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The development of ratite production through continued research

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This paper summarises research on farmed ratites and their industries over the past 100 years. Commercial ratite products include meat, skins, feathers and oil. Research on ratites has attempted to enhance the quantity and quality of these products by focusing on the disciplines of breeding and genetics, reproduction and incubation, assisted reproduction, nutrition and animal welfare. Advances in these disciplines are discussed, and directions for future research are provided.

Keywords: breeding; genetics; incubation; reproduction; nutrition; welfare

Introduction

The association between mankind and farmed ratites has been short when compared to other livestock species. Commercial ostrich production began in the 1860's, while the other farmed ratites (Emu and Rhea) have been in commercial production for shorter periods (Cloete and Malecki, 2011). Ratite production is thus, comparatively speaking, still in its fledgling stage. Notwithstanding this, a substantial body of research has accumulated over the past 100 years. This review summarises this research to date, but is by no means exhaustive, given the scope of this paper.

Ratite products

The main products obtained from ratites are meat, skin, feathers, eggs and oil. Research

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efforts have been focused on high value products according to market trends over the years, focusing on ostrich feather quality during the feather boom early in the 20th century and moving toward leather and meat research at the end of the twentieth century as these products gained value.

Duerden (1910; 1911) did the bulk of the original work on ostrich feathers, which was followed by a study by Swart (1979) to quantify the quality traits of feathers and their relative economic importance. The collapse of the feather industry resulted in a cessation of ostrich research from approximately 1915 to 1954. Since then, various books and research articles have been published, increasing exponentially during the last 15 years or so, after the deregulation of the ostrich industry. Aspects of ostrich skin production and leather quality (Cooper, 2001; Engelbrecht *et al.*, 2009), ostrich meat (Sales and Oliver-Jones, 1996; Hoffman, 2005), emu meat (Sales, 2007), ratite meat (Sales and Horbanczuk, 1998) and the processing of ratite meat (Hoffman, 2008) have been reviewed recently.

An investigation into emu products, focusing on improvement of emu leather quality and emu oil was accordingly conducted (O'Malley and Snowden, 1999). Emu farming gained momentum from approximately 1990 (O'Malley, 1990) and high prices were paid for emu fat due to claims regarding the benefits of emu oil. Snowden and Whitehouse (1997), Bennett *et al.* (2008) and Lindsay *et al.* (2010) have since demonstrated the anti-inflammatory and antioxidant properties of emu oil. Emu oil, as well as ostrich and rhea oils, was also found to protect human erythrocyte membranes from oxidative damage due to their fatty acid composition (Bennett *et al.*, 2008).

Based on the economic importance of production levels for ratite commodities, it is clear that the objective of research should be to improve the number of offspring, the survival of these offspring to marketing age, as well as sustained and efficient growth to slaughter. The quality of leather and feathers, in particular, is of strong secondary importance, along with validating continued research. Although meat quality is considered in scientific studies, the application of such studies has not yet found their way to price determination in the market place. Against this background, research in disciplines such as breeding, genetics, reproduction, incubation, nutrition and animal welfare focussed on the improvement of ratite production and the quality of ratite products.

Breeding and genetics

Marked progress has been made over the past 20 years as far as the genetic evaluation of farmed ostriches is concerned. Unfortunately, the same progress has not been reported for other ratites.

GENETIC PARAMETERS AND ADDITIVE GAINS

Emphasis has been placed upon the development of a structured breeding plan for the ostrich industry to enable genetic improvement of commercial ostriches (Cloete *et al.*, 2008c). Such an assignment is impossible without knowledge of genetic parameters, as summarised by Cloete *et al.* (2008c). In essence, quantitative reproduction traits (egg production and chick production) exhibited very high levels of phenotypic variation (coefficients of variation > 50%), backed by moderate to high heritability estimates (0.12 – 0.29 for egg production and 0.11 – 0.26 for chick production on an annual basis) when annual records of females were considered. Usable levels of genetic variation remains, even when monthly records were analysed (Fair *et al.*, 2011). Marked additive gains, amounting to 3.1% per annum was accordingly reported for traits such as chick

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production (Cloete *et al.*, 2008b). Qualitative reproduction traits (average egg and chick weights) exhibited lower levels of phenotypic variation (~10%), but with higher heritability estimates of 0.43 – 0.74 (Cloete *et al.*, 2008c; Fair *et al.*, 2011). The genetic correlation between egg and chick production is unity, indicating that these traits depends on the same genes, while quantitative traits are not unfavourably related to qualitative traits (Cloete *et al.*, 2008c). Likewise, there are no unfavourable genetic correlations of quantitative reproduction traits with mature live weight (Cloete *et al.*, 2008b; 2008c). The lack of unfavourable genetic correlations facilitates the compilation of a selection index for ostriches.

