GENETIC EVALUATIONS OF DAIRY BULLS AND COWS FOR PRODUCTION

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Introduction

Procedures for genetic evaluations of dairy bulls for production evolved rapidly over the past few decades. Following (1) the herdmate comparison, came (2) the modified herdmate comparison, (3) BLUP (Best Linear Unbiased Prediction), (4) the Modified Contemporary Comparison and (5) the Animal Model. Today various versions of the Animal Model are used for bull and cow evaluations in all important dairy populations. For at least the next decade and likely for longer, the Animal Model will be the method of choice for genetic evaluations in dairy cattle.

The innovative and most important features of the animal model are twofold. First, equations are developed for each animal that include all of the environmental and genetic influences that affect the trait being evaluated. Second, the genetic relationships of each animal being evaluated to every other related one that is identified - sire, dam, offspring, sisters, brothers, aunts, uncles, cousins, etc. - are included simultaneously by adding the inverse of the genetic relationship matrix (A^{-1} in genetic jargon) to the genetic equations for cows. The net result is that everything that affects a cow's performance for a trait - genetics, location (herd), year and season of calving, weather, nutrition, exposure to disease - can be included in one of the many equations and the cow's record will be adjusted for it. Effects of nutrition, weather and exposure to disease are generally accounted for by the herd-year-season equations. Equations for environmental affects and those for cows, which may together number in the millions, are then solved simultaneously to get the most accurate measure of the animal's genetic value possible.

The final set of equations is as follows:

1. Herd-year-season equations.
2. An equation for the genetics of each cow having one or more milk records, modified to account for genetic relationships.
3. Equations for all sires, grandsires and ancestor cows that do not have records in the data sets.
4. An equation for each cow to account for her unique but permanent environmental circumstances.

The basic equations are set up by the following steps:

1. <u>Equation for each herd-year-season combination</u>. For example, an equation would be formed by summing the records of all cows that calved in January and February of 1991 in Herd A. Equation 2 would be the sum of those calving in March and April 91 in herd A, Equation 3 would be those calving in January and February in Herd B, and so on until every herd-year-season combination was covered.
2. <u>Equation for the genetic value of each cow</u>. The record of each cow is added to her equation and to the proper herd-year-season equation. This accomplishes what is described in (1) above.
3. <u>Equations that describe all additive genetic relationships</u>. The genetic relationships among cows with records with those of their ancestors are formed as a set of genetic relationship equations. An equation for each ancestor is also formed. The net result

is that all genetic relationships among all cows in the data set and their relatives, dead or alive, are included in this set of equations. The inverse of the set of genetic relationship equations (A^{-1} in genetic jargon) is obtained. The rows of the A^{-1} are added to the proper cow genetic equations. Rows and columns of A^{-1} corresponding to ancestors without records themselves (all sires and ancestor cows that do not have records in the data) are set up as new equations.

4. Equations for the permanent environmental effect of each cow. These adjust for the unique non-genetic impact of calfhood illnesses, injuries, accidents, etc., on each cow within a herd.

Most articles written about the animal model have focused on the complex mechanics of forming and solving the equations rather than the basic principles. Indeed, the techniques necessary are complex, especially for traits where information is available on a large number of animals. My point is that many have been overwhelmed by the procedures for forming the equations and did not see the essential simplicity of the method and its general usefulness for genetic evaluations.

Since information on all collateral relatives, ancestors and descendants are included, predictions of genetic merit made with the Animal Model are a combination of current data, hindsight (ancestors) and foresight (descendants). This simultaneous 3-way use of records is unique among methods of genetic evaluation that have been proposed or developed. Previous procedures either ignored some data or incorporated only part of it in a stepwise rather than simultaneous fashion, a less accurate method. Since all genetic relationships are included in the Animal Model, any special merit being transmitted by a breeding line, such as that of the "cow families" so widely admired by dairy breeders, is included.

Another unique feature of the Animal Model is self-correction as more information is added. If data used for initial estimates were biased either deliberately - that is by a "thumb on the scales" - or accidentally, estimates of genetic merit are corrected as data became available on descendants. Previous methods have been "top down", since records on descendants were not used to correct errors in estimates of genetic merit of parents and other ancestors. But the Animal Model is both "top down" and "bottom up". Corrections for both ancestors and descendants lead to accuracy in the really important prediction, that of the genetic values of the young animals being chosen as the breeding group to produce calves for the future.

The essential information needed to construct an Animal Model for a trait is limited. The first is an accurate estimate of the proportion of variation in the trait in question that is genetic. For milk yield, this is about 30%. The second is a list of all environmental factors that have significant influences on the trait so they can be included in equations. For yield and growth traits these usually include age of animal and possibly that of its mother, season of the year, and the time and herd or management group the animal was in. Often it is most effective to pre-adjust for age rather than include it in the equations.

