Analysis of survival in dairy cows using supplementary data on type scores and housing systems

Annette Bünger and Hermann H. Swalve
Institute of Animal Breeding and Genetics, University of Göttingen
Albrecht-Thaer-Weg 3, D-37075 Göttingen, Germany

Abstract

Modern methods of survival analysis allow the use of censored (date of culling not known) and uncensored (date of culling known) records when estimating genetic effects, variance components and environmental effects on survival. In a survival analysis, type traits can be included as covariates to evaluate their use as predictors for survival. One problem in such an analysis is the availability of suitable data. Ideally, data from all cows in a population should be used. Whereas data on the length of productive life (LPL) of individual cows can be retrieved from milk recording data, for type traits this requires that all cows in the population are scored for type at least once. In the present analysis a data set from the Osnabrueck region in North-Western Germany, which fulfilled this requirement in recent years was used. Data consisted of 169,733 cows with information on LPL for calving years 1980 to 1996 (data set 1) and of 39,233 cows with information on LPL and type for calving years 1990 to 1996 (data set 2). A further data set (data set 3) contained 43116 cows from calving years 1987 to 1996 and included information on the housing system for each herd. The basic model used included stage of lactation, relative production within herd, change of herd size and year-season as time dependent effects, age at calving as a time independent effect, and herd-year-season and sire as random effects. Other effects (information on type, housing system) were included additionally. For data set 2, the scores for 15 linear type traits were also included as corrected phenotypic values, estimated breeding values and residuals from a previous BLUP analysis. The package SURVIVAL KIT 3.01, developed by Ducrocq and Sölkner (1998) was used for all analyses. The results indicate a moderate heritability of 0.22 and 0.21 for true and functional LPL (data set 1). Almost all type traits analyzed (data set 2) exceed a 0.001 level of significance in their effect on survival. Strongest relationships between survival and type were found for udder depth, fore udder attachment, and front teat placement. The main result from the comparison of housing systems (data set 3) was that bedding has a positive effect on survival.

Keywords: Dairy cattle, longevity, type traits, housing systems

1. Introduction

In dairy production, longevity of cows is of increasing importance since as a functional trait longevity has a significant impact on the profitability. This is especially true for countries producing under a milk quota system (Essl, 1998). The longevity of a cow reflects its ability of not getting culled. According to Ducrocq (1987) longevity can be separated into true longevity, the ability of a cow to avoid culling no matter for what reasons and into functional longevity, the ability of a cow to avoid involuntary culling, i.e. culling for reasons other than the cow's own milk production.

In general, longevity may be modeled in a survival analysis in a variety of ways. Earlier work (e.g. Everett et al., 1976) proposed to use the stayability of a cow up to a certain limit of lifetime or productive life. Other approaches defined survival as a continuous trait in terms of the number of completed lactations (e.g. Brotherstone and Hill, 1994) or as a binomial trait in terms of having survived culling in consecutive lactations (e.g. Visscher and Goddard, 1995). All of these approaches can not avoid a loss of information arising from the definition of fixed dates at which survival is measured. Furthermore, the information on the lifespan of a cow actually reported as culled and the information from a cow that is still alive at the fixed dates of measurement can not adequately be modeled.

Modern methods of survival analysis allow the use of censored (date of culling not known) and uncensored (date of culling known) records when estimating genetic effects, variance components and environmental effects on survival. These approaches rely on the concept of the hazard rate, the limiting probability of being culled among animals still alive

(Smith and Quaas, 1984; Ducrocq, 1987). The hazard rate can be modeled for all records, whether censored, or not. In most cases, the hazard rate is described as the product of a baseline hazard rate, representing the aging process of the population, and an exponential function of covariates.

In a recent study comparing continuous and binomial definitions of longevity and their respective analyses with modeling of survival based on the concept of the hazard rate Boettcher et al. (1999) concluded that the survival analysis seemed to provide the best fit to the true genetic model for survival or herd life.

