

From research to application: A summary of scientific developments and possible implementation to the genetic improvement for functional traits

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Abstract

This paper discusses how recent advances in recording and evaluation for functional traits in various countries may lead to international genetic evaluations. An ideal picture for the future is painted considering data recording, data ownership, scientific methodology and status of the international genetic evaluation service. An account of the current stage of development recognises that international genetic evaluations for somatic cell count can be a reality within 1-2 years, followed by two fertility and two reproductive traits, whereas for some others (e.g. longevity and metabolic stress) the process will probably have to be very long. Action needed to get closer to the ideal situation and the role of various organisations is discussed.

1. Introduction

The emphasis in dairy cattle production is gradually shifting from increasing volume to improving the efficiency of production. Simple economics have instigated such a shift. World-wide decreasing milk prices have considerably narrowed profit margins for dairy farmers. Decreasing costs of production has become a major thrust for staying competitive and increasing profit margins. Although other strategic options may be also emerging, such as niche marketing and biological production systems, decreasing costs and optimising the efficiency of milk production will probably remain the key target of many farmers world-wide.

Reducing the production cost per cow plays a major role in reducing the overall cost of a dairy operation. This implies healthy cows, free of fertility problems, with good locomotion, without metabolic stress, that calve and

milk well; in other words, cows that will not be involuntarily removed from production. At the same time, animal welfare issues and increasing consumer awareness and involvement in commercial product development and acceptance point to the same direction. Clearly, operational practices of the 70s, 80s and even early 90s are now things of the past.

Several traits associated with desirable animal properties exhibit quantitative inheritance and high degree of genetic variability. This means selection can be practised for such traits resulting in the improvement of livestock, with direct consequence the gradual minimisation of related problems, reduction of production costs and satisfaction of the public opinion.

Effective selection presupposes accurate genetic evaluation of individual animals and comparison of their genetic merit for traits of interest. This is now a routine practice in many countries

(INTERBULL, 1997, 1998, 1998, 1999). At the same time, increasing globalisation of dairy cattle breeding and international trade have brought about the need for international genetic evaluations. Such evaluations are currently available for milk production and conformation traits only (see home page: www.interbull.org).

This article discusses international genetic evaluations for other functional traits in dairy cattle. Although issues related to data recording, selection strategies and breeding programmes are equally important in genetic improvement, the focus here will be on the genetic evaluation process.

2. Ideal picture

According to me, the ideal future international genetic evaluation system for functional traits will have to consider issues and depend on assumptions related to:

- Data recording
- Data (record) availability/ownership
- Methods of computing genetic evaluations
- Status of organisation offering the service

Let's look at each one of these areas. Functional traits with economic importance to farm operations should be routinely recorded in countries with active breeding programmes. Recorded traits should cover the entire spectrum of functional attributes including disease resistance, reproduction, fertility, feed efficiency, management and behaviour. Ideally, trait definition will be the same in all countries, following harmonisation efforts by the international scientific community. Breed societies and

international organisations like ICAR (International Committee for Animal Recording) and its subcommittee INTERBULL (International Bull Evaluation Service) may play the leading role in such efforts.

Harmonised data of well-defined functional traits from individual countries should then become readily available to the body that will compute international genetic evaluations. Currently in most cases data collection is part of the national milk-recording scheme in each country. With some notable exceptions, the latter is run by farmer-based organisations implying that data ownership rests with the farmers. This facilitates the development of data-dependent services (herd management advice, genetic evaluation) and delivery back to the farmers. Ideally in all countries such farmer-owned organisations will assume responsibility for data collection and service delivery at the national level, under the guidance of ICAR and INTERBULL. Good relations between national and international organisations will ensure data availability at the international level.

Once recording and availability of functional trait data have been secured, international genetic evaluations can be computed. Current schemes for milk production and conformation traits may provide useful experience. There is, of course, plenty of room for technical improvement and specific considerations regarding individual functional traits. Ideally, international genetic evaluations will be available for all functional traits that exhibit genetic variability. Different evaluation models will have been developed for each trait category to reflect its specific nature. Thus, the categorical nature of some traits will have to be considered. Also the direct

and maternal component of some traits will have to be thoroughly investigated as well as the age effect on the genetics of such traits. Other issues including genotype by environment interaction and heterogeneity of variance will have also been studied and accounted for in the evaluation process, if needed.

International genetic evaluation is an international parallel to recording and national genetic evaluation in each individual country. They are all services based on farm-collected data that address farmer needs for information and advice. An important attribute of these services is that their perceived benefit is directed primarily towards the farmers. Implicit farmer ownership of the data and independence of the service source would support this attribute. Ideally, this scenario will be preserved and enhanced in the future. Independence of the international genetic evaluation source will guarantee that the only commercial interests served are those of the farmers. This will increase the value and secure acceptability of the service.

