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Some Factors Affecting Fertility and Hatchability in the Farmed Ostrich: A Review

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Abstract: This review highlights some of the factors that affect fertility and hatchability in the farmed ostrich, considering the enormous impediments that these two parameters present on ostrich productivity and enterprise viability. Fertility may be influenced by cock and/or hen factors. Cock fertility is influenced by age, stage of the breeding season, frequency of ejaculation, sperm supply, disease and nutrition. Hen fertility is influenced by reproductive age, feed energy levels, disease and efficiency in sperm storage. Pre-season breeding soundness examination and artificial insemination are animal production technologies that should be implored further, while the effective grouping of breeders based on compatibility should be emphasized in order to optimize reproductive efficiency. Hatchability can be improved through, the use of contamination free eggs, appropriate incubation temperature and humidity and the attainment of the recommended 15% moisture loss during incubation among others.

Key words: Farmed ostrich, fertility, hen factors, cock factors, hatchability, technological advances

INTRODUCTION

Despite advances in almost all aspects of ostrich production, fertility and hatchability remain unsatisfactory and need improvement if ostrich farming is to remain competitive (Deeming, 1999; Bronneberg and Tarvene, 2003). This is because the profitability of an ostrich enterprise depends on the rearing of an optimal number of viable ostrich chicks to a sellable age and this directly relates to the production of an optimal quantity of fertile eggs and the attainment of high levels of hatchability (Cloete *et al*., 1998; Deeming, 1999). The low and highly variable levels of both fertility and hatchability of 40-90% (Hicks, 1993; Deeming, 1995; Dzama *et al*., 1995; Deeming, 1996a; More, 1996; Schalkwyk van *et al*., 2000; Mushi *et al*., 2008; Dzoma and Motshegwa, 2009) compare unfavourably with the high levels of around 90% in poultry. However, the high poultry levels give optimism for improvement of ostrich levels. This study aims at highlighting some of the factors associated with low levels of fertility and hatchability in the farmed ostrich and to recommend some areas that could be improved on.

INFERTILITY

Fertility of ostriches is a very important measure of their reproductive efficiency (Malecki *et al*., 2004). The problem of unfertilized eggs has long been identified as one of the most critical factors limiting the success of breeding programmes and ranges from 10.0-98.2% both within and between farms (Hicks, 1993; Deeming, 1995, 1996a; Dzama *et al*., 1995; More, 1996; Badley, 1997; Schalkwyk van *et al*., 2000; Park *et al*., 2001; Malecki and Martin, 2003a; Mushi *et al*., 2008; Dzoma and Motshegwa, 2009). Breeder infertility can broadly be categorized into hen infertility, mainly involving the failure to lay eggs (barrenness) and cock infertility, involving mainly the inability to supply viable spermatozoa and the subsequent production of candling-clear eggs. Candle-clear eggs indicate infertility and therefore a breeding problem and are often, but not always, associated with an infertile cock. Candling is the act of shining a light through an egg to observe, whether it is clear (infertile), or not. It is also used to identify eggshell abnormalities and dead-in-shell problems and is usually carried out at days 7, 14, 28 and 38 of incubation.

Eggs are deemed to be infertile when candling results at days 7-10 of incubation show an apparent lack of embryonic development (Ley *et al*., 1986). However, such cases may be difficult to distinguish from eggs, whose embryos died early in the incubation period, generally referred to as Early Embryonic Death (EED), because in both cases, the candling results may be similar. However, when EED eggs are opened up, an embryonic disc, which is absent in infertile eggs, can be seen floating (Hicks, 1993).

Breeder factors that influence fertility include young and old age, disease, nutrition, mating behavior and efficiency and possibly testicular cysts, while the non breeder factors include high stocking densities, extreme environmental temperatures and season (Hicks, 1993; Deeming, 1995, 1996a; Aire *et al*., 2003; Lambrechts *et al*., 2004). It is unclear, whether fertility is inheritable in the ostrich (Badley, 1997), but it can be affected by inbreeding (Dzama *et al*., 1995). Inbreeding is known to cause elevated rates of infertility in domesticated animals, primarily because of homozygous expression of recessive lethal alleles (Charlesworth and Charlesworth, 1987; Thornhill, 1993).