Ducrocq and Sölkner (1994, 1998) developed a computer package (The Survival Kit) for the survival analysis suitable for animal breeding data. The availability of this package greatly facilitated the estimation of environmental effects and variance components as well as the genetic evaluation of animals. The package is used in national routine genetic evaluations for dairy sires in France, Austria and Germany. However, at the time when most selection is practised among young sires having a first proof for dairy production and type characteristics, the reliability of proofs for longevity for these bulls is still very limited since their daughters have just entered their first lactation. This situation raises the question whether type traits have some value as predictors of longevity since dairy cows usually are scored for type traits on a linear scale very early in life. Numerous studies exist that deal with the relationship between survival and type traits. In studies applying a survival analysis using the Survival Kit (e.g. Ducrocq, 1997; Dürr, 1997; Vollema, 1998; Larroque, 1998) as well as in other studies using different methodology it was found that the results are highly dependent on the data used. Differences exist between breeds, countries, status of registry, etc.

One problem in such an analysis is the availability of suitable data. Ideally, data from all cows in a population should be used. Whereas data on the length of productive life (LPL) of individual cows can be retrieved from milk recording data, for type traits this requires that all cows in the population are scored for type at least once. In the present analysis a data set from the Osnabrueck region in North-Western Germany, for which this requirement was fulfilled in recent years was used.

A question arising from discussions stirred by animal health and welfare groups is whether todays housing systems for dairy cows are adequate. An earlier study by Sölkner and Essl (1990) attempted to find relationships between housing systems and longevity. Unfortunately, their data did not contain enough herds with free-stall systems as are commonly used today to include them into the analysis. For part of the data used in the present study it was possible to collect information on the housing systems. The aim of the present study thus was to estimate heritabilities for true and functional LPL and analyze the relationships of LPL with type traits and the effect of different housing systems.

2. Materials and methods

Data was supplied by the Agricultural Computing Centre (VIT), Verden and by the Osnabruck Herdbook Association (OHG), Melle. For the three types of analysis, i.e. estimation of the heritability, relationships with type traits, and effect of housing systems, three different data sets had to be used.

After appropriate edits data set I comprised 169,733 cows calving for the first time within the period of 1980 to 1996. These cows belonged to 2578 herds with an average of 66 cows per herd and were sired by 808 bulls. Daughters of sires with fewer than 10 daughters were excluded from the analysis. Data set I contained information on dates of birth, calving and disposal as well as milk production lactation records. Lactation records were standardized to yield M.E. records. From cows that changed herds, only the information from the first herd was used and the record thereafter considered as censored.

Data set 2 contained linear type scores (15 traits) for 39,233 cows also found in data set 1 from calving years 1990 to 1996. However, most of this data stemmed from the period (year of scoring) of 1992 to 1996. Classification had been done by two classifiers only (20,487 vs. 18,747 classifications). 273 Sires with a minimum of 5 classified daughters (range: 5 to 2204) were found in this data set. The percentage of censored records was 66.26.

Data set 3 consisted of 43,116 cows included in data set 1 from 548 herds for which information on the housing system had been collected. The collection of information on housing systems was carried out concentrating on 900 bigger herds according to the herd size in 1996 and consisted of the housing system as of end of 1997. In order to minimize errors arising from changes in housing system, only cows calving for the first time between 1987 and 1996 were used. The distribution across housing systems is given in Table 1:

Table 1: Distribution of cows across housing systems

Code	Housing system	No. of records	(%)
1	Tie stall house with short standing and straw bedding	4187	9.7
2	Tie stall house with dung grid and rubber mat	14481	33.6
3	Cubicle house with bedding and slatted floor	3496	8.1
4	Cubicle house with rubber mat and slatted floor	4064	9.4
5	Cubicle house with rubber mat plus bedding and slatted floor	5076	11.8
6	Cubicle house with deep box, bedding and slatted floor	11812	27.4

For all analyses, the package SURVIVAL KIT (Ducrocq and Sölkner, 1994, 1998) was used. A Weibull model was assumed. For the combined effect of herd-year-season, a log-gamma distribution was assumed whereas sire effects were assumed to follow a mutivariate normal distribution. Relationships were considered among sires. After the effect of herd-year-season had been integrated out, the parameter (could be estimated along with the other effects.

