Foster parenting, human imprinting and conventional handling affects survival and early weight of ostrich chicks

M.D. Wang[1], S.W.P. Cloete[1,2#], K. Dzama[1], M. Bonato[1] & I.A. Malecki[1,3,4]

[1] Department of Animal Sciences, University of Stellenbosch, Private Bag X1, Matieland 7602, South Africa
[2] Institute for Animal Production: Elsenburg, Private Bag X1, Elsenburg 7607, South Africa
[3] School of Animal Biology, Faculty of Natural Agricultural Science, University of Western Australia, 35 Stirling Highway, Crawley, WA, 6009
[4] UWA Institute of Agriculture, The University of Western Australia, 35 Stirling Highway, Crawley, WA, 6009

Abstract

The effects of human imprinting and foster parenting by adult ostriches on the survival and growth performance of ostrich chicks were compared to conventional chick-rearing practices in two separate experiments. In the first experiment, the growth rate and survival of chicks imprinted onto humans were compared with those of chicks reared by adult foster parents (n = 100 for both groups). Survival is expressed as proportions, while weights were measured in kg. Treatment did not affect chick survival to 3 weeks (0.90 for imprinted chicks vs. 0.89 for foster chicks), or from 4 to 12 weeks (0.86 vs. 0.83, respectively). Chick weight was not significantly different between groups at 4 weeks, but at older ages, those chicks reared by foster parents consistently outperformed imprinted chicks (means ± SEs being 12.8 ± 0.4 vs. 8.2 ± 0.4 kg at 9 weeks, 37.1 ± 0.8 vs. 19.9 ± 0.80 kg at 18 weeks and 46.2 ± 1.1 vs. 28.6 ± 1.2 kg at 22 weeks). In the second experiment, the treatments consisted of a human-imprinted group of chicks and a group subjected to conventional rearing methods (as customary on the research farm). Chick survival to four weeks was significantly higher for imprinted chicks than for conventionally reared chicks (0.97 vs. 0.84), although chick weight was independent of treatment at 4 weeks (6.27 ± 0.16 kg for the imprinted group vs. 6.18 ± 0.17 kg for the conventional group) and at 15 weeks (respectively 16.5 ± 0.68 vs. 15.2 ± 0.70 kg). Overall, chicks reared by foster parents were heavier than human-imprinted chicks, while early survival of imprinted chicks was better than that of chicks reared by conventional handling. Imprinting thus affected survival of ostrich chicks relative to conventional rearing practices. Because most ostrich chicks are reared with conventional methods, the present study indicates that improvements can be made by adopting alternative approaches. Further studies are needed to ascertain how foster parenting and imprinting may be utilized to optimize chick performance, including the long-term consequences of these practices.

Keywords: Parental care, *Struthio camelus*, animal welfare, animal behaviour
[#] Corresponding author: schalkc@elsenburg.com

Introduction

Considerable progress on human–animal interactions in agriculture has been achieved recently as a consequence of growing concerns about farmed animal welfare (Rushen *et al*., 1999; Zulkifli & Azah, 2004). Habituation to human handling and environmental enrichment during rearing are two methods that may reduce the overall stress levels of farm animals, with positive effects on their behaviour, productivity and welfare (Mills & Faure, 1990; Jones & Waddington, 1992; Hemsworth *et al*., 1993; Reed *et al*., 1993; Rushen *et al*., 1999). Environmental enrichment is a vague concept, referring to improvements to the environment of captive animals (Newberry, 1995). The imprinting phenomenon is potentially a method of environmental enrichment (Savatierra *et al*., 1994). In avian species, recent hatchlings form an attachment with any individual present at the time of hatching (Matsushima *et al*., 2003; Slagsvold & Hansen, 2008).

URL: http://www.sasas.co.za
ISSN 0375-1589 (print), ISSN 222-4062 (online)
Publisher: South African Society for Animal Science
http://dx.doi.org/10.4314/sajas.v42i2.4

This attachment, often irreversible, is termed 'filial imprinting' and accounts for a number of the most fundamental animal behaviours and social preferences (Slagsvold & Hansen, 2008). Environmental enrichment and regular handling have been shown to improve growth, reproductive performance, egg production, feed conversion rate, antibody production, disease resistance, survival and general behaviour in chickens (Jones *et al*., 1980; Jones & Hughes, 1981; Collins & Siegel, 1987; Gvaryahu *et al*., 1989; Jones & Waddington, 1992; 1993; Barnett *et al*., 1994; Hemsworth *et al*., 1994). They may thus, potentially, have profound effects on the way farm animals are handled.

