Growth of Dairy Replacement Heifers and its Relationship with First Lactation Milk Production Traits

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Introduction

Progeny testing of young bulls in contract herds represents an alternative to the progeny testing scheme which is commonly used in Germany. A program with the aim of improving the lifetime production per cow was initiated in 2005 by a German breeding association. 22 herdbook herds with an average size of 759 dairy cows and an average herd level of production of 9,870 kg milk per cow and year became contract herds. One of the new traits recorded is bodyweight at first service of heifers. The purposes of this study were (1) to estimate the variance components of bodyweight and age at first service and average daily gain from birth until the first insemination and (2) to study the genetic and phenotypic relationships with first lactation milk production traits.

Material and Methods

Production, fertility, calving, and culling data were extracted from the data base of the official genetic evaluation by VIT, Verden. Bodyweights were added from data obtained from the contract herds. After edits and checks for plausibility as well as inspection of the distribution of the traits, a dataset consisting of 10,040 cows from 14 farms was extracted. An upper limit of the difference between the weighing date and the date of first insemination had to be defined since some differences between these two dates were observed. Bodyweights that were recorded within 50 days before or after the first breeding were accepted as bodyweight at first service. Data was restricted to herd-year-seasons with at least 4 contemporaries. Further editing included that the age at first service had to be between 300 and 720 days and that weights varied between 280 and 650 kg. Additionally, average daily gain (adg) from birth until first breeding was computed as follows:

$$\text{adg} = \frac{\text{weight first service} - \text{birth weight}}{\text{age first service}}$$

The birth weight was assumed to be 40 kg.
A second dataset was extracted to quantify the relationship between the heifer traits and total lactation milk yield in first lactations: Test day records were merged with animals and total lactation milk yield was computed according to standard milk recording procedures. Cows with less than 8 test days or less than 250 days in milk were discarded. A maximum of

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13 test days were considered. Furthermore, cows that changed the herd within lactation were discarded. Calving intervals had to be 0 (not calving again) or between 250 and 700 days. Cows below a threshold of 3,000 kg milk yield were deleted. Classes of the effect of herd-year-season of calving were restricted to contain at least two animals. These editing procedures yielded a second dataset comprised of 5,942 cows. For the analysis of first lactation milk production the following traits were included: 305-d-milk (mkg), 305-d-protein (pkg), and 305-d-fat yield (fkg), as well as the mean contents of protein (p%), fat(f%), and mean somatic cell score (SCS). Additionally, persistency (p) was computed following the recommendation of Gengler et al. (1995) (see Appendix).
The SAS package, version 9.1. was used for data preparation and model validation. (Co)variance components were estimated using PEST (Groeneveld, 1990) for data preparation and VCE6 (Groeneveld, Kovač, Mielenz; 2008) using a multiple trait animal model. Models for the individual traits were defined as follows:

$$\begin{aligned}
weight_{ijkm} &= hys_i + wa + diff + ait_j + sire_k + a_m + e_{ijkm} \\
age_{ijkm} &= hys_i + ait_j + sire_k + a_m + e_{ijkm} \\
adg_{ijklm} &= hys_i + diff_l + ait_j + sire_k + a_m + e_{ijklm} \\
mkg_{mnop}, pkg_{mnop} &= hys_c_n + ci_o + dim_p + a_m + e_{mnop} \\
fkg_{mnopq} &= hys_c_n + ci_o + dim_p + afc_q + a_m + e_{mnopq} \\
p\%_{mn}, SCS_{mn} &= hys_c_n + ci_o + a_m + e_{mn} \\
f\%_{mnoq}, p_{mnoq} &= hys_c_n + ci_o + afc_q + a_m + e_{mnoq}
\end{aligned}$$

where:

hys_i	- fixed effect of herd-year-season of first service (i = 1,..,197)
wa	- covariable age at weighing
diff / $diff_l$	- covariable / fixed effect of difference age at first service – age at weighing (l = -50,..,50)
ait_j	- fixed effect of AI technician (j = 1,..,46)
$sire_k$	- fixed effect kind of sire (k = 1,.,3) (proven sire, young bull or natural service sire)
hys_c_n	- fixed effect of herd-year-season of first calving (n = 1,..,193)
ci_o	- fixed effect of calving interval (o = 1,..,8)
afc_q	- fixed effect of age at first calving (q = 20,..,40)
dim_p	- fixed effect of number of days in milk (p =250 - 305)
a_m	- random animal effect
e	- random residual effect

Results and Discussion

Raw means for age at first breeding, bodyweight, and ADG were 471 days (± 50 days), 409 kg (± 38 kg), and 828 g/day (± 98 g/day).
The results of the variance component estimation for age and bodyweight at first service as well as for average daily gain from birth up to first breeding are presented in Table 1. All traits are characterized by moderate heritabilities. In the literature heritabilities for bodyweight at various time points are moderate to high. However, there is a wide range, reaching from 0.14 (Lee et al., 1992) to 0.82 (Brotherstone et al., 2007). In previous studies,

the heritabilities estimated for growth are low or moderate, varying between 0.05 (Mäntysaari et al., 2002) and 0.48 (Groen and Vos, 1995). Bodyweight and average daily gain show a highly positive genetic correlation. The genetic relationship of these traits with age at first breeding is moderate or even highly negative.