All effects included in the final model were tested for their significance using a likelihood-ratio test comparing an expanded model with the respective reduced model. For data set 1 the following model was used for functional longevity:

$$\lambda(t) = \lambda_0(t) * \exp\{ls_i(t'') + fe_j(t''') + hgr_k(t'''') + js_l(t') + eka_m + hjs_n(t') + v_o\}$$

$\lambda\ (t)$ is the hazard-rate of a cow t days after her first calving

$\lambda_0(t) = \rho(\kappa t)^{\rho-1} = \rho\, t^{\rho-1}\, e^{\rho \log \kappa}$ is the baseline-hazard-function with parameters ρ und κ, where κ is a general mean.

$ls_i(t'')$ is a time-dependent lactation number*stage of lactation effect with changes t'' days after calving (with t = 60, 150, 240 and 280 or date of drying-off within each lactation).

$fe_j(t''')$ is the time-dependent effect of the relative production of fat and protein of each cow within her herd. Changes are effective with each new calving date

$hgr_k(t'''')$ is the time-dependent effect of changes in herd size with changes effective every January, 1st of each year

$js_l(t')$ is the time-dependent year-season effect with changes every March, 1st and December, 1st of each year

eka_m is the effect of age at first calving in months (time-independent)

$hjs_n(t')$ is the random (log-gamma distributed) herde*year*season-effect with changes every March, 1st and December, 1st of each year

v_o is the random (normally distributed) effect of the sire

When analyzing true longevity, the above model was reduced by the factor fe_j.

Heritabilities were estimated on the log-scale and transformed to the original scale as described by Ducrocq and Casella (1996).

For the analysis of relationships between longevity and type traits (data set 2) the type scores were included as covariates in the above model except that the genetic component was not considered. Analyses were done one type trait at a time. In the SURVIVAL KIT, risk ratios are expressed on a scale relative to the class with most observations. In Germany, a scale of 1 to 9 is used. For the analysis of corrected phenotypic values, breeding values and residuals the data was standardized to a 1 to 9 scale. Corrected phenotypic values, breeding values and residuals were obtained from a previous BLUP animal model analysis. In this model, the effects of age at first calving, stage of lactation, herd-year and year-season-classifier were included.

When analyzing the effect of the housing system on longevity the basic model as given above was augmented by the time-independent effect of the housing system. In a previous analysis, a year x housing system effect was used in order to check whether differences among systems were also present in former vs. recent years in an analogous manner. This could be confirmed and thus can be interpreted in such a way that changes in housing systems within herd were not too frequent. Another previous analysis included the interaction of the time-dependent effect of herd size and housing system. This was done since obviously housing systems are not equally distributed across all herd sizes. For intermediate classes of herd sizes, the effects found were in general agreement with the results from the model dropping the herd size effect, i.e. the model presented here.

3. Results

Estimates for true and functional LPL are given in Table 2. For the Weibull parameter κ a value of 2 was assumed.

