Non-genetic factors influencing early growth traits in the Elsenburg Dormer sheep stud

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Received 3 January 1992; accepted 13 November 1992

Records of the Elsenburg stud where the Dormer sheep breed originated in 1941, were analysed from 1941 to 1990 to investigate non-genetic factors contributing to early growth traits. The fixed effects, identified as having a significant ($P < 0.01$) effect on birth weight, weaning weight, average daily gain and Kleiber ratio, were year-season, age of dam, sex, birth status and level of inbreeding. Although some significant interactions were found, they were subsequently ignored owing to their very small effects. A model best describing the data, which can be used for further analyses, is constructed and discussed. It is advocated that the uniqueness of each population and situation necessitates such an analysis in each specific case.

Rekords van die Elsenburgstoet waaruit die Dormerskaapras in 1941 ontstaan het, is van 1941 tot 1990 ontleed om die moontlike bydraende nie-genetiese faktore op vroeë groei-eienskappe te ondersoek. Die vaste effekte wat 'n betekenisvolle ($P < 0.01$) invloed op geboortegewig, speengewig, gemiddelde daaglikse toename en Kleiberverhouding het, sluit jaar-seisoen, ouderdom van ooi, geslag, geboortestaat en vlak van inteling in. Sekere betekenisvolle interaksies is verkry, maar is weens geringe effekte geïgnoreer. 'n Model wat die data die beste pas en vir verdere analises gebruik kan word, is saamgestel en word bespreek. Die uniekheid van elke populasie en situasie noodsaak 'n soortgelyke analise in elke spesifieke geval.

Keywords: Dormer sheep, early growth traits, non-genetic factors.

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Introduction

Genetic improvement through selection in a breeding programme depends on the accuracy of identifying genetically superior animals. This requires that non-genetic factors (fixed effects) influencing the accuracy of predicted breeding values be either controlled experimentally or eliminated statistically.

Prior to the estimation of breeding values, a model must be specified to describe the biological processes that influence the specific measured trait. This requires study of non-genetic sources of variation, so that a model can be found which (according to the available data) best describes the biological processes concerned. The effects of non-genetic factors such as age, sex, birth status (type of birth) and age of dam have been well documented. However, information on the magnitude of these effects is limited in this specific breed and population (Van der Merwe, 1976). Since inbreeding is inevitable in any closed population of finite size and the effects of inbreeding depression are well known, it was decided to include level of inbreeding as a fixed effect in the model in an effort to make it more descriptive. The high levels of inbreeding encountered, however, warrant a more in-depth study (Van Wyk *et al.*, 1993).

The objective of this study was to analyse the records of the originator of the Dormer sheep breed, the Elsenburg Dormer stud, to investigate the importance of possible contributing non-genetic sources of variation on early growth traits. This information is necessary if adjustments for effective selection on genotype are to be made.

Material and Methods

Animals and environment

Data were obtained from the registered Dormer sheep stud comprising a flock of 180 breeding ewes at the Elsenburg Agricultural Development Institute near Stellenbosch. The farm Elsenburg is situated in the Boland subregion of the Winter Rainfall Region, about 50 km east of Cape Town and 10 km north of Stellenbosch at an altitude of approximately 177 m above sea level (33° 51′ S, 18° 30′ E). The farm has an average annual rainfall of 642 mm which falls predominantly in winter (June—August). Average maximum (minimum) summer and winter temperatures are 25.4 °C (12.6 °C) and 17.9 °C (8.1 °C), respectively.

All sheep were kept on dryland pastures throughout the year until 1988. Since then they have been kept on irrigated pastures consisting of clover, kikuyu and oats in winter and predominantly kikuyu during the summer months. An energy lick consisting of 50% maize, 25% bone meal and 25% salt was provided. From four weeks of age until weaning at 14 weeks, all lambs received commercial lamb creep feed pellets. A drenching and innoculation programme as prescribed by the State Veterinarian was followed.

The Dormer sheep breed originated from a small number of animals (two first-cross rams and 77 first-cross ewe lambs), but it can be assumed that, being a cross between two unrelated breeds, the inbreeding coefficients of the base animals were zero.

