Genetic variation in disease traits and their relationships with survival in Danish dairy cattle

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Abstract

Data from the Danish health recording system on clinical mastitis, feet and leg diseases, metabolic diseases, reproductive dieseases and stayability has been analysed for Danish Holsteins, Red Danish and Danish Jerseys. Traits analysed were the incidence of the four diseases in the period ¸10 to 100 days from calving in 1st lactation. Records on 128,842 Danish Holstein cows initiating a 1st lactation in the period 1990-1995 were included in the analysis.

The diseases were analysed as separate traits in multivariate analysis. The incidence in the period ¸10 to 100 days from calving in 1st lactation for clinical mastitis, feet and leg, metabolic and reproductive diseases were 26.3%, 6.2%, 6.2% and 11.1%, respectively.

Stayability was defined as the incidence of cows that completed a 305-day record in 2nd lactation. (Co)variance components were estimated using a bivariate REML method with a linear sire model even though all traits analysed were observed on a binary scale.

Estimates for heritabilities on the observed scale for clinical mastitis, feet and leg, metabolic and reproduction diseases were 0.05, 0.01, 0.01 and 0.02, respectively. The genetic correlations between disease and survival through 2nd lactation were 0.52, 0.43, 0.17 and 0.18 for clinical mastitis, feet and leg, metabolic and reproduction diseases. Further analyses will be carried out to develop an index for other diseases than Clinical mastitis based on health recordings in the first 3 lactations.

1. Introduction

Diseases reduce animal welfare and result in economic losses for the farmer in the form of extra veterinary treatments, extra labour, decreasing milk production, discarded milk and involuntary early culling. A reduction of the frequency of diseases by selection and less involuntary culling is desirable from a general ethical point of view as it might increase consumer acceptance - and it is of course of economic importance.

In 1992 a breeding value for mastitis resistance was introduced in Denmark. The index has been very successful and is paid a lot of attention when both farmers and AI-organisations select bulls. Mastitis is the category of diseases with the highest frequency, but a lot of other diseases influence production, too. In Denmark we want to investigate the possibilities of estimating a breeding value for resistance against other diseases than mastitis. This is possible if the traits show genetic variation and are related to involuntary culling.

If an improvement of the disease resistance is included in dairy cattle breeding programs, it is necessary to obtain estimates of heritabilities, genetic and phenotypic correlations for the disease traits and to have some indicators showing how severe different disease traits are as regards avoiding involuntary culling.

The objectives of this project were:

- to estimate the genetic parameters for four categories of disease traits
- to estimate the genetic relationships between disease traits in different lactations
- to estimate the genetic relationships between disease traits and survival

2. Material and methods

2.1. The data

Data from the Danish health recording system were analysed separately for Red Danish cattle (RD), Danish Holstein (DH) and Danish Jerseys (DJ). Only cows that initiated a first lactation after 1990 were included. Another requirement was that

the herd had participated in the disease recording program for at least 3 years after the 1st lactation. A third requirement was that only 1st lactation data from herds with more than 30 calvings in the 305-day lactation period were included. For 2nd and 3rd lactation the only restriction was that the herd had systematic disease recording and the cow had her first lactation record in the data set.

The records observed were treatments by veterinarians or farmers in the period 10 days before to 100 days after calving. Cows culled within 100 days after 1st calving were excluded. The disease traits were defined as a categorical trait within a category of disease (categories of diseases are defined below).

Survival was defined as survival in the period from 1st calving to the end of the 2nd 305-day lactation.

Average results and number of observations are shown in table 1.

2.2. Disease categories

The treatments were summarized for all diseases in the four main categories: udder diseases, reproductive diseases, digestive diseases and feet and leg diseases. The four categories included the following diseases:

