# Preliminary genetic parameters of growth during different growth phases in sheep

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Twenty-four sets of full-sib ram lambs, each born from a different sire, were kept individually in pens and hand-reared from birth up to 50 kg live mass. Feed intake and mass of each lamb were determined every third day. Growth curves [ln(mass) against ln(cumulative feed intake)] were plotted for each lamb. Three growth phases could be identified. Very low heritabilities ($h^2$) were calculated for feed conversion ratio in the second and third phases whereas the $h^2$ in Phase I was 0.32 ± 0.40. Heritability of average daily gain (ADG), estimated with least squares means and regression methods, was 0.40 and 0.39 in Phase I, 0.68 and 0.48 in Phase II, and 0.26 and 0.18 in Phase III. Heritability of the Kleiber ratio followed the same trend but was generally higher. Only the product–moment correlations between feed conversion, ADG and the Kleiber ratio within the same growth phase, differed significantly from zero ($P < 0.01$). Genetic and phenotypic correlations between traits over phases, were low and insignificant.

Vier-en-twintig stelle volsib-ramlammers, elk van 'n verskillende vader, is kunsmatig vanaf geboorte tot 50 kg lewende massa in individuele kratte grootgemaak. Individuele voerinnames en massas is elke derde dag bepaal. Groeikurwes [ln(massa) teen ln(kumulatiewe voerinname)] is vir elke lam bepaal. Drie relatief duidelike groeifases is waargeneem. Lae oorerflikhede ($h^2$) is vir voeromset in die tweede en derde fases bereken terwyl $h^2$ in die eerste fase 0.32 ± 0.40 was. Oorerflikheid van gemiddelde daaglikse toename (GDT), bepaal met die kleinste kwadrate en regressiemetodes, was onderskeidelik 0.40 en 0.39 in Fase I, 0.68 en 0.48 in Fase II, en 0.26 en 0.18, respektiewelik in Fase III. Oorerflikheid van die Kleiberverhouding het dieselfde patroon gevolg maar was in die algemeen hoër. Slegs die produk–momentkorrelasies tussen voeromset, GDT en die Kleiberverhouding binne dieselfde groeifase, het betekenisvol ($P < 0.01$) van nul afgewyk. Genetiese en fenotipiese korrelasies tussen kenmerke oor fases, was laag en onbeduidend.

**Keywords:** Genetic parameters, growth, sheep.

Growth occurs in different phases and changes in the growth curve of animals were shown to coincide with certain physiological changes (Brody, 1945; Scholtz & Roux, 1980). The genetic correlation between body masses at different ages over the whole growth period is generally positive (Martin *et al.*, 1980). Mavrogenis *et al.* (1980) also reported a positive genetic and phenotypic correlation between preweaning growth rate and postweaning growth rate in sheep. Contrary to these findings, Riska *et al.* (1984) found a negative genetic correlation between preweaning and postweaning growth rate in rats, while Thiesen & Taylor (1986) reported a negative between-breed genetic correlation between preweaning and postweaning feed conversion in cattle. Badenhorst (1989) also found a negative genetic correlation between preweaning (birth — 120 days of age) and postweaning (weaning — 12 months of age) growth rate in Afrino sheep. These results question the general conception that the relationship between different growth phases is positive.

This experiment was therefore initiated to study the genetic relationship between growth rate, feed conversion and the Kleiber ratio over the different natural growth phases and not for a fixed period.

Twenty-four sets of twin ram lambs, each set from a different sire of a synthetic composite breed (J.C. Greeff, 1988, unpublished work), were separated from their dams at birth and hand-reared in individual pens from birth until 50 kg live mass. Milk intake was determined daily while creep feed, feed intake and live mass were recorded every third day.

