International Workshop on Genetic Improvement of Functional Traits in Cattle.

General introduction

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1. Animal breeding principles

Animal breeding is aimed at changing the genetic merit of animals in coming generations such that they will produce the desired products more efficiently (relative to the present generation) under future farm economic, natural and social circumstances. The definition of "efficiency" is relative to an overall objective for the species in question. In the simplest case this overall objective includes only economic variables but may be extended to accommodate also aspects like ethics of production, biodiversity et cetera. It is important to remember that animal breeding is a part of strategic (long-term) planning of production.

In selecting females and males to be used as parents of the next generation, a major problem is the optimum relative emphasis to be put on different traits, to obtain optimum relative levels of improvement in each trait, thus obtaining maximum possible improvement of the overall objective. A first step towards a solution is to define the breeding goal - that part of the overall objective which is possible to improve by genetic means. Selection index theory (Hazel, 1943) provides the framework for the concrete definition of the breeding goal in terms of an aggregate genotype selected for by a correlated information index. The aggregate genotype is used to represent the genetic merit of an animal: the weighted sum of its genotypes for several traits. To optimize relative levels of improvement of aggregate genotype traits, traits are weighted by their predicted contribution to the increase in the overall objective. This contribution (the economic weight for a trait) is determined by (1) time and frequency of future expression of genetic superiority for the trait, and (2) economic benefit at the moment of expression of genetic superiority for the trait (Brascamp, 1978). This latter aspect is generally referred to as the economic value of a trait.

Selection for improved genetic merit is practiced by selecting for a correlated information index. The information index is based on phenotypic performance of the animal itself and/or of related animals. The calculation of regression coefficients for phenotypic performance traits in the information index maximizes the correlation between aggregate genotype and information index, considering the number of phenotypic observations for the information index traits, the relationship between the animal being evaluated and the source of the information, the genetic and phenotypic (co)variances among aggregate genotype and information index traits, and the economic weights of the aggregate genotype traits.

In summary, which traits should be included in the aggregate genotype and the information index, and the relative emphasis the traits obtain, depends upon three aspects (Harris, 1970):

1. the relative contributions of improvement traits to improvement of future efficiency of production,
2. the potential for genetic improvement of traits

(i.e. variance and heritability),

3. the cost of accurate measurement of phenotypic performance of traits (in labour, facilites and time).

In other words, animal breeding involves three key-items:

I. **breeding goal definition**: setting up the aggregate genotype and deriving economic weights,

II. **breeding value estimation**: deciding what traits to be included in the information index, derivation of regression coefficients to be used in the information index, estimation of the information index value, i.e. breeding value, for each trait and for each potential breeding animal,

III. **breeding programme**: the system or organization to routinely gather information on potential breeding animals, and to select and mate breeding animals to breed the next generation.

Gathering information is mentioned as the last item, but in fact it is the base for breeding practices. The presence of (automated) information networks with regard to animal identification, pedigree recording and (uniform) performance recording is essential. It is not only the amount of information that matters, but also the precision and unbiasedness of information gathered.

2. Cattle breeding practice

In most European countries, selection emphasis is mainly on **milk production traits** (Table 1). The reason for this prominent position of milk production is that the economic values of milk production traits are high (and relatively easy to derive), the potential for genetic improvement of milk production traits is relatively high (large variance and high heritability), and the costs of accurate measurement of milk production traits (or better the marginal costs of breeding decisions) are relatively low, due to the presence of automated information networks used for on-farm decision making (milk recording schemes). The current market situation with quota on milk production does not allow the farmer to increase his revenues by increasing the milk production of the herd. This decreases the economic value of milk production and other traits, which decrease the cost of production (e.g. veterinary costs, labour costs, costs of replacement heifers), gain importance.

Selection on **beef production traits** in dairy or dual purpose cattle is practiced for some breeds in a few countries. Selection emphasis practiced depends strongly on the contribution of dairy breeds to total beef production in the country, as this aspect largely determines the contribution to improved efficiency of future production. In some countries, dairy breeds produce a major part of total beef supply (e.g., Germany, The Netherlands, Scandinavia), in other countries the larger part is produced by specialized beef breeds (e.g., France, Italy), or crossbred animals (e.g., Great Britain). Phenotypic performance recording schemes are based on performance testing station data (growth, feed efficiecy), slaughter house information (carcass weight, classification) or type recording on living animals (muscularity score). Production level traits are relatively easy to record and have moderate to high potential for genetic improvement; quality traits are more difficult to record uniformly, and have (partly therefore) only a low to moderate potential for genetic improvement.

