Reproductive Performance of Breeding Ostriches in Australia and Studies Aimed at Improving Hatchability

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Introduction

Ostrich eggs are normally artificially incubated on commercial ostrich farms in Australia. The main reason for this is to maximise the number of eggs produced by each breeding hen. If the eggs are left to be incubated naturally a breeding hen typically lays a clutch of approximately 15 eggs over a four to five week period before commencing the six week incubation process. If the chicks are left with the parent birds, the hen is likely to lay only two clutches in a breeding season. Removing the chicks after hatching can increase the number of clutches laid to three or four (Langdon, pers. comm.). The process of natural incubation is unlikely to be successful on most Australian ostrich farms because the incubating birds would be too easily disturbed from the nest (Millington, 1990) and because our ostriches are not bred to incubate naturally.

For commercial reasons, therefore, the eggs are typically removed soon after laying and incubated artificially. Hastings (1991) suggests that daily removal of eggs can treble egg production. This way the breeding birds are able to maintain their normal daily intake of feed (and hence condition) which they would not be able to do under the conditions of natural incubation.

Artificial incubators used in the ostrich industry within the last ten years have been developed and adapted from sophisticated equipment used for chicken eggs. Considerable research and development has been done on incubation in the poultry industry and much is known about the chicken egg and its incubation requirements and hence the hatch rate in commercial chicken hatcheries is usually very high. Much of this success can be attributed to the consistently good quality of the chicken egg.

The situation in the ostrich industry is quite different with individual enterprises mostly very small. Here, egg quality and hatchability are very variable between seasons, regions, farms and breeding hens. This industry is still young and our farmers generally have had little experience with artificial incubation of ostrich eggs. Information is often extrapolated from the chicken industry and we know little about the particular requirements of the ostrich egg during incubation. Because of the relatively small numbers and high value of eggs it is very difficult to obtain information on ostrich eggs by controlled experimentation. Much of what we do know about incubating ostrich eggs comes from empirical field observation and from studies of naturally incubated eggs in wild nests mainly in Africa (e.g. Siegfried and Frost, 1974, Bertram and Burger, 1981 and Swart, 1988) in which egg and nest temperature and nest relative humidity have been measured. But even when these conditions are simulated in artificial incubation hatch rates generally are not as successful as those achieved in the wild. Brake *et al* (1994) believe that this is because our artificial conditions do not mimic the natural environment closely enough. Certainly, we still have a lot to learn from nature and one area that has not been studied in wild nests is gaseous exchange during incubation. The significance of oxygen and carbon dioxide exchange is discussed later.

The hatchability of artificially incubated, fertile ostrich eggs on farms in Australia is relatively poor. A recent survey by Badley (1994) of the reproductive performance and productivity of ostriches on 94 Australian farms showed that during the 1992/93 breeding season the hatchability (percentage of fertile eggs hatching successfully) Australia wide was only 51.1%. While some farmers achieve much higher hatch rates there are many more who do not and it is the high variability referred to earlier and the causes of poor hatchability on ostrich farms that is of concern.

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The Australian Ostrich Association (AOA) has identified low hatchability of artificially incubated fertile ostrich eggs as one of the most important constraints on the development of ostrich industry and is, therefore, a top priority for research. At the moment the industry is in the breeding-up phase only and significant improvements in hatchability have to be made before the ostrich industry can move quickly and effectively into viable commercial slaughtering.

The industry has sent itself a target of 90% hatchability to be achieved consistently on all Australian farms. To this end, the AOA and RIRDC (Rural Industries Research and Development Corporation) are jointly funding a three year research project which commenced in August 1993 aimed at improving the hatchability of ostrich eggs. The first year of this project was done collaboratively between the Victorian Department of Agriculture's Regional Veterinary Laboratory at Bairnsdale and The University of Queensland's Department of Farm Animal Medicine and Production.

In the first year of this study the objective was to determine the current level of reproductive performance and productivity of our breeding ostriches in Australia and attempt to identify the major causes of poor hatchability. As part of this, The University of Queensland conducted the Australia wide survey referred to above (Badley, 1994) and a study of more than 250 fail-to-hatch ostrich eggs submitted by AOA member farmers around southern Queensland and northern NSW.