Cock infertility: Cock infertility is generally associated with the production of candling-clear eggs. Male ostriches mature sexually at about 36 months of age. The reproductive organs of the male ostrich consist of the testis and the (ductus) epididymis. The size and appearance of the testis varies with age and stage of the testicular cycle, enlarging up to 400% of its normal size during breeding (Bezuidenhout, 1986; Madekurozwa *et al*., 2002). With sexual maturity generally comes the ability to produce viable spermatozoa capable of fertilizing the egg following a successful mating. Attempts to breed the male ostrich before it attains sexual maturity can lead to the production of infertile eggs since juvenile male ostriches only exhibit spermatogenic activity, but are devoid of viable spermatozoa (Madekurozwa *et al*., 2002).

The ostrich cock is a low-latitude bird and considered a photoperiod dependent seasonal breeder, where spermatogenesis undergoes seasonal changes (Degen *et al*., 1994; Hicks-Alldredge, 1998; Madekurozwa *et al*., 2002). The breeding season of the ostrich depends on daylength, with testicular activity being restricted to long daylengths (Hicks, 1992; Mellet, 1993; Degen *et al*., 1994; Soley and Groenewald, 1999). Artificial light has also been found to initiate testicular growth in adult ostriches (Jensen *et al*., 1992). Consequently, ostriches are primarily breed during late winter to summer, most likely to coincide with lengthening daylengths. The breeding season generally spans for 6-8 months in a year, approximately from July-February in the Southern hemispheres and from March-September in the Northern hemispheres (Jarvis *et al*., 1985; Shanawany, 1994; More, 1996; Deeming and Ar, 1999; Soley and Groenewald, 1999).

Seasonal infertility may occur, when hens produce eggs early in the season before cocks are able to produce functional spermatozoa, or when hens continue laying eggs at the end of the breeding season. In a study involving 56 healthy male ostriches, peak sperm concentrations were found at the beginning of the breeding season, while the lowest values were found at the end of the breeding season (Hemberger *et al*., 2001). Hormonal imbalances of testosterone or Follicular Stimulating Hormone (FSH) levels in cocks may interfere with spermatozoa production (Degen *et al*., 1994; Black, 1995; Rozenboim *et al*., 2003). These hormones are also responsible for the crimson colour of shins and skin around the eyes of the cock, as well as the aggressive behavior of male ostriches during breeding. The latter behaviour is also thought to positively influence egg production in the hen through the initiation of ovulation (Lambrechts *et al*., 2000). The ostrich testicle goes through 4 cycles, namely the active (September-January), regressive (February-March), quiescent (April-June) and recrudescent (July and August) in the Southern hermisphere (Madekurozwa *et al*., 2002). Breeding the cock, when it is out of the active testicular cycle is therefore, bound to result in the production of infertile eggs. In the emu (*Dromaius novaehollandiae*), a bird that together with the ostrich belongs to the ratite family, male fertility also appears to fall towards the end of the laying season (Malecki and Martin, 2002).

Not much work has been done regarding the specific association between breeding ratios and fertility rates. However, Deeming (1996a) observed higher fertility (>90%) in females kept in male: female breeding ratios of 1:2 than in females in groups with larger numbers of females per male. In contrast, Lambrechts *et al*. (2004) observed that increasing the number of females per male did not have negative influences on reproductive traits (fertility, hatchability and total number of eggs produced) and observed significantly higher production among breeders in male: female ratios of 1:3. This concurred with the study of Malecki and Martin (2003a) of sperm supply on the Germinal Discs (GD) of fertilized eggs. They observed less sperms on the GD of eggs from pens with less females per male and concluded that it was a waste of a male's capability to keep him with only one or two females and that the most efficient ratio would be 1 male with 3 females. Various other researchers have also noted the use of breeder sex ratios averaging 1:2.5 and recorded quite variable fertility results (Dzama *et al*., 1995; Hicks-Aldredge, 1996; More, 1997; Mushi *et al*., 1999; Horbanczuk, 2002; Lambrechts *et al*., 2002a). In a study of ostrich spermiograms, the highest quality ejaculate was obtained from males whose semen was collected once a week (Hemberger *et al*., 2001). This finding may favour those males that cover fewer hens, assuming that they would be able to mate less often. However, ostrich hens do have sperm storage tubules near the utero-vaginal junction (Bezuidenhout *et al*., 1995; Madekurozwa, 2002) and may probably not need to mate frequently to maintain fertility. More studies are therefore indicated in order to clarify the near complex issue of appropriate breeder ratios.

