Modelling Egg Production Of Ostrich Females Over Years Using Random Regression Models

M.D. Fair[*], J.B. van Wyk[*], S.W.P Cloete[†‡], and A.R. Gilmour[§]

Introduction

Knowledge of genetic and non genetic influences on the important economic production traits are needed to improve egg production. Early identification of superior birds that maintain high production levels over their lifetime is desirable. Studies are thus required to investigate the relationships between repeated cycles of reproduction over years, to ascertain whether adequate genetic variation for accurate selection is present early in the productive life of the animals.

This study focuses on the use of random regression to model production over years. Random regression models are commonly used to analyse longitudinal or repeated measures data in animal breeding (Schaeffer, 2003).

Pedigree and census data collected over several years allowed the fitting of an animal model using mixed model methodologies, while also considering the longitudinal nature of egg production over time in a random regression model.

Material and methods

Pedigree and performance data for 80 943 individual egg records were obtained from a large pair breeding flock maintained at the Klein Karoo Agricultural Development Centre (KKADC), near Oudtshoorn, South Africa. The data were collected from 1991 to 2005 and were produced by 540 females and 530 males forming 654 unique breeding pairs. All breeding pairs were kept in separate breeding paddocks to facilitate ancestry identification of the offspring. Egg weights, parent details and date of lay of eggs were recorded. Eggs were collected daily. The general management of the breeding pairs and the eggs has been described in detail (Cloete *et al.,* 1998).

The trait analysed here was Egg production (EP), treated as a trait of the hen and defined as the total number of eggs laid per year per hen. The 80 943 individual records were edited to form 2 460 hen by year records. To assess the influence of non genetic effects on the trait, the following fixed effects were fitted in a linear model: age of hen (2 to 20 years) and sire (2

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[*] Department of Animal Wildlife and Grassland Sciences, UFS, Bloemfontein 9300, South Africa
[†] Department of Animal Sciences, University of Stellenbosch, Matieland 7602, South Africa, Elsenburg,
[‡] Agricultural Development Institute, Private Bag X1, Elsenburg 7607, South Africa
[§] *Cargo Vale*, Cargo, 2800, Australia

to 21 years), and contemporary groups (CG, 47 levels), formed from year of egg production (1991 to 2005) combined with some nutritional experimental groups, as well as some ostrich genotypes (SA Blacks and Zimbabwean Blues). Number of production days was added as a linear covariate.

EP was analysed in a single-trait mixed model with a random regression fitted as a linear polynomial for the random direct animal (a) and permanent environmental (p) effects using M_1 as defined below. Fixed effects as described above with the four random effects of direct hen (a) and permanent environment (p) as a random regression with a linear polynomial with intercepts for each age of hen (fage) and, service sire (s) (the male mate of the breeding pair) and breeding paddock (b) as random effects. The effect of female age was fitted as a cubic spline.
The mixed model with fixed and random effects is given below in matrix notation:

$$\mathbf{y} = \mathbf{X}\beta + \mathbf{Z}_1\mathbf{a} + \mathbf{Z}_2\mathbf{p} + \mathbf{Z}_3\mathbf{s} + \mathbf{Z}_4\mathbf{b} + \mathbf{e} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots M_1$$