This paper outlines the main findings of these studies and describes areas where future research is indicated.

1. Survey of the Reproductive Performance of Ostriches in Australia in 1992/93

1.1 Australia wide

A total of 94 Australian ostrich farms having birds of a breeding age at the start of the 1992/93 breeding season returned completed questionnaires (69 questions) in the postal survey. These farms had an average of 2.1 hens with a range of 0-13 and 1.9 cocks (1-13) in 1.6 pairs (0-13). There were five times less trios (1C, 2H) than pairs per farm. 65.7% of the breeding hens were in their first breeding season or approximately two years old (YO). 21.3% were in their second breeding season (3YO) and the remainder in up to their sixth breeding season (7YO). This data gives an indication of the relatively young age of the breeding flock in Australia and the inexperience of the birds in breeding and of the ostrich farmers in incubation given that 75.3% of farmers indicated that they artificially incubate the eggs themselves rather than contract out to more experienced farmers.

Using data from all hens (up to sixth breeding season) Australian hens each laid an average of 31 (range 14-38) eggs of which 23 (10-32) (75.6%) were recorded as fertile, 12 (8-17) (51.1%) hatched out and seven (4-12) (61.7%) of the chicks survived to three months of age. Thus, around Australia only 23.8% of the eggs laid produced surviving chicks (productivity). These data are from only one breeding season but they do given an indication of the current situation as regards breeding performance of our ostrich flock. Productivity is generally poor in Australia and it does appear that the reproductive process is quite inefficient on ostrich farms where artificial methods of incubation and chick rearing are used.

When the reproductive process is broken down into its three components of egg fertility (proportion of total eggs fertile), hatchability and chick survival it appears from the above figures that egg hatchability (proportion of fertile eggs hatching) and chick survivability (proportion of hatched chicks surviving to three months of age) are the poorest performing parts of the process. The breeding birds are doing their part with quite high fertility but it is after the eggs are laid and collected that the system is falling down.

The greater efficiency of the "natural" part of reproduction is further illustrated in Figure 3. This shows that egg fertility in the 1992/93 season increased with an increase in hen age.

Overall fertility increased linearly from a low of 68.0% for hens in their first breeding season to 84.2% for hens in their fourth breeding season. There was a decline in egg fertility for hens in their sixth breeding season. Unfortunately the data gathered for the fifth breeding season came from only one hen in Australia and is, therefore too unreliable to use. Since no data was available from the survey for any hens older than in their sixth breeding season it is not possible to come to any definite conclusions about the effect of age on fertility on hens past their sixth breeding season.

There were no such improvements in egg hatchability or chick survivability with an increase in hen age. In fact, there was considerable variation between breeding season in these factors giving further weight to the conclusion that there is a problem with the methods used to produce chicks on our ostrich farms. However, there were significant differences in the reproductive components between regions within Australia and these are discussed in the next section.

In order to find the cause of poor hatchability and chick failure in Australia during the 1992/93 season in the survey farmers were asked to indicate what they thought was the main cause of the failures. The largest proportion of farmers (27.9%) believed that hatch failure was caused by the eggs being infertile while 17.2% cited incubation problems and 8.6% poor egg shell quality. Very few (4.3%) thought nutrition or infection were implicated in hatch failure. A large proportion (22.6%) were unsure of the cause. The "unsure" group was much higher in Queensland (53.8%) and this is indicative of the difficulties in diagnosing hatch failure and the current level of knowledge in our industry.

Chick mortality is easier to diagnose. 32.3% of farmers responding to the survey indicated that leg problems were the main cause of mortality and 26.3% cited infection. While particular diseases were not specified it is interesting that yolk sac infections were not recorded as a common problem. Other nominated causes of chick failure were trauma (6.4%), impaction (5.4%) and Fading Chick Syndrome (4.3%).

1.2 Reproductive Performance by Region

Figures 1-3 show the reproductive performance of the breeding ostriches during the 1992/93 season in each region compared with Australia as a whole. Because of regional differences in hen numbers used in the calculations, the average of the regions do not necessarily equal the Australian average. Because the first three breeding season hens were common to all the regions only data for these hens are used in the calculations in Figures 1-2.

