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Sire Evaluations for Health and Fitness Traits

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Introduction

Dairy producers have selected for higher milk production for many years. Genetic improvement causes an average Holstein cow born in 2003 to produce over 7,000 pounds more milk in one lactation than her ancestor born in 1960 produced. Type traits, particularly udders and feet and legs, have also improved because of intensive selection. However, the health and fertility of dairy cows cannot be included among these success stories. Genetic trend was responsible for half of a 9-point decline in pregnancy rate in Holsteins between 1960 and its low point in 1995. Dairy-cattle breeders responded by developing national genetic evaluation programs for a number of fitness traits in recent years. This publication documents the genetic evaluation systems for these traits. It also explains a strategy to make economically sound genetic improvements simultaneously in production, type, and fitness traits through use of a selection index to locate outstanding bulls in AI service. The genetic evaluations discussed in this document already exist, but changes to existing systems as well as evaluations for additional traits should be expected in the coming years.

Genetic Improvement – an Historical Perspective

The first young sire sampling program in the United States began in New York State in the 1950s. That program was designed to improve milk production. National sire evaluations for milk production using herd-mate comparisons were introduced in April 1962, and also focused on improved milk production. Breeders wanted to improve the type of dairy animals, and proofs for overall type score were available by 1970. Dairy farmers weren't much interested in traits other than production and type in those days, probably because of the prevalence of low-producing cows with poor udders and/or foot and leg problems. The first trait to break the pattern was calving difficulty in the late 1970s. Dairy producers wanted to choose calving ease bulls to use on Holstein heifers. By the mid 1990s, interest in health and fitness traits was increasing. The USDA published proofs for productive life and somatic cell score for the first time in 1994. Most recently, proofs for fertility (daughter pregnancy rate) and stillbirths ("direct" or service-sire stillbirth rate and "maternal" or daughter stillbirth rate) have been published. Data collection systems and producer interest in additional traits continue to grow. Modern dairy parlors monitor electrical conductivity and daily milk weights. Some parlors weigh cows following each milking. Science has yet to fully utilize these data for the management and genetic information they contain, but research is underway. The growth of genetic information for more comprehensive dairy-cattle breeding programs will continue.

Health and Fitness Traits

The first requirement for genetic evaluations of any trait is that performance information be routinely recorded on many dairy animals. Potentially useful traits like resistance to specific diseases are not yet summarized because the data are not plentiful or accurate enough to evaluate lots of cows and bulls. The traits that are summarized, however, enable dairy farmers to make lasting genetic changes in traits that affect costs of production. Table 1 lists and describes features of different health and fertility traits evaluated on Holstein bulls. There are some differences among breeds in trait definitions, how the traits are scored, and so forth. The differences are largest for the type composites, where breeds run their own evaluation program. Type composites are combinations of linear traits like fore udder attachment, teat length, and udder depth that are related to udders, for example. Some of details specific to individual breeds are omitted in this publication in

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order to cover important concepts about health and fitness traits more clearly.

Genetic evaluations are calculated relative to some genetic base. A genetic base is the group of animals, traditionally animals of one sex born in a certain period of time, against which all animals are compared. For the first traits or composites shown, the genetic base is the same as for production traits: all proofs are scaled so that cows born in 2000 have an average PTA of 0.0. Proofs for calving difficulty and stillbirths use bulls to form the genetic base because proofs are not calculated for cows for these traits. The genetic evaluation procedure used is called a "sire-maternal grandsire model." Males only are evaluated based on their pedigrees and the performance of their progeny. The genetic base year for service sire calving difficulty is 2000, while the base for daughter calving difficulty proofs is bulls born five years earlier. The base for stillbirths is a five-year period rather than a single year, because of less complete reporting of stillbirth information than for other traits in the table. This policy may change in the future when stillbirth data are reported more completely.

Productive Life (PL)

Productive life measures how long dairy cows survive in a herd after they calve for the first time. It is based on calving dates, culling or death dates, and days in milk (based on dry dates) in each lactation for cows on DHI test. Cows receive credit for each month in milk, including time beyond 305 days of lactation, starting with their first calf and continuing until they die or are culled from the herd, regardless of age. This approach differs from genetic evaluations for milk production, which include only the first five records, even if cows continue to make additional records. Each month in production receives a slightly different weight based on a standard lactation curve, so that months around peak yield receive more weight than months in late lactation. The heritability of PL is low at 0.085, and cows express this trait only once in their lifetime.

