in the following successive seasons. The improvement in fertility with the progress of the season might be attributed to the fact that females come into production earlier than the males. The same effect could be a result of the slow increase in production of the luteinizing hormone and delayed increase in male plasma testosterone concentration at the beginning of the season (Murton and Westwood, 1977). The comparatively low fertility rate in eggs laid during July months (42.2% in 1999 season) could be due to the negative effect of the high ambient temperature (Gangwar, 1983). The improvement in fertility rate in Farm B ostrich eggs during 2003 season in contrast to 2002 season could be attributed to the established maturity attained by the male breeders in 2003 season (Fasenko *et al.,* 1992). Female breeders in communal pens could be mated by more males than in single pens leading to higher fertility rates (Malecki and Martin, 2003). However, the lower fertility rate in Farm A ostrich eggs compared to Farm B could very well be due to the fact that the dominant sterile or less fertile males would not allow other fertile, but less dominant males to mate. However, genetic and/or management reasons could also be responsible for the better fertility in Farm B ostriches (Gowe *et al.,* 1993; Deeming, 1995b).

The drop in fertility rate of emu eggs in the subsequent seasons compared to 1998/1999 season was attributable to the change in husbandry system. The keeping pattern, which was of the communal system in 1998/1999 season in which the fertility rate is usually higher (Malecki and Martin, 2003), was changed to single couple system in the following seasons leading to lower fertility. However, this advantage of increased fertility should be weighed against the higher incidence of defective eggs (i.e. eggs that could not be incubated). Since it was reported that emu eggs were found to contain male sperms for as long as 21 days after copulation, however, it might be concluded that mating on weekly basis in emus could be sufficient to produce acceptable fertility levels (Malecki and Martin, 2002).

The hatchability of ostrich eggs is considered to be low. It is reported to be around 50% in Britain and ranged from 35% to 70% in South Africa (Horbanezuk and Sales, 1998). Hatchability in the two farms observed for five seasons in this study ranged from 64.6% to 87.1%. There are no previous studies in Saudi Arabia with which these findings could be compared although the Arabian ostrich (*Struthio camelus syriacus*) once roamed in the desert plains of Saudi Arabia. The haphazard hunting of this Arabian subspecies resulted in its fragmentation into remote inhospitable regions within the Arabian Peninsula which ultimately resulted into extinction by the 1950s (Seddon and Khoja, 1998). However, currently the National Commission for Wildlife Conservation and Development (NCWCD) in Saudi Arabia is implementing a programme of captive breeding and reintroduction of the closest living relative of the Arabian ostrich, the red neck *Struthio camelus camelus*, from Sudan. This red neck subspecies is adapted to hot arid conditions and it is hoped that birds released in Saudi Arabia will survive and breed in the wild. The drop in hatchability pattern towards the mid of the season could be attributed to the negative effect of high ambient temperature on the efficiency of the incubating and hatching machines (Gangwar, 1983; Deeming, 1996). The improved annual mean hatchability rate of Farm A ostrich eggs compared to Farm B might be attributed to the better management and efficiency of hatching equipments in Farm A. Farm A incubators had an in-built water chilling system, which controls and regulates the internal temperature in contrast to Farm B incubation equipments which lack this facility leading to reduced hatchability rates (Sainsbury, 1992). The amount of egg weight loss during incubation as well as proper egg handling and storage are also important influencing factors on hatchability of ostrich eggs (Nahm, 2001).

In comparing the fertility and hatchability efficiency in ostriches and emus, it can be concluded that ostrich eggs had higher annual mean hatchability rate than the annual mean fertility rate. Malecki and Martin (2003) stated that ostrich flocks, generally, have high rates of egg fertilization and they attributed the infertility occurring in ostrich eggs to lack of sperm supply. Emus, on the other hand, had higher fertility rate and lower hatchability rate despite the fact that they copulate less frequently (once a week) compared to ostriches (Malecki and Martin, 2002).

The majority of ostrich and emu chicks were produced in the middle of the season for each species (April – August for the ostrich chicks and January – March for the emus) coinciding with the period of high egg laying. The continuation of chick production activity throughout the season, particularly in the last 2 – 3 seasons in Farm A, might indicate better adaptation of the breeders to the Saudi climate or that breeders had attained more maturity (Deeming and Ar, 1999).

An average of 60% late embryonic mortality was recorded in ostrich and emu eggs compared to 40% early embryonic mortality. The high percentage of late embryonic mortalities in ostrich and emu eggs could be due to insufficient water loss during incubation. This produces a too small air cell that brings about some difficulties in the hatching process such as suffocation (Ley *et al.,* 1986; Horbanezuk and Sales, 1998). Some other workers, on the other hand, considered the vertical positioning method of the longitudinal axis of the eggs, which has been used in these two farms, as a cause of embryonic deaths (Smith *et al.,* 1995). It was claimed that horizontal positioning for the first 2 – 3 weeks and then vertical positioning for the rest of the incubation period yielded better hatchability results and reduced embryonic mortality (Smith *et al.,* 1995). Yolk sac infection was also blamed as a cause of late embryonic mortality due to contamination of hatching eggs with bacteria which penetrate the egg shell leading to infection of the yolk sac and consequently embryonic mortality (Huchzermeyer, 1998). Pre-incubation of eggs, particularly by the male breeders, due to late egg collection with subsequent cooling and storage of the pre-incubated egg, was considered a main cause for early embryonic mortality (Shane and Tully, 1996). Other possible causes of early embryonic mortality include poor quality eggs, microbial contaminated eggs, poor storage conditions and incorrect incubation temperature (Deeming, 1997; Hassan *et al.,* 2004).

The remarkable variation in congenital deformities between ostriches and emus (4.1% versus 19.4%, respectively) might be attributed to genetic or managerial reasons in the incubation and hatching procedure (Deeming, 1997). The incidence and causes of malformations and other developmental abnormalities in ostriches are poorly documented in the literature (Deeming and Ar, 1999). Oedematous chick (Plate 1) could be due to high humidity rate in the incubator particularly during late incubation period (Ley *et al.,* 1986). Congenital deformities of the head, neck and limbs were attributed to nutritional deficiencies in parents, faulty incubation or to genetics (Huchzermeyer, 1998).