Malecki and Martin (2003a) concluded that ostrich hens generally have high fertility and that any infertility could be associated with a lack of sperm supply. This was based on an apparent difference in sperm supply between breeder pens with different cocks. It would then appear that what is lacking in ostrich reproduction is an effective tool for pre-season Breeding Soundness Examination (BSE) of cocks, a routine practice in other animal production systems. The assessment of semen quality characteristics of the poultry species gives an excellent indicator of their reproductive potentials and is a sine quanon to effective artificial insemination programmes (Zahraddeen *et al*., 2005). Hemberger *et al*. (2001) noted wide ranges in vital spermiogram parameters of Namibian ostriches. The parameters included sperm concentrations (8.9-78.1 million μL^{-1}), pH values (6.4-8.0, μ = 7.3) and individual sperm motility (42-96%, μ = 78%). In the same study, no mass motility was detectable in 42% of the ejaculates, weak mass motility was found in 46%, clear mass movements were found in only 12% of samples (n = 411), 5-26% of the sperms were abnormal (μ = 17%), while 4-28% (μ = 20%) were dead. These results lend weight to the call for routine and effective BSE for ostrich cocks since many cocks might currently be included in breeding programmes, when they do not meet minimum breeding standards. The lack of a BSE tool leaves ostrich producers having to increase their chances of success through the costly and speculative use of fewer hens per cock, resulting in an unnecessarily high number of cocks on the farm.

As feed is the greatest input cost in ostrich production (Aganga *et al*., 2003), the use of fewer hens per cock, like the 1:1.4 noted in the work of Mushi *et al*. (1999) in some farms in Botswana could jeopardize the economics of ostrich production through the unnecessary feeding of extra males. When all the breeders are in optimal breeding condition, the use of male:female ratios of 1:3 (quads) (Lambrechts *et al*., 2004) would significantly reduce production cost at no further cost to productivity.

Naturally, the male ostrich is polygamous, usually having one major hen and two or more minor ones and copulates up to three times a day, while the clutch is being laid (Bertram, 1992; Kimwele and Graves, 2003). While the importance of the frequency of copulation has not been well studied, it could, as in other birds, be related more to sperm competition and paternity assurance than to the necessity to fertilize eggs (Birkhead *et al*., 1987, 1989).

The female ostrich has sperm-storage tubules at the utero-vaginal junction of the oviduct (Bezuidenhout *et al*., 1995; Madekurozwa, 2002) and have a fertile period that ranges from 5-28 days post-coitus (Birkhead, 1988; Bezuidenhout *et al*., 1995; Swan and Sicouri, 1999; Malecki *et al*., 2004). These observations lend weight to the hypothesis that the lack of a routine and effective BSE mechanism in the ostrich has necessitated the use of more cocks on the farms since indications are that frequent matings are not necessary to maintain egg fertility.

Another factor that can affect egg fertility is the mixing of incompatible breeders (Deeming, 1996a), resulting in no mating activity. In a study involving two breeding groups, Bonato *et al*. (2009) noted that about 77.5% of offspring were sired by only about 50% of the males, suggesting very limited participation by the other 50% of the males. The researchers inferred that female ostriches mate preferentially with one specific male. However, it could also have been a reflection of the mating efficiency of the males, with the other 50% not in optimal breeding soundness, since no examination had been carried out prior to breeding. As earlier discussed, Hemberger *et al*. (2001) observed wide ranges in vital spermiogram parameters in breeding males. Therefore, in addition to BSE, compatible birds have to be selected before the start of the breeding season. The mixing of incompatible breeders may have been responsible for the use of more cocks on the farm in a bid to circumvent the effects of breeder incompatibilities that manifest as infertility.