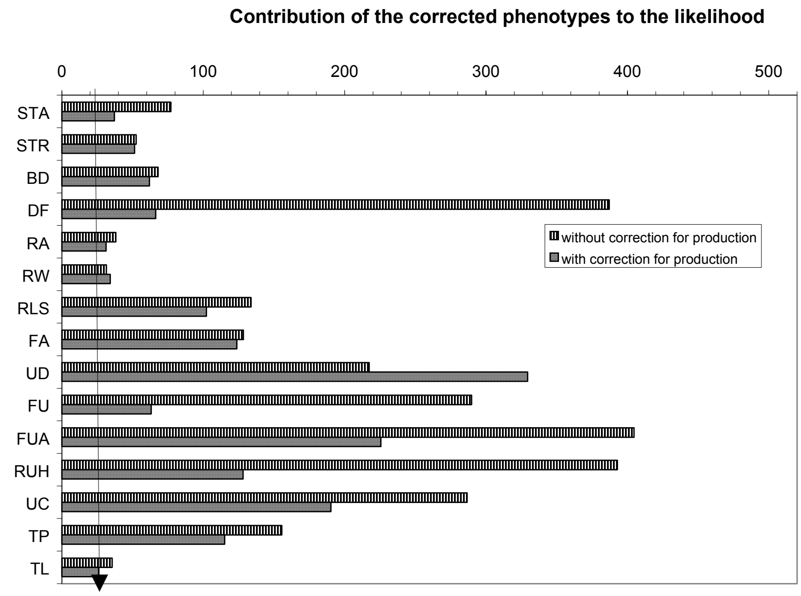
Table 2: Estimates of heritabilities for true and functional length of productive life on log and original scale (data set 1)

Trait	Sire variance	(	h² (log scale)	h² (original scale)
True LPL	0.05174	6.3353	0.116	0.22
Functional LPL	0.05158	11.5357	0.111	0.21

Figures 1 and 2 present the results for the significance of the type traits in their effect on true and functional LPL for corrected phenotypic values and for breeding values estimated from the previous BLUP analysis. The vertical arrow is representing the 0.001 level of significance.

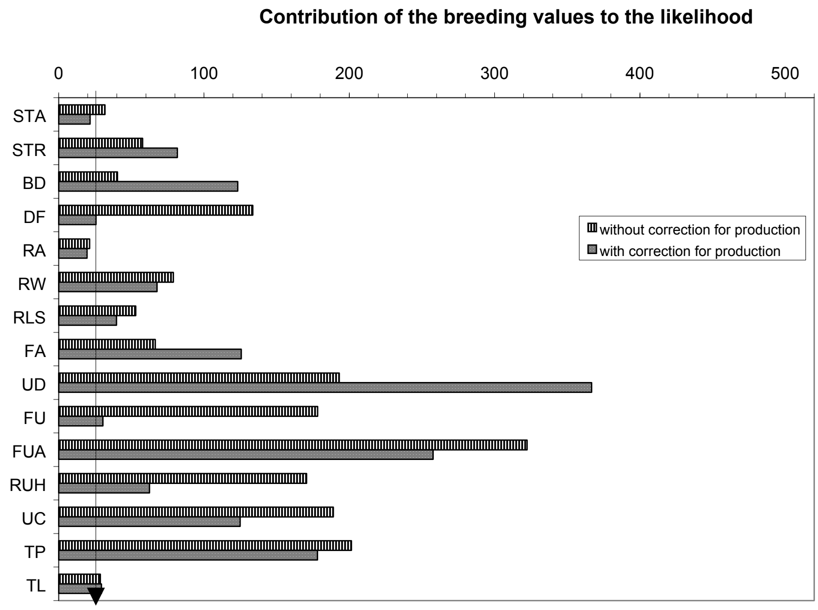
In general, corrected phenotypic values show a slightly higher effect on LPL than the estimated breeding values. Both analyses reveal that udder traits and foot angle are more important indicators for survival than body characteristics.

Figure 1: Significance of the relationship between type traits and longevity for corrected phenotypic values



0.001 level of significance

Figure 2: Significance of the relationship between type traits and longevity for breeding values



0.001 level of significance

Coding of traits	
STA	Staure
STR	Strength
BD	Body Depth
DF	Dairy Form
RA	Rump Angle
RW	Rump Width
RLS	Rear Legs - Side View
FA	Foot Angle
UD	Udder Depth
FU	Fore Udder
FUA	Fore Udder Attachment
RUH	Rear Udder Height
UC	Udder Cleft
TP	Teat Placement
TL	Teat Length

Figure 3: Deviation of functional LPL (days) from the reference class (5) for Foot Angle