Poor or negative weight gain in young ostrich chicks during the first few days of life recorded in this study could be due to loss of body fluids and the utilization of the yolk material which usually takes place within the first 7 – 10 days (Guittin, 1987; Jensen *et al.,* 1992) or 2 – 3 weeks (Smit, 1963) post hatch. The lack of consistency in weight gain of young ostrich chicks has been attributed to high susceptibility to diseases, feeding habits, gastric impaction, embryo weakness (that necessitated assistance during hatching) and environmental alterations (Deeming and Ayres, 1994; Huchzermeyer, 1998). Similar observations were made by Deeming and Ayres (1994) who recorded negative weight gain in ostrich chicks up to 7 weeks post hatch. Female chicks were, however, reported to grow faster than their male partners (Deeming et al., 1993). The negative weight gain recorded in Farm B ostriches in their first week of life (-10 grams) compared to the positive weight gain in Farm A ostrich chicks (580 grams) could be due to variations between the two farms in management, hatchery equipments and hatching efficiency (Deeming, 1995b). The mean weekly weight gain of ostrich chicks in Botswana (1.3 kg) (Mushi *et al.,* 1998a) was higher than that recorded for Farm A ostrich chicks (0.71 kg) but lower than that recorded for Farm B ostrich chicks (2.2 kg). The remarkable variation in weight gain between Farms A and B ostrich juvenile birds could be due to managerial or genetic reasons since there were no differences in feed composition between the two farms (Jarvis, 1998). The influence of the ostrich breed on the bird growth rate was remarkable to the extent that Blue necks were cross-bred with the African blacks in Italy to improve body size (Sabbioni *et al.,* 1999). As of yet there are no standard ostrich breeds similar to those recognized in chickens. The designations Black, Blue or Red-necked ostriches are broad categories of ostrich ecotypes that do not strictly correspond to breeds. The sex effect on mature weight was reported to be less significant although adult males yielded heavier weights than females (Cilliers *et al.,* 1995). The slower growth rate of young ostriches in cold weather compared to warmer weather could be due to the energy expenditure for keeping warmth for the birds during winter and due to the increased number of feeding hours during the summer longer day hours (Jarvis, 1998). In this study, the maximal rate of growth in Farm B ostriches was found to be between 77 and 98 days of life (week 11 and week 14) which is similar to the age reported by Angel (1996) in ostrich chicks in Indiana, USA. Therefore, the growth of ostrich chicks can be considered as an important indicator for breeding quality (Guittin, 1987).

Although the fluctuation in growth rate of emu chicks was less than that in ostrich chicks, however, this fact indicates that ratite chicks, particularly ostriches, are delicate and their growth can be affected easily by many inhibiting factors (Huchzermeyer, 2002). The more stability in growth rate and the absence of negative weight gain in the first few weeks of life of emu chicks could indicate that emu chicks are less affected by growth inhibiting factors such as diseases and harsh environmental stresses compared to ostrich chicks. It can also be concluded that the regular weighing of chicks and their isolation and segregation into weight groups could have a role in the improvement of artificial rearing of ostrich chicks (Mushi *et al,* 1998a).

The negative influence of growth inhibiting factors on young ratites could also be seen in the fluctuating and inconsistent pattern of mortality in ostrich and emu chicks during the rearing phase. Certain periods in the season experienced higher mortality rates than other periods (Fig. 19). In this study, the mortality rate in Farm A ostrich chicks throughout one year (29.1%) was far less than the rates reported in South Africa by Smith et al. (1995) and Cloete *et al.* (2001) (40% – 50% and 78.4%, respectively). Cloete *et al.* (2001) also reported higher mortality rates at the beginning and end of the breeding season. Chicks with low body mass (below 762.5 g) at day-one or chicks hatched from eggs with excessive water loss (>18%) had higher mortality rates than heavier chicks. Mortality rates in rearing chicks were found to be proportionally related to the ambient temperature and the rate of mortality was decreased when a semi extensive rearing method was adopted by rearing young chicks on lucerne pasture (Verwoerd *et al.,* 1999b). Unspecified stress factors in the rearing environment of chicks were blamed as predisposing causes of high chick mortality (Cloete *et al.,* 2001). Again it can be concluded that emu chicks, unlike the ostriches, were less affected by lethal factors as they showed relatively lower overall mortality during rearing phase (21.6%) compared to ostriches (29.1%).

The significant role of leg deformities as a leading cause of mortality in ostrich and emu chicks cannot be overlooked. Leg deformities were identified as a major constraint on farmed ostrich production and the main cause of chick mortality both in Australia (More, 1996c) and South Africa (Bezuidenhout and Burger, 1993). The fading chick syndrome and Newcastle disease were other important causes of mortality, particularly in ostrich chicks. Fading chick syndrome is a phenomenon of not so well known aetiology characterized by gradual wasting out of affected chicks till mortality ensues. Verwoerd *et al*. (1999b) attributed the delay in immediate provision of feed to young chicks as a predisposing factor for this syndrome while others attributed the condition to a multiplicity of microbial agents (Shane and Tully, 1996). Newcastle disease was the cause of high mortality during one season (the year 2000) but was successfully controlled thereafter and was not incriminated in further mortality among Farm A ostriches beyond that season. The original immunization programme calling for first vaccination at 21 days was modified (Table 1) after the occurrence of the Newcastle disease outbreak by starting vaccine administration at day-one. In areas where Newcastle disease is known to be endemic in poultry, the risk of contracting the disease should be at highest for ratite farming and an efficient prophylactic programme is mandatory (Verwoerd, 2000). In this study, ostrich chicks below 21 days were affected proving that maternal immunity was not sufficient to protect chicks against infection by NCD. Vaccination of ostrich chicks when one day old was effective in controlling the disease. Enteritis, a multifactorial cause of mortality in intensively reared ostrich and emu chicks, was a significant cause of mortality in ostrich chicks. The disease assumed more severity during unfavourable conditions which lowered the bird's resistance. Hines *et al*. (1995) reported combined adenovirus and rotavirus infection with *Escherichia coli* septicaemia in an emu chick. Woolcock *et al.* (1996), on the other hand, isolated a paramyxovirus serotype 7 from the intestinal contents of two ostrich growers manifesting proliferative nonsuppurative enteritis and *Campylobacter jejuni* was incriminated as the primary pathogen. Necrotic or ulcerative enteritis caused by *Clostridium perfringens* type C could also be involved as a cause of chick mortality since these young birds were frequently subjected to stress conditions, particularly environmental extremes such as excessive cold and heat (Huchzermeyer, 1998). For prevention of enteritis, young chicks should be reared on pasture and enough amount of fibre should be included in the feed. Moreover, stressors and excessive use of antibiotics or proteins in the chick diets should all be avoided (Deeming *et al.,* 1996).

