The Animal Model

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The Animal Model is the procedure used by USDA to evaluate genetic merit of dairy animals for production. Production records on cows are influenced by effects shared by a management group within a herd, effects shared by daughters of a sire in a herd, and permanent environmental effects peculiar to all records of a particular cow. Genetic merit of the cow affects evaluations of all known relatives. Repeated calculations based on updated values from previous rounds produce solutions for all relatives and mates, male or female, in a breed. Use animal model evaluations to estimate genetic differences between animals and to rank animals for production traits. Then let the best animals reproduce most frequently.

The animal model is a system for genetic evaluations that estimates breeding values of bulls and cows at the same time. The system uses production data on all known relatives in calculating a genetic evaluation. Even very remote relatives have some impact, however small, on cows milking in herds today. Each generation which separates two relatives involves a halving of genetic relationships, meaning that close relatives, parents and sons or daughters, have greatest impact on animal model evaluations. A major difference from the previous system is that dam and son evaluations will affect a bull's genetic evaluation, while information from sons and daughters will affect cow evaluations.

Animal model calculations start with the cow as the source of production information. Previous systems grouped progeny of a bull together, used their performance to estimate his genetic merit, and then evaluated the cows almost as an afterthought. The animal model evaluates males and females together, at the same time, compared to the same genetic base. The evaluations for males and females no longer have different names. The genetic evaluations in both sexes are called Predicted Transmitting Ability or PTA. Other changes in terminology have been made as the following list shows.

New terms

Predicted Transmitting Ability (PTA): PTA replaces Predicted Difference and Cow

Index. PTA is the part of an animal's genetic makeup that is transmitted to offspring. PTA's have the same genetic base, the same meaning, and the same interpretation for cows and bulls. PTA's are published for milk, fat, protein, component percentages, and the economic indexes PTA$ from milk and fat, PTA$ including protein, and Cheese Yield Dollars. A PTA value of 1,000 lbs milk is the expected difference in a single lactation 305d-2X-ME milk yield between an average daughter of the animal with PTA=1,000 and an average daughter of an animal with PTA=0. PTA does not tell how much milk a daughter of a bull will give. PTA's only have meaning relative to PTA's on other animals.

Reliability: This term has the same meaning as Repeatability did in the MCC. It ranges from 0 to .99 and measures the accuracy with which PTA is estimated. Reliability includes information from all three possible sources available to the animal model - pedigree, performance, and progeny. For additional discussion of how Reliability is calculated and how to use the information, see Dairy Guideline 404-092.

Predicted Producing Ability: This term is often referred to as PPA. It is different from any information produced by USDA in the past in that it measures the expected future production of a lactating cow relative to herdmates in the same herd. PPA reflects genetic ability and permanent effects such as damaged quarters, a teat injury, and positive or negative effects of calfhood rearing. PPA can be used by producers (in conjunction with other information) to identify potential cull cows within the herd. PPA's are much like Estimated Relative Producing Ability (see Dairy Guideline 404-083) except that PPA's are all calculated from the same genetic base. Comparison of PPA on cows in different herds, while not entirely accurate, is much more useful than across herd comparison of ERPA.

Details of the animal model

The animal model removes environmental differences between cows by making comparisons with other cows in the same management group. Management groups are formed within each herd, placing cows into first or later lactation groups, then subdividing these groups by season of freshening using 2 months of freshenings in each group. For Holsteins, the resulting groups are further divided into registered and grade management groups. If there are fewer than five cows in a group, groups are combined in the following order until at least 5 cows are in a group:

1. 2 months of freshenings to 4 months.
2. Registered and grade cows combined.
3. 4 months of freshenings to 6 months.
4. First and later lactations combined.
5. 6 months of freshenings to 12 months in increments of 2 months.

The old MCC eliminated half sisters from contemporary groups to which a bull's daughters were compared. The animal model does not eliminate those half sisters, but, if only daughters of one bull appear in a management group, those daughters do not contribute to that sire's evaluation.

Genetic relationships

An important new feature of the animal model is the use of all related animals in each animal's evaluation. The process might seem quite complex when first

imagined, but the application is really quite simple. Each animal's evaluation affects evaluations of all relatives by first affecting evaluations on parents and offspring. Since animal model calculations are repeated several times (a process called iteration), those close relatives' evaluations influence more remote ancestors and descendants in the next round of calculations. One cow's dam is her daughter's granddam so a remote ancestor to one individual could be a close relative to another individual in the same pedigree. The influence of a cow's PTA on relatives is like a ripple on a farm pond, ever wider in its influence, but less dramatic in impact as more and more remote ancestors and descendants are affected by her evaluation.