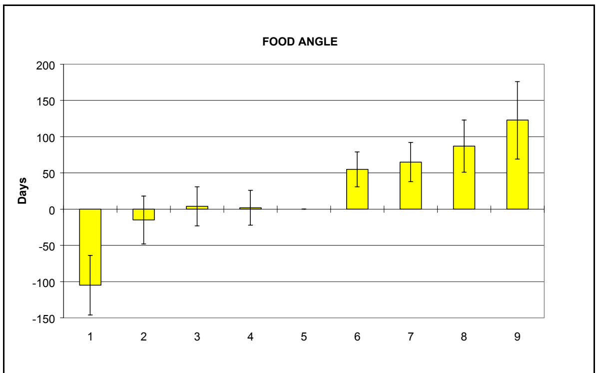
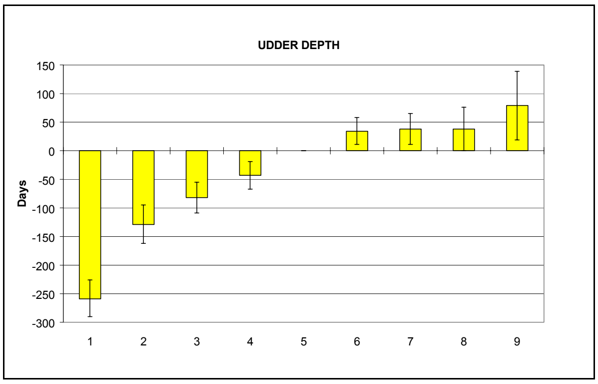


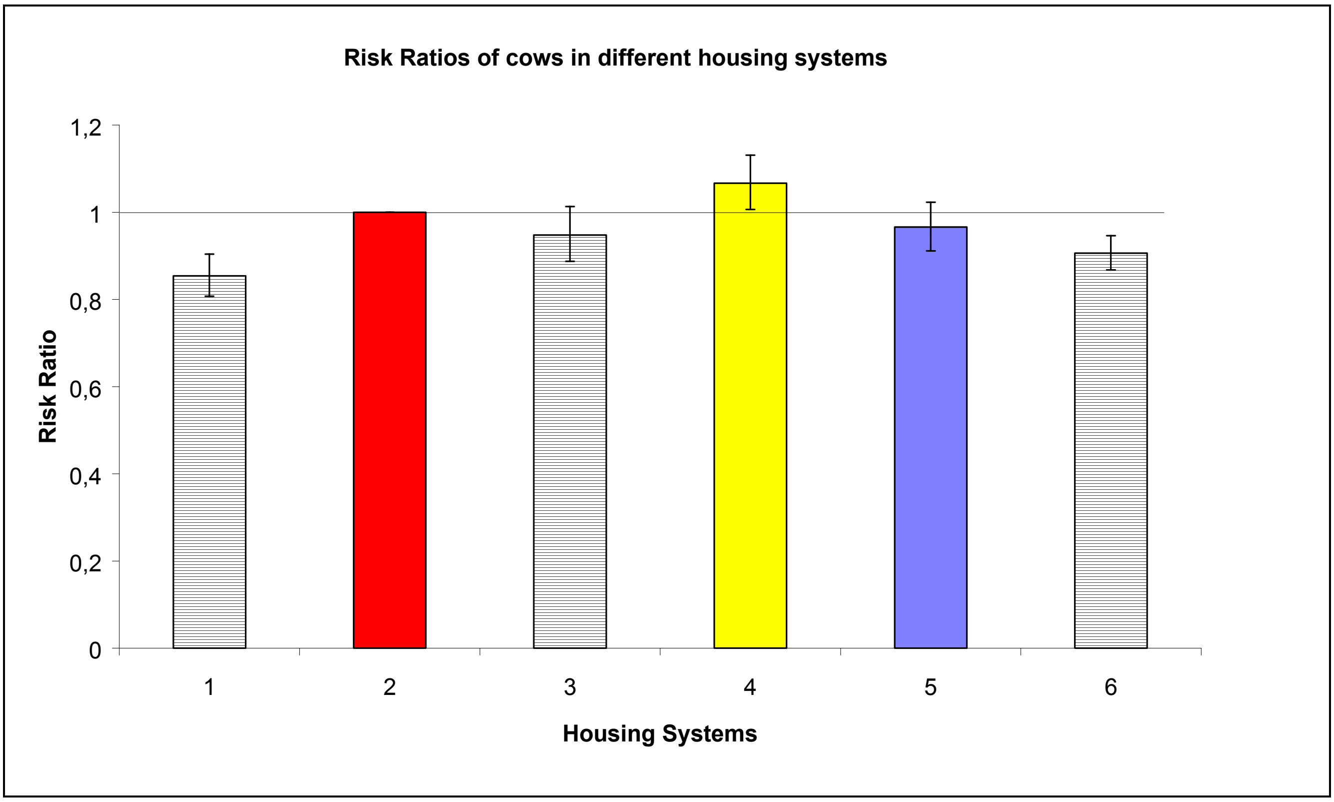
Figure 4: Deviation of functional LPL (days) from the reference class (5) for Udder Depth