The data, before editing, consisted of 9 551 individual lamb records collected from 1941—1990. A number of animals were used on the Outeniqua Experimental Farm near Oudtshoorn for slaughter lamb experiments. Since some of these progeny were used for breeding purposes in the Elsenburg stud in later years, these data were included in the analysis as a separate contemporary group. According to Johnson & Garrick (1990), crossbred performance records should be excluded or analysed as a separate contemporary group to remove the possible average effect of heterosis. Records of the two years 1941 and 1942 which represent the progeny of the intial crosses, were excluded from all analyses except for the calculation of inbreeding coefficients. Also, sires were nested within years in these first two years.

Management and selection

Single sire mating was practised with 25 to 30 ewes allocated to each ram. A spring breeding season (six weeks duration) was used throughout the study with the exception of years 1966, 1967 and 1973—1976 when accelerated mating systems were practised. Season therefore had to be included as a fixed effect as a birth year-season concatenation.

During lambing the ewes were inspected daily and dam and sire numbers, date of birth, birth weight, birth status (type of birth) and sex of lamb were recorded. When the first lamb reached an age of 107 days, all the lambs which were 93 days of age and older were weaned and live weight of each lamb was recorded. The same procedure was repeated every two weeks until all the lambs were weaned.

The stud was closed since its inception with all replacements coming from within. To minimize the level of inbreeding, pedigree information was taken into account when preparing mating lists. During the early stages, selection emphasis was mainly on visually assessed conformation. In later years, rams and ewes were selected on the reproduction performance and fecundity of their dams and high lamb growth performance. Additionally, replacements had to comply with the breed standards necessary for purebred Dormer registration. Sires were used in two consecutive years and then culled, whereas ewes were not replaced after any specific time but were culled for failure to lamb in any one season, unsoundness or teeth wear in order to maintain numbers.

Traits analysed in this study were birth weight (BW), weaning weight (WW), average daily gain (ADG) and the Kleiber ratio (KL). All weaning weights were adjusted to a 100-day equivalent before analysis by using the following formula:

$$\left(\frac{\mathrm{WW} - \mathrm{BW}}{\text{Age at weaning}}\right) 100 + \mathrm{BW}$$

The Kleiber ratio ($\mathrm{ADG}/\mathrm{WW}^{0.75}$) has been suggested as an indirect selection criterion for efficiency of feed conversion under field conditions (Kleiber, 1936; Roux & Scholtz, 1984; Scholtz, 1985; Scholtz & Roux, 1988; Bergh, 1990) and was included as an additional trait.

Statistical analysis

Preliminary analysis was performed on the effects of age of dam, sex, birth status, year-season, level of inbreeding (fixed) and all two-way interactions among the first three factors using Henderson's Method 3 (Harvey, 1988). No attempt was made to estimate interactions with year of birth. Although some interactions proved to be significant ($P < 0.05$), inclusion of interactions in the model only reduced residual variance marginally, ranging from 0% for ADG to 0.41% for KL. Thus it was decided to fit the following model:

$$Y_{ijklmn} = \mu + r_i + h_j + a_k + s_l + p_m + f_n + e_{ijklmn}$$

where Y_{ijklmn} = an observation of a trait on the i^{th} animal* of the n^{th} class of inbreeding of the m^{th} birth status of the l^{th} sex of the k^{th} dam age group born in the j^{th} year-season,
μ = overall mean,
r_i = random effect of the i^{th} animal with zero mean and variance $I\sigma^2_r$,
h_j = fixed effect of the j^{th} year-season,
a_k = fixed effect of the k^{th} age of dam ($k = 2, ..., 9$ and older),
s_l = fixed effect of the l^{th} sex ($l = 1, 2$),
p_m = fixed effect of the m^{th} birth status ($m = 1, 2, 3$),
f_n = fixed effect of the n^{th} class of inbreeding ($n = 1, ..., 7$), and
e_{ijklmn} = random error with zero mean and variance $I\sigma^2_e$.

(* Animals were absorbed into the other effects as described by Harvey (1988), but instead of repeatability, heritability – estimated as σ^2_a/σ^2_p – was used. The model is then in fact an 'animal' model but in this case not utilizing the relationship matrix.)

As mentioned, inbreeding was included as a fixed effect in the model. For breeding value prediction, inbreeding can simply be included either as a covariate or in the relationship matrix. Inbreeding coefficients were calculated using the algorithm as described by Quaas (1976). Seven groups of inbreeding coefficients were created as follows:

Group	Inbreeding coefficient (%)
1	0
2	1.5— 4.99
3	5.0— 9.99
4	10.0—14.99
5	15.0—19.99
6	20.0—24.99
7	≥25

Results and Discussion

Analysis of variance indicated that all the effects included were highly significant ($P < 0.001$) for all traits analysed (Tables 1 & 2). Least-squares estimates for the effects of age of dam, sex, birth status and level of inbreeding are given in Tables 3 & 4. The estimates are expressed as deviations from the least-squares mean. Environmental (year) effects will be discussed in a study on environmental and genetic trends.