3. Current stage of development

Let's try to assess the current situation in relation to the ideal status for the above mentioned areas, with primary emphasis on data recording and international genetic evaluation methods.

3.1. National level

More and more countries appreciating the value of functional traits for their breeding programmes develop recording and genetic evaluation systems. The number of countries with recording and national genetic

evaluations in place has increased considerably from the time of the last INTERBULL survey (INTERBULL, 1996) as reported in the previous GIFT workshops (INTERBULL, 1997, 1998, 1998, 1999; British Society of Animal Science, 1999).

Table 1 attempts to summarise the degree of record availability and consistency in record definition drawing on information from various reports at the previous GIFT workshops

Classification of record availability in Table 1 is rather subjective. An effort was made to relate it to the number of countries with active breeding programmes that currently participate in international genetic evaluations for production and conformation traits. Thus, when data from more than 15 countries become available, the operational scale would be comparable to that for production and conformation. With 10-15 participating countries, the degree of data availability would be considered sufficient for meaningful international genetic evaluations. When less than five countries may participate, an international genetic evaluation would have limited global scope. It should be noted that availability of cow records rather than national genetic evaluations is considered in Table 1.

For all traits except clinical mastitis and traits related to metabolic stress, there is currently sufficient national data availability for international genetic evaluations. For somatic cell count, record availability is comparable to production and conformation traits. Recent developments in various countries have also led to increasing record availability for stillbirth rate, calving performance, female fertility, milking speed and longevity.

Table 1. Summarised information on record availability and consistency in record definition by trait category; source previous GIFT workshops 1996-1999: introductory (Gembloux), health (Uppsala), fertility & reproduction (Grub), intermediate (Warsaw), metabolic stress (Edinburgh) and longevity (Jouy-en-Josas).

Trait category	Degree of national Record availability ⁱ	Number of conceptually distinct traits ⁱⁱ	Degree of consistency in record definition (within trait) ⁱⁱⁱ
Somatic cell count	High	Single	High
Stillbirth rate	Medium-high	Single	High
Calving performance	Medium-high	Single	Medium
Milking speed	Medium-high	Single	Medium
Longevity	Medium-high	Multiple	Low
Fertility	Medium	Multiple	Medium-high
Mastitis	Low	Single	High
Metabolic stress	Low	Multiple	-

ⁱ **High: > 15 countries, Medium-high: 12-15 countries, Medium: 9-11 countries, Medium-low: 6-8 countries, Low: 0-5 countries**

ⁱⁱ **Single: 1-2 distinct trait definitions, Multiple: >2 distinct trait definitions**

ⁱⁱⁱ Percentage of countries with approx. the same record definition: High: >85%, Medium-high: 70-85%, Medium: 60-70%, Medium-low: 50-60%, Low: <50%.

Availability of national records for functional traits alone does not guarantee acceptable input to international genetic evaluation systems. Consistency in trait definition across country is also required. When traits are defined in different ways across country, correlation estimates among countries may be low and the value of information in international genetic evaluations reduced.

The degree of trait harmonisation is associated here with the consistency with which records for a trait are being defined and the number of conceptually distinct trait definitions for each functional trait category. Table 1 gives a summary for various traits. Again, consistency of the record at phenotypic rather than genetic evaluation level is considered. Therefore, differences in national genetic evaluation models do not influence the perceived trait harmonisation as shown in Table 1.

For most trait categories there is one conceptually distinct, prevalent trait definition. However, multiple such

definitions exist for longevity (survival to a certain point in time, herd life, stayability, lifespan, durability etc; binary or continuous), fertility (various non-return rates, interval traits, success 0/1 scores) and metabolic stress (feed intake, converted feed efficiency, body condition, energy balance etc).

The relationship between the number of conceptually distinct traits and degree of consistency in record definition is not necessarily perfect. For several trait categories with a single prevalent trait definition, consistency in record definition is relatively high (somatic cell count, mastitis, stillbirth rate). This means trait harmonisation across country can be easily achieved. However, for other traits like calving performance and milking speed, record definition is less consistent despite the fact that records intend to describe conceptually similar biological functions. For example, there is still discrepancy in the number and definition of categories that describe the ease of calving or speed of milking in various countries.

Similarly, presence of multiple conceptually distinct traits per trait category may be associated with low level of consistency in record definition across country (e.g. longevity). For fertility, however, this is not necessarily true as most conceptually distinct traits (non-return rates, interval traits) may be objectively measured in various countries; for such traits, across country harmonisation may be easily achieved.

3.2. International level

Much of the research on international genetic evaluations has considered production and conformation traits. Scientific advances have led to the development of routine international genetic evaluations for such traits based on the principles of MACE (Multiple Across Country Evaluation) first presented by Schaeffer (1994).