Table 1: Estimates of genetic parameters of age and bodyweight at first calving and average daily gain (adg)[1]

	age	weight	adg
age	0,23/ 0,23 (0,03)	-0,33 (0,11)	-0,84 (0,03)
weight	0,26	0,23/ 0,17 (0,02)	0,79 (0,05)
adg	-0,61	0,59	0,38/ 0,38 (0,03)

[1]heritabilities on the diagonal univariat/bivariat, phenotypic and genetic correlation below and above diagonal, s. e. in parenthesis.

The genetic and phenotypic relationships between the traits measured around the first breeding and milk production traits of first lactations are presented in Table 2. The genetic correlations for age at first service with all yield traits are moderately negative. Bodyweight and average daily gain are moderately positive correlated with yield traits. This applies to the phenotypic as well as the genetic level. Sejrsen et al. (2000) found a positive genetic relationship between growth capacity and milk yield potential. The genetic correlation between age at first service and fat content as well as persistency is slightly positive. In contrast to this, the genetic correlation with SCS is slightly negative. The correlations of weight and average daily gain with protein and fat content and SCS are negligible.

Table 2: Estimates of heritabilities of first lactation production traits and their genetic and phenotypic correlations with age and weight at first service and average daily gain (adg)[2]

trait	h^2	r (age)		r (weight)		r (adg)	
		r_g	r_p	r_g	r_p	r_g	r_p
milk yield (mkg)	0,41 (0,04)	-0,43 (0,10)	-0,05	0,23 (0,10)	0,12	0,32 (0,09)	0,13
protein yield (pkg)	0,33 (0,04)	-0,52 (0,11)	-0,04	0,28 (0,10)	0,18	0,40 (0,09)	0,17
fat yield (fkg)	0,36 (0,04)	-0,45 (0,09)	-0,11	0,23 (0,10)	0,16	0,35 (0,09)	0,20
protein% (p%)	0,62 (0,04)	0,05 (0,04)	0,02	-0,02 (0,06)	0,07	-0,02 (0,08)	0,05
fat% (f%)	0,68 (0,03)	0,13 (0,09)	0,00	-0,05 (0,09)	0,02	-0,07 (0,08)	0,02
SCS	0,16 (0,03)	-0,23 (0,14)	-0,04	0,02 (0,13)	0,06	0,09 (0,12)	0,07
persistency (p)	0,04 (0,02)	0,20 (0,22)	0,02	-0,22 (0,19)	-0,03	-0,25 (0,18)	-0,05

[2]s.e. in parenthesis

Conclusion

The results show that there is a positive genetic relationship between growth capacity and milk yield potential. A correlated selection response arising from the selection on milk yield leads to an increase of the genetic potential for growth since increasing milk yield was and still is an important breeding goal. Knowledge on the growth potential is important for an optimal management during the rearing period. Some results found in the literature suggest that a high feeding level in the prepubertal rearing period may lead to an impaired mammary development which subsequently would cause a permanent reduction of the potential for high milk yield. On the other hand a restricted feeding would increase the age at first breeding and would lead to economic losses. Other implications are that the optimal average daily gain genetically increases with an increased milk yield and that recommendations for the rearing of replacement heifers are not static and have to be validated in certain intervals.

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References

Brotherstone, S., Coffey, M.P., Banos, G. (2007). *J. Dairy Sci.*, 90:444–450.

DLG (2000). Empfehlungen zum Einsatz von Mischrationen bei Milchkühen. *DLG-Information1/2000*, DLG-Verlag, Frankfurt/Main.

Gengler, N., Keown, J. F., VanVleck, L. D. (1995). *Brazil. J. Genet.* 18:237–243.

Groen, A.F., Vos, H. (1995). *Livest. Prod. Sci.* 41:201–206.

Groeneveld, E. (1990). *PEST* User's Manual.

Groeneveld, E., Kovač, M., Mielenz, N. (2008). *VCE User's Guide and Reference Manual,* Version 6.0.

Lee, A. J., Boichard, D. A., McAllister, A. J. et al. (1992). *J. Dairy Sci.* 75:145–3154.

Mäntysaari, P., Ojala, M., Mäntysaari, E. (2002). *Livest. Prod. Sci.* 75:313–322.

Sejrsen, K., Purup, S., Vestergaard, M. et al. (2000). *Dom. Animal Endocrinology* 19:3–104.

Appendix

Measurement of persistency according to Gengler et al. (1995):

$$P = -\ {}^{1}/_{305} \sqrt{{}^{ecm1^2}/_{100} + {}^{ecm2^2}/_{100} + {}^{ecm3^2}/_{305} - {}^{ecm305^2}/_{305}}$$

where:

ecm1 - total milk yield day 1 to 100
ecm2 - total milk yield day 101 to 200
ecm3 - total milk yield day 201 to 305
ecm305 - 305-d-milk yield

Before computing persistency the measured milk yield was transformed into energy-corrected -milk yield following recommendations of DLG (2000).