Indices for Resistance Against Diseases

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Introduction

Diseases result in economic losses for the farmer in the form of extra treatments and labour, decreasing milk production, discarded milk and involuntary early culling. A reduction in the number of diseases by selection is therefore of economic importance. Unfortunately, diseases have low heritabilities and are generally unfavourable correlated to milk production traits.

The objectives of this project were :

- to estimate the genetic parameters for disease traits
- to analyse the possibilities of improving the current Danish index for mastitis resistance
- to develop an index for other diseases than mastitis

Definition of traits

The diseases were subdivided into four main categories: udder diseases, reproductive diseases, digestive and metabolic diseases and feet and leg diseases.

- ***Udder diseases*** include diseases reported as 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 and metabolic diseases*** include diarrhoea, traumatic reticuloperitonitis, ludigestion, hypomagnesaemia, 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.

Genetic parameters

Material and Methods

Data from the Danish health recording system were analysed for Danish Black and White cattle. The basic measurement was the number of treatments in the period ÷10 to 305 days from calving. Records of 163,361 1st lactation, 191,557 2nd lactation and 115,844 3rd lactation cows initiating a lactation in the period 1990-1994 were included in the analysis.

(Co)variance components were estimated using a bivariate REML method (Jensen & Madsen, 1994) with a linear sire model. The following sire model was applied:

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

Results

The Tables 1 and 2 show the estimated genetic parameters on the observed scale. In these Tables the results are shown with bold characters whereas the other figures in the Tables are used for analyses of alternative indices. The parameters for mastitis in first, second and third lactation are shown (Table 1) while the parameters for the other categories of diseases are shown for first and second lactation only (Table 2), because the parameters in second and third lactation were nearly equal and the genetic correlations were high.

The main results were:

- Estimates of the heritability of mastitis on the observed scale were 4.4% for all three lactations. The genetic correlations between the lactations were high (0.86-0.98). SCC in 1st lactation had a heritability of 14.4% and the genetic correlation to mastitis in 1st lactation was 0.57.

- For reproductive diseases the heritability was 1.6% in both lactations and the genetic correlation between first and second lactation was 0.64.

- For digestive and metabolic diseases the heritabilities were 1.2% and 1.6% in first and second lactation and the genetic correlation between the lactations was 0.78.

- Feet and leg diseases had lower heritabilities (0.8%) and a very high correlation between the lactations. Both the phenotypic and the genetic correlation between digestive and metabolic diseases and feet and leg diseases were very high.

There were low genetic correlations between SCC and the three disease categories excluding mastitis (0.02, 0.02 and ÷0.02, first lactation). These results are not shown in Table 1 and 2.

For the analysis of indices for mastitis resistance and for other diseases it was necessary to obtain additional phenotypic and genetic correlations. The remaining genetic parameters were estimated from correlations between breeding values, indirectly by multiplying correlations with another trait or from the literature. All the parameters used are listed in Table 1 and 2. Especially it must be noted that all possible indicator traits for mastitis resistance are genetically unfavourably correlated to protein yield (÷0.12 to ÷0.33).

Indices for mastitis and for health traits

Indices for mastitis resistance (MRI) and indices for resistance to other diseases than mastitis (RODI) based on various sources were made to :

- investigate the possibilities of improving the current Danish MRI and to introduce a new index, RODI, using various traits as information sources.

- estimate the genetic response to selection for protein yield with a restricted selection index for MRI and for RODI.

The responses were only measured as genetic superiorities of selected bulls with a selection intensity of 1.00 and as correlations between index and aggregate genotype (r_{ih}).

Index for mastitis resistance (MRI)

A total of 11 alternative selection indices were analysed. The alternatives differ with respect to the combination of observed traits. The different combinations of observed traits in the indices are shown in Table 3 and 4. The current Danish index for mastitis resistance is marked by the shaded area in Table 3.

Two aggregate genotypes have been analysed:

- resistance to mastitis in 1st lactation (results in Table 3).

- protein yield with the restriction that resistance to mastitis is kept constant (results in Table 4).

The current Danish MRI uses information about mastitis frequency and SCC in 1st lactation only. For this index the correlation between the index and the aggregate genotype (r_{ih}) for a 1st lactation mastitis resistance index was 0.77. When 2nd and 3rd lactation records for mastitis frequency and SCC were added, the r_{ih} increased to 0.80 and adding the two udder conformation traits gave a further increase of r_{ih} by 4% to 0.83. The results in Table 3 indicate that the two udder conformation traits are as effective as SCC for evaluation of mastitis resistance.

If records of clinical mastitis were not available, r_{ih} was lower than for the all indicies including mastitis frequencies. Using SCC records from 1st to 3rd lactation and the two udder conformation traits gave a reduction of 6% compared to our current MRI.

