Future development in genetic evaluation of Danish dairy cattle

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1. Introduction

The genetic evaluation of dairy cattle is very dependent on the computer capacity for several reasons:

- All the data used in the evaluation is recorded in commercial dairy farms under very varying environmental conditions. This data recording system requires complex evaluation models.
- Due to the long generation interval and the low reproduction rate the benefits of crossbreeding systems are not as large as in other livestock species. Therefore all traits of economic interest - also low heritability traits - must be included in the selection process and thus evaluated within each breed.
- In dairy cattle there are no distinct breeding seasons and the selection decisions are made continuously around the year. This requires frequent evaluations.

The benefits of more accurate models are of course higher reliability and less bias of the estimated breeding values and consequently increased genetic progress. Even though intensive nucleus breeding programs have been introduced during the recent years, most of these new programs are most effective when they are combined with a traditional evaluation scheme. The purpose of this paper is to describe the current Danish evaluation system and the plans for developments during the coming years.

2. Status on the Danish evaluation system

Figure 1 gives a survey of the current Danish evaluation system. A total of 41 traits are evaluated. The 41 estimates of breeding values are summarized in 10 sub-indices and a total merit index. Among the 10 sub-indices, 5 describe conformation traits that are all evaluated by the same type of model. Only 6 different groups of traits are evaluated:

- Milk production
- Beef production
- Fertility
- Calving performance
- Resistance to mastitis
- Conformation

The genetic evaluation of Danish dairy cattle includes 5 million cows and 10,000 AI-sires (40,000 including private and pedigree bulls). Around 250,000 new cows and 550 new AI-sires (totally 1800 sires) are added each year. The evaluations are all made separately for the four breeds: Danish Holsteins, Red Danish, Danish Jerseys and the small breed Danish Red and White. Danish Holsteins is the dominant breed in Denmark accounting for nearly 70% of the cows and only results from Danish Holsteins are mentioned in this paper. All evaluations are made by the DMU-program developed by Jensen & Madsen (1993). One round of evaluation is completed in less than 3 weeks including data preparation. The available computers are 2 IBM RS/6000 (1 GB RAM and 280 MB RAM).

Table 1 shows some technical facts from the evaluation of each of the 6 groups traits for Danish Holsteins, including the number of records, fixed equations, random equations and total number of equations.