Water loss to 21 and 35 days of incubation was highly heritable at respectively 0.34 - 0.41 and 0.27 - 0.41, while the genetic correlation between these traits amounted to 1.00, suggesting that these traits depends on essentially the same genes (Brand *et al.*, 2008; 2009). Embryonic mortalities assessed as a trait of the egg was moderately heritable at 0.16-0.22 (Brand, 2011), and responded to selection for chick production and live weight.

Survival post-hatch constrains efficient ostrich production. Low but significant heritability estimates were derived for survival to 4 weeks of age (0.06), and from 4 – 12 weeks of age (0.05), but subsequent chick survival did not exhibit genetic variation (Wang *et al.*, 2011). This aspect requires further investigation.

Various studies reported that most ostrich leather traits exhibited significant genetic variation (see review by Engelbrecht *et al.*, 2009). The economically important quantitative and qualitative traits were mostly moderately heritable, with the exception of skin damage, for which no significant additive genetic variation exists (Cloete *et al.*, 2008c). No unfavourable genetic correlations among quantitative and qualitative skin traits have been reported so far (Engelbrecht *et al.*, 2009; Cloete *et al.*, 2008c).

The effects of genetics on feather traits were reported early in the 20th century (Duerden, 1910; 1911). The first real estimate of heritability for number of wing quills (0.16) was reported after interest in ostriches was revived in the 1960's (Louw and Swart, 1982). The heritability of different feather types was low to moderate, ranging between 0.11 – 0.16 (Brand and Cloete, 2009). The heritability of total feather weight was fairly high at 0.30. Genetic correlations among all categorised feather weights were moderate to very high at 0.49 to 0.91 (Brand and Cloete, 2009).

BREED CHARACTERISTICS AND HETEROSIS

There are three distinct ostrich genotypes available for commercial production, namely the South African Black (SAB), the Zimbabwean Blue (ZB) and the Kenyan Redneck (KR). Jarvis (1998) characterised these (and other strains) on the morphological level, but the production levels of these strains have not been quantified accurately (Petite and Davids, 1999). Molecular genetic evaluation of ostriches lag behind that of other livestock species, but a preliminary linkage map has been drawn up (Huang *et al.*, 2008). Genetic distances between these strains have been confirmed (Kawka *et al.*, 2007; Davids, 2011). Comparative studies suggested that SAB females reproduce better than their ZB (Cloete *et al.*, 2008a; Davids, 2011) and KR contemporaries (Davids, 2011). Heterosis (relative to mid-parent performance) amounted to 12% for egg production and 19% for chick production in crosses between the SAB and ZB strains (Davids, 2011).

The post-hatching survival of ZB chicks was substantially lower than that of SAB chicks. Chick survival of particularly the cross between the ZB male and the SAB female was substantially improved relative to purebred ZB chicks, leading to positive heterosis estimates (Engelbrecht *et al.*, 2008).

Slaughter birds of the ZB strain were heavier than SAB contemporaries (Hoffman *et al.*, 2007; Engelbrecht *et al.*, 2008; Davids *et al.*, 2010). Crossbred slaughter birds

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resembled the ZB parent for quantitative slaughter traits (Engelbrecht *et al.*, 2008; Hoffman *et al.*, 2008; Davids *et al.*, 2010), and the SAB parent for qualitative meat traits (Hoffman *et al.*, 2007; Davids *et al.*, 2010). Heterosis for slaughter weight was significant, amounting to 6.9% in the study of Engelbrecht *et al.* (2008) and 6.7% in the study of Davids (2011).