Table 1. Frequency of diseases and number of observations used in the analyses

	Number of observations			Average results		
	RD	DH	DJ	RD	DH	DJ
Udder diseases, 1st lact.	24,155	128,842	30,300	0.28	0.26	0.30
Udder diseases, 2nd lact.	17,852	94,653	22,479	0.30	0.31	0.26
Udder diseases, 3rd lact.	10,520	60,807	15,200	0.34	0.36	0.28
Reproductive d., 1st lact.	24,115	128,842	30,300	0.14	0.11	0.04
Reproductive d., 2nd lact.	17,852	94,653	22,479	0.15	0.14	0.06
Reproductive d., 3rd lact.	10,520	60,807	15,200	0.17	0.15	0.06
Digestive diseases, 1st lact.	24,155	128,842	30,300	0.03	0.03	0.03
Digestive diseases, 2nd lact.	178,852	94,653	22,479	0.07	0.05	0.05
Digestive diseases, 3rd lact.	10,520	60,807	15,200	0.13	0.10	0.12
Feet and legs, 1st lact.	24,155	128,842	30,300	0.07	0.06	0.04
Feet and legs, 2nd lact.	17,852	94,653	22,479	0.05	0.05	0.025
Feet and legs, 3rd lact.	10,520	60,807	15,200	0.06	0.05	0.03
Survival until end of 2nd lact.	25,621	136,484	32,179	0.50	0.55	0.57

- *Udder diseases* include summer mastitis, teat dermatitis, teat amputation, teat surgery, teat tramp, mastitis, acute mastitis, necrotzing mastitis, subclinical mastitis, dry period mastitis, mastitis due to teat tramp and other udder diseases.
- *Reproductive diseases* include abortion, endometritis, uterine prolapse, uterine torsion, endometritis treatment, follicular cysts, retained placenta, caesarian section, vaginitis

and other reproductive diseases.

- *Digestive diseases* include diarrhoea, traumatic reticuloperitonitis, ludigestion, hypomagnesemia, ketosis, milk fever, abomasal displacement, abomasal indigestion, rumen acidosis, enteritis, bloat and other digestive and metabolic diseases.
- *Feet and leg diseases* include heel erosion, interdigital dermatitis, claw trimming by veterinarian, interdigital necrobacillosis, interdigital skin hyperplasia, laminitis, arthritis, sole ulcer, pressure injuries, tenosynovitis of hoofs and other leg diseases.

2.3. Estimation

Diseases in different lactations were regarded as different traits. (Co)variance components were estimated using a REML method (Madsen et al., 1994) with a linear sire model. The DMU-program developed by Jensen & Madsen (1994) was used. All data were analysed on the observed scales, i.e. no transformations were applied and there was no accounting for the non-continuous type of distributions.The variances of the (co)variance components were estimated from the average of the observed and the expected information matrices. The standard errors of the population parameters were then calculated, using Taylor series approximations. The DMU-program includes a routine for these calculations.

The following linear sire model was applied for RD for all traits:

		Effect	Type of effect
Y	=	herd × year	fixed
	+	year × month	fixed
	+	calving age	fixed (only first lactation)
	+	additive breed effects	covariable
	+	heterosis effects	covariable
	+	sire	random
	+	residual	random

For DJ it was not possible to separate the additive breed effects and the effect of heterosis and consequently the heterosis effects were excluded from the DJ model. Both additive breed effects and heterosis effects were excluded for DH. These effects have no effect on the results, because the proportion of Holstein genes is very high in all animals.

The (co)variance components for the three lactations within udder diseases, reproductive, digestive and feet and leg diseases were estimated in trivariate analyses whereas the (co)variance component for the the disease categories within the same lactation was estimated in fourvariate analyses. The covariance between the disease traits and survival was estimated in bivariate analysis.

3. Results and discussion

The tables 2 - 5 show the estimated genetic parameters. These genetic parameters were not estimated for all possible combinations of the traits and therefore there are empty cells in the tables.

3.1. Udder diseases

The heritabilities of udder diseases were 0.04 - 0.08 in RD, 0.05 in DH and a little lower in DJ (0.02 - 0.04). With the exception of udder diseases in 1st lactation in DJ, there were very high genetic correlations for udder diseases in subsequent lactations. The estimates were above 0.82. For all breeds the genetic correlations were close to 1.0 between udder diseases in 2nd and 3rd lactation. The phenotypic correlations were low, 0.05-0.12. For DJ the genetic correlation between first and third lactation were only 0.64. The frequency of udder diseases in beginning of first lactation was very high in DJ. We do not have any explanation for this.