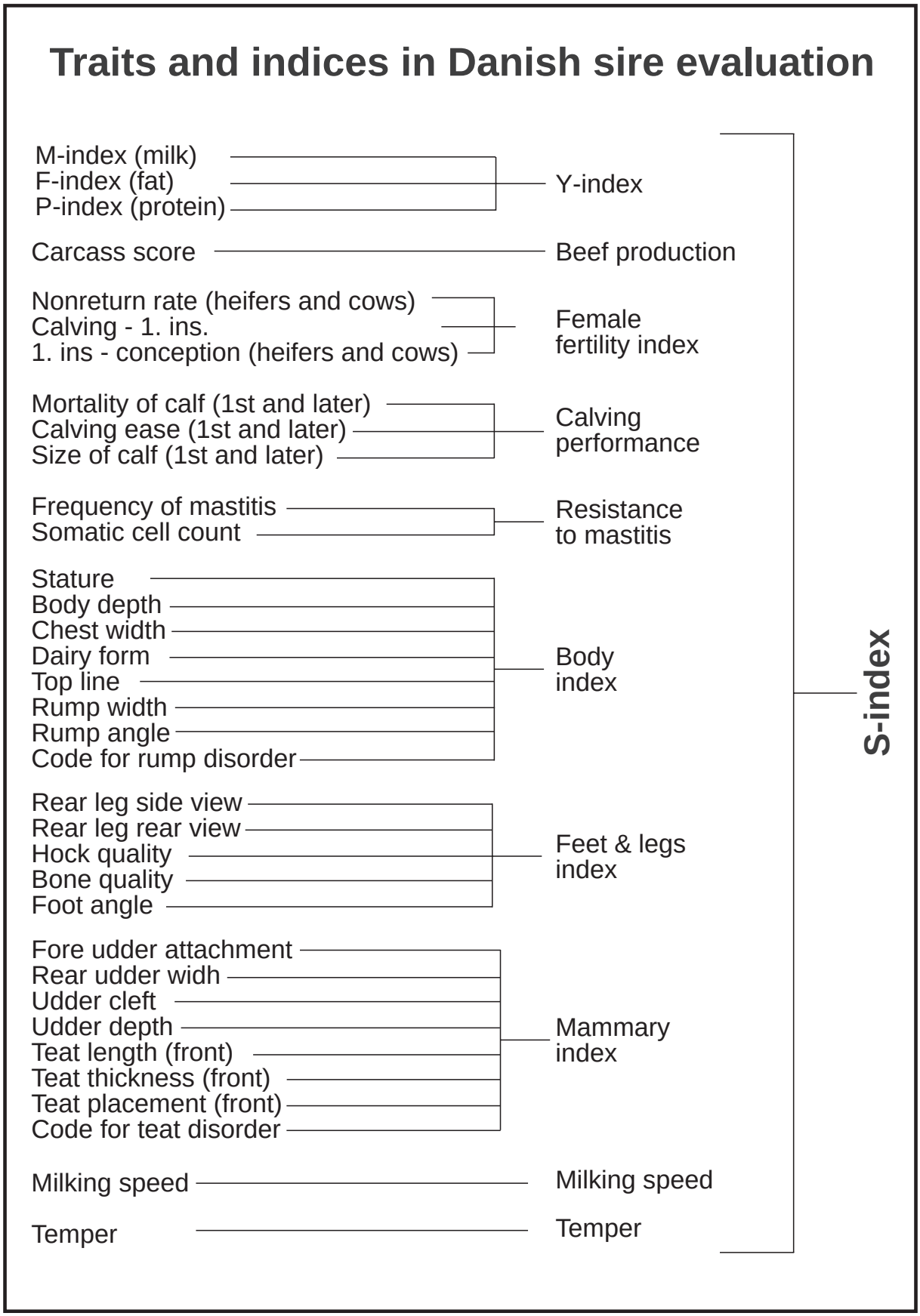

Figure 1. Survey of genetic evaluation of dairy cattle in Denmark.

Table 1. Size of evaluation systems for Danish Holsteins.

Group	AM or sire model	No of traits	Traits per run	Eval. per year	Total no of eq. Mill.	Fixed GS eq. Mill.	Random animal or sire eq.	Other random effects Mill.	No records Mill.
Yield	AM	3	1	12*	6.70	0.48	3,500,000	2.70	5.40
Beef	Sire	2	2	4	0.16	0.13	26,880	0	0.80
Mastitis	Sire	2	2	4	0.22	0.96	29,800	0	1.30
Fertility heifers	Sire	2	2	4	0.20	0.18	15,000	0	1.46
Fertility cows		3	3		0.39	0.36	22,500	0	3.27
Calving perform.**	Sire	6	6	4	1.00	0.80	206,000	0	5.77
Conformation	AM	23	1	8	0.49	0	461,000	0.03	0.17

* 8 normal evaluations and 4 for Interbull with foreign information excluded
** Additionally 6 direct random effects are evaluated (a total of 12 random effects per sire)

Milk production traits

Milk, fat and protein 305-day yields are evaluated in single trait repeatability animal models with 3 lactations included. The animal model was introduced last year (1998). In this model the only major precorrections are extension of part lactations and correction for heterogeneity of variance between lactations, herds and lactations of different length (Pedersen et al., 1999). From a computational point of view this evaluation is the most comprehensive model that is used in Denmark right now. In total, the system includes 6.7 million equations, 500,000 fixed effects, 3.5 million animal effects and 2.7 million permanent environmental effects. The evaluation is run for 3 traits 8 times per year and additionally 4 times per year for the Interbull evaluation. In the Interbull evaluations foreign information is excluded from the system.

Beef production

A new evaluation system for beef production traits based on slaughterhouse recordings was introduced in march 1999. It is a multiple-trait evaluation of growth rate and carcass score in a sire model (Pedersen et al., 1999). The estimated breeding values from this evaluation have replaced the results from the performance test station that was closed in 1998. From a computational point of view it is a fairly small system with only 160,000 equations in total.

Resistance to mastitis

The evaluation comprises 2 traits: Somatic cell count and occurrence of mastitis in 1st lactation. The model used is a multiple trait sire model (Nielsen et al., 1992)

Fertility

The evaluation of fertility comprises 5 traits: Non-return rate and days from 1st to last insemination as separate traits in heifers and cows and days from calving to 1st insemination in cows. The models are multiple-trait sire models for heifers (2 traits) and a multiple-trait sire model for cows (3 traits) (Pedersen & Jensen, 1996). In the evaluation system for fertility of cows 385,000 equations are included.

Calving performance

Registrations of calf mortality, calving ease and size of calf are used for the evaluation. These traits are considered to be different traits at 1st and at later calvings. Both direct and maternal genetic effects are estimated. The maternal effects are included in the index system (calving performance, figure 1) whereas the direct effects are published and used only as management information (Pedersen et al., 1995). The system comprises 200,000 random equations and 1 million equations in total.

Conformation traits

A total of 23 conformation traits are evaluated in single-trait animal models.

3. Future development

In general terms the plans for the next years are more intensive utilization of existing information by including genetic and environmental correlations and exploitation of existing information that has not yet been used for genetic evaluation. At some time in the future it is also intended to replace the linear models currently used with more appropriate models for traits as calf mortality, calving ease and diseases.

Table 2 gives a survey of the Danish evaluation system with focus on utilization of genetic and environmental correlations and the possibilities for future development. Up to now the development has been concentrated towards the correlations within groups of similar traits, except for milk production and conformation traits. Lately, the attention has turned to the correlations to conformation traits and longevity. The important but very complex relationships between yield, fertility and resistance to mastitis and other diseases have not yet been considered.