Foster parenting, on the other hand, may promote the welfare, survival and performance of ratite chicks (Barri *et al*., 2005; Janse van Vuuren, 2008). Ostrich chicks reared by breeding pairs exhibit superior survival to that of chicks reared with conventional intensive methods (Janse van Vuuren, 2008). In addition, chicks exhibit reduced stress, and breeder pairs are provided with the opportunity to express natural parental care (Janse van Vuuren, 2008; Cloete & Malecki, 2011). The environment of both the chicks and the breeding pairs may thereby have been enriched. Rabbits have also been seen to effectively supplement the mother figure and improve the welfare of the chicks (Madeiros, 1997). Consumption of rabbit dung by the ostrich chicks may provide them with vitamins B and K while inoculating the chicks' intestines with beneficial bacteria, preventing yolk sac problems and other diseases associated with poor colonisation of their guts (Madeiros, 1997). The adoption approach necessitates less effort and investment than rearing chicks in special facilities, while preventing the imprinting of chicks onto humans (Bubier *et al*., 1996; Labaque *et al*., 1999). Imprinting is seen as problematic in commercially farmed ostriches, as the imprinted bird may subsequently direct its sexual attention to those humans on whom it was imprinted (Bubier *et al*., 1996). In contrast, imprinting on humans may play an important role in efforts to devise a viable protocol for assisted reproduction in this species (Malecki & Rybnik-Traskowska, 2011). Such a development would lead to improved industry data for analysis by allowing the accurate partitioning of random effects (Cloete *et al*., 2008) and would reduce the number of males required in industry flocks, leading to an obvious decrease in feeding costs.

Environmental enrichment, imprinting, foster parenting and regular handling are powerful tools and their independent or integrated application may alleviate stress, thereby satisfying many of the limitations imposed by stress-related behaviour (Jones & Waddington, 1993). The potential alleviation of stress in ostriches through regular human handling and environmental enrichment techniques is therefore an important objective in animal welfare and production (Jones & Waddington, 1993). Foster parenting, on the other hand, provides a low-cost alternative for rearing ratite chicks. This practice has direct advantages in terms of growth of greater rhea chicks (Barri*et al*., 2005) and survival of ostrich chicks (Janse van Vuuren, 2008), possibly reflecting an alleviation in the stress experienced by the young chick as a result of the presence of foster parents.

Against this background, a preliminary study was conducted to investigate whether imprinting on humans as a potential form of environmental enrichment and regular handling can improve the survival and growth of ostrich chicks. The effectiveness of the practice of foster parenting was assessed simultaneously as a low-cost alternative rearing method.

Materials and Methods

Day-old chicks to use in the study were obtained from the pair-bred ostrich flock at Oudtshoorn Research Farm. The management of the breeding pairs and eggs in this flock has been described (Bunter & Cloete, 2004; Cloete *et al*., 2008). Two experiments were performed.

Experiment 1: Two hundred ostrich chicks, hatched over four days, were randomly assigned to two groups. The first group comprised chicks raised by breeder pairs as foster parents in an extensive rearing environment with minimal human contact to prevent imprinting onto humans (Bubier *et al*., 1996). Three breeder pairs (referred to as pairs 21, 23 and 29) were selected from previous knowledge of their foster-parenting ability from the breeder pairs maintained on the farm. The ages of the male (M) and female (F) of each respective pair were M21: 9 years, F21: 13 years, M23: 18 years, F23: 17 years, M29: 11 years and F29: 10 years. The selected breeder pairs incubated and hatched at least one of their own eggs. The experimental chicks (n = 100 divided 33 : 33 : 34) were incubated in the hatchery in synchronization with those eggs incubated naturally by the breeder birds. On hatching, chicks from the artificially incubated eggs were added to those of the breeder birds (Labaque *et al*., 1999). Each breeder pair, together with their respective chicks, was maintained in 1 - 2 ha lucerne camps with water and feed available *ad libitum*. The