Effective genetic evaluations include all information, even if it is partial or incomplete. Failure to do so leads to biases that make animals appear less different genetically than they really are. Usually such biases reduce genetic improvement. Granted, partial or incomplete records are not as valuable as complete ones and must be given less value. Including partial or incomplete lactations does make setting up the equations more complicated but the gain in accuracy is more than worth the extra effort.

I am convinced that including all milk records in genetic evaluations, even those of cows that only lactated for a few days, was a significant factor in vaulting the genetic merit of the American Holstein over that of other Black and White dairy breeds. Including this information insured that bulls transmitting any genes for susceptibility to major health problems in early lactation had lower genetic values for yield. The lower values caused them to contribute fewer genes to the breed since they were culled at younger ages. Since some countries do not include partial lactations with less than 90 days in milk, their animal model evaluations are not the same as those of the USA. They simply are less accurate. Breeders and producers from the USA should not be too concerned because the errors of competitors will work to our advantage.

Basic Strategy for Comparing Lactation Records

The basic principle for accurately comparing records of cows is that comparisons be made among cows in as nearly as similar environmental conditions as possible. For instance, the USDA-DHI Animal Model compares animals calving in the same herd and year-season. A year-season is only 2 months long, that is cows calving in January and February of 1992 constitute a year-season in most herds. In a large herd with many management groups, comparisons should ideally be made within management group. Since registered and grade (unregistered) cows are treated differently in some herds, they are also put into separate equations in the USDA-DHI procedure.

For the highest accuracy, records of first lactation cows should only be compared to those of other first lactations. This is an effective way to account for any differences in pre-calving management normal for heifers and cows. Also, it partially adjusts for the specific age effects on production within each herd, especially if they differ from the values in regional age correction factors. Variation in culling policy by herd and time is automatically considered with such comparisons.

Adjustment for Age at Calving and Days Open

On average within parity, cows calving at younger ages yield less than those initiating lactation at older ages. Exceptions are those relatively few cows past the age of maturity or peak production. Research has shown that pre-adjustment for age is easier and as effective as any other practice, so it is the general rule.

Adjustment for days open from calving to conception is more controversial. Cows with longer intervals from calving to conception yield more milk, but does it result from them being genetically superior for yield or is it an environmental effect? Research is not absolutely clear but the bulk of the evidence points to mostly an environmental effect.

Cows that conceive earlier then 60 days post partum are denied an opportunity to complete 305 days in milk unless their dry period is shortened below 60 days. This is clearly an environmental effect and should be adjusted for to improve accuracy. Since about half of the effect of days open is the shorter lactation, many agree that lactations of such cows should be projected to a 305-day basis. Records of cows with few days open are projected prior to use in USDA-DHI genetic evaluations. Cows open most or all of their 305 day lactations are not adjusted downward as I think they should be.

Which Records To Use

Ideally all records of all cows should be included. Each should be weighted according to its correlation with the true genetic value of the cow. Lactations of cows given an opportunity to milk for 305 days or more should receive full weight. Those of cows culled prior to 305 days should be given a lesser weight, after projection to a 305-day basis. To my knowledge, the

USDA-DHI system is only one that assigns differential weightings based on how many days the cow had an opportunity to lactate.

Although the USDA-DHI Animal Model uses the first five lactations, many other countries only use the first three and a few still only use the first one. Whether use of the first three or the first five gives a more accurate summary is not absolutely proven. Using the first five gives more comparisons among genetically different cows and should give slightly more accurate results. Since few cows have more than 5 lactations, eliminating later ones has little if any impact on accuracy. Research findings have led most countries to currently use more than one lactation, in contrast to many systems of the past that only used the first lactation.

Expression of Results

In the USA and Canada genetic evaluations are expressed as the superiority or inferiority a bull or cow is predicted to transmit to offspring. Hence the PTA (Predicted Transmitting Ability) used in the USA. European countries generally report genetic merit of the bull or cow, Breeding Value. This is twice what the animal will transmit to offspring. To me the North American approach is more effective, although both would rank potential parents exactly the same if based on the same data and methodology since Breeding Value = 2 x PTA.

Summary

The Animal Model method of genetic evaluation for yield and other traits is the most accurate procedure yet developed. It is based on simultaneously solving equations that account for all known environmental and genetical influences on a cow's record. Parallel developments in computer hardware and computer programming techniques made it feasible to solve the millions of equations resulting when all factors are included rather than inclusions of only part as done in previous methods.

All production records of all cows must be included to obtain the most accurate predictions of genetic merit of each cow and bull. Variation in the number and length of lactation records used, especially those of cows denied an opportunity of milk 305 days, cause some differences in results between countries. The Animal Model is likely to have a much longer useful life than previous methods of genetic evaluations.