Lambs were offered 1 *l* of milk (240 g full cream milk powder per litre of water) in the morning and 1 *l* in the afternoon up to 70 days of age. From 70 days of age milk intake was gradually reduced until 100 days of age after which they received no milk. This ensured that lambs did not experience a weaning shock that would affect their growth pattern negatively. From 14 days of age a creep feed, and from 30 days of age a complete pelleted diet (Table 1) was available *ad libitum.*

**Table 1** Composition of the pelleted diet (air-dry basis)

| | |
|---|---|
| Lucerne hay | 50% |
| Maize-meal | 38% |
| Fish-meal | 10% |
| Monosodium phosphate | 1% |
| Calcium carbonate | 0.5% |
| Salt | 0.5% |
| Vitamins and minerals[1] | 0.1% |
| Moisture (%) | 10.5% |
| Crude protein | 16.2% in DM |
| Digestible energy | 11.8 MJ/kg DM |

[1] Commercial mixture.

The energy content of milk and creep feed consumed by each lamb was converted to its equivalent in terms of the pelleted diet. A regression function of ln(body mass) against ln(cumulative feed intake) was fitted as described by Roux (1976). Body mass at the beginning and end of each growth phase was estimated from the regression line of each phase. The date at that particular point was also determined. These estimates were used to calculate the average daily gain (ADG), feed conversion ratio (kg feed intake/kg body mass increase) and the Kleiber ratio [ADG during a phase/(mass at the end of that phase)$^{0.75}$ ] for each phase.

Variances and covariances of ADG, feed conversion ratio and Kleiber ratio for the estimation of genetic parameters of each phase, were estimated with Model 1 of the LSMLMW computer program of Harvey (1987), and also by regression of the performance of one member on the other member of each full-sib group (Becker, 1984).

Figure 1 indicates the relationship between ln(body mass) and ln(cumulative feed intake) of a typical lamb.

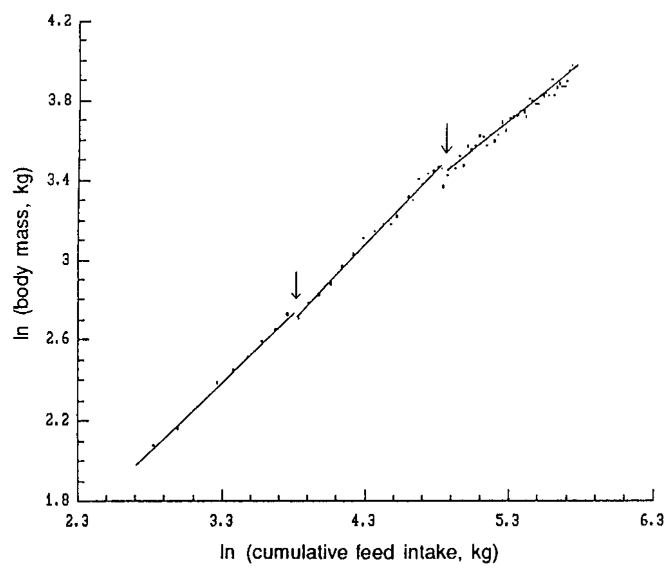


**Figure 1** The relationship between ln (body mass) and ln (cumulative feed intake) of a lamb from birth until 50 kg live mass, illustrating the distinct growth phases.

Siebrits (1984) indicated that results which were not a true reflection of the raw data were obtained if the different phases during growth were ignored. In most cases three growth phases could clearly be recognized as indicated in Figure 1. In some cases, however, an inflexion point could not be clearly identified but a point on the growth curve which may represent the inflexion point was used as the end of that growth phase.

The end of the first phase varied between 34 and 43 days of age, while the end of the second phase varied between 78 and 94 days of age. The third phase ended when the animals had reached 50 kg live mass. It would appear that the end of the first phase coincided with the ability of the animal to initiate the utilization of solids while the end of the second phase coincided with the time when the animal became a ruminant and the beginning of pubertal development. Whether or not these are the real reasons for the inflextion point is, however, beyond the scope of this paper.