second group, the human imprinting group, consisted of 100 chicks that were reared using conventional chick-rearing practices (Bunter & Cloete, 2004) in an intensive rearing facility. Food and potable water were available *ad libitum*, while artificial heating was supplied. According to Bunter & Cloete (2004) conventional rearing implies that chicks were not reared by their parents, but were maintained in small groups of between 80 and 150 chicks up to approximately 12 weeks of age. Human imprinting was achieved by chicks remaining in the hatchery before being transferred to an intensive rearing facility. For 30 days they were given human contact according to this schedule: from hatching to 10 days of age, human presence was established for 100% daylight hours (5:45 - 18:30). The chicks were familiarized to touch, voice, hand feeding and a general human presence. The person who remained with them wore a white laboratory overcoat at all times. The degree to which ostriches distinguish individuals as yet has not been fully ascertained, although it has been suggested that in livestock, habituation to the original handler is rapidly generalized to similarly dressed, but otherwise unfamiliar humans (Hemsworth *et al*., 1996). After 10 days, the human presence was decreased to 50% daylight hours (6:00 - 7:00; 9:00 - 10:00; 11:00 - 12:00; 13:00 - 14:00; 15:00 - 16:00; 17:00 - 18:00) for another 10 days. From day 21 to day 30 a human remained with the chicks from 7:00 to 8:00, and then a human was present for 30 minutes every 1.5 hours until 17:00, followed by a full hour from 17:00 to 18:00. At 10 days post hatch, the chicks were split into three groups that were placed in adjacent pens. Chicks were weighed at hatching and again at 4, 9, 18 and 22 weeks of age. In addition, all mortalities were recorded for both treatment groups.

It is conceded that the management systems resulted in treatments differing in more ways than only imprinting versus foster-parenting. The fostered birds were accommodated outside, with access to lucerne pasture as well as standard balanced rations, whereas the imprinted chicks had only the same standard balanced ration (Cooper, 2004) as a food source. When the imprinted chicks were placed outside at 12 weeks, they had access to the same food sources as those supplied to the foster-parented chicks (a balanced diet and lucerne pasture).

Experiment 2: A group of day-old chicks were divided into two groups. One group (control), comprising 97 chicks, were distributed between two adjacent pens and exposed to the standard intensive rearing protocol of Oudtshoorn Research Farm, with human contact limited to daily provision of food and fresh water (Bunter, 2002). The other group (treatment) encompassed the 'imprinting, human foster group' that were raised under the same conditions, but in identical separate rooms distributed between two adjacent pens, with the addition of a regular human presence. Chicks that were used had hatched over a period of three days. From days 1 - 5 a person remained with the chicks from 6:00 to 18:00. Thereafter, the time spent with the chicks decreased by three hours every five days. The hours spent with the human subject were evenly spread according to three pivotal times (8:00, 12:00 and 16:00). Chicks were familiarized with human speech, touch, movement, and hand feeding, along with a general human presence. The human would sit on a chair in each of the two adjacent pens, sit on a cushion on the floor or walk around the pen. All mortalities were recorded. The imprinting phase of the trial concluded at day 21. Thereafter all experimental chicks were combined and exposed to the same standard chick-rearing protocol. Weighing took place at hatching and at 4 and 9 weeks of age.

Individual chicks were used as experimental units in both experiments. It is conceded that groups of chicks treated as experimental units would be a better way of approaching the problem. However, the limited facilities available for the sizes of groups needed for such an experiment, the number of indoor pens available, as well as the number of foster parents, would have made experiments with such a design impossible. Moreover, the research was designed as a preliminary study to explore potential benefits associated with the alternative management options. It could be argued that the comparison of individual chicks would be appropriate, especially in Experiment 2, as all facilities were similar, with the exception of human imprinting. It was also possible to combine these chicks soon after the cessation of the imprinting period. A more definite difference was present in Experiment 1, where the chicks could be combined only after recording for this experiment ceased.