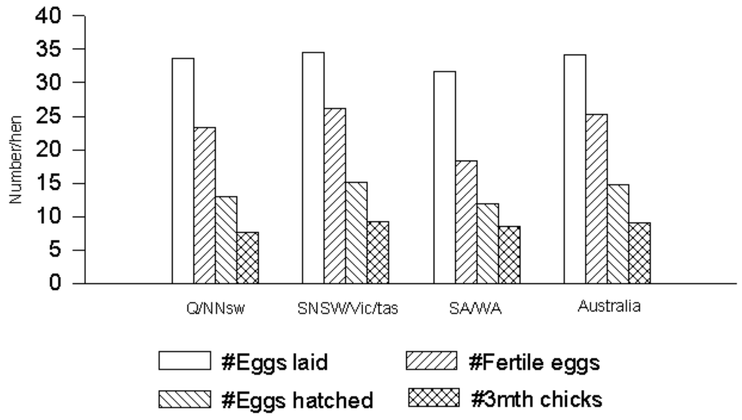

Figure 1 Reproductive performance of breeding ostriches in 1992/93

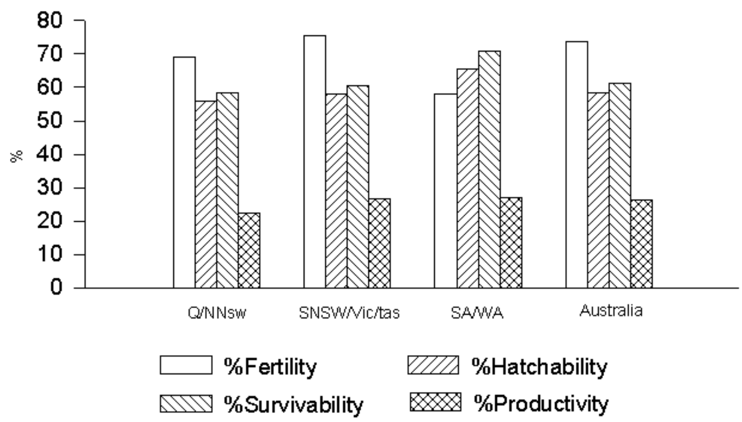

Figure 2 Ostrich egg and chick productivity in 1992/93

In summarising the data in Figure 1, Figure 2 gives more meaningful results. This shows that egg fertility was well below the Australian average in the western region (SA/WA) while in this region hatchability and chick survivability were higher. In the northern region (Q/NNSW) these parameters were slightly below average and in the south eastern region (SNSW/Vic/Tas) where hen numbers are higher the figures matched the Australian average. Productivity was lower in the North than the other regions.

It is not possible to account for the low fertility in the western region at this time. It was not related to hen age as the hens in this region were generally older than those in the other regions. A statistical analysis of the data will be conducted later to determine whether there were any specific factors, e.g. nutrition, affecting the components of reproductive performance.

Figure 3 shows that apart from the northern region egg fertility clearly increased with age (an advance in the hens' breeding season) up to the fourth breeding season and declined in the sixth breeding season.

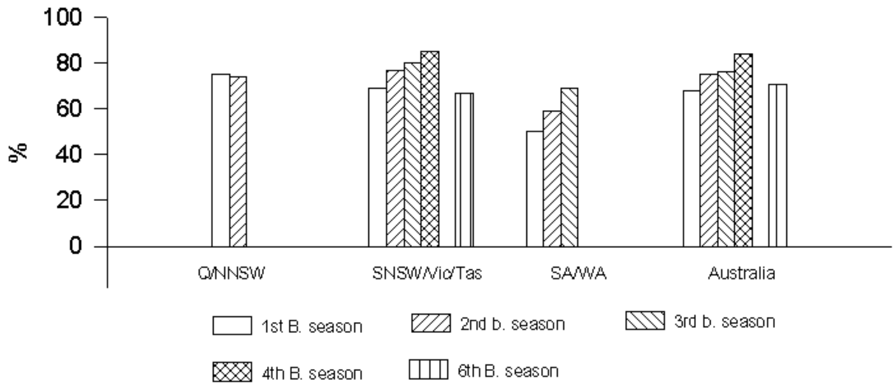

Figure 3 Trends in ostrich egg fertility in 1992/93. Data unreliable where not shown.