3.2. Reproductive diseases

The heritabilities of the reproductive diseases were 0.02-0.04 for RD and DH and 0.00-0.01 for DJ.

The genetic correlations between second and third lactation were very high in RD and DH and lower between 1st lactation and later lactations (0.61-0.93). For DJ the heritabilities were very low and the standard errors large. Therefore the genetic correlations are not mentioned.

3.3. Digestive diseases

The heritablitities of the digestive diseases were 0.01-0.02 for RD, 0.00-0.02 for DH and 0.00-0.05 for DJ. For all breeds the heritabilities were lowest i 1st lactation and highest in 3rd lactation. The

heritability was especially high for DJ. Genetic correlations between lactations varied for the different breeds. For DH the digestive diseases in 1st and 2nd lactation tended to be more similar genetically (0.96) than the diseases in 2nd and 3rd lactation (0.85).

3.4. Feet and leg diseases

The heritabilities for feet and leg diseases were low (0.00-0.01). The genetic correlations between lactations were high, especially for DH (0.90-0.99).

3.5. Genetic correlations between categories of diseases

Genetic correlations between categories were only stated for RD and DH. For DJ the standard error was very large, and the results were omitted. In general, there were moderate correlations between udder diseases and the other three categories of diseases. For DH the correlations were highest in 1st lactation (0.44-0.53) and smallest in 3rd lactation (0.19-0.28). The same tendency was found between reproductive diseases on one the hand and digestive and feet and leg diseases on the other hand but at a lower level. For RD the genetic correlations were lower and some negative. In general, there were positive correlations between digestive diseases and feet and leg diseases.

3.6. Survival until the end of the 2nd 305-day lactation

The heritabilities for survival until the end of the 2nd 305-day lactation were 0.04-0.07. RD had the highest heritabitity (0.07). RD also had less cows that survived to the end of the second lactation. The genetic correlation between survival and the disease categories in 1st lactation showed the same tendency for all breeds. The genetic correlation between survival and udder diseases was -0.75 , -0.52 and -0.37 for RD, DH and DJ, respectively. These correlations indicate that resistance to mastitis in the first period of 1st lactation is a very good indicator for longevity in cattle. The lowest correlation was found in DJ, but the genetic correlations for udder diseases between lactations were also lowest for DJ.

The genetic correlations between survival and feet and legs were -0.42 and -0.43 for RD and DH. This indicates that in spite of low frequencies of reported feet and leg diseases, the feet and legs diseases invalidate the cows.

Reproductive diseases seem to have only little influence on the cows' chance of surviving. The genetic correlation between survival and reproductive diseases was 0.12 and -0.18 for RD and DH. 90 % of the diseases in the reproductive category were retained placenta and endometritis treatment. This does not indicate, that infertility problems have no effect on the cows' chance of surviving. Problems of infertility are seldom treated by veterinarians in the first part of the lactation. Survival was not corrected for production and there is in general a favourable correlation between production and survival and a unfavourable correlation between production and reproductive diseases. These correlations may also have little influence on reproductive diseases and survival.

The genetic correlations between survival and digestive diseases were -0.37 and -0.26 for RD and DH.

The results confirm that health traits are the most important group of traits affecting longevity of dairy cows. The genetic correlations estimated in this study show that health traits, especially mastitis, recorded within the first 100 days of 1st lactation are better indicators of involuntary culling than type traits recorded in 1st lactation (e.g. Dekkers et al., 1994). In most breeding programs selection of bulls is based on part records of 1st lactation of the daughter group to ensure a short generation interval.

At this stage estimated breeding values for survival will have improved considerably if disease traits are included. Indirect prediction of longevity based on 1st lactation records of health traits, type traits and stayability results in maximum correlation between index and breeding goal.

In breeding programs without registration of health traits, selection for longevity will have a relatively large positive effect on disease resistance to udder diseases and feet and legs problems and a minor positive effect to digestive diseases.

4. Conclusions

- The results of the breeds Red Danish and Danish Holstein were similar. The number of

observations available for estimating genetic parameters was lowest in Red Danish and the standard errors of the estimates were quite high and consequently the results varied more for Red Danish than for Danish Holstein. The heritabilities of Danish Jerseys were in general lower from those obtained in the other two breeds. This might be due to differences in the frequencies of the diseases, but some of the results also indicate that the genetic relationship between the traits differs in Danish Jerseys.