Using data of individual chicks, Chi-square analyses were used to compare treatment effects on age-specific chick survival. The effect of different treatments on age-specific weights was ascertained through standard one-way ANOVA procedures. A supplementary analysis comparing the survival and performance of the chicks raised by the three separate breeding pairs was accordingly done via Chi-square analysis and one-way ANOVA.

Results and Discussion

In Experiment 1 there was no difference between fostered and imprinted chicks in chick survival to 12 weeks or chick weight at 4 weeks of age. However, as the chicks got older, the foster-reared chicks outperformed the imprinted chicks, exhibiting higher weights and elevated survival from 13 to 24 weeks post hatch (Table 1). Relative to the imprinted group, the weights of the foster-parented group were improved by 0.56 at 9 weeks, 0.86 at 18 weeks, and 0.62 at 22 weeks. These results are comparable with those of Barri *et al*. (2005), who reported no difference in survival rates of adopted greater rhea chicks compared with those reared intensively. They also proposed adoption to be potentially more beneficial in chick growth and the cost of chick-rearing. Other potential favourable effects, such as the possible benefit of coprophagy on the microbial constituents and subsequent digestion of young chicks have also been referenced (Cooper, 2000). Ostrich chicks have a preference for pecking at green objects (Bubier *et al*., 1996), although Cooper (2004) suggested that lucerne should not be fed to young chicks as it corresponded with elevated mortalities owing to impaction. In this study, however, lucerne was available to the foster chicks (Bubier *et al*., 1996). Since feeding behaviour is learned from observing adults in the wild, the presence of the foster parents may enhance this inclination (Aganga *et al*., 2003). Although it was not quantified, it was observed that the human-imprinted chicks exhibited a greater degree of feather pecking, pecking at the air and general pecking behaviour that was alleviated when the group was split into three separate pens, but which may have contributed to inhibited growth (Lambert *et al*., 1995). The human-imprinted chicks may also have experienced stress after the perceived abandonment by the imprinting subject at 30 days post hatch. This stress may have inhibited the growth of the imprinted chicks (Laugero & Moberg, 2000), but it was not reflected in their survival from 4 to 12 weeks. When late chick survival (from 13 to 24 weeks) was considered, chicks reared by foster parents had an improved survival relative to the imprinted chicks (Table 1). Although the results are not directly comparable, it is notable that in her study Janse van Vuuren (2008) reported that chicks with foster parents survived better than those subjected to conventional rearing.

Table 1 The effect of rearing by foster parents and imprinting on 0 to 24 week survival (0–24 wks), 0 to 12 week survival (0–12 wks), 0 to 3 week survival (0–3 wks), 4 to 12 week survival (4–12 wks), 13 to 24 week survival (13–24 wks), 4 week chick weight, 9 week chick weight 18 week chick weight and 22 week chick weight with their respective *P*-values and Chi-square (Chi^2) values for survival

Trait	Foster parents	Imprinted	Chi^2 or F*	df*	*P* value
Survival (proportions)					
0–24 wks	0.70	0.52	6.71	1	<0.05
0–12 wks	0.77	0.74	0.24	1	>0.05
0–3 wks	0.89	0.90	0.00	1	>0.05
4–2 wks	0.83	0.86	0.06	1	>0.05
13–24 wks	0.91	0.61	9.38	1	<0.05
Chick weight (kg)					
4 weeks	2.1 ± 0.07	2.3 ± 0.08	2.60	1, 108	>0.05
9 weeks	12.8 ± 0.4	8.2 ± 0.4	70.7	1, 106	<0.001
18 weeks	37.1 ± 0.8	19.9 ± 0.80	221.8	1, 109	<0.001
22 weeks	46.2 ± 1.1	28.6 ± 1.2	119.9	1, 109	<0.001

* Denotes the appropriate Chi^2- or F-values, as well as the degrees of freedom (df) for the 2 x 2 contingency table for the Chi^2 analysis, as well as for the denominator (treatments) and the numerator (residual) in the F-table of the one-way ANOVA, separated by a comma.