The causes of hatch and chick failure in the 1992/93 season recorded by farmers varied somewhat between regions. 66.7% of western region farmers believed that egg infertility was the major cause of hatch failure compared with less than 30% in the other regions. Incubation and egg shell quality were considered less of a problem in the western region than in the other regions.

Leg problems in chicks were higher (42.1%) in the northern region compared with the other regions (27-29%). In the western region infection caused no chick failures while trauma was a much greater problem (27.3%) than in the other regions (3-5%).

The survey has shown that the overall productivity of the breeding ostrich flock in Australia at the current time is quite poor with only 24% of the eggs laid producing chicks surviving to three months of age. There is room for improvement in all components of the reproductive process particularly in egg hatchability and chick survival. At 75% egg fertility is quite high but varies from region to region. However, this factor does increase with breeding flock age.

If fertility, hatchability and survivability were each raised to a consistent figure of 80%, which is not an unreasonably target, the current level of productivity of the breeding flock would double to around 50%.

2. Fail-To-Hatch Egg Study

In the 1992/93 survey egg hatchability (at approximately 50%) was identified as the poorest performing component of reproductivity in Australia's breeding ostriches. Improving hatchability to the industry target of 90% is the main objective of the AOA/RIRDC funded project currently being undertaken by The University of Queensland's Department of Farm Animal Medicine and Production in Brisbane.

As part of this project, a study of fail-to-hatch (FTH) ostrich eggs was conducted to attempt to determine the causes of hatch failure during the 1993/94 breeding season and to support the study of 1000 FTH eggs being diagnosed by Dr C. Button at the Regional Veterinary Laboratory in Bairnsdale. In our study 291 failed eggs were submitted for diagnosis by AOA member breeders from 27 farms around southern Queensland (25) and northern NSW (2).

These eggs were broken open and classified as either infertile or fertile with early, mid or late embryonic mortality. The embryo classifications were done according to size (crown to rump length, CR) and stage of development as indicated by the appearance of various body parts and feathers extrapolated from the developmental features of chicken embryos. Early deaths were taken as approximately 0-10 days of incubation, mid-term as 11-28 days and late deaths as 29-42 days.

Before breaking open the eggs a number of features were scored and measurements taken. These included ratings (0-5 scale) of egg shell gloss, smoothness, colour and dirt and the weight, length and breadth of the eggs which were also candled. After opening, measurements taken included yolk sac, albumen and embryo weight, CR length and thigh and neck muscle oedema. With late embryos, an estimate of yolk sac externalisation was made and any malpositions recorded. Weight loss of the egg to day 38 of incubation was obtained from breeders' records. Culturing of failed eggs was done only when there were signs of likely infection (such as smell or appearance).

These data were used not only in diagnosing the causes of hatch failure but also to gain information on the normal development of ostrich eggs. Candling is considered to be an important tool in determining the development of the embryo and the study provided an opportunity to relate the features observed during candling with the actual stage of development of the embryo.

The results of this study show that of the 291 FTH eggs, 110 (37.8%) were found to be infertile and 171 (58.8%) were fertile with dead embryos. The number of infertile eggs tended to be greater early in the breeding season than in the middle part but this was difficult to define because egg laying in the 1993/94 season commenced at widely differing times (from June to January).

The proportion of infertile eggs was high and there would have been a significant number of eggs that breeders considered to be infertile by candling that were not submitted for confirmation. There is a concern that if these eggs are not broken open a proportion that appear to be infertile may, in fact, be fertile with an early dead embryo. If this is the case then it is quite possible that the level of egg fertility was higher than 1992/93 survey indicated.

Distinguishing between an infertile and a fertile egg with an early dead embryo is important because the two problems have quite different causes. Infertility can indicate a problem with the cock bird while an early dead embryo could be caused by a problem with the hen, infection, poor egg shell quality or the egg management practice including storage and handling. It would be very useful if candling were able to differentiate between fertile and infertile eggs in the early stages of development.