In some cases, females with black pigment and rudimentary male sexual organs are recognized as males and rejected for mating (Mushi *et al*., 2008). Also that coloration of wing and neck feathers and the brightness of the black feathers of males appear to influence the size of the egg laid by females mated to them (Bonato *et al*., 2009) further emphasizes the need for continued studies on reproductive behavior of ostriches.

Alternatively, in an attempt to clear male factor obstacles, Artificial Insemination (AI) could be developed as an integral tool in ostrich reproduction. Already, techniques have been applied for semen collection in the male ostrich (Rozenboim *et al*., 2003; Rybnik *et al*., 2007; Malecki and Rybnik, 2008). AI is a vital tool for the rapid improvement of fertility and allows the maximum use of the best males on numerous hens (Zahraddeen *et al*., 2005). The researchers argue that AI is one of the animal production technologies that augment production and returns from livestock and poultry at a faster rate and enhances crossbreeding programmes.

Another technique that can be adopted in order to diagnose reproductive wastage and to detect low fertility cocks is the assessment of sperm numbers in the outer perivitelline layer of eggs, combined with observing the appearance of the germinal disk in unincubated eggs

(Malecki and Martin, 2003b). This facility could increase the efficiency of breeding flocks either by selecting superior males or by optimizing sex ratios for the mating.

Hen infertility: Egg production per hen per year is an important parameter to estimate reproductive performance in breeding farmed ostriches (Bronneberg *et al*., 2007b). The female ostrich matures sexually at about 24 months of age, after which it starts laying eggs, undergoing varying stages of ovarian activity. It remains fertile for about 40 years, during which period annual egg production varies between 20 and 70 eggs (De Jong, 1994; Bronneberg *et al*., 1999; Deeming and Ar, 1999; Madekurozwa, 2004).

The ostrich hen is an opportunistic, indeterminate breeder, laying an egg every other day in late afternoon during the breeding season and will continue to lay eggs for long as the eggs are removed from the nest (Degen *et al*., 1994; Shanawany, 1994). However, to preserve their vigor, the breeding season is usually restricted to only 6-8 months in a year.

Egg production fluctuates greatly within and between breeding seasons (Bronneberg *et al*., 1999; Deeming and Ar, 1999). This scenario puts enterprise viability at risk. In the wild ostrich, clutch sizes vary between 5 and 36 eggs (Navarro and Martella, 2002). In poultry, egg production has been guaranteed as a result of knowledge gained on genetic selection, feeding, light-schemes and reproductive management among others (Etches, 1990). In the ostrich, such advances are research in progress (Degen *et al*., 1994; Lambrechts *et al*., 2002b; Bronneberg and Tarvene, 2003; Bronneberg *et al*., 2007a, b; Madekurozwa, 2007).

The reproductive organs of the ostrich hen comprise the ovary and oviduct with only the left ovary and oviduct being the ones that develop (Fowler, 1991). Ovarian size, shape and ultrastructural morphology vary with stages within the breeding cycle and resemble a bunch of grapes in mature, reproductively active hens (Bezuidenhout, 1986; Medekurozwa, 2007).

Hen infertility is generally regarded as failure to lay eggs. It may be temporary and a failure to lay eggs should not immediately preclude the hen from future breeding. Biologically, egg production in the hen involves a cascade of events involving hormonal stimulation in sexually mature hens (Degen *et al*., 1994).