Selection for **efficiency of production**, i.e. live weight and feed intake capacity is not often practiced. Only little work is done in deriving economic values for live weight and feed intake capacity. The potential for genetic improvement of these traits is high, but covariances with milk and beef production traits are not consistent, as they depend on a large number of environmental factors (e.g., lactation stage, feeding regime). No national recording schemes are available. Only within nucleus herds for (raising) young (potential A.I) bulls and potential bull dams, selection is sometimes practiced.

Selection for **functional traits** is not well developed. Records on both male and female ***fertility*** are usually available, but often only an estimate is made for the fertilizing capacity of widely used AI-bulls (i.e., Non-Return rate). Female fertility traits (such as days open, number of inseminations to obtain pregnancy) have low heritabilities; in other words, the

Table 1. Breeding goal traits and example of possible information index traits

Breeding goal traits		Possible information index traits for selection
Production traits		
Milk	Carrier	
	Fat	
	Protein	
	Milk quality (SCC, protein composition)	
Beef	Carcass weight	
	Lean meat yield	
	Meat quality	
Functional traits		
Fertility	Showing heat	Interval calving to first heat, interval calving to 1st insemination
	Pregnancy rate	Non-return, interval 1st insemination to pregnancy, number of insem. per pregnancy
	Calving ease	rump angle
	Stillbirth	
Health	Mastitis	Teat placement, suspensory ligament, udder depth, SCC, milking speed, longevity
	Feet and legs	Rear legs set, claw diagonal, longevity
	Other diseases	Longevity
Efficiency	Body weight	linearly scored type traits or body measurements
	Feed intake capacity	
Milkability	Milking speed	
	Behaviour	

decision making of the farmer has a very large impact on the cow's performance. However, low heritabilities do not mean that selection is impossible, only difficult and requiring relatively more information than selection for e.g. milk production traits to obtain the same level of precision.

Other important traits associated with the fertility complex are ***calving ease*** and ***stillbirths***. In some populations the stillbirth rates and the calving problems can be quite severe and cause serious economic and animal welfare losses.

Apart from low heritabilities, other problems usually associated with selection for fertility traits are difficulties in estimating economic values, difficult statistical properties (categorial traits, non-normal distribution, non-linear relationships), and inconsistent correlations (among female fertility in different parities, and among male and female fertility).

Selection for ***health traits*** largely suffers from the same problems as selection for fertility, but moreover has the problem of absence of uniform recording systems in most countries. Only Scandinavian countries have nationwide recording schemes. If no recording scheme is present, indirect selection for correlated traits that are more easily recorded could be practiced. In many countries much selection emphasis is put on type traits and other traits (thought to be) related to functional traits (such as somatic cell counts (SCC), longevity (Table 1)), but hardly any scientific base is given to this selection emphasis.

Despite the relatively minor position of selection for functional traits in current breeding practices, breeding for functional traits is important. Low fertility and incidences of diseases reduce animal welfare, decrease length of life, and cause economic losses in animal production systems. Major health disorders in dairy cattle include mastitis and feet and legs problems. An important incentive to include selection for fertility and these important diseases in dairy cattle breeding goals is the unfavourable positive genetic correlation with milk yield, indicating that high selection pressure on milk yield would increase fertility problems and susceptibility to diseases.

3. Research topics

In the previous section we have outlined that current breeding progammes are largely optimised for milk production traits. Selection for other traits does by and large not follow the same scientific rules (definition of breeding goal, collection of relevant data, breeding value estimation, and appropriate inclusion into the breeding programme). Instead, selection is often based on poorly measured traits, very rough approximations of the genetic values of individuals and the selection pressure applied does not correspond to the relative merits of traits. Expertise and on-going projects on various topics mentioned are available in some countries but a joint effort is clearly of advantage for improving the situation across the countries of the European Union. The following list of research items that might be of interest for collaboration and concerted action is split into two groups: general topics in the area of improvement of functional traits and topics relating to specific traits.