As expected, all the early growth traits were affected by age of dam. Older dams gave birth to heavier lambs than younger dams. The trend in this study for birth weight was an increase with an increase in age of dam up to seven years of age.

Table 1 Analysis of variance of birth weight (BW)

Source	df	MS
Year-season	56	11.77**
Age of dam	7	38.85**
Sex	1	133.34**
Birth status	2	460.76**
Inbreeding	6	1.64**
Error	8 892	0.42

** $P < 0.001$.

Table 2 Analysis of variance of weaning weight (WW), average daily gain (ADG) and Kleiber ratio (KL)

		MS		
Source	df	WW	ADG	KL
Year-season	54	702.70**	71174.47**	67.56**
Age of dam	7	753.13**	54768.32**	27.77**
Sex	1	13293.66**	1087347.18**	475.95**
Birth status	2	22955.07**	1743721.92**	720.30**
Inbreeding	6	140.44**	11453.58**	5.75**
Error	7707	19.33	1174.63	1.53

** $P < 0.001$.

Table 3 Least-squares (LS) and standard error (*SE*) estimates for birth weight by age of dam, sex, birth status, and inbreeding

Effect	n	LS (*SE*) (kg)
Least-squares mean	8965	3.83 (0.02)
CV%		20.12
Age of dam (years)		
2	2203	–0.401 (0.019)
3	2085	–0.106 (0.019)
4	1743	0.020 (0.019)
5	1283	0.059 (0.021)
6	844	0.131 (0.024)
7	512	0.150 (0.029)
8	200	0.106 (0.045)
≥9	95	0.041 (0.063)
Sex		
Male	4376	0.131 (0.007)
Female	4589	–0.131 (0.007)
Birth status		
Single	3229	0.638 (0.016)
Twin	5373	–0.043 (0.014)
Triplet	363	–0.595 (0.026)
Inbreeding (%)		
0	397	0.183 (0.052)
< 5	205	0.151 (0.048)
5 < 10	748	–0.005 (0.030)
10 < 15	2017	–0.046 (0.022)
15 < 20	4754	–0.066 (0.023)
20 < 25	715	–0.066 (0.032)
≥25	129	–0.151 (0.055)

Table 4 Least-squares (LS) and standard error (*SE*) estimates for weaning weight (WW), average daily gain (ADG) and Kleiber ratio (KL) by age of dam, sex, birth status and inbreeding

		LS (*SE*)		
Effect	n	WW (kg)	ADG (g/d)	KL
Least-squares mean	7778	29.14 (0.165)	252 (1.577)	19.974 (0.046)
CV%		19.01	20.78	7.53
Age of dam (years)				
2	1907	-1.151 (0.137)	-7.491 (1.315)	0.002 (0.039)
3	1804	0.523 (0.137)	6.400 (1.316)	0.255 (0.039)
4	1537	1.276 (0.142)	12.542 (1.358)	0.339 (0.040)
5	1122	0.946 (0.156)	8.974 (1.495)	0.231 (0.044)
6	728	0.430 (0.179)	3.223 (1.720)	0.031 (0.050)
7	437	0.046 (0.219)	-1.071 (2.095)	–0.133 (0.061)
8	166	–0.985 (0.333)	-10.836 (3.193)	–0.353 (0.094)
9	77	-1.085 (0.476)	-11.742 (4.563)	–0.372 (0.134)
Sex				
Male	3775	1.402 (0.053)	12.677 (0.512)	0.265 (0.015)
Female	4003	-1.402 (0.053)	-12.677 (0.512)	–0.265 (0.015)
Birth status				
Single	2931	4.327 (0.121)	37.000 (1.159)	0.725 (0.034)
Twin	4585	-1.087 (0.113)	-10.420 (1.081)	–0.247 (0.032)
Triplet	262	-3.240 (0.204)	-26.580 (1.954)	–0.478 (0.057)
Inbreeding (%)				
0	365	2.143 (0.375)	19.292 (3.595)	0.426 (0.105)
< 5	179	0.621 (0.346)	4.662 (3.320)	0.040 (0.097)
5 < 10	672	0.341 (0.216)	3.502 (2.066)	0.088 (0.061)
10 < 15	1782	–0.204 (0.161)	-1.494 (1.543)	0.001 (0.045)
15 < 20	4060	–0.547 (0.170)	–4.731 (1.631)	–0.092 (0.048)
20 < 25	617	–0.596 (0.233)	-5.241 (2.234)	–0.112 (0.065)
≥ 25	103	-1.758 (0.419)	-15.989 (4.017)	–0.351 (0.118)