As stated under male infertility, the breeding season of the ostrich depends on increasing daylength (Hicks, 1992; Mellet, 1993; Degen *et al*., 1994; Soley and Groenewald, 1999). In seasonal breeding birds, increased daylength results in the hypothalamus producing and secreting Gonadotrophin Releasing Hormone (GnRH), which in turn stimulates the anterior pituitary gland to produce and release Follicle Stimulating Hormone (FSH) and Leutenising Hormone (LH) into the circulatory system (Sharp, 1996). The ostrich hen has a 48 h ovarian cycle. Ovarian follicles grow under the influence of LH, resulting in the production and secretion of gonadal steroids such as estrogen (Bronneberg *et al*., 2007b). Plasma LH significantly increases one month before the start of the breeding season and decreases toward the end of the season (Degen *et al*., 1994; Bronneberg *et al*., 2007b). Estrogen levels increase at the start of the egg laying season, peaks, when egg production is maximal and remains elevated for the rest of the breeding season (Bronneberg *et al*., 2007b). The same researchers further noted that ovulation occurs about 2 h after oviposition, while progesterone, LH and estrogen reach peak concentrations shortly before ovulation. Ultra-structural differences (Madekurozwa, 2007), most likely associated with hormonal levels, have also been noted between uteri of ostriches in and out of their active ovarian phases. Ostrich breeding should therefore always involve sexually mature hens in their active ovarian phases to ensure optimal egg production (Black, 1995). Breeder age positively influences the number of eggs laid per female per season and fertility of eggs (Ipek and Sahan, 2004).

The development of the ovarian follicles and reproductive health status in the female ostrich can be detected and monitored by ultrasonography (Bronneberg and Taverne, 2003). This technological development could play a major role in the future with respect to determining and intervening on some hen related causes of infertility. Ultrasonography could also play a big role in breeder selection, in discriminating between ovulating and non-ovulating hens and in quantifying the egg production potential of individual hens at the start of the season, considering that characteristics like egg production are satisfactorily repeatable and predictable (Schalkwyk van *et al*., 1996; Lambrechts *et al*., 2002b; Bronneberg and Taverne, 2003; Bronneberg *et al*., 2007a, b). These advances may, as is the case with poultry (Etches, 1990), set the stage for improved egg production and ultimately enterprise viability.

Hen infertility can also be a result of females that retain too few sperms after mating, or that retain sperms for a shorter time in their sperm storage tubules (Malecki and Martin, 2002).

Nutritional causes of infertility: Nutrition is a vital aspect of animal breeding. Birds, like other animals need energy to carry out the actual process of mating and also invests some nutrients in the eggs. In ostriches, egg size, an indicator of maternal investment (Heaney and Monaghan, 1995), is actually also a good predictor of hatchling mass as well as chick survival at 1 month of age (Bonato *et al*., 2009). Starving ostriches are also less likely to be able to breed, while deficiencies of macro and micro nutrients can adversely affect fertility, hatchability and chick survival.

Feeds containing energy levels lower that 8.5 MJ Metabolisable Energy (ME) kg^{-1} Dry Matter (DM) can affect body condition of breeders and can decrease egg production by as much as 28% (Brand *et al*., 2003). Brand *et al*. (2003) concluded that diets containing 8.5 MJ ME kg^{-1} DM and 105 g kg^{-1} protein should be regarded as the minimum that can be used for breeding female ostriches without compromising egg production. Overfeeding of breeders can lead to obesity, which condition is associated with a decrease in libido (Aganga *et al*., 2003). The recommended feeding rate of ostriches during the breeding season is 2 kg/bird/day of breeder ration, translating to 17 MJ ME of energy and 210 g protein daily. Ostriches should be pre-conditioned 4 weeks prior to the commencement of the breeding season in order to get them back into shape for breeding following the off season, when they are fed a maintenance ration that is lower in almost all nutrient levels.

An interesting aspect of feeding breeder ostriches is the documented competition for absorption from the gastro-intestinal tract between calcium and zinc (Gregor, 1988; Somer, 1995). Calcium is required for egg production among other important functions, while zinc is vital for spermatogenesis, where its supplementation in poultry enhances fertility and hatchability (Barney *et al*., 1968; Anshan, 1990). Theoretically therefore, increasing dietary calcium to cater for the hen's needs may compromise intestinal absorption of zinc in the male since both sexes are fed on the same ration. The question would be whether the sexes would need to be fed separately and if it would be feasible since they need to be together to encourage mating. Growing replacement cocks and breeder cocks during the off breeding season need to be fed separately from hens and on a low calcium diet to allow for a sufficient uptake of zinc to promote testicular development and regeneration respectively. Vitamin A and E deficiencies have often been associated with infertility.