The use of related animals is so complete that every animal evaluated by the animal model traces back to some "unknown" ancestor on every path. "Unknown" has a special definition in the animal model. Animals with only one progeny and no records are considered to be "unknown" because they do not contribute to new information or to relationships between animals with records or progeny. Cows with records but no sire identification are eliminated and become "unknowns." Unknowns contribute something to the animal model, however. By forming groups of such animals and keeping track of genetic merit of descendants from these groups, the animal model can make a fairly reasonable guess about the genetic merit of the unknowns themselves. These guesses, properly weighted, are used in evaluating each animal further downstream.

The actual impact of all these relationships on any animal's PTA under the animal model depends on other information available. Remote ancestors contribute little to evaluations, especially relative to information such as a large group of daughters on an AI sire. The animal model properly weights each item of information relative to other indicators of merit on each cow or bull evaluated. For instance, pedigree information is all that is initially available on a young sire. Once progeny begin to freshen, pedigree information becomes less important, until it plays very little role when (if) the bull has thousands of daughters.

Records used in the animal model

Lactation records used include the first five 305 day, 2X, mature equivalent lactations produced by a cow as long as a first record is present. When first records are missing, special rules (explained later) are followed. Freshenings as long ago as 1960 are included in evaluations. Exclusion of lactations after the fifth removes very few records. Less than 10% of dairy animals have a sixth record and the percentage of records from sixth or later parities is much smaller than that. Discarding very mature production records from genetic evaluations may actually improve accuracy of PTA's on mature cows as most herds have few real contemporaries against which to compare such records. Also, by sixth lactation, permanent environmental effects can overwhelm genetic differences.

Other changes

Merit of mates: Under the old system, the genetic merit of the dam of progeny was ignored when using those progeny to evaluate a sire. The animal model adjusts for the genetic merit of the other parent before including progeny information in PTA's of cows or bulls. Such an adjustment will eliminate the possibility that proofs on very popular bulls with high semen prices were biased upwards in their advanced years as they are bred to better and better cows. Any attempts to influence the proof of a bull in sampling by selecting mates will be eliminated by this adjustment. Use of only the very best sires on elite cows will not affect PTA's of

those cows when the progeny begin to contribute records.

Special procedures for cows missing first lactations and cows changing herds: A cow must have a first lactation to be included in PTA's of her relatives. Otherwise, cows could be "selected" on their first (non-tested) lactation, and the best placed on test for later production. Later records on such cows will be used to evaluate the cow herself. All of her relatives contribute to her evaluation. This procedure protects animal model evaluations from bias due to selection, yet permits the most accurate possible evaluations of cows lacking first records. The rules for cows missing first lactations are not used for protein evaluations when first lactation milk and fat records are present. All young cows in Virginia have protein information in first lactation.

Cows which change herds present a computing problem with their permanent environment effects. Some of the cows which change herds are very special, high priced animals for which permanent environment effects could be quite large. When a cow changes herds, only records from the first herd are used to evaluate relatives of the cow. However, records from herds in which the cow later appeared do affect the evaluation of the cow herself.

Rank percentiles: Rank Percentiles are based on PTA$ values from milk, fat, and protein. Addition of protein to rank percentiles reflects changes in the milk marketing arena. The ranks produced are most appropriate for dairies receiving a premium for protein production, but are adequate for herds not receiving such payments. For bulls, rankings will be based on sires in active AI service following the previous evaluation. Cow ranks will be based on cows with recent lactations. A rank percentile of 80 means that the cow or bull in question has a PTA$ (including protein) that is superior to 80% of last run's active AI bulls or cows with recent records.

Using animal model evaluations

The animal model is the most accurate method ever used to evaluate breeding values of dairy animals for production traits. The system uses all available information, appropriately weighting each item in the final evaluation of each animal. Producers should use PTA's to rank animals and to estimate genetic differences between animals. Sires, and when possible, cows with low PTA's should be ignored when semen is purchased or culled as dams of future herd replacements. As with previous genetic evaluations, PTA's from the animal model can be used for only 2 purposes:

        1. To rank individuals on a genetic basis,
        2. To estimate genetic differences between individuals.

The animal model offers producers the opportunity to continue the pace of genetic trend in the US. Users are cautioned against abuses resulting from manipulation or misrepresentation, however. The animal model cannot overcome such situations. Subjective judgement regarding the credibility of original data will always be required, regardless of the complexity of the evaluation system. When the original records were produced under conditions where profit from production was the objective, animal model evaluations predict future performance with the greatest accuracy ever possible.