Of the 59% fertile eggs with dead embryos 20% were early deaths, 10% mid-term deaths and 28% late deaths. 41-56% or approximately half of these deaths were found to be due to unknown or no obvious causes. 29% of the early deaths were due to poor egg shell quality which often resulted in excessive weight loss from the egg and dehydration of the contents. This problem was implicated in 41% of the mid-term and 12% of the late deaths.

Shell quality was a significant factor in hatchability in this study and we believe that the high proportion of porous or defective eggs was probably due to the immaturity in the breeding hens. In some cases an infection in the hen may have caused the poor egg shell quality.

9% of the early and 10% of the mid-term deaths were thought to be caused by infection. These included *Aeromonas hydrophyla*, *Pseudomonas fluorescens* and *P. pseudomallei*. *Acinetobacter anitratus* was found in a few eggs but this bacteria is not considered to be pathogenic. Other nonpathogenic environmental contaminants were also cultured. None of the late deaths were caused by infection and the incidence of pathogenic bacteria in the eggs in the study was very low overall (<5%).

11% of the late dead embryos were considered to be oedematous and 16% were malpositioned. At the current state of our knowledge we do not know whether these factors actually caused the deaths of the embryos. We believe that incorrect incubator settings were the causes of 14% of the late deaths. There is no reason to suspect that nutrient deficiency was a significant factor in these embryonic deaths. Brake *et al* (1994) suggested that most nutrient deficiencies mainly manifested themselves in mid-term embryonic mortality and this only when the deficiency was severe. Our study showed that only 10% of the embryonic deaths occurred in the mid-term period of incubation.

Our study has thus established that most embryos die either early (a third of the deaths) or late (half of the deaths) in incubation. At this stage the cause of more than half of the total mortality could not be identified.

3. Future Research

Our research effort in the coming 1994/95 ostrich breeding season will mainly concentrate on trying to find the hitherto unknown causes of embryonic mortality specifically targetting early and late embryos.

3.1 Gaseous Exchange in the Egg

We believe that some embryonic mortality may be caused by an oxygen deficiency at both the early and late stage of incubation. Brake *et al* (1994) in the US suggested that it is at these times that the embryo is most sensitive to any disruption in gas exchange and oxygen supply is a critical factor.

The developing embryo is supplied with oxygen from outside the egg. Oxygen enters the egg via the pores as water is released. In the early stages before the development of the chorio-allantoic membrane (CAM) oxygen diffuses through the shell and its membranes and across the albumen. Carbon dioxide (and water vapour) diffuses out of the egg as the gases are exchanged.

Brake *et al* (1994) believe that albumen quality varies according to the position of the egg in the laying cycle and is a key factor in the supply of oxygen to the early embryo. High quality, thicker albumen probably restricts gas exchange in the egg, gives greater protection of the embryo and takes longer to break down than thin albumen. If this is so it could explain why, in the wild, ostrich eggs laid first in a clutch are able to withstand much longer periods of "storage" before incubation than later eggs, which may have thinner albumen, and still hatch at the same time.

It is likely in ostriches that the main purpose of the high quality albumen in these early season eggs is to reduce water loss during "storage". Also, until incubation begins, the requirements of the embryo for oxygen are minimal. It follows that under artificial conditions the early laid eggs should be stored for a longer period than later eggs before incubation in order for the albumen to break down to facilitate gas exchange.

An early egg set too soon after laying may not be able to release sufficient water and supply oxygen quickly enough for normal development of the embryo. Conversely a later egg stored too long may lose water too quickly. Either situation would predispose the death of the embryo. So, it is quite possible that some of the embryonic mortality currently occurring on our farms is due to inappropriate egg storage duration and conditions.

By analysing farmers' records from the 1993/94 breeding season we should be able to determine whether there was any relationship between early embryonic mortality, time of egg lay and storage duration and condition. This season we plan to conduct on-farm experiments to investigate whether hatchability of ostrich eggs can be improved by altering the duration of egg storage according to the position of the egg in a laying cycle.