MACE utilises results of national genetic evaluations and all known genetic relationships among bulls both within and across country. The flexibility and technical superiority of MACE over the previously used conversion method have been well recognised. In the majority of countries MACE results are now considered official and have replaced converted evaluations (see home page: www.interbull.org).

Limited research results have been available on MACE applications to traits other than production and conformation. Some work with somatic cell counts has resulted in relatively high genetic correlation estimates between different countries (Fikse, 1995), showing promise for further development. Work relating health traits in Scandinavian countries with somatic cell count and longevity in the US (Rogers *et al.*, 1998;

Rogers *et al.*, 1999) found moderately high correlation estimates raising some optimism for the future of the approach.

The main limitation of international genetic evaluations based on MACE is their dependence on national genetic evaluation results. The latter may be good predictors of the genetic merit at national level but are often based on different models and assumptions in various countries. For example, current national evaluation systems are based on sire models, repeatability animal models, multi-trait animal models or test-day models. Such plethora of national evaluation models presents us with increased inconsistencies in national results leading to decreasing correlation estimates among individual countries. The value of international genetic evaluations then decreases. This may be especially crucial for functional traits where different trait definitions and lower heritability may imply low genetic correlations among countries in the first place. An additional limitation of MACE is that only genetic evaluations for bulls can be computed.

The method that would avoid such problems and result in international genetic evaluations for bulls as well as cows would be based on the analysis of animal performance records rather than national genetic evaluation results. Several considerations are associated with this method, though, including data quality and validation, international genetic evaluation model, genetic parameter estimation, modelling of environmental effects, genotype by environment interaction, genetic base and result expression, just to name a few.

Current and planned research projects investigate the feasibility of the procedure considering the above and

other issues. These projects are run co-operatively by various institutes world-wide including INTERBULL, the University of Wisconsin, the University of Guelph and the World Guernsey Federation. Applications to production traits will be the first to be tested; however, the methodology is being developed with the view to implement across the wider range of traits.

4. Action needed

From the previous two chapters the gap between the ideal situation and current stage of development, regarding data recording and genetic evaluation methodology, can be easily seen. Although considerable action may be needed in certain cases in order to get closer to the ideal situation, most of it is certainly within the realm of reality.

4.1. Recording and standardising

Recording has increased for several functional traits world-wide. It is important, for international genetic evaluation purposes, to focus on a finite number of important traits for which record availability and harmonisation can be realistically achieved. Table 1 suggests that this can be possible for traits related to health (somatic cell count), reproduction (stillbirth rate and calving performance), fertility (non-return rate and interval from parturition to first insemination) and management (milking speed). Choosing from multiple definitions for such traits, and drawing on results presented in previous GIFT workshops, possible standard definitions are shown in Table 2.

Table 2. Possible standard definition of some functional traits routinely recorded internationally within the scope of an international genetic evaluation.

Functional trait category	Individual recorded trait	Possible trait definition	Objective or subjective
Health	Somatic cell count	Linear score based on the logarithm of somatic cell concentration in milk	Objective
Reproduction	Stillbirth rate: primiparous and older cows separately	Dead or alive within 24 hours from birth	Objective
Reproduction	Calving performance: primiparous and older cows separately	Score from 1 (very easy) to 4 (caesarean);	Subjective
Fertility	Non-return rate in 56 days: heifers and older cows separately	Percentage of cows not returning to service	Objective
Fertility	Interval from parturition to first insemination: heifers and older cows separately	Number of days	Objective
Management	Milking speed	Score from 1 (very slow) to 5 (very fast)	Subjective

According to Table 2, objective measures can be recorded for somatic cell count, stillbirth rate, non-return rate and interval from parturition to first insemination, leading to directly comparable information across country.

Computation of international genetic evaluations would then be substantially facilitated.

Subjective scoring will be required, however, for calving performance and milking speed. It is important that

standard definitions are developed across country for each category of scoring. For example, ease of calving and milking speed scores may be associated with time-related variables. Precedence in standardising subjective scores has been set by the World Holstein Federation initiative with conformation traits. Computation of routine international genetic evaluations for such traits has been made possible thanks largely to these efforts.

Leadership in deciding on the definition standards for the above functional traits and monitoring their implementation should lay with world breed organisations and ICAR. The close relation of the concerted action GIFT with ICAR/INTERBULL will certainly facilitate this development.

4.2. Genetic evaluation research

Implementation of current methodology of international genetic evaluations (MACE) to functional traits should be further investigated. Ongoing research with somatic cell count in Denmark and Sweden will shed light on the suitability of the methodology for this trait. Since for somatic cell count objective measures are being recorded, national genetic evaluations are available in several countries, and earlier across country correlation estimates (Fikse, 1995) seem reasonable, computation of international genetic evaluations with MACE should be possible. Pending on completion of the ongoing research, INTERBULL should be able expand its international genetic evaluation service, currently based on production and conformation traits, to include somatic cell count.