A restricted index which keeps mastitis resistance at a constant level and maximizes the genetic response in protein yield was constructed based on various indicators for mastitis. The results are presented in Table 4.

The results in Table 4 show that at a constant level of mastitis resistance the genetic response for protein yield was depending on construction of the MRI. If the MRI included records of mastitis incidence the response highest. Genetic response for protein yield could be increased by 2% compared to the current Danish MRI by using all information about mastitis, SCC and udder conformation traits. On the other hand, at a constant level of mastitis resistance indirect selection on only SCC and udder conformation traits reduced the genetic response in protein yield by 5-10%.

Selection based on the registrations of mastitis was superior to selection based on indicator traits because the indicators, SCC, udder depth and fore udder attachment are genetically unfavourably correlated to protein yield. If the breeding goal was protein yield, the genetic superiority was 12.91 kg protein. Restricting the genetic level of mastitis resistance reduced the genetic response in protein yield by 9% when all traits were used in the MRI index.

Index for other health traits than mastitis resistance (RODI)

A total of 4 alternative indices were analysed. The alternatives differ with respect to the combination of observed traits, while the aggregate genotype is improvement of the three health traits in 1st lactation with the relative economic weights 1:1:1. The maximum correlation between index and aggregate genotype (r_{ih}) was 0.67.

The correlation was reduced to 0.64 when only records in first lactation were used. Excluding mastitis reduced the r_{ih} to 0.65 indicating that the information on mastitis is as important as information on the three disease categories in later lactations. The value of conformation traits as indicators of other diseases than mastitis will be investigated in the future.

A restricted index, which kept the reproductive diseases and digestive and metabolic diseases at a constant level but allowed genetic change in feet and leg diseases and maximized response in protein yield, were also analysed. The index included all traits listed in Table 5 (but the results are not shown). The genetic superiority of the selected bull with a selection intensity of 1 was 11.85 kg protein. Compared to selection only for protein yield, the superiority was reduced by 1.07 kg protein.

Conclusions

- Udder diseases have heritabilities of 4-5%. Reproductive diseases and digestive and metabolic diseases have heritabilities of 1-2% and the traits are moderately correlated. Digestive and metabolic diseases are highly correlated to feet and leg diseases.

- For most traits the genetic correlations between the lactations were very high. The lowest genetic correlations were observed between 1st and 2nd lactation for reproductive diseases (0.64) and digestive and metabolic diseases (0.78)

- Using clinical mastitis in an index for mastitis resistance gives maximum response when the breeding goal is to maximize the protein yield and keeping clinical mastitis at a constant level. SCC and a few udder traits are also useful but have not the same effect as clinical mastitis.

- SCC is not useful as an indicator trait for other diseases than mastitis.

References

Jensen J. and Madsen P. 1994. DMU: A package for the analysis of multivariate mixed models. Proc. of the 5th World Congress on Genetics Applied to Livestock Production, august 7-12, 1994, Guelph, Canada, Vol 22, 45-46.

Table 1. Genetic parameters and progeny group size (n). Heritabilities on diagonal, phenotypic correlations above diagonal, genetic correlations below diagonal; s.d. is the phenotypic standard deviation

Trait	1	2	3	4	5	6	7	8	9	s.d.	n
1. Mastitis, 1st lactation	.044	.11	.07	.20	.20	.20	÷.10	÷.06	÷.01	0.715	60[e)]
2. Mastitis, 2nd lactation	.95[a]	.044	.11	.20	.20	.20	÷.10	÷.06	÷.01	0.715	36
3. Mastitis, 3rd lactation	.86[a]	.98[a]	.044	.20	.20	.20	÷.10	÷.06	÷.01	0.715	22
4. SCC, 1st lactation	.57[a]	.50[d]	.50[d]	.144	.35	.35	÷.08	÷.07	÷.06	0.8	100
5. SCC, 2nd lactation	.50[d]	.57[a]	.54[d]	.90[c]	.144	.35	÷.08	÷.07	÷.06	0.8	60
6. SCC, 3rd lactation	.50[d]	.54[d]	.57[a]	.85[c]	.97[c]	.144	÷.08	÷.07	÷.06	0.8	36
7. Udder depth, 1st lactation	÷.58[b]	÷.58[b]	÷.58[b]	÷.29[b]	÷.29[b]	÷.29[b]	.36	.40	÷.22	1.16	80
8. Fore udder attachm., 1st lact.	÷.35[b]	÷.35[b]	÷.35[b]	÷.28[b]	÷.28[b]	÷.28[b]	.70[b]	.24	.02	1.72	80
9. Protein yield, 1st lactation	.33[b]	.33[b]	.33[b]	.22[b]	.22[b]	.22[b]	÷.32[b]	÷.12[b]	.30	25	100

a) Estimate based on Danish data (1996).
b) Estimated approximately from correlations among breeding values.
c) Literature figures.
d) Estimated indirectly by multiplying correlations with another trait.
e) Sire and maternal grandsire are included with 1000 daughters recorded for mastitis in 1st lactation.