Chicks in the care of breeder pair 21 exhibited reduced survival and growth compared with the other two breeder pairs (Table 2). The cumulative proportion of chicks that survived to 24 weeks post hatch was 0.54 for those chicks raised by breeder pair 21, which was significantly lower than that of the breeder pairs

23 and 29 (Table 2; 0.90 and 0.71, respectively). Breeder pair 23, on the other hand, had the highest chick survival to 24 weeks of age, as well as the heaviest chicks at all ages measured (Table 2). It is significant that breeder pair 21 had the youngest male (9 years), whereas breeder pair 23 had the oldest male and female. Bolton (1991) proposed that parental quality attributes such as age, breeding experience and condition potentially contribute to a large extent to the offspring fitness in a study on precocial lesser black-backed gulls. The performance of the various pairs may thus reflect age and parental experience. These components should be investigated further.

Table 2 The effect of rearing by different foster parents (BP21, BP23 and BP29) on 0 to 24 week survival (0–24 wks), 0 to 12 week survival (0–12 wks), 0 to 3 week survival (0–3 wks), 4 to 12 week survival (4–12 wks), 13 to 24 week survival (13–24 wks), 4-week chick weight, 9-week chick weight and 22-week chick weight with their respective *P*-values and Chi-square (Chi²) values for survival.

Trait	BP21	BP23	BP29	Chi² or F*	df*	*P* value
Survival (proportion)						
0–24 wks	0.54	0.90	0.71	6.23	2	<0.05
0–12 wks	0.58	0.90	0.95	7.06	2	<0.05
0–3 wks	0.87	0.95	0.90	0.77	2	NS
4–12 wks	0.67	0.95	0.93	7.10	2	<0.05
13–24 wks	0.93	1.00	0.85	0.54	2	NS
Chick weight (kg)						
4 weeks	1.67 ± 0.14	2.35 ± 0.13	2.16 ± 0.11	6.74	2, 54	<0.05
9 weeks	10.27 ± 0.71	13.67 ± 0.65	13.54 ± 0.54	8.11	2, 54	<0.001
22 weeks	35.8 ± 1.73	38.43 ± 1.54	36.62 ± 1.34	0.72	2, 54	NS

* Denotes the appropriate Chi²- or F-values, the degrees of freedom (df) for the Chi² analysis, as well as for the denominator (treatments) and the numerator (residual) in the F-table of the one-way ANOVA, separated by a comma.

In Experiment 2, chicks raised with deliberate and regular human care exhibited better early chick survival to three weeks of age compared with the conventional rearing treatment ($P < 0.05$; Table 3). This resembles findings in young poultry where antibody production, disease resistance and mortality were all positively affected by regular handling (Jones & Waddington, 1992; 1993; Barnett *et al*., 1994; Hemsworth *et al*., 1994). Several studies across a wide variety of species have shown that regular handling corresponds with a distinct reduction in the degree of anxiety and is an effective method for reducing fear of humans, presumably via habituation (Jones & Waddington, 1992; 1993; Hemsworth *et al.*, 1993; Barnett *et al*., 1994; Tanida *et al.*, 1994; Jones, 1994; Hemsworth *et al.*, 1996a; Rushen *et al*., 1999; Zulkifli & Azah, 2004). Because stress contributes to elevated mortalities (Verwoerd *et al.*, 1997), enhanced survival during the period that the chicks experienced regular handling may reflect a state of lowered stress. This, however, needs to be further verified, together with a means of determining levels of stress in ostriches. After four weeks of age, chick survival was independent of treatment. It is worth noting that both groups of chicks were treated similarly from four weeks post hatch, being maintained on outdoor paddocks with *ad libitum* balanced rations available. These results suggest that imprinting, regular handling and the corresponding monitoring of conditions, stressors, and possible other impediments may have contributed to the higher early survival of imprinted chicks. The degree to which the chicks imprinted onto the human subject, however, needs to be deliberated because some chicks exhibited a greater tendency to approach, follow and remain in general close proximity to the human subject than others. The ability of chicks to distinguish between individual people and whether habituation to one individual may extend to another should also be investigated further (Jones, 1994; Rushen *et al*., 1999). The human who was primarily involved in the regular handling was absent after four weeks, after which survival was no longer affected. Birds do appear to be highly sensitive to visual stimulus characteristics of people in their environment and apparently utilize

these characteristics to discriminate between humans (Bolhuis & Horn, 1992; Barnett *et al.*, 1994; Rushen *et al*., 1999). At this stage, it is not known, however, whether ostriches can differentiate between people.