Sand impaction constituted the main cause of mortality in Farm A ostrich growers and was also an important cause of mortality in Farm A ostrich chicks. Mushi *et al.* (1998b), who described the condition in ostriches where sand was impacted in the proventriculus, gizzard and sometimes intestines, considered this problem as one of the major causes of debility and death in intensively farmed ostriches. Although the latter authors claimed that this condition has no age predisposition, the problem was observed only in juvenile and young growing ostriches (<5 months). Adult birds were not clinically affected although they were often seen ingesting large amounts of sand. The problem was controlled in Farm A rearing section by concreting the chicks grow-out runs. However, using small rock aggregates as litter in Farm A ostrich growers pens to combat the problem of sand impaction was not successful and impaction persisted (Plate 2). Later, in Farm B 2003 season, the problem was successfully controlled by using dried alfalfa hay as litter in the grow-out runs. The hay was consumed as a feed and also prevented ostriches from eating sand (Plate 3). Therefore, no mortalities were attributed to sand impaction among Farm B ostrich chicks or growers in 2003 season. Sand impaction causes gastric and intestinal stasis leading to starvation due to cessation of food passage, loss of weight and eventually death of the affected bird (Plates 4 and 5). It is also a leading predisposing factor for *Clostridial* enterotoxaemia (Shane and Tully, 1996). Adequate housing, better nutrition and care were considered as crucial in prevention of sand impaction (Yuksek *et al.,* 2002). Avoidance of using sand as a bedding for young chicks or growing ostriches is a common-sense preventive measure (Dinnes, 1972). Deaths in young ostriches due to stomach impaction by solid masses of lucerne or maize were not uncommon (Sato *et al.,* 1994). It worths mentioning that sand impaction was never recorded as a cause of death in emu chicks or growers in this study. This is perhaps because emus, unlike ostriches, are selective and good discriminate feeders.

Due to the propensity of ostriches to sit out in rainy weathers rather than seeking shelter (Deeming, 1997) and due to the fact that ostrich chicks have little subcutaneous fat (Jensen *et al.,* 1992), a notable percentage of mortality rate among ostrich chicks

(2.3%) was attributed to hypothermia resulting from cold stress and rains. Therefore, during weather extremes, ostrich chicks should be cared for and brought into shelter. This also helps to avoid certain thermoregulatory behaviours like huddling together as it might compete with other important activities such as feeding (Brown and Prior, 1998). There is also a need to increase potassium-calorie intake during cold weathers in order to satisfy the metabolic demands of extreme ambient conditions (Drenowatz, 1995).

The significant role of yolk sac retention or infection in Farms A and B ostrich chick mortality could be due to lack of yolk utilization and absorption or due to microbial infection by pathogens such as *Escherichia coli* and *Staphylococcus aureus.* This problem is particularly important in cases of poor hatcher hygiene and lack of bio-security measures (Grilli *et al.,* 1996). Yolk sac retention could result from low yolk utilization due to lowered overall energy expenditure for tissue maintenance as compared to other species (Gefen and Ar, 2001).

Although adult ostrich breeders are relatively resistant to diseases (Gonzalez, 1992), septicaemic pasteurellosis was a significant cause of mortality in adult ostriches (Plate 6). The disease was predisposed for by the heat stress during the summer season. Migratory birds were also suspected to transmit the infection to ostriches in Saudi Arabia (Elfaki *et al.,* 2002). Many efforts were taken to minimize the effects of septicaemic pasteurellosis on ostrich growers and breeders in Farm B during the summer as the disease constituted a leading cause of mortality among these two age groups. Preventive efforts included using water sprinklers and fog sprayers during hot hours of the mid day in order to reduce the heat stress. Secondly, antibiotics were added in the drinking water as a successful prophylactic measure against the opportunistic and normal inhabitant of the respiratory tract, *Pasteurella multocida* (Verwoerd, 2000). Presence of a stress factor such as sudden rainfall, relative humidity or temperature was claimed as the main predisposing factors for an outbreak of pasteurellosis in Kano Zoo (Okoh,, 1980). It worths mentioning that Farm B witnessed a severe outbreak of septicaemic pasteurellosis in the year 2001 in which 37% of the stock was affected and 41.7% case fatality rate was reported with the isolation of four different serotypes of *Pasteurella multocida* (Elfaki *et al.,* 2002). Due to the seriousness of this problem it might be justifiable to recommend the vaccination of ostrich birds using locally isolated serotypes of *Pasteurella* sp. (Elfaki *et al.,* 2002). On the other hand, emu breeders might be more resistant to *Pasteurella* infection since only 8.3% of the breeders mortality were attributed to pasteurellosis in contrast to 65.6% among ostrich breeders. Accidents, particularly neck and leg fractures (Plate 7) or accidents on fences during rainy nights as well as fighting between incompatible couples, all constituted other main causes of mortality among adult ostriches.

In Farm B, There were higher mortalities in ostrich chicks attributed to fading chick syndrome and suffocation compared to Farm A. This could be due to the overcrowding of chicks as a result of fewer number of rearing rooms and lack of suitable air conditioning facilities during extreme weather conditions. These unfavourable housing conditions subjected the young birds to severe stress and further suppressed their fragile immune system leading to more mortalities (Deeming and Ayres, 1994). The experience in NCD outbreaks in Farm A ostrich chicks and growers during the year 2000 season was utilized and a modified vaccination programme was applied in Farm B. Therefore, no incidence of NCD was reported in Farm B during the two seasons under study (2002 and 2003). Due to the outdoor system of ostrich housing, every effort should be taken to prevent the introduction of NCD into the farm. This particularly includes the control of wild birds (Huchzermeyer, 1998) as well as the strict application of prophylactic vaccination as the major tool for the control of NCD in ostriches (Bolte *et al.,* 1999). The sharp increase in mortalities caused by enteritis and fading chick syndrome among Farm B ostrich chicks in 2003 season compared to 2002 season was attributable to the shift in housing the chicks during the rearing period from a closed well-ventilated vacant quarter in the hatchery building in 2002 season to another building lacking proper ventilation and other necessary cooling facilities (Plate 8). That shift subjected the chicks to severe stress conditions in 2003 season leading to higher mortalities.

Emu chicks and growers were far less affected by microbial infections than ostriches. The main causes of mortalities in these emu chicks and growers were leg deformities and suffocation. Enteritis resulted in only 0.7% of the mortalities among emu chicks. This conclusion could also be supported by the fact that NCD outbreaks which affected Farm A ostrich chicks and growers during the 2000 season did not affect emu chicks sharing the same premises with the affected ostrich chicks. However, Heckert *et al*. (1999) was able to reproduce the disease by the experimental infection of two emus using a mesogenic strain of NCD virus.