Table 2 indicates that feed conversion rate increased from 3.79 kg/kg in Phase I to 6.98 kg/kg in Phase III. The same tendency was found for the Kleiber ratio, confirming the general tendency of a decrease in efficiency of feed utilization with an increase in age and body mass (Thompson *et al.*, 1985). Growth rate increased from 248 g/d in Phase I to 272 g/d in Phase II, whereafter it decreased to 221 g/d in Phase III showing a typical sigmoid curve from birth to 50 kg live mass.

The heritabilities (Table 3) had relatively large standard errors due to the small number of animals involved. The heritabilities estimated with the least squares and regression methods were, however, very similar and showed the same

**Table 2** Mean feed conversion ratio, average daily gain (ADG) and Kleiber ratio for the different growth phases

| | $\bar{x} \pm SE$ |
|---|---|
| **Feed conversion (kg/kg)** | |
| Phase I | 3.79 ± 0.53 |
| Phase II | 4.70 ± 0.82 |
| Phase III | 6.98 ± 0.81 |
| **ADG (g/d)** | |
| Phase I | 248 ± 36.4 |
| Phase II | 272 ± 56.3 |
| Phase III | 221 ± 34.9 |
| **Kleiber ratio** | |
| Phase I | 0.03327 ± 0.0044 |
| Phase II | 0.02198 ± 0.0043 |
| Phase III | 0.01173 ± 0.0016 |

**Table 3** Heritabilities ($h^2 \pm SE$) of feed conversion, ADG and Kleiber ratio of the different growth phases

| | $h^2$ (1) | $h^2$ (2) |
|---|---|---|
| **Feed conversion (kg/kg)** | | |
| Phase I | 0.32 ± 0.40 | 0.35 ± 0.33 |
| Phase II | 0.06 ± 0.40 | −0.01 ± 0.35 |
| Phase III | −0.03 ± 0.42 | −0.06 ± 0.35 |
| **ADG (g/d)** | | |
| Phase I | 0.40 ± 0.40 | 0.39 ± 0.43 |
| Phase II | 0.68 ± 0.37 | 0.48 ± 0.26 |
| Phase III | 0.26 ± 0.41 | 0.18 ± 0.34 |
| **Kleiber ratio** | | |
| Phase I | 0.66 ± 0.37 | 0.55 ± 0.36 |
| Phase II | 0.60 ± 0.38 | 0.63 ± 0.29 |
| Phase III | 0.21 ± 0.28 | 0.28 ± 0.41 |

[1] Heritabilities estimated with the least squares mean method for twin data (Becker, 1984).
[2] Heritabilities estimated with regression method (Becker, 1984).

trends. The heritabilities of feed conversion in Phase I and average daily gain and Kleiber ratio in all three phases exhibit a fair amount of genetic variation especially during Phase II. A low and negative heritability for feed conversion ratio was found in Phases II and III. These low heritability estimates is a matter of concern, as it implies that there is no or very little genetic variation or that certain environmental factors increased the phenotypic variation.

No heritability estimates of preweaning growth rate of artificially-reared lambs could be found in the literature, but heritabilities of preweaning growth of lambs suckling their dams were abundant. Badenhorst (1989) reported a heritability of 0.165 for preweaning growth rate in Afrino sheep, while Kotze (1976) and Vosloo (1967) reported heritabilities of respectively 0.09 and 0.08 in SA Mutton Merino sheep. The high heritability estimates for growth rate in Phases I and II, are an indication that genetic variation for preweaning growth rate is high enough for selection to act upon. Heritability of growth rate in Phase III was much lower than in Phase I or Phase II and agrees well with the heritability 0.22 for postweaning growth rate in Afrino sheep (Badenhorst, 1989). These results are contrary to the results of Atkins (1986) that heritabilities for growth from 14 weeks of age until maturity, were in general higher than the heritabilities prior to 14 weeks of age. Maternal effects appear to be the major cause for this discrepancy.

Falconer (1989) indicated that the heritability calculated from full-sibs is positively biased because of the 0.25 dominance variation which exists between full-sibs. This fact and the reduction of the common environmental variance due to individual feeding may have resulted in the higher heritabilities. This, however, indicates that a fair amount of genetic variation probably exist in the different growth phases.