Growth, as reflected by weight, was independent of treatment group in this experiment (Table 3). This is similar to the studies of Reichman *et al*. (1978) and Leonard & Fairfull (1992), who found regular handling to have no effect on the growth of young broilers and layers. Jones & Hughes (1981), however, demonstrated an improvement in growth and performance with regular handling. The effect of handling on production is evidently inconsistent, exhibiting an extensive array of influential variables (Rushen *et al.*, 1999). The precise mechanisms of this relationship in ostriches should be further investigated (Hemsworth *et al*., 1994).

Table 3 The effect of conventional handling and imprinting on mean 0 to 3 week survival (0–3 wks), 4 to 12 week survival (4–12 wks), 4 week chick weight and 9 week chick weight with their respective *P*-values and Chi-square (Chi^2) values for survival

Trait	Conventional handling	Imprinting	Chi^2 or F	df	*P* value
Survival (propotions)					
0–3 wks	0.84	0.97	6.44	1	<0.05
4–12 wks	0.69	0.73	0.14	1	Ns
Chick weight (kg)					
4 weeks	6.18 ± 0.17	6.27 ± 0.16	0.14	1, 93	Ns
9 weeks	15.2 ± 0.70	16.5 ± 0.68	1.90	1, 93	Ns

* Denotes the appropriate or Chi^2- or F-values, as well as the degrees of freedom (df) for the 2 x 2 contingency table for the Chi^2 analysis, as well as for the denominator (treatments) and the numerator (residual) in the F-table of the one-way ANOVA, separated by a comma.

Overall, the present study indicated that chicks reared by foster parents and those imprinted onto humans with regular handling exhibited similar 4-week chick weight and chick survival to three months of age. The chicks reared by foster parents, however, attained substantially higher mean weights at older ages. Differences in the survival and growth of the various foster groups of chicks also suggest an effect of parenting ability on the performance of chicks, which probably needs further research. On the other hand, human imprinting and regular handling corresponded with improved chick survival during the first few weeks post hatch, in comparison with chicks reared according to conventional procedures in an intensive rearing facility, although chick weights were unaffected. Imprinting and early regular handling regimens, however, had no effect on survival at older ages when compared with the conventionally reared group. It is important to note that foster parenting is indeed a practical and feasible management practice that is occasionally implemented during the rearing of ratite chicks (see Barri *et al*., 2005; Janse van Vuuren, 2008; Cloete & Malecki, 2011). In contrast, the method of imprinting ratite chicks is not commonly practiced, as it is more intensive and time consuming in nature. However, the practical applications of both approaches have not been clarified satisfactorily, confirming the need for further study.

Conclusions

This preliminary study suggests that ostrich chicks reared under semi-intensive conditions by foster parents are heavier than chicks reared under intensive conditions and imprinted onto humans. Foster parents, however, differ in their chick-rearing ability, resulting in significant differences in chick performance. In intensive rearing facilities, early survival of imprinted chicks was better than that of chicks reared by conventional practices. Imprinting thus affected early survival of ostrich chicks relative to conventional rearing. These results indicate a number of potential further studies as important. Such studies need to assess how imprinting and foster parenting may be utilized to optimize chick performance, as both systems seem to be viable alternatives to conventional rearing. To achieve this, the innate components of behavioural

preferences and stress susceptibility in ostrich chicks, as well as the behavioural aspects of good foster parenting and imprinting, need to be investigated. Imprinting onto humans takes much time and effort and may be impractical in commercial farming industries. The potential of imprinting onto objects, however, should be considered, together with diverse forms of environmental enrichment (classical music, dummies) that may be more practical, with similar outcomes associated with reduced stress. Research differentiating regular handling and human imprinting and its effects could also be of benefit. This information will be crucial to determine how these two divergent strategies may be utilized to optimize survival, performance and welfare of ostrich chicks. Similarly, the obvious advantage of foster parenting for commercial chick production in terms of affordability needs to be elucidated.