3.1. General topics

3.1.1. Data recording

The focus should be on definition of traits and installation of automated information networks. The definition of traits that cannot be measured objectively but have to be assessed using subjective scales (e.g. type traits, severity of health disorders, dystocia) should be similar or equal in different countries so that results are comparable across countries. Expertise with respect to data recording systems available in some countries (e.g. in Scandinavia for health traits) should be utilized in devising common concepts. The European regulations already valid for animal identification might be capitalized on. Session I of this workshop will deal with some of these aspects.

3.1.2. Statistical techniques

Statistical models in animal breeding are used for estimating the heritability, the phenotypic and genetic relationships between traits, and for the genetic evaluation of animals. The nature of many functional traits (categorical traits; survival data, where only partial information is available on many animals) calls for the use of statistical methods that are not routinely used now. Non-linear models and models for survival analysis have to be developed or adapted. Especially in the area of multivariate estimation and prediction with different kinds of models for different traits much work has yet to be done. For instance, estimated breeding values for longevity from non-linear models should be possible to use together with breeding values for milk yield from ordinary linear models.

Furthermore, current statistical models for the analysis of genetic relationships between traits assume implicitly that those relationships are linear (use of correlations). This will not be true for many combinations of functional traits and functional traits with production traits (e.g. type traits and longevity, fertility and production). Session III and IV will discuss some of these problems.

3.1.3. *Computer programs*

Implementation of new statistical techniques requires the design of complex computer programs. Exchange of new programs between groups is an extremely important means of saving time and manpower. Such an exchange has not been utilized enough up to date. As those programs are usually not fully documented such an exchange demands short visits of researchers to the department that developed the program.

3.1.4. *Selection for optima*

Current selection strategies aim at increasing or decreasing the population mean for a given trait. For functional traits, often optimal expressions are being sought (e.g. milking speed, foot angle). Theory for this type of stabilizing selection is not well established, especially not in the context of multiple trait selection (session III).

3.1.5. *Integration of functional traits into breeding programmes*

Several problems have to be considered in relation to the use of functional traits in breeding programmes (session III). The traits have to be weighted according to their respective economic weights (including ethical and social aspects). Methodology to derive such weights is studied by a recently installed EAAP working group. The derivation of optimal indexes is complicated by the fact that one has to deal with traits with intermediate optima and curvilinear genetic relationships with other traits. Also, the sensitivity of indexes including a large number of traits should be assessed, including too many traits might decrease the efficiency of selection.

3.2. *Trait-specific items*

3.2.1. *The role of longevity*

Different views can be held with respect to longevity. It may be used as a trait providing information on more specific health or fertility traits (i.e. an index trait only). It is also possible to define an increase of functional longevity as a breeding goal trait and calculate an economic weight value for this. A further economic and methodological on this subject would be of great value (session IId).

3.2.2. *Mastitis and Somatic Cell Count*

Somatic Cell Count (SCC) is often used as an indicator for mastitis. Data are routinely collected on SCC and it is included in selection. It is still not quite clear though, whether one should select for an optimum expression of SCC or for a minimum SCC (session IIa).

3.2.3. *Fertility*

Fertility is a complex trait that is influenced by the genetic constitution of three animals (the father, the mother, and the foetus). Appropriate models are available. These models applied in breeding programmes should be studied in more detail (session IIb).

3.2.4. *Feed intake capacity and feed efficiency*

One possible production environment in the future is the more self-sufficient farm producing "ecological" milk in a more sustainable system. For cows to be efficient in this situation it might be necessary that they are better at eating high quantities of roughage and more efficient at converting it to milk than are the current dairy cows. Are the same cows the most efficient under both production environments or is there a genotype by environment interaction? The complex physiological relations between milk production, live weight, and feed intake capacity might also be studied in more detail, for example considering individual animal variation in negative energy balance in early lactation

4. Concluding remarks

The list of research topics above is by no means exhaustive. If we, the working group, could have presented all interesting research topics possible for collaboration within Europe, then there would have been little use for this workshop. In the same way that the list is not exhaustive, neither will this workshop be. There are most likely interesting topics that will not be covered by the sample of researchers in the workshop. However, it is our hope that in the discussion concluding the workshop, the participants will come to some agreement on the most important topics to have collaboration about.

One end-product of this workshop will be an EU grant application. It is important to remember that we are not attempting to apply for money for the actual research projects as such (they must exist already or be funded from other sources), only for exchange of researchers, costs of travel, meetings et cetera, what in EU parlance is called concerted action.

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