The phenotypic and genetic correlations between traits, and between the same trait in different phases are presented in Table 4. In certain cases the genetic correlations could not be estimated because negative genetic variances are set to zero in the computer program of Harvey (1987).

The standard errors of the genetic correlations were very high rendering interpretation of the correlations difficult. This, however, is a common problem in the estimation of genetic correlations particularly when small data sets are used.

In the majority of cases the genetic and phenotypic correlations between traits in the different phases were rather low, indicating a large degree of independence in the additive genetic effects at different ages. The phenotypic and genetic relationship between average daily gain and feed conversion was found to be generally negative and in agreement with published results (Badenhorst, 1989; Thompson *et al.*, 1985). Very high genetic correlations of 0.946 and 0.859 were found between the Kleiber ratio and average daily gain within Phase II and Phase III, respectively. The highest genetic correlations of 1.319 between average daily gain and the Kleiber ratio in Phase III, and 1.381 between average daily gain in Phase I and average daily gain in Phase III, should be viewed with care as this falls outside the parameter space since a genetic correlation cannot be greater than unity (Falconer, 1989).

Tests of significance indicated that only the correlations between feed conversion ratio, average daily gain and Kleiber ratio within the same growth phase were significantly ($P <$ 0.01) different from zero. Definite trends were, however, shown. With regard to the main purpose of this study to determine whether the genetic relationship between growth phases was positive or negative, it would appear that all the phenotypic and genetic correlations between growth phases are positive but not significant ($P > 0.05$). Definite conclusions can therefore not be made.

No clear conclusion can be made from the results, mainly because of the small number of animals involved. However, it would appear that growth from birth up to 50 kg live mass in sheep, occurs in different phases and that genetic variation exists for growth in these phases. The genetic correlations between growth rate in the different phases of the growth curve were generally positive but not significant. Discrepancies, especially in respect of feed conversion ratio, exist. This matter should be investigated further.

**Table 4** Phenotypic (above diagonal) and genetic (below diagonal) correlations between feed conversion, average daily gain (ADG) and Kleiber ratio within and between growth phases

| | Feed conversion | | | Average daily gain (g/d) | | | Kleiber ratio | | |
|---|---|---|---|---|---|---|---|---|---|
| | Phase | | | Phase | | | Phase | | |
| Trait | I | II | III | I | II | III | I | II | III |
| **Feed conversion (kg/kg)** | | | | | | | | | |
| Phase I | – | 0.112 | 0.164 | –0.623 | –0.249 | –0.231 | –0.609 | –0.169 | –0.248 |
| Phase II | – | – | –0.051 | –0.267 | –0.696 | 0.081 | –0.036 | –0.531 | 0.072 |
| Phase III | – | – | – | –0.098 | 0.025 | –0.756 | –0.088 | –0.071 | –0.791 |
| **ADG (g/d)** | | | | | | | | | |
| Phase I | –0.127(1.093) | – | – | – | 0.389 | 0.238 | 0.624 | 0.235 | 0.231 |
| Phase II | –0.236(0.758) | – | – | 0.680(0.462) | – | 0.032 | 0.216 | 0.820 | 0.063 |
| Phase III | –0.301(1.239) | – | – | 1.381(1.274) | 0.260(0.740) | – | 0.066 | 0.015 | 0.958 |
| **Kleiber ratio** | | | | | | | | | |
| Phase I | –0.220(0.922) | – | – | 0.356(0.624) | 0.314(0.432) | –0.302(0.744) | – | 0.321 | 0.092 |
| Phase II | 0.082(0.719) | – | – | 0.566(0.235) | 0.946(0.120) | –0.237(0.785) | 0.185(0.465) | – | 0.096 |
| Phase III | 0.137(1.256) | – | – | 1.319(0.231) | 0.448(0.860) | 0.859(0.254) | –0.397(0.254) | 0.130(0.825) | – |

Standard errors are indicated in brackets.

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