Relative to lambs from two-year-old dams, those from seven-year-old dams had 0.55 kg higher birth weights (Table 3). Results from the literature indicate that there is a consistent pattern in different breeds and flocks for the effect of age of dam on birth weight. An increase in birth weight was observed up to an age of four years in SA Mutton Merino ewes (Vosloo, 1967), up to five years in Bikaneri ewes (Chopra & Acharya, 1971) and Döhne Merino ewes (Schoeman, 1990), up to six years of age in Merino (Heydenrych, 1975) and Dormer ewes (Van der Merwe, 1976), and up to seven years of age in Döhne Merino ewes (Fourie & Heydenrych, 1982).

Previous research has indicated that the weaning weight and early growth of a lamb is greatly influenced by the age of the dam. The average weaning weight of lambs increased with age of dam up to four years and then decreased. The heaviest lambs were from three- to seven-year-old dams and the lightest from two-, eight- and nine-year-old dams. Lambs from three- to six-year-old dams grew faster from birth to weaning than those of the very young and very old dams. Differences of 2.43 kg and 20 g/d were observed for weaning weight and ADG between two-year-old and four-year-old dams, respectively. Corresponding differences between four- and nine-year-old dams were 2.36 kg and 24 g/d, respectively. Since Kleiber ratio is a function of WW and ADG, the highest value was observed at the same age of dam as for the other two traits.

These age of dam effects on weaning weight are in agreement with the findings of Shelton & Campbell (1962), Bichard & Cooper (1966), Olson *et al.* (1976), Ransom & Mullaney (1976), Van der Merwe (1976) and Mavrogenis (1988). Failure to adjust for age of dam will result in selection biased against the progeny of younger dams with a resulting increase in generation interval and reduced selection differential.

Single lambs were heavier at birth and weaning and had a higher preweaning growth rate and Kleiber ratio than twins or triplets (Tables 3 & 4). Lambs born as singles out-performed their twin counterparts for birth weight, weaning weight, growth rate and Kleiber ratio by 0.68 kg, 5.41 kg, 47 g/d and 0.972, respectively. The corresponding differences between singles and triplets were 1.23 kg, 7.57 kg, 64 g/d and 1.203, respectively. The superiority of lambs born as singles over multiples is well documented (Bichard & Cooper, 1966; Van der Merwe, 1976; Fourie & Heydenrych, 1982; Shrestha & Vesely, 1986; Mavrogenis & Constantinou, 1990). Failure to adjust for birth status will result in selection favouring lambs born as singles.

Male lambs were consistently heavier ($P < 0.01$), grew faster ($P < 0.01$) and had a higher Kleiber ratio ($P < 0.01$) than female lambs (Tables 3 & 4). A difference of 0.26 kg in weight at birth increased to 2.80 kg at weaning. Published research indicates that males usually have higher weaning weights and faster preweaning growth rates (Bichard & Cooper, 1966; Vosloo, 1967; Van der Merwe, 1976; Fourie & Heydenrych, 1982; Shrestha & Vesely, 1986; Mavrogenis & Constantinou, 1990).

An increase in the level of inbreeding resulted in an adverse effect on all traits studied (Tables 3 & 4). As expected, non-inbred lambs (0%) out-performed ($P < 0.01$) their inbred counterparts (>0%) except for birth weight where a non-significant difference between 0% and <5% inbreeding was observed (Van Wyk, 1992). Differences of 3.90 kg, 35 g/d and 0.777 were observed for weaning weight, ADG and Kleiber ratio, respectively, between 0% and ≥25% inbreeding.

The results indicate that several non-genetic factors and inbreeding have a significant influence on early growth traits.

Acknowledgements

The authors thank the Director, Winter Rainfall Region, Department of Agricultural Development and the National Mutton Sheep Performance and Progeny Testing Scheme for kind permission to use the data.

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