where y was a vector of phenotypic observations for EP*,* **X** was an incidence matrix relating records to the fixed effects and random spline components (β); $\mathbf{Z}_1$, $\mathbf{Z}_2$, $\mathbf{Z}_3$ and $\mathbf{Z}_4$ were incidence matrices relating records to the additive genetic effects (Z_1), permanent environmental effects ($\mathbf{Z}_2$), service sire effects ($\mathbf{Z}_3$) and holding pen ($\mathbf{Z}_4$) and **a**, **p**, **b**, **s** and **e** were vectors of additive genetic, permanent environmental, service sire, breeding pen and residual effects, respectively. Under an animal model it was assumed that: Var(**a**) = $A\sigma^2_a$; where A is a matrix describing the relationships between animals (i.e., the Numerator Relationship Matrix). The remaining effects were assumed to be distributed as Var(**p**)= $I\sigma^2_p$; Var(**s**)= $I\sigma^2_s$, Var(**b**)= $I\sigma^2_b$; and Var(**e**)= $I\sigma^2_e$ where I = identity matrices of order equal to the number of hens (for p), number of service sires and number of breeding pens respectively and σ^2_a, σ^2_p, σ^2_s, σ^2_b, and σ^2_e direct genetic variance, permanent environmental variance (female over year), variance due to service sire, variance due to breeding pen and environmental (residual) variance respectively. The random effects of animal direct and permanent environment were fitted as random linear polynomials over hen age using the ASREML program (Gilmour *et al*., 2006). Convergence was considered to have been obtained when the REML log-likelihood changed less than 0.002 and the individual variance parameter estimates changed less than 1 % (Gilmour *et al*., 2006).

Results and discussion

The breakdown of mean yearly egg production per hen age combined with the total number of hens per hen age group are shown in Figure 1, while ratios of heritability and permanent environmental effects are presented in Figure 2. Mean number of eggs produced per hen per age of hen increased sharply from 18 to 33 eggs per year for two to three year old hens and then increased more steadily up to 42 eggs per year for 11 year olds. After 11 years of age the production decreased to around 40 eggs per year. The number of hens per hen age class peaked at 368 hens for 3-year olds then dropped steadily to 57 for 11 year old hens. There were some older birds aged 12 to 21 years old and they maintained a relatively high number of eggs per year. However, these were excluded from the analysis as there were less than 50 in these age groups. Selection of younger hens would also lower the generation interval possibly increasing the rate of genetic improvement of EP.

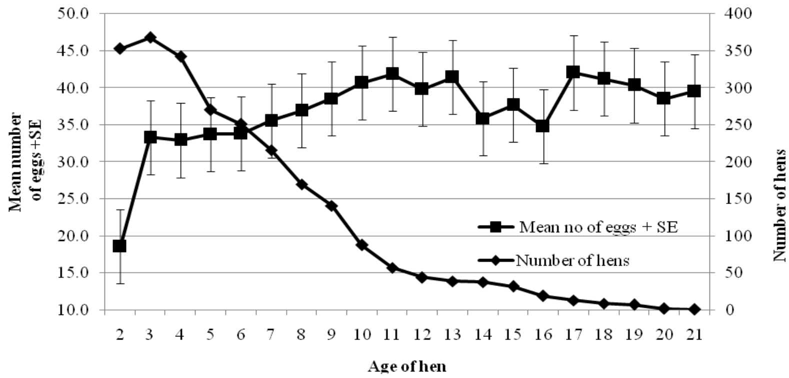

Figure 1 Mean number of eggs produced (EP) and total number of hens per year of hen age. Vertical lines about the means denote standard errors.

The permanent environment variance ratio increased markedly and consistently from four year old hens onwards (0.17-0.47) while heritability estimates were moderate and remained relative constant 0.12-0.17 for all hen ages (Figure 2). It could be speculated that the increased permanent environmental effect over time could be due to the physiological maturing of the hen.

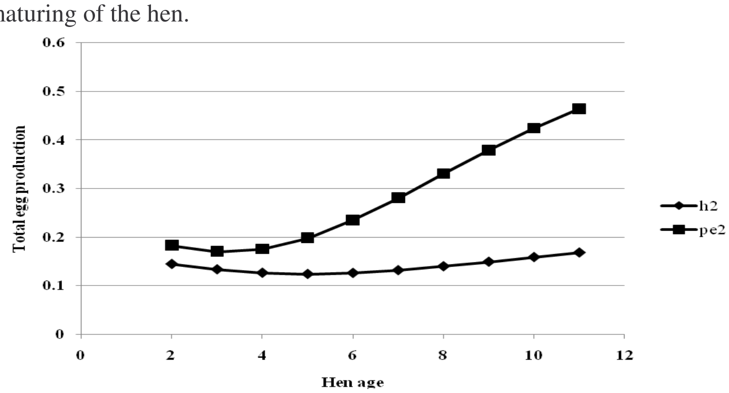

Figure 2 Direct heritability (h^2) and permanent environment (pe^2) as a ratio of the phenotypic variance of total egg production for ages of hens when estimated as linear polynomials with intercepts using random regression.