Vitamin A is important in the maintenance of epithelia, including testicular epithelium. Ostrich eggs have been found to contain high levels of selenium in shell and shell membranes at 1785 and 1904 μg Se kg^{-1}, respectively, which is available for use by the developing embryo (Golubkina and Papazyan, 2006). Vitamin and mineral requirements and deficiency syndromes in poultry are well documented (NRC, 1994). Such data for ostriches is scant. However, Angel (1993) summarized some reproductive effects associated with mineral and vitamin deficiencies in ostriches (Table 1).

Table 1: Some effects of vitamin and mineral deficiencies and excesses in ostrich breeders on egg production and embryo and chick performance (Angel, 1993)

Vitamins	Effects
Vitamin E	Early embryonic mortality-circulatory failure
	High mortality of chicks soon after hatch
Riboflavin (B2)	Embryos exhibit dwarfing, altered limb and mandible development, edema, defect in the down development (clubbed down)
Folic acid	Defects of the mandible, deformed beaks
Minerals	
Manganese	Skull deformities, parrot beak
	Increased incidence of thin shelled and shell less eggs
Iodine	Incomplete closure of navel
Selenium excess	Reduced egg production
	Reduced hatchability
	Embryonic abnormalities

Influence of disease on fertility: The importance of good health on reproduction can never be over emphasized. Many diseases may result in reproductive failure, either through failure to produce eggs or through production of abnormal or contaminated eggs (Cabassi *et al*., 2004). Diseases affect an animal's fertility in a number of ways. Chronic diseases such as aspergillosis or avian tuberculosis may cause reduced fertility before clinical signs become noticeable. Internal parasites may result in debility directly or via a decrease in the availability of essential nutrients to the animal (Shanawany, 1999). External parasites may cause irritation, general disturbance and sometimes blood loss.

Influence of husbandry on fertility: In an experiment involving heat stress in broilers, high temperatures were found to decrease male fertility (Karaca *et al*., 2002). Average egg production, fertility and hatchability are also compromised when stocking rate is high in ostriches (Lambrechts *et al*., 2004).

HATCHABILITY

Hatchability denotes the percentage of fertile eggs that hatch successfully following an appropriate incubation period, which is about 42 days in the ostrich at 36.9°C and 25-40% dry bulb humidity. Hatchability therefore, basically involves losses owing to embryonic death at various stages of development.

Various hatchability rates have been noted the world over, ranging from 27-67% and is on average below those found in wild ostriches (Bertram and Burger, 1981; Deeming, 1996a; More, 1996; Badley, 1997). Bertram (1992) reported 65% hatchability for wild ostriches in Kenya. Apart from the wide range noted above, the hatchability results are also way <95% commonly achieved in poultry, probably indicating room for optimizing ostrich production. Embryonic mortality peaks during the first and last few days of incubation with few losses occurring during the middle period of incubation (Deeming, 1993, 1995; Brown *et al*., 1996).

Influence of temperature on hatchability: The incubation temperature for ostrich eggs is 36.5°C (Stewart, 1996; Hassan *et al*., 2004). The researchers also noted an increase in the incidences of dead-in-shell embryos and total number of dead embryos, when eggs are incubated at 37.5°C. Towards the end of incubation, the temperature inside the egg rises by 2.0°C above the surrounding air temperature, as a result of metabolic heat production by the embryo (French, 1997). This may result in the death of the embryos due to hyperthermia, when the same incubation temperatures are maintained through out incubation (Meir and Ar, 1990; Hassan *et al*., 2004). Ideally, incubation temperatures should regress, decreasing slightly as the embryo develops (Deeming, 1993).

Moisture loss and hatchability: The incubation humidity for ostrich eggs is considered to be 25-40% dry bulb humidity. This humidity enables incubating eggs to lose between 13 and 15% of their original weight in the form of moisture and is an important determinant of hatchability (Rahn *et al*., 1977; Philbey *et al*., 1991; Foggin and Horneywill, 1992; Deeming, 1995; Christensen *et al*., 1996; Nahm, 2001).