In the late stages of incubation the oxygen requirement of the embryo increases with an increase in embryo size and metabolism as it prepares to hatch. The period prior to internal pipping (breaking through the inner membrane into the air cell) when the embryo changes from CAM respiration to pulmonary respiration is critical and it is essential that effective gas exchange is maintained by keeping the relative humidity low until the embryo internally pips. Brake *et al* (1994) suggest that this is best achieved by keeping the eggs in the incubator through to this stage before transfer to the hatcher.

The rate of exchange of gases in the egg depends on a number of factors including eggshell porosity, partial pressures of the gases, temperature and the relative humidity outside the egg. A study by Bowsher (1992) indicated that large embryonic mortality may occur as a result of low shell porosity. Deeming (1993) has suggested that low shell porosity may restrict gas exchange and cause late embryonic mortality as a result of an oxygen deficiency.

Hoyt *et al* (1978) showed that oxygen consumption in ostrich eggs first peaked around day 34 of incubation, declined to about 75% of peak consumption for six days then rose to a similar rate and peaked again just before internal pipping. While the decline may be due to a reduction in growth rate of the embryo prior to pipping there is still a high demand for oxygen in the last week of incubation.

It is possible that during artificial incubation these demands for oxygen are not being met because insufficient oxygen levels are available in the incubator at the critical times. This coming breeding season we plan to investigate this possibility by (i) enriching the oxygen supply and (ii) reducing the relative humidity of the incubator in order to force greater gas exchange (oxygen in, water vapour and carbon dioxide out) in the egg. The objective of this group of on-farm experiments is to reduce the incidence of late embryonic mortality and improve hatchability of ostrich eggs by enhancing gaseous exchange during artificial incubation.

Because of the relatively low numbers and high value of ostrich eggs it will not be possible in these experiments to impose any conditions that are likely to reduce the hatchability of the eggs. Parallel studies using chicken eggs as a model will be conducted at The University of Queensland's Veterinary Science Farm. In these studies it will be possible to explore the effect of potentially deleterious treatments.

3.2 Egg Turning Method

In the 1993/94 breeding season a number of ostrich farmers changed their incubators from types which turn the eggs through the vertical to machines which roll the eggs horizontally. The latter method is considered to more closely mimic the egg turning method used by ostriches during natural incubation.

Farmers are claiming improved hatchability with these machines suggesting a reduction in malpositions and less late embryonic mortality as the principal reason. While in our study malpositioned embryos was not considered a significant factor in late embryonic mortality, the success of this alternative turning method needs to be quantified under controlled experimental conditions. It is proposed that a number of on-farm experiments be conducted in order to compare the effects of the two types of turning methods on egg hatchability.

A parallel study will be conducted on chicken eggs at the Veterinary Science Farm using the two different types of turning methods in the one incubator so that incubation conditions are essentially identical. As far as we are aware the alternative method (horizontal) of turning has not been tested in chicken eggs. From this study if should be possible to demonstrate the effects of egg turning method or hatchability.

4. Summary

In the first year of this project, which aims to improve the hatchability of fertile ostrich eggs, the survey showed that hatchability was only about 50% on average on commercial ostrich farms in Australia during the 1992/93 breeding season.

The fail-to-hatch egg study during 1993/94 showed that the majority (>80%) of embryonic deaths occurred during the early or later part of incubation. The causes of more than half these deaths could not be identified.

Oxygen deficiency may be causing some of the embryonic mortality both at the early and late stage. In our study we found that many of the late deaths occurred in the last week of incubation when the oxygen requirement is at its maximum.

A number of on-farm experiments are planned for the 1994/95 breeding season to investigate the possibility that gaseous exchange and, in particular the supply of oxygen is implicated in embryonic failure. One group of experiments will target early embryonic mortality and the effect of egg storage duration on hatchability while a second group of experiments will investigate the effects of incubator conditions and gas exchange on late embryonic mortality.

A third group of experiments will be conducted to investigate the effect of egg turning method on hatchability. All the ostrich egg experiments will be supported by experiments on chicken eggs where potentially deleterious treatments can be applied.

5. Acknowledgments

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