Deaths due to suffocation could be avoided or reduced through managerial precautions, such as keeping birds in smaller groups, because emu chicks and, to a lesser extent, growers tend to huddle together during the cold nights. This huddling results in the death of some of these birds due to suffocation particularly if the number of the birds was too large. Emu growers also have great tendency towards fighting and usually the defeated or injured birds isolate themselves and roam along the fences seeking their ways out of the pen. This leads to more lacerations and skin injuries which aggravate the clinical condition of the bird leading to death (Plate 9). Deaths in emu growers due to predators, particularly foxes, could be lessened or controlled through poisoning of these foxes or use of better fencing materials. This latter precaution could also be useful in reducing deaths due to broken neck and legs. These took place mainly as a result of using inadequate and unsuitable fencing material especially when the birds were scared or disturbed (Dinnes, 1972). Since mortality is often directly linked to management conditions on the farm (Huchzermeyer, 2002), adequate shelters, proper fencing and enough space allocation are considered as the foundations of ratite flock health (Raines, 1998). The use of well designed and protected feeders and drinkers for each age groups can reduce unnecessary mortality due to falling in feed troughs or drowning in drinkers (Plates 10 and 11). Mounting of feeders or drinkers at the bird's chest height would be an additional satisfactory precautionary measure.

Deaths due to egg peritonitis in emu breeders might be due to the breakage of the thin-shelled emu eggs inside the oviduct and then passage of the contaminated yolk material into the peritoneum. Therefore, mortality due to egg peritonitis in emus could be minimized through better management and closer observation of the breeding stock for early identification of the affected female and immediate attendance and action.

The successful isolation of *Salmonella* species from dead ostrich and emu chicks necessitates more attention towards the control and elimination of these food-borne pathogens. Verwoerd (2000) considered *Salmonella typhimurium* as common in multispecies collections, causing considerable mortality in young ostrich chicks. After successful experimental infection of juvenile emus with *Salmonella pullorum*, Tully and Shane (1993) suggested that agglutination test could be included in routine health examinations in ratite farms. The high prevalence of *Escherichia coli* in dead ostrich chicks reported in this study was in line with the results of Ley *et al.* (2001) who found that 91% of the dressed ostrich carcasses sampled in the United States of America yielded *Escherichia coli* isolates while 0.7% yielded *Salmonella* isolates. Moreover, in their study on the microbial quality of ostrich carcasses produced at an export-approved South African abattoir, Karama *et al.* (2003) reported that the majority of *E. coli* isolated from these carcasses were collected after evisceration. Therefore, it is strongly recommended that the ostrich abattoirs personnel should observe, with more attention, the highest hygienic measures during operation to avoid contaminating the carcasses with these microbes. Since the isolation of the anaerobic bacteria from dead ostrich chicks was not attempted in this study, however, such bacteria are a possible cause of mortality. *Clostridium difficile*, *C. perferingens* and *C. sordelli* were recently isolated from young ostrich chicks that died of hepatitis (Shivaprasad, 2003). *Erysipelothrix rhusiopathiae* infection was described among adult emus in a semi-intensively managed farm in Australia in which 5% mortality was reported. Management agents were blamed as predisposing factors for this latter outbreak (Griffiths and Buller, 1991).

The role of tibiotarsal rotation (Plates 12 and 13) as the main killing type of leg deformities among captive ratites is well documented in the literature (Bezuidenhout and Burger, 1993; Bezuidenhout *et al.*, 1994; Huchzermeyer, 1998; Aisha, 2001). Mushi *et al.* (1999) reported 73% incidence rate of tibiotarsal rotation among the leg-deformed ostrich chicks in Botswana. The findings of the present study regarding the age group mostly involved and the right leg as being more affected were in line with the findings of Bezuidenhout and Burger (1993) and Mushi *et al*. (1999). The fact that the right foot of the hatching embryo has an important role in breaking the shell during pipping (Deeming, 1995a) might explain the higher incidence of tibiotarsal rotation affecting that extremity compared to the rarely affected left one. While analyzing the serum mineral profiles of ostrich chicks affected with tibiotarsal rotation, some authors found the mean serum manganese and zinc levels to be higher in the deformed chicks than the levels reported for the normal ones (Mushi *et al.,* 1999). However, others (Bezuidenhout *et al.,* 1994) reported increased serum zinc values and decreased serum calcium and phosphorus levels in affected chicks which resulted in poor bone mineralization and reactive osteoid formation. Moreover, in their observations on the development of long bones of ratite birds, Reece and Butler (1984) considered the presence of large cones of embryonic cartilage in the tibiotarsal bones of 3-week old ostriches while either not occurring or disappearing at earlier age in other species, as a contributing factor in this problem. In this study, no significant differences were encountered in the mineral profile of both affected and control ostrich chicks except for the enzyme alanine aminotransferase (ALT). The affected chicks had higher levels than the control chicks. The elevated ALT levels among affected chicks might be an indication of some damage to the skeletal and cardiac muscles or damage to the renal and pancreatic cells (Brar *et al.,* 2000). That damage, particularly to the cardiac and skeletal muscles, might, be a sequel to the leg affection and improper attitude during bird's movement. Other contributing factors in tibiotarsal rotation included heavy body weight laid by the fast growing chicks on their fragile cartilaginous tissues and the lack of enough exercise required by these young chicks (Guittin, 1986) as well as the weakness of the adductor muscles in the juvenile ostriches (LaBonde *et al.,* 1994). Splayed legs, the second common type of leg deformities in Farm A ostrich chicks, is the inability of the chick to adduct its legs due to the heavy weight of its distended abdomen. Thus the chick lies down most of the time and may die due to starvation. Tying the legs together using a piece of string was successful in restoring the lives of many ostrich chicks suffering from splayed legs (Plates 14 and 15). Slipped tendon, the second common type of leg deformities among ostrich growers, was too difficult to treat since the affected birds struggle to stand and the friction of the condyles of the hock joint eventually lead to a compound dislocation with an open wound which ultimately terminates fatally (Plate 16). However, by close observation, some developing cases could be identified before onset, and the swollen stifle joint together with the partially slipped gastrocnemius tendon were compressed together using a cotton bandage for 2 – 3 weeks after which some birds were successfully saved. Other notable, non-killing leg deformities included valgus rotation (Plates 17 and 18) and osteomalacia (Plate 19).