Figures 3 and 4 show the relationship between estimated breeding values for type scores and functional LPL for two selected traits, foot angle and udder depth. Very clear trends are observed for these two traits: For foot angle, deviations of -100 and +50 days are found for extreme classes (worst/best). For udder depth values of -250 and +75 days are estimated.

The results for the analysis of the effect of housing systems on functional LPL are given in Figure 5:

Figure 5: Effect of housing systems on risk ratios relative to system 2 (coding see Table 1)



From Figure 5 a clear trend is observed showing a positive effect of bedding (straw, saw dust, etc.) on longevity. The risk ratios of system 1 and 6 were significant lower ($p \leq 0.001$) than those of system 2. Compared with the risk ratio of system 2, cows in system 4 (cubicle house with rubber mat) have a significant higher risk ratio ($p \leq 0.05$). The risk ratios of cows in cubicle houses with rubber mat and bedding was not significantly lower than the one of system 2.

4. Discussion

Estimates of heritabilities are at the upper end of those given in the literature as reviewed by Vollema (1998). This may be attributed to the homogeneity of the region supplying the data.

Type traits, especially udder traits and foot angle seem to be valuable indicators of longevity. When comparing the significance of corrected phenotypic values, estimated breeding values and residuals (not shown) it can not be ruled out that voluntary culling other than for milk production does indeed take place. This is supported by the effect of the residuals on LPL which is almost of the same magnitude than the one of the estimated breeding values. Despite this, it appears to be worthwhile to create an index from the type traits as an indicator for longevity. The results for individual traits partly show pronounced non-linearity in the relationship between type scores and longevity. The traits stature, dairy form, rear legs side view, and teat length are clearly identified as traits exhibiting an intermediate optimum.

Despite obvious limitations of the data, i.e. that housing systems were defined at one fixed date and the fact that housing systems were unequally distributed across herd sizes, the results of the this study support the present trend in dairy management: The comfort of the cow is very decisive for her functionality. One way to increase the comfort is to care for an appropriate bedding.

5. Conclusion

The magnitude of the heritabilities estimated (0.22, 0.21, for true and functional LPL, respectively) indicate that longevity can be increased by selection. Since longevity is of great economic importance, this trait should be included in the aggregate genotype.

Type traits, especially udder traits, have their value as early predictors of longevity. When combining type traits into an index jointly with longevity as estimated from a survival analysis, the genetic correlations necessary can be estimated via procedures analogous to the MACE procedure as was proposed by Larroque (1998). When assigning weights to individual type traits, care has to be taken in correctly treating traits with an intermediate optimum.

Bedding (straw or sawdust) has a positive effect on a cow’s LPL. Cows in housing systems with no bedding at all reached the highest risk ratios.

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