In previous studies, estimates of direct heritability and permanent environment as a ratio of phenotypic variance ranged from 0.12-0.29 and from 0.17-0.32 respectively when using repeatability models (Table 2). Heritability and permanent environment ratio estimates for the present study ranged from 0.12-0.17 and from 0.17-0.47 respectively. The consistence between estimates was not unexpected, as some animals formed part of all the analyses. Estimates for service sire as a ratio of phenotypic variance was 0.04 and is in accordance with previously published results.

Table 2 Summary of published heritability estimates and variance ratios (± s.e.) of egg production in ostriches

Source	*n*	h^2_a	c^2_p	c^2_s
Bunter *et al*. (2001*a*)	708	0.12 ± 0.11	0.32 ± 0.10	n.a.
Cloete *et al*. (2004)	1177	0.26 ± 0.09	0.16 ± 0.08	n.a.
Cloete *et al*. (2005)	1487	0.29 ± 0.04	n.a.	0.07 ± 0.03
Fair *et al.* (2005)	7502	0.14 ± 0.03	n.a.	0.06 ± 0.02
Cloete *et al*. (2008)[A]	1936	0.18 ± 0.06	0.17 ± 0.06	0.03 ± 0.01
Present study (2010)	**2460**	**0.12-0.17**	**0.17-0.47**	**0.04 ± 0.01**

The model fitted by Fair *et al.* (2005) differed from previous analyses as monthly egg production data were assessed. h^2_a = direct heritability, Expressed as proportion of phenotypic variance: c^2_p = permanent environmental variance, c^2_s = service sire variance. n.a. = not applicable, [A]Derived from a three-trait repeatability model, involving mature female live weight, egg production and chick production.

Conclusion

Selection of superior hens from three years onwards seems possible. Hens older than eleven years should be replaced with younger, genetically superior hens which would decrease the generation interval and improve EP genetically. When linked to moderate and fairly constant levels of genetic variation across the age trajectory, selection decisions on own performance should possibly be taken at three years of age. In addition to the present analysis, quality of the eggs produced should also be analysed.

Acknowledgements

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References

Bunter, K.L., Cloete, S.W.P., Van Schalkwyk, S.J. & Graser, H-U., 2001a. *Proc. Assoc. Advmnt. Anim. Breed. Genet.* 14, 43-46.

Cloete, S.W.P., Brand Z., Bunter, K.L. & Malecki, I.A., 2008. *Austr. J. Exp. Agric.* 48, 1314-1319.

Cloete, S.W.P., Bunter, K.L. & Brand, Z., 2005. *Proc. Assoc. Advmnt. Anim. Breed. Genet.* 16, 132-155

Cloete, S.W.P., Bunter, K.L., Brand, Z. & Lambrechts, H., 2004. *S. Afr. J. Anim. Sci.* 34 (suppl. 2), 17-19.

Cloete, S.W.P., Van Schalkwyk, S.J. & Brand, Z., 1998. *Proc. 2nd International Ratite Cong, Oudtshoorn, South Africa,* pp. 55-62.

Fair, M.D., Van Wyk, J.B. & Cloete, S.W.P., 2005. *Proc. 3rd International Ratite Sci. Symp. and 12th World ostrich congr., Madrid, Spain*'. (Ed. E Carbajo) pp. 21-27.

Gilmour, A.R., Gogel, B.J., Cullis, B.R., Welham, S.J. & Thompson, R., 2006. *ASREML-User Guide Release 2.0 VSN International Ltd, Hemel Hempstead, HP11ES, UK*

Schaeffer, L.R., 2003. *Livest. Prod. Sci.* 86, 35-45.