The trial of feeding emus on low-cost feed alternatives was carried out because Farm A had a big stock of the emu species (more than 3500 birds) which was costly to be fed on commercial feed supplies. Pellets made of pure alfalfa (lucerne) (Group A) and pellets made of a mixture of alfalfa and grasses and shrubs (Group C) proved that they can be used, at least temporarily, to sustain growing emu birds during periods of feed scarcity. However, pellets made of pure grasses and shrubs (Group B) were found, due to their poor nutritional value, unsuitable for supporting emus during feed scarcity periods because they resulted into continuous drop in body weight. Feeding low-protein diets to ratites was proved to induce loss of body weight, production of fewer eggs at longer intervals and hatching of fewer chicks with poor survivability (Brand *et al*., 2003). These latter authors have concluded that a diet containing 8.5 MJ ME /Kg dry matter should be regarded as the minimum that can be used for breeding female ostriches. Moreover, this feeding trial could indicate that emus, like ostriches, are efficient in fibre digestion and utilization, thus, justifying feeding them on relatively low-cost bulky, high-fibre feed alternatives to economize ratite production. However, the ability of the emu to digest and metabolize plant fibre may assist its survival during periods of decreased food quality (Herd and Dawson, 1984). Since plant protein sources could make a considerable energy contribution to diets for ostriches, it is essential to use energy values of foodstuffs determined using ostriches and not extrapolated values derived from poultry in diet formulation for ostriches (Cilliers *et al.,* 1999).

The poor success of the natural incubation trials of ostrich eggs in this intensive farming system (Plate 20) might be attributed to several reasons. These include the very high ambient temperature during the period of experimentation compared to the optimum incubation temperature required for ostrich eggs leading to unsuitable nest microclimate. This drastically affects embryonic growth and development (Bertram and Burger, 1981; Swart *et al.,* 1987). Other possible reasons for the natural brooding failure include the long period that the eggs have to wait for in the hot ambient temperature and low humidity before incubation begins (Horbanezuk and Sales, 1998). Another not well studied factor could be the unsuitability of the noisy farming conditions in intensive ostrich farms, compared to the calm conditions and more suitable ecology in the wild where natural brooding usually takes place. Human interference through handling and transferring of eggs from the natural nests to the special brooding shades erected purposely for the experiment might have contributed in the natural brooding failure. Although bacterial infection might not have been a common cause of incubation failure in the well managed artificial incubation practice (More, 1996b), however, it could be a contributing factor in the failure of this natural brooding trial since the eggs were not subjected to any microbial disinfection. Successful natural incubation trials in British zoos were reported but with low production levels (Deeming, 1997). Many African producers prefer natural incubation of ostrich eggs because they feel that chicks hatched with artificial incubation are not as healthy. However, fewer chicks survive under natural incubation since in the nature only the strongest and fittest chicks survive and dominate (Sell, 1993).

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

5.1 Conclusions

There has been a world-wide increase in the number of farm-raised ratites. Ostriches, emus and rheas are being produced commercially outside their natural or native habitat resulting in new and unique disease manifestations. Scientific knowledge of ostrich diseases is incomplete and highly fragmented with almost complete absence of specific details on technical aspects of diagnostic and screening tests. Biosecurity, balanced nutrition and adequate management will reduce the likelihood of flock exposure to pathogens and limit the mortality in cases of infection episodes (Tully and Shane, 1996a). Artificial rearing of ostriches requires high standards of management and allocation and expenditure of big financial capital thus emphasizing the need for total commitment from the farmer to ensure the success of this industry and avoid failure of investment. Due to the paucity of data regarding ostrich diseases and the invalidated state of most poultry diagnostic tests in this unique group of birds, strict observation of a pre-slaughter quarantine of thirty days in endemic regions is strongly recommended while live exports and fertile eggs should be screened through the additional use of sentinel chickens and/or young ostriches (Verwoerd, 2000). Being highly stress susceptible, ostriches should be kept away from stressors by measures such as adequate husbandry techniques and proper housing facilities, sited away from the main roads to minimize noise from traffic.

Production-wise, ratite industry, particularly ostrich breeding, will remain as a viable and highly feasible branch of animal production. However, it is an expensive farming business with the cost of feed, labour and stock purchases being the most costly aspects in this industry. Thus, until further expansion in production and marketing promotion efforts occur, ratite operations are likely to be faced with low or even non-existent profits (Gillespie and Schupp, 1998). Although ostrich production is in the market introduction stage of evolution, lack of sufficient consumer demand constitutes a major constraint to this industry in Saudi Arabia. There are low or even non-existent profits coming out of this commercial enterprise at the present time. Therefore, in order for the ostrich industry to become a more viable agricultural enterprise, markets for meat, leather and feathers need to be further developed. Although, the demand for ostrich meat is increasing worldwide at a slower rate than supply, prices might show further decreases which would depress the industry producers (Gillespie and Schupp, 1998). Locally, many producers are thinking seriously to quit this field of investment although some producers were observing a slow but significant progress towards market development for the ostrich industry while the future of the emu industry was considered to be much less certain.

In the meantime, a nucleus of Ostrich Producers Trade Union was under establishment in order to coordinate, organize and consolidate the different activities and to solve the problems facing ostrich production in Saudi Arabia. In order for the ratite industry to flourish and be popular, significant promotional efforts should be made to advertise and introduce this product to the Saudi community.

5.2 Recommendations for future research

1- There is a need to optimize and improve fertility and hatchability rates of ostrich and emu eggs.

2- Further research on causes of mortality in ostriches and emus and proposition of effective preventive and prophylactic measures to reduce these losses is needed.

3- Special emphasis should be paid to research the causes of mortality of chicks during rearing period and establishment of curative and prophylactic measures in order to improve the survivability of these young chicks.

4- Further research on the congenital deformities in young ostrich and emu chicks are recommended to determine the genetic aspects of these ailments.

5- Research to establish specific diagnostic methods and techniques for ostrich and emu diseases as well as development of specific medicaments for ratites are needed.

6- Research on the effectiveness of immunization of ostriches against septicaemic pateurellosis should be conducted.

7- In-depth research on the different factors affecting growth rate of young ratites should be undertaken.

8- Development of less costly feed alternatives to minimize feeding cost is justified.

9- Further research on the factors affecting natural incubation of ostrich eggs is required.

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List of Appendices

Appendix I

Form No. 01

Daily Egg Production Record

Month: Season: Species:

Date	Original Breeders		New Breeders		Remarks
	No. of Birds	No. of Eggs	No. of Birds	No. of Eggs	
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
Total					

Appendix II
Form No. 02
Pattern of egg laying in ostriches and emus

Species:…………………….. Month:…………………….