Table 2. Genetic parameters and progeny group size (n). Heritabilities on diagonal, phenotypic correlations above diagonal, genetic correlations below diagonal; s.d. is the phenotypic standard deviation

Trait	1	2	3	4	5	6	7	8	9	s.d.	n
1. Mastitis, 1st lactation	.044	.11	.01	.00	.00	.00	.00	00	.00	.715	60[e)]
2. Mastitis, 2nd lactation	.95[a]	.044	.00	÷.01	.00	.00	.00	.00	.00	.715	36
3. Reproduction, 1st lactation	32[a]	.06[d]	.016	.14	.03	.02	.01	.01	.00	.332	60
4. Reproduction, 2nd lactation	.06[d]	.18[a]	.64[a]	.016	.02	.02	.01	.01	.00	.332	36
5. Metabolic, 1st lactation	.25[a]	.06[d]	.60[a]	.20[d]	.012	.05	.79	.00	.00	.42	60
6. Metabolic, 2nd lactation	.06[d]	.25[a]	.20[d]	.33[a]	.78[a]	.016	.04	.64	.00	.35	36
7. Feet & legs, 1st lactation	.28[a]	.06[d]	.54[a]	.18[d]	.93[a]	.77[d]	.008	.04	.00	.313	60
8. Feet & legs, 2nd lactation	.06[d]	.21[a]	.18[d]	.34[a]	.77[d]	.83[a]	.86[a]	.008	.00	.313	36
9. Protein yield	÷.33[c]	÷.33[c]	÷.24[c]	÷.24[c]	÷.24[c]	÷.24[c]	÷.14[c]	÷.14[c]	.30	25	100

a) Estimate based on Danish data (1996).
b) Estimated approximately from correlations among breeding values.
c) Literature figures.
d) Estimated indirectly by multiplying correlations with another trait.
e) Sire and maternal grandsire are included with 1000 daughters recorded for mastitis in 1st .lactation.

Table 3. Relative genetic response and the correlation between the index and the aggregate genotype (r_{ih}) for a 1st lactation mastitis resistance index calculated from different combinations of observations on mastitis, SCC, udder depth, fore udder attachment and yield (current Danish MRI is shaded)

Mastitis 1st lact.	Mastitis 2nd lact.	Mastitis 3rd lact.	SCC 1st lact.	SCC 2nd lact.	SCC 3rd lact.	Udder depth 1st lact.	Fore udder attachm. 1st lact.	Protein yield	r_{ih}
x	x	x	x	x	x	x	x	x	.84
x	x	x	x	x	x	x	x		.83
x			x			x	x		.81
x	x	x	x	x	x				.80
x						x	x		.77
x			x						.77
x	x	x							.77
x									.72
			x	x	x	x	x		.68
						x	x		.55
			x	x	x				.51

Table 4. Genetic response in protein yield keeping mastitis resistance in 1st lactation at a constant level using a MRI with different combinations of observations on mastitis, SCC, udder depth, fore udder attachment and protein yield

Mastitis 1st lact.	Mastitis 2nd lact.	Mastitis 3rd lact.	SCC 1st lact.	SCC 2nd lact.	SCC 3rd lact.	Udder depth 1st lact.	Fore udder attachm. 1st lact.	Protein yield	Superiority protein kg	r_{ih}	Relative
x	x	x	x	x	x	x	x	x	11.80	.90	100
x	x	x	x	x	x			x	11.76	.90	99.7
x			x			x	x	x	11.74	.90	99.4
x	x	x						x	11.68	.89	99.0
x			x					x	11.67	.88	98.9
x								x	11.55	.86	97.9
			x	x	x	x	x	x	11.26	.82	95.4
						x	x	x	10.57	.68	89.6
			x	x	x			x	10.54	.67	89.3

Table 5. Relative genetic response and correlation between index and aggregate genotype (r_{ih}) for a 1st lactation resistance index against other diseases than mastitis consisting of different combinations of traits. The aggregate genotype is improvement of reproductive, metabolic and feet and leg diseases in 1st lactation with the relative weights 1:1:1

Mastitis 1st lact.	Mastitis 2nd lact.	Repro-duction 1st lact.	Repro-duction 2nd lact.	Meta-bolic 1st lact	Meta-bolic 2nd lact.	Feet & legs 1st lact.	Feet & legs 2st lact.	Protein yield	r_{ih}
x	x	x	x	x	x	x	x	x	.67
x	x	x	x	x	x	x	x		.66
		x	x	x	x	x	x		.65
x		x		x		x			.64
		x	x	x	x				.65
				x	x	x	x		.56
		x	x			x	x		.61
		x	x						.50
				x	x				.55
						x	x		.49