Egg shell properties play an important role in determining hatchability. During development, oxygen, carbon dioxide and water vapor are transported in to and out of the egg through pores in the egg shell (Rahn, 1981). The ability of the ostrich egg to lose moisture therefore, depends on parameters like shell porosity, shell thickness and incubation humidity among others (Gonzalez *et al*., 1999). It is thought that advances in ostrich breeding will lead to the production of eggs with consistent size and shell characteristics that could lead to improved hatchability as in poultry (Deeming, 1996a; Badley, 1997). According to the researchers, ostrich eggs that possess low porosity and have increased thickness hatch poorly. Egg weight has also been shown to influence hatchability, with large eggs having problems losing the required amount of water, having reduced oxygen uptake and being consequently frequently associated with edema chicks (Deeming, 1993; Hassan *et al*., 2005). However, Bonato *et al*. (2009) noted better chick survival at 1 month of age in larger eggs. Excessive moisture loss above 18% to about day 35 of incubation puts chicks hatching from such eggs at higher risk of dying before they attain the age of 28 days (Cloete *et al*., 2001).

Egg contamination and hatchability: Egg contamination can be lethal to the embryo even at low doses. The degree of yolk contamination is influenced by the degree of egg contamination before egg setting (Deeming, 1995, 1996b; Musara and Dziva, 1999; Cabassi *et al*., 2004). Mushi *et al*. (2008) observed a 7.3% hatchability depression associated with microbial contamination of eggs. Microbial contamination of eggs can result from the dipping or washing of eggs in liquid disinfectants before setting them into incubators that possibly leads to the disruption of the protective cuticle of the egg shell (Huchzermeyer, 1996; Richards *et al*., 2002). As a result, fumigation should be routinely carried out before setting eggs in to the incubator in order to avoid egg washing (Huchzermeyer, 1996; Mushi *et al*., 2008). Various microbes have been associated with ostrich egg contaminations and include bacteria (*Escherichia coli*, *Aeromonas* sp., *Enterobacter* sp., *Acinetobacter* sp., *Citrobacter* sp., *Streptococcus faecalis*, *Klebsiella* sp., *Staphylococci* sp., *Bacillus licheniformis* and *Achromobacter* sp.) and fungi (*Penicillium* sp. and *Fusarium* sp.) (Foggin and Honywill, 1992; Deeming, 1995a, b, 1996b; More, 1996; Welsh *et al*., 1997; Musara and Dziva, 1999; Cabassi *et al*., 2004; Mushi *et al*., 2008).

Other factors affecting hatchability: Reports suggest that prolonged pre-incubation storage of over 14 days below 21°C and high breeder stocking density have a negative effect on hatchability (Deeming, 1996a, b; Badley, 1997; Gonzalez *et al*., 1999; Nahm, 2001; Lambrechts *et al*., 2002a; Sahan *et al*., 2004; Hassan *et al*., 2005). Hatchability can also be affected by poor nutrition, especially that involving a deficiency or imbalance of minerals and vitamins (Perelman *et al*., 2001). Breeder age as measured from the first season of breeding, as well as breeding season also affects hatchability. Other factors include altering the setting, turning and angle of rotation in the incubator (Schalkwyk van *et al*., 2000; Ipek and Sahan, 2004; Brand *et al*., 2007).

CONCLUSION

The low and varied fertility and hatchability rates in ostrich production are a major impediment to optimal productivity and enterprise viability. The female ostrich is regarded as having high fertility rates and the adoption and nurturing of technologies such as BSE and AI could significantly improve reproductive efficiency. There are hen and cock factors that affect fertility. The grouping of breeders based on compatibility before the start of the breeding season also need to be emphasized. Some aspects of breeder feeding and nutrition, as well as heritability of fertility in the ostrich need further research. Hatchability can be affected by the use of contaminated eggs, inappropriate incubation temperature and humidity and the failure to attain the recommended 15% moisture loss during incubation.

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