Date	No. collected late afternoon	Total No. collected	Percentage (%)	Remarks
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				

17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
Total				

Appendix IV

Form No. 04

Fertility of ostrich and emu eggs

Production season:
Batch number: Species:
Date of incubation: Number of eggs incubated:
Number of fertile eggs: Fertility rate:

Pen number	No. of incubated eggs	No. of fertile eggs	Fertility rate (%)	Remarks

Appendix V

FORM NO. 05

Incidence and Types of Ostrich and Emu chick deformities

Batch # :___________ Species:___________ Year :__________

No. of eggs transferred to hatcher:_____________________

No. of hatched chicks:________ Hatchability rate:___________

No. of normal chicks:_______ Percentage:_________

No. of deformed chicks:______ Percentage:________

Types of deformities:

Type	No. affected	Remarks
Oedematous chicks		
Eye abnormality		
Beak abnormality		
Leg abnormality		
Nervous signs (circling)		
Star-gazing condition		
Head between legs		

Extra finger		
Finger in abnormal position		
Open navel		
Neck deformity		
Head deformity		
Others		

Appendix VII
Form No. 07
Hatchers report and hatchlings condition

Species:

Batch No.	Date of hatch	Eggs transferred to hatcher	No. of hatched chicks	Dead-in-shell	Early mortality	Late mortality	Assisted chicks	Wet chicks

-Early mortality refers to embryos died in shell during the first four weeks of incubation.
-Late mortality refers to embryos died in shell during the last two weeks of incubation.

Appendix X

Form No. 10

Summary of chick mortality during rearing phase

Species :

Batch No.	Date received	Number received	Number died	No. transferred as growers	Remarks

Appendix XV

Form No. 15

Daily flock control sheet

Month / Year: .... Room No: .... Batch No : ....
Species : .... Date Hatched: ....
Vaccination Status: ....
Next vaccination date: ....

Date	No. of birds at the beginning of the day	Mortality during the day	Causes of mortality	No. of birds at the end of the day	Remarks
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					

28					
29					
30					
31					

Appendix XVI
Drugs used for treatment and prophylaxix during the study period

Vaccines

1-Twinvax-MR Newcastle-bronchitis vaccine: Live virus, B1 type, B1 strain Mass.

strain Mass. and Conn types (Schering-Plough Animal Health, Millsboro, Delaware, U.S.A.). The vaccine was received as dehydrated, lyophilized freeze-dried live virus of 2500 doses per ampoule. After reconstitution according to the manufacturer's instructions the vaccine was administered by aerosol spray on eyes and oral mucous membranes.

2-Binewvax : Combined vaccine against Newcastle disease and infectious bronchitis

(Merial Laboratories, Lyon, France). The vaccine was in the form of oil-adjuvant, injectable, inactivated liquid vaccine. It was administered through subcutaneous or intramuscular route at a dose rate of 0.3 ml/kilogram body weight.

3-Diftosec: Vaccine against avian pox (Merial Laboratories, Lyon, France). The

vaccine was in the form of lyophilized, freeze-dried live virus. After reconstitution, the vaccine was administered by scratching the skin on the wing web or at the thigh muscles using the needle provided by the supplier.

Antibiotics and antibacterials

1-Tylo-kel 20: Kela B-2320 Hoogstraten/Belgium.

Generic: Tylosin tartarate (200 mg base per ml).

Form: Injectable solution

Dose rate: 5 –10 mg / kg body weight for 1 – 5 days by deep intramuscular injection.

Indications: Against infections caused by Gram-positive bacteria, some Gram-negative bacteria, spirochetes and mycoplasmas.

2-Baytril 5%: Bayer Turk

Generic: Enrofloxacin.

Form: Injectable solution for subcutaneous administration.

Dose rate: 0.5 ml/10 kilogram body weight for 3 days.

Indications: Treatment against infections caused by Gram-negative and Gram-positive bacteria as well as Mycoplasmas.

3-Enrol: Medmac (Vet. Division), Amman , Jordan.

Generic: Enrofloxacin (1 ml contains 100 mg of Enrofloxacin).

Form: Oral solution.

Dose rate: 100 ml / 200 litres of drinking water for five days.

Indications: Treatment and prevention of respiratory diseases and other infections caused by Gram-positive and Gram-negative bacteria.

Anti-inflammatories and antirheumatics

1-Phenylbutazone Sodium 20% with Aminophenazone 20%: Farmaceutici Gellini S.P.A. Aprilla, Italy.

Generic: Phenylbutazone Sodium and Aminophenazone.

Form: Injectable solution.

Dose rate: 4 – 5 mg/kg body weight.

Indications : Treatment of inflammations, rheumatoid and joint affections.

Tonics and multivitamins

1-Ultra b: Schering-Plough Veterinaire, Levallois Perret, France.

Generic: Vitamins B1, B6, Sodium edetate, methyl parahydroxybenzoate and propyl parahydroxybenzoate.

Form: Injectable or oral solution.

Dose rate: 1 ml/kilogram body weight.

Indications: Vitamin therapy in cases of deficiency.

2-Tonivit-S Powder: Sedico Pharmaceutical Co., 6 October City - Egypt.

Generic: Vitamins A, D3, E, K3, B1, B2, B6, Nicotinamide, D-Calcium Pantothenate, Vitamin B12, Folic Acid, Vitamin C and D.L.Methionine.

Form: Water-soluble powder to be used in feed or drinking water.

Dose rate: 100 gram/200 litre of drinking water for 5 – 7 days.

Indications: Increase productivity, in cases of exhaustion, improve feed conversion and in cases of muscular dystrophy and rickets.

3-Vitaflorzoo 2: Farmaceutici Gellini S.p.A. Aprilia (LT), Italy.

Generic: Vitamins and amino acids. Vitamin A, D3, E, K, B1, B2, B6, B12, PP, H1, D-Pantothenic acid, Folic acid, Biotin, Choline HCl, Methionine and sugars.

Form: Water-soluble powder to be used in feed or drinking water.

Dose rate: 2 gram/litre of drinking water or 4 gram/kilogram of feed.

Indications: As a tonic and in cases of mineral and vitamin deficiency or in cases of stress and to activate immunity.

4-Zoosol Lisovit NF: Istituto Delle Vitamine S.p.A. Milano, Italy.

Generic: Vitamins and amino acids. Vitamin A, D3, E, B1, B2, B6, B12, PP, K, D-Pantothenic acid, Biotin, Choline chloride, L-Lysine HCl, DL-Methionine, L-Tryptophan and L-Threonine.

Form: Solution to be used in drinking water.

Dose rate: 2 – 5 ml/litre of drinking water for 5 – 6 days.

Indications: In cases of vitamin deficiency, weakness and stress conditions.

5-Zoosol AD3E: Istituto Delle Vitamine S.p.A., Milano, Italy.

Generic: Vitamins A, D3 and E.

Form: Solution to be used in drinking water.

Dose rate: 5 ml/litre of drinking water.