Commercial crossbreeding using SAB females (with an improved reproduction – see Cloete *et al.*, 2008a; Davids, 2011) with ZB males (with a higher live weight – see Cloete *et al.*, 2008a; Davids, 2011) could be viable. Results indicate that chicks produced in this way would have a better survival (Engelbrecht *et al.*, 2008), heavier slaughter weight (Engelbrecht *et al.*, 2008; Hoffman *et al.*, 2007; Davids *et al.*, 2010) and favourable qualitative meat quality (Hoffman *et al.*, 2008; Davids *et al.*, 2010).

Reproduction and artificial incubation

THE EFFECT OF AGE AND SEASONALITY ON REPRODUCTIVE PERFORMANCE

Reproductive performance of farmed ratites (ostriches, emus and rheas) still faces multiple challenges in terms of improving hatchability of eggs, fertility of breeding birds and reducing chick mortality to three months of age (Navarro and Martella, 2002). Emphasis has been placed on identifying factors that could influence ratites reproductive output, and specifically on egg and chick production. The hen's age influenced hatchability, chick production, egg weight and hatchling weight whereby three to seven year old females outperform two and 12+ year old contemporaries (Fair *et al.*, 2011). Furthermore, seasonality in egg production has been described in several ratite species. For instance, peak egg production in emus occurs from mid-winter to mid-spring (Malecki and Martin, 2002) while in ostriches, eggs are laid from mid-winter to mid-summer (Cloete *et al.*, 1998; Lambrechts, 2004). Interestingly, an age specific seasonal production also showed differences in the production patterns of two year-old and older female ostriches (Fair *et al.*, 2011). Fertility of male ostriches also appears to be age and season dependent, with males up to nine years old showing greater fertilisation success (Bunter and Graser, 2000; Lambrechts, 2004) and semen output and characteristics are at peak production and quality in spring (Bonato *et al.*, 2011).

THE EXPRESSION OF SEXUAL BEHAVIOUR AND REPRODUCTIVE PERFORMANCE OF FARMED RATITES

Ratite mating systems are widely diverse, ranging from promiscuity in the ostrich (Bertram, 1992; Deeming and Bubier, 1999) and in the rhea (Smith, 1977), to sequential polyandry in the emu (Coddington and Cockburn, 1995). Recent studies suggest that mate preferences and differential maternal investment at the egg stage as described in the ostrich (Deeming, 1996; Bonato, 2009; Bonato *et al.*, 2009) and in the emu (Taylor *et al.*, 2000; Blache *et al.*, 2000) could complicate breeding programs, as they rely on pairs, trios, quads or colonies, while emus are mostly kept in pairs or colonies (Cloete and Malecki, 2011). Mate preferences could potentially alter the full expression of normal sexual behaviour in both sexes, leading to stress and subsequently infertility, low egg production and within pair fighting. Similarly, separation of partners (a common practice in ostrich farming) reduced egg output and egg fertility (Cloete *et al.*, 1998; Malecki *et al.*, 2004). Thus, a better understanding of mating preferences is required not only to improve the overall performance of ratites under intensive breeding conditions, but also to improve the welfare of this group of birds.

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THE HATCHABILITY OF ARTIFICIAL INCUBATED EGGS

Artificial incubation is an integral part of the commercial ostrich production system, therefore an improvement of incubation has been the subject of many studies. Successful artificial incubation has been found to be affected by a number of factors including storage conditions and duration prior to setting, water loss from the egg during incubation and year-season effects of female age (Van Schalkwyk *et al.*, 1999; Blood *et al.*, 1998; Brand *et al.*, 2007; Brand, 2011).

Artificial insemination (AI) technology development

Attempts to develop AI for ostrich farming were made more than 30 years ago when semen collection and artificial insemination methods were proposed (Van Rautenfeld, 1977) as a strategy to improve the efficiency of ostrich farming. Reliable semen collection and artificial insemination methods have, however, only been developed recently (emu: Malecki *et al.*, 1997, Malecki and Martin, 2004; ostrich: Rybnik *et al.*, 2007; Malecki and Rybnik, 2008) through training that is based on expression of normal sexual behaviour (Malecki and Rybnik-Trzaskowska, 2011). Those methods may provide a solution to development of a new ratite industry and lead to creation of an optimal and effective farming environment. However, feasibility of AI has not yet been fully established. We have determined that both emus and ostriches have about a two week duration of the fertile period after the last mating (Malecki and Martin, 2002, Malecki *et al.*, 2004) and if the artificial insemination can match this, aided by selection for traits such as the rate of sperm loss or fertile period duration, female ostriches and emus could produce sufficient number of eggs from one insemination to make the system economically viable. Thus far, female ostriches appear more efficient than female emus because they lay eggs every two days while emus lay every three days, and they can achieve longer duration of sperm storage having low initial sperm numbers. Moreover, recent observations suggest that female ostriches can lay eggs in the absence of males or mating (Malecki *et al.*, 2008, Brand *et al.*, 2010b), which is difficult to achieve in the emu.