The suitability of MACE for the other traits in Table 2 has not been tested. Admittedly, national genetic evaluation systems for such traits, although available, may not be as well developed as for somatic cell count. This, together with low heritability estimates and the categorical nature of some of these traits (calving performance, stillbirth rate and milking speed) may have adverse effect on the estimation of across country genetic correlations. Although it would still be worthwhile investigating along these lines, advances in international genetic evaluations based on performance records rather than national genetic evaluation results may prove particularly useful for these traits. Such research is currently being conducted with emphasis on production traits. Although the broad methodology principles will still apply to functional traits, genetic evaluations based on individual animal records should also take into consideration the following:

Categorical nature of such traits. Although linear models may be applicable in most cases, binary traits showing substantial deviation from normality (e.g. stillbirth rate) may require non-linear methodology. Experience from the development of national genetic evaluations for such traits may be useful in this context.

Age differences. Genetic aspects of traits related to health and reproduction are known to be different in young and older animals. This must be taken into consideration in any genetic evaluation model, by treating repeated records as different traits, as needed. The international genetic evaluation model is expected then to be more complex.

Direct and maternal effects. This distinction is particularly important for

reproduction traits (stillbirth rate, calving performance). International genetic evaluations should consider appropriate genetic parameters for such effects.

Genotype by environment interaction. This has been an issue in production traits and is being addressed by estimating genetic correlations across country in the international genetic evaluation procedure. Ongoing research looks also at establishing across country classification of environmental and management variables and compute international genetic evaluations for each environmental condition defined by this model (Weigel and Rekaya, 1999). There is currently little evidence of genotype by environment interaction for functional traits, largely because of limited work in this area.

The international scientific community should undertake the research task on international genetic evaluations. INTERBULL should be playing a monitoring role ensuring key scientific issues are being addressed and presented at international meetings and workshops. INTERBULL should eventually be integrating scientific research results into the development of

international genetic evaluations for functional traits.

4.3. Timetable

Setting a firm timetable for all these developments is a challenging task. Issues that need to be addressed include data availability, speed of deciding trait definition and record harmonisation, rate of technology development (research) as well as organisation of INTERBULL to expand its services. Several other organisations also get involved at national and international level.

Because of data availability and objectivity in measurement, somatic cell count will probably be the next candidate to be included in an international genetic evaluation scheme. On the other end, because of lack of data or substantial differences in trait definition, the process for traits like longevity and metabolic stress may be delayed considerably. Other traits will probably fall in the middle.

A possible timetable, based on data availability and current stage of development and know-how, is shown in Table 3.

Table 3. Possible timetable for international genetic evaluations for functional traits and key technical areas of consideration.

Trait	Possible timetable	Key considerations
1 Somatic cell count	1-2 years	Methodology research, organisation
2 Non-return rate 56 days	2-4 years	Methodology research, organisation,
3 Interval from parturition to Insemination		decision on trait definition, standardisation of subjective scores
4 Stillbirth rate		
5 Calving performance		
6 Milking speed		
7 Longevity	>4 years	Methodology research, organisation,
8 Metabolic stress		decision on trait definition, standardisation of subjective scores, data collection

5. Additional considerations

Considerable changes are currently taking place in the dairy industry world-wide. De-regulation and increased competition is prompting rapid consolidation of the sector as attested to by mergers and vertical integration of breeding companies. As consolidation expands beyond country borders, the situation regarding bull testing and genetic evaluation becomes more complicated.

A particular area that is being affected by such changes is data ownership and accessibility. This was identified in the beginning of this article as one of the assumptions of the ideal picture for international genetic evaluations, which calls for complete and free accessibility to all data. If this situation changes, the future of independent international genetic evaluations will be questionable. Other services such as recording, national evaluations and registration, that are currently being offered in almost every country at the national level, will be affected in similar ways.

There is a distinct need for the farmers to recognise the value of independent information and for organisations currently providing such information to promote its value. Up until now, dairy farmers, unlike their swine and poultry counterparts, have been more or less free to choose the source of their genetics based on widely available independent information in the form of national and international evaluations. In a way, both farmers and organisations offering these services might have been taking the situation for granted.

6. Conclusions

Computation of international genetic evaluations for functional traits is possible to begin within the next couple of years. It can start with somatic cell count where the current stage of development is closer to the ideal situation than for other traits. Stillbirth rate, calving performance, milking speed and two fertility traits (non-return rate in 56 days and interval from parturition to first insemination) can be the second bunch of traits for which international genetic evaluations may be computed within the next four years.

Such timetable will be pending on continuous data recording at national level, decision on trait definition at international level, completion of ongoing and planned scientific research, continuous accessibility to national records and organisation of INTERBULL to expand its services.

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