Indications: During stress conditions and for breeders before and during egg laying season.

6-Zoosol Sel-E 200: Istituto Delle Vitamine S.p.A. Milano, Italy.

Generic: Vitamin E and Selenium.

Form: Solution to be used in drinking water,

Dose rate: 1ml/2 litre of drinking water for 7 days.

Indications: To eliminate vitamin E and Selenium deficiency and to favour immune response.

Antiseptics

1-Iodin spray: Troy Laboratories Pty Limited. NSW 2164, Australia.

Generic: Povidine-Iodine. 5 gram/litre.

Indications: Treatment and prevention of skin infections.

2-Cloramivet Spray: Divasa Farmavic S.A., Barcelona, Spain.

Generic: Chloramphenicol and Gentian Violet.

Indications: Treatment of wounds and open abscesses.

Ophthalmic ointments

1-Chan-Eye: Chanelle Veterinary Ltd. Galway, Ireland.

Generic: Procaine Penicillin G, Kanamycin sulphate and Prednislone.

Indications: In cases of conjunctivitis, blepharitis, corneal ulcers and keratitis.

2-Oftalcen Pomada: Cenavisa 43205 Reus, Spain.

Generic: Chloramphenicol and Neomycin sulphate.

Indications: In all cases of ophthalmic infections and inflammations.

Mineral supplements

1-Mineral TS: Laboratoires Biove, France.

Generic: Minerals and trace elements. Phosphorus, Magnesium, Calcium, Sodium, Iron, Manganese, Cobalt, Zinc and Copper.

Form: Liquid form to be used in drinking water.

Dose rate: 15 ml/10 litre of drinking water.

Indications: To correct mineral and trace elements deficiencies.

2-Mineral Salt Premix: Bulaimy Minerals and Salts, Mekka, Saudi Arabia.

Generic: Minerals and trace elements. Sodium Chloride, Magnesium, Manganese, Iron, Zinc, Copper, Cobalt, Iodine and Selenium.

Form: Water soluble powder to be used in feed or drinking water.

Dose rate: 15 – 25 gm/day for small animals and 50 – 75 gm/day for large animals.

Indications: In cases of minerals and trace elements deficiencies.

3-Biacalcium: Laboratoires Biove, France.

Generic: Minerals, vitamins and amino acids. Calcium, Phosphorus, Iron, Zinc, Manganese, Vitamins A, D3, E, B1, B2, C and K3. Also it contains Betaine, Methionine and Choline.

Form: Water soluble powder to be used in feed or drinking water,

Dose rate: 1 gram/kilogram of feed for continuous use.

Indications: In cases of minerals deficiency or during egg laying season.

4-Windmill dicalphos: Tessenderlo Group, made in E.U.

Generic: Di-calcium phosphate (Ca 25%, P 20%)

Form: Powder to be mixed with feed.

Indications: As minerals supplement before and during egg laying season and to increase Calcium and Phosphorus levels in juvenile ostrich feed.

Antifungals

Clinafarm spray: Janssen Pharmaceutica, Belgium.

Generic: Enilconazole (150 gm/litre)

Form: Emulsifiable concentrate in a liquid form**.**

Dose rate: To be diluted in water at a rate of 1: 99 and then used at a dose rate of 20 mg Enilconazole per square meter ground surface.

ملخص الأطروحة

أجريت هذه الدراسة لرصد وتحليل ومناقشة النتائج الخاصة بالنواحي العملية اليومية وكذلك المشكلات التي تعوق التربية والإنتاج التجاري للنعاميات بالمملكة العربية السعودية. تمت الدراسة في مزرعتين (أ) و (ب) بمنطقة القصيم حيث كان بالمزرعة أ نوعان من النعاميات هما النعام الأفريقي أسود الرقبة ثم النعام الأسترالي (الإيميو) بينما كان بالمزرعة ب النعام الأفريقي الأسود الرقبة فقط.

في المزرعة أ تم رصد عمر بداية الإنتاج لأمهات النعام الجديدة حيث بدأت في وضع البيض عند عمر 19 شهر بينما بدأت أمهات الإيميو الجديدة في وضع البيض عند عمر 22 شهر. تلاحظ أن إناث النعام (الأصلية والجديدة) تضع غالبية بيضها (73.5% و 64.9% على التوالي) أثناء اليوم وقبل غروب الشمس بينماإناث الإيميو تضع غالبية بيضها (98.1%) أثناء الليل.

تلاحظ من الدراسة أن معظم أمهات النعام والإيميو الأصلية تستمر في وضع بيضها لمدة أطول من أمهات النعام والإيميو الجديدة التي تتوقف سريعاً عن وضع البيض. وجدت الدراسة أن حوالي 11% من بيض النعام الذي تم وضعه في المزرعة أ خلال ثلاثة مواسم كان تالفاً بينما بلغت نسبة البيض التالف في المزرعة ب حوالي 6.7%. بلغت نسبة بيض الإيميو التالف 8.9 %. أغلب بيض النعام التالف في المزرعة أ (34.5%)

كان بسبب صغر حجمه بينما غالبية البيض التالف في المزرعة ب (34.9%) وكذلك بيض الإيميو (24.9%) كان بسبب وجود ثقوب فيه.

تلاحظ أن معدل خصوبة بيض النعام في المزرعة أ كانت تتحسن تدريجياً وبإضطراد من موسم لآخر وكذلك تتحسن كلما تقدم الموسم قبل أن تنخفض في نهايته. أثبتت الدراسة كذلك إنخفاض معدلات الخصوبة عند إرتفاع درجات حرارة الطقس. ثبت من خلال هذه الدراسة إرتفاع متوسط معدل الخصوبة في بيض الإيميو (70.3%) مقارنة بالنعام في المزرعتين أ و ب (52.5% و 58.4% على التوالي).

أثبتت الدراسة إرتفاع متوسط معدل الفقس في بيض النعام (72.2%) على متوسط معدل خصوبة بيض النعام (52.2%) خلال المواسم التي شملتها الدراسة. أما بالنسبة لبيض الإيميو فكان متوسم معدل الخصوبة (70.3%) أعلى من متوسط معدل فقس بيض الإيميو خلال فترة الدراسة (62.9%). أثبتت الدراسة وجود نفوق جنيني متأخر بنسبة أعلى في بيض النعام والإيميو (60% و 66.4% على التوالي) مقارنة بالنفوق الجنيني المبكر (40% و33.6% على التوالي). بالنسبة للعيوب الخلقية وجدت الدراسة نسبة أعلى في صيصان الإيميو(19.4%) مقارنة بصيصان النعام (4.1%). أكثر أنواع العيوب الخلقية في صيصان الإيميو والنعام كانت عدم إنسداد الحبل السري (25% و 39.5% على التوالي) ثم تعوج الأرجل (25% و 21.9%على التوالي).