Reliable protocols for short (liquid) and long (frozen) storage will be essential, but this research has only recently been able to start as normal ejaculates have become available routinely. Ratite semen can be stored short term (up to 24h) in liquid form (Malecki *et al.*, 2008) and AI with liquid stored semen should yield satisfactory conception. Effective freezing of semen has always been a challenge so it is no surprise that development of protocols for freezing ratite semen will require some effort and time. In the emu, after freezing, almost 60% of sperm capable of fertilisation (as assessed by *in vitro* sperm function tests) can be recovered (Sood *et al.*, 2012). The knowledge gained should help to speed up protocol development for ostriches.

Nutrition

The first book on ostrich nutrition was published as early as 1913 (Dowsley and Gardner, 1913). From that time several publications on ostrich nutrition have been published. For example Swart (1987), du Preez (1991), Cilliers (1995), Smith *et al.* (1995), van Niekerk (1995), Angel (1996), Cilliers and Angel (1999), Brand and Gous (2006), Gous and Brand (2008) as well as Brand and Olivier (2011) published pioneering work and reviews on ostrich nutrition. Published work on the nutrition of emus is rather scarce and limited to only a few recent publications (for example O'Malley, 1999).

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Initially ostrich diets were composed according to requirements for producing good quality feathers, while growth rate was not important (Smith, 1963). In the next phase of industry development, birds were primarily used for leather production (1975 – 2008) and birds were slaughtered at ~14 months for large skins, with prominent nodules. However, diet composition, to enhance maximum growth, was still considered to be not very important. Relatively slow growth rates and poor feed conversion rates were common (Swart and Kemm, 1985).

The ostrich industry went through a stage of rapid expansion during the mid-1990's and breeding stock, for example, commanded exceedingly high prices while the price of ostrich products were favourable. At that stage, the industry could afford very expensive diets and feed formulators and manufacturers used generous specifications based on those of chickens (Farrel *et al.*, 2000) or turkeys (Ullrey and Allen, 1996). During this time ostriches were mainly used to provide low-cholesterol meat (*c.* 50% of commercial income) compared to durable high-quality skins (*c.* 45% of commercial income) and plumes for the fashion market (*c.* 5% of commercial income) (South African Ostrich Business Chamber, 2002).

The shift in the market from skins to meat lead to the development of diets that was able to maximize growth, but still give a reasonable quality skin (Brand *et al.*, 2000; Brand *et al.*, 2004a; 2004b; Cloete *et al.*, 2006). Overfeeding of certain nutrients, however, led to digestive problems, which necessitated intensive investigations into the digestive physiology of the bird (Iji *et al.*, 2003; Viljoen *et al.*, 2004) as well as other dietary factors (Kruger, 2007; Janse van Vuuren, 2008). The more intensive farming practices also necessitated that more attention was given to the nutrition of breeding birds (Brand *et al.*, 2003; Olivier *et al.*, 2009).

With current ostrich production systems there may be a conflict in production of hides, meat and feathers. The commercial value of these end products, in relation to each other, changes markedly according to the age of the bird (Brand *et al.*, 2010a). Current markets require the skin of a bird of at least 12 months of age, while for meat production *per se,* it may be more economical to feed the bird to achieve its maximum growth rate at an earlier stage. That will result in birds being ready for slaughter at too young an age to maximize returns from the sale of the skin as well as feathers. Simulation models can assist the producer in deciding on the most economic feeding strategy (Gous and Brand, 2008). The information on the relative growth rate and composition of different body parts and feathers of ostriches as well as other related research data to develop these models were collected recently (Brand *et al.*, 2010a; Kritzinger *et al.*, 2010).