Resistance to mastitis

The genetic evaluation of resistance to mastitis is currently being improved. The new system for evaluation of resistance to mastitis will include

- Occurrence of mastitis during the first three lactations, each lactation considered a separate trait.
- Somatic cell count during the first three lactations, each lactation considered a separate trait.
- Three conformation traits:
  - Fore udder attachment
  - Udder depth
  - Dairy form

Only the occurrence of mastitis has economic weight whereas the remaining traits will be used as information traits in a multiple-trait sire model. The new evaluation system for resistance to mastitis will then include 9 different traits. The total number of equations will probably be around 500,000.

Table 2. Survey of genetic and environmental correlations included in the Danish evaluation system, "+" correlations included, "÷" correlations that might improve the evaluation.

Traits groups in breeding goal	Information trait groups							
	Milk prod.	Beef prod.	Ferti-lity	Mastitis	Disea-ses	Calving perf.	Confor-mation	Longe-vity
Milk production	÷		÷	÷	÷			÷
Beef production		+			÷		÷	
Fertility	÷		+		÷			÷
Mastitis	÷			+	÷		÷	÷
Other diseases*	÷	÷	÷	÷	+		÷	÷
Calving perf.						+	÷	
Conformation							÷	
Longevity*	÷		÷	÷	÷			÷

* Not yet included in the evaluation system

Resistance to other diseases

In 1999 it is also planned to develop a new genetic evaluation system for other diseases than mastitis. These diseases are grouped in 3 categories: Reproduction diseases, digestive diseases and feet and leg diseases. The intention is to evaluate each of these groups as different traits in the first three lactations. Then additionally 2 or 3 conformation traits may be included as information traits. Then the new system for other diseases will comprise at least 9 traits in a multiple trait sire evaluation. The size of this system will be very equal to size of the system for evaluation of resistance to mastitis.

Longevity, calving performance, fertility, conformation

In 1999 or 2000 it is planned to develop a relatively simple evaluation model for longevity. Major changes in the other evaluation systems are not planned within the next 2 - 3 years and not before we are ready to introduce more advanced models (threshold models, survival models).

Milk production

In the year 2000 it is planned to start the development of a test-day model for milk yield traits in Denmark. The test-day model is attractive for several reasons:

- Improved modeling of year, season and management effects.
- Avoid precorrection for part lactations (extension of part lactations). In general, precorrection has created problems in the genetic evaluation and especially the extension of part lactations has very often caused problems.
- More detailed description of the milk production traits.
- Reduced number of test days per year will be possible from October this year.
- Robot milking systems seem to become quite common within the next couple of years.
- Then daily recordings of daily milk yield will become available for a substantial number of cows.

Some preliminary estimates of the size of a future evaluation of lactation records or test-day records is shown in table 3. The major disadvantage of test-day models is the heavy requirement to computer capacity. An essential requirement is that each round of evaluations should be completed in less than

Table 3. Estimated size of system for Danish Holsteins in genetic evaluation of milk production (milk, fat and protein), 3.5 million animals, 2.6 with records.

	Lactation models			Test day model with 3 fixed and random regressions			
Type of model	Single trait	Multi trait	Multi trait	Single trait	Single trait	Multi trait	Multi trait
Model for lactation	Repeatability 3 lactations	Repeatability 3 lactations	Multi trait 3 lactations	Single trait 1st lactation	Repeatability 3 lactations	Single trait 1st lactation	Multi trait 3 lactations
				Size of system			
Records	5300000	5,300,000	2,600,000	21,000,000	52,000,000	21,000,000	52000000
Management/ test days	475000	475000	700000	1,000,000	1,000,000	1000000	1000000
Total no of equations	6,700,000	20,000,000	34000000	21000000	41000000	61000000	190000000
Memory for data, MB	250	570	790	1280	3470	2240	8530
Memory for vectors, MB	200	770	2080	810	1560	3910	24900

2-3 weeks. It is only possible to fulfil this requirement if the computing capacity is increased very significantly and the choice of model will depend on the computing capacity that will become available 2-3 years from now.

4. Integration with management information systems

There has been an increasing interest in using the results from the genetic evaluation in management information system. Lately, the herd-year-season effects for milk production traits have been published and it has been considered to publish the changes over time. This service could easily be extended to other traits as well. However, this integration of genetic evaluation and management information is only possible if the genetic evaluations are very frequent.

The extended lactation records have been used for prediction of production for many years. When the test-day model is introduced, the accuracy of this prediction can probably be increased considerably.

5. Conclusion

For many years the situation of dairy cattle evaluation has been that the theoretical development of the evaluation has been far ahead of the possible computational capacity. As capacity increased, the models used in evaluations increased accordingly. It is important to notice that computing capacity includes software and that speed is a very important factor. A round of evaluation of all traits should be completed in less than three weeks, including data preparation.

As the systems include more and more genetic correlations, it is increasingly important to be able to explain to the breeders the effects of genetic correlations on the estimates of breeding values for the individual animals.

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