- The estimates of the heritabilities of udder diseases were 0.04-0.08 and the genetic correlations between lactations were high. All figures were lower for DJ.
- The estimates of the heritabilities of reproductive disease were 1-4%.
- The estimates of the heritabilities of digestive diseases were 1-3%. The heritabilities were largest in 3rd lactation.
- The estimates of the heritabilities of feet and leg diseases were 1% or below. The genetic correlations between lactations were very large.
- The estimates of the heritabilities of survival until the end of 2nd lactation were 4-7%.
- Genetic correlations between survival and udder diseases in first lactation varied from -0.37 to -0.75.
- Genetic correlations between survival and feet & leg diseases in first lactation were approx. -0.40.
- Genetic correlations between survival and reproductive diseases and digestive diseases were low.
- Diseases and especially udder disease are good predictors of survival.

References

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Table 3. Genetic parameters of udder diseases, reproduction diseases, digestive diseases and feet &l eg diseases in first, second and third lactation and survival until the end of 305-day lactation. Red Danish.

Genetic correlations below diagonal. Phenotypic correlations above diagonal and heritabilities on diagonal; the subscripts are the standard errors of the estimates.

	M^1	M^2	M^3	R^1	R^2	R^3	D^1	D^2	D^3	L^1	L^2	L^3	S^2
Mastitis 1st lact. (M1)	$0.048_{.008}$	0.10	0.07	0.01			0.00			0.01			-0.13
Mastitis 2nd lact. (M2)	$0.87_{.07}$	$0.044_{.009}$	0.12		-0.01			0.03			0.01		
Mastitis 3rd lact. (M3)	$0.82_{.08}$	$0.99_{.05}$	$0.082_{.017}$			0.00			0.04			0.01	
Reproduction 1st lact. (R1)	$0.06_{.16}$			$0.032_{.007}$	0.11	0.05	0.02			0.01			-0.04
Reproduction 2nd lact. (R2)		$0.22_{.19}$		$0.89_{.08}$	$0.024_{0.016}$	0.11		0.05			0.01		
Reproduction 3rd lact. (R3)			$-0.10_{.21}$	$0.93_{.10}$	$0.99_{.10}$	$0.036_{.01}$			0.08			0.01	
Digestive 1st lact. (D1)	$0.06_{.21}$			$0.36_{.21}$			$0.008_{.002}$	0.02	0.02	0.03			-0.03
Digestive 2nd lact. (D2)		$0.81_{.11}$			$0.31_{.19}$		$0.86_{.15}$	$0.024_{0.006}$	0.06		0.02		
Digestive 3rd lact. (D3)			$0.60_{.18}$			$-0.03_{0.009}$	$0.81_{.19}$	$0.85_{.12}$	$0.032_{0.009}$			0.02	
Feet and legs 1st lact. (L1)	$0.46_{.21}$			$0.11_{.24}$			$-0.25_{.30}$			$0.008_{.003}$	0.05	0.04	-0.04
Feet and legs 2nd lact. (L2)		$0.38_{.25}$			$-0.30_{.27}$			$0.47_{.27}$		$0.99_{.23}$	$0.008_{.004}$	0.03	
Feet and legs 3rd lact. (L3)			$0.19_{.26}$			$-0.70_{.24}$			$0.65_{.25}$	$0.83_{.24}$	$0.73_{.25}$	$0.02_{.008}$	
Survival until end of 2nd lact. (S^2)	$-0.75_{.07}$			$+0.12_{.13}$			$-0.37_{.16}$			$-0.42_{.20}$			$0.072_{.01}$
Phen. std. dev.	0.45	0.45	0.47	0.34	0.36	0.37	0.19	0.26	0.34	0.25	0.21	0.25	0.49

Table 4. Genetic parameters of udder diseases, reproduction diseases, digestive diseases and feet & leg diseases in first, second and third lactation and survival until the end of 305-day lactation. Danish Holstein.

Genetic correlations below diagonal. Phenotypic correlations above diagonal and heritabilities on diagonal; the subscripts are the standard errors of the estimates.