PL is a difficult trait to improve through selection because of low heritability and expression of the trait late in life. Genetic evaluations for PL in AI bulls rely on genetically correlated traits when progeny are too young for complete lifetimes. Traits used for predicting PL on younger cows include yield traits, fertility, somatic cell score, the calving difficulty traits, and the three type composites shown in Table 1. Proofs are expressed in months of PL.

Somatic Cell Score (SCS)

The "raw" data for this genetic evaluation are the somatic cell counts (SCC) from milk samples collected on test day. These counts, which range from a few thousand to 10 million somatic cells per milliliter of milk, are converted to "log equivalents" (log base 2 (SCC / 100,000) + 3) and averaged for each test day in the first 305 days of lactation. SCS records are extended to 305-day equivalents just as milk records, so that very recent information from records in progress can be used in genetic evaluations. One unusual feature of this trait is that the PTA for each animal (which averages 0.0 for cows born in 2000, the current genetic base year) is scaled by adding 3.00. Thus, all published PTAs are positive and vary about a breed average of 3.0 for cows born in the genetic base year. Another unique feature of the trait is that lower PTAs are desirable for SCS. Heritability is 0.12, one of highest heritabilities for any of the health traits. SCC are expressed simultaneously with milk production, so accurate proofs are available earlier in the life of a cow than are some other traits such as fertility or as an extreme, PL.

Type Composites

The linear traits which make up the composites are scored on a 50-point scale in Holsteins. Each cow is evaluated for all the linear type traits at one time by a trained evaluator from the breed association. Individual traits are scored from one biological extreme to another. Udder depth, for instance, is scored from 10 points or lower for a very deep udder to 40 points or more for extreme height of the floor of the udder above the point of the hock. As reference to "point of hock" shows, classification programs work hard to make objective evaluations of physical features of cows. In Holsteins, most "first-crop" daughter scores used in genetic evaluations for young bulls in AI sampling come from special classifications of young-sire daughters. The regular herd classification programs contribute linear type data to bull proofs as "second-crop" daughters mature. Producers are encouraged not to consider bulls to be "extreme" for linear type traits until substantial numbers of daughters are included in proofs. The same advice can be applied to a number of non-type traits as well, but the two-stage data collection system for type is unique.

Table 1. Health and fitness traits for which national dairy cattle genetic evaluations are available.

Trait	Units used	Breeds included	h² [a]	Evaluations per year	Genetic base
Productive life	Months in milk in the herd, weighted	All[b]	0.085	4	Cows born in 2000
Somatic cell score	Log scores (0-9) from lactation average somatic cell counts	All	0.12	4	Cows born in 2000[c]
Udder composite	Original data on 50 point scale	All	0.27	4	Cows born in 2000
Feet and Legs composite	Original data on 50 point scale	All	0.15	4	Cows born in 2000
Size composite	Original data on 50 point scale	All	0.40	4	Cows born in 2000
Daughter pregnancy rate	Original data are days open on individual cows	All	0.04	4	Cows born in 2000
Calving Ability	A composite of calving difficulty and stillbirths expressed in dollars	Hol	0.07	2	Differs as shown below
Service-sire calving difficulty	Five point scale	BSw, Hol	0.086	2	Bulls born in 2000
Daughter calving difficulty	Five point scale	BSw, Hol	0.048	2	Bulls born in 1995
Service-sire stillbirths	Three point scale	Hol	0.030	2	Bulls born 1996-2000
Daughter stillbirths	Three point scale	Hol	0.065	2	Bulls born 1991-1995

[a] Heritability – percent of differences between animals for a trait due to genetic effects that can be transmitted from one generation to another

[b] Ayrshire, Brown Swiss (BSw), Guernsey, Holstein (Hol), and Jersey

[c] Published PTA = Calculated PTA + 3.0

Udder composite:

Each of the major dairy breeds runs its own type classification program, and standards vary from breed to breed for traits of the same name. For Holsteins, udder composite includes PTAs for fore udder, rear udder height, rear udder width, udder cleft, udder depth, and teat placement. Udder depth receives the most weight of these linear traits. Combined heritability is fairly high at 0.27. For Jerseys, those same traits plus teat length are included in udder composite, with fore udder, rear udder, udder depth, and teat length receiving most weight, from 18 percent to 26 percent per trait.

Feet/legs composite:

Breed differences in the feet/legs composite are even greater than for udder composite. Holsteins use rear legs – side and rear legs – rear view, foot angle, and "feet and legs score" (which gets half the weight) to calculate the composite. In Jerseys, this composite is based on two traits, rear legs side view and foot angle, with foot angle receiving 70 percent of total weight. Combined heritability of feet/leg composite in Holsteins is 0.15.