لاحظت الدراسة أن معدل الزيادة في أوزان صيصان النعام الصغيرة يكون قليلاً جداً في الأيام الثلاثة الأولى لحياة الطائر مقارنة بالأيام التالية مع عدم وجود نمط ثابت لمعدلات الزيادة في الوزن. تلاحظ في الدراسة أن جملة الزيادة في أوزان خمسة من صيصان النعام في نهاية الأسبوع الرابع عشر من عمرها في المزرعة ب (18350 جرام) كان أكبر من جملة الزيادة في أوزان خمسة صوص نعام في نهاية الأسبوع الرابع عشر في المزرعة أ (2600 جرام). ثبت في الدراسة أن متوسط الزيادة الأسبوعية في أوزان صيصان النعام المفقوسة في فصل الصيف في المزرعة أ (657.5 جرام) أعلى من متوسط الزيادة الأسبوعية لدى الصيصان المفقوسة في بداية فصل الشتاء (356.75 جرام). لاحظت الدراسة أن معدلات الزيادة في أوزان صيصان الإيميو تتميز بعدم الثبات كما هو في صيصان النعام.

وجدت الدراسة أن معدل نفوق صيصان النعام خلال فترة الرعاية (الأشهر الثلاثة الأولى من العمر) قد بلغ 29% مع عدم وجود نمط ثابت لذلك النفوق خلال تلك الفترة. عند مقارنة معدلات النفوق خلال شهر مايو بالمزرعتين أ و ب وجدت الدراسة إرتفاع معدل النفوق (47.8% و 57.6% على التوالي) مقارنة بالمعدل العام للنفوق خلال فترة الرعاية (29%). المتوسط العام لمعدل النفوق لصيصان الإيميو خلال فترة الرعاية كان أقل من نظيره لدى صيصان النعام (21.6%) مع تميزه بعدم وجود نمط ثابت لذلك النفوق.

أهم أسباب نفوق صيصان النعام بالمزرعة أ كان تعوج الأرجل ثم متلازمة ذبول الصيصان ثم مرض النيوكاسل ثم الإلتهابات المعوية. أما أهم أسباب نفوف النعام النامي بالمزرعة أ فكان تلبك الجهاز الهضمي الرمال ثم مرض النيوكاسل ثم تعوج الأرجل ثم الإلتهابات المعوية. بالنسبة لأمهات النعام بالمزرعة أ فكان أهم أسباب نفوقها هو مرض التسمم الدموي ثم حالات تلوث الجروح ثم الحوادث والإصابات خاصة التي تؤدي إلى كسر الرقبة ثم حالات إلإلتهاب البريتوني.

وجدت الدراسة أن أهم أسباب نفوق الصيصان في المزرعة ب كانت متلازمة ذبول الصيصان ثم تعوج الأرجل ثم الإلتهاب المعوي ثم تلبك الجهاز الهضمي بالرمال. بالنسبة للنعام النامي في المزرعة ب فكانت أهم أسباب النفوق هي تعوج الأرجل ثم حالات التسمم الدموي. أما أهم أسباب نفوق الأمهات بالمزرعة ب فكانت حالات التسمم الدموي ثم حالات الإصابات والكسور.

عند مقارنة نفوق النعام بالمزرعة ب خلال موسمين إنتاجيين (2002 و 2003) لاحظت الدراسة عدم وجود نفوق ناتج عن تلبك الجهاز الهضمي بالرمال في الموسم 2003 وذلك نتيجة لإستخدام البرسيم الجاف لتغطية أرضيات غرف وأحواش الصيصان والطيور النامية مما لم يترك لها مجالاً للوصول إلى الرمال لأكلها.

حالات تعوج الأرجل كانت أهم أسباب النفوق في صيصان الإيميو مع عدم وجود نفوق ناتج عن الإصابة بمرض النيوكاسل أو تلبك الجهاز الهضمي بالرمال كما في النعام. بالنسبة لطيور الإيميو النامية كانت أهم أسباب النفوق هي تعوج الأرجل ثم حالات الإختناق ثم حالات التلوث الميكروبي لجروح العراك مع عدم وجود نفوق ناتج عن الإصابة بمرض النيوكاسل أو تلبك الجهاز الهضمي بالرمال. أما بالنسبة لأمهات الإيميو فكانت أهم أسباب النفوق هي الإلتهاب البريتوني الناتج عن تلوث بيض النعام المكسور بداخل قناة المبيض ثم حالات الإصابات والكسور.

تم عزل باكتيريا الإيشيريشيا كولاي بنسبة 35.5% من العينات المأخوذة من صيصان نعام نافقة فيما تم عزل باكتيريا السالمونيلا من 12.9% من العينات بينما كانت 22.6% من العينات سالبة للعزل الباكتيري.

بالنسبة للإيميو تم عزل باكتيريا الإيشيريشيا كولاي من 33.3% من العينات المأخوذة من صيصان إيميو نافقة وتم عزل باكتيريا السالمونيلا من 16.7% من العينات بينما كانت 33.3% من العيناتسالبة.

وجدت الدراسة أنه بالنسبة للأنواع المختلفة من حالات تعوج الأرجل التي أدت إلى نفوق النعام والإيميو كان تعوج الساق هو النوع الرئيسي المؤدي إلى النفوق لدى كل من صيصان النعام (84%) وصيصان الإيميو (98.8%) وكذلك النعام النامي (78.5%) والإيميو النامي(99.4%).

أثبتت الدراسة إمكانية إستخدام مكعبات الأعلاف المصنعة من البرسيم الصافي أو البرسيم المخلوط مع الأعشاب البرية وذلك لتغذية طيور الإيميو كبدائل علفية رخيصة الثمن خاصة في حالات ندرة الأعلاف. أما إستخدام مكعبات الأعلاف المكونة من الأعشاب والحشائش البرية فقط فقد ثبت عدم جدواها كبدائل غذائية لأثرها السلبي إذ نتج عنها إنخفاض في أوزان طيور الإيميو التي أستخدمت في الدراسة.

ثبت من هذه الدراسة أن إستخدام التحضين الطبيعي لتفقيس بيض النعام غير مجدي إقتصادياً خاصة في أوقات إرتفاع حرارة الطقس حيث إن 60% من الأمهات التي شملتها الدراسة لم تقم بتحضين بيضها أو فسد البيض نتيجة لإرتفاع درجة حرارة الطقس التي أدت إلى نفوق جنيني مبكر نتج عنه فساد البيض.