Acknowledgements

The study was partly funded by the Western Cape Agricultural Research Trust and the Technology and Human Resources for Industry Programme (THRIP) of South Africa. The cooperation of the personnel at Oudtshoorn Research Farm is also gratefully acknowledged.

References

Aganga, A.A., Aganga, A.O. & Omphile, U.J., 2003. Ostrich feeding and nutrition. Pak. J. Nutr. 2, 60-67.

Barnett, J.L., Hemsworth, P.H., Hennessy, D.P., McCallum, T.H. & Newman, E.A., 1994. The effects of modifying the amount of human contact on behavioural, physiological and production responses of laying hens. Appl. Anim. Behav. Sci. 41, 87-100.

Barri, F.R., Navarro., J.L., Maciera, N.O. & Martella, M.B., 2005. Rearing greater rhea (*Rhea americana*) chicks: is adoption more effective than the artificial intensive system? Br. Poult. Sci. 46, 22-25.

Bolhuis, J.J. & Horn, G., 1992. Generalization of learned preferences in filial imprinting. Anim. Behav. 44, 185-187.

Bubier, N.E., Lambert, M.S., Deeming, D.C., Ayres, L.L. & Sibly, R.M., 1996. Time budget and colour preference (with specific reference to feeding) of ostrich (*Struthio camelus*) chicks in captivity. Br. Poult. Sci. 37, 547-551.

Bubier, N.E., Paxton, C.G.M., Bowers, P. & Deeming, D.C., 1998. Courtship behaviour of farmed ostriches in relations to humans. Br. Poult. Sci. 39, 477-481.

Bunter, K.L., 2002. The genetic analysis of reproduction and production traits recorded for farmed ostriches (S*truthio camelus*). PhD dissertation, University New England, Armidale, Australia.

Bunter, K.L. & Cloete S.W.P., 2004. Genetic parameters for egg-, chick-, and live-weight traits recorded in farmed ostriches (Struthio camelus). Livest. Prod. Sci. 91, 9-22.

Cloete, S.W.P. & Malecki, I.A., 2011. Breeder welfare: Past, present and future. In: The Welfare of Farmed Ratites. Eds Glatz, P., Lunam, C. & Malecki, I.A., Springer, Berlin. pp.13-44.

Cloete, S.W.P., Engelbrecht, A., Olivier, J.J. & Bunter, K.L., 2008. Direct response in breeding values to selection of ostriches for liveweight and reproduction. Aust. J. Exp. Agric. 48, 1247-1256.

Collins, J.W. & Siegel, P.B., 1987. Human handling, flock size and responses to an *E. coli* challenge in young chickens. Appl. Anim. Behav. Sci. 19, 183-188.

Cooper, R.G., 2000. Critical factors in ostrich (*Struthio camelus australis*) production: a focus on southern Africa. Wrld's Poult. Sci. J. 56, 247-265.

Cooper, R.G., 2004. Ostrich (*Struthio camelus*) chick and grower nutrition. Anim. Sci. J. 75, 487-490.

Gvaryahu, G., Cunningham, D.L. & Van Tienhoven, A., 1989. Filial imprinting, environmental enrichments and music application effects on behavior and performance of meat strain chickens. Poult. Sci. 68, 211-217

Hemsworth, P.H., Barnett, J.L. & Coleman, G.J., 1993. The human-animal relationship in agriculture and its consequence for the animal. Anim. Welf. 2, 33-35.

Hemsworth, P.H., Coleman, G.J. & Barnett, J.L., 1994. Improving the attitude and behaviour of stockpersons towards pigs and the consequences on the behaviour and reproductive performance of commercial pigs. Appl. Anim. Behav. Sci. 39, 349-362.

Hemsworth, P.H., Coleman, G.C., Cransberg, P.H. & Barnett, J.L., 1996. Human factors and the productivity and welfare of commercial broiler chickens. Research Report on Chicken Meat Research and Development Council Project, Attwood, Australia.

Janse van Vuuren, M., 2008. Faktore wat die oorlewing van volstruiskuikens (*Struthio camelus*) verhoog (in Afrikaans). M.Tech. thesis, Nelson Mandela Metropolitan University, Port Elizabeth, South Africa.