Size composite:

Size has been a controversial topic in dairy-cattle breeding for a long time. Size composite provides information for selection decisions, regardless of whether the objective is larger or smaller cows. In Holsteins, the size composite is calculated from stature, strength, body depth, and rump width, with stature receiving half the weight. Heritability is high at 0.40. Size can be changed through selection and quickly, compared to many other traits. Consensus among most commercial breeders is that mature Holsteins would last longer, and cost less to maintain, if they were somewhat smaller. Those with an opposing view are not hard to find, however.

Daughter Pregnancy Rate (DPR)

Pregnancy rate measures fertility over a period of time and includes all the activities associated with fertility of the cow from heat expression to detection to conception itself. Data to evaluate this trait have improved in recent years as more herds report all inseminations and pregnancy check results through DHI. Calculation of DPR begins with days open, the interval between calving and a successful breeding date. For cows born many years ago, the calculation is based on calving intervals computed from successive calving dates, with an assumed gestation interval of 280 days. Thus, genetic evaluations for DPR include records back to 1960, well before pregnancy diagnosis was a routine part of dairy-herd management. For cows born more recently, and in herds where reproductive events have been fully reported, successful breeding dates are used to calculate days open. For herds reporting confirmed pregnancies, days open can be calculated on a record in progress by using the breeding date that produced the pregnancy. Timeliness of such information improves DPR for sire selection, as it increases the accuracy of DPR proofs on younger, proven bulls.

Days open can be converted to a pregnancy rate as follows. Interval from calving to successful breeding (or a maximum of 250 days) is adjusted for a 60-day voluntary waiting period. Next, the number of 21-day heat cycles until successful breeding is calculated. Finally, PR is the reciprocal of number of cycles. Here is an example. A cow with 180 days open would have 180 – 60 = 120 days in which the herdsman was trying to get her bred. In those 120 days, 120 / 21 = 5.7 heat cycles are expected. Thus, the pregnancy rate for this cow would be 1 / 5.7 = 17.5 percent. Pregnancy rates of 17.5 percent are low, but common in dairy herds, since the Virginia state average for days open is presently over 160 days. Days open of 120 days would produce PR of 35 percent, which is exceptional for a high-producing herd on concrete, but may be only marginal for a grazing herd with a tight calving window.

Heritability of PR is quite low, at 0.04, which indicates that many non-genetic factors such as heat detection, health of cows, and AI techniques contribute to PR in dairy herds. Genetic change to improve PR will be slow, even with intensive selection. Further, reliability of genetic evaluations for DPR will be lower than for almost any other trait until bulls have several thousand daughters. Consistent and persistent selection pressure will be needed to reverse unfavorable trends in fertility in high-producing dairy cattle, but this trait provides a means to accomplish that objective.

Calving Ability

Calving ability, or CA$, is a composite that combines four different genetic evaluations for calving difficulty and stillbirth in Holsteins. It was first introduced in August 2006 and was developed as a way to include those traits in the Net Merit selection index described in *The Merit Indexes – 2006 Version*, Virginia Cooperative Extension publication 404-088. CA$

is expressed as dollar value received from healthier births (rather than costs associated with difficult births or calf death), so higher numbers are more desirable. The four genetic evaluations are direct and maternal expressions of calving difficulty and stillbirth percentage. A "direct" genetic effect is the effect a service sire has on the calf to be born, whether the trait is calving difficulty or stillbirth percentage. To complete the concept, keep in mind that the dam also contributes genes to the direct effect, including some of the genes she inherited from her sire. "Direct" effect genes act on the calf, whereas "maternal" genetic effects, measured by daughter calving difficulty and daughter stillbirth proofs, are expressed by the dam of the calf. They may include such factors as body structure of the mother that affect the birth process, persistency of labor, and aggressiveness in cleaning the calf after birth.

The four genetic evaluations in calving ability are service-sire calving difficulty (SCE), daughter calving difficulty (DCE), service-sire stillbirth percentage (SSB), and daughter stillbirth percentage (DSB). These four proofs on each bull are published separately for producers who wish to use them. As this guideline is written, calving ability may or may not be published separately. It will, however, be the mechanism through which calving difficulty and stillbirth proofs affect Net Merit. The calving ability composite is calculated as shown in the equation. Negative weights mean that lower genetic evaluations produce more favorable (more positive or less negative) CA$ values. The greatest weight is given to daughter stillbirth evaluations (DSB).

CA$ = -4(SCE-8)-3(DCE-8)-4(SSB-8)-8(DSB-8)

Genetic Relationships between Health and Fitness Traits and Other Traits

Genetic relationships between health and fitness traits and some of the more familiar traits or indexes are shown in Table 2. The index shown is Net Merit, which has been created for use by commercial dairy farmers to improve lifetime economic merit of dairy cattle. Details are in *The Merit Indexes – 2006 Version*, Virginia Cooperative Extension publication 404-088.