	M^1	M^2	M^3	R^1	R^2	R^3	D^1	D^2	D^3	L^1	L^2	L^3	S^2
Mastitis 1st lact. (M1)	$0.048_{.004}$	0.09	0.07	0.01			0.05			0.01			-0.12
Mastitis 2nd lact. (M2)	$0.89_{.03}$	$0.044_{.004}$	0.11		-0.01			0.03			0.00		
Mastitis 3rd lact. (M3)	$0.85_{.04}$	$0.98_{0.01}$	$0.052_{.005}$			0.00			0.01			0.00	
Reproduction 1st lact. (R1)	$0.47_{.09}$			$0.020_{0.002}$	0.12	0.04	0.04			0.01			-0.05
Reproduction 2nd lact. (R2)		$0.16_{.11}$		$0.68_{.06}$	$0.024_{0.002}$	0.12		0.03			0.00		
Reproduction 3rd lact. (R3)			$0.19_{.11}$	$0.61_{.07}$	$0.99_{.01}$	$0.036_{0.004}$			0.05			0.00	
Digestive 1st lact. (D1)	$0.53_{.11}$			$0.50_{.13}$			$0.004_{.001}$	0.04	0.03	0.02			-0.03
Digestive 2nd lact. (D2)		$0.30_{.11}$			$0.00_{.14}$		$0.96_{.04}$	$0.012_{.002}$	0.06		0.02		
Digestive 3rd lact. (D3)			$0.22_{.13}$			$0.21_{.13}$	$0.77_{.08}$	$0.85_{.07}$	$0.020_{.004}$			0.02	
Feet and legs 1st lact. (L1)	$0.44_{.12}$			$0.20_{.15}$			$0.38_{.17}$			$0.008_{.001}$	0.04	0.04	-0.03
Feet and legs 2nd lact. (L2)		$0.15_{.12}$			$0.27_{.13}$			$0.71_{.10}$		$0.90_{.05}$	$0.012_{.002}$	0.05	
Feet and legs 3rd lact. (L3)			$0.28_{.16}$			$0.13_{.17}$			$0.23_{.19}$	$0.90_{.05}$	$0.99_{.04}$	$0.012_{.003}$	
Survival until end of 2nd lact. (S^2)	$-0.52_{.06}$			$-0.18_{.10}$			$-0.17_{.13}$			$-0.43_{.12}$			$0.048_{.008}$
Phen. std. dev.	0.44	0.46	0.48	0.32	0.35	0.37	0.19	0.23	0.31	0.24	0.22	0.23	0.49

Table 5. Genetic parameters of udder diseases, reproduction diseases, digestive diseases and feet & leg diseases in first, second and third lactation and survival until the end of 305-day lactation. Danish Jersey.

Genetic correlations below diagonal. Phenotypic correlations above diagonal and heritabilities on diagonal; the subscripts are the standard errors of the estimates

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	M^1	M^2	M^3	R^1	R^2	R^3	D^1	D^2	D^3	L^1	L^2	L^3	S^2
Mastitis 1st lact. (M1)	$0.024_{.005}$	0.06	0.05										
Mastitis 2nd lact. (M2)	$0.76_{.14}$	$0.016_{.005}$	0.10										
Mastitis 3rd lact. (M3)	$0.64_{.14}$	$0.98_{.13}$	$0.036_{0.01}$										
Reproduction 1st lact. (R1)				0.000									
Reproduction 2nd lact. (R2)					0.004								
Reproduction 3rd lact. (R3)						0.004							
Digestive 1st lact. (D1)							$0.004_{.002}$						
Digestive 2nd lact. (D2)								$0.012_{.004}$					
Digestive 3rd lact. (D3)									$0.048_{.01}$				
Feet and legs 1st lact. (L1)										0.000			
Feet and legs 2nd lact. (L2)											0.004		
Feet and legs 3rd lact. (L3)												0.004	
Survival until end of 2nd lact. (S^2)	-0.37												$0.040_{.008}$
Phen. std. dev.	0.46	0.44	0.45	0.20	0.24	0.24	0.27	0.27	0.35	0.19	0.16	0.16	0.49