Jones, R.B., 1994. Regular handling and the domestic chick's fear of human beings: generalisation of response. Appl. Anim. Behav. Sci. 42, 129-143.

Jones, R.B. & Hughes, B.O., 1981. Effects of regular handling on growth in male and female chicks of broiler and layer strains. Br. Poult. Sci. 22, 1033.

Jones, R.B. & Waddington, D., 1992. Modification of fear in domestic chicks, *Gallus gallus domestica*, via regular handling and early environmental enrichment. Anim. Behav. 43, 1021-1033.

Jones, R.B. & Waddington, D., 1993. Attenuation of the domestic chicks; fear of human beings via regular handling: In search of a sensitive period. Appl. Anim. Behav. Sci. 36, 185-l95.

Jones, R.B., Harvey, S., Hughes, B.O. & Chadwick, A., 1980. Growth and the plasma concentration of growth hormone and prolactin in chicks: effects of environmental enrichment, sex and strain. Br. Poult. Sci. 21, 457-462.

Labaque, M.C., Navarro, J.L. & Martella, M.B., 1999. A note on chick adoption: a complementary strategy for rearing rheas. Appl. Anim. Behav. Sci. 63, 165-170.

Lambert, M.S., Deeming, D.C., Sibly, R.M. & Ayres, L.L., 1995. The relationship between pecking behavior and growth rate of ostrich (*Struthio camelus*) chicks in captivity. Appl. Anim. Behav. Sci. 46, 93-101.

Laugero, K.D. & Moberg, G.P., 2000. Energetic response to repeated restraint stress in rapidly growing mice. Am. J. Phys. Endocr. Metab. 279, 44-49.

Leonard, M.L. & Fairfull, R.W., 1992. Effect of early handling on growth, mortality and feed efficiency in White Leghorns. Appl. Anim.Behav. Sci. 34, 121-128.

Madeiros, C.A., 1997. The use of rabbits in ostrich rearing. Vet. Rec. 140, 688.

Malecki, I.A. & Rybnik-Straskowska, P.K., 2011. In: The Welfare of Farmed Ratites. Eds Glatz, P., Lunam, C. & Malecki, I.A., Springer, Berlin. pp. 45-60.

Matsushima, T., Izawa, E., Aoki, N. & Yanagihara, S., 2003. The mind through chicks' eyes: memory, cognition and anticipation. Zool. Sci. 20, 395-408.

Mills, A.D. & Faure, J.M., 1990. Panic and hysteria in domestic fowl: a review. In: Social Stress in Domestic Animals. Eds Zayan, R. & Dantzer, R., Dordrecht: Kluwer Academic Publishers. pp. 248-272.

Newberry, R.C., 1995. Environmental enrichment: Increasing the biological relevance of captive environments. Appl. Anim. Behav. Sci. 44, 229-243.

Reed, H.J., Wilkins, L.J., Austin, S.D. & Gregory, N.G., 1993.The effect of environmental enrichment during rearing on fear reactions and depopulation trauma in adult caged hens. Appl. Anim. Behav. Sci. 36, 39-46.

Rushen, J., Taylor, A.A. & de Passille, A.M., 1999. Domestic animals' fear of humans and its effect on their welfare. Appl. Anim. Behav. Sci. 65, 285-303.

Savatierra, N.A, Marin, R.H., Arce, A. & Martijena, I.D., 1994. Chick imprinting performance and susceptibility to acute stress associated to flunitraze pan receptor increase. Brain Res. 648, 39-45.

Slagsvold, T. & Hansen, B.T., 2008. Imprinting. Beh. Ecol. pp.1943-1948.

Verwoerd, D.J., Olivier, A.J., Henton, M.M., Gerde, G.H., Williams, R. & Van der Walt, M., 1997. Veterinary aspects of important diseases of ostrich chicks in South Africa. In: Proc. 50th Anniversary Congress of the Veterinary Association of Namibia. Namibian Veterinary Association, Windhoek, Swakopmund, Namibia, 3-38.

Zulkifli, I. & Azah, A.S.N., 2004. Fear and stress reactions and the performance of commercial broiler chickens subjected to regular pleasant and unpleasant contacts with human beings. Appl. Anim. Behav. Sci. 88, 77-87.