The nutrition of ostriches remains important as feed normally comprises 75% of the total costs of an intensive ostrich production unit (Jordaan *et al.*, 2008). Ostriches are monogastric herbivores with a large digestive tract, which enables them to utilise fibrous plant material. The strategic use of pasture with accompanied supplementary concentrates and fibrous plant material later in the production system may therefore also play an important role in economic ostrich production (Strydom *et al.,* 2009; 2010). The choice of feedstuffs to use as raw materials will always be price related, since feed conversion and growth of the bird increase markedly with the replacement of fibrous feed sources with concentrated diets (Brand and Olivier, 2011). The prediction of a nutritional strategy for ostriches during the different growth stages by mathematical optimisation models (simulation models) to optimise production, will allow customised feed formulation in future, which will largely differ from the fixed nutritional programs currently in use (Gous and Brand, 2008).

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Welfare

Research on some of the welfare issues associated with the farming of ratites has only recently been undertaken. Codes of Practice have been developed for ratite farming in a number of countries (Cloete and Malecki, 2011). The codes place importance on management of birds to minimise welfare and health problems for birds (Black and Glatz, 2011). Nevertheless there are a number of issues that require further research to improve the code and welfare of farmed ratites (Glatz and Miao, 2008).

The current management of on-farm breeding colonies attempts to match the natural conditions ratites experience in the wild. However, in larger breeding colonies, birds need the space to separate from the flock and form smaller natural breeding groups. A concern is that farmers may select breeding pairs that are not compatible. This can cause fighting, injury and pain to birds as well as poor fertility. However, research has identified welfare friendly methods for semen collection and artificial insemination. Breeder welfare has been enhanced by obtaining normal sexual responses of birds through a positive human-ratite relationship that leads to voluntary bird ejaculation and birds that are receptive to artificial insemination (Malecki and Rybnik-Trzaskowska, 2011).

Intensively raised ratite chicks are subject to considerable welfare risks associated with poor diets (deficiencies and imbalances), inappropriate feeding space and conditions, environmental extremes, handling and transport issues, poor water management and lack of trained stockpersons. There has been little research undertaken in the ratite industry on the skills of stockpersons but it is essential that animal handlers have the skills to look after their stock and develop a good affinity with their birds. Livestock which are housed in facilities with good air quality grow faster and consume more feed than animals exposed to poor air quality. Improving air quality in ratite brooding facilities could improve production and provide a better working environment for farm employees (Glatz, 2011).

Poor handling, transport and lairage of ratites prior to slaughter can impact on the welfare of ostriches. The design of holding facilities, feedlot, lairage and breeding camp facilities is critical to ensure the welfare of ostriches is not compromised; incorrect facility design can have an adverse influence on skin quality.

Partial amputation of the toes of ratites has welfare implications. It causes ratites acute pain; they become flatfooted and change their gait and they can slip and fall over in wet paddocks and handling areas. The high vascularisation near the surface of the ratite skin can increase the incidence of skin bruises from interactions between birds as well as abrasions during handling and transport. Injury to the skin will inflict pain via stimulation of nerves. However the blunting of the claws reduces the bird's ability to deliver kicks and injuries to other birds during aggressive encounters and improves skin quality in the flock and reduces the potential for handlers suffering injuries (Glatz and Miao, 2008).

Some ratite species are under threat as land is cleared for cropping and grazing by ruminants. Captive breeding for conservation purposes should promote a level of animal welfare that does not jeopardize post-release survival and reproduction in the wild. Release should be carried out in the non-breeding season, using either a hard or soft release techniques (Navarro and Martella, 2011).

Conclusions

It is clear that substantial progress has been made in commercial ostrich production. Research on other ratite species seem to lag behind somewhat. However, there are still many challenges. Ratite breeding would benefit from the development of a commercial

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industry, possibly with the help of assisted reproduction techniques. Despite advantages, ratite reproduction and artificial incubation outcomes remain below par, and further fine-tuning is needed. The continuous cost-squeeze experienced by ratite producers prompts the use of optimal diet formulations as well as an increased reliance on pasture and other fibrous feedstuffs. Substantial further efforts are needed in the field of ratite behaviour, to ensure that commercial ratite enterprises are run in an efficient and sustainable way, while also catering for the welfare needs of the animals. Future generations of scientists will thus still face numerous challenges to ensure sustainable and profitable ratite industries.

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