Productive life has the highest genetic correlation with Net Merit of any of the fitness traits. Somatic cell score and calving ability are moderately correlated with Net Merit, as is daughter pregnancy rate. The type composites have smaller, but still useful genetic correlations with Net Merit. Most fitness traits have low genetic correlations with production. Daughter pregnancy rate is an exception and the relationship is unfavorable. Higher producing cows tend to be less fertile, a relationship that is well known to producers. The final column in Table 2 shows which traits contribute most to longevity. The strongest relationship is with daughter pregnancy rate, again a relationship well known to dairy producers everywhere who lose otherwise useful cows to poor fertility. Calving ability is another trait with a sizeable correlation with productive life. Difficulty at calving time shortens the productive life of dairy cows, through cow death during parturition or from subsequent fertility or health problems. USDA developed genetic evaluations for DPR and CA because they were important to lifetime economic merit and to longevity of dairy cows.

Table 2. Genetic relationships between health and fitness traits and Net Merit, milk production, and productive life.

	Genetic correlation with		
Fitness trait	**Net Merit**	**Milk production**	**Productive life**
Productive life	0.67	0.08	1.00
Somatic cell score	-0.37	0.20	-0.38
Udder composite	0.17	-0.20	0.30
Feet/legs composite	0.13	-0.02	0.19
Body size	-0.17	-0.10	-0.16
Daughter pregnancy rate	0.27	-0.32	0.51
Calving ability	0.34	0.15	0.40

The production traits, milk, fat, and protein, are not shown in Table 2 since this is a guideline about fitness traits. Production traits receive just under half (45 percent) of total weight to different traits in Net Merit. High production remains an important element of lifetime economic merit.

Using Genetic Evaluations for Fitness Traits

- **A comprehensive index like Net Merit is the best way to make economically sound selection decisions.**

  The best way to use fitness traits is through selection indexes that combine production, health, and fitness proofs. Net Merit, or the related indexes, Fluid Merit and Cheese Merit, is designed to identify AI bulls whose daughters have optimum combinations of favorable genes for many traits for lifetime economic merit. Breed societies also offer selection indexes that have been designed for a similar purpose. The Holstein Association index, TPI, is one such example. The economic values used in Net Merit make it especially useful for commercial producers. Fluid Merit is a good choice for farmers who sell to high Class I milk markets with no protein premiums.

- **Bulls with extremely unfavorable proofs for calving difficulty or stillbirth percentage should be used with caution, or not at all.**

  For many years, Holstein breeders have used service-sire calving difficulty proofs to choose mates for virgin heifers. Bulls with less desirable proofs for calving difficulty were used on older cows. I have recommended this practice in the past, but temper that advice today. The reason is that use of exceptionally difficult calving bulls on older cows perpetuates unfavorable genes in the Holstein population. A mature cow will likely be able to successfully deliver a heifer calf sired by such a bull, but that heifer calf inherits calving difficulty genes from the sire. Those genes will be expressed in her first calf, and all subsequent calves, should she survive the first experience. Holstein breeders should discriminate against calving difficulty bulls by limiting use of extreme calving difficulty bulls, even if their overall merit is outstanding. This recommendation is for selection against difficult births rather than a mating system to temporarily avoid problems.

- **Selection for individual fitness traits can have adverse effects on genetic progress for other economically important traits.**

  Producers should be careful not to be too attracted to bulls outstanding for one or two fitness traits or type composites, unless those bulls have acceptable rank for a comprehensive index like Net Merit. An example of judicious use of individual fitness traits would be using bulls with the higher DPR ratings among the top 20 percent of all AI bulls for Net Merit. The type composites or the fitness traits can be used to make corrective mating decisions. Make sure the overall genetic merit of the bulls involved is acceptable before selection to improve individual health or fitness traits.

- **Which is better, a high proof or a low proof? It depends.**

  Higher proofs are favorable for PL, DPR, calving ability, udder composite, and feet/legs composite. Lower proofs are better for SCS or the individual traits in the calving ability composite: service-sire calving difficulty, daughter calving difficulty, service-sire stillbirth rate, and daughter stillbirth rate. For most commercial herds, lower values for size composite are favorable. The merit indexes described in *The Merit Indexes – 2006 Version*, Virginia Cooperative Extension publication 404-088, account for differences in direction of selection, the economic value of each trait, and how it relates genetically to other traits in the index. Comprehensive selection indexes like Net Merit are the preferred method for